

METHOD AND DEVICE FOR SWITCHING, AMPLIFICATION, CONTROLLING AND MODULATION OF OPTICAL RADIATION

Technical Field

5 The present invention relates in general to nonlinear integrated and fiber optics and more specifically to completely optical switches and optical transistors and may be used in both fiber-optic and air-path optical communications, in optical logical schemes and in other fields, where all-optical switching, amplification, controlling and modulation optical radiation is need.

Background Art

10 Methods for switching are heretofore-known in optical bistable devices with opposite-directional coupled waves, in particular, in Fabry-Perot resonators with cubic-nonlinear medium (Felber F.S., Marburger J.H., *Appl. Phys. Lett.*, 28, 731, 1976; Marburger J.H., Felber F.S., *Phys. Rev.*, A 17, 335, 1878), and also in systems with a distributed coupling of waves (Winful H.G., Marburger J.H., Garmire E., *Appl. Phys. Lett.*, 35, 379, 1979; Winful H.G., Marburger J.H., *Appl. Phys. Lett.*, 36, 613, 1980).

Extensive opportunities for creation of optical switching, modulating and amplifying information signal are provided by different class of systems with so called unidirectional distributively coupled waves (UDCWs), if these waves propagate in nonlinear medium. For the first time the methods and devices for optical switching, amplifying and modulating optical radiation based on the self-switching of the UDCWs was described in the papers (A.A.Maier, "The method of signal switching in tunnel coupled optical waveguides", USSR Patent No 1152397 (Sept. 1982, publ. 1998). [Byull. Izobret. (46), 300 (1988)]; A.A.Maier, "Optical transistors and bistable elements on the basis of nonlinear transmission of light in systems with unidirectional coupled waves", *Kvantovaya Elektron.* 9, pp.2296-2302 (1982). [Sov. J. Quantum Electron. v.12, 1490 (1982)]; A.A.Maier, "On self-switching of light in a directional coupler", *Kvantovaya Elektron.* 11, pp.157-162 (1984). [Sov. J. Quantum Electron. v.11, p.101 (1984)]; A.A.Maier, "Self-switching of light in integrated optics", *Izv. Acad. Nauk SSSR, ser. Fis.* v.48, 1441-1446 (1984)). Later said methods and devices are extensively developed in the whole world.

30 In particular, in the heretofore-known method for all-optical switching of radiation in tunnel-coupled optical waveguides [A.A.Maier, "The method of signal switching in tunnel-coupled optical waveguides", USSR Patent No 1152397 (Sept. 1982); Byull. Izobret. (46), 300

(1988)], a signal optical radiation with a variable small power and a pump optical radiation with a power more than threshold value are fed into cubic-nonlinear tunnel-coupled optical waveguides.

A method for switching and modulating of UDCWs (P.Li.Kam Wa, P.N.Robson, J.S.Roberts, M.A.Pate, J.P.R.David. «All-optical switching between modes of a GaAs/GaAlAs multiple quantum well waveguide», *Appl.Phys.Lett.* v.52, No24, 2013-2014, 1988.) is also heretofore-known. The method consists in switching and modulating waves, propagating as different waveguide modes in nonlinear-optical waveguide, made on the basis of layered semiconductor multiple quantum well (MQW) structure with alternating layers. The switching and modulating are achieved through changing power transmission coefficient from one wave to another under power changing at input of the optical waveguide. Wavelengths are chosen to be closed to an exciton resonance wavelength λ_r to provide for maximum cubic-nonlinear coefficient of the waveguide.

With the method and device it is very difficult to fit the exciton resonance wavelength with the wavelength of pump optical radiation and/or signal optical radiation accurately. So it is very difficult to achieve maximum of nonlinear-optical coefficient, and therefor to decrease threshold and critical powers of pump optical radiation in sufficient degree. Besides, it is not possible to adjust (control, regulate) values of threshold and critical powers, choosing predetermined regime of operation of the device. Thereto impossibility to adjust values of threshold and critical powers leads to high demands to stability in time of pump optical radiation source, because even a small variation of pump optical radiation power can cause accidental radiation switching, i.e. in this case probability of accidental mistake in switching and modulation at the output is high. Besides, the method has the following large shortcoming. If exciton resonance wavelength is close to wavelength of the pump and/or signal optical radiation then large loss of the optical radiations take place. For carrying the method into effect they use nonlinear-optical waveguide made on the basis of nonlinear-optic semiconductor MQW wafer structure. At input and output of the nonlinear-optical waveguide micro objectives are placed. Besides the shortcomings mentioned above the device also has loss at the input and output due to shortcomings of collimating optics at the input and output, which ignores a shape (form) of profile (section) of the nonlinear-optical waveguide. A complicity of a placing and a mounting micro objectives relative to the nonlinear-optical waveguide, and insufficient small size of the device are also shortcomings of the method and the device.

One prior-art switching device (R.Jin, C.L.Chuang, H.M.Gibbs, S.W.Kohh, J.N.Polky, G.A.Pubans "Picosecond all-optical switching in single-mode GaAs/AlGaAs strip-loaded nonlinear directional coupler", *Appl. Phys. Lett.*, 53 (19), 1977, p.1791-1792), is also known to comprise nonlinear TCOWs, made on the basis of layered nonlinear-optic semiconductor MQW structure with alternate layers GaAs/AlGaAs. Wavelength of input optical radiation is chosen close to exciton resonance wavelength to provide large cubic-nonlinear coefficient of the waveguides. By this device it is possible to carry the method for switching, modulating, amplifying and controlling into effect, consisting in feeding (launching) optical radiation into nonlinear TCOWs, switching of coupled waves in the nonlinear-optical waveguides and separating coupled waves in neighboring optical waveguides at output of the device.

In said device and method it is also very difficult to adjust the threshold and critical power. Besides in the device the transmission of radiation through the nonlinear TCOWs is only 1%, that is due to maximum of absorption at exciton resonance wavelength. Small transmission and impossibility to adjust threshold and critical power, and regime of operation restricts the field of using the device.

Besides shortcomings mentioned above this switching device has optical power losses because of the faults of collimating optics placed at input and output of the device.

Small efficiency of focusing and collimating elements at the input and output of heretofore-known devices is because of difficulties of precision positioning and mounting of focusing and collimating elements (objectives) relative to the nonlinear-optical waveguides. Besides, the focusing and collimating elements in the known device did not take into account an asymmetry of the cross-section of the nonlinear-optical waveguide(s).

Thereto heretofore-known methods for launching light into an optical waveguide (for example, Inventors Certificate SU No 1238569, 1984), do not give a possibility to control and check of efficiency of launching optical radiation into the optical waveguide. Said method does not provide for mounting of focusing and collimating optical elements relative to the nonlinear-optical waveguide with precision, satisfying high requirements to efficiency of feeding radiation into and/or feeding radiation out from the nonlinear-optical waveguide. Said method can not also use for mounting a semiconductor laser or laser module relative to the nonlinear-optical waveguide or nonlinear TCOWs.

Unification (joining) aforesaid devices in the united chip is of great interest for devices processing optical signals, for example, for logical optical schemes, for optical computing devices and optical communications systems.

Heretofore-known switching and logical schemes, for instance described in paper Hector-E. Escobar «All-optical switching systems near practical use», Laser Focus World, October 1994, pp.135-141, have restrict possibilities due to insufficient speed of operation.

Thereto aforesaid known methods and devices places limitation upon the value of the amplification factor of a variable signal.

Disclosure of the Invention

Technical aim of the invention is a drastic decreasing of pump power at input of the device with possibility increasing gain (and sensitivity of the device to signal variation) and depth of switching, and also providing possibility for adjustment of threshold and critical powers and controlling differential amplification factor of a variable optical signal and a ratio of powers of coupled waves at output of device, and achievement of a reliability of its operation, and small sizes of the device.

A positive technical result of the present invention is expressed also in providing favorable conditions for creating an optical transistor, as well as devices based thereon.

Technical aim of the invention is also increasing the speed of operation of the optical switching devices by use of quadratic-nonlinear-optical waveguide(s).

In the first and second variants of the method of switching, amplification, controlling and modulation of optical radiation are carried out with use of the nonlinear-optical waveguide, made on the basis of layered semiconductor MQW-type structure with alternating layers containing at least two hetero-transition, and nonlinear-optical waveguide is made with an opportunity of propagation in it of two UDCWs, and including input of coherent optical radiation with power above the threshold power into the nonlinear-optical waveguide, or pump optical radiation with power above the threshold power and at least one coherent signal optical radiation into the nonlinear-optical waveguide, interaction of UDCWs in the nonlinear-optical waveguide and separation of UDCWs at the output of the nonlinear-optical waveguide, the put task is solved by that

cubic and/or quadratic-nonlinear-optical waveguide are used,

wavelength of radiation choose from a condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is a wavelength of the one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of semiconductor structure of the nonlinear-optical waveguide,

through the nonlinear-optical waveguide an electrical current is passed,

at input of optical radiation or signal optical radiation in the nonlinear-optical waveguide -
they carry out change of power, or polarization, or wavelength, or angle of input of
continuous waves or signal optical radiation, or external electrical or magnetic field
applied to the nonlinear-optical waveguide.

5 In the third and fourth variants of the method of switching, amplification, controlling and
modulation of optical radiation carried out with use of nonlinear-optical waveguide, made on
the basis of layered semiconductor structure such as MQW with alternating layers containing at
least two hetero-transition, and nonlinear-optical waveguide is made with an opportunity of
propagation in it of two UDCWs, including input of the polarized optical radiation with power
10 above threshold or polarized pump optical radiation with power above threshold and of at least
one polarized signal optical radiation in the nonlinear-optical waveguide, interaction of UDCWs
of various polarizations in the nonlinear-optical waveguide and separation of the waves of
various polarizations after the output of the nonlinear-optical waveguide, put task is solved by
that

15 nonlinear-optical waveguide is made cubic and/or quadratically-nonlinear,
nonlinear-optical waveguide is made birefringent and/or optically active,
through nonlinear-optical waveguide an electrical current is passed,
wavelength of radiation choose from a condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is a wavelength
of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap
20 resonance and/or half-band-gap resonance of the semiconductor structure of the nonlinear-
optical waveguide,

they carry out a change of power, or polarization, or wavelength, or an angle of input of
continuous waves or the signal optical radiation, or external electrical or magnetic field applied
to the nonlinear-optical waveguide.

25 In the fifth and sixth variants of the method of switching, amplification, controlling and
modulation of optical radiation carried out with use of nonlinear-optical TCOWs, at least one of
which is made on the basis of semiconductor layered MQW-type structure with alternating
layers containing at least two hetero-transition, and including input of optical radiation with
power above threshold power or at least one signal optical radiation at least into one of the
30 nonlinear-optical waveguides and pump optical radiation with power above threshold at least
into one nonlinear-optical waveguide, interaction of UDCWs in nonlinear TCOWs and
separation and/or separation out of the optical waves after the output of the nonlinear-optical

waveguides by a feeding radiations out from various waveguides and/or by means of separator, the put task is solved by that

nonlinear-optical waveguides are made as cubic and/or quadratic-nonlinear,
at least through one nonlinear-optical waveguide an electrical current is passed,

5 wavelength of optical radiation is chosen from a condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is wavelength of the one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance in semiconductor structure at least one nonlinear-optical waveguide,

at input of optical radiation in nonlinear-optical waveguide they carry out a change of
10 power, and/or wavelength, and/or of polarization of entered optical radiation, and/or of external electrical or magnetic field applied to at least one nonlinear-optical waveguide.

Thus in all variants of the method the nonlinear-optical waveguide has the length not smaller than the length necessary for switching and/or of transfer of at least 10 % of power from one of UDCWs into another, and the length of the nonlinear-optical waveguide, necessary for
15 switching and/or transfer of at least 10% of power from one of said UDCWs into another, does not exceed the length, at which the power of more strongly attenuated wave from the UDCWs decreases in 20 times or less.

In more preferable embodiment of the suggested method and device the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching
20 and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer at least 50% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the
25 power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

In even more preferable embodiment of the suggested method and device the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching
and/or the transfer of at least 80% of power of one of said unidirectional distributively coupled
30 waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer at least 80% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the

power of the most attenuated wave from said unidirectional distributively coupled waves is-
attenuated by a factor 10.

Thus, in special cases, they establish power of radiation or power of pump optical
radiation on an input of the nonlinear-optical waveguide from a condition of maintenance of the
5 given value of differential factor of amplification and/or of the given ratio of powers and/or
difference in phases UDCWs at the output, stabilize average power of continuous waves
radiation or peak power of pulse radiation, or power of pump optical radiation.

For increase of differential gain and maintenance linearity of the amplification in the case
of cubic-nonlinear-optical waveguide or cubic-nonlinear TCOWs, as a rule they choose power
10 of the fed continuous waves radiation, or peak power of the fed pulse radiation, or power of the
said pump optical radiation in the range from $0,4 P_M$ up to $3P_M$, where P_M - the critical power
(considered below); or mainly - in a range from $0,6 P_M$ up to $1,5 P_M$, or even more preferably
from $0,8 P_M$ up to $1,2 P_M$.

As a rule, they stabilize average power of radiation or power of pump optical radiation ,
15 entered in the nonlinear-optical waveguide.

In the other special case in quality of optical radiation, or the pump optical radiation
and/or of signal optical radiation they use pulse radiation, in particular, solitons.

Thus, in special cases, they set temperature of nonlinear-optical waveguide or at least one
nonlinear-optical waveguide from a condition of choice and maintenance of the given value of
20 threshold power and/or of critical power and/or of differential factor of amplification and/or
given ratio of powers and/or differences in phases UDCWs at the output of the nonlinear-optical
waveguide and/or differences in phases between them, and stabilize temperature the nonlinear-
optical waveguide.

For decrease of threshold radiation intensity (by drawing together of wavelength of
25 radiation and of the exciton resonance of semiconductor structure) and elimination of influence
of external temperature influences, they adjust and/or stabilize the temperature of the nonlinear-
optical waveguide or nonlinear TCOWs with thermostate and/or at least one Peltier element,
supplied by regulator and/or a stabilizer of temperature.

In all variants of the method the power of pump optical radiation can be at least by the
30 order more than power of signal optical radiation, or the powers of signal optical radiation and
pump optical radiation can differ from their average geometrical value no more than by the
order.

As a rule, for exception of existence of opposite-directional distributed-coupled waves in the nonlinear-optical waveguide at least one end face of the nonlinear-optical waveguide is clarified.

As a rule, the wavelength λ of the optical radiation is chosen from the conditions
5 $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.

In variant of the method in which the UDCWs having different polarizations (as a rule, having mutually orthogonal polarizations) are used, as a rule, the nonlinear-optical waveguide is made as birefringent and/or optically active. It should be mentioned that said MQW-type structure almost always has birefringence, however to reach predetermined, sufficiently large
10 birefringence, the difference in refractive indexes of the layers should be sufficiently large; hence value of «x» in such structure as $GaAs / Al_x Ga_{1-x} As$ should be sufficiently large, e.g. $x > 0,1$.

In special cases the UDCWs represent waves of various wavelengths, and/or various polarizations and/or various waveguide modes.

Under this, in special cases of all variants of the method continuous waves or pulse
15 radiation, or pump optical radiation and/or the signal optical radiation fed into the nonlinear-optical waveguide includes waves of two frequencies differing by the value larger, than τ^{-1} , where τ is characteristic time of change of a parameter of the optical radiation; the parameter of the optical radiation is meant the power, or the phase, or the polarization, or the frequency of the optical radiation; the parameter of the signal optical radiation is meant the power, or the
20 phase, or the polarization, or the frequency of the signal optical radiation; in particular, the carrying frequencies of signal optical radiation and pump optical radiation differ by value larger, than τ^{-1} , where τ is characteristic time of a change of parameter of the signal optical radiation; in particular, use pump optical radiation and signal optical radiation of various wavelengths, thus after the output of the nonlinear-optical waveguide(s) the radiations of various wavelengths
25 are separated or at least one of them is separated out by means of the separator.

In other special cases in the quality of coherent optical radiation fed into at least one nonlinear-optical waveguide, they use optical radiation of linear, or elliptic or circular polarization, or the pump optical radiation contains waves of at least two polarizations or two wavelengths, or two waveguide modes.

30 In particular, they use pump optical radiation and signal optical radiation having identical or opposite circular polarizations, or they use pump optical radiation and signal optical radiation having identical or various linear or elliptic polarization, thus at the output of the nonlinear-

optical waveguides radiation of various polarizations are separated or at least one of them is separated by means of the separator.

In particular, they use pump optical radiation and signal optical radiation with linear or elliptic mutually orthogonal polarizations.

5 In specific case difference in phases between the UDCWs having orthogonal polarizations in optical radiation fed into the nonlinear-optical waveguide, is installed from the condition of maintenance of the given value of differential gain and/or the ratio of the UDCWs powers at the output of the nonlinear-optical waveguide and/or the differences between the UDCWs phases at the output.

10 In special cases, with one birefringent nonlinear-optical waveguide, a vector of an electrical field or an axis of an ellipse of polarization in optical radiation (or in signal and/or pump optical radiation) fed into the said nonlinear-optical waveguide is directed at an angle of $10^\circ < \alpha < 80^\circ$ to a «fast» or «slow» axis of the said nonlinear birefringent optical waveguide, in particular, the vector of the electrical field or the axis of the ellipse of polarization in the optical
15 radiation (or signal and/or pump optical radiation) entered said nonlinear-optical waveguide is directed at an angle of $10^\circ < \alpha < 80^\circ$, or $30^\circ < \alpha < 60^\circ$, or 45° , or $-15^\circ < \alpha < 15^\circ$ to the «fast» or «slow» axis of the nonlinear-optical waveguide, either vector of the electrical field or the axis of the ellipse of polarization in optical radiation (or in the signal and/or the pump optical radiation) entered the nonlinear-optical waveguide coincides with the «fast» or «slow» axis of the
20 nonlinear-optical waveguide.

Under this they orient the vector of electrical field or the axis of the ellipse of polarization in optical radiation entered the nonlinear-optical waveguide relative to «fast» or «slow» axis of the nonlinear-optical waveguide, by turn of optical elements of the nonlinear-optical module (connected by fiber-optic sockets and/or by optical connectors) around of a longitudinal axis of
25 the nonlinear optic module.

In special cases they use pump optical radiation and signal optical radiation with the same wavelength.

In special cases the pump optical radiation contains waves of at least two polarizations or two wavelengths, or two waveguide modes.

30 As a rule, in quality of coherent optical radiation, or pump optical radiation and/or signal optical radiation fed into the nonlinear-optical waveguide or nonlinear TCOWs they use optical radiation of the semiconductor laser and/or of the laser module. Under this for reduction, regulation or choice of given threshold and critical powers and for increase or regulation of

differential gain (by increase or the regulation of nonlinear factor of the nonlinear-optical waveguide due to regulation of a degree of vicinity to an exciton resonance of wavelength of radiation of the laser) they additionally adjust and/or stabilize temperature of radiating semiconductor structure of the laser and/or of the laser module.

5 To increase an efficiency of the feeding of optical radiation into the nonlinear-optical waveguide and/or to increase an efficiency of feeding out of optical radiation from the nonlinear-optical waveguide, the optical elements for the input/output of the optical radiation (hereinafter referred to as «input/output elements») are mounted accordingly at the input and/or at the output of said nonlinear-optical waveguide, thereto the input/output elements are
10 mounted relative to the nonlinear-optical waveguide with precision provided by their positioning (adjustment) by luminescent radiation of the nonlinear-optical waveguide, arising when electrical current is passed through said nonlinear-optical waveguide.

As a rule, the «input/output elements» are made with taking into account the asymmetry of cross-section of the nonlinear-optical waveguide. In other words the «input/output elements»
15 are usually made with taking into account an asymmetry divergence of beam launching into the nonlinear-optical waveguide; and/or asymmetry divergence of beam leaving the nonlinear-optical waveguide. That is why the efficiency of input/output of the optical radiation is very high (the efficiency is about 70% and higher).

As a rule the «input/output elements» are mounted at the input and output ends of the
20 nonlinear-optical waveguide, with making up the compact united nonlinear-optic module.

In specific preferred embodiment the «input/output elements» are made as objectives; thereto, as a rule, the objective comprises a cylindrical lens and a gradan. In other words, to increase the efficiency of input/output of optical radiation before the input the optical radiation is focused and/or after the passage through the nonlinear-optical waveguide the optical
25 radiation is collimated by a cylindrical lens and/or gradan; as a rule, the surfaces of cylindrical lenses and/or gradans are antireflection coated

The positioning and/or mounting input and/or output elements, made as objectives, relative to the nonlinear-optical waveguide is accomplished up until the formation of collimated optical radiation beam outside (beyond) the said objectives. As a rule the collimated optical
30 radiation beam has cylindrical symmetry.

In the other special preferred embodiment the input/output elements are made as input and/or output optical waveguides (hereinafter referred to as «input/output waveguides»); In this case the feeding of optical radiation into the nonlinear-optical waveguide and/or the feeding of

radiation out from the nonlinear-optical waveguide is carried out by input and/or output waveguide; as a rule, on output and/or input end of input and/or output optical waveguide a lens is made and/or gradan is mounted; usually said lens is made as a cylindrical lens or a parabolic lens or a conic lens. It should be mentioned that output end of input waveguide is
5 adjoined to the input of the nonlinear-optical waveguide, and so the lens, by means of which the radiation is launched into nonlinear-optical waveguide is formed just on the output end of the input waveguide. Similarly input end of output optical waveguide is adjoined to the output of the nonlinear-optical waveguide, and so the lens, by means of which the radiation is fed out from the nonlinear-optical waveguide is formed just on the input end of the output optical
10 waveguide. As a rule, input and/or output end of said optical waveguides and/or gradans are antireflection coated.

The input and output waveguides are preferred to be surrounded by defending buffer covers. As a rule the 3mm and 0.9 mm buffer covers can be used.

The nonlinear-optical waveguide together with firmly mounted the input/output elements
15 at the ends of the nonlinear-optical waveguide can made up a nonlinear-optical module. Thus, the nonlinear-optical module comprises at least one nonlinear-optical waveguide and input/output elements. Besides the nonlinear-optical module can comprise other optical elements: separator of UDCWs, an optical polarizer, an optical isolator, laser, phase compensator, polarization controller and etc. optically and firmly mechanically connected
20 between each other; and others elements: thermo-electrical Peltier element, sensor of temperature, mountings elements and others subsidiary elements firmly connected between each other.

For a possibility of modulation of optical radiation by an electrical current on the basis of Faraday effect the input waveguide is made from a magneto-optic material and is placed in the
25 solenoid, through which the variable electrical current modulating polarization of the optical radiation is passed, or is made as electrooptical rotator of a plane of polarization; or the input waveguide contains Y-mixer, into one input input branch of which the signal optical radiation is fed, and into other input branch - the pump optical radiation is fed; under this the input branch, into which the signal optical radiation is fed, is made from a magneto-optic material and is
30 placed in the solenoid, through which the variable electrical current modulating polarization of signal optical radiation is passed, or is made as electrooptical rotator of a plane of polarization.

As a rule, in all variants of the method a constant electrical current from 0,5 mA up to 10mA is carried (passed) across the nonlinear-optical waveguide, thereto the current spread from an average value over the time does not exceed 0,1mA.

In that specific case, with the purpose of a possibility of controllability (in particular, for rejection of noise and jamming in optical communication lines) the electrical current is passed through the nonlinear-optical waveguide in the given intervals of time.

In the other special case for elimination of atmosphere fluctuations, noise and jamming dependences on time of powers of the UDCWs, separated after the output of the nonlinear-optical waveguide, are compared and their amplified opposite-modulation in powers is selected out by means of a correlator and/or differential amplifier.

It is preferred for elimination of return influence of radiation reflected before the input of the nonlinear-optical waveguide and/or after its output an optical isolator is mounted. In particular the optical isolator is made as waveguide optical isolator, e.g., fiber-optic isolator.

In all variants of the method the separation of UDCWs after the output of the nonlinear-optical waveguide is executed by the separation of waves of various polarizations and/or of various wavelengths, and/or of waves in different TCOWs, and/or of various waveguide modes or by the separation out of one wave of predetermined polarization, or predetermined wavelength, or from one of TCOWs, or predetermined waveguide mode.

In case of using UDCWs of various polarizations their separation after the output of the nonlinear-optical waveguide is carried out by polarizer, which, as a rule, is made as polaroid, or polarizing prism, or a birefringent prism, or a directional coupler, separating polarization, or as a polarizer on the basis of a single optical waveguide.

In special cases, for decrease of the requirements to stability of a source of pump optical radiation they choose pump optical radiation and/or at least one signal optical radiation with various wavelengths, and thereto wavelength of the exciton resonance λ_r in the semiconductor MQW-type structure of the nonlinear-optical waveguide is set by regulation of its temperature, and/or wavelength of laser radiation is set by regulation of the temperature of radiating semiconductor structure of the laser in such manner that difference between wavelength of signal optical radiation(s) and wavelength of the exciton resonance in the semiconductor MQW-type structure of the nonlinear-optical waveguide is less, than difference between the wavelength of the pump optical radiation and the wavelength of the exciton resonance in the semiconductor MQW-type structure of the nonlinear-optical waveguide.

In special cases, for decrease of the requirements to stability of a source of pump they choose pump optical radiation and/or at least one signal optical radiation with various wavelengths, and wavelength of the exciton resonance λ_r in the semiconductor MQW-type structure of the nonlinear-optical waveguide is set by regulation of its temperature, and/or
5 wavelength of laser radiation is set by regulation of the temperature of radiating semiconductor structure of the laser in such manner that a difference between wavelength of signal optical radiation(s) and wavelength of the exciton resonance in the semiconductor MQW-type structure of the nonlinear-optical waveguide is more, than the difference between the wavelength of the pump optical radiation and the wavelength of the exciton resonance in the semiconductor MQW-
10 type structure of the nonlinear-optical waveguide.

In the seventh variant of the method of switching, amplification, controlling and modulation of optical radiation carried out with use of at least one nonlinear-optical waveguide, made on the basis of layered semiconductor structure such as MQW with alternating layers containing at least two hetero-transition, and nonlinear-optical waveguide is made with an
15 opportunity of propagation in it of opposite-directional coupled waves, and including feeding of at least one optical radiation with power above threshold in the nonlinear-optical waveguide, power switching between the coupled waves at output and input of the nonlinear-optical waveguide(s) caused by change of at least one of parameters of optical radiation at the input, the put task is solved by that

20 they feed optical radiation with at least one changeable parameter and power above threshold or pump optical radiation with power above threshold and at least one signal optical radiation with at least one changeable parameter,

they use optical waveguide or optical waveguide, having cubic and/or quadratic nonlinearity,

25 through the nonlinear-optical waveguide(s) they pass an electrical current,

wavelength of optical radiation with changeable parameter, or pump optical radiation, or signal optical radiation, or the pump and signal optical radiation they choose from conditions $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of in the
30 semiconductor MQW-type structure of the nonlinear-optical waveguide,

thereto they carry out change in the power, and/or phase(s), and/or polarization of the entered optical radiation, and/or wavelength, and/or an angle of input of the entered optical

radiation, and/or an external electrical or magnetic field applied to the nonlinear-optical waveguide.

In specific case, they set average power of optical radiation with changeable parameter, or power of pump optical radiation, entered the nonlinear-optical waveguide(s) at the input waveguide from the condition of maintenance of the given value of differential factor of amplification and/or of the given ratio of powers of the coupled waves at output and input of the nonlinear-optical waveguide(s).

As a rule, they stabilize average power of optical continuous waves radiation with changeable parameter, or peak power of pulse optical radiation, or power of pump optical radiation.

In the other special case they use pump optical radiation as pulses, for example, as solitons.

In specific case, they set the temperature of at least one nonlinear-optical waveguide from the condition of maintenance of the given value of threshold power and/or of differential factor of amplification and/or the ratio of powers of the coupled waves at output and input ends of the nonlinear-optical waveguide(s), and they stabilize the temperature of the nonlinear-optical waveguide(s).

For decrease of threshold intensity of the optical radiation (due to rapprochement of wavelengths of the radiation and the exciton resonance of the MQW-type structure) and elimination of influence of external temperature influences they set and/or regulate and/or stabilize the temperature of the nonlinear-optical waveguide and the said MQW-type structure by at least one Peltier element and temperature sensor and/or thermostat.

In specific case they choose the wavelength λ of the optical radiation with changeable parameter, or pump optical radiation, or/and signal optical radiation from the conditions $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.

In special cases they switch power of the opposite-directional coupled waves of various frequencies, thus the switching of power is made between the coupled waves of various frequencies and/or of opposite directions.

As a rule, they pass across the nonlinear-optical waveguide(s) the constant electrical current in the range from 0,5 mA up to 10mA, thereto the current spread from an average value over time does not exceed 0,1mA.

With the purpose of a possibility to control the gain (in particular, to reject noise and jamming in optical communication lines) an electrical current pass through waveguide in the given intervals of time.

For elimination of return influence of radiation reflected from ends of waveguides on a source of radiation or other optical elements located before the waveguides, and also for elimination of influence of the reflected radiation on nonlinear-optical waveguide, before the input of the nonlinear-optical waveguide and/or after its output an optical isolator is mounted. In particular the optical isolator is made as waveguide optical isolator, e.g., fiber-optic isolator.

As a rule, in a quality of optical continuous waves or pulse radiation and/or of pump optical radiation and/or of signal optical radiation they use radiation of the semiconductor laser and/or of the laser module, thereto they adjust and/or stabilize temperature of radiating semiconductor structure of the laser and/or of the laser module.

In that specific case, for decrease the requirements to stability of a source of pump optical radiation, they choose pump optical radiation and/or at least one signal optical radiation with various wavelengths, and wavelength λ_r of the said resonance in said semiconductor structure of nonlinear-optical waveguide is set by regulation of its temperature, and/or wavelength of radiation of the laser is set by regulation of temperature of radiating semiconductor structure of the laser in such way that the difference in wavelengths of signal optical radiation and of the exciton resonance of semiconductor structure of nonlinear-optical waveguide is less, than difference in wavelengths of pump optical radiation and of the exciton resonance in said semiconductor structure of the nonlinear-optical waveguide.

In the other special case, for reduction of threshold power, they choose pump optical radiation and/or signal optical radiation with various wavelengths, and wavelength λ_r of the said resonance in the semiconductor structure of the nonlinear-optical waveguide is set by regulation of its temperature, and/or wavelength of laser radiation is set by regulation of temperature of radiating semiconductor structure of the laser in such way that a difference in wavelengths of signal optical radiations and of the said resonance in said semiconductor structure nonlinear-optical waveguide is more, than difference in wavelengths of pump optical radiation and of the said resonance of the semiconductor structure of the nonlinear-optical waveguide.

In that specific case for increase of efficiency of input/output of radiations before feeding of radiation into at least one nonlinear-optical waveguide radiation is focused and/or after its passage through the nonlinear-optical waveguide(s) said optical radiation is collimated with the

help of a cylindrical lens and/or gradan; as a rule, the surfaces of cylindrical lenses and/or gradans are clarified.

In the other special case for increase of efficiency of input/output of optical radiation the feeding of radiation into the nonlinear-optical waveguide(s) and/or feeding of radiation from a nonlinear-optical waveguide(s) is carried out by means of accordingly input and/or output waveguide; as a rule, at output and/or input end of input and/or output optical waveguide a cylindrical lens and/or parabolic lens and/or conic lens is made or a gradan is mounted; as a rule, the input and/or the output end of the waveguide(s) and/or gradan(s) are antireflection coated.

In the first and second variants of the device for switching, amplification, controlling and modulation of optical radiation containing nonlinear-optical waveguide, made on the basis of layered semiconductor structure such as MQW with alternating layers containing at least two hetero-transition, and nonlinear-optical waveguide is made with an opportunity of propagation in it of at least two UDCWs, and also the device contains optical elements of an input/output located accordingly at the input and/or the output of the nonlinear-optical waveguide, and separator of UDCWs at the output of the device, the put task is solved by that

nonlinear-optical waveguide is made as cubic and/or quadratic nonlinear,

nonlinear-optical waveguide is supplied with contacts for passage of an electrical current through it ,

wavelength λ_r of the one-photon and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance in said semiconductor structure of at least one nonlinear-optical waveguide satisfies to the inequality $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ - wavelength of at least one optical radiation fed into the nonlinear-optical waveguide,

the input / output elements are mounted relative to nonlinear-optical waveguide with precision provided by their positioning with use of luminescent radiation of the nonlinear-optical waveguide, the luminescent radiation is appeared when electrical current is passed through the nonlinear-optical waveguide,

the device in addition contains at least one Peltier element, one side of which is in thermal contact with the nonlinear-optical waveguide and with at least one sensor of temperature.

In the second variant of performance of the device for switching, amplification, controlling and modulation of optical radiation, comprising two nonlinear TCOWs, at least one of which is made on the basis of layered semiconductor structure such as MQW with alternating layers, containing at least two hetero-transition, and optical elements of an input/output located

accordingly at the input and/or the output of at least one of nonlinear TCOWs, the put task is solved by that

nonlinear TCOWs are made as cubic and/or quadratic-nonlinear,

at least one nonlinear-optical waveguide is supplied with contacts for passage of electrical
5 current through it,

wavelength of one-photon and/or two-photon exciton resonance λ_r of the semiconductor structure of at least one nonlinear-optical waveguide satisfies to the inequality $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ is the wavelength of at least one optical radiation fed into the nonlinear TCOWs,

the input / output elements are mounted relative to nonlinear-optical waveguides with
10 precision provided by their positioning with use of luminescent radiation of nonlinear-optical waveguides, arising when electrical current is passed through them,

the device in addition contains at least one Peltier element, one side of which is in thermal contact with at least one nonlinear-optical waveguide and with at least one sensor of temperature,

15 a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least 10% of power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for the switching or transfer of at least 10% of the power from one of said nonlinear
20 tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 20 or less.

In more preferable embodiment a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least
25 50% of power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for the switching or transfer of at least 50% of the power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which the power of
30 the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

As a rule, at least one sensor of temperature and at least one Peltier element are electrically connected to a regulator of temperature and/or to the stabilizer of temperature.

As a rule the end faces of nonlinear-optical waveguide(s) have AR- coatings.

In particular, the AR- coatings at ends of nonlinear-optical waveguide are made decreasing the reflection factor of optical radiation from input and/or output ends up to value no more than 1 %.

5 As a rule, the device contains a source of current (which usually made as a controller and stabilizer of the current) connected to electrical contacts of the nonlinear-optical waveguide; in particular, the source of current is a source of constant current supplying the electrical current across the nonlinear-optical waveguide with values from 0,5mA to 10mA in operation, thereto the current spread from an average value in time does not exceed 0,1mA

10 In that specific case, with the purpose to control the gain (in particular, for rejection from noise and jamming in optic communication lines) the source of constant current is supplied with the high-speed switch.

In other special case after the separator of UDCWs at the output of the device a correlator of optical waves and/or differential amplifier are set.

15 In particular cases, aforesaid semiconductor MQW-type structure is made as alternating layers $GaAs / Al_xGa_{1-x}As$, or $In_xGa_{1-x}As / InP$, or $In_{1-x}Ga_xAs_yP_{1-y} / In_{1-x'}Ga_{x'}As_{y'}P_{1-y'}$, where $x \neq x'$ and/or $y \neq y'$, or $CdSe_{1-x}S_x / CdSe$ or $InAs_{1-x}Sb_x / InAs$, or $PbS_xSe_{1-x} / PbSe$, or Ge_xSi_{1-x} / Si or alternating layers of other semiconductor materials.

In case of using TCOWs, as a rule, they make both nonlinear TCOWs on the basis of 20 united semiconductor layered MQW-type structure with alternating layers.

In special cases, when the device is used for switching, amplification, controlling and modulation of optical radiation the separator of the UDCWs at the output of the device is made as the separator of waves with various polarizations; under this before the nonlinear-optical waveguide the polarizer can be mounted.

25 The function of a polarizer can be carried out by an optical isolator mounted before the input of the nonlinear-optical waveguide; the optical isolator also eliminates return influence of radiation reflected from waveguides ends and other optical elements, on the source of optical radiation or other optical elements placed before the nonlinear-optical waveguide. In particular the optical isolator is made as a waveguide optical isolator, e.g., as a fiber-optic isolator.

30 In the specified cases the separator of waves of various polarizations and/or the polarizer, mounted before the nonlinear-optical waveguide or nonlinear TCOWs, is made as a polaroid, or

a polarizing prism, or a birefringent prism, or a directional coupler, separating waves of different polarizations, or a polarizer on the basis of a single optical waveguide.

The function of the separator of optical waves with various polarizations can be carried out by the nonlinear-optical waveguide as such, or the optical isolator mounted after the output of the nonlinear-optical waveguide; in the latter case the influence of the reflected radiation on the nonlinear-optical waveguide is eliminated. In particular the optical isolator is made as a waveguide optical isolator, e.g., a fiber-optic isolator.

In special cases, when the optical radiation of various wavelengths is used, the separator of the UDCWs at the output of the device is made as the separator of waves of various wavelengths.

In this case the separator of waves of various wavelengths is made as an dispersive element, or a frequency filter, or a directional coupler.

In special cases, when the optical radiation of various optical waveguide modes is used, the separator is made as diaphragm for separation of the various waveguide modes or as the waveguide separator of the modes.

In case of use of the nonlinear TCOWs, as a rule, the TCOWs as such operate as the separator of coupled waves in the neighboring waveguides: one of UDCWs leaves the zero waveguide, and another wave leaves the first waveguide.

Sometimes, the nonlinear TCOWs can be made as TCOWs separating of radiation of various polarizations and/or of various wavelengths and/or of various waveguide modes at the output of the device.

To provide a possibility of orientation of "fast" and "slow" axes of the nonlinear-optical waveguide relative to a vector of an electrical field of the linearly polarized optical radiation or axes of an ellipse of polarization of optical radiation, the semiconductor laser and/or laser module, and/or nonlinear-optical waveguide with optical elements for input and output of radiation, and/or the separator of the UDCWs at the output of the device, and/or the polarizer, mounted at the input of the nonlinear-optical waveguide, and/or the optical isolator are connected among themselves by fiber-optic sockets and fiber-optic connectors ensuring an opportunity of turn of mentioned elements relative to each other around of the optical axis of the device. Under this the optical isolator is made as a waveguide optical isolator, as a rule, in the form of a fiber-optic isolator.

As a rule, the nonlinear-optical waveguide is oriented relative to a vector of polarization of optical radiation entered the nonlinear-optical waveguide, in such way that the vectors of an

electrical field of the linearly polarized optical radiation entered the nonlinear-optical waveguide, or axis of an ellipse of polarization of the elliptically polarized optical radiation entered nonlinear-optical waveguide, are set at an angle of $10^\circ < \alpha < 80^\circ$ to the "«fast" and/or «slow» axes in the birefringent nonlinear-optical waveguide; in specific case - at an angle of $40^\circ < \alpha < 50^\circ$; in particular - at an angle of 45° ; In the other special case the nonlinear-optical waveguide is oriented relative to a vector of polarization of optical radiation entered the nonlinear-optical waveguide, in such a way that the vectors of an electrical field of the linearly polarized optical radiation entered the nonlinear-optical waveguide, or axis of an ellipse of polarization of the elliptically polarized optical radiation entered the nonlinear-optical waveguide, are directed at an angle $-10^\circ < \alpha < 10^\circ$ to «fast» and/or to «slow» axes of the nonlinear-optical waveguide, in particular, the vector of an electrical field of the linearly polarized optical radiation entered the nonlinear-optical waveguide, or axis of an ellipse of polarization of the elliptically polarized optical radiation entered nonlinear-optical waveguide, coincides with the «fast» and/or by a «slow» axis of the nonlinear-optical waveguide.

In particular, the opportunity of relative turn of elements provides use of fiber-optic sockets and connectors such as FC/PC.

Let us mention that if UDCWs are UDCWs having orthogonal polarizations, then an angle position of separator, which in this case is made as polarizer (e.g. polaroid), determines (chooses) two UDCWs, which are under consideration. So the opportunity of relative turn (or rotation) of the separator relative to the nonlinear-optical waveguide should be provided. It can be supplied by use of the fiber-optic sockets and connectors such as FC/PC.

In specific case, for a possibility of input into the nonlinear-optical waveguide of two and more optical radiations (pump optical radiation and at least one signal optical radiation) the input waveguide is made as at least one Y-mixer or directional coupler.

Thus for a possibility of modulation of optical radiation by an electrical current on the basis of Faraday effect one input branch of the optical waveguide mixer is made from magneto-optic material and is surrounded by solenoid, or is made as electrooptical rotator of a plane of polarization.

In the other special case the device in addition contains the mixer of pump optical radiation and at least one signal optical radiation mounted at the input of the device; in particular, the mixer is made as waveguide mixer, which output branch is the input waveguide.

As a rule, the elements of input and/or output are connected with the nonlinear-optical waveguide by glue, or by splice, or by welding, or by soldering, or by means of tiny mechanical connector.

For setting the given difference in phases of the UDCWs at the input and/or at the output of the nonlinear-optical waveguide before and/or after the nonlinear-optical waveguide the phase compensator, or phase controller is mounted; in particular, the phase compensator or phase controller is made as an optical waveguide.

As a rule, the device in addition contains at least one semiconductor laser and/or the laser module with modulated output power of radiation, and/or the laser module as a source of pump optical radiation, which power exceeds threshold power, semiconductor laser and/or the laser module with modulated output radiation power; under this the semiconductor laser and/or the laser module is mounted relative to the nonlinear-optical waveguide with precision provided by its positioning by luminescent emission of the nonlinear-optical waveguide, arising at passing electrical current across it, and/or by the control of change of optical radiation power, transmitted through the nonlinear-optical waveguide at switching on and/or switching off the electrical current (with a value less than that required for the positioning) carried across it; in particular, they use the semiconductor laser and/or the laser module with spectrum-line width not exceeding $20\text{\AA}$.

Under this the semiconductor laser and/or the laser module is connected with at least one nonlinear-optical waveguide by means of an input element made as an input waveguide.

For stabilization of radiation wavelength (i.e. frequency) and/or for obtaining one-frequency mode of generation the semiconductor laser and/or the laser module is made with the external resonator and/or includes a dispersive element.

In specific case, in quality of at least one mirror of the external resonator they use periodic grating representing partially or completely reflecting Bragg reflector.

In particular, the said mirror of the external resonator (of the semiconductor laser and/or laser module including the semiconductor laser and optical waveguide) is made as a periodic grating of refractive index in the optical waveguide made in the form of fiber-optic waveguide contiguous to the laser; or the said mirror is made as a corrugation on surface of optical waveguide contiguous to the laser.

In the other special case the dispersive element is made as a diffracted grating.

For decrease of threshold radiation intensity and elimination of influence of external temperature actions the device additionally contains at least one Peltier element, one side of

which is in thermal contact with the nonlinear-optical waveguide and with at least one temperature sensor.

Under this at least one sensor of temperature and at least one Peltier element are electrically connected to temperature controller (driver) and/or to the stabilizer of temperature.

5 Under this in the quality of the sensor of temperature they use a thermistor, and/or a thermocouple, and/or a sensor in the form of integrated circuit.

In specific case the device contains a radiator for heat rejection taking place in thermal contact with one («hot») side of Peltier element .

10 For elimination of influence of external temperature actions the radiating semiconductor structure of laser is additionally supplied with at least one thermoelectric Peltier element, a side of which is in thermal contact with the radiating semiconductor structure and with at least one sensor of temperature, thereto at least one sensor of temperature and at least one thermoelectric Peltier element are electrically connected with controller and/or stabilizer of temperature

15 The device for switching, amplification, controlling and modulation of optical radiation is easily united with similar devices, i.e. it is easily «cloning»; for this purpose it in addition contains at least one device similar to the first one, and at least one input element of each subsequent device is connected optically with at least one output element of the previous device.

20 Under this in specific case the input/output elements of the located consistently devices are made as the united optical waveguide or as joined optical waveguides.

In the third variant of the device for switching, amplification, controlling and modulation of optical radiation containing at least one nonlinear-optical waveguide, made on the basis of layered nonlinear-optical semiconductor MQW-type structure with alternating layers containing at least two hetero-transition , and the device is made with an opportunity of propagation in the
25 nonlinear-optical waveguide at least two opposite-directional coupled waves, the put task is solved by that

nonlinear-optical waveguides are quadratic- and/or cubic- nonlinear,

at least one nonlinear-optical waveguide is supplied with contacts for passage of an electrical current through them,

30 wavelength λ_r of one-photon and/or two-photon exciton resonance in the said semiconductor structure of at least one nonlinear-optical waveguide satisfies to the inequality $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ is wavelength of the optical radiation,

the elements of input and/or output are mounted relative to the nonlinear-optical waveguide(s) with precision provided by their positioning by luminescent emission of the nonlinear-optical waveguide(s), arising at passing the electrical current through it (them),

the device in addition contains at least one Peltier element, one side of which is in thermal contact with at least one nonlinear-optical waveguide and with at least one sensor of temperature.

In particular cases, the semiconductor structure is made as alternating layers $GaAs / Al_xGa_{1-x}As$, or $In_xGa_{1-x}As / InP$, or $In_{1-x}Ga_xAs_yP_{1-y} / In_{1-x}Ga_xAs_yP_{1-y}$, where $x \neq x'$ and/or $y \neq y'$, or $CdSe_{1-x}S_x / CdSe$ or $InAs_{1-x}Sb_x / InAs$, or $PbS_xSe_{1-x} / PbSe$, or Ge_xSi_{1-x} / Si or alternating layers of other semiconductor materials.

In special cases as the sensor of temperature they use a thermistor, and/or a thermocouple, and/or the sensor as the integrated circuit.

As a rule, at least one sensor and at least one Peltier element are electrically connected to temperature controller (regulator) and/or the stabilizer of temperature.

In specific case the device contains a radiator for heat rejection placed in thermal contact with at least one Peltier element.

As a rule, the device in addition contains the electrical current source, electrically connected with the electrical contacts of the nonlinear-optical waveguide.

As a rule, a current through the nonlinear-optical waveguide pass in the direction, perpendicular the layers of said semiconductor structure.

As a rule, the electrical current source is the precision constant current source providing the electrical current across the nonlinear-optical waveguide in operation (in service) with values from 0,5mA to 10mA, thereto the current spread from an average value in time does not exceed 0,1mA.

As a rule, the contacts for passage of an electrical current through nonlinear-optical waveguide are electrically connected to the driver (regulator, controller) and/or by the stabilizer of the current.

In special cases, the device additionally contains at least one semiconductor laser and/or the laser module with modulated output power of radiation, and/or the laser module as a source of pump optical radiation, which power exceeds threshold power, semiconductor laser and/or the laser module with modulated output radiation power; under this the semiconductor laser and/or the laser module is mounted relative to the nonlinear-optical waveguide with precision

provided by its positioning (adjustment) by luminescent emission of the nonlinear-optical waveguide, arising at passing electrical current across it, and/or by the control (check) of change of optical radiation power, transmitted through the nonlinear-optical waveguide at switching on and/or switching off the electrical current (with a value less than that required for the positioning) carried across it; in particular, they use the semiconductor laser and/or the laser module with spectrum-line width not exceeding $20\text{\AA}$

For exception of temperature influences and for stabilization of frequency of the laser radiation, the radiating semiconductor structure of the laser and/or of the laser module is in addition supplied with at least one Peltier element, one side of which is in thermal contact with radiating laser semiconductor structure and with at least one sensor of temperature, thereto at least one sensor of temperature and at least one Peltier element are electrically connected to temperature controller and/or stabilizer of temperature.

In special cases the semiconductor laser and/or laser module is used with spectrum-line width of radiation, which is not more than $20\text{\AA}$.

For stabilization of wavelength of radiation and/or maintenance of one-frequency mode of generation, the semiconductor laser and/or laser module is made with the external resonator and/or includes a dispersive element.

In specific case, in quality of at least one mirror of the external resonator they use periodic grating representing partially or completely reflecting Bragg reflector.

In particular, the mirror of the external resonator of the semiconductor laser and/or of the laser module including the semiconductor laser and waveguide, is made as a periodic grating of refraction index contiguous to the laser waveguide, made as a fiber-optic waveguide, or as a corrugation on a surface of optical waveguide, contiguous to the laser.

In one special case at ends of the nonlinear-optical waveguide the mirrors are made with formation of Fabry-Perot element.

In particular, the mirrors are made by means of natural cleave, or by coating reflected coatings, or as periodic gratings representing Bragg reflectors.

In the other special case in the nonlinear-optical waveguide the periodic grating with formation of an optical bistable element with the distributed feedback is made.

In special cases the nonlinear-optical waveguide is birefringent and/or magneto-optic and/or electrooptical and/or acousto-optic.

In the third special case the device in addition contains the second nonlinear-optical waveguide, and the both nonlinear waveguides are TCOWs.

In one special case to increase the radiation input/output efficiency the input and/or output elements are made as objectives consisting from cylindrical lens and/or gradan; as a rule, the surfaces of the cylindrical lenses and/or gradans are antireflection coated.

In the other special case the elements of input and/or output are made as input and/or output waveguides; as a rule, on output and/or input face of the said input and/or output optical waveguide the cylindrical lens and/or parabolic lens and/or conic lens is formed and/or gradan is mounted; as a rule, the input and/or output faces of the said optical waveguides and/or gradans are antireflection coated.

In special cases the semiconductor laser is connected to at least one nonlinear-optical waveguide by means of an input element with formation of united optical waveguide.

The put task is solved also in the method of assembly of the nonlinear-optical module comprising positioning, mounting and connection of at least one nonlinear-optical waveguide, made on the basis of layered nonlinear-optical semiconductor structure such as MQW with alternating layers containing at least two hetero-transition, and input and/or output elements for input and/or output of optical radiation, and comprising the mounting and positioning of elements of input and/or output relative to the nonlinear-optical waveguide, and mounting and positioning of the input and/or output elements relative to the nonlinear-optical waveguide, supplied by contacts for passage of an electrical current through the nonlinear-optical waveguide is carried out by luminescent radiation of the nonlinear-optical waveguide, arising at passing electrical current through it. The nonlinear-optical module comprises at least one nonlinear-optical waveguide and input/output elements.

In special cases they additionally mount the semiconductor laser or the laser module at least at one input of the nonlinear-optical module, they position (adjust) and connect the laser or the laser module with the nonlinear-optical module, and under this the positioning of the laser or the laser module is carried out by change of a mutual position of the laser or laser module and the nonlinear-optical module up until coincidence of the laser or of the laser module radiation beam and the luminescent radiation beam of the nonlinear-optical waveguide, when the said luminescent radiation beam arising by passing the electrical current across the nonlinear-optical waveguide; the said coincidence must take place before and/or after the nonlinear-optical module.

When carrying out the positioning (adjustment) they pass the current, as a rule, more than 30 mA across the nonlinear-optical waveguide.

As a rule, they additionally supervise the precision of positioning of the laser or laser-module relative to the nonlinear-optical module by comparison of power of optical radiation of the laser or of the laser module transmitted through the nonlinear-optical module at absence of the electrical current across the nonlinear-optical waveguide and at passing of the current across it; under the said control they usually use the current by the order of magnitude less than the current providing the aforesaid luminescent radiation of the nonlinear-optical waveguide.

Under this they pass the current, as a rule, from 1 up to 10mA across the nonlinear-optical waveguide.

At association of several optical modules (so called «cloning») they additionally position and mount the other (i.e. the second) similar nonlinear-optical module at output of the first nonlinear-optical module, thereto the second similar nonlinear-optical module is adjusted relative to the first nonlinear-optical module by means of luminescent radiation of the nonlinear-optical waveguide of the first and/or the second nonlinear-optical module, arisen under carrying electrical current across the nonlinear-optical waveguide.

Under this they additionally control (supervise) precision of positioning and mounting of the second nonlinear-optical module relative to the first nonlinear-optical module by comparison of power of optical radiation of the laser and/or of the laser module and/or of the first nonlinear-optical module transmitted through the second nonlinear-optical module at absence of the electrical current across the nonlinear-optical waveguide of the second nonlinear-optical module and at passing the current across it .

At assembling, as a rule, the optical elements of the nonlinear-optical module and the nonlinear-optical modules are connected by means of fiber-optic connectors with physical contact, optical fiber sockets, connecting sockets, splices. Optical isolators in the form of optical waveguides, usually as fiber-optic isolators can be placed between the optical elements, and/or before the nonlinear-optical module input, and/or after its output and/or between the nonlinear-optical modules.

The put task is solved also in the device of processing of optical signals including at least two optical modules, each of which contains one or two nonlinear-optical waveguide(s), made on the basis of layered semiconductor MQW-type structure with alternating layers containing at least two hetero-transition, and nonlinear-optical waveguide made with an opportunity of propagation of two UDCWs in it, and the outputs and inputs of the optical modules are connected among themselves in the circuit appropriate to the function of processing of the optical signal, thereto the nonlinear-optical waveguide are supplied with electrical contacts for

passage of the electrical current through them, the outputs and inputs of the previous and subsequent of optical modules are mounted relative to each other with precision provided by their positioning with use luminescent radiation of the nonlinear-optical waveguide of the previous and/or subsequent nonlinear-optical module, arising at passing the electrical current through the said nonlinear-optical waveguide.

As a rule, the output/ input elements of optical modules, appropriate outputs and inputs of which are optically connected, are made as optical waveguides and are connected by splice or by optical connectors.

Brief Description of the Drawings

The present inventions is illustrated by the following drawings, wherein:

FIG.1 shows a cross-sectional view of the strip birefringent nonlinear-optical waveguide (1) of ridge-type made on the basis of the semiconductor layered MQW-type structure, e.g., such as $GaAl / Ga_{1-x}Al_xAs$; with electrical contacts (2,3).

FIG.2 is a cross-sectional view of the nonlinear tunnel coupled optical waveguides, of ridge-type made on the basis of the semiconductor layered MQW-type structure, e.g., such as $GaAl / Ga_{1-x}Al_xAs$; with electrical contacts (2,3).

FIG.3 shows a distribution of the effective refractive index in a cross-section of the birefringent nonlinear-optical waveguide and orientation of vectors of polarization X, Y relative to the «fast» and «slow» axes X', Y' of the birefringent nonlinear-optical waveguide.

FIG.4 shows a typical dependence of the radiation power transmission coefficient of one of UDCWs (with linear distributive coupling) through the nonlinear-optical waveguide (or nonlinear TCOWs) on the input power. Vertical lines correspond to the threshold power and the critical power.

FIG.5 is the schematic view of a device for carrying into effect the proposed method of switching optical radiation, based on the nonlinear-optical waveguide(s) (1).

FIG.6 shows schematic views of variants of the device with single nonlinear-optical waveguide and objectives, made as a cylindrical lens (10) and a gradan (11).

FIG.7 shows schematically a device with use of Faradey optical sell.

FIG.8 shows schematic views of variants of the device as united module comprising the single nonlinear-optical waveguide and input and output optical waveguides.

FIG.9. shows schematic views of variants of the device with inputs for two signal optical radiations.

FIG.10. shows schematic views of variants of the device on the basis of nonlinear TCOWs with objectives, made as a cylindrical lens and a gradan.

FIG.11. shows schematic views of variants of the device on the basis of the nonlinear TCOWs with input and output optical waveguides. It can operate as small signal amplifier (e.g., as re-translator in fiber-optic communications), or as a device processing optical signals (e.g., as an optic logical scheme).

FIG.12. shows schematic views of variants of the device on the basis of quadratic nonlinear TCOWs, in which switching, amplification and modulation of UDCWs at different frequencies can occur.

FIG.13. represents constructive execution of the device in the form of air-path nonlinear-optical module (a, b, c, d) and all-waveguide nonlinear-optical module (e). Arrows show the direction of propagation of input and output optical radiation.

FIG.14 shows photos of oscilloscope screen, on which amplified signal is represented. The gain is about 100. Initial signal, having a form of square pulses (meander), because of its small amplitude, merges with a streak of a beam of the oscilloscope and so is not shown. «Supplementarity» between UDCWs having orthogonal polarizations is seen: the amplified signal meanders (at top and below) have different «polarities»; i.e. they are amplified in opposed phase.

FIG.15 also shows photo of oscilloscope screen, on which amplified signal is represented. The gain is about 100. Low-noise precision current source and temperature controller and stabilizer (for the nonlinear-optical waveguide and laser) are used. Unlike Fig.14, a polarizer and/or an optical isolator, mounted before the input of the nonlinear-optical waveguide, is used.

Fig. 16 shows gain in percentage modulation due to self-switching of the UDCWs having orthogonal polarizations in said nonlinear-optical waveguide (on the top), and absence of modulation without said nonlinear phenomenon (below). In both cases Faraday effect is.

FIG.17 shows control of differential gain by adjust of level of input average power of optical radiation fed into the nonlinear-optical waveguide, having small modulation before the input of the nonlinear-optical waveguide.

FIG.18 shows switching and controlling of ratio between UDCWs (after separation) having mutually orthogonal polarizations by adjusting of input average power of optical radiation fed into the nonlinear-optical waveguide, having small modulation before the input of the nonlinear-optical waveguide. «Polarity» (phase) of meander is inverted (a, b), whereas initial

laser optical signal (amplified by electronic means and seen at the above oscilloscope) does not invert the «polarity» (phase).

FIG.19 is a photo of the cross-sectional view of the nonlinear-optical waveguide 1. The photo is done by scanner electron microscope, and the distribution of Ga and Al in the direction perpendicular to the layers of the structure is shown. There is a slight localized peak of Ga in the area of the radiation-carrying layer, grown as the MQW structure such as $GaAl / Ga_{1-x}Al_xAs$. The nonlinear-optical waveguide 1 is made as a ridge waveguide. The top surface of the waveguide is coated by thin layer of Au, representing electric contact (electrode) (2), shown on Fig.1. For comparison of sizes there is vertical solid line which size is equal to $10 \mu m$.

FIG.20 is a view from the top on the nonlinear-optical waveguide; electrical contact plates for soldering of tiny wires (for carrying electrical current) are seen.

FIG.21 represents a photo of manufactured of the nonlinear-optical module operating as optical transistor. For comparison of sizes the Switzerland coin 5 Francs is shown.

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Modes for carrying out the invention

Unidirectional distributively coupled waves (UDCWs) are the whole class of waves in optics. We can divide UDCWs into two groups: with the linear coupling and nonlinear coupling. The UDCWs of the first (larger) group are: waves in TCOWs, waves with different (usually mutually orthogonal) polarizations in a birefringent, or magneto-active, or optically active optical waveguide, different waveguide modes in an in-homogeneous optical waveguide, transmitted and diffracted waves in a periodic structure, etc. In linear regime when the wave intensities are low and the nonlinearity of the medium in which they are travelling can be ignored, periodic exchange of power takes place between such waves as they propagate. Thus, if in linear regime one of the identical ($\alpha = \beta_1 - \beta_0 = 0$) UDCWs (with index «0») is fed into the input ($z = 0$), then at the output ($z = l$) we have $I_{0l}(L) = I_{00} \cos^2(L/2)$, $I_{1l}(L) = I_{00} \cos^2(L/2)$, where $L = 2\pi Kl / \lambda \beta$, and parameter L / π shows, roughly speaking, how many times the waves exchange power, K - coefficient of linear distributed coupling, l - length of distributed coupling of the waves, β - average effective refractive index of wave in optical waveguide, λ - wavelength.

The power transfer coefficient of radiation from one of UDCWs to another (by certain length $z = l$) and therefore transmission power coefficient $T_k = \frac{P_k}{\sum_k P_{k0}}$

through the optical waveguide (or through TCOW) by one of the UDCWs depends on the difference between the effective refractive indices of the waves (so called parameter $\alpha = \beta_1 - \beta_0$). The index «k» ($k=0,1..$) in the formula denotes number of the coupled wave and is explained below in detail.

So if refractive index of an optical waveguide or TCOWs, in which such waves propagate depends on intensity, i.e. the optical waveguide or the TCOWs is/are optically nonlinear, then optical power transfer coefficient of radiation from one of UDCWs to another (by certain length) and hence T_k as well depends on input optical radiation power (intensity). It means that nonlinear transmission of optical radiation power through the nonlinear-optical waveguide or nonlinear TCOWs takes place. In other words, the nonlinear-optical power transfer between the UDCWs occurs.

Theoretical estimations confirmed by experiments shows that not only the simple nonlinear-optical power transmission, but very interesting phenomenon of self-switching of UDCWs can occur if input intensities of waves is large enough and certain conditions are accomplished.

Under this phenomenon slight change in input intensity, phase or polarization causes much more change in output intensity; so it can be amplified in many times (as shown in Fig.4), e.g., in hundred times, without distortion. Therefore optical transistors may be created on the basis of such waves (A.A.Maier, "Optical transistors and bistable elements on the basis of nonlinear transmission of light in systems with unidirectional coupled waves", *Kvantovaya Elektron.* 9, pp.2296-2302 (1982). [*Sov. J. Quantum Electron.* v.12, 1490 (1982)]).

In the quality of nonlinear medium the semiconductor layered MQW-type structure, containing at least two hetero-transitions can be used (Fig.1). In the case of two hetero-transitions the semiconductor layered structure is also called SQW (single quantum well) structure.

The second group of the UDCWs includes waves of different frequencies in quadratic and cubic nonlinear-optical waveguide. If the waves of different frequencies in cubic-nonlinear-optical waveguide are considered then we mean waves in unidirectional four-waves interaction or waves in unidirectional third harmonic generation. If the waves of different frequencies in

quadratic-nonlinear-optical waveguide are considered, then we mean unidirectional coupled waves under three-waves interaction when $\omega_1 + \omega_2 = \omega_3$; in first place we mean the unidirectional coupled waves under second harmonic generation, when $\omega_3 = 2\omega$, $\omega_1 = \omega_2 = \omega$.

UDCWs of orthogonal polarizations and UDCWs of different waveguide modes can have both linear and nonlinear distributed coupling.

Another class of coupled waves are the opposite-directional coupled waves includes: waves in Fabry-Perot resonator; transmitted and reflected waves in optical waveguide with distributed coupling by periodic structure, e.g., in the form of the grating; waves of different frequencies in opposite-directional four-frequency interaction. Under interaction of such waves in cubic-nonlinear medium optical bistable elements are realized.

The method of switching in the most interesting and perspective variants is based on nonlinear interaction of UDCWs (with linear and/or nonlinear coupling, including interaction of the waves of different frequencies and polarizations).

Besides, it includes a variant, based on interaction of opposite-directional coupled waves, namely based on an optical bistability of the nonlinear-optical waveguide(s) with: a distributed feedback, or a Fabry-Perot resonator, or a opposite-directional four-wave interaction. In the case of opposite-directional coupled waves a power switching between counter directional coupled waves takes place.

The method is carrying into effect due to sharp redistribution of power between the coupled waves in a nonlinear-optical waveguide or in nonlinear TCOWs. In one of variants of the method a pump optical radiation and a signal optical radiation are fed into the input of the nonlinear-optical waveguide. The signal optical radiation is a controlling and informative signal; the pump optical radiation is launched into at least one of the nonlinear-optical waveguide(s) in order to achieve nonlinear mode of operation, i.e. to achieve differential coefficient of amplification (gain) essentially more than unity. As a rule, a pump optical radiation power is larger than a signal optical radiation power at least by the order of magnitude. As a rule a signal optical radiation power is at least by order of magnitude less than a pump optical radiation power. However sometimes the powers of said optical radiations may have values of the same order of magnitude.

For UDCWs with linear distributed coupling coefficient K , a length of a nonlinear-optical waveguide (or nonlinear TCOWs) l is satisfied to inequalities $l \geq l_c \geq l_a$, $l \geq l_n \geq l_a$, where

$l_c = \frac{\lambda\beta}{2K}$ - a length, at which optical radiation power is transferred from one of UDCWs to

another one in linear regime; $l_a \approx \frac{\lambda}{\delta}$ - a length of attenuation (absorption), δ - attenuation coefficient of the most attenuated wave from the UDCWs; l_n - typical (characteristic) scale of nonlinear interaction, so called «nonlinear» length, at which nonlinear addition to refractive index causes phase change by order of $\pi/2$ (under $K = 0$). E.g., for TCOWs K - coefficient of tunnel coupling between the optical waveguides. For UDCWs of orthogonal polarizations in a birefringent optical waveguide $K \propto |\beta_e - \beta_o| \sin(2\vartheta)$, where ϑ is an angle between a vector of electrical field of radiation, launched into the optical waveguide and «fast» and/or «slow» axis of the waveguide, β_e и β_o - effective refractive indexes of waves polarized along «fast» and «slow» axis of the optical waveguide (in other words of ordinary and extraordinary waves).

- 10 For UDCWs having orthogonal polarizations in a birefringent optical waveguide, if electrical field vector of fed radiation is oriented at angle 45° to the «fast» and/or «slow» axis of the optical waveguide then $l_c \approx \frac{\lambda}{4|\beta_o - \beta_e|}$ is a length at which radiation power is transferred from a wave of one polarization to other wave of orthogonal polarization in linear regime. $l_a \approx \frac{\lambda}{\delta}$ - a length of the UDCWs attenuation, δ - maximum attenuation coefficient of the most attenuated wave from the UDCWs having orthogonal polarizations. As a rule, the attenuation is caused by absorption.

For cubic-nonlinear-optical waveguide $l_n \approx \frac{\lambda}{|\theta|I_p}$, θ - cubic-nonlinear coefficient of the

nonlinear-optical waveguide. For quadratic-nonlinear-optical waveguide $l_n \approx \frac{\lambda}{\chi\sqrt{I_p}}$, χ -

- quadratic-nonlinear coefficient of the nonlinear-optical waveguide. If $\ell_c \ll \ell_n$, then we have linear mode. If $\ell_c \gg \ell_n$, then power radiation transfer from a wave of one polarization to UDCWs of different (orthogonal) polarization is negligible and almost all power at the output remains in the wave of initial polarization. In the most interesting case when the switching takes place, «nonlinear» length $l_n \approx \frac{\lambda}{|\theta|I_p}$ equal to the length l_c of an energy transfer in linear regime; to realize this case the input radiation power is close or equal to so called critical intensity $I_M \approx \frac{4|\beta_o - \beta_e|}{|\theta|}$. In particular, if the wave with Y-polarization is the most attenuated,
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then $I_y(z) \equiv I_y(z=0) \exp(-z\delta/\lambda)$. If they fed optical radiation intensity closed to critical intensity into the nonlinear-optical waveguide, then $l \geq l_c \equiv l_n \geq l_a$.

Let us emphasize that in a laser and/or a «laser» amplifier the inverse inequality: $l \leq l_c \leq l_a$ takes place. This one of the principle features distinguishing our invention from the «laser» amplifiers.

For UDCWs with nonlinear coupling coefficient linear transfer may be absent. In this case «nonlinear» length is also typical length scale of power exchange between the UDCWs, so a length of the nonlinear-optical waveguide has to satisfy the inequality: $l \geq l_n \geq l_a$.

In other words, for carrying the proposed method into effect, it is necessary that in the nonlinear-optical waveguide or nonlinear TCOWs at least two coupled waves have possibility to propagate. As one of the coupled waves can have attenuation coefficient larger than another, the following condition must be accomplished: a length of the nonlinear-optical waveguide or nonlinear TCOWs, necessary for effective switching, must not exceed a length, at which a power of the most attenuated wave from the interacting coupled waves (e.g., having orthogonal polarizations) is attenuated in e^2 times. In this case a difference in attenuation for UDCWs, e.g., having different polarizations, may be caused not only by absorption anisotropy of the nonlinear-optical waveguide, but also by absorption anisotropy of metal film coated the surface of the semiconductor wafer in which the nonlinear-optical waveguide is, and thereto by absorption anisotropy of the semiconductor structure layers, having more high conductivity than other ones, and adjoining to the nonlinear-optical waveguide.

As experiments show, for noticeable differential gain it is necessary to switch or transfer at least 10% of radiation power from one wave to another coupled wave, due to that under small amplitude of signal optical radiation even transfer of 10% of power between the UDCWs can result in achievement of noticeable magnitude of differential gain of signal optical radiation at the output, and power of the most attenuated wave from the interacting coupled waves (e.g., having orthogonal polarizations) is attenuated in 20 times or less.

This value is by the order of magnitude less than a ratio of powers of two waves having mutually orthogonal polarizations in a semiconductor laser or laser module, where interaction of the waves having different orthogonal polarizations do not take place, and power exchange between these waves is absent.

In more preferable embodiment of the suggested method and device the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching

and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer at least 50% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

In even more preferable embodiment of the suggested method and device the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 80% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer at least 80% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated in 10 times.

The optical radiation switching, amplification, controlling and modulation are achieved by changing power transfer coefficient from one coupled wave to another in nonlinear-optical waveguide(s) firstly due to nonlinear changing of refractive index under changing of radiation intensity in the nonlinear-optical waveguide, and secondly due to dependence of coefficient of power transfer between the UDCWs on the difference in effective refractive indexes of the coupled waves. The more cubic- and/or quadratic- nonlinear coefficients of the nonlinear-optical waveguide (or waveguides) the less input intensity (power) necessary to reach the operation mode of the optical radiation switching, amplification, controlling and modulation.

So, for decreasing input power needed for the switching and amplification, the nonlinear-optical waveguide should be done on the basis of wafer semiconductor structure of the type of multiplicity of quantum wells (MQW) (as shown in Fig.1,2); and the wavelength of at least one optical radiation fed into the nonlinear-optical waveguide is need to be close to the wavelength λ_r of the resonance in said MQW-type structure.

This structure as a rule has birefringence, that is «fast» and «slow» axis exist and ellipsoid of effective refractive index in its cross section (Fig.3). The birefringence of said structure is another clue factor (besides high nonlinear coefficient) of such structure which allow

us to realize effective all-optical transistor on the basis of said structure, using self-switching of the UDCWs having orthogonal polarizations.

To avoid terminology confusion let us emphasize that the resonance in said MQW-type structure is meant to be one-photon exciton resonance or two-photon exciton resonance and/or
5 band-gap resonance, or half-band-gap resonance in said MQW-type structure. It is also can mean one-photon absorption resonance or two-photon absorption resonance.

In Claims in Disclosure of the Invention and in Modes for carrying out the invention we sometimes use terms: one-photon exciton resonance or two-photon exciton resonance. But if exciton resonance is absent or is not essential, then we can mean also band-gap resonance in said
10 MQW-type structure and half-band-gap resonance. It is also meant one-photon absorption resonance or two-photon absorption resonance.

In this case maximum of cubic- and/or quadratic- nonlinear coefficients of the waveguide is achieved. However it is very difficult technically to make the semiconductor structure for nonlinear-optical waveguide, having wavelength accurately equal to the predetermined
15 wavelength.

Under changing of temperature of the semiconductor structure of the nonlinear-optical waveguide, the wavelength of exciton resonance in the structure is changed, usually as 0,25-0,3 nm/grad. Thus, the requirement wavelength can be achieved by adjustment of temperature; after this achievement the temperature of the nonlinear-optical waveguide is stabilized to provide
20 stable operation of the suggested nonlinear-optical device in time. By means of up-to-date devices it is possible to obtain precision of temperature stabilization of order of 0,01°.

Besides achievement of maximum nonlinear coefficient of nonlinear-optical waveguide or waveguides it is possible to provide a larger sensitivity of switch and modulator to variation of input power of controlling signal optical radiation, than to variation of input power of pump
25 optical radiation. I.e. differential gain of a signal optical radiation is to be higher than differential amplification coefficient of a pump optical radiation. For that it is need to choose and install a difference between signal optical radiation wavelength and exciton resonance wavelength to be less than a difference between pump optical radiation wavelength and exciton resonance wavelength. Then nonlinear coefficient for signal optical radiation will be larger than that for
30 pump optical radiation and so variation of signal optical radiation amplitude will cause stronger influence on the ratio of powers of switched coupled waves at the output of the device than variation of pump optical radiation amplitude will do. I.e. the differential gain of signal optical radiation is larger than differential amplification factor of pump optical radiation.

To provide a nonlinear regime of operation a power (or intensity) of optical radiation fed into the nonlinear-optical waveguide or pump optical radiation power must exceed threshold power $P_{thr} = I_{thr} S_{eff}$, where S_{eff} is an area of effective section of the nonlinear-optical waveguide, I_{thr} - threshold intensity. Let us define threshold power as power of optical radiation, fed into the nonlinear-optical waveguide or into the nonlinear TCOWs, under exceeding of which at least one absolute value of at least one differential gain $\partial P_k / \partial P_{00}$, $\partial P_k / \partial P_{10}$, $\partial P_k / \partial P_{s0}$ exceeding 1,05 exists, where:

index $k=0,1,\dots$ - number of one of the coupled waves, participating in the switching; i.e. the waves between which optical power re-distribution occurs in the nonlinear-optical waveguide or in the nonlinear TCOWs; in the case of switching of the UDCWs having different polarizations, the index "k" is a number of the polarization; e.g., in the case of UDCWs of mutually orthogonal polarizations the index «0» denotes one linear polarization, and the index «1» denotes another linear polarization orthogonal to the first one; in the case of UDCWs with circular polarizations, the index "k" is a number of the clockwise and counterclockwise polarizations; in the case of power switching between UDCWs, having different frequencies, index "k" is a number of a frequency; in the case of the nonlinear TCOWs, the index "k" is a number of the nonlinear-optical waveguide because each wave from the interacting UDCWs propagates in its own waveguide; in the case of optical bistable element based on Fabry-Perot resonator and in the case of optical bistable element based on distributed feedback, the index "k" is a number of wave traveling in direct ($k=0$) and opposite ($k=1$) directions; in the case of UDCWs under Bragg diffraction in periodical structure or grating (in a planar optical waveguide), the index «k» is a number of transmitted wave ($k=0$) and diffracted wave ($k=1$); in the case of UDCWs as different optical waveguide modes k is a number of an optical waveguide mode.

l - index, taking into account, that intensity (or power) relates to radiation at the output of the nonlinear-optical waveguide; and letter l denotes a length of the nonlinear-optical waveguide or a length of nonlinear TCOWs, i.e. a value of power (intensity) at $z=l$ is considered;

second index 0 of I_{00} and I_{10} indicates that intensity is taken at the input of a nonlinear-optical waveguide (or nonlinear TCOWs), i.e. at $z=0$.

Index s denotes signal optical radiation at the input of the device, and $\partial P_k / \partial P_{s0}$ - differential gain of signal optical radiation.

If phase and/or frequency modulation takes place then P_{thr} can be defined from the condition $(\partial T_k / \partial \omega_{k0})_{nl} = 1,05 (\partial T_k / \partial \omega_{k0})_{lin}$, $(\partial T_k / \partial \varphi_{k0})_{nl} = 1,05 (\partial T_k / \partial \varphi_{k0})_{lin}$, indexes «nl» and «lin» denotes linear and nonlinear modes of operation. As a rule, aforesaid definitions are almost equivalent. For particular case P_{thr} is shown in Fig.4.

- 5 Let us now assume that input optical radiation power is predetermined and we consider the suggested device carrying out the suggested method into effect. Then to achieve effective operation of the suggested device under rather small predetermined input power, the sufficient large nonlinear coefficient of the nonlinear-optical waveguide is needed. To carrying the suggested device into effect under certain sufficiently small input radiation power the nonlinear
- 10 factor of the nonlinear-optical waveguide must be larger than the threshold value. This value depends on the linear wave-coupling coefficient and the input optical power fed into the nonlinear-optical waveguide. Usually it is proportional to the linear wave-coupling coefficient and to the input power fed into the nonlinear-optical waveguide. The threshold value of the nonlinear-optical coefficient can be defined as the value of the nonlinear coefficient of the
- 15 nonlinear-optical waveguide, under exceeding of which, at least one absolute value of at least one differential gain $\partial P_{kl} / \partial P_{00}$, $\partial P_{kl} / \partial P_{10}$, $\partial P_{kl} / \partial P_{30}$ exceeding 1,05 exists, where: $k=0,1,\dots$ - number of one of the coupled waves (defined above).

- If the device comprises nonlinear tunnel-coupled optical waveguides and its operation based on them, then nonlinear-optical coefficient of the nonlinear tunnel-coupled optical
- 20 waveguides is meant to be arithmetic average of nonlinear-optical coefficients of these nonlinear tunnel-coupled optical waveguides. Say, if two nonlinear tunnel-coupled optical waveguides having nonlinear coefficients θ_0 , θ_1 are used, then the nonlinear-optical coefficient of these nonlinear tunnel-coupled optical waveguides is $\theta = (\theta_0 + \theta_1) / 2$. The given above definition of the threshold value of the nonlinear-optical coefficient is applied both for quadratic and cubic
- 25 nonlinear-optical coefficients.

- Although the method may be carried into effect under exceeding the threshold power, the method is of the most interest in the vicinity of critical intensity I_M , corresponding to so-called middle point M of the optical self-switching. The critical intensity I_M may be defined as intensity at the nearest region of which the greatest differential gain is achieved and linearity of
- 30 signal amplification takes place. I.e. amplification of signal occurs without a distortion of a signal form (as shown in Fig.4). Thus all-optical transistor based on the suggested method of switching and amplifying can be created.

E.g., in the simplest case when radiation is fed into one of identical cubic-nonlinear-TCOWs critical intensity I_M is calculated by formula $I_M = 4K/|\theta|$, and differential gain at the middle point M is calculated by formula $\partial P_{01} / \partial P_{00} \approx -\partial P_{11} / \partial P_{00} \approx \exp(L) / 8$. For example, for the Fig.4 $L = 1,4\pi$ and at the point M we have $\partial I_{01} / \partial I_{00} \approx 10,16$. Similar formulas and characteristics describe the optical switching of other UDCWs in cubic nonlinear-optical waveguide, e.g., the switching of UDCWs of orthogonal or circular polarizations in birefringent or magnito-optical nonlinear-optical waveguide.

Effective switching is observed under feeding linear polarized radiation into a birefringent nonlinear-optical waveguide based on semiconductor layered MQW-type structure, if at input a vector of electrical field of fed radiation makes an angle of approximately 45 degrees with «fast» and/or «slow» axis of the nonlinear-optical waveguide.

In general case critical intensity (power) may be determined from the condition of $r = 1$, where r is a module of elliptical functions, through which powers of UDCWs are expressed at the output of the device (as shown in aforesaid papers).

As a rule the most differential gain is achieved when input power is close to critical power. In particular this situation takes place when only one from UDCWs is at the input of the nonlinear-optic waveguide, or the input power of one of the UDCWs is much greater than input power of another, thereto linear coupling between the UDCWs is essential then

In some important cases effective switching and obtaining large gain are possible under input radiation powers essentially larger or essentially smaller than critical power.

E.g., when there are two UDCWs with close input powers ($P_{00} \approx P_{10}$) and close phases at the input of the nonlinear-optical waveguide or at the input of TCOWs, then the sharp switching between the UDCW powers (at the output) takes place not only if input power close to critical power, but also if input power $P_{00} > 0,25P_M$; thereto the differential gain increases under increasing of P_{00} even if $P_{00} > P_M$. Note that in this under $P_{00} > 0,25P_M$ the condition $r = 1$ is also fulfilled, where r is a module of elliptical functions, through which powers of the UDCWs are expressed at the output of the device (as shown in aforesaid papers).

In other special case when at the input $P_{00} \approx 3P_M$, $P_{10} \approx P_M$, and the difference in input phases of the UDCWs equal to $\pm \pi / 2$ the effective switching also can take place and differential gain is much larger than unity.

Thus in some cases, the values of input optical radiation power essentially larger and essentially smaller than critical power can be also of practical interest for suggested switch and amplifier.

For UDCWs in cubic-nonlinear-optical waveguide or TCOWs I_{thr} and I_M are usually proportional to $K/|\theta|$, where θ is a cubic-nonlinear coefficient of the nonlinear-optical waveguide. E.g., in the case of UDCWs having different polarizations in the birefringent nonlinear-optical waveguide I_{thr} and I_M are proportional to $|\beta_e - \beta_o|/|\theta|$, thereto the critical intensity is larger than threshold intensity (as shown in Fig.4).

For UDCWs in quadratic-nonlinear waveguide or TCOWs I_{thr} and I_M are usually proportional to $K^2/|\chi|^2$, where χ is a quadratic-nonlinear coefficient of the nonlinear-optical waveguide.

Together with intensity I one can operate with power P , which is associate with intensity by single-valued ratio: $P = IS_{eff}$, where S_{eff} is an area of effective section of a nonlinear-optical waveguide. So let us say once more, that threshold intensity I_{thr} corresponds to threshold power P_{thr} , and critical intensity I_M corresponds to critical power $P_M = I_M S_{eff}$.

Estimations and experiments show that when pump optical radiation power achieving value larger than threshold power and a signal optical radiation parameter (e.g., power or phase or polarization) slightly varies, the optical power switching occurs from one UDCWs to another one (i.e. major change in the ratio between powers of different UDCWs at output of nonlinear waveguide or nonlinear TCOWs takes place) and at the output of the device amplified information optical signal is appeared. Due to said change in the ratio of intensities of the waves we can do modulation of the waves, i.e. carry some information into coherent optical radiation. Under this pump optical radiation and signal optical radiations can have both the same frequencies and polarizations and different frequencies (wavelengths) and polarizations.

Besides, signal optical radiation and pump optical radiation can be in the form as solitons or another ultrashort pulses (e.g., with shape close to rectangular).

In the case when frequency of signal optical radiation differs from frequency of pump optical radiation in cubic-nonlinear-optical waveguide or TCOWs, the pump optical radiation switching (at the output, from one of the UDCWs to another) is caused by a slight change in signal optical radiation power at input. Thus, one can do major transfer of high power radiation (of given frequency) at the output of a nonlinear device from one of UDCWs to another one (say, from one of TCOWs to another, or from wave of one polarization to another coupled

wave of different polarization), as a result of a small change in the power of weak radiation of different frequency. Under this a filtration of radiation is needed after the output of the nonlinear-optical waveguide or nonlinear TCOWs for separation out of amplified controlling or information signal at frequency of the pump. Said filtration can be done there where the remote receiver is placed.

Under three-frequencies interaction ($\omega_3 = \omega_1 + \omega_2$) in quadratic-nonlinear waveguide or TCOWs and under the certain conditions small variation of input signal power gives rise to an abrupt radiation switching from one frequency to another frequency. Pump optical radiation has one of said frequencies. In the wide-spread case of doubling and/or dividing frequency ($\omega_1 = \omega_2 = \omega, \omega_3 = 2\omega$) the pump optical radiation as a rule has frequency ω or 2ω whereas the signal optical radiation has frequency 2ω or ω correspondingly.

Phase-matching between waves at base (ω) and double (2ω) frequencies can be achieved by using of so-called «coupled waves» or «coupled modes» synchronism in TCOWs and in other systems with UDCWs (A.A.Maier «Coupled modes» phase matching and synchronous nonlinear wave interaction in coupled waveguides». (Kvantovaya Electron. vol.7, No.7, 1980, pp.1596-1598; *Sov.J.Quantum.Electron.* v.10, p.925 (1980)) and/or partially by birefringence of the nonlinear-optical waveguide. So quadratic-nonlinear TCOWs or one quadratic-nonlinear-optical waveguide with UDCWs gives good possibilities to switch optical radiation power from one frequency to another one.

Besides, in quadratic-nonlinear TCOWs (or in one quadratic-nonlinear-optical waveguide with UDCWs) under certain conditions optical radiation switching from one waveguide to another one (at the output of TCOWs) can take place, with high differential gain.

Thus, if TCOWs possesses sufficiently large quadratic nonlinearity, then the UDCWs may be both coupled waves in adjacent waveguides and the coupled waves of different frequencies.

The similar switching and amplifying are possible and for other UDCWs with linear distributed coupling coefficient if the UDCWs propagate in the quadratic-nonlinear-optical waveguide. For example, under certain conditions an optical radiation power switching from wave of one polarization to another of UDCWs of different polarization can take place. Under another conditions, optical radiation power switching from one frequency to another frequency can occur.

The speed of response characterizing the switching devices based on quadratic nonlinear waveguide or TCOWs is significantly higher (at least by an order of magnitude) than that for

analogous devices using the cubic nonlinearity of the optical waveguide(s) due to response time of quadratic nonlinearity is significantly less.

For increasing birefringence of the layered structure with the aim of increasing of efficiency frequency conversion and switching due to improvement of the phase matching
5 between waves of different frequencies one can use layered structure GaAs/AlAs; under this for increasing birefringence of the structure AlAs may be transform (convert) to oxide having significantly less refractive index.

Synchronism can be achieved by periodical modulation of nonlinearity and/or effective refractive index of a nonlinear-optical waveguide. Synchronism can be also achieved by
10 interaction of modes of different orders having different frequencies.

Temperature, electrooptical or mechanical adjustment (tuning) into phase-matching condition can be also applied. In particular case the temperature tuning into phase-matching condition is done by Peltier element and/or sensor of temperature, which are electrically connected to a controller and/or stabilizer of the temperature.

To put the method into effect a separation of UDCWs after the output of the nonlinear-optical waveguide or TCOWs is needed. TCOWs themselves usually separate the waves at their output. In one nonlinear-optical waveguide the separation is done by the separator of the waves. For UDCWs of different polarizations the separation is usually done by a polarizer. Sometimes the nonlinear-optical waveguide can operate as the separator, if attenuation of wave of one
15 polarization is much more than that of another polarization.

As a rule, the optical radiation switching and modulation are run into effect by variation of input signal optical radiation power or phase.

Besides, the optical radiation switching and modulation can be run into effect by variation of input signal optical radiation polarization or frequency. It is revealed by estimations and
25 experiments and, in particular, may be explained by following.

Power transfer coefficient from one of the UDCWs to another depends on distributed coupling coefficient of the UDCWs. The distributed coupling coefficient usually depends on frequency and polarization of the UDCWs. For instance, under change of the polarization of the input optical radiation the angle between field vector and axis of refractive index ellipse in cross
30 section of the nonlinear-optical waveguide (i.e. «fast» or «slow» axis, which as a rule, coincide with plane of layers of the MQW-type structure or is perpendicular to it) the change of refractive index of the nonlinear-optical waveguide takes place and this in turn gives rise to change of tunnel-coupling coefficient

Besides, the optical radiation switching and modulation can be run into effect by changing - of electrical or magnetic field applied to the nonlinear-optical waveguide due to change in difference of refractive indexes of the nonlinear-optical waveguide (or TCOWs).

We can switch, amplify and modulate optical radiation by modulation of input signal
5 polarization caused by variable electric current due to Faraday effect.

To switch, to amplify and to modulate optical radiation is also possible by modulation of a vector of polarization under action of an electrical current. For this purpose the Faraday effect is used. At passing through the solenoid surrounding the input waveguide, variable electrical current, change of which corresponds to a useful variable signal (analog or digital), the
10 orientation of a vector of an electrical field relative to layers of the MQW-type structure at the output of the Faraday cell changes. So the vector of an electrical field changes accordingly at the input of the nonlinear-optical waveguide, made on a basis of the MQW-type structure. These changes of the vector of an electrical field result in change of input amplitudes of UDCWs at the input of the nonlinear-optical waveguide (and sometimes in coefficient of the
15 distributed coupling between the UDCWs in the nonlinear-optical waveguide). According to the estimations and experiment (Fig.16) this gives rise to the sharp switching of the UDCWs and the amplifying the signal at the output of the device.

As a rule, in the quality of a source of optical radiation fed into the nonlinear-optical waveguide, the semiconductor laser (laser diode) or semiconductor laser module is used. To
20 change of a wavelength of radiation of the laser it is possible changing temperature of radiating semiconductor structure of the laser with the help of change of a current through an Peltier element, which is in thermal contact to semiconductor structure of the laser. Thus, it is possible precisely to be adjusted on wavelength of an exciton resonance of semiconductor structure of the nonlinear-optical waveguide or nonlinear TCOWs, thus reaching recordly high nonlinear factors
25 waveguide and, hence, of recordly small threshold powers; or to choose required threshold and critical power. Other way of change of wavelength of radiation of the laser - by mechanical compression and stretching fiber-optic waveguide (optically connected with the laser), in which a mirror of the external resonator of the laser is made in the form of a periodically varied refractive index of the waveguide .

30 Analytical, numerical accounts and the experiments show, that the switching of power of radiation between UDCWs at the output of the nonlinear-optical waveguide or nonlinear TCOWs can be reached also by change of a phase of signal optical radiation (for brevity sometimes named by a signal) at the input of the nonlinear-optical waveguide (or phase of pump

optical radiation). In this case the signal power as a rule does not vary. The strong influence of a phase on redistribution of power between UDCWs is caused by interference of a signal and pump optical radiations at the input and by dependence of resulting intensity on the input difference in phases of a signal and pump.

5 The method of switching, amplification and modulation can be carried out also by small modulation of one beam of enough powerful radiation (with average power above threshold). In this case modulating parameter is the intensity of radiation, either frequency of radiation, or its polarization. In case of change of intensity, the switching is reached due to change of an effective refractive index of a wave in nonlinear-optical waveguide; in case of modulation of
10 frequency or polarization of radiation - due to change of factor of the distributed coupling of the UDCWs in the nonlinear-optical waveguide or nonlinear TCOWs, and also due to change of a difference of effective refractive indexes of the UDCWs.

At change of temperature of said semiconductor layered structure of the nonlinear-optical waveguide it is possible to be adjusted at any predetermined section of the characteristic (Fig.4),
15 and thus, to choose required mode of operations (switching, amplification, controlling or modulation). For example, it is possible to be adjusted to middle of the linear section of the characteristic corresponding to critical intensity. For logic devices or other controlling elements other section of the characteristic, for example, point M_0, M_1 (Fig.4) can be chosen, where differential factor is equal to zero, but the submission of small logic signals can change
20 transmission coefficient of each of UDCWs from value close to zero, up to value close to unit (logic "0" и "1"). For maintenance of steady mode of operations of the device the temperature of the nonlinear-optical waveguide or nonlinear TCOWs is stabilized (as a rule, with precision about $0.01^\circ C$; in some cases this precision can be reduced or it is necessary to increase) by Peltier element (Fig.5,13) or by thermostat.

25 The same adjustment in the predetermined mode of operation (with predetermined differential gain (Fig.17)) can be reached by a choice of average power of continuous optical radiation or peak power of pulse radiation fed into the nonlinear-optical waveguide, and in case of feeding of signal optical radiation and pump optical radiation into the nonlinear-optical waveguide(s) - by choice of power of pump optical radiation.

30 The switching also can be carried out with use of several independent signal optical radiations, in each of which the same parameter is changeable. The choice of ratio between powers P_{s0} of the signal optical radiations and the width of a section of amplification of a

characteristic $T_k(P_{s0})$ (Fig.4) determines a mode of switching ("AND" or "OR"). This choice can be carried out due to choice of temperature of said semiconductor structure of the nonlinear waveguide or the nonlinear TCOWs and/or temperature of radiating semiconductor structure of the laser or laser module. For a logic element "AND" peak power of signal optical radiations and width of a section of amplification (Fig.4) are chosen in such a way that the switching occurs only in case of presence of several signal optical radiations at the input of nonlinear-optical waveguide(s) simultaneously. The switching in a mode "OR" is carried out for each of the signal optical radiations which have arrived at the input of nonlinear-optical waveguide(s), that also is reached by a choice of ratio between power of signal optical radiations and the width of the section of amplification.

The control element can carry out also functions of the stabilizer, i.e. device reducing noise on an input. Thus the section of the characteristic gets out, at which differential factor of amplification is close to zero (points M_0 and M_1 (shown in Fig.4)).

As a rule, the wavelength of radiation is picked out to be close to the wavelength of one photon exciton and/or of the two-photon exciton resonance in said semiconductor structure, thereto under this the cubic and quadratic nonlinear factor of the nonlinear waveguide is maximal, and, hence, the switching of the coupled waves is provided at the least threshold and critical powers. The choice of value of deviation of optical radiation wavelength from the exciton resonance wavelength is connected to the predetermined value of nonlinear-optical waveguide coefficient. However absorption of radiation on the exciton resonance wavelength is very large. Therefore across the nonlinear-optical waveguide the electrical current is passed; the current decreases the absorption near resonance area. Due to the current passing, the populations of the top and bottom energy levels in semiconductor structure of nonlinear-optical waveguide are approached to each other, and the absorption decreases, and, thus, critical intensity and threshold intensity in the nonlinear-optical waveguide is sharply reduced.

In the method of switching, amplification, controlling and modulation the stabilization of critical power and differential gain is carried out by adjusting and stabilization of temperature of nonlinear-optical waveguide(s).

The method can also ensure larger sensitivity of the switch and modulator to power change of the signal optical radiation, than to power change of pump optical radiation. For this purpose it is necessary to set the difference of wavelengths of radiation of a signal and of the exciton resonance, smaller, than difference of wavelengths of pump optical radiation and of the exciton resonance. Then nonlinear coefficient for a signal optical radiation will be more, than for

pump optical radiation, and the change of power of signal optical radiation will render stronger influence on the output power than the change of power pump optical radiation.

At the certain input optical radiation power and certain value of the current it is possible to ensure two modes of operations of the switch: in absence of the current the switching and gain are not present or are very small, and at passage of the current there are effective switching and gain of signal (at the same values of input radiation power). It creates an opportunity of controlling of modes of switching. Such controlling can occur by the beforehand given program or by a special (service) signal, which is separated out from information signal optical radiation and sets borders of a temporary interval, during which the signal is subject to amplification.

Thus noise, jamming and false signals are cut off.

At switching and amplification at the output of the nonlinear-optical waveguide or nonlinear TCOWs powers of the separated UDCWs change in opposite phase, but the forms of their change (kind of their dependence on time) are correlated: the power dip in one wave is accompanied by power ejection (spike) in another, i.e. peak or flat-top peak downwards in one is accompanied by peak or flat-top peak upwards in another and on the contrary (Fig.14). Thus in change of the powers of the separated UDCWs at the output of the device so-called «supplimentarity» is observed (Fig.14). In other words their amplified opposite-modulation in powers takes place. Under this the amplitudes of changes of powers of these waves can differ slightly.

Therefore to reduce the noise they invert the form of power change of one of the UDCWs, then feed the signals (optical or electrical after photo-receiver), each of which corresponds to its UDCWs, to the correlator. In other case they directly feed separated optical signal to photo-receivers and then to the inputs of differential amplifier, in which difference in powers between the amplified opposite-modulated signal is singled out.

Thus it is additional opportunity to clear the amplified information signal from noise, jamming, atmospheric fluctuations and casual distortions, which usually cause sin-phase distortions.

The separator of said UDCWs can be placed not only at the output of the nonlinear-optical waveguide immediately after (in close proximity to) output of the waveguide but can be removed from the output together with optical receiver. In some cases such removed separator is preferred.

Firstly it gives additional possibility for secret transmission of information by optical communications, say by air-path optical communications. The total power of all waves leaving

the nonlinear-optical waveguide is not change in time and not modulated. But when they separated said UDCWs at the removed end of the optical communication line by means of said separator before the receivers they obtain modulation and amplified signal.

Secondly it gives additional opportunity to clear the amplified information signal from noise, jamming and casual distortions. For reduction of noise the signals from the output of the separator can be fed to the correlator and/or differential amplifier, in which the common part of amplification of signals (with taking account their opposite phases in modulation) is separated out, and, thus, noise are cut off.

It should be explained the following. When we say hereinafter and in the Claims about the separation of said UDCWs after the nonlinear-optical waveguide by a removed separator, we mean the distributed coupling of these UDCWs is within the nonlinear-optical waveguide. Just this distribution coupling between the waves within the nonlinear-optical waveguide is meant when we write about UDCWs. And without the nonlinear-optical waveguide, especially in air-path communications, these waves of course are not coupled.

The dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear tunnel-coupled optical waveguides, are compared and their common part (with taking into account the changing of the UDCWs are in opposite phases occur (as shown in Fig.14)) is selected by means of a correlator and/or difference amplifier. In other words the «supplimentarity» in the dependences of the output UDCWs powers on time is taking into account by differential amplifier.

The jamming cause sin-phase changing in powers of transmitted UDCWs through the atmosphere, whereas in suggested device for modulation of optical radiation and transmitting the information the changing in powers of the UDCWs occur in opposite phases. So their difference in powers can be selected out by means of a correlator and/or differential (also called as «operation») amplifier. Under this the atmosphere fluctuations and jamming are rejected.

The achievement of required wavelength of the exciton resonance can be checked by observation of output parameters, in particular, by value of the differential gain and/or by depth of the switching.

The method is put into effect by means of the following device (described below) - nonlinear-optical module (see Fig.1,5,13,19,20,21). Nonlinear-optical waveguide is fabricated on the basis of (nonlinear-optical) semiconductor layered MQW-type structure, containing at least two hetero-transitions.

At the top and below surfaces of the semiconductor wafer, in which nonlinear-optical waveguide 1 is formed, tiny contact metal plates 2 and 3 are made (as shown in Fig 1,5,19,20). The plates 2 and 3 are made to carry electrical current across the nonlinear-optical waveguide 1 to the direction perpendicular to the layers of the structure. The lower contact plate (side) is mounted (directly or through intermediate elements) on at least one thermo-electric Peltier element (also named thermo-electric cooler) 4 (Fig.5,13), electrically connected with a temperature controller 4 (Fig.5), which can operate as a temperature stabilizer as well. (Instead of the temperature controller the temperature stabilizer may be used.) So the nonlinear-optical waveguide is in thermal contact with one side of thermo-electrical Peltier element 4. Besides, the nonlinear-optical waveguide and the side of Peltier element 4 are also in thermal contact with at least one sensor of temperature. Adjustment of temperature of the nonlinear-optical waveguide may be put into effect by means of the sensor and the Peltier element 4. The sensor of temperature may be made as a thermistor and/or a thermoelectric couple and/or a sensor in the form of an integrated scheme, e.g., AD 590 or LM 335. For dissipation of surplus heat a radiator 6 may be used. As a rule, for the sake of convenient (comfortable) work, the device is provided with indicators of the current and temperature, as in the capacity of which figure voltmeters may be used. They represent the values of current and temperature on their liquid-crystal screens. Mounting details 7 and 8 made from metal are shown in the Fig.5.

Electrical current, carried across the nonlinear-optical waveguide, is regulated by means of current driver (also called precision current source) 9 (Fig.5), which usually is made with possibility to stabilized the current value. Up-to-date precision current source can install the value of current with precision of order of 0.1mA

In the device nonlinear TCOWs may be used (Fig.2). In this case said temperature controlling and/or stabilization and said current controlling and/or stabilization for the said nonlinear-optical waveguides can be done simultaneously.

To eliminate or diminish reflection from the ends of the nonlinear-optical waveguide or TCOWs, anti-reflected interference coatings are made on the said ends.

To provide optimal conditions for launching of optical radiations into the nonlinear-optical waveguide and feeding the optical radiations out from the nonlinear-optical waveguide an input objective and an output objective or an input waveguide and an output waveguide are used. Input objective usually consists from cylindrical lens 10 and gradan 11 (Fig.6,9,10); between them a diaphragm 12 may be placed. In other case an effective feeding radiation into nonlinear-optical waveguide and feeding radiation out of the nonlinear-optical waveguide may be achieved

by means of additional input waveguide 13 (Fig.7-9) or output optical waveguide 14 (Fig.7-9), having lens 15 (Fig.7-9), formed at the end of the waveguide adjoining to the input or output end of the nonlinear-optical waveguide 1 correspondingly. In our experiments the diameter of the input cylindrical lens was about $20\text{ }\mu\text{m}$; the diameter of the output cylindrical lens was about 100 μm .

Modulation of such radiation by one of its parameters (a power or a polarization direction) can be done by modulator 16 (Fig.6,7). In more simple case the modulator 16 is absent and a semiconductor laser module 21 (Fig.7,11) is a source of modulated continuous waves optical radiation which can be small (e.g., 1% or 0,1% of average power) but this modulation is amplified in high degree (e.g. in 100 times, as shown in Fig.14-18) after transmission of the optical radiation through the nonlinear-optical waveguide and the separator.

Fig.6,7 shows a variant of the device, in which optical radiation is fed to the input of the device. Modulation or switching are achieved by variation of some parameter of the optical radiation.

In the case of using signal optical radiation and pump optical radiation (Fig.6,8,9,10,11) optical mixer 17 may be used for their mixing and joining.

In the case of using optical radiations of different frequencies and/or polarizations and/or waveguide modes, at the output of the nonlinear-optical waveguide or nonlinear TCOWs separator of radiations 18 is mounted. In different variants of the device the separator 18 has different fabrication. Say, in a device, in which separation of UDCWs with different polarizations is required, the separator 18 is a polaroid, or a polarizing prism, or a birefringent prism. In the case of use of output waveguide 14 optical separator of UDCWs with different polarizations may be done in the form of a directional coupler (as shown in Fig.7-9), or as an optical waveguide, absorbing and/or attenuating a wave of one polarization.

In a device, in which separation of UDCWs of different wavelengths is required, the separator 18 is a dispersive element, e.g., a diffraction grating or a prism, or a filter, say, an interference filter. The optical separator 18 may be made as a directional coupler (as shown in Fig.7,8,9). It can be united with the output waveguide 14 (as shown in Fig.7,8,9).

In a device, in which separation of UDCWs of different waveguide modes optical separator 18 may be a device of selection of waveguide modes, say, made in the form of diaphragm or in the form of optical waveguide separator (output waveguide 14, Fig.7,8,9).

With use of Faraday effect in the device the input waveguide 13 is made from magneto-optic glass and it is placed into a solenoid 19 (as shown in Fig.7).

The optical mixer 17 can be made as Y- type waveguide mixer (as shown in Fig.8), thereto output branch of the mixer is united with input waveguide 13. And through one of input branch 20 of the waveguide mixer 17 the signal optical radiation is fed (Fig.8). Through another branch of the mixer 17 the pump optical radiation with power larger than threshold ($I_p > I_{thr}$) is fed (Fig.8).

In particular case the solenoid envelopes one input branch 20 of the Y- type waveguide mixer (it is not shown in Fig.8). The solenoid is electrically, connected to modulating current source. In ordinary Faradey elements, using magnitioptic glass only small level of modulation or a small speed of modulation is achieved. In suggested devices these parameters are in many times higher. To reach amplification mode of the suggested device through another branch of the waveguide mixer 17 the pump optical radiation with power larger than threshold ($I_p > I_{thr}$) is fed.

Input waveguide 13 may be connected with a laser or laser module 21, under this all elements of the device and a laser are formed a united (single) module. The devices, shown on Fig.6-8, allow to achieve high level of modulation together with high speed of the modulation.

Variants of the device, shown in Fig.9 (below), represents optic logic elements («AND» or «OR»).

The device can be made as united (single) construction - air-path nonlinear-optical module 22 (shown in Fig.13a-d, 21), containing nonlinear-optical waveguide 1 (Fig.1,2,5-13,19) and input and output objectives, comprising cylindrical lenses 10 and gradans 11 and also diaphragm 12 (shown in Fig.6,9,10,13); or as the all-waveguide nonlinear-optical module 22 (shown in Fig.13e) with input waveguide 13 (Fig.7-9,11) and output waveguide 14 (Fig.7-9,11), (e.g., made in the form of fiber-optic waveguides), connected with the ends of the nonlinear-optical waveguide and semiconductor laser and/ or laser module 21 (Fig.7,8,11,12), operating as the pump optical radiation source, or the signal optical radiation source. In the last case the laser or laser module can be made with modulation of its output power.

Input waveguide can be made as Y-connector (i.e. mixer, rather say Y-type waveguide mixer), in the second branch of which a signal optical radiation can be fed. Output optical waveguide can be made as Y-connector or TCOWs. At the ends of the input/output waveguides lenses 15 (Fig.7-9,11) are usually done.

United nonlinear-optical module can comprise also a polarizer 23 (Fig.6,8) and/or an optical isolator 24 (Fig.6,8,10,11), and a phase compensator 25 (Fig.8,12), which is used to provide necessary difference in phases between UDCWs at the input of the nonlinear-optical

waveguide. The phase compensator can be made as an optical waveguide. The optical isolator can be made as a waveguide optical isolator, e.g., fiber-optic isolator.

The polarizer, mounted before the nonlinear-optical waveguide, or optical isolator 24 is used to diminish ellipticity of the optical radiation, fed into the nonlinear-optical waveguide and to provide a possibility for a rotation of polarization vector of said radiation fed into the waveguide. The optical isolator besides said diminishing the ellipticity of said radiation (due to its input polarizer), eliminates or attenuates in high degree a transmission of reflected (from optical elements and/or face and/or end of the nonlinear-optical waveguide) optical radiation in opposite direction (i.e. to the laser).

If UDCWs of different (usually, orthogonal) polarizations are under consideration, then the following important fact is need to be mentioned.

A rotation of electrical field vector in optical radiation, fed into the nonlinear-optical waveguide, and output polarizer relative to the «fast» and «slow» axis of the nonlinear-optical waveguide, provides the possibility to control the process of the optical switching and/or the amplifying and/or the modulation by means of regulation of amplitudes of UDCWs of different polarizations at the input of the nonlinear-optical waveguide and/or the ratio α / K , where $\alpha = |\beta_e - \beta_o| \cos(2\vartheta)$, $K = |\beta_e - \beta_o| \sin(2\vartheta)$, ϑ is an angle between «fast» or «slow» axis and electrical vector of one of considered UDCWs.

The rotation of electrical field vector in optical radiation, fed into the nonlinear-optical waveguide, relative to the «fast» and «slow» axis of the nonlinear-optical waveguide is convenient to be done by azimuth rotation or turn of the fiber-optic waveguide in optic-fiber connector 26 (Fig.8) with physical contact; and/or by relative turn of two optical connectors (e.g., FC/PC-type) in connecting socket, or in the similar fiber-optic connection. It is also convenient to turn and rotate in similar way the polarizer, placed after the nonlinear-optical waveguide and operating as the separator 18.

In the device possibility is provided for rotation of input polarizer 23, and that also gives possibility for controlling the process of the switching by regulation of input amplitudes of the UDCWs with different polarizations and the ratio of α / K . However the rotation of the polarizer should be accompanied by corresponding rotation of electrical field vector in input optical radiation; i.e. it should be accompanied by the rotation of the laser and/or laser module; otherwise the rotation of the input polarizer may cause change in fed into the input power launched into the nonlinear-optical waveguide.

Nonlinear-optical module can be optically connected with semiconductor laser and/or laser module 21, which can be done with external resonator, one of a mirror of which is made in the form Bragg reflector 27 (Fig.8). The Bragg reflector can be made as periodic grating of refractive index in fiber-optic waveguide adjoined to the laser. It can be also made as a corrugation in optical waveguide. External resonator provides stability of wavelength of the laser radiation in time and sufficiently narrow spectrum-line width of the laser radiation (not more than 3A).

Radiating semiconductor structure of laser 21 may be in thermal contact with at least one thermal-electrical Peltier element (with one side of it), electrically connected with temperature controller and/or stabilizer. This provides additional possibility to choose and/or regulate and/or stabilize a regime of operation of the device, i.e. to choose the threshold power and the critical power, the differential gain, the ratio between powers of the coupled waves at the output of the device and the difference of phase between them by adjustment of the temperature controller. This is possible due to regulation and stabilization of wavelength of the pump and/or signal optical radiation from the laser or/and laser module.

On the basis of observations we can do conclusion that the used nonlinear-optical waveguide based on the semiconductor MQW-type structure better transmits radiation of one polarization than that of another polarization. So the nonlinear-optical waveguide itself even without polarizer at the output mainly select out the radiation of the certain polarization at the output thus it operates partially as a polarizer.

Polarizer, mounted at the input of the nonlinear-optical waveguide, optical isolator and phase compensator may be done in the form of an optical waveguide.

Fabrication of the device in the form of the united waveguide module is achieved due to method of fabrication, comprising positioning and control with the use of luminescent radiation of the nonlinear-optical waveguide, arisen when electrical current is carried across it. Thus, the electrical contacts for carrying electrical current across the nonlinear-optical waveguide, allow also to carry out the positioning and to increase in high degree the precision of the positioning. Under carrying sufficiently large current ($>30\text{mA}$) nonlinear layered semiconductor radiation-carrying MQW-type from the face and the end of the nonlinear-optical waveguide, structure begins to emit a luminescent radiation. This allows, using the luminescent radiation, emitting from the ends of the nonlinear-optical waveguide, to mount cylindrical lenses and gradans at the input and/or output ends of the nonlinear-optical waveguide. The mounting input and/or output elements, made as cylindrical lenses and gradans, relative to the nonlinear-optical waveguide is

accomplished up until formation of collimated optical radiation beam outside the said gradans. As a rule the cylindrically symmetrical optical radiation beam is achieved.

In the other «waveguide» variant this permits, using the luminescent radiation, emitting from the ends of the nonlinear-optical waveguide, to mount the end of the additional so-called «input waveguide» at the input of the nonlinear-optical waveguide, and/or to mount the end of the additional so-called output waveguide at the output end of the nonlinear-optical waveguide.

In both variants the efficiency of feeding the radiation in/out the nonlinear-optical waveguide is increased in high degree. Under this the all-optical switching, amplifying, modulating, controlling device (optical transistor, modulator, logical element) became as a single fabricated module. The input and/or output waveguide usually is made in the form of fiber-optic waveguide(s).

The value of the current, carried across the nonlinear-optical waveguide to provide its luminescence, is by the order of magnitude larger than the current, carried across the nonlinear-optical waveguide in operation of the device: under mounting cylindrical lens and/or gradan and/or input/output optical waveguide the current is usually 20-40mA and larger; whereas in service of the device the current is of the order of 1mA.

Besides the possibility of precision mounting of input/output elements and other elements of the module relative to the nonlinear-optical waveguide, the method of construction of the nonlinear-optic (waveguide) module comprises also the control of efficiency of launching radiation into the nonlinear-optical waveguide by means of changing power transmission coefficient of the nonlinear-optical waveguide under switching on and switching off electrical current across the nonlinear-optical waveguide. I.e. a magnitude (value) of the power change of radiation, transmitted (transferred) through the nonlinear-optical waveguide under switched on and switched off electrical current is the criterion of the efficiency of launching the optical (signal and/or pump) radiation into the nonlinear-optical waveguide.

The criterion of the efficiency of launching the radiation beam of laser module into the nonlinear-optical waveguide (i.e. the criterion of the precision of mounting of laser module relative to the nonlinear-optical module) can be the control by means of achievement of coincidence of the laser module radiation beam and the nonlinear-optical module radiation beam at the input and/or at the output of the nonlinear optic module.

Mentioned above technologies allow to realize compact, small optical radiation power supplied, fast and reliable optical integrated schemes of required architecture. The device for processing optical signals comprises several nonlinear-optic modules, and each of them contains

nonlinear-optical waveguide or nonlinear TCOWs. The input and output of the nonlinear-optic-modules are connected between each other by scheme, corresponding the function of processing of the signal. Input/output elements of such nonlinear-optic modules, as a rule, are made as input/output waveguides and connected by splice, glue, welding or connectors.

5 *About optical radiation sources.*

In the quality of the source of optical radiation and/or pump optical radiation, and/or signal optical radiation fed into said nonlinear-optical waveguide a laser can be used. It is preferred to use tunable by wavelength, single-mode laser (i.e. with cross-single-mode), with narrow spectrum-line width (usually not larger than $20\text{\AA}$). One of the best variants is the single-
10 frequency laser. In other case mode-locked laser can be used. In particular, soliton laser can be used. E.g., the dye laser can be used. The wavelength of optical radiation of the laser is to be close to wavelength of exciton resonance of the semiconductor structure of said nonlinear-optical waveguide(s). Compactness of the laser is also important.

So the most preferable source of optical radiation and/or pump optical radiation, and/or
15 signal optical radiation fed into said nonlinear-optical waveguide(s) is a semiconductor laser or even better semiconductor laser module. The semiconductor laser module can be done firstly as air-path module with use of a cylindrical lens and a gradan for obtaining a collimated optical radiation beam. Secondly a semiconductor laser module can be done as a waveguide laser module, usually as fiber-optic source module. In this case an output of optical radiation from a
20 laser diode is done through a fiber-optic waveguide adjoined to the laser diode. Usually a lens is done at the end of the fiber-optic waveguide adjoined to the laser diode. Usually the lens is done as parabolic, conic, or cylindrical. At another end of the fiber-optic waveguide a gradan can be mounted, which gives a collimated beam. The laser module in the form of a fiber-optic source module can include a fiber-optic amplifier, say an erbium doped fiber amplifier.

25 In both cases the semiconductor laser module is additionally supplied with at least one thermoelectric Peltier element (i.e. thermoelectric cooler), a side of which is in thermal contact with the radiating semiconductor structure of the laser (i.e. laser diode) and with at least one sensor of the temperature, thereto at least one sensor of temperature and at least one thermoelectric Peltier element are electrically connected to a controller and/or stabilizer of
30 temperature. It is also preferred to supply said laser module with a precision current source for passing electrical current through its laser diode; usually said current source is made as a controller (driver) and/or stabilizer of the current. The optical power of the semiconductor laser or laser module is controlled and/or stabilized. It is done by controlling and stabilization of

electrical current passing through the laser diode and/or by measuring and taking into account the output power of the laser diode, with use of an electrical feedback scheme and with use the precision current source made as the controller and stabilizer of the current through the laser diode; and hence the output power is controlled and stabilized. The measuring of the output
5 power of optical radiation of the laser diode is done by measuring of current of a monitoring photo-diode.

The semiconductor laser or more preferably the semiconductor laser module can be comprised in the suggested device for switching, amplification, controlling and modulation of optical radiation.

10 The semiconductor laser or laser module can operates in different regimes: its output radiation can be both in the form of pulses and in the form of continuos waves. It can operate both as mode-locked and continuos waves laser or laser module. If it gives optical pulses, say ultra-short pulses, then the controller (driver) and stabilizer of current through the laser diode controls and stabilizes an average output power of the laser or laser module in time. In
15 particular, the laser or laser module can provide with a continuous sequence of solitons, or soliton-like supershort pulses with constant peak power.

One of the most preferable regime of operation of the semiconductor laser or laser module comprised in the suggested device is continuos waves regime.

As a rule the semiconductor laser and/or laser module is used with spectrum-line width of
20 radiation, which is not more than $20\text{\AA}$. The semiconductor laser or the laser module is needed to be single-moded, i.e. its output optical radiation has one cross mode. In one of the most preferable variants the semiconductor laser and/or the laser module is made as a single-frequency laser module, say a single-frequency waveguide laser module; e.g., as a single-frequency and single-mode fiber-optic source module.

25 To obtain a narrow spectral line width and a stable frequency in time the semiconductor laser or the laser module is made with an external resonator and/or includes a dispersive element. The dispersive element can be made in the form of a diffraction grating. As a rule at least one mirror of the external resonator is made as a periodical grating, representing a partially or fully reflecting Bragg reflector. In particular, the mirror of the external resonator of the
30 semiconductor laser and/or the laser module, including the semiconductor laser and an optical waveguide, is made in the form of a periodical grating of refractive index in the optical waveguide adjacent to the laser, or as a corrugation on a surface of the optical waveguide adjacent to the laser. E.g., the mirror of said external resonator is made as a refractive index

periodical grating in the fiber-optic waveguide adjoined to the laser diode, thereto the laser diode end closest to said fiber-optic waveguide has an antireflection coating and another end of said laser diode has a reflection coating. The semiconductor laser and/or the laser module with distributed feedback can also be used.

- 5 The power of optical radiation of laser or laser module comprising in the device is chosen in the range from $0,5 P_M$ up to $1,5 P_M$, where P_M is the critical power. In more preferable case the power of optical radiation of laser or laser module comprising in the device is chosen in the range from $0,9 P_M$ up to $1,1 P_M$.

In other preferable case the power of the laser or laser module is to be larger than
 10 $3|\beta_o - \beta_e|/|\theta|$, say $5|\beta_o - \beta_e|/|\theta|$. This case, in particular, corresponds to orientation of electrical vector when $E_y \gg E_x$, and $\vec{E}_y$ is directed along «fast» or «slow» axis of the birefringent nonlinear-optical waveguide, i.e. $\vartheta = 0$ (see Fig.1). In this special case the linear wave-coupling between the UDCWs is closed to zero, but nonlinear coupling between waves is essential.

- 15 Estimations show that in the cases when power of the laser or laser module optical radiation is larger than $0,5 P_M$ is also can be of interest. The power larger than $1,5 P_M$ sometimes also can be of interest. But powers of laser in ten times larger than P_M is hardly to be of interest, because almost all power is in one of the UDCWs only, and power transfer between the UDCWs is almost absent and so they hardly obtain essential gain in modulation. Detailed
 20 explanation and definition of the critical power is done in (A.A.Maier. All-optical switching of unidirectional distributedly coupled waves. UFN 1995, v.165, N9, p.1037-1075. [Physics-Uspekhi v.38, N9, p.991-1029, 1995]).

About initial modulation.

- In one of the most preferable embodiment, the laser or laser module provides output
 25 optical radiation of constant power exceeding the threshold power, thereto the power spread in time does not exceed 1%. In this case the initial (i.e. before the nonlinear-optical waveguide(s)) modulation is achieved by an external modulator, placed between the laser or laser module and said nonlinear-optical waveguide(s), thereto the modulator is optically connected with the output of the laser or laser module, and the modulator is optically connected with the input of
 30 said nonlinear-optical waveguide(s) through said input element. In one of the most preferable embodiment said modulator is an amplitude modulator, i.e. it modulates the power of optical radiation passing through it. In other preferable embodiment it is a phase modulator, which

modulates the difference in phases of UDCWs at the input of said nonlinear-optical waveguide(s). It can also modulate the difference in phases of signal and pump optical radiations. It can be also made as a frequency modulator, modulating the frequency of optical radiation transmitted through it.

- 5 In other case the modulation of optical radiation before the input of said nonlinear-optical waveguide(s) is achieved by modulation of output optical radiation of the laser or laser module. The modulation is achieved by modulation of electrical current passing through the laser diode. For this purpose said current source is made with possibility of modulation of current through the laser diode. Under this an average value of the current in time and hence an average power
10 of output radiation of the laser or laser module in time is usually stabilized.

In both cases of the modulation the initial modulation can be small (i.e. its percentage modulation can be small), due to the amplification of the modulation after said nonlinear-optical waveguide(s) and said separation of the UDCWs. So the frequency band and speed of the modulation can be much more than that without said nonlinear-optical waveguide(s). For
15 example, an amplitude of the variation of modulated current passing through the laser diode can be small, and hence the time of its variation can be small. Hence frequency band and speed of the modulation can be much more than that without said nonlinear-optical waveguide(s). In the case of external modulation, say, by electrical field applied to electro-optical modulator, an amplitude of this electrical field can be small, and therefor a speed of modulation can be much
20 higher than that without nonlinear-optical waveguide(s) as well.

Example 1. We created all-optical compact nonlinear-optical waveguide module (Fig.21, Fig.13), amplifying with gain 100 small modulation of continuous waves semiconductor air-path laser module radiation. In essence all-optical transistor and all-optical switch is created (Fig.14-17). Its operation is based on nonlinear-optical phenomenon of self-switching of UDCWs of
25 different mutually orthogonal polarizations (Fig.14-17), which implies that a small variation of the input intensity for one of the UDCWs gives rise to abrupt change in the UDCWs intensities ratio at the device output. The phenomenon takes place under certain choice of input intensities and input phases of the UDCWs. Amplified differentially in 100 times mutually orthogonal waves separated at the output of the device change in opposite phases (Fig.14). We obtain all-
30 optical switch between «0» and «1» levels of output power by adjusting of input average power of the laser module (Fig.18).

We also regulated differential gain (Fig.17) by adjusting of average power of the laser module or by nonlinear waveguide temperature controlling.

Previously the phenomenon was observed in pulse regime under powers of order of hundreds watts and more, and differential gain not more than 3-5 was obtained. Even in nonlinear waveguides based on semiconductor MQW structures, the powers, at which the phenomenon was observed were of order of hundreds watts, and differential gain only slightly larger than unity was achieved (see, e.g., H.K.Tsang et.al. *ELECTRONICS LETTERS* Vol.27, No22, p.1993, October 1991).

The continuous waves radiation with $\lambda=0,86$ from semiconductor laser module (with average power approximately equal to 10mW) in the form of collimated beam (with axial symmetry) was passed through polaroid and phase plate (which was used as phase compensator, but may be absent), and further through the nonlinear-optical waveguide module. The module comprises the nonlinear-optical waveguide (based on the semiconductor wafer MQW-type structure $GaAs / Ga_yAl_{1-y}As$) (Fig.1, 19), supplied with input and output cylindrical lenses and gradans, by means of which collimated beam was fed into the nonlinear-optical waveguide and further fed out from the nonlinear-optical waveguide, without micro-objectives. By means of the cylindrical lenses we take into account asymmetry of cross-section Further (at the output of the device) the radiation of certain polarization was selected out by means of polaroid. Before it a phase plate may be placed. Optical radiation, transmitted through polaroid was fed in input of photodiode, an electric signal from which was applied to the input of oscilloscope.

The laser module was single-moded. The laser module was supplied with a precision current source for passing electrical current through the laser diode. Thereto it was supplied with a thermoelectric Peltier element and two temperature sensors, which were connected to temperature controller. The temperature controller also operated as a temperature stabilizer.

The nonlinear-optical waveguide was made as a ridge optical waveguide (Fig.1,19). The width of the ridge nonlinear-optical waveguide was $4\mu m$ (Fig.19). The nonlinear-optical waveguide was single-moded. The length of the nonlinear-optical waveguide was approximately 1mm.

The MQW-type structure was a multiplicity of quantum wells. The period of the structure - $200\text{\AA}$. A thickness h (Fig.1) of light-carrying (radiation-carrying) layer of the nonlinear-optical waveguide is $0,5\mu m$; it comprises approximately 25 periods of the structure. From above MQW-type structure and from below MQW-type structure the horizontal layers $Ga_yAl_{1-y}As$ with $y = 0,23$ and thickness $1\mu m$ were grown and further (for the better waveguide restriction) - layers $Ga_yAl_{1-y}As$ with $y=0.35$ and thickness $0.5\mu m$ were grown. Thus, the area of cross-

section of the nonlinear-optical waveguide is of order of 10^{-7} cm^2 . The nonlinear-optical waveguide was singlemoded.

A small electrical current of order of 1-10mA was carried across the nonlinear-optical waveguide in the direction perpendicular to the layers of the MWQ structure was carried. For this from above the semiconductor wafer a Au-film electrode was coated (Fig.1,19,20), to which tiny metal (Au) wires were welded by thermo-compression.

The top layer (with thickness $0,35 \mu\text{m}$) of the semiconductor wafer structure, directly adjoined to the film electrode, was highly doped GaAs p^+ -type with concentration of electrons 10^{19} cm^{-3} .

Due to carrying electrical current across the nonlinear-optical waveguide we achieved four main aims.

Firstly, decreasing radiation absorption (at small currents: 1-10mA) we have possibility to «operate» in vicinity of the exciton resonance, where the most nonlinearity is achieved, and, therefore threshold and critical intensities are the least. Experiment reveal very interesting fact that current with small value by only 1-2 mA across the nonlinear-optical waveguide results in increase of differential gain of the modulation of the optical radiation and power of optical radiation transmitting through the nonlinear-optical waveguide by an order of magnitude compare with the case of absence of the current.

Secondly, we got possibility to mount (at essentially larger current than in service of the device, usually larger than 30-40mA) cylindrical lenses 10 and gradans 11 at the ends (faces) of the nonlinear-optical waveguide with a high precision. The gradans had AR-coatings. The cylindrical lenses also can have the AR-coatings. In mounting in construction of the nonlinear-optical waveguide module (Fig.13, Fig.21) we also used diaphragm 12 and cubs from quartz and mountings rings. The input/output elements (comprising the cylindrical lenses 10 and gradans 11) were mounted at the input/output ends of said nonlinear-optical waveguide in so way that said nonlinear-optical waveguide together with said optical input/output elements make up a nonlinear-optical module.

Thirdly when we mounted a semiconductor laser module before the nonlinear-optical module, we position the semiconductor laser module relative to the nonlinear-optical module by changing their relative positions up until coincidence of the laser or laser module optical radiation beam with the nonlinear-optical module luminescence beam before the input and/or after output of the nonlinear-optical module, thereto the luminescence beam is appeared when

electrical current is carried through the nonlinear-optical waveguide, and then they mount the semiconductor laser or laser module relative to said nonlinear-optical module. Under this the current more than 20mA is carried across said nonlinear-optical waveguide.

Fourthly we additionally control precision of positioning of the semiconductor laser module relative to the nonlinear-optical module by means of comparison of power of the laser module optical radiation transmitted through said nonlinear-optical module in the case of absence of electrical current through said nonlinear-optical waveguide and in the case of carrying current through said nonlinear-optical waveguide. Under this the current from 0,5mA up to 10mA is carried across the nonlinear-optical waveguide. If laser module optical radiation transmitted through the nonlinear-optical waveguide then switching on and switching off the electrical current caused accordingly larger increase and decrease of output power and the differential gain of modulation of the optical radiation.

If laser module optical radiation did not transmit through the nonlinear-optical waveguide then switching on and switching off the electrical current carried across the nonlinear-optical waveguide did not cause any change in the gain and power of optical radiation received by photo-diode.

From below the semiconductor wafer was welded to the metal plate, mounted on thermo-electrical Peltier element 4 (Fig.13, Fig.5). According to estimations, in close vicinity of exciton resonance at the used wavelength nonlinear coefficient θ of the waveguide is of order of 10^{-4} e.s.u. It depends on λ_r and λ in high degree. The wavelength corresponding to the exciton resonance in the said structure is approximately equal to $\lambda_r = 0,86\mu m$. This λ_r was adjusted gradually from estimate 0,25nm/grad and installed then as stable (it was stabilized), adjusting and installing temperature by adjusting a current through the element Peltier 4. In so doing we adjust θ and hence adjust critical power and gain, i.e. mode of operation of the device by means of ordinary temperature controller.

We smoothly adjusted into area of exciton resonance (where θ is maximal) and adjusted (and then fixed) a degree of vicinity to it. As approaching to the exciton resonance the critical power, near to which there was the phenomenon of self-switching of the UDCWs, decreased. Varying and setting with the controller (regulator) the temperature of the Peltier element, it was possible to vary, to choose and to stabilize the critical power and the differential gain and the ratio of powers and phases between UDCWs at the output of the device. The tuning into the exciton resonance (or rather on the given vicinity to it) was carried out by adjustment and subsequent stabilization of the temperature both nonlinear-optical waveguide, and the laser

diode. In the latter case the wavelength of the laser module was adjusted and stabilized by temperature controller (driver) for the laser.

The used layered MQW- structure and the nonlinear-optical waveguide on its base, have not only large nonlinearity, but they also have a significant birefringence due to refractive indexes for waves having polarization along and across the layers of the structure are differed. By theoretical estimations the difference between them is approximately $4 \cdot 10^{-3}$. The birefringence provides linear distributed coupling between the waves of different (orthogonal) polarizations in the nonlinear-optical waveguide. The laser field was oriented approximately at an angle 45° to the «fast» and/or «slow» axis of the MQW-structure and the nonlinear-optical waveguide; i.e. it was oriented approximately at an angle 45° to the axis of ellipse of effective refractive index in cross-section of the nonlinear-optical waveguide (Fig.3), which was directed perpendicular to the layers of the MQW-structure (in the particular case - vertically). To obtain sufficient value of the birefringence the value of x in the formula $GaAs / Ga_{1-x}Al_xAs$ of said layered MWQ-type structure is to be sufficiently large. In consider case it was 0.2. Besides the attenuation of both said UDCWs of mutually orthogonal polarization (mainly due to their absorption) are to be sufficiently small. It means that radiation-carrying layer of the nonlinear-optical waveguide is to be sufficiently optically isolated from any metal coating at the surfaces of the semiconductor wafer. In other words sufficiently large waveguide restriction of the nonlinear-optical waveguide is to be done. In the same time the nonlinear-optical waveguide is to be done as single-moded for radiation fed into it.

In accordance with the theory the phenomenon of self-switching of UDCWs with different polarizations, separated by polaroid at the output of the device, took place: amplitude of initial modulation (in the form of meander) was abruptly amplified approximately by a factor of hundred times (Fig.14-17.). There were ejections of power. The rotation of external polaroid caused change of polarity of amplified meander (and ejection of power: the ejection upwards was replaced by ejection downwards, and «polarity» of the meander varied on opposite (Fig.14), i.e. between UDCWs of orthogonal polarizations so-called «supplimentarity» was observed. It is explained by sharp redistribution of energy between UDCWs of various polarizations: the ejection of radiation power of one polarization was replaced by ejection of radiation power of other (orthogonal to it) polarization. The ejection downwards is possible to treat and as a dip in power. These a dip and ejection were reached at two mutually perpendicular angle positions rules of polaroid 18 at output. Let's note, that «supplimentarity»

shown in Fig.14, and sharp (by two order) differential amplification of a signal are impossible to be explained by linear effects and linear theory.

The strong influence of value of a small angle between a laser beam and normal to a surface of a phase plate on the form and amplitude of a signal on the oscilloscope screen is revealed also. Slightly varying this angle, we thus vary a difference in phases between orthogonal polarized waves on an input of the nonlinear-optical waveguide, which strongly influences on process of switching, and, thus, on output power. It means an opportunity of effective controlling of intensity at the output of the device by change of an input difference in phases of the UDCWs and/or of the signal and the pump optical radiations. For example, instead of a phase plate (e.g., a quarter-wave plate) 25 it is possible to mount an electrooptical crystal or optical waveguide and to applied to it a variable signal electrical voltage.

At the same time, amplification of weak input modulation and «supplimentarity in polarizations at output » were observed and without the phase compensator (as a plate wave plate) 25, i.e. at feeding the linearly polarized radiation to the input of the nonlinear-optic module.

Further, having mounted polarizer and/or the optical isolator before the nonlinear-optical waveguide and having reduced noise of the stabilizers of temperature and current of the laser at least by the order, it was possible to observe the described above effects (including transistor amplification of weak modulation) in purer (cleaner) form: the amplified regular modulation had the large amplitude (depth), almost in all screen, and small noise, and in oscilloscope screen there was no so-called «base" line, corresponding to modulation, close to initial.

Varying a level of the average input power and/or the temperature of the nonlinear-optical waveguide, a gain of differential amplification can be changed (Fig.17) and mode of operation of the device can be changed and can be chosen.

Thus, we could receive large differential factor of amplification (i.e. gain) of a signal with a small current through nonlinear-optical waveguide.

As against known optical bistable elements based on Fabry-Perot resonator, the given device is much steadier against instability of frequency of the laser and consequently its operation is much more stable in course of time.

The considered device, used as the amplifier, has important advantage in comparison with semi-conductor quantum amplifiers based on inverse population and requiring passage of large currents (about 100mA and higher), necessary for creation of essential inverse population. In the invented switches the amplification is differential and it is reached not due to the inverse population, but due to the sharp redistribution of power between the coupled waves, in the first

part, between UDCWs and consequently a current through structure is by one-two orders of magnitude less, than that in the "inverse" amplifiers. It creates additional prospect for association of the offered switches in the logic circuits.

As the powers of UDCWs at the output of the separator 18 change in opposite phase (Fig.14), then, having inverted the form of change of power of one of the waves, we can feed signals (optical or electrical), each of which corresponds to one of the UDCWs, from the output of the device to the correlator and/or differential amplifier, in which the common part in opposite phase is separated out; this opposed phase common part can be separated out, and, thus, noise are cut. Thus there is additional possibility to separate out the amplified information signal, cleared from noise, jamming, atmosphere fluctuation and casual distortions.

Example 2. Nonlinear-optical waveguide is on a contact plate from oxygenless copper, mounted on the copper cylinder, which with the help fixing flange 7, was mounted on cooling bar 8, representing a metal plate (for example, from aluminium, copper, brass, duralumin, steel, etc.), thickness 2mm with a hole in the middle, through which the electrical tiny wires are passed (Fig.5). With the help of these wires, the electrical current about 1-2 mA was passed across the nonlinear-optical waveguide. To cooling bar 8 the sensors (sensor controls) of temperatures, which are taking place in thermal contact with it, were attached. As the temperature sensors (sensor controls), thermistors, and/or thermocouples (RTD) and/or sensors executed on the basis of the integrated circuits, e.g., such as AD590 and/or LMT 335 can be applied. Cooling bar 8 was in thermal contact both with nonlinear waveguide, and with one of plates (sides) of thermo-electric elements Peltier, for example, with top (conditionally speaking, "cold") plate (Fig.5,13). For improvement of thermal contact between various contacting elements (say, flange 7 and cooling bar 8) contacting surfaces were greased with heat-conducting paste, for example, such as organo-silicon heat-conducting paste. In the considered example two elements Peltier were applied, and as temperature sensors - two thermistors (having resistance 15 kilo-ohm at 20°C). One of these sensors was applied in a circuit of a feedback of the controller and stabilizer of temperature, and the second one was used as the sensor of temperature of the circuit of indication of temperature. Another (is conditional - "hot") plate (side) of the element Peltier was in thermal contact with a radiator of heat and was mounted on a little positioning (adjustment) table from steel. The thickness of elements Peltier was 2mm. For heat insulating, electroisolation and isolation from vibrations of the "hot" side of the Peltier element from the "cold" side, the teflon shock-absorbers as washers were used. The current through the element Peltier was about 100mA, the removed heat capacity was less than 1W. Due to the radiator, a

temperature of elements Peltier was much less than extreme allowable temperature in 160° C. The considered device allowed to adjust and to stabilize the temperature of the birefringent nonlinear-optical waveguide with degree of precision within 0,005° C. At change of temperature of the nonlinear-optical waveguide the wavelength of the exciton resonance in MQW - structure (containing not less than two hetero-transition) changed approximately at the rate of 0.3 nm / grad.

Example 3. Optical radiation with wavelength $\lambda = 0,86 \mu m$ from the single-mode semiconductor laser module linearly polarized along the vertical axis, was passed through a Glan prism (to improve the degree of the radiation polarization), then - through the magneto-optical element, made from magneto-optic glass, doped with terbium (that is diamagnetic Faraday glass), placed in the solenoid, and then the optical radiation is fed into the nonlinear-optical waveguide, radiation-carrying layer of which was made of layered structure such as $GaAs / Al_x Ga_{1-x} As$, with $x=0.2$, representing a multiplicity of quantum wells (MQW) and having birefringence. The laser module was supplied with precision current source. The optical axis of this birefringent structure was oriented along a vertical axis. The period of the structure was 200 Å. The thickness h of the radiation-carrying layer was $0.5 \mu m$, and within it approximately 25 periods of the MQW structure were stacked. The wavelength corresponding to the exciton resonance in the aforesaid structure, was approximately equaled to $0.859 \mu m$. From above and from below of the MQW structure the symmetrically horizontal layers $GaAs / Al_y Ga_{1-y} As$ with $y=0.22$ by thickness $1 \mu m$ and further (for best waveguide restriction) - layers $Al_y Ga_{1-y} As$ by thickness $0.5 \mu m$ with $y=0.35$ settled down. The width of the strip ridge-type waveguide was $4 \mu m$. The difference of refractive indices of two orthogonal-polarized waves was $\Delta n \approx 4 \cdot 10^{-3}$. The area of cross-section was approximately $10^{-7} cm^2$. The nonlinear-optical waveguide was singlemoded. Across the nonlinear-optical waveguide a weak electrical current about 1-2 mA was carried (passed). For this purpose on the waveguide a film electrode from above was put (coated), to which by thermocompression the thin metal wires were soldered. The top layer of the semiconductor structure, adjoining directly to the film electrode and ensuring electrical contact, represented strongly doped GaAs such as p+ with concentration of carriers $10^{19} cm^{-3}$ and had thickness $0.35 \mu m$. From below the waveguide was soldered to a metal plate which was mounted on the Peltier element. So it was in thermal contact with one side of the Peltier element and with one or two sensor (s) of temperature. A

sensor was made as thermoresistor. By means of temperature controller electrically connected with the Peltier element the temperature of the nonlinear-optical waveguide was controlled and stabilized; the temperature of the nonlinear-optical waveguide was set to achieve the maximal depth of the modulation at the output of the modulator. In the vicinity of the exciton resonance on the used wavelength nonlinear factor of the nonlinear-optical waveguide was about $\theta \approx 10^{-4}$ esu. The length of the nonlinear-optical waveguide was 1.6mm. Input and output of radiation was carried out by means of cylindrical lenses and clarified gradans, mounted at an input and output of the nonlinear-optical waveguide. All device containing input gradan, input cylindrical lens, the nonlinear-optical waveguide, output cylindrical lens and output gradan, looked like the united nonlinear-optical module.

If electrical current through the solenoid is equal to zero, then the linear polarization is directed along the vertical (y) axis both at the output and at the input of the solenoid.

Through the solenoid the variable electrical current was passed. The change of the current corresponds to the useful (modulating) variable signal (analog or digital). The value and sign of an angle of a deviation (turn) of the polarization plane of the optical radiation, from the vertical axis at the output of the magneto-optical element corresponds to the value and sign of the electrical current passed through the solenoid, and, hence, corresponds to the value and sign of the useful signal. The horizontal component of the electrical field vector at small angles of a deviation (turn) from the vertical axis is proportional to the angle of the deviation (turn); and at the same time the vertical component of the electrical field vector almost does not vary. So it is possible to consider (count), that into the input of the nonlinear optical waveguide (made on the basis of MQW structure), having birefringence (under this the axes of a refractive index ellipse in cross-section of the nonlinear-optical waveguide (Fig.3) are directed along axes x and y), the weak variable optical signal with a vector of polarization, directed along a horizontal axis x, and carrying the useful information, arrived. According to the theory in this case the phenomenon of optical self-switching of UDCWs of orthogonal polarizations with nonlinear coupling took place.

At an output of a polarizer, positioned after the output of the nonlinear-optical waveguide, a useful signal amplified in 10^{-10^2} times was received, and the powers of the orthogonal polarized waves at the output of the system (i.e. device) changed in opposite phase and the change of each of them in 10^{-10^2} times exceeded the change of signal amplitude at the input of the nonlinear-optical waveguide .

At the output of polarizer, positioned after the output of the nonlinear-optical waveguide, a useful signal amplified in $10\text{-}10^2$ times was received, and the powers of the orthogonal polarized waves at the output of the device changed in opposite phase and the change of each of them in $10\text{-}10^2$ times exceeded the change of signal amplitude at the input of the nonlinear-optical waveguide (as shown in Fig.16).

If threshold is exceeded by input optical power, then switching on sinusoidal electrical current through the solenoid, creating magnetic field in optical element, caused initiation polarization modulation at the input of the nonlinear-optical waveguide, which results in the effect of much higher, observable (sinusoidal) modulation at the output of the device (Fig.16a).

If input power is less than threshold optical power, then switching on the same electrical current through the solenoid does not cause any observable magneto-optical modulation (Fig.16b). The threshold power was of order of critical power.

Let us mention that slight modulation in the form of meander seen in the Fig.16 is due to modulation of the used laser module optical radiation caused by slight modulation of the current through the laser diode. By the way this is initial signal modulation at the input of the nonlinear-optical module for Fig.15.

The current of used laser module monitoring photo-diode (proportional to the input optical radiation power) for photo 16a is about $120\text{-}130\mu\text{A}$, whereas for photo 16a it is about $45\text{-}50\mu\text{A}$. Thus input optical radiation power for Fig.16a is not more than in three times greater than that for Fig.16b. I.e. the amplified signal in Fig.15 should be compare with initial signal in Fig.16b.

If input power is considered as predetermined then we can say that for Fig.16a the threshold is exceeded by nonlinear coefficient of the nonlinear-optical waveguide, and for Fig.16b it is not exceeded.

In essence all-optical transistor operating as amplifier of Faraday effect is created for the first time, and result of its operation is shown in Fig.16. This all-optical transistor is made in the form of compact nonlinear-optical module.

Under these conditions at the output of the device a depth of modulation was in 10^2 times more, than in the case of absence of the nonlinear-optical waveguide in the modulator.

The powers of the orthogonal polarized waves at the output of device changed in opposite phase. Therefore for reduction of noise it is possible, having inverted the form of change of power of one of waves, to feed from an output of the device output information signals (optical or electrical), each of which corresponds to its UDCWs, to the correlator with electrical

differential amplifier, in which the common part of the change of the output signals is separated out, and, thus, noise are cut. Thus it is possible to separate out the amplified information signal cleared from noise, jamming and casual distortions.

Example 4. Pump as a sequence of super-short pulses by duration 10ps, with wavelength $\lambda = 1,55 \mu m$ from mode-locked NaCl:OH laser polarized along a vertical axis, passed through a Glan prism, then passed through the Faraday cell, representing ferromagnetic a crystal garnet (YIG, yttrium-ferrous garnet) placed in the solenoid, and then entered the nonlinear-optical waveguide, radiation-carrying layer of which was made on the basis of the layered MQW-type structure such as $GaAs / Al_xGa_{1-x}As$, with $x=0.2$, representing a set of quantum wells. The period of one well was $200 \text{ \AA}$. The thickness of the radiation-carrying layer was $1 \mu m$, and on it approximately 40 periods of the structure were stacked. The wavelength, corresponding to an exciton resonance in the said MQW structure, was approximately equaled $0.78 \mu m$. Strip waveguide width was $4 \mu m$. The area of cross section approximately was of order of 10^{-7} cm^2 . The difference of refractive indexes of two orthogonal-polarized waves was $\Delta n \approx 4 \cdot 10^{-3}$. Across the nonlinear-optical waveguide a weak electrical current about 1-2 mA was carried (passed). For this purpose on waveguide a film electrode from above was coated, to which with the aid of thermocompression the thin metal wires were soldered. From below waveguide was soldered to a metal plate which mounded on an Peltier element. In area of a two-photon exciton resonance on used wavelength nonlinear factor waveguide was of order of $\theta \approx 10^{-11} \text{ esu}$. The waveguide length was 1 mm. The input of radiation into the nonlinear optic waveguide and output of radiation from said waveguide was carried out by means of cylindrical lenses and gradan, mounted at the input and output of the said nonlinear-optical waveguide. All design containing input gradan, input cylindrical lens, the nonlinear-optical waveguide, output cylindrical lens and output gradan looked like the uniform nonlinear-optical module. Through the solenoid passed a variable electrical current, which change corresponded to a useful variable signal (analog or digital). At the output polarizer, located after the output of the nonlinear-optical waveguide, a useful signal amplified in 10 time was received, and the powers of the orthogonal polarized waves at the output of the device were changed in opposite phase and the change of each of them in 10 times exceeded change of signal amplitude at the input of the nonlinear optical waveguide.

Example 5. Pump with wavelength $\lambda = 1.3 \mu m$ from the semiconductor laser polarized along a vertical axis, passed through a Glan prism, then - through a Faraday cell, representing a

Ferro-magnetic crystal of garnet (YIG, yttrium-ferrous garnet), placed in the solenoid, and then entered in nonlinear-optical waveguide, radiation-carrying lived which was made of layered structure such as $In_{1-x}Ga_xAs_yP_{1-y} / InP$, with $x=0.2$, $y=2,2x$, representing a set of quantum wells. The period of structure was $200 \text{ \AA}$. The thickness radiation-carrying core was $0.5 \mu m$, and on it 20 periods of structure were stacked approximately. Wavelength appropriate to the exciton resonance in the specified structure, was approximately equaled $1.3 \mu m$. Width strip waveguide made $4 \mu m$. Length of the waveguide was approximately 1 mm. The difference of refractive indexes of two orthogonal-polarized waves made $\Delta n \approx 4 \cdot 10^{-3}$. The area of cross section approximately 10^{-7} cm^2 . Across the waveguide a weak electrical current about 1-10 mA was passed. For this purpose on waveguide a film electrode from above was put, to which with thermo-compression the thin metal wires were soldered. From below the waveguide was soldered to a metal plate which is mounted on the Peltier element. In area of a exciton resonance on used wavelength nonlinear factor of the nonlinear-optical waveguide was about $\theta \approx 10^{-4} \text{ esu}$. The input and output of radiation from waveguide was carried out by means of cylindrical lenses and gradan, mounted at the input and output of the nonlinear-optical waveguide. All design containing input gradan, input cylindrical lens, nonlinear waveguide, output cylindrical lens and output gradan looked like the uniform module. Through the solenoid the variable electrical current was passed, which change corresponded to a useful variable signal (analog or digital). At an output of polarizer, positioned for an output of the nonlinear-optical waveguide, have received a useful optical signal amplified in 1000 times, and the powers of the orthogonal polarized waves at an output of system changed in opposite phase and the change of each of them in 1000 times exceeded change of signal strength at an input nonlinear waveguide.

As the powers of the orthogonal polarized waves at an output of system changed in opposite phase, for reduction of noise it is possible, having inverted the form of change of power of one of waves, to feed from an output of the device signals (optical or electrical), each of which corresponds UDCWs, on the correlator, in which the common part of change of signals is separated out, and, thus, noise are cut. Thus it is possible to separate out cleared from noise, jamming and casual distortions the amplified information signal. For reduction of noise the signals from an output of the device can fed to the correlator, in which the common part of amplification of signals is allocated, and, thus, noise are cut.

Example 6. The lasers and the nonlinear-optical waveguide from examples 1-3 were used, but at a zero current through the solenoid the polarization of a field at an output and input of

the solenoid, and also at an input of the nonlinear-optical waveguide was directed at an angle 45° to the «fast» and/or to the «slow» axis of the nonlinear birefringent optical waveguide, which can be chosen as x and y axes.

The alternating current causes a deviation of a vector of a field from initial angular position (not changing its size). This increases a x-component and reduces a y-component (or on the contrary), creating a small variable difference in intensities between waves polarized along axes y and x at an input of a nonlinear element. Under this at an output of a nonlinear element this difference grows in many times. The gain was due the self-switching of UDCWs with orthogonal polarizations, which arose in the nonlinear-optical waveguide.

Example 7. Was used strip optical waveguide on a basis of layered MQW-type structure $GaAs / Al_xGa_{1-x}As$ with $x=0.2$. The period of structure made $200\text{\AA}$. The thickness of layers GaAs was $100\text{\AA}$. The thickness light-carrying wave guide of a layer was $1\text{ }\mu\text{m}$ and on it 50 periods MQW of structure were stacked. Width of strip waveguide was $4\text{ }\mu\text{m}$. Length of the nonlinear-optical waveguide was approximately 1 mm. Wavelength appropriate to edge of a zone of absorption, was approximately equaled to $0.85\text{ }\mu\text{m}$. The radiation with wavelength $\lambda=0.86\text{ }\mu\text{m}$ from the semiconductor laser module was weak modulated on amplitude and was launched into the nonlinear-optical waveguide by means of a cylindrical lens and gradan. The maximal amplitude of modulation of power was on three - four order less than average power. Before input into nonlinear-optical waveguide to this radiation was given either linear, or the circular polarization (for example, by transmission through a quarter wave plate or through optical waveguide, to which an electrical voltage was applied). The output of radiation from waveguide also was carried out by a cylindrical lens and gradan. Thus all design consisting from nonlinear-optical waveguide, input and output cylindrical lenses and gradan was made out as the uniform nonlinear-optical module. Across the nonlinear-optical waveguide the electrical current about 1mA was passed, with which the absolute value of a difference of populations between valent zone and zone of conductivity decreased and accordingly resonant absorption of radiation was sharply reduced. At the same time, due to vicinity to a resonance, rather large nonlinear factor waveguide about 10^{-4} esu was reached. Threshold average power, at which differential factor of amplification appreciably exceeded unit, was 2-3mW. Critical average power pump, near to which there was an effective self-switching of radiation, was about 10 mW. The small change of entered power at an input about $1\text{ }\mu\text{W}$ caused in one thousand time stronger change of powers at an output of the nonlinear-optical waveguide of order of 1 mW,

and the powers of the coupled waves at an output of said waveguide in orthogonal polarizations changed in opposite phase and these waves were separated by polarizer. The complete power (in both polarizations) at an output and input nonlinear-optical waveguide was approximately identical, that confirms the fact of sharp reduction of the absorption of the nonlinear-optical waveguide. Let's note, that used as the pump the radiation of the semiconductor laser module

Example 8. There was used the same nonlinear-optical waveguide, through which in a cross direction an electrical current about 1 mA was passed. The radiation to waveguide was fed by an fiber-optic waveguide, from which this radiation through optical contact (by means of a lens executed on the end waveguide) was entered in nonlinear-optical waveguide. The input end fiber-optic waveguide had Y- connection, to one branch of which an signal optical radiation of the left circular polarization, and into another - optical pump optical radiation of the right circular polarization were fed. At an input the power pump was about 10 mW, and power of a signal was about 1 μ W, and input power of a signal changed by value about 1 μ W. The change of power at an output of the nonlinear-optical waveguide in a wave of one polarization was about 1 mW.

Example 9. There was used the same nonlinear-optical waveguide, through which in a cross direction an electrical current about 1-5 mA passed. The radiation was fed to the nonlinear-optical waveguide by fiber-optic waveguide (so called input waveguide), from which this radiation through optical contact (by means of a lens formed on the waveguide end) was entered nonlinear-optical waveguide. Into the input fiber-optic waveguide with the help of Y-type optical mixer an signal optical radiation of one linear polarization was fed, and a pump optical radiation of other linear polarization, orthogonal to the polarization of the signal optical radiation was fed (Fig.8). The electrical field vector of the pump optical radiation was directed approximately at the angle 45° to planes of the layers of the MQW - structure of the nonlinear-optical waveguide. The entered pump power was about 10 mW, and power of a signal optical radiation was about 1 μ W. The variation of power at the output of the nonlinear-optical waveguide in a wave of one linear polarization was about 1 mW.

Example 10. There was used the same nonlinear-optical waveguide, through which in a cross direction an electrical current about 1-10mA passed. The radiation to the nonlinear-optical waveguide was fed by an fiber-optic waveguide (with Y-type mixer), from which this radiation through optical contact (by means of a lens on the end of the fiber-optic waveguide) was entered in nonlinear-optical waveguide. Into waveguide radiation of one circular polarization by

power approximately 10 mW was fed, and its intensity was varied at an input on value about 1 μ W. The maximal change of power at an output of the nonlinear-optical waveguide in left and right circular polarizations was about 1 mW and occurred in opposite phase.

Example 11. The period of structure was 400 Å. ^{There} was used strip optical waveguide on a basis MQW of layered structure $In_{0.47}Ga_{0.53}As / InP$. The thickness of layers $In_{0.47}Ga_{0.53}As$ was grown 200 Å, and within all thickness of the waveguide (on a vertical), equal to 1 μ m, 20 periods of the said structure was stacked. Strip waveguide width was 4 μ m. The waveguide length was approximately 1 mm. Wavelength appropriate to edge of a zone of absorption, was approximately equaled to 1.55 μ m. Radiation with wavelength $\lambda = 1.55 \mu$ m from the semiconductor laser module entered in specified waveguide by means of a cylindrical lens and gradan. The output of radiation from the said waveguide also was carried out by a cylindrical lens and gradan. Thus all design consisting from optical waveguide, input and output cylindrical lenses and gradans was made out as the uniform nonlinear-optical module. Across the nonlinear-optical waveguide (e.g., in vertical direction) the electrical current about 1-2 mA was passed, due to which the absolute value of a difference of populations between a valent zone and zone of conductivity decreased and accordingly resonant absorption of the radiation was reduced in high degree. At the same time, due to vicinity to a resonance, very large nonlinear factor waveguide (about 10^{-3} esu) was achieved. Entered power poorly modulated on amplitude; the deviation of power from average value and relative change of power did not exceed 0.1 % from average power of the laser module. Such modulation was reached by weak modulation of a current through the laser diode or by an external modulator, mounted after the laser module. The threshold power was approximately 2mW. Critical power, near to which there was an effective self-switching of radiation was about 5 mW. The small change of power of a signal at an input was about 1 μ W. And it caused in thousand times stronger change in power of the wave of each polarization at the output of the waveguide (about 10 mW), and the powers at the output of the nonlinear-optical waveguide in orthogonal polarizations changed in opposite phase. The complete power at the output and input of the nonlinear-optical waveguide was of one order, that confirms the fact of sharp reduction of absorption. Let's note, that used as the pump the radiation of the semiconductor laser module was formed into collimated axially symmetric beam by means of the cylindrical lens and gradan mounted at the output of the nonlinear-optical waveguide.

Example 12. There was used the nonlinear-optical waveguide from an example 2, through which in a cross direction an electrical current about 1mA was passed. Pump optical radiation with wavelength close to $1.7\ \mu\text{m}$ of linear, or circular polarization, or elliptic polarization, and signal of other or same linear, or circular polarization, or elliptic polarization with wavelength close to $0.85\ \mu\text{m}$ were fed into the said waveguide. If radiation of linear polarization was fed, then the vector of an electrical field in it was directed at the angle from 10° up to 80° to the layers of the MWQ - structure of the nonlinear birefringent optical waveguide. The entered pump power was about 50 mW, and the power of a signal was about 1 μW , and the fed signal power changed by value about 1 μW . The output power change in a wave of one polarization at the output of the nonlinear-optical waveguide was about 5 mW.

Example 13. Pump optical radiation by power about 60 mW with wavelength $\lambda \approx 0.78\ \mu\text{m}$ from the semiconductor laser module polarized along an axis, perpendicular to layers of the MWQ structures of the birefringent nonlinear-optical waveguide, entered the nonlinear-optical waveguide, radiation-carrying of which was made of layered structure such as $\text{GaAs} / \text{Al}_x\text{Ga}_{1-x}\text{As}$, with $x=0.3$, representing a set (multiplicity) of quantum wells. The period of structure was $200\ \text{\AA}$. The thickness radiation-carrying layer was $0.5\ \mu\text{m}$ and it comprised approximately 25 periods of the structure. Wavelength appropriate to the exciton resonance in the specified structure, was approximately equaled $0.77\ \mu\text{m}$. Width of the strip waveguide was $4\ \mu\text{m}$. Length of the waveguide was approximately 1 mm. The difference of refractive indexes of two orthogonal polarized waves $\Delta n \approx 4 \cdot 10^{-3}$. The area of cross section was approximately $10\ \mu\text{m}$. Across the said waveguide a weak electrical current about 1-10 mA was passed. For this purpose on waveguide a film electrode from above was mounted, to which with thermocompression the thin metal wires were soldered. From below the waveguide was soldered to a metal plate which was mounted on the thermo-electric Peltier element. In area of the exciton resonance on used wavelength the quadratic-nonlinear factor waveguide was about 10^{-4} esu. The length of the nonlinear-optical waveguide was 1 mm. The input and output of radiation from waveguide was carried out by means of cylindrical lenses and gradan, mounted at an input and output nonlinear optical waveguide. All design, containing input gradan, input cylindrical lens, the nonlinear-optical waveguide, output cylindrical lens and output gradan, looked like the uniform nonlinear-optical module. If simultaneously into the same nonlinear-optical waveguide by means of the optical mixer the power modulated signal optical radiation with wavelength $\lambda=1.55\ \mu\text{m}$ and maximal power 0.5 mW, polarized orthogonal to the

polarization of pump optical radiation, was fed, then at the output of the waveguide an amplified radiation (with power about 50 mW) with wavelength $\lambda=1.55 \mu\text{m}$ appeared, which modulation almost without distortions repeated the modulation of input signal optical radiation, but its maximal power was about 40 mW. At absence of signal optical radiation at the input, the output radiation with wavelength $\lambda=1.55 \mu\text{m}$ was not present. If the signal optical radiation at an input was also fed (with power 0.5 mW), then output power of the radiation with $\lambda=1.55 \mu\text{m}$ was 40mW.

In the given example the parametrical transformation of frequency downwards, i.e. separation of frequency is considered. It is based on quadratic-nonlinearity of the nonlinear-optical waveguide, which as well as cubic-nonlinearity grows in high degree when radiation wavelength is approached close to λ_r , where λ_r is wavelength of the exciton resonance. And in the given example pump optical radiation gets in area of the one-photon exciton resonance, and the signal optical radiation - in area of the two-photon exciton resonance.

For increase the birefringence of the layered structure with the purpose of increase of efficiency of transformation of frequency and switching due to improvement of the phase matching of waves on various frequencies (ω and 2ω) it is possible to use the structure GaAs/AlAs, in which the layers AlAs are transformed to oxide with a refractive index $n \approx 1.6$.

Example 14. There was used nonlinear-optical waveguide, similar considered in the example 1, but with the twice greater thickness of the radiation-carrying layer. Therefore in the nonlinear-optical waveguide two cross modes could propagate. At the input of the nonlinear-optical waveguide the pump optical radiation as zero cross mode and signal optical radiation in the form of the first cross mode were fed with the help of Y - connection, i.e. mixer. At the output of the nonlinear-optical waveguide radiations of the zero and the first modes were spatially separated. The linear distributed coupling between modes can be present (due to spatial heterogeneity of the nonlinear-optical waveguide), but it may be absent as well. In the second case the nonlinear distributed coupling was. Both in first and in the second cases the switching between modes occurred and amplification of input modulation at excess pump of threshold value took place.

Example 15. There was used nonlinear semiconductor waveguide, similar considered in the example 1. The signal optical radiation before feeding into the mixer was passed through the phase modulator, representing waveguide, on sides of which film electrodes were located. To these electrodes the modulating electrical voltage varying shift of phases between the signal and

the pump at the input of the nonlinear-optical waveguide was applied. (The specified phase modulator is represented, for example, in the book «Guided-Wave optoelectronics. Theodor Tamir (Ed.), Berlin, "«Springer-Verlag", 1988.)

5 Example 16. There was used nonlinear semiconductor waveguide, similar considered in the example 1. To said waveguide the stationary electrical field formed by means of periodic electrode structure («Guided-Wave optoelectronics. Theodor Tamir (Ed.), Berlin, "«Springer-Verlag", 1988; p.256,257) was applied. In a linear regime in such structure there was a rotation of a plane of polarization. In the nonlinear regime (at excess by pump optical radiation power of the threshold power) small variation of input signal resulted in a sharp switching of radiation
10 from TE - polarization into TM-polarization or on the contrary, accompanying by large amplification of the modulation.

Example 17. There were used strip nonlinear TCOWs on a basis MQW of layered structure $GaAs / Al_xGa_{1-x}As$ with value $x=0.2$. The period of structure was grown 200Å. The thickness of layers GaAs was 100Å. Width of the strip waveguide was $3 \mu m$. Distance between
15 waveguide was approximately $2 \mu m$. Radiation with wavelength $\lambda=0.86 \mu m$ from the semiconductor laser entered into one of waveguides by means of a cylindrical lens and gradan. The output of radiation from every waveguide also was carried out by a cylindrical lens and gradan. Thus all design consisting from TCOWs, input and output cylindrical lenses and gradans was made out as the uniform module. The waveguides were singlemoded. Across the nonlinear
20 TCOWs the electrical current approximately 2 mA was carried (passed). For this purpose on waveguide a film electrode 3 (Fig.2) from above was coated, to which by means of thermo-compression the thin metal wires were soldered. The top layer of semiconductor structure directly contiguous to a film electrode and ensuring electrical contact, represented highly doped GaAs such as p+ with concentration of carriers $10^{19} cm^{-3}$ and had thickness $0.35 \mu m$. From
25 below the waveguide was soldered to a metal plate which was mount on the Peltier element. Wavelength appropriate to the exciton resonance in specified MQW- structure, was approximately equaled to $0.86 \mu m$. This wavelength was smoothly adjusted (at the rate of: $0.25 nm/grad$) and installed then stable, adjusting and establishing temperature of structure by means of adjustment and stabilization of a current through the Peltier element, in thermal
30 contact with one side of which the layered semiconductor structure was. Thus these parameters were smoothly adjustable in area closed to exciton resonance (where the nonlinearity - is maximal) and adjusted (and then fixed) a degree of vicinity to it. As approaching to the exciton

resonance decreased value of critical intensity, near to which there was a phenomenon of self-switching UDCWs. Varying and establishing by means of a regulator it was possible to vary temperature of the side of the Peltier element, to choose, to install and to stabilize critical intensity. The adjustment into the exciton resonance (or to the given degree of vicinity to it) was carried out by adjustment and subsequent stabilization of temperature both the nonlinear-optical waveguides, and the laser diode. In the latter case the wavelength of the laser was adjusted and stabilized. In area of the exciton resonance on used wavelength, due to vicinity to a resonance, large nonlinear factor of the waveguide, according to estimations about 10^{-4} esu was reached.

Critical pump power, near to which there was an effective self-switching of radiation was about 10 mW. The small change of power of input radiation at an input about $1 \mu W$ caused in one thousand time stronger change of powers (about 1 mW) at an output of the waveguides, and the powers at the output of the nonlinear waveguides changed in opposite phase. The estimation of total power at the output of the device confirmed the fact of sufficient reduction of absorption due to the electric current. Let's note, that used as the pump the radiation of the semiconductor laser was formed into collimated an axially symmetric beam by means of a cylindrical lens and gradan.

Example 18. There were used same TCOWs, through which in a cross direction an electrical current about 1-10 mA was passed. The radiation to each of the TCOWs was fed by optical fiber waveguide, from which this radiation through optical contact was entered into one of the TCOWs. Into one of TCOWs a signal optical radiation, and into another or into the same waveguide - a pump optical radiation with intensity close to critical, were fed. The carrying frequency of the signal could differ from frequency of the pump, but could coincide with it. The power pump was installed at value 10 mW, and the power of a signal was about 10 μW , thereto the power of the signal changed by value about 10 μW . The change of power at the output of the waveguide was about 1 mW at concurrence of frequencies (wavelengths) signal and pump, and approximately 0,1mW at discrepancy of wavelengths of the signal and the pump.

Example 19. There were used the same TCOWs, that in examples 1 and 2, and the frequency of a signal coincided with frequency pump, and intensity pump chose close to critical. But under this not input signal power (amplitude), but its phase was changed. For this purpose the signal before input into one of TCOWs was passed through the electrooptical modulator representing optical waveguide from an electrooptical material, or electrooptical crystal. To this optical waveguide or crystal by means of electrodes the signal variable electrical voltage modulating an input phase of a signal was applied. Under this the sharp redistribution of

radiation power at the output of nonlinear TCOWs between waveguides took place, and, thus, output radiation appeared as modulated in amplitude, i.e. the phase modulation at an input of the TCOWs created in an electrooptical element, was transformed (with high efficiency) to the amplitude modulation.

5 Example 20. There were used the same TCOWs, across which an electrical current about 5 mA was passed (carried). The radiation to each of TCOWs was fed by fiber-optic waveguide, from which this radiation through optical contact was entered one of TCOWs. Into both waveguides the pump optical radiation was fed. Into both TCOWs or into one of them controlling signal or signals were fed. Intensity of signal (or signals) was varied in the range
10 from zero to maximum value. In other case phase of the signal (or signals) were varied, when leaving power of signals constant. The pump power was about 10 mW. The maximum signal power signal was about 1 μ W, and power of a signal changed by value about 1 μ W. The change of power at the output of each nonlinear-optical waveguide was about 1 mW.

Example 21. There were used strip TCOWs on the basis of layered MQW structure
15 $In_{0,47}Ga_{0,53}As / InP$. The period of structure was grown about $200\text{\AA}$. The thickness of layers $In_{0,47}Ga_{0,53}As$ was grown $200\text{\AA}$. The width of the strip waveguide was $4\text{ }\mu\text{m}$. The space (gap) between the waveguides was approximately $3\text{ }\mu\text{m}$. Wavelength appropriate to edge of a zone of absorption, was approximately equaled $1.55\text{ }\mu\text{m}$. Radiation with wavelength $\lambda=1.55\text{ }\mu\text{m}$ from the semiconductor laser module entered into one of waveguide by means of a cylindrical lens
20 and gradan. The output of radiation from everyone waveguide also was carried out by a cylindrical lens and gradan. Thus all design consisting from TCOWs, input and output cylindrical lenses and gradans was made out as the uniform module. Through TCOWs in a cross beam a direction (e.g., vertical) the electrical current about 1-10 mA was passed, due to which the absolute size of a difference of populations between a valent zone and zone of conductivity
25 decreased and accordingly resonant absorption of radiation was sharply reduced. The smooth temperature tuning into the exciton resonance by change and stabilization of temperature both nonlinear TCOWs and laser diode was carried out. It was reached (achieved) by change and subsequent stabilization of a current through Peltier elements, on which laser diode and nonlinear TCOWs settled down. Due to vicinity to the resonance, large nonlinear factor
30 waveguide about 10^{-4} esu was achieved. Critical power pump, near to which there was an effective self-switching of radiation was about 10 mW. The small change of power of a signal at an input of the nonlinear TCOWs (about 1 μ W) caused in one thousand time stronger change

of powers at the output of the waveguides (about 1 mW), and the powers at the output of the TCOWs changed in opposite phase. The total power at an output and input waveguide was approximately identical, that confirms the fact of sharp reduction of the absorption of the nonlinear-optical waveguide due to electrical current through it. Let's note, that used in quality pump the radiation of the semiconductor laser was formed into collimated and axially symmetric beam by means of a cylindrical lens and gradan.

Example 22. Pump by power about 60 mW with wavelength $\lambda=0.78 \mu\text{m}$ from the semiconductor laser module polarized along a vertical axis, entered into one of two cubic-nonlinear TCOWs, radiation-carrying lived which was made of layered structure such as $\text{GaAs} / \text{Al}_x\text{Ga}_{1-x}\text{As}$, with $x=0.3$, representing a set of quantum wells (multiple quantum well). The period of structure was $200 \text{\AA}$. The thickness radiation-carrying core was $0.5 \mu\text{m}$ and on it 25 periods of structure were stacked approximately. Wavelength appropriate to the exciton resonance in the specified structure, was approximately equaled $0.78 \mu\text{m}$. Width of the strip nonlinear-optical waveguide was $3 \mu\text{m}$, and gap between them was about $1 \mu\text{m}$. Length of tunnel coupled waveguides was approximately 3 mm. Factor of tunnel coupling of the waveguides was $K \approx 2 \cdot 10^{-3}$ at wavelength $\lambda=0.78 \mu\text{m}$ and $K \approx 5 \cdot 10^{-3}$ at wavelength $\lambda=1.56 \mu\text{m}$. The difference of refractive indexes of two orthogonal polarized waves in every waveguide $\Delta n \approx 4 \cdot 10^{-4}$. The area of cross section of one waveguide was approximately 10^{-7} cm^2 . Across the nonlinear-optical waveguide a weak electrical current about 1-3 mA was passed. For this purpose on the waveguide from above film electrodes were coated, to which by means of thermocompression the thin metal wires were soldered. From below waveguides were soldered to a metal plate which is taking place on an Peltier element. In area of the exciton resonance on used wavelength nonlinear factor waveguide was approximately $2 \cdot 10^{-5}$ esu. The input and output of radiation from waveguide was carried out by means of cylindrical lenses and gradan, mounted at an input and output nonlinear-optical waveguide. All design containing input gradan, input cylindrical lens, nonlinear waveguide, output cylindrical lens and output gradan looked like the uniform module. If simultaneously in the same or the next nonlinear-optical waveguide by means of the mixer, modulated on intensity signal optical radiation with wavelength $\lambda=1.56 \mu\text{m}$ and maximal power 0.5 mW was entered, polarized orthogonal to the pump optical radiation, at an output of the waveguide there was an amplified radiation (with power about 50 mW) with wavelength $\lambda=1.56 \mu\text{m}$, which modulation almost without distortions repeated modulation of signal optical radiation at an input, and the maximal power

was 40 mW. At absence of signal optical radiation at an input, the radiation with wavelength $\lambda=1.56 \mu\text{m}$ at an output is not present. If the signal optical radiation at an input was also present and its power was 0.5 mW, then at the output the radiation power with $\lambda=1.56 \mu\text{m}$ was 40 mW. In the given example the parametric transformation of frequency downwards, i.e. division of frequency, was considered. It is based on quadratic nonlinearity of the waveguides, which as well as the cubic nonlinearity grows in high degree in the vicinity of the exciton resonance. And in the given example pump gets in area of the exciton resonance, and signal optical radiation - in area two-photon of the exciton resonance.

The synchronism between waves on basic (ω) and double (2ω) frequencies was achieved by use of synchronism of the coupled waves in TCOWs and partially for the account of birefringence of each waveguide.

Example 23. There were used the same waveguides, but pump (by power 10mW) had a wavelength $\lambda = 1.55 \mu\text{m}$, and weak modulated signal - wavelength $\lambda = 0.78 \mu\text{m}$. Smaller factor of amplification of a signal in this case was reached(achieved) than in the example 22.

Example 24. There were used planar TCOWs, each radiation-carrying layer of which represented layered MQW structure: $\text{GaAs} / \text{Al}_x\text{Ga}_{1-x}\text{As}$, with $x=0.22$. The period of structure was $200 \text{ \AA}$. The thickness of radiation-carrying layer (core) was about $1 \mu\text{m}$ and within it approximately 50 periods of structure were stacked. Wavelength corresponding to the exciton resonance in the specified structure, was approximately equaled $0.78 \mu\text{m}$. In the gap (space) between these two MQW-type waveguides the flat layer $\text{GaAs} / \text{Al}_y\text{Ga}_{1-y}\text{As}$ was grown with $y \approx 0.25$ and thickness $0.7 \mu\text{m}$. From above and from below of MQW-structures the rather thick layers $\text{Al}_z\text{Ga}_{1-z}\text{As}$ with $z=0.27$ by thickness more than $2 \mu\text{m}$ were grown. In such TCOWs there was achieved the large factors of tunnel coupling: $K \approx 10^{-2}$ by the wavelength $\lambda \approx 0.78$, and $K \approx 4 \cdot 10^{-2}$ by the wavelength $\lambda = 1.56$; that allowed in conditions of «synchronism of the coupled waves» in the greater degree, than in previous examples to compensate frequency dispersion of the optical waveguides and achieve approximately by the order greater gain of the signal optical radiation. As well as in the previous examples through the waveguides in the cross direction the current about 20mA was passed. The wavelengths and other parameters of a signal and pump approximately corresponded to examples 21 and 22.

Example 25. There were used the same quadratic-nonlinear TCOWs, as in examples 21 and 22, the feeding of optical radiation into the nonlinear TCOWs were carried out with fiber-optic waveguides (Fig.12). The semiconductor laser 21 for pump optical radiation with

wavelength $\lambda=0,78 \mu m$ was joined with one of the fiber-optic waveguides, at the end (face) of which a parabolic or conic lens was formed, and the end (face), contiguous to it, waveguide of radiating semiconductor structure of the laser was clarified (i.e. antireflection was coated), and in itself fiber-optic waveguide by a distance 2mm from the lens the grating of refractive index of being a output mirror of the external resonator of the semiconductor laser module is executed. Such design of the laser module provided stable in the course of time frequency of radiation with width of a line not more 0,3nm. The signal optical radiation with wavelength $\lambda=1,56 \mu m$ was fed by fiber-optic waveguide (line). Before the input in one of nonlinear waveguide the electrooptical element 25, in particular, made as a piece of waveguide can be mounted, which allowed to choose an optimum difference in phases of signal and pump optical radiations, at which the maximal amplification of the signal is reached. At the output of the device there was information signal, amplified by three order, with $\lambda=1,56 \mu m$, which could then be transferred further by the fiber-optic communication line.

The device can additionally contain frequency conversion element 28, in which frequency conversion takes place. It can be made as part of quadratic-nonlinear-optical waveguide. It can operates as frequency divider (as shown in Fig.12), or doubling frequency element, or element providing other predetermined conversion of frequency.

The given design represented in essence compact, effective, low-noise, super-high speed, all-optical, all-waveguide re-translator for the fiber-optic communication line.

Example 26. The same connection waveguide was used, as in an example 24 (Fig.12), but the nonlinear TCOWs were used as cubic-nonlinear TCOWs on the basis of MQW-structure with the exciton resonance near to the wavelength $\lambda=0,78 \mu m$. At the output of system amplified by two order information signal on carrying frequency corresponding to wavelength $\lambda=0,78 \mu m$ arose. Under this the transformation of carrying frequency of radiation in nonlinear TCOWs was absent.

Example 27. There were used the same quadratic-nonlinear TCOWs, as in previous examples, transfer and input of optical radiation into nonlinear TCOWs were carried out with fiber-optic waveguides (Fig.12). The radiation with wavelength $\lambda=1,56 \mu m$ was launched into the zero waveguide with the help of fiber-optic waveguide, adjoined to laser diode; under this in the waveguide channel attenuator and optical isolator 24 can be placed. In other nonlinear-optical waveguide, joined (by means of fiber-optic waveguide) with this laser and the nonlinear-optical waveguide, the radiation from the semiconductor laser with wavelength $\lambda=0,78 \mu m$ was

entered. In one of fiber-optic channels the electrooptical element 16 made as a piece of waveguide from an electrooptical material for a possibility of change of a difference in phases of pump and signal optical radiations at the input of the nonlinear TCOWs was mounted. When applying an electrical signal to the electrooptical element, amplitude modulation was achieved of radiation at the output of the device. In this case element 16 operates not as phase compensator but as phase modulator.

The device additionally contains frequency conversion element 28, in which frequency conversion takes place. It can be made as part of quadratic-nonlinear-optical waveguide. It can operate as frequency divider (as shown in Fig.12), or doubling frequency element, or element providing other predetermined conversion of frequency ($\omega_3 = \omega_1 + \omega_2$).

The semiconductor MQW-type structure, which is the radiation-carrying layer (core) (with thickness of order $1 \mu m$) and the basis of the nonlinear-optical waveguide, can be made as alternating thin layers (with thickness of order $100 \text{ \AA}$) of $GaAs / Al_x Ga_{1-x} As$, or $In_x Ga_{1-x} As / InP$, or $In_{1-x} Ga_x As_y P_{1-y} / In_{1-x} Ga_x As_y P_{1-y'}$, where $x \neq x'$ and/or $y \neq y'$, or $CdSe_{1-x} S_x / CdSe$ or $InAs_{1-x} Sb_x / InAs$, or $PbS_x Se_{1-x} / PbSe$, or $Ge_x Si_{1-x} / Si$ containing at least two hetero-transitions or alternating layers of other semiconductor materials.

As a rule said MQW-type structure is grown on a substrate, made from the material, comprising in the composition of the MQW-type structure radiation-carrying layer. But the combined variant, when the MQW-type structure radiation-carrying layer is grown on the substrate wafer made from different material is also possible and sometimes can be favorable. For example, the alternating thin layers $Ge_x Si_{1-x} / Si$ are chief and durable but poorly emit luminescent radiation. The latter circumstance restrict the use of the layers $Ge_x Si_{1-x} / Si$ for carrying out the suggested method and device into effect.

So combined variant can be favorable, when $GaAs / Al_x Ga_{1-x} As$ layers are grown on Ge-substrate. The Ge-wafer substrate is not only low-cost compare with GaAs-wafer substrate, but it is also more light and more durable. This is valuable, e.g., for space devices. The possibility of said combination is possible for other materials, if the growing of the MQW-type structure is possible on the substrate material.

Let us mention that the case when the MWQ-type structure contains only two hetero-transition is also under our consideration if in the nonlinear-optical waveguide based on said MWQ-type structure at least two aforesaid UDCWs can propagate and interact.

Industrial applicability

An all-optical transistor, amplifying (approximately by a factor of hundred times) a small amplitude of signal modulation of continuous waves radiation of a semiconductor laser (with average power approximately equal to 10 mW) has been created. It looks like a compact waveguide module. The all-optical transistor has a linear amplitude characteristic (Fig.15), i.e. it does not distort a form of an amplified signal. So it can be used as an ultra-fast super-effective compact modulator or all-optical small signal amplifier in optical communications and also as a transformer of modulation from one optical frequency to another. In the last case a modulated optical signal and optical pump radiation (with another frequency) are fed into input of the all-optical transistor and the modulation of the optical signal is transferred (with large amplification) to the pump optical radiation.

It can also operate as an all-optical switch, a controlling element and a logic element and can serve as a base element for an optical computer. Many such elements are convenient to be joint into an optical integrated scheme.

At another regime of operation the device can be used as a shortener and a re-shaper of pulses. It can form, shorten and reshape super-short pulses. Certainly it can switch, control and amplify them as well.

The invention gave a possibility to improve parameters drastically when compared with known before: a pump power was decreased by four orders and amplification of signal was increased by two orders (Fig.15). The technological reserves can improve already achieved record parameters.

Claims

1. A method for switching, amplification, controlling and modulation of optical radiation, accomplished with using nonlinear-optical waveguide made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, thereto the nonlinear-optical waveguide is made with possibility of propagation in it at least two unidirectional distributively coupled waves, including feeding of optical radiation with a power to be higher than the threshold power into said nonlinear-optical waveguide, an interaction of the unidirectional distributively coupled waves in the nonlinear-optical waveguide, and separation of the unidirectional distributively coupled waves after the output of said nonlinear-optical waveguide,

CHARACTERIZED in that

cubic-nonlinear and/or quadratic-nonlinear-optical waveguide is used,

the wavelength λ of said optical radiation is selected from the condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide,

electrical current is carried through the nonlinear-optical waveguide,

the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 10% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 10% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 20 or less,

before the input of said nonlinear-optical waveguide they vary the power or the polarization, or the wavelength of said optical radiation, or the angle of the feeding of said optical radiation into said nonlinear-optical waveguide, or they vary the difference in the phases of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, and/or they vary the ratio between the powers of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, or they vary external electrical or magnetic field applied to said nonlinear-optical waveguide.



2. The method as set above in claim 1, CHARACTERIZED in that the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 50% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

3. The method as set above in claim 1, CHARACTERIZED in that the average power of the optical radiation, fed into said nonlinear-optical waveguide, is installed from the condition of obtaining predetermined differential gain and/or the ratio of the powers of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide.

4. The method as set above in claim 3, CHARACTERIZED in that a power of fed optical radiation is chosen in interval from $0,25 P_M$ up to $4P_M$, where P_M is the critical power.

5. The method as set above in claim 4, CHARACTERIZED in that a power of fed optical radiation is chosen in interval from $0,5 P_M$ up to $1,5 P_M$.

6. The method as set above in claim 3, CHARACTERIZED in that an average power of optical radiation, fed into said nonlinear-optical waveguide, is stabilized.

7. The method as set above in claim 1, CHARACTERIZED in that radiation, fed into said nonlinear-optical waveguide, is used in the form of pulses.

8. The method as set above in claim 7, CHARACTERIZED in that the pulses are solitons.

9. The method as set above in claim 1, CHARACTERIZED in that the temperature of said nonlinear-optical waveguide is installed from the condition of obtaining certain value of the threshold power, and/or the critical power, and/or the differential gain and/or the ratio of the powers of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and the temperature of said nonlinear-optical waveguide is stabilized.

10. The method as set above in claim 9, CHARACTERIZED in that temperature of the nonlinear-optical waveguide is controlled and/or stabilized by means of a thermostat and/or at



least one thermoelectric Peltier element, supplied with a controller and/or a stabilizer of the temperature.

11. The method as set above in claim 1, CHARACTERIZED in that at least one of the ends of said nonlinear-optical waveguide has an antireflection coating.

5 12. The method as set above in claim 1, CHARACTERIZED in that the wavelength λ of the optical radiation is selected from the conditions $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.

13. The method as set above in claim 1, CHARACTERIZED in that the nonlinear-optical waveguide is made as birefringent and/or optically active.

10 14. The method as set above in any of claims 1-13, CHARACTERIZED in that said unidirectional distributively coupled waves are the waves of the different wavelengths, and/or the different polarizations, and/or the different waveguide modes.

15 15. The method as set above in any of claims 1-13, CHARACTERIZED in that the optical radiation, fed into said nonlinear-optical waveguide, includes waves of two frequencies, differing by the value more than τ^{-1} , where τ is characteristic time of change of a parameter of the optical radiation.

16. The method as set above in any of claims 1-13, CHARACTERIZED in that by means of a separator the waves of different polarizations and/or different wavelengths and/or different waveguide modes are separated, or the wave of one polarization and/or of one wavelength and/or of one waveguide mode is selected out.

20 17. The method as set above in any of claims 1-13, CHARACTERIZED in that said coherent optical radiation fed into the nonlinear-optical waveguide is used in the form of the radiation of linear or elliptical or circular polarization.

25 18. The method as set above in claim 17, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of optical radiation fed into the nonlinear-optical waveguide is directed at an angle ν , $10^\circ < \nu < 80^\circ$ relative to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

19. The method as set above in claim 18, CHARACTERIZED in that electrical field vector or the axis of polarization ellipse of optical radiation fed into the nonlinear-optical waveguide is directed at the angle of 45° to the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

30 20. The method as set above in claim 17, CHARACTERIZED in that the electrical field vector or axis of polarization ellipse of optical radiation fed into the nonlinear-optical waveguide is directed at an angle ν , $-10^\circ < \nu < 10^\circ$ relative to the «fast» and/or «slow» axis of the nonlinear-optical waveguide.



21. The method as set above in claim 20, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of optical radiation fed into the nonlinear-optical waveguide is coincided with the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

22. The method as set above in claim 14, CHARACTERIZED in that the difference in the phases of said unidirectional distributively coupled waves in optical radiation fed into the nonlinear-optical waveguide is installed from the condition of obtaining the certain differential gain and/or the powers ratio of said unidirectional distributively coupled waves at the output of the nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of the nonlinear-optical waveguide.

23. The method as set above in any of claims 1-13, CHARACTERIZED in that as coherent optical radiation fed into the nonlinear-optical waveguide, the optical radiation of a semiconductor laser and/or laser module is used, thereto a temperature of emitting semiconductor structure of the laser and/or laser module is controlled and/or stabilized.

24. The method as set above in any of claims 1-13, CHARACTERIZED in that at the input of the nonlinear-optical waveguide said optical radiation is focused and/or at the output of the nonlinear-optical waveguide said optical radiation is collimated by means of a cylindrical lens and/or a gradan .

25. The method as set above in any of claims 1-13, CHARACTERIZED in that the feeding of the optical radiation into the nonlinear-optical waveguide and/or the feeding of the optical radiation out from the nonlinear-optical waveguide is done by means of input and/or output optical waveguide correspondingly.

26. The method as set above in claim 25, CHARACTERIZED in that at the output and/or input end of input and/or output optical waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

27. The method as set above in claim 25, CHARACTERIZED in that at least a part of the input waveguide is made from magneto-optic material and set into a solenoid, through which variable electrical current, modulating the optical radiation polarization, is carried, or at least a part of the input waveguide is made as an electro-optical rotator of a polarization plane.

28. The method as set above in any of claims 1-13, CHARACTERIZED in that said electrical current is carried through the direction perpendicular to the layers of aforesaid semiconductor layered MWQ-type structure.



29. The method as set above in claim 28, CHARACTERIZED in that constant electrical current from 0,5mA to 10mA is carried, thereto the current spread from an average value over time does not exceed 0,1mA.

30. The method as set above in claim 28, CHARACTERIZED in that electrical current is
5 carried through the nonlinear-optical waveguide in certain intervals of time.

31. The method as set above in any of claims 1-13, CHARACTERIZED in that dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear-optical waveguide, are compared and their amplified opposite modulation in powers is selected out by means of a correlator and/or differential amplifier.

10 32. The method as set above in any of claims 1-13, CHARACTERIZED in that before the input of the nonlinear-optical waveguide and/or after the output of the nonlinear-optical waveguide at least one optical isolator is mounted.

33. The method as set above in any of claims 1-13, CHARACTERIZED in that said nonlinear-optical waveguide is made as singlemoded for optical radiation fed into said
15 nonlinear-optical waveguide.

34. A method for switching, amplification, controlling and modulation of optical radiation, accomplished with using nonlinear-optical waveguide made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, thereto said nonlinear-optical waveguide is made with possibility of propagation in it at least
20 two unidirectional distributively coupled waves, including feeding of pump optical radiation with a power to be higher than the threshold power and at least one coherent signal optical radiation into the nonlinear-optical waveguide, an interaction of said unidirectional distributively coupled waves in the nonlinear-optical waveguide, and separation of said unidirectional distributively coupled waves after the output of said nonlinear-optical waveguide,

25 CHARACTERIZED in that

cubic-nonlinear and/or quadratic-nonlinear-optical waveguide is used,

the wavelength λ of the pump optical radiation and/or the signal optical radiation is selected from the condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap
30 resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide,

electrical current is carried through the nonlinear-optical waveguide,



the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 10% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 10% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 20 or less,

before the input of said nonlinear-optical waveguide they vary the power or the phase, or the polarization, or the wavelength of said signal optical radiation, or the angle of the feeding of said signal optical radiation into said nonlinear-optical waveguide, and/or they vary the difference in the phases of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, and/or they vary the ratio between the powers of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, or they change the difference in the phases of said signal optical radiation and said pump optical radiation.

35. The method as set above in claim 34, CHARACTERIZED in that the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 50% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

36. The method as set above in claim 34, CHARACTERIZED in that the power of the pump optical radiation, fed into said nonlinear-optical waveguide, is installed from the condition of the choice of the certain value of the differential gain and/or the ratio of powers of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and/or the difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide.



37. The method as set above in claim 36, CHARACTERIZED in that in a case of using cubic nonlinear-optical waveguide the power of fed pump optical radiation is chosen in the range from $0,25 P_M$ up to $4 P_M$, where P_M is the critical power.

38. The method as set above in claim 37, CHARACTERIZED in that in a case of using cubic nonlinear-optical waveguide the power of fed pump optical radiation is chosen in the interval from $0,5 P_M$ up to $1,5 P_M$, where P_M is the critical power.

39. The method as set above in claim 36, CHARACTERIZED in that said pump optical radiation power is stabilized.

40. The method as set above in claim 34, CHARACTERIZED in that the pump optical radiation power is larger than the signal optical radiation power at least by the order of magnitude.

41. The method as set above in claim 34, CHARACTERIZED in that the power of the pump optical radiation and the power of the signal optical radiation are differed from their geometric average value not larger than by the order of magnitude.

42. The method as set above in claim 34, CHARACTERIZED in that said pump optical radiation and/or said signal optical radiation is used in the form of pulses.

43. The method as set above in claim 42, CHARACTERIZED in that said pulses are solitons.

44. The method as set above in claim 34, CHARACTERIZED in that the temperature of said nonlinear-optical waveguide is installed from the condition of obtaining predetermined value of the threshold power, and/or the critical power, and/or the differential gain and/or the ratio of powers of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and temperature of the nonlinear-optical waveguide is stabilized.

45. The method as set above in claim 44, CHARACTERIZED in that the temperature of the nonlinear-optical waveguide is controlled and/or stabilized by means of a thermostat and/or by means of at least one thermoelectric Peltier element, supplied with a controller and/or a stabilizer of the temperature.

46. The method as set above in claim 34, CHARACTERIZED in that at least one of the ends of said nonlinear-optical waveguide has an antireflection coating.



47. The method as set above in claim 34, CHARACTERIZED in that the wavelength λ of the pump optical radiation and/or signal optical radiation is selected from the conditions $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.

48. The method as set above in claim 34, CHARACTERIZED in that said nonlinear-optical waveguide is made as birefringent, and/or optically active.

49. The method as set above in any of claims 34-48, CHARACTERIZED in that said unidirectional distributively coupled waves are the waves of different wavelengths, and/or different polarizations, and/or different waveguide modes.

50. The method as set above in any of claims 34-48, CHARACTERIZED in that said signal optical radiation and said pump optical radiation have center carrier frequencies, differing from each other by the value more than τ^{-1} , where τ is characteristic time of change of a parameter of the signal optical radiation.

51. The method as set above in any of claims 34-48, CHARACTERIZED in that said signal optical radiation and said pump optical radiation contains waves of at least two polarizations, or two wavelengths, or two optical waveguide modes.

52. The method as set above in any of claims 34-48, CHARACTERIZED in that signal optical radiation and pump optical radiation have the same polarization and/or the same wavelength.

53. The method as set above in any of claims 34-48, CHARACTERIZED in that separation of said unidirectional distributively coupled waves after the output of said nonlinear-optical waveguide is done by means of separation of waves of different polarizations and/or different wavelengths and/or different waveguide modes.

54. The method as set above in any of claims 34-48, CHARACTERIZED in that as said pump optical radiation and/or said signal optical radiation they use the optical radiation of a semiconductor laser or a laser module, thereto the temperature of the emitting semiconductor structure of the laser or the laser module is controlled and/or stabilized.

55. The method as set above in claim 53, CHARACTERIZED in that aforesaid pump optical radiation and aforesaid signal optical radiation have the same or different linear or elliptical polarizations.

56. The method as set above in claim 55, CHARACTERIZED in that the pump optical radiation and the signal optical radiation have linear mutually orthogonal polarizations or elliptical polarizations with mutually orthogonal axes of polarization ellipses.



57. The method as set above in claim 55, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of said pump and/or signal optical radiation fed into the nonlinear-optical waveguide is directed at the angle ν , $10^\circ < \nu < 80^\circ$ relative to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

5 58. The method as set above in claim 57, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of said pump and/or signal optical radiation is directed at the angle of 45° to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

59. The method as set above in claim 55, CHARACTERIZED in that the electrical field vector or the axis of the polarization ellipse of said pump and/or signal optical radiation fed into
10 said nonlinear-optical waveguide is directed at the angle ν , $-10^\circ < \nu < 10^\circ$ relative to the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

60. The method as set above in claim 59, CHARACTERIZED in that the electrical field vector or the axis of the polarization ellipse of said pump and/or signal optical radiation is coincided with the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

15 61. The method as set above in claim 53, CHARACTERIZED in that the pump optical radiation and the signal optical radiation have the same or reverse circular polarizations.

62. The method as set above in any of claims 34-48, CHARACTERIZED in that before the feeding of the pump optical radiation and the signal optical radiation into the nonlinear-optical waveguide said radiations are focused, and/or after transmission of the radiations
20 through the nonlinear-optical waveguide the optical radiation is collimated by a cylindrical lens and/or a gradan.

63. The method as set above in any of claims 34-48, CHARACTERIZED in that the feeding of the pump optical radiation and the signal optical radiation into said nonlinear-optical waveguide and/or the feeding of the optical radiation out from the nonlinear-optical waveguide
25 is done by means of the input and/or output optical waveguide correspondingly.

64. The method as set above in claim 63, CHARACTERIZED in that at the output and/or input end of input and/or output optical waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

65. The method as set above in claim 63, CHARACTERIZED in that the input waveguide
30 contains at least two input branches, at least into one of which the signal optical radiation is fed and into another branch the pump optical radiation is fed, thereto at least a part of the branch, into which the signal optical radiation is fed, is made of magneto-optic material and set in solenoid, through which variable electrical current, modulating the polarization of the signal



optical radiation, is carried, or at least the part of the branch is made as an electro-optic rotator - of the polarization plane of optical radiation.

66. The method as set above in any of claims 34-48, CHARACTERIZED in that before the input of said nonlinear-optical waveguide and/or after the output of said nonlinear-optical waveguide at least one optical isolator is mounted and optically connected with said nonlinear-optical waveguide.

67. The method as set above in any of claims 34-48, CHARACTERIZED in that said electrical current through the nonlinear-optical waveguide is carried in the direction perpendicular to the layers of said semiconductor layered MWQ-type structure.

10 68. The method as set above in claim 67, CHARACTERIZED in that constant electrical current from 0,5mA to 10mA is carried, thereto the current spread from an average value in time does not exceed 0,1mA.

69. The method as set above in claim 67, CHARACTERIZED in that electrical current is carried through the nonlinear-optical waveguide in certain intervals of time.

15 70. The method as set above in any of claims 34-48, CHARACTERIZED in that dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear-optical waveguide, are compared and their amplified opposite modulation in powers is selected out by means of a correlator and/or differential amplifier.

20 71. The method as set above in any of claims 34-48, CHARACTERIZED in that pump optical radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength λ_r of exciton resonance of said semiconductor structure of said nonlinear-optical waveguide is installed by controlling of its temperature, and/or the wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is less than absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the
25 exciton resonance: $|\lambda_s - \lambda_r| < |\lambda_p - \lambda_r|$.

72. The method as set above in any of claims 34-48, CHARACTERIZED in that pump optical radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength λ_r of exciton resonance of said semiconductor structure of said nonlinear-optical waveguide is installed by controlling of its temperature, and/or the wavelength λ_p
30 and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal



optical radiation and the wavelength λ_r of the exciton resonance is larger than absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| > |\lambda_p - \lambda_r|$.

73. The method as set above in claim 54, CHARACTERIZED in that the wavelength of the laser and/or laser module radiation is installed by controlling temperature of the radiating semiconductor structure of the laser and/or laser module, and/or by squeezing or stretching of fiber-optic waveguide in which a refractive index periodical grating is made, and the said fiber-optic waveguide is comprised in the laser module and adjoined to the laser diode.

74. The method as set above in any of claims 34-48, CHARACTERIZED in that said nonlinear-optical waveguide is made as singlemoded to both signal and pump optical radiations.

75. A method for switching, amplification, controlling and modulation of optical radiation, carried out with using nonlinear-optical waveguide made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, thereto the nonlinear-optical waveguide is made with possibility of propagation in it at least two unidirectional distributively coupled waves having different polarizations, comprising the feeding of polarized optical radiation with a power to be higher than the threshold power into said nonlinear-optical waveguide, the interaction of said unidirectional distributively coupled waves having different polarizations in said nonlinear-optical waveguide, and separation of said unidirectional distributively coupled waves having different polarizations after the output of said nonlinear-optical waveguide,

CHARACTERIZED in that

cubic-nonlinear and/or quadratic-nonlinear-optical waveguide is used,

the nonlinear-optical waveguide is made as birefringent and/or optically active,

wavelength λ of the radiation is selected from the condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide,

electrical current is carried through said nonlinear-optical waveguide,

the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 10% of power of one of said unidirectional distributively coupled waves having different polarizations to other one from said unidirectional distributively coupled waves of different polarization, and the length of said



nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 10% of the power of the one of said unidirectional distributively coupled waves having different polarizations to the other one from said unidirectional distributively coupled waves of different polarization, does not exceed the length, at which the power of the most attenuated wave from
5 said unidirectional distributively coupled waves is attenuated in 20 times or less,

before the input of said nonlinear-optical waveguide they vary the power or the polarization, or the wavelength of said optical radiation, or the angle of the feeding of said optical radiation into said nonlinear-optical waveguide, or they vary the difference in the phases of said unidirectional distributively coupled waves at the input of said nonlinear-optical
10 waveguide, and/or they vary the ratio between the powers of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, or they vary external electrical or magnetic field applied to said nonlinear-optical waveguide.

76. The method as set above in claim 75, CHARACTERIZED in that the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves having different polarizations to other one from said unidirectional distributively coupled waves of different polarization, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 50% of the power of the one of said unidirectional distributively coupled waves having different polarizations to the other one from
20 said unidirectional distributively coupled waves of different polarization, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated in 10 times.

77. The method as set above in claim 75, CHARACTERIZED in that the average power of the optical radiation, fed into said nonlinear-optical waveguide, is installed from the condition
25 of the obtaining a predetermined differential gain and/or a ratio of the powers of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide.

78. The method as set above in claim 77, CHARACTERIZED in that in a case of using
30 cubic nonlinear-optical waveguide a power of fed optical radiation is chosen in interval from $0,25 P_M$ up to $4P_M$, where P_M is the critical power.



79. The method as set above in claim 78, CHARACTERIZED in that in a case of using cubic nonlinear-optical waveguide a power of fed optical radiation is chosen in interval from $0,5 P_M$ up to $1,5 P_M$.

80. The method as set above in claim 77, CHARACTERIZED in that the average power of the polarized optical radiation, fed into said nonlinear-optical waveguide, is stabilized.

81. The method as set above in claim 75, CHARACTERIZED in that the polarized optical radiation, fed into said nonlinear-optical waveguide, is used in the form of pulses.

82. The method as set above in claim 81, CHARACTERIZED in that the pulses are solitons.

83. The method as set above in claim 75, CHARACTERIZED in that the temperature of said nonlinear-optical waveguide is installed from the condition of obtaining certain value of the threshold power, and/or the critical power, and/or the differential gain and/or the ratio of the powers of said unidirectional distributively coupled waves having different polarizations at the output of said nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and the temperature of said nonlinear-optical waveguide is stabilized.

84. The method as set above in claim 83, CHARACTERIZED in that the temperature of the said nonlinear-optical waveguide is controlled and/or stabilized by means of a thermostat and/or at least one thermoelectric Peltier element, supplied with a controller and/or a stabilizer of the temperature.

85. The method as set above in claim 75, CHARACTERIZED in that at least one of the ends of said nonlinear-optical waveguide has an antireflection coating.

86. The method as set above in claim 75, CHARACTERIZED in that the wavelength λ of said optical radiation is selected from the condition $0,8\lambda_c < \lambda < 1,2\lambda_c$.

87. The method as set above in any of claims 75-86, CHARACTERIZED in that said polarized optical radiation fed into the nonlinear-optical waveguide is used in the form of the optical radiation of linear or elliptical or circular polarization.

88. The method as set above in claim 87, CHARACTERIZED in that said separation of waves of different polarizations after the output of said nonlinear-optical waveguide is fulfilled by a polarizer made as a polaroid, or a polarizing prism, or a birefringent prism, or a directional coupler, separating waves with different polarizations, or a polarizer based on an optical waveguide, or as an air-path optical isolator, or a fiber-optic isolator, or a circular polarizer, or the polarizer comprises a phase compensator.



89. The method as set above in any of claims 75-86, CHARACTERIZED in that before the input of the nonlinear-optical waveguide and/or after the output of the nonlinear-optical waveguide at least one optical isolator is placed.

90. The method as set above in claim 89, CHARACTERIZED in that said optical isolator
5 mounted before said nonlinear-optical waveguide is used as an optical polarizer, and/or optical isolator mounted after the nonlinear-optical waveguide is used for separating out one of said unidirectional distributively coupled waves.

91. The method as set above in any of claims 75-86, CHARACTERIZED in that before the input of the nonlinear-optical waveguide and/or after the output of the nonlinear-optical
10 waveguide at least one phase compensator or a controller is placed, by means of which they control the difference in phases of said unidirectional distributively coupled waves or they set a predetermined difference in phases of said unidirectional distributively coupled waves at the input and/or at the output of the nonlinear-optical waveguide, thereto the phase compensator or controller is made as an air-path phase compensator or controller, or a waveguide phase
15 compensator or controller, and/or a fiber-optic waveguide phase compensator or controller.

92. The method as set above in any of claims 75-86, CHARACTERIZED in that a difference in phases of said unidirectional distributively coupled waves of different polarizations at the input of said nonlinear-optical waveguide is installed from the condition of a choice of a value of the differential gain and/or the ratio of powers of said unidirectional distributively
20 coupled waves of different polarizations at the output of said nonlinear-optical waveguide and/or the difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide.

93. The method as set above in any of claims 75-86, CHARACTERIZED in that before the input of the nonlinear-optical waveguide and/or after the output of the nonlinear-optical
25 waveguide at least one polarizer controller is mounted, by means of which they set predetermined polarization of fed optical radiation at the input of the nonlinear-optical waveguide, thereto the polarization controller is made as an air-path polarization controller, or a waveguide polarization controller, and/or a fiber-optic polarization controller.

94. The method as set above in claim 87, CHARACTERIZED in that the electrical field
30 vector or the axis of polarization ellipse of the polarized optical radiation fed into the nonlinear-optical waveguide is directed at an angle ν , $10^\circ < \nu < 80^\circ$ relative to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.



95. The method as set above in claim 94, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of polarized optical radiation fed into the nonlinear-optical waveguide is directed at an angle ν , $40^\circ < \nu < 50^\circ$ relative to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

5 96. The method as set above in claim 95, CHARACTERIZED in that electrical field vector or the axis of polarization ellipse of optical radiation fed into the nonlinear-optical waveguide is directed at the angle of 45° to the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

10 97. The method as set above in claim 87, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of the polarized optical radiation fed into the nonlinear-optical waveguide is directed at an angle ν , $-10^\circ < \nu < 10^\circ$ relative to the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

15 98. The method as set above in claim 97, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of the polarized optical radiation fed into the nonlinear-optical waveguide is coincided with the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

20 99. The method as set above in any of claims 75-86, CHARACTERIZED in that as polarized optical radiation, fed into the nonlinear-optical waveguide, an optical radiation of a semiconductor laser or a laser module is used, thereto a temperature of radiating semiconductor structure of the laser or the laser module is controlled and/or stabilized.

100. The method as set above in any of claims 75-86, CHARACTERIZED in that at the input of the nonlinear-optical waveguide radiation is focused and/or at the output of the nonlinear-optical waveguide radiation is collimated by means of a cylindrical lens and/or a gradan.

25 101. The method as set above in any of claims 75-86, CHARACTERIZED in that the feeding of the optical radiation into the nonlinear-optical waveguide and/or the feeding of the optical radiation out from the nonlinear-optical waveguide is done by means of an input and/or an output optical waveguide correspondingly.

30 102. The method as set above in claim 101, CHARACTERIZED in that at the output and/or input end of the input and/or output optical waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

103. The method as set above in claim 101, CHARACTERIZED in that at least part of the input waveguide is made of magneto-optic material and set in a solenoid, through which



variable electrical current, modulating polarization of aforesaid polarized optical radiation, is carried, or at least part of the input waveguide is made as an electro-optic rotator of a polarization plane.

104. The method as set above in claim 101, CHARACTERIZED in that following optical
5 elements: a semiconductor laser or laser module or fiber-optic source module, which serves as a source of said polarized optical radiation, and/or said nonlinear-optical waveguide, and/or said input optical waveguide, and/or said output optical waveguide, and/or an optical isolator made in the form of an optical waveguide, and/or an optical polarizer made in the form of an optical waveguide and used for separation of said unidirectional destrubutively coupled waves having
10 different polarizations, and/or an optical phase compensator or a controller made in the form of an optical waveguide, are optically connected in a united optical waveguide or in a nonlinear-optical module.

105. The method as set above in claim 104, CHARACTERIZED in that a semiconductor laser or laser module or fiber-optic source module is made with an external resonator.

15 106. The method as set above in claim 105, CHARACTERIZED in that the mirror of said external resonator is made as a refractive index periodical grating in fiber-optic waveguide adjoined to the laser diode, thereto said laser diode end the closest to said fiber-optic waveguide has an antireflection coating and another end of said laser diode has a reflection coating.

107. The method as set above in claim 104, CHARACTERIZED in that the said optical
20 elements are optically connected by fiber-optic connectors and/or connecting sockets.

108. The method as set above in claim 107, CHARACTERIZED in that the said optical elements are optically connected by fiber-optical connectors and/or connecting sockets with possibility of rotation or turn of said optical elements of the nonlinear-optical module, connected by means of optical fiber connectors and/or sockets, around the longitudinal axis of
25 the nonlinear-optical module.

109. The method as set above in claim 108, CHARACTERIZED in that the electrical field vector or the axis of the polarization ellipse of the polarized optical radiation fed into the nonlinear-optical waveguide is orientated relative to the «fast» and/or «slow» axis of the nonlinear-optical waveguide by rotation of optical elements of the nonlinear-optical module,
30 connected by means of optical fiber connectors and/or sockets, around the longitudinal axis of the nonlinear-optical module.

110. The method as set above in any of claims 75-86, CHARACTERIZED in that the polarized optical radiation, fed into the nonlinear-optical waveguide, includes waves of two



frequencies differing by the value more than τ^{-1} , where τ is a characteristic time of a change of a parameter of the radiation.

111. The method as set above in any of claims 75-86, CHARACTERIZED in that said electrical current is carried in the direction perpendicular to the layers of said semiconductor layered MWQ-type structure.

112. The method as set above in claim 111, CHARACTERIZED in that constant electrical current from 0,5mA to 10mA is carried, thereto the current spread from an average value in time does not exceed 0,1mA.

113. The method as set above in claim 111, CHARACTERIZED in that electrical current is carried through the nonlinear-optical waveguide in predetermined intervals of time.

114. The method as set above in any of claims 75-86, CHARACTERIZED in that dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear-optical waveguide, are compared and their amplified opposite modulation in powers is selected out by means of a correlator and/or differential amplifier.

115. The method as set above in any of claims 75-86, CHARACTERIZED in that said nonlinear-optical waveguide is made as single-mode for said polarized optical radiation.

116. The method as set above in any of claims 75-86, CHARACTERIZED in that said unidirectional distributively coupled waves of different polarizations are the waves of mutually orthogonal polarizations.

117. A method for switching, amplification, controlling and modulation of optical radiation, accomplished with using nonlinear-optical waveguide made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, thereto said nonlinear-optical waveguide is made with possibility of propagation in it at least two unidirectional distributively coupled waves having different polarizations, comprising the feeding of polarized pump optical radiation with a power to be higher than the threshold power and at least one polarized signal optical radiation into said nonlinear-optical waveguide, an interaction of the unidirectional distributively coupled waves having different polarizations in the nonlinear-optical waveguide, and separation of said unidirectional distributively coupled waves having different polarizations after their output from said nonlinear-optical waveguide,

CHARACTERIZED in that

cubic-nonlinear and/or quadratic-nonlinear-optical waveguide is used,

the nonlinear-optical waveguide is made as birefringent and/or optically active,



the wavelength λ of the pump optical radiation and/or the signal optical radiation is selected from the condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide,

electrical current is carried through said nonlinear-optical waveguide,

the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 10% of power of one of said unidirectional distributively coupled waves having different polarizations to other one from said unidirectional distributively coupled waves of different polarization, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 10% of the power of the one of said unidirectional distributively coupled waves having different polarizations to the other one from said unidirectional distributively coupled waves of different polarization, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated in 20 times or less,

before the input of said nonlinear-optical waveguide they vary the power or the phase, or the polarization, or the wavelength of said signal optical radiation, or the angle of the feeding of said signal optical radiation into said nonlinear-optical waveguide, and/or they vary the difference in the phases of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, and/or they vary the ratio between the powers of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, or they change the difference in the phases of said signal optical radiation and said pump optical radiation.

118. The method as set above in claim 117, CHARACTERIZED in that the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves having different polarizations to other one from said unidirectional distributively coupled waves of different polarization, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 50% of the power of the one of said unidirectional distributively coupled waves having different polarizations to the other one from said unidirectional distributively coupled waves of different polarization, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated in 20 times.



119. The method as set above in claim 117, CHARACTERIZED in that the power of the pump optical radiation, fed into said nonlinear-optical waveguide, is installed from the condition of obtaining predetermined value of the differential gain and/or the ratio of powers of said unidirectional distributively coupled waves having different polarizations at the output of said nonlinear-optical waveguide and/or the difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide.

120. The method as set above in claim 119, CHARACTERIZED in that the power of fed pump optical radiation is chosen in the range from $0,25 \cdot P_M$ up to $4P_M$, where P_M is the critical power.

121. The method as set above in claim 120, CHARACTERIZED in that the power of fed pump optical radiation is chosen in the interval from $0,5P_M$ up to $4P_M$, where P_M is the critical power.

122. The method as set above in claim 119, CHARACTERIZED in that said pump optical radiation power is stabilized.

123. The method as set above in claim 117, CHARACTERIZED in that the pump optical radiation power is larger than the signal optical radiation power at least by the order of magnitude.

124. The method as set above in claim 117, CHARACTERIZED in that the power of the pump optical radiation and the power of the signal optical radiation are differed from their geometric average value not larger than by the order of magnitude.

125. The method as set above in claim 117, CHARACTERIZED in that said pump optical radiation and/or said signal optical radiation is used in the form of pulses.

126. The method as set above in claim 125, CHARACTERIZED in that said pulses are solitons.

127. The method as set above in claim 117, CHARACTERIZED in that the temperature of said nonlinear-optical waveguide is installed from the condition of obtaining predetermined value of the threshold power, and/or the critical power, and/or the differential gain and/or the ratio of powers of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and/or the difference in the phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide and temperature of the nonlinear-optical waveguide is stabilized.

128. The method as set above in claim 127, CHARACTERIZED in that the temperature of the nonlinear-optical waveguide is controlled and/or stabilized by means of a thermostat



and/or by means of at least one thermoelectric Peltier element, supplied with a controller and/or a stabilizer of the temperature.

129. The method as set above in claim 117, CHARACTERIZED in that at least one of the ends of said nonlinear-optical waveguide has an antireflection coating.

5 130. The method as set above in claim 117, CHARACTERIZED in that the wavelength λ of the pump optical radiation and/or signal optical radiation is selected from the conditions $0,8\lambda_r \leq \lambda \leq 1,2\lambda_r$.

10 131. The method as set above in any of claims 117-130, CHARACTERIZED in that said unidirectional distributively coupled waves are the waves of different wavelengths, and/or different polarizations, and/or different waveguide modes.

132. The method as set above in any of claims 117-130, CHARACTERIZED in that said signal optical radiation and said pump optical radiation have center carrier frequencies, differing from each other by the value more than τ^{-1} , where τ is characteristic time of change of a parameter of the signal optical radiation.

15 133. The method as set above in any of claims 117-130, CHARACTERIZED in that said signal optical radiation and said pump optical radiation contains waves of at least two polarizations, or two wavelengths, or two optical waveguide modes.

20 134. The method as set above in any of claims 117-130, CHARACTERIZED in that signal optical radiation and pump optical radiation have the same polarization and/or the same wavelength.

135. The method as set above in any of claims 117-130, CHARACTERIZED in that separation of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide is done by means of a separator of waves of different polarizations and/or different wavelengths and/or different waveguide modes.

25 136. The method as set above in any of claims 117-130, CHARACTERIZED in that as said pump optical radiation and/or said signal optical radiation the optical radiation of a semiconductor laser and/or a laser module is used, thereto the temperature of the emitting semiconductor structure of the laser and/or the laser module is controlled and/or stabilized.

30 137. The method as set above in ^{any of} claims 117-130, CHARACTERIZED in that aforesaid pump optical radiation and aforesaid signal optical radiation have the same or different linear or elliptical polarizations.



138. The method as set above in claim 137, CHARACTERIZED in that the pump optical radiation and the signal optical radiation have linear mutually orthogonal polarizations or elliptical polarizations with mutually orthogonal axes of polarization ellipses.

139. The method as set above in claim 137, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of said pump and/or signal optical radiation fed into the nonlinear-optical waveguide is directed at the angle ν , $10^\circ < \nu < 80^\circ$ relative to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

140. The method as set above in claim 139, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of said pump and/or signal optical radiation fed into the nonlinear-optical waveguide is directed at the angle ν , $40^\circ < \nu < 50^\circ$ relative to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

141. The method as set above in claim 140, CHARACTERIZED in that the electrical field vector or the axis of polarization ellipse of said pump and/or signal optical radiation is directed at the angle of 45° to the «fast» and/or «slow» axis of said nonlinear-optical waveguide.

142. The method as set above in claim 137, CHARACTERIZED in that the electrical field vector or the axis of the polarization ellipse of said pump and/or signal optical radiation fed into said nonlinear-optical waveguide is directed at the angle ν , $-10^\circ < \nu < 10^\circ$ relative to the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

143. The method as set above in claim 142, CHARACTERIZED in that the electrical field vector or the axis of the polarization ellipse of said pump and/or signal optical radiation is coincided with the «fast» and/or «slow» axis of the nonlinear-optical waveguide.

144. The method as set above in any of claims 117-130, CHARACTERIZED in that a difference in phases of said unidirectional distributively coupled waves of orthogonal polarizations at the input of said nonlinear-optical waveguide is installed from the condition obtaining predetermined value of the differential gain and/or the ratio of powers of said unidirectional distributively coupled waves of orthogonal polarizations at the output of said nonlinear-optical waveguide and/or the difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear-optical waveguide.

145. The method as set above in claim 117, CHARACTERIZED in that the pump optical radiation and the signal optical radiation have the same or reverse circular polarizations.

146. The method as set above in any of claims 117-130, CHARACTERIZED in that before the feeding of the pump optical radiation and the signal optical radiation into the



nonlinear-optical waveguide said radiations are focused, and/or after transmission of the radiations through the nonlinear-optical waveguide the optical radiation is collimated by a cylindrical lens and/or a gradan.

147. The method as set above in any of claims 117-130, CHARACTERIZED in that the feeding of the pump optical radiation and the signal optical radiation into said nonlinear-optical waveguide and/or the feeding of the optical radiation out from the nonlinear-optical waveguide is done by means of the input and/or output optical waveguide correspondingly.

148. The method as set above in claim 147, CHARACTERIZED in that at the output and/or input end of input and/or output optical waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

149. The method as set above in claim 147, CHARACTERIZED in that the input waveguide contains at least two input branches, at least into one of which the signal optical radiation is fed and into another branch the pump optical radiation is fed, thereto at least a part of the branch, into which the signal optical radiation is fed, is made of magneto-optic material and set in solenoid, through which variable electrical current, modulating the polarization of the signal optical radiation, is carried, or at least the part of the branch is made as electro-optic rotator of polarization plane.

150. The method as set above in any of claims 117-130, CHARACTERIZED in that before the input of said nonlinear-optical waveguide and/or after the output of said nonlinear-optical waveguide at least one optical isolator is installed.

151. The method as set above in any of claims 117-130, CHARACTERIZED in that said electrical current through the nonlinear-optical waveguide is carried in the direction perpendicular to the layers of said semiconductor layered MWQ-type structure.

152. The method as set above in claim 151, CHARACTERIZED in that constant electrical current from 0,5mA to 10mA is carried, thereto the current spread from an average value in time does not exceed 0,1mA.

153. The method as set above in claim 151, CHARACTERIZED in that electrical current is carried through the nonlinear-optical waveguide in certain intervals of time.

154. The method as set above in any of claims 117-130, CHARACTERIZED in that dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear-optical waveguide, are compared and their difference in powers is selected out by means of a correlator and/or differential amplifier.



155. The method as set above in claim 132, CHARACTERIZED in that pump - optical radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength λ_r of exciton resonance of said semiconductor structure of said nonlinear-optical waveguide is installed by controlling of its temperature, and/or the
5 wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is less than absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| < |\lambda_p - \lambda_r|$.

156. The method as set above in claim 132, CHARACTERIZED in that pump
10 optical radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength λ_r of exciton resonance of said semiconductor structure of said nonlinear-optical waveguide is installed by controlling of its temperature, and/or the wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is larger than
15 absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| > |\lambda_p - \lambda_r|$.

157. The method as set above in claim 136, CHARACTERIZED in that the wavelength of the laser and/or laser module radiation is installed by controlling temperature of the radiating semiconductor structure of the laser and/or laser module, and/or by squeezing or
20 stretching of fiber-optic waveguide in which a refractive index periodical grating is made, and the said fiber-optic waveguide is comprised in the laser module and adjoined to the laser diode.

158. The method as set above in any of claims 117-130, CHARACTERIZED in that said nonlinear-optical waveguide is made as single-mode to both said signal and pump optical radiations.

25 159. The method as set above in any of claims 117-130, CHARACTERIZED in that said unidirectional distributively coupled waves having different polarizations are the unidirectional distributively coupled waves having mutually orthogonal polarizations.

160. A device for switching, amplification, controlling and modulation of optical radiation, comprising nonlinear-optical waveguide, made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, and said
30 nonlinear-optical waveguide is made with possibility of propagation in it at least two



unidirectional distributively coupled waves, thereto the device contains optical input/output elements for feeding of optical radiation into said nonlinear-optical waveguide and/or feeding of optical radiation out from said nonlinear-optical waveguide correspondingly, and a separator of said unidirectional distributively coupled waves for the separation of said unidirectional distributively coupled waves placed after output end of said nonlinear-optical waveguide,

CHARACTERIZED in that

said nonlinear-optical waveguide is made as cubic-nonlinear and/or quadratic-nonlinear,

said nonlinear-optical waveguide is supplied with electrical contacts for carrying an electrical current through said nonlinear-optical waveguide,

the wavelength λ_r of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide is selected from the conditions $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ is the wavelength of at least one optical radiation fed into the nonlinear-optical waveguide,

thereto said optical input and/or output elements are mounted at the input and/or output of said nonlinear-optical waveguide,

said optical input/output elements are positioned and mounted relative to the said nonlinear-optical waveguide with precision, provided by their positioning by luminescent radiation of said nonlinear-optical waveguide, appeared when electrical current with value above the threshold current value is carried through said nonlinear-optical waveguide,

thereto the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 10% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 10% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 20 or less,

thereto the nonlinear coefficient of said nonlinear-optical waveguide is larger than the threshold nonlinear coefficient.

161. The device as set above in claim 160, CHARACTERIZED in that the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 30% of power of one of said unidirectional distributively coupled



waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 30% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

162. The device as set above in claim 161, CHARACTERIZED in that the length of said nonlinear-optical waveguide is not less than the length, which is necessary for the switching and/or the transfer of at least 50% of power of one of said unidirectional distributively coupled waves to other one from said unidirectional distributively coupled waves, and the length of said nonlinear-optical waveguide, which is necessary for the switching and/or the transfer of at least 50% of the power of the one of said unidirectional distributively coupled waves to the other one from said unidirectional distributively coupled waves, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

163. The device as set above in claim 160, CHARACTERIZED in that said nonlinear-optical waveguide is made as birefringent and/or optically active and/or magneto-active.

164. The device as set above in claim 160, CHARACTERIZED in that the semiconductor layered MQW-type structure is made in the form of alternating layers $GaAs / Al_xGa_{1-x}As$, or $In_xGa_{1-x}As / InP$, or $In_{1-x}Ga_xAs_yP_{1-y} / In_{1-x}Ga_xAs_yP_{1-y}$, where $x \neq x'$ and/or $y \neq y'$, or $CdSe_{1-x}S_x / CdSe$ or $InAs_{1-x}Sb_x / InAs$, or $PbS_xSe_{1-x} / PbSe$, or Ge_xSi_{1-x} / Si .

165. The device as set above in claim 160, CHARACTERIZED in that said nonlinear-optical waveguide is made as single-mode for said optical radiation fed into said nonlinear-optical waveguide

166. The device as set above in claim 160, CHARACTERIZED in that thereto the device contains at least one thermoelectric Peltier element and at least one sensor of temperature, thereto a side of said Peltier element is in thermal contact with said nonlinear-optical waveguide and with at least one sensor of temperature.

167. The device as set above in claim 166, CHARACTERIZED in that the sensor of temperature is made as a thermistor and/or a thermoelectric couple and/or a sensor in the form of an integrated scheme.



168. The device as set above in claim 166, CHARACTERIZED in that for heat rejection - it contains radiator, which is in thermal contact with at least one thermoelectric Peltier element.

169. The device as set above in claim 166, CHARACTERIZED in that at least one said thermoelectric Peltier element and at least one said sensor of temperature are electrically
5 connected to a controller and/or a stabilizer of the temperature.

170. The device as set above in claim 160, CHARACTERIZED in that input and/or output ends of the nonlinear-optical waveguide have antireflection coating(s).

171. The device as set above in claim 170, CHARACTERIZED in that antireflection coating decreases relative reflectivity at the input/output end up to value not more than 1%.

10 172. The device as set above in claim 160, CHARACTERIZED in that said input/output elements are made in the form of objectives.

173. The device as set above in claim 172, CHARACTERIZED in that said objectives comprise at least one cylindrical lens and/or at least one gradan.

15 174. The device as set above in claim 173, CHARACTERIZED in that the surfaces of the said cylindrical lens and/or said gradan have antireflection coating(s).

175. The device as set above in claim 160, CHARACTERIZED in that said input/output elements are made in the form of input and/or output optical waveguide.

176. The method as set above in claim 175, CHARACTERIZED in that at the output and/or input end of input and/or output optical waveguide a lens is made and/or a gradan is
20 mounted.

177. The device as set above in claim 176, CHARACTERIZED in that said lens is made as parabolic and/or conic and/or cylindrical.

178. The device as set above in claim 160, CHARACTERIZED in that it provides with an electrical current source, electrically connected to the electrical contacts of said nonlinear-
25 optical waveguide.

179. The device as set above in claim 178, CHARACTERIZED in that the electrical current source is a constant current source supplying the electrical current across the nonlinear-optical waveguide with values from 0,5mA to 10mA in operation of the device, thereto the current spread from an average value in time does not exceed 0,1mA.

30 180. The device as set above in claim 178, CHARACTERIZED in that the electrical current source supplies with the threshold current value equals 20mA and higher current values of said current across said nonlinear-optical waveguide, during said positioning and mounting of said input/output elements by said luminescent radiation of said nonlinear-optical waveguide.



181. The device as set above in claim 178, CHARACTERIZED in that said current source is supplied with fast switch.

182. The device as set above in claim 160, CHARACTERIZED in that said unidirectional distributively coupled waves are the waves of different polarizations.

5 183. The device as set above in claim 182, CHARACTERIZED in that said unidirectional distributively coupled waves of different polarizations are the waves of mutually orthogonal polarizations.

10 184. The device as set above in claim 182, CHARACTERIZED in that said separator of the unidirectional distributively coupled waves is made as separator of the waves of different polarizations.

185. The device as set above in claim 184, CHARACTERIZED in that said separator of the waves of different polarizations is made in the form of a polaroid or a polarizing prism, or a birefringent prism or a directional coupler, separating waves with different polarizations, or a polarizer based on an optical waveguide, or an optical isolator.

15 186. The device as set above in claim 184, CHARACTERIZED in that the nonlinear-optical waveguide as such operates as the separator of the waves of different polarizations.

20 187. The device as set above in claim 160, CHARACTERIZED in that said unidirectional distributively coupled waves are the waves of different wavelengths the distribution coupling of which is due to their quadratic- nonlinear interaction and quadratic-nonlinearity of the nonlinear-optical waveguide

188. The device as set above in claim 187, CHARACTERIZED in that separator of the unidirectional distributively coupled waves at the output of the device is made as separator of the waves of different wavelengths.

25 189. The device as set above in claim 188, CHARACTERIZED in that said separator of the waves of different wavelengths is made as a dispersive element or a filter or a directional coupler.

190. The device as set above in claim 160, CHARACTERIZED in that said nonlinear-optical waveguide is made as waveguide having at least two waveguide modes for said optical radiation fed into said nonlinear-optical waveguide.

30 191. The device as set above in claim 190, CHARACTERIZED in that the separator is made as radiation beam diaphragm for separation of waves of different waveguide modes or waveguide separator of the modes.



192. The device as set above in claim 160, CHARACTERIZED in that before the input of said nonlinear-optical waveguide and/or after the output of the nonlinear-optical waveguide a phase compensator and/or polarization controller optically connected to said nonlinear-optical waveguide is mounted, thereto the optical connection is done through aforesaid input and/or output elements.

193. The device as set above in claim 192, CHARACTERIZED that said phase compensator and/or said polarization controller is made as an optical waveguide.

194. The device as set above in claim 193, CHARACTERIZED that said phase compensator and/or said polarization controller is made as a fiber-optic waveguide.

195. The device as set above in claim 160, CHARACTERIZED in that before the input of said nonlinear-optical waveguide an amplitude or phase or frequency or polarization modulator optically connected to said nonlinear-optical waveguide is mounted, thereto the optical connection is done through aforesaid input element.

196. The device as set above in claim 160, CHARACTERIZED in that before the input of the said nonlinear-optical waveguide at least one a polarizer is mounted.

197. The device as set above in claim 196, CHARACTERIZED in that the polarizer is made in the form of a polaroid or a polarizing prism, or a birefringent prism or a directional coupler, separating waves with different polarizations, or a polarizer based on an optical waveguide, or an optical isolator.

198. The device as set above in claim 160, CHARACTERIZED in that before the input of the nonlinear-optical waveguide and/or after its output at least one optical isolator optically connected to said nonlinear-optical waveguide is mounted, thereto the optical connection is done through at least one input and/or output element.

199. The device as set above in claim 198, CHARACTERIZED in that the optical isolator is made as a waveguide optical isolator or an air-path optical isolator.

200. The device as set above in claim 160, CHARACTERIZED in that said input/output elements are connected with nonlinear-optical waveguide by glue or by splice or by soldering or by welding or by tiny mechanical connector.

201. The device as set above in claim 200, CHARACTERIZED in that said optical input/output elements are mounted at the input/output ends of said nonlinear-optical waveguide so that said nonlinear-optical waveguide together with said optical input/output elements make up a nonlinear-optical module.



202. The device as set above in any of claims 160-201, CHARACTERIZED in that it additionally contains at least one semiconductor laser or laser module optically connected to the nonlinear-optical waveguide through at least one input element.

203. The device as set above in claim 202, CHARACTERIZED in that radiating semiconductor structure of said laser or laser module is additionally supplied with at least one thermoelectric Peltier element, a side of which is in thermal contact with the radiating semiconductor structure and with at least one sensor of the temperature, thereto at least one sensor of temperature and at least one thermoelectric Peltier element are electrically connected with controller and/or stabilizer of temperature

204. The device as set above in claim 202, CHARACTERIZED in that said laser or laser module is supplied with precision current source for passing electrical current through its laser diode, thereto the current source is made as a controller and/or stabilizer of current through the laser diode.

205. The device as set above in claim 204, CHARACTERIZED in that said current source is made with possibility of modulation of current passing through the laser diode.

206. The device as set above in claim 202, CHARACTERIZED in that the semiconductor laser and/or laser module is used with spectrum-line width of radiation, which is not more than $20\text{\AA}$.

207. The device as set above in claim 202, CHARACTERIZED in that the semiconductor laser and/or the laser module is made as single-moded.

208. The device as set above in claim 206, CHARACTERIZED in that the semiconductor laser and/or the laser module is made as single-frequency laser and/or the laser module.

209. The device as set above in claim 206, CHARACTERIZED in that the semiconductor laser and/or the laser module is made with an external resonator and/or includes a dispersive element.

210. The device as set above in claim 209, CHARACTERIZED in that the mirror of the external resonator of the semiconductor laser and/or the laser module, including the semiconductor laser and an optical waveguide, is made in the form of periodical grating of refractive index in the optical waveguide adjacent to the laser, or as corrugation on a surface of the optical waveguide adjacent to the laser.

211. The device as set above in claim 202, CHARACTERIZED in that the laser or laser module is mode locked.



212. The device as set above in claim 202, CHARACTERIZED in that the laser module is made as a fiber-optic source module.

213. The device as set above in claim 202, CHARACTERIZED in that said laser or laser module provides output optical radiation with constant power exceeding the threshold power, thereto the power spread in time does not exceed 1%.

214. The device as set above in claim 213, CHARACTERIZED in that between the input of said nonlinear-optical waveguide and the laser or laser module an amplitude or phase or frequency or polarization modulator is mounted, thereto the modulator is optically connected with input of said nonlinear-optical waveguide through said input element and with output of the laser or laser module.

215. The device as set above in claim 202, CHARACTERIZED in that thereto the semiconductor laser and/or laser module is mounted relative to the nonlinear-optical waveguide and/or to the nonlinear-optical module with precision, provided by their positioning by coincidence of the laser and/or laser module radiation beam and the nonlinear-optical module or nonlinear-optical waveguide luminescent radiation beam appeared when electrical current with value larger than threshold current value is carried across said nonlinear-optical waveguide.

216. The device as set above in claim 215, CHARACTERIZED in that said threshold current value is 20mA.

217. The device as set above in claim 202, CHARACTERIZED in that thereto contains at least one semiconductor laser or laser module, thereto the semiconductor laser or laser module is mounted relative to the nonlinear-optical module and/or to the nonlinear-optical waveguide with precision, provided by their positioning by means of control of change of optical radiation power of said laser or laser module transmitted through the nonlinear-optical waveguide, under switching on and/or switching off the electrical current carried across the nonlinear-optical waveguide.

218. The device as set above in claim 217, CHARACTERIZED in that said current value lies in the range from 0.5mA to 10mA.

219. The device as set above in claim 202, CHARACTERIZED in that thereto it contains at least one semiconductor laser and/or laser module with modulated output radiation power, and average power not less than the threshold power.

220. The device as set above in claim 202, CHARACTERIZED in that the semiconductor laser or laser module, and said nonlinear-optical waveguide with said input/output elements, and/or a separator of the unidirectional distributively coupled waves at the output of the device,



or a polarizer, installed at the input of the nonlinear-optical waveguide and/or optical isolator are connected by means of fiber-optic connectors and/or sockets.

221. The device as set above in claim 220, CHARACTERIZED in that fiber-optic connectors such as FC/PC are used.

5 222. The device as set above in claim 220, CHARACTERIZED in that the connection is made with opportunity to rotate said elements relative to each other around the longitudinal axis of the device.

223. The device as set above in any of claims 160-201, CHARACTERIZED in that it additionally contains a mixer of pump optical radiation and at least one signal optical radiation,
10 mounted before the input of said nonlinear-optical waveguide and optically connected to the nonlinear-optical waveguide through at least one said input element.

224. The device as set above in any of claims 160-201, CHARACTERIZED in that it additionally contains a mixer of the pump optical radiation and at least one signal optical radiation, thereto the mixer is made as an optical Y-type waveguide mixer, or directional
15 coupler, thereto the output branch of said mixer is aforesaid input waveguide, or is optically connected with aforesaid input optical waveguide, thereto said optical Y-type waveguide mixer contains at least two input branches.

225. The device as set above in claim 224, CHARACTERIZED in that at least part of at least one input branch of said optical Y-type waveguide mixer is made from of magneto-optic
20 material and mount into a solenoid or is made as an electro-optic rotator of polarization plane.

226. The device as set above in any of claims 160-201, CHARACTERIZED in that said nonlinear-optical waveguide is oriented relative to the electrical field vector of linear or elliptically polarized optical radiation fed into the nonlinear-optical waveguide so that the «fast» and/or the «slow» axis of the nonlinear-optical waveguide is directed at an angle of ν ,
25 $10^\circ < \nu < 80^\circ$ relative to the electrical field vector or to the axis of polarization ellipse of said optical radiation fed into the nonlinear-optical waveguide.

227. The device as set above in claim 226, CHARACTERIZED in that said nonlinear-optical waveguide is oriented relative to the electrical field vector of linear or elliptically polarized optical radiation fed into the nonlinear-optical waveguide so that the «fast» and/or the
30 «slow» axis of the nonlinear-optical waveguide is directed at the angle of 45° relative to the electrical field vector or to the axis of polarization ellipse of said optical radiation fed into the nonlinear-optical waveguide.



228. The device as set above in any of claims 160-201, CHARACTERIZED in that said nonlinear-optical waveguide is oriented relative to the electrical field vector of linear or elliptically polarized optical radiation fed into the nonlinear-optical waveguide so that the «fast» and/or the «slow» axis of the nonlinear-optical waveguide is directed at an angle of ν , -
5 $15^\circ < \nu < 15^\circ$ relative to the electrical field vector or to the axis of polarization ellipse of said optical radiation fed into the nonlinear-optical waveguide.

229. The device as set above in claim 228, CHARACTERIZED in that said nonlinear-optical waveguide is oriented relative to the electrical field vector of linear or elliptically polarized optical radiation fed into the nonlinear-optical waveguide so that the «fast» and/or the
10 «slow» axis of the nonlinear-optical waveguide coincides with the electrical field vector or with the axis of polarization ellipse of said optical radiation fed into the nonlinear-optical waveguide.

230. The device as set above in any of claims 160-201, CHARACTERIZED in that after said separator of said unidirectional distributively coupled waves a correlator and/or differential amplifier for treating said separated opposite-modulated waves is set.

15 231. A method for switching, amplification, controlling and modulation of optical radiation, accomplished with using nonlinear tunnel-coupled optical waveguides at least one of which is made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, comprising the feeding of coherent optical radiation with a power to be higher than the threshold power into at least one of said nonlinear
20 tunnel-coupled optical waveguides, an interaction of unidirectional distributively coupled waves in the nonlinear tunnel-coupled optical waveguides, and a separation of the unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides, by feeding out of the said coupled waves from different tunnel-coupled optical waveguides and/or by a separator

25 CHARACTERIZED in that

cubic-nonlinear and/or quadratic-nonlinear-optical waveguides are used,

wavelength λ of the radiation is selected from the condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type
30 structure of said nonlinear-optical waveguide,

electrical current is carried through at least one said nonlinear tunnel-coupled optical waveguides,



a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least 10% of a power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for switching or transfer of at least 10% of a power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 20 or less,

before the input of said nonlinear tunnel-coupled optical waveguide they vary the power or the polarization, or the wavelength of said optical radiation, or the angle of the feeding of said optical radiation into said nonlinear tunnel-coupled optical waveguide, or they vary the difference in the phases of said unidirectional distributively coupled waves at the input of said nonlinear tunnel-coupled optical waveguide, and/or they vary the ratio between the powers of said unidirectional distributively coupled waves at the input of said nonlinear-optical waveguide, or they vary external electrical or magnetic field applied to said nonlinear tunnel-coupled optical waveguide.

232. The method as set above in claim 231, CHARACTERIZED in that a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least 50% of a power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for switching or transfer of at least 50% of a power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

233. The method as set above in claim 231, CHARACTERIZED in that average power of the optical radiation, fed into at least one of said nonlinear tunnel-coupled optical waveguides, is installed from the condition of obtaining a predetermined value of a differential gain and/or a ratio of powers of said unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides and/or a difference in phases of said unidirectional distributively coupled waves at the output of the nonlinear tunnel-coupled optical waveguides.



234. The method as set above in claim 233, CHARACTERIZED in that in a case of using cubic nonlinear tunnel-coupled optical waveguides the average power of optical radiation, fed into at least one of said nonlinear tunnel-coupled optical waveguides, is chosen in range from $0,25 P_M$ up to $4P_M$, where P_M is the critical power.

5 235. The method as set above in claim 234, CHARACTERIZED in that in a case of using cubic nonlinear tunnel-coupled optical waveguides an average power of optical radiation, fed into at least one of the nonlinear tunnel-coupled optical waveguides, is chosen in interval from $0,5 P_M$ up to $1,5 P_M$, where P_M is critical power.

10 240. The method as set above in claim 233, CHARACTERIZED in that in a case of using cubic nonlinear tunnel-coupled optical waveguides an average power of optical radiation, fed into at least one of the nonlinear tunnel-coupled optical waveguides, is stabilized.

241. The method as set above in claim 231, CHARACTERIZED in that radiation, fed at least into one of the nonlinear tunnel-coupled optical waveguides, is used in the form of pulses.

15 242. The method as set above in claim 231, CHARACTERIZED in that the pulses are solitons.

243. The method as set above in claim 231, CHARACTERIZED in that temperature of at least one of said nonlinear tunnel-coupled optical waveguides is installed from the condition of obtaining a predetermined value of the threshold power, and/or the critical power, and/or the differential gain and/or the ratio between powers of said unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides and/or the difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides and the temperature of at least one of said nonlinear-optical waveguides is stabilized.

25 244. The method as set above in claim 243, CHARACTERIZED in that temperature of at least one of said nonlinear tunnel-coupled optical waveguides is controlled and/or stabilized by means of thermostat and/or at least one thermoelectric Peltier element, supplied with controller and/or stabilizer of the temperature.

30 245. The method as set above in claim 231, CHARACTERIZED in that at least one of ends of at least one of said nonlinear tunnel-coupled optical waveguides has an antireflection coating.

246. The method as set above in claim 231, CHARACTERIZED in that wavelength λ of the optical radiation with variable parameter is selected from conditions $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.



247. The method as set above in claim 231, CHARACTERIZED in that said nonlinear - tunnel-coupled optical waveguides are made as birefringent and/or optically active.

248. The method as set above in any of claims 231-247, CHARACTERIZED in that said unidirectional distributively coupled waves are waves of different wavelengths, and/or of
5 different polarizations, and/or of different waveguide modes and/or of waves in neighboring tunnel-coupled waveguides.

249. The method as set above in claim 248, CHARACTERIZED in that coherent optical radiation, fed into at least one of the nonlinear-optical waveguides, is used in the form of linear or elliptical or circular polarization optical radiation.

10 250. The method as set above in any of claims 231-247, CHARACTERIZED in that optical radiation, fed into at least one of said nonlinear tunnel-coupled optical waveguides, includes waves of two frequencies, differing by the value more than τ^{-1} , where τ is characteristic time of change of a parameter of the optical radiation.

251. The method as set above in any of claims 231-247, CHARACTERIZED in that by
15 means of the separator of waves of different polarizations and/or different wavelengths and/or different waveguide modes are separated, or wave of at least one polarization and/or one of wavelength and/or one of waveguide mode is selected out.

252. The method as set above in any of claims 231-247, CHARACTERIZED in that as coherent optical radiation, fed into at least one of the nonlinear tunnel-coupled optical
20 waveguides, an optical radiation of a semiconductor laser and/or a laser module is used, thereto a temperature of radiating semiconductor structure of the laser and/or the laser module is controlled and/or stabilized.

253. The method as set above in any of claims 231-247, CHARACTERIZED in that before the feeding of radiation into at least one of the nonlinear-optical waveguide the radiation
25 is focused by means of a cylindrical lens and/or a gradan and/or after the transmission of optical radiation through the nonlinear tunnel-coupled optical waveguides the optical radiation is collimated by means of a cylindrical lens and/or a gradan.

254. The method as set above in any of claims 231-247, CHARACTERIZED in that the feeding of the optical radiation into at least one of said nonlinear tunnel-coupled optical
30 waveguides and/or the feeding of the optical radiation out from at least one of said nonlinear tunnel-coupled optical waveguides is done by means of input and/or output waveguide correspondingly.



255. The method as set above in claim 254, CHARACTERIZED in that at the output and/or input end of input and/or output waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

5 256. The method as set above in claim 254, CHARACTERIZED in that at least a part of said input waveguide is made from magneto-optic material and mounted into solenoid, through which variable electrical current, modulating a polarization of the optical radiation, is carried, or at least a part of the input waveguide is made as an electro-optical rotator of the polarization plane of the optical radiation.

10 257. The method as set above in any of claims 231-247, CHARACTERIZED in that electrical current is carried across the layers of said semiconductor layered MWQ-type structure.

258. The method as set above in claim 257, CHARACTERIZED in that constant electrical current from 0,5mA to 10mA is carried, thereto the current spread from an average value in time does not exceed 0,1mA.

15 259. The method as set above in claim 257, CHARACTERIZED in that said electrical current is carried across said nonlinear tunnel-coupled optical waveguides in predetermined intervals of time.

20 260. The method as set above in any of claims 231-247, CHARACTERIZED in that dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear-optical waveguide, are compared and their difference in powers is selected out by means of a correlator and/or differential amplifier.

25 261. The method as set above in any of claims 231-247, CHARACTERIZED in that before the input of at least one of said nonlinear tunnel-coupled optical waveguides and/or after the output of at least one of said nonlinear tunnel-coupled optical waveguides at least one optical isolator is mounted.

262. The method as set above in any of claims 231-247, CHARACTERIZED in that said nonlinear tunnel-coupled optical waveguides are made as single-moded for the optical radiation fed into said nonlinear tunnel-coupled optical waveguides.

30 263. A method for switching, amplification, controlling and modulation of optical radiation, accomplished with using nonlinear tunnel-coupled optical waveguides at least one of which is made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, including a feeding coherent



pump optical radiation with a power exceeding the threshold power into at least one of said nonlinear tunnel-coupled optical waveguides and a feeding at least one signal optical radiation into at least one of said nonlinear tunnel-coupled optical waveguides, an interaction of unidirectional distributively coupled waves in said nonlinear tunnel-coupled optical waveguides, and a separation of said unidirectional distributively coupled waves at the output of the said nonlinear tunnel-coupled optical waveguides by feeding out of the said coupled waves from the different tunnel-coupled waveguides and/or by a separator

CHARACTERIZED in that

cubic-nonlinear and/or quadratic-nonlinear-optical waveguides are used,

a wavelength λ of the pump optical radiation and/or signal optical radiation is selected from the condition $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide,

electrical current is carried across at least one the nonlinear tunnel-coupled optical waveguides,

a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least 10% of power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for the switching or transfer of at least 10% of the power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by factor 20 or less,

before the input of said nonlinear tunnel-coupled optical waveguides they vary the power or the phase, or the polarization, or the wavelength of said signal optical radiation, or the angle of the feeding of said signal optical radiation into said nonlinear tunnel-coupled optical waveguides, and/or they vary the difference in the phases of said unidirectional distributively coupled waves at the input of said nonlinear tunnel-coupled optical waveguides, and/or they vary the ratio between the powers of said unidirectional distributively coupled waves at the input of said nonlinear tunnel-coupled optical waveguides, or they change the difference in the phases of said signal optical radiation and said pump optical radiation.

264. The method as set above in claim 263, CHARACTERIZED in that a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for



switching or transfer of at least 50% of power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for the switching or transfer of at least 50% of the power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which the power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

265. The method as set above in claim 263, CHARACTERIZED in that a power of the pump optical radiation, fed into at least one of said nonlinear tunnel-coupled optical waveguides, is installed from the condition of obtaining a predetermined value of a differential gain and/or a ratio between the powers of said unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides and/or a difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides.

266. The method as set above in claim 265, CHARACTERIZED in that a power of fed pump optical radiation is chosen in interval from $0,25 \cdot P_M$ up to $4P_M$, where P_M is the critical power.

267. The method as set above in claim 266, CHARACTERIZED in that a power of fed pump optical radiation is chosen in interval from $0,5P_M$ up to $1,5P_M$, where P_M is the critical power.

268. The method as set above in claim 265, CHARACTERIZED in that pump optical radiation power is larger than signal optical radiation power at least by the order of magnitude.

269. The method as set above in claim 263, CHARACTERIZED in that a power of the pump optical radiation and a power of signal optical radiation are differed from their geometric average value not larger than by the order of magnitude.

270. The method as set above in claim 263, CHARACTERIZED in that pump optical radiation power is stabilized.

271. The method as set above in claim 263, CHARACTERIZED in that the pump optical radiation is used in the form of pulses and/or the signal optical radiation is used in the form of pulses.

272. The method as set above in claim 271, CHARACTERIZED in that the pulses are solitons.



273. The method as set above in claim 263, CHARACTERIZED in that the temperature of at least one of said nonlinear tunnel-coupled optical waveguide is installed from the condition of obtaining a predetermined value of the threshold power, and/or the critical power, and/or the differential gain and/or the ratio between powers of said unidirectional distributively coupled waves at the output of the nonlinear tunnel-coupled optical waveguides and/or the difference in phases of said unidirectional distributively coupled waves at the output of said nonlinear tunnel-coupled optical waveguides and the temperature of at least one of the nonlinear tunnel-coupled optical waveguides is stabilized.

274. The method as set above in claim 273, CHARACTERIZED in that temperature of the nonlinear-optical waveguides is controlled and/or stabilized by means of a thermostat and/or at least one thermoelectric Peltier element, supplied with a controller and/or stabilizer of the temperature.

275. The method as set above in claim 263, CHARACTERIZED in that at least one of ends of at least one of the nonlinear tunnel-coupled optical waveguides has antireflected coating.

276. The method as set above in claim 263, CHARACTERIZED in that the wavelength λ of said pump optical radiation and/or said signal optical radiation is selected from the conditions $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.

277. The method as set above in claim 263, CHARACTERIZED in that said nonlinear tunnel-coupled optical waveguides are made as birefringent and/or optically active.

278. The method as set above in any of claims 263-277, CHARACTERIZED in that said unidirectional distributively coupled waves are waves of different wavelengths, and/or different polarizations, and/or different waveguide modes.

279. The method as set above in any of claims 263-277, CHARACTERIZED in that said signal optical radiation and pump optical radiation, fed into at least one of said nonlinear tunnel-coupled optical waveguides, have center carrier frequencies, differing from each other by the value more than τ^{-1} , where τ is characteristic time of change of a parameter of the signal optical radiation, thereto at the output of the nonlinear tunnel-coupled optical waveguides the waves of different frequencies are separated or at least one of them is separated out by the separator.

280. The method as set above in any of claims 263-277, CHARACTERIZED in that said signal optical radiation and said pump optical radiation, fed into at least one of the nonlinear-



optical waveguides, contains waves of at least two polarizations or two wavelengths or two waveguide modes.

281. The method as set above in any of claims 263-277, CHARACTERIZED in that signal optical radiation and pump optical radiation, fed into at least one of the nonlinear-optical waveguides, have the same polarization and/or the same wavelength and/or the same waveguide modes.

282. The method as set above in any of claims 263-277, CHARACTERIZED in that the waves of different polarizations and/or different wavelengths and/or different waveguide modes are separated or wave at least one of polarizations and/or one of wavelengths and/or one of waveguide modes is selected out by means of the separator.

283. The method as set above in any of claims 263-277, CHARACTERIZED in that pump optical radiation and signal optical radiation with the same polarization and/or the same wavelength are used.

284. The method as set above in claim 263, CHARACTERIZED in that pump optical radiation and signal optical radiation are used with the same or opposite circular polarizations, thereto at the output of said nonlinear tunnel-coupled optical waveguides the waves of different polarizations are separated or at least one of them is separated out by the separator.

285. The method as set above in claim 263, CHARACTERIZED in that pump optical radiation and signal optical radiation are used with the same or different linear or elliptical polarization, thereto after the output of said nonlinear tunnel-coupled optical waveguides the waves of different polarizations are separated or at least one of them is separated out by the separator.

286. The method as set above in claim 285, CHARACTERIZED in that pump optical radiation and signal optical radiation are used with linear or elliptical mutually orthogonal to one another polarizations.

287. The method as set above in any of claims 263-277, CHARACTERIZED in that in the quality of the pump optical radiation and/or the signal optical radiation an optical radiation of a semiconductor laser and/or a laser module is used, thereto a temperature of radiating semiconductor structure of the laser and/or the laser module is controlled and/or stabilized.

288. The method as set above in any of claims 263-277, CHARACTERIZED in that before the feeding of said optical radiations into at least one of said nonlinear tunnel-coupled optical waveguides the optical radiations are focused by means of a cylindrical lens and/or a gradan and/or after transmission of the optical radiations through said nonlinear tunnel-coupled



optical waveguides the optical radiations are collimated by means of a cylindrical lens and/or a gradan.

289. The method as set above in any of claims 263-277, CHARACTERIZED in that the feeding said optical radiations into at least one of said nonlinear tunnel-coupled optical waveguides and/or the feeding the optical radiations out from said nonlinear-optical waveguides is done by means of at least one input and/or at least one output optical waveguide correspondingly.

290. The method as set above in claim 289, CHARACTERIZED in that at least at one of input and/or output ends of input and/or output optical waveguides a parabolic lens and/or conic lens and/or cylindrical lens is made and/or a gradan is mounted.

291. The method as set above in claim 289, CHARACTERIZED in that at least part of at least one said input waveguide is made from magneto-optic material and mounted into a solenoid, through which alternating electrical current, modulating polarization of said signal optical radiation, is carried, or at least part of said input waveguide is made as an electro-optic rotator of polarization plane of the signal optical radiation.

292. The method as set above in any of claims 263-277, CHARACTERIZED in that said electrical current is carried in the direction perpendicular to the layers of said semiconductor layered MWQ-type structure.

293. The method as set above in claim 292, CHARACTERIZED in that constant electrical current from 0,5mA to 10mA is carried, thereto the current spread from an average value in time does not exceed 0,1mA.

294. The method as set above in claim 292, CHARACTERIZED in that electrical current is carried through the nonlinear-optical waveguide in certain intervals of time.

295. The method as set above in any of claims 263-277, CHARACTERIZED in that dependences of powers on time of said unidirectional distributively coupled waves, separated after the output of said nonlinear-optical waveguide, are compared and their difference in powers is selected out by means of a correlator and/or differential amplifier.

296. The method as set above in any of claims 263-277, CHARACTERIZED in that before the input of at least one of said nonlinear tunnel-coupled optical waveguides and/or after the output of at least one of said nonlinear tunnel-coupled optical waveguides at least one optical isolator is mounted.

297. The method as set above in any of claims 263-277, CHARACTERIZED in that pump optical radiation and signal optical radiation are selected with different wavelengths λ_p



and λ_s , thereto wavelength λ_r of exciton resonance of said semiconductor structure of said nonlinear-optical waveguide is installed by controlling of its temperature, and/or the wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is less than absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| < |\lambda_p - \lambda_r|$.

298. The method as set above in any of claims 263-277, CHARACTERIZED in that pump optical radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength λ_r of exciton resonance of said semiconductor structure of said nonlinear-optical waveguides is installed by controlling of its temperature, and/or the wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is larger than absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| > |\lambda_p - \lambda_r|$.

299. The method as set above in claim 287, CHARACTERIZED in that the wavelength of the laser and/or laser module optical radiation is installed by controlling temperature of the radiating semiconductor structure of the laser and/or laser module and/or by squeezing or stretching of a fiber-optic waveguide in which a refractive index periodical grating is made, and the said fiber-optic waveguide is comprised in the laser module and adjointed to the laser.

300. A device for switching, amplification, controlling and modulation of optical radiation, comprising nonlinear tunnel-coupled optical waveguides, at least one of which is made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, thereto the device contains optical input/output elements for feeding of optical radiation into said nonlinear tunnel-coupled optical waveguides and/or feeding of optical radiation out from said nonlinear-optical waveguide correspondingly,

CHARACTERIZED in that

the nonlinear tunnel-coupled optical waveguides are made as cubic-nonlinear and/or quadratic-nonlinear,

at least one nonlinear-optical waveguide is supplied with electrical contacts for carrying of an electrical current through it,



the wavelength λ_r of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance in said semiconductor MQW-type structure of at least one of said nonlinear tunnel-coupled optical waveguides is satisfied the inequalities $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ is wavelength of at least one optical radiation fed into the
5 nonlinear tunnel-coupled optical waveguides,

thereto said optical input and/or output elements are mounted at the input and/or output of at least one of said nonlinear tunnel-coupled optical waveguides,

said optical input/output elements are positioned and mounted relative to said nonlinear tunnel-coupled optical waveguides with precision, provided by their positioning and mounting
10 by luminescent radiation of said nonlinear tunnel-coupled optical waveguides appeared when electrical current with value above the threshold current value is carried through at least one of said nonlinear tunnel-coupled optical waveguides,

thereto a length of said nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least 10% of a power from one of said
15 nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for switching or transfer of at least 10% of a power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which power of the most attenuated wave
20 from said unidirectional distributively coupled waves is attenuated by a factor 20 or less,

thereto the nonlinear coefficient of said nonlinear tunnel-coupled optical waveguides is larger than the threshold nonlinear coefficient.

301. The device as set above in claim 300, CHARACTERIZED in that thereto the device contains at least one thermoelectric Peltier element and at least one sensor of temperature,
25 thereto a side of said Peltier element is in thermal contact with at least one nonlinear-optical waveguide and with at least one sensor of temperature.

302. The device as set above in claim 301, CHARACTERIZED in that the sensor of temperature is made as a thermistor and/or a thermoelectric couple and/or a sensor in the form of an integrated scheme.

30 303. The device as set above in claim 301, CHARACTERIZED in that for heat rejection it contains a radiator, which is in thermal contact with at least one thermoelectric Peltier element.



304. The device as set above in claim 301, CHARACTERIZED in that at least one said thermoelectric Peltier element and at least one said sensor of temperature are electrically connected to a controller and/or a stabilizer of the temperature.

305. The device as set above in claim 300, CHARACTERIZED in that a length of said
5 nonlinear tunnel-coupled optical waveguides is not less than the length, which is necessary for switching or transfer of at least 50% of a power from one of said nonlinear tunnel-coupled optical waveguides to other one from said nonlinear tunnel-coupled optical waveguides, thereto the length of said nonlinear tunnel-coupled optical waveguides, which is necessary for switching or transfer of at least 50% of a power from one of said nonlinear tunnel-coupled optical
10 waveguides to other one from said nonlinear tunnel-coupled optical waveguides, does not exceed the length, at which power of the most attenuated wave from said unidirectional distributively coupled waves is attenuated by a factor 10.

306. The device as set above in claim 300, CHARACTERIZED in that it provides with an electrical current source, electrically connected to the electrical contacts of said nonlinear-
15 optical waveguide.

307. The device as set above in claim 306, CHARACTERIZED in that the electrical current source is a constant current source supplying the electrical current across the nonlinear-optical waveguide with values from 0,5mA to 10mA in operation of the device, thereto the current spread from an average value in time does not exceed 0,1mA.

20 308. The device as set above in claim 306, CHARACTERIZED in that the electrical current source supplies with the threshold current value equals 20mA and higher current values of said current across at least one of said nonlinear tunnel-coupled optical waveguides, during said positioning and mounting of said input/output elements by said luminescent radiation of said nonlinear-optical waveguide.

25 309. The device as set above in claim 306, CHARACTERIZED in that said current source is supplied with a fast switch.

310. The device as set above in claim 306, CHARACTERIZED in that said current source is made as a controller and/or stabilizer of the current.

30 311. The device as set above in claim 300, CHARACTERIZED in that said nonlinear-optical waveguides are made as single-mode for said optical radiation fed into at least one of said nonlinear-optical waveguides.

312. The device as set above in claim 300, CHARACTERIZED in that the semiconductor layered MQW-type structure of at least one of said nonlinear tunnel-coupled optical waveguides



is made in the form of alternating layers $GaAs / Al_xGa_{1-x}As$, or $In_xGa_{1-x}As / InP$, or $In_{1-x}Ga_xAs_yP_{1-y} / In_{1-x}Ga_xAs_yP_{1-y}$, where $x \neq x'$ and/or $y \neq y'$, or $CdSe_{1-x}S_x / CdSe$ or $InAs_{1-x}Sb_x / InAs$, or $PbS_xSe_{1-x} / PbSe$, or Ge_xSi_{1-x} / Si .

313. The device as set above in claim 300, CHARACTERIZED in that both nonlinear
5 tunnel-coupled optical waveguides are made on the basis of the same semiconductor layered MQW-type structure with alternating layers.

314. The device as set above in claim 300, CHARACTERIZED in that input and/or output ends of at least one of said nonlinear-optical waveguides have antireflection coating(s).

315. The device as set above in claim 314, CHARACTERIZED in that antireflection
10 coating is made as a coating decreasing a relative reflectivity at the input/output end up to value not more than 1%.

316. The device as set above in claim 300, CHARACTERIZED in that said input/output elements are made in the form of objectives.

317. The device as set above in claim 316, CHARACTERIZED in that said objectives
15 comprise at least one cylindrical lens and/or at least one gradan.

318. The device as set above in claim 317, CHARACTERIZED in that the surfaces of the said cylindrical lens and/or said gradan have antireflection coating(s).

319. The device as set above in claim 300, CHARACTERIZED in that said input/output elements are made in the form of input/output waveguides.

20 320. The method as set above in claim 319, CHARACTERIZED in that at the output and/or input end of input and/or output waveguide a lens is made and/or a gradan is mounted.

321. The device as set above in claim 320, CHARACTERIZED in that said lens is made as parabolic and/or conic and/or cylindrical.

322. The device as set above in claim 300, CHARACTERIZED in that input/output
25 elements are connected with at least one of said nonlinear-optical waveguides by splice, or by glue, or by welding or by mechanical connectors.

323. The device as set above in claim 322, CHARACTERIZED in that said optical input/output elements are mounted at the input/output ends of at least one of said nonlinear tunnel-coupled optical waveguides so that said nonlinear tunnel-coupled optical waveguides
30 together with said optical input/output elements make up a nonlinear-optical module.

324. The device as set above in claim 300, CHARACTERIZED in that before the input of said nonlinear tunnel-coupled optical waveguides and/or after the output of said nonlinear



tunnel-coupled optical waveguides at least one phase compensator and/or polarization controller optically connected to at least one of said nonlinear tunnel-coupled optical waveguides is mounted, thereto the optical connection is done with input and/or output elements.

5 325. The device as set above in claim 324, CHARACTERIZED that said phase compensator and/or said polarization controller is made as an optical waveguide.

326. The device as set above in claim 325, CHARACTERIZED that said phase compensator and/or said polarization controller is made as a fiber-optic waveguide.

10 327. The device as set above in claim 300, CHARACTERIZED in that before the input of said nonlinear tunnel-coupled optical waveguides an amplitude or phase or frequency or polarization modulator optically connected to at least one of said nonlinear tunnel-coupled optical waveguides is mounted, thereto the optical connection is done through at least one input element.

15 328. The device as set above in claim 327, CHARACTERIZED in that the modulator is made on the basis of an optical waveguide.

329. The device as set above in claim 300, CHARACTERIZED in that before the input of the said nonlinear tunnel-coupled optical waveguides at least one polarizer optically connected to at least one of said nonlinear tunnel-coupled optical waveguides is mounted, thereto the optical connection is done with at least one input element.

20 330. The device as set above in claim 329, CHARACTERIZED in that the polarizer is made in the form of a polaroid or a polarizing prism, or a birefringent prism or a directional coupler, separating waves with different polarizations, or a polarizer based on an optical waveguide, or an optical isolator.

25 331. The device as set above in claim 300, CHARACTERIZED in that before the input of said nonlinear tunnel-coupled optical waveguides and/or after output of said nonlinear tunnel-coupled optical waveguides at least one optical isolator optically connected to at least one of said nonlinear tunnel-coupled optical waveguides is mounted, thereto the optical connection is done with at least one input and/or output element.

30 332. The device as set above in claim 331, CHARACTERIZED in that the optical isolator is made as a waveguide optical isolator or an air-path optical isolator.

333. The device as set above in claim 300, CHARACTERIZED in that it additionally contains a mixer of pump optical radiation and at least one signal optical radiation, mounted before the input of said nonlinear tunnel-coupled optical waveguides and optically connected to



at least one of nonlinear tunnel-coupled optical waveguides through at least one said input element.

334. The device as set above in claim 319, CHARACTERIZED in that it additionally contains a mixer of the pump optical radiation and at least one signal optical radiation, thereto the mixer is made as an optical Y-type waveguide mixer, or a directional coupler, thereto the output branch of said mixer is aforesaid input waveguide, or is optically connected with aforesaid input waveguide, thereto said optical Y-type waveguide mixer contains at least two input branches.

335. The device as set above in claim 300, CHARACTERIZED in that it additionally contains a separator of waves having different wavelengths, optically connected with output of said nonlinear tunnel-coupled optical waveguides through said output waveguide and made as a dispersive element or a filter or a directional coupler and mounted after the output of said nonlinear tunnel coupled optical waveguides.

336. The device as set above in claim 300, CHARACTERIZED in that it additionally contains a separator of waves having different polarizations, optically connected with output of said nonlinear tunnel-coupled optical waveguides through said output waveguide and made as a polaroid or a polarizing prism, or a birefringent prism or a directional coupler, separating waves of different polarizations, or a polarizer based on an optical waveguide.

337. The device as set above in claim 300, CHARACTERIZED in that said nonlinear tunnel-coupled optical waveguides are made as birefringent.

338. The device as set above in any of claims 300-337, CHARACTERIZED in that at least two of said optical elements are optically connected by optical fiber connectors or sockets.

339. The device as set above in claim 338, CHARACTERIZED in that fiber-optic connectors such as FC/PC are used.

340. The device as set above in any of claims 300-337, CHARACTERIZED in that it additionally contains at least one semiconductor laser or laser module optically connected to at least one of said nonlinear tunnel-coupled optical waveguides through at least one input element.

341. The device as set above in claim 339, CHARACTERIZED in that radiating semiconductor structure of said laser or laser module is additionally supplied with at least one thermoelectric Peltier element, a side of which is in thermal contact with the radiating semiconductor structure and with at least one sensor of the temperature, thereto at least one



sensor of temperature and at least one thermoelectric Peltier element are electrically connected with controller and/or stabilizer of temperature

342. The device as set above in claim 340, CHARACTERIZED in that said laser or laser module is supplied with precision current source for passing electrical current through laser diode, thereto the current source is made as a controller and/or stabilizer of current through the laser diode.

343. The device as set above in claim 342, CHARACTERIZED in that said current source is made with possibility of modulation of current passing through the laser diode.

344. The device as set above in claim 340, CHARACTERIZED in that the semiconductor laser and/or laser module is used with spectrum-line width of radiation, which is not more than $20\text{\AA}$.

345. The device as set above in claim 340, CHARACTERIZED in that the semiconductor laser and/or the laser module is made as single-mode.

346. The device as set above in claim 344, CHARACTERIZED in that the semiconductor laser or the laser module is made as a single-frequency laser or the laser module.

347. The device as set above in claim 344, CHARACTERIZED in that the semiconductor laser and/or the laser module is made with an external resonator and/or includes a dispersive element.

348. The device as set above in claim 347, CHARACTERIZED in that at least one mirror of the external resonator is made as a periodical grating, representing a partially or fully reflecting Bragg reflector.

349. The device as set above in claim 348, CHARACTERIZED in that the mirror of the external resonator of the semiconductor laser and/or the laser module, including the semiconductor laser and an optical waveguide, is made in the form of periodical grating of refractive index in the optical waveguide adjacent to the laser, or as corrugation on a surface of the optical waveguide adjacent to the laser.

350. The device as set above in claim 340, CHARACTERIZED in that the laser or laser module is mode locked.

351. The device as set above in claim 340, CHARACTERIZED in that the laser module is made as a fiber-optic source module.

352. The device as set above in claim 340, CHARACTERIZED in that said laser or laser module provides output optical radiation with constant power exceeding the value $0,5P_M$, where P_M is the critical power, thereto the power value spread in time does not exceed 1%,



thereto the optical radiation of said laser or laser module is used as the pump optical radiation, or optical radiation intended to be modulated.

353. The device as set above in claim 352, CHARACTERIZED in that between the input of at least one of said nonlinear tunnel-coupled optical waveguides and the laser or laser module an amplitude or phase or frequency or polarization modulator is mounted, thereto the modulator is optically connected with input of at least one of said nonlinear tunnel-coupled optical waveguides through said input element and with output of the laser or laser module.

354. The device as set above in claim 340, CHARACTERIZED in that thereto the semiconductor laser and/or laser module is mounted relative to the nonlinear-optical waveguide and/or to the nonlinear-optical module with precision, provided by their positioning by coincidence of the laser and/or laser module radiation beam and the nonlinear-optical module or nonlinear-optical waveguide luminescent radiation beam appeared when electrical current with value larger than threshold current value is carried across said nonlinear-optical waveguide.

355. The device as set above in claim 354, CHARACTERIZED in that said threshold current value is 20mA.

356. The device as set above in claim 340, CHARACTERIZED in that thereto contains at least one semiconductor laser and/or laser module, thereto the semiconductor laser and/or laser module is mounted relative to the nonlinear-optical module and/or to the nonlinear-optical waveguide with precision, provided by their positioning by means of control of change of optical radiation power of said laser and/or laser module transmitted through the nonlinear-optical waveguide, under switching on and/or switching off the electrical current carried across the nonlinear-optical waveguide.

357. The device as set above in claim 356, CHARACTERIZED in that said current value lies in the range from 0.5mA to 10mA.

358. The device as set above in claim 340, CHARACTERIZED in that thereto it contains at least one semiconductor laser and/or laser module with modulated output radiation power, and average power being in the range from $0,5P_M$ up to $4P_M$, where P_M is the critical power.

359. The device as set above in claim 340, CHARACTERIZED in that the semiconductor laser and/or laser module, and/or said nonlinear-optical waveguide with said input/output elements, and/or optical isolator are connected by means of fiber-optic connectors and/or sockets.

360. The device as set above in claim 359, CHARACTERIZED in that fiber-optic connectors such as FC/PC are used.



361. The device as set above in any of claims 300-337, CHARACTERIZED in that after the output of the nonlinear tunnel-coupled optical waveguides a correlator of optical radiations is installed.

362. The device as set above in any of claims 300-337, CHARACTERIZED in that it additionally contains at least one following device, similar to the first one, thereto at least one input element of each following device is optically connected with at least one output element of the previous device.

363. The device as set above in ^{any of/}claims 300-337, CHARACTERIZED in that it comprises the aforesaid devices set one after another, thereto the input/output elements of the set one after another devices are made as the united optical waveguide(s).

364. A method for switching, amplification, controlling and modulation of optical radiation, accomplished with using at least one nonlinear-optical waveguide, made on the based of semiconductor layered MQW-type structure with alternating layers, containing at least two heterotransitions, thereto nonlinear-optical waveguide is made with possibility of propagation in it at least two opposite-directional coupled waves, including a feeding of at least one coherent optical radiation with a power to be higher than the threshold value into the nonlinear-optical waveguide, a switching of power between opposite-directional coupled waves at input and output ends of the nonlinear-optical waveguide or waveguides under changing at least one of the parameters of the radiation at the input,

CHARACTERIZED in that

optical radiation with at least one variable parameter, or optical pump radiation with power larger than threshold power and at least one signal optical radiation with at least one variable parameter are fed,

cubic-nonlinear and/or quadratic-nonlinear-optical waveguide(s) is used,

electrical current is carried through the nonlinear-optical waveguide(s),

a wavelength λ of the optical radiation is selected from the conditions $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ_r is the wavelength of one-photon exciton resonance and/or two-photon exciton resonance and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered MQW-type structure of said nonlinear-optical waveguide(s),

they vary the power or phase, or polarization or wavelength or angle of the feeding of the fed optical radiation is changed, or they vary an external electrical or a magnetic field applied to the nonlinear-optical waveguide(s).



365. The method as set above in claim 364, CHARACTERIZED in that an average power of the optical radiation, or power of the pump optical radiation, fed into said nonlinear-optical waveguide, is installed from the condition of obtaining a predetermined differential gain and/or ratio between powers of coupled waves at the output and input ends of said nonlinear-optical waveguide(s).

366. The method as set above in claim 364, CHARACTERIZED in that an average of power optical radiation with variable parameter or power of pump optical radiation, fed into said nonlinear-optical waveguide(s), is stabilized.

367. The method as set above in claim 364, CHARACTERIZED in that said optical radiation with at least one variable parameter, or said pump optical radiation and/or said signal optical radiation, fed into said nonlinear-optical waveguide(s), is used in the form of pulses.

368. The method as set above in claim 367, CHARACTERIZED in that the pulses are solitons.

369. The method as set above in claim 364, CHARACTERIZED in that temperature of at least one nonlinear-optical waveguide is installed from the condition of obtaining a predetermined value of a threshold power, and/or a differential gain and/or a ratio of powers of opposite-directional coupled waves at the output and input ends of the nonlinear-optical waveguide or nonlinear-optical waveguides and the temperature of the nonlinear-optical waveguide(s) is stabilized.

370. The method as set above in claim 369, CHARACTERIZED in that the temperature is installed and/or stabilized by means at least one thermoelectric Peltier element or a thermostat.

371. The method as set above in claim 364, CHARACTERIZED in that wavelength of the optical radiation with variable parameter or pump optical radiation and/or signal optical radiation is selected from the conditions $0,9\lambda_r \leq \lambda \leq 1,1\lambda_r$.

372. The device as set above in any of claims 364-371, CHARACTERIZED in that switching of power between coupled waves of different frequencies and/or different directions is fulfilled.

373. The device as set above in any of claims 364-371, CHARACTERIZED in that electrical current is carried in the direction perpendicular to the layers of said semiconductor layered MWQ-type structure.



374. The method as set above in claim 373, CHARACTERIZED in that constant electrical current with values from 0,5mA to 10mA is carried, thereto the current spread from an average value in time does not exceed 0,1mA.

375. The method as set above in claim 364, CHARACTERIZED in that electrical current
5 is carried through the nonlinear-optical waveguide in predetermined intervals of time.

376. The method as set above in any of claims 364-371, CHARACTERIZED in that at the input of the nonlinear-optical waveguide and/or at its output at least one optical isolator is mounted.

377. The method as set above in any of claims 364-371, CHARACTERIZED in that in
10 the quality of optical radiation with variable parameter and/or pump optical radiation and/or signal optical radiation an optical radiation of a semiconductor laser and/or laser module is used, thereto a temperature of radiating semiconductor structure of the laser and/or laser module is controlled and/or stabilized.

378. The method as set above in claim 364, CHARACTERIZED in that pump optical
15 radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength of exciton resonance λ_r of said semiconductor structure of said nonlinear-optical waveguide(s) is installed by controlling of its temperature, and/or the wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is less than absolute value of difference
20 between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| < |\lambda_p - \lambda_r|$.

379. The method as set above in claim 364, CHARACTERIZED in that pump optical radiation and signal optical radiation are selected with different wavelengths λ_p and λ_s , thereto wavelength of exciton resonance λ_r of said semiconductor structure of said nonlinear-optical
25 waveguide(s) is installed by controlling of its temperature, and/or the wavelength λ_p and/or λ_s is installed so that absolute value of difference between wavelength λ_s of the signal optical radiation and the wavelength λ_r of the exciton resonance is larger than absolute value of difference between wavelength λ_p of the pump optical radiation and the wavelength of the exciton resonance: $|\lambda_s - \lambda_r| > |\lambda_p - \lambda_r|$.

380. The method as set above in claim 377, CHARACTERIZED in that the wavelength of the laser and/or laser module radiation is installed by controlling temperature of the radiating



semiconductor structure of the laser and/or laser module and/or by squeezing-or stretching of fiber-optic waveguide in which a refractive index periodical grating is made, and the said fiber-optic waveguide is comprised in the laser module and adjoined the laser.

381. The method as set above in any of claims 364-371, CHARACTERIZED in that
5 before the feeding of optical radiation into at least one said nonlinear-optical waveguide the optical radiation is focused by means of a cylindrical lens and/or a gradan and/or after transmission of the optical radiation through the nonlinear-optical waveguide(s) the radiation is collimated by means of a cylindrical lens and/or a gradan.

382. The method as set above in any of claims 364-371, CHARACTERIZED in that the
10 feeding of the optical radiation into at least one nonlinear-optical waveguide and/or the feeding of the optical radiation out from at least one said nonlinear-optical waveguide is done by means of input and/or output waveguide correspondingly.

383. The method as set above in claim 382, CHARACTERIZED in that at the output
15 and/or input end of the input and/or output waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

384. A device for switching, amplification, controlling and modulation of optical
radiation, containing at least one nonlinear-optical waveguide, made on the base of
semiconductor layered MQW-type structure with alternating layers, containing at least two
hetero-transitions, and nonlinear-optical waveguide is made with possibility of propagation in it
20 at least two opposite-directional coupled waves, thereto the device contains optical input/output
elements for feeding of optical radiation into said nonlinear-optical waveguide and/or feeding of
optical radiation out from said nonlinear-optical waveguide correspondingly,

CHARACTERIZED in that

nonlinear-optical waveguide is made as cubic-nonlinear and/or quadratic-nonlinear,

25 at least one nonlinear-optical waveguide is supplied with electrical contacts for carrying of
an electrical current through it,

the wavelength λ_r of one-photon exciton resonance and/or two-photon exciton resonance
and/or band-gap resonance and/or half-band-gap resonance of said semiconductor layered
MQW-type structure of said nonlinear-optical waveguide(s) is satisfied to the inequalities
30 $0,5\lambda_r \leq \lambda \leq 1,5\lambda_r$, where λ is a wavelength of at least one optical radiation fed into the nonlinear-
optical waveguide(s),

thereto said optical input and/or output elements are mounted at the input and/or output
of at least one of said nonlinear-optical waveguide(s),



said optical input/output elements are positioned and mounted relative to said nonlinear-optical waveguide(s) with precision, provided by their positioning and mounting by luminescent radiation of said nonlinear-optical waveguide(s) appeared when electrical current with value above the threshold current value is carried through said nonlinear-optical waveguide(s),

thereto the nonlinear coefficient of said nonlinear-optical waveguide(s) is larger than the threshold nonlinear coefficient,

thereto the device contains at least one thermoelectric Peltier element and at least one sensor of temperature, a side of which is in thermal contact with the nonlinear-optical waveguide and with at least one sensor of temperature.

385. The device as set above in claim 384, CHARACTERIZED in that the semiconductor laminar MQW structure is made in the form of alternating layers $GaAs / Al_xGa_{1-x}As$, or $In_xGa_{1-x}As / InP$, or $In_{1-x}Ga_xAs_yP_{1-y} / In_{1-x}Ga_xAs_yP_{1-y}$, where $x \neq x'$ and/or $y \neq y'$, or $CdSe_{1-x}S_x / CdSe$ or $InAs_{1-x}Sb_x / InAs$, or $PbS_xSe_{1-x} / PbSe$, or Ge_xSi_{1-x} / Si .

386. The device as set above in claim 384, CHARACTERIZED in that said sensor of temperature is made as a thermistor and/or a thermoelectric couple and or a sensor in the form of an integrated scheme.

387. The device as set above in claim 384, CHARACTERIZED in that at least one sensor of temperature and at least one thermoelectric Peltier element are electrically connected to a temperature controller and/or temperature stabilizer.

388. The device as set above in claim 384, CHARACTERIZED in that for heat rejection it contains radiator, which is in thermal contact with at least one thermoelectric Peltier element.

389. The device as set above in claim 384, CHARACTERIZED in that it additionally contains an electrical current source, electrically connected with the electrical contacts of said nonlinear-optical waveguide(s), for carrying electrical current through said nonlinear-optical waveguide(s).

390. The device as set above in claim 389, CHARACTERIZED in that electrical current is carried in the direction of perpendicular to the layers of semiconductor MWQ structure.

391. The device as set above in claim 389, CHARACTERIZED in that electrical current source is a constant current source supplying the electrical current across the nonlinear-optical waveguide in operation with values from 0,5mA to 10mA, thereto the current spread from an average value in time does not exceed 0,1mA.



392. The device as set above in claim 389, CHARACTERIZED in that the electrical current-source supplies with the threshold current value equals 20mA and higher current values of said current across said nonlinear-optical waveguide, during said positioning and mounting of said input/output elements by said luminescent radiation of said nonlinear-optical waveguide.

5 393. The device as set above in any of claims 384-392, CHARACTERIZED in that the electrical contacts for carrying of current across the nonlinear-optical waveguide are electrically connected with controller and/or stabilizer of the current and/or precision current source.

394. The device as set above in any of claims 384-392, CHARACTERIZED in that it thereto contains at least one semiconductor laser or laser module as pump optical radiation
10 source, a power of which is not less than threshold power, and/or a semiconductor laser or laser module with modulated output power, thereto the semiconductor laser or laser module is mounted relative to the nonlinear-optical waveguide with precision, provided by its or their positioning and mounting by luminescent radiation of the nonlinear-optical waveguide, appeared when electrical current is carried across it.

15 395. The device as set above in claim 394, CHARACTERIZED in that the semiconductor laser or laser module is mounted relative to the nonlinear-optical waveguide with precision, provided by its or their positioning and mounting by control of change of power of optical radiation of said laser and/or laser module, transmitted through said nonlinear-optical waveguide, under switching on and/or switching off the electrical current carried across the said
20 nonlinear-optical waveguide.

396. The device as set above in claim 394, CHARACTERIZED in that semiconductor laser and/or a laser module is optically connected with at least one nonlinear-optical waveguide, thereto radiating semiconductor structure of the laser and/or the laser module is additionally supplied at least one thermoelectric Peltier element, a side of which is in thermal contact with
25 the radiating semiconductor structure and with at least one sensor of temperature, thereto at least one sensor of temperature and at least one thermoelectric Peltier element are electrically connected with controller of temperature and/or stabilizer of temperature.

397. The device as set above in claim 394, CHARACTERIZED in that the semiconductor laser and/or the laser module is made as single-mode.

30 398. The device as set above in claim 394, CHARACTERIZED in that the semiconductor laser and/or laser module is used with spectrum-line width of radiation, which is not more than 20Å.



399. The device as set above in claim 398, CHARACTERIZED in that the semiconductor laser and/or the laser module is made with external resonator and/or includes dispersive element.

5 400. The device as set above in claim 398, CHARACTERIZED in that the semiconductor laser and/or the laser module is made as single-frequency laser and/or the laser module.

401. The device as set above in any of claims 384-392, CHARACTERIZED in that in the nonlinear-optical waveguide periodic grating is made with formation of optical bistable element with distributed feedback.

10 402. The device as set above in any of claims 384-392, CHARACTERIZED in that the nonlinear-optical waveguide is birefringent and/or magneto-active and/or acousto-optical.

403. The device as set above in any of claims 384-392, CHARACTERIZED in that at least two nonlinear-optical waveguides are tunnel-coupled waveguides.

404. The device as set above in any of claims 384-392, CHARACTERIZED in that input/output elements are made as objectives consisting from cylindrical lens and gradan.

15 405. The device as set above in any of claims 384-392, CHARACTERIZED in that input/output elements are made as input and/or output waveguides.

406. The device as set above in claim 405, CHARACTERIZED in that at the input and/or output end input and/or output waveguide a lens is made and/or gradan is installed.

20 407. The device as set above in claim 406, CHARACTERIZED in that the lens is made as parabolic and/or conic and/or cylindrical.

408. The device as set above in claim 405, CHARACTERIZED in that semiconductor laser is connected with at least one nonlinear-optical waveguide through said input waveguide with a formation of the united optical waveguide.

25 409. The device as set above in any of claims 384-392, CHARACTERIZED in that said nonlinear-optical waveguide(s) is/are made as single-moded for said optical radiation fed into said nonlinear-optical waveguide(s).

30 410. A method of construction of a nonlinear-optical module, comprising positioning, mounting and connection of at least one nonlinear-optical waveguide, made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, and input and/or output elements, by means of which a feeding of optical radiation into said nonlinear-optical waveguide and/or feeding of optical radiation out from said nonlinear waveguide is fulfilled,

CHARACTERIZED in that



the positioning and mounting of input and/or output elements relative to said nonlinear-optical waveguide(s), supplied with contacts for carrying electrical current through the nonlinear-optical waveguide(s), is done by luminescent radiation, appeared under carrying electrical current through said nonlinear-optical waveguide(s).

5 411. The method as set above in claim 410, CHARACTERIZED in that input and/or output elements are made as objectives, thereto the positioning and mounting of said objectives relative to the nonlinear-optical waveguide is accomplished up until formation of collimated optical radiation beam outside the said objectives.

412. The method as set above in claim 411, CHARACTERIZED in that said objectives
10 comprise a cylindrical lens and a gradan.

413. The method as set above in claim 411, CHARACTERIZED in that the said collimated optical radiation beam is axial symmetric beam.

414. The method as set above in claim 410, CHARACTERIZED in that input and/or output elements are made as input/output waveguides.

15 415. The method as set above in claim 414, CHARACTERIZED in that at the output and/or input end of input and/or output optical waveguide a parabolic lens and/or a conic lens and/or a cylindrical lens is made and/or a gradan is mounted.

416. The method as set above in claim 410, CHARACTERIZED in that input/output waveguides are positioning and/or mounting relative to said nonlinear-optical waveguide(s) with
20 taking into account the symmetry or asymmetry of luminescent radiation from said nonlinear-optical waveguide(s) and symmetry or asymmetry of the input/output elements.

417. The method as set above in claim 414, CHARACTERIZED in that input/output waveguides are positioning and/or mounting relative to said nonlinear-optical waveguide(s) up until obtaining the maximum of input radiation power into the said optical waveguides.

25 418. The method as set above in claim 414, CHARACTERIZED in that the control of obtaining of maximum of input optical radiation power into the said optical waveguide(s) is accomplished by control of maximum output optical radiation power from said input/output waveguide(s).

419. The method as set above in claim 414, CHARACTERIZED in that additional optical
30 radiation is fed into another end of input/output waveguide, and positioning and/or mounting said input and/or output waveguide(s) relative to said nonlinear-optical waveguide(s) is accomplished by means of both luminescent radiation of said nonlinear-optical waveguide(s) and optical radiation fed out from input and/or output waveguide.



420. The method as set above in any of claims 410-419, CHARACTERIZED in that they additionally mount a semiconductor laser or laser module before the nonlinear-optical module, thereto the semiconductor laser or laser module is optically connected with the nonlinear-optical module, thereto they position the semiconductor laser or laser module relative to the nonlinear-optical module by changing their relative positions up until coincidence of the laser or laser module optical radiation beam with the nonlinear-optical module luminescence beam before the input and/or after output of the nonlinear-optical module, thereto the luminescence beam is appeared when electrical current is carried through the nonlinear-optical waveguide, and then they mount the semiconductor laser or laser module relative to said nonlinear-optical module.

421. The method as set above in claim 420, CHARACTERIZED in that the current more than 20mA is carried across said nonlinear-optical waveguide.

422. The method as set above in claim 420, CHARACTERIZED in that precision of positioning of the laser or laser module relative to said nonlinear-optical module is controlled additionally by means of comparison of power and/or differential gain of said laser or laser module optical radiation transmitted through said nonlinear-optical module in the case of absence of electrical current through said nonlinear-optical waveguide and in the case of carrying current through said nonlinear-optical waveguide.

423. The method as set above in claim 422, CHARACTERIZED in that a current from 0,5mA up to 10mA is carried across the nonlinear-optical waveguide.

424. The method as set above in any of claims 410-419, CHARACTERIZED in that at least at one output of the nonlinear-optical module another similar nonlinear-optical module is additionally installed, thereto the second similar nonlinear-optical module is adjusted relative to the first nonlinear-optical module by luminescent radiation of the nonlinear-optical waveguide of the first and/or the second nonlinear-optical module, appeared under carrying electrical current through the nonlinear-optical waveguide.

425. The method as set above in claim 424, CHARACTERIZED in that the current more than 20mA is carried across said nonlinear-optical waveguide.

426. The method as set above in ^{any of} claims 410-419, CHARACTERIZED in that precision of installation of the second nonlinear-optical module relative to the first nonlinear-optical module is controlled additionally by means of comparison of power of laser or laser module and/or the first nonlinear-optical module optical radiation transmitted through the second nonlinear-optical module in the case of absence of electrical current through the nonlinear-optical waveguide of



the second nonlinear-optical module and in the case of carrying current through the nonlinear-optical waveguide of the second nonlinear-optical module.

427. The method as set above in claim 426, CHARACTERIZED in that a current from 0,5mA up to 10mA is carried across the nonlinear-optical waveguide.

5 428. The method as set above in any of claims 410-419, CHARACTERIZED in that at least one semiconductor laser or laser module and/or at least one nonlinear-optical module are optically connected through fiber-optic connectors with physical contact, and/or connecting socket, and/or splices, and/or fiber-optic isolators.

10 429. The method as set above in any of claims 410-419, CHARACTERIZED in that at least one nonlinear-optical module is optically connected to at least one another similar nonlinear-optical module through fiber-optic connectors with physical contact, and/or connecting socket, and/or splices, and/or optic isolators made as waveguide.

15 430. A device of processing of optical signals, comprising at least two nonlinear-optical modules, each of which contains one or two nonlinear-optical waveguide(s), made on the basis of semiconductor layered MQW-type structure with alternating layers, containing at least two hetero-transitions, thereto the nonlinear-optical waveguide(s) is/are made with possibility of propagation in it/them at least two unidirectional distributively coupled waves, thereto outputs and inputs of the optical modules are connected with each other by scheme, according to the function of processing of the optical signal,

20 CHARACTERIZED in that

nonlinear-optical waveguide(s) are supplied with contacts for carrying electrical current through them,

25 the outputs and inputs of previous and following optical modules are mounted relative to each other with precision, provided by their positioning by luminescent radiation, appeared under carrying electrical current across the nonlinear-optical waveguide of the previous or following nonlinear-optical module,

30 thereto the outputs and inputs of previous and following optical modules are mounted relative to each other with precision, provided by their positioning by control of change of optical radiation power transmitted through at least one nonlinear-optical module under switching on and/or switching off electrical current carrying across the nonlinear-optical waveguide of the nonlinear-optical module.

431. The device as set above in claim 430, CHARACTERIZED in that output and input elements of optical modules, corresponding output and input of which are connected, are made



in the form of optical waveguides and connected by optical connectors or by glue or by splice or by fiber-optic connectors with physical contact, and/or connecting socket, and/or fiber-optic isolators.

