

07 SEP 2001

Integrated semiconductor laser source

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to an integrated semiconductor laser light source and more particularly to a wavelength locked semiconductor laser array for use in the high power erbium-doped fiber amplifiers or Raman amplifiers for optical communication system.

2. DESCRIPTION OF THE RELATED ART

Recent years have seen a tremendous advancement of the optical fiber communication technology, and wide-spread application of the erbium-doped fiber amplifier (EDFA) due to its operating characteristics such as high gain and low noise figure.

In practice, laser sources with high output power, is often desirable in many terrestrial and underwater applications. To achieve high power laser source, a laser diode array with multiple semiconductor light emitters is often employed. Several techniques are developed in the past with certain degree of success. The U.S. Patent No. 4, 831,630, to Scifres et al, disclosed an approach to achieve a high output power using phase-locked array laser emitters.

The problem arises, however, when coupling the light from all the emitters into an optical fiber. To this end, microlenses may be used for such coupling. FIG.1 shows schematic drawing of a prior art pump light device incorporating a lens array to achieve collimated light, as disclosed in the U.S. Patent No. 5,668,825, to Karpinski,

et al. In such structure the lens support structure for supporting an array of microlenses to collimate or focus the emission of the laser diode bars in the array. The structure includes a base which is a passive or an active optical element having one or more grooves formed therein. The grooves in the base are formed precisely, in a predetermined relationship to the pitch of the grooves in the laser diode array, so that when the laser diode array and the lens support structure are matched, the light from the laser bars in the array reaches the optical elements disposed in the grooves in the lens support structure. One of the disadvantages of the above laser source is that the complex structure results in high fabrication cost. There is also a lack of compactness for this type of device. Difficulty of coupling the emitted light into a fiber is yet another drawback of this method.

The arrayed waveguide grating (AWG) multiplexer consists of two star couplers combined with a waveguide array acting as a diffraction grating, as shown in Fig. 2. The waveguide array is integrated with input channel waveguides, and output channel waveguides, and two concave slab waveguides acting as star couplers. The integrated AWG multiplexer has been successfully fabricated by several waveguide technologies, such as silica waveguides on a silicon or silica substrate and InGaAsP waveguides on an InP substrate. An AWG multiplexer can be designed to route channel from in-port to out-port. Considering an $N \times N$ AWG multiplexer, by employing a suitable design, an N -channel WDM signal with equal channel space injected from an input channel waveguide can be divided and distributed into the corresponding output waveguide according signal wavelength, due to the diffraction of the arrayed waveguide. As a result, the N -channel WDM signal is demultiplexed as N separated signal and draw out from N different output waveguides. Due to the invertible characteristics of light propagation, N channel signals with equal channel space can thus be combined effectively by the AWG multiplexer if the signals are incident from the corresponding out-port of the AWG.

The present invention describes a high power laser source which incorporates laser diode array and AWG on a semiconductor substrate.

SUMMARY OF THE INVENTION

The objective of the present invention is to provide a semiconductor light source with high power output and reliability, suitable for use in the high power erbium-doped fiber amplifiers or Raman amplifiers to achieve compactness of the laser pump source devices that are required in various applications. The semiconductor laser source integrated on a single substrate comprises a plurality of light emitters in the form of a laser diode array, and an arrayed waveguide grating (AWG) portion, wherein a plurality of input channel waveguides are connected to a first slab waveguide which is in turn connected to a second slab waveguide through internal channel waveguides. The said AWG has at least one output channel waveguide connected to the second slab waveguide. The light emitted from each light emitter of the said laser diode array propagates in the input channel waveguide which is of the wider band-gap than that of the gain medium of the said emitter. Bragg grating means is provided on each of the input channel waveguide of the AWG to lock the light emitted from the emitter. The input channel waveguides are adopted for a plurality of wavelengths ($\lambda_1, \lambda_2, \dots, \lambda_i, \dots, \lambda_n$), being within the bandwidth of the said light emitters of the laser diode array. Since the lasing wavelength of each emitter is determined by the corresponding wavelength locker enabled by the Bragg grating, the total spectrum width can be preset in a wavelength range from λ_1 to λ_n .

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention may be obtained by reading the following description of specific illustrative embodiment of the invention in conjunction with the appended drawing in which:

- FIG.1 shows schematic drawing of a prior art pump light device incorporating a lens array to achieve collimated light.
- FIG.2 shows a schematic diagram of arrayed waveguide grating (AWG) incorporated in preferred embodiment of the present invention.

FIG.3 shows an integrated semiconductor laser source in accordance with one of the embodiments of the present invention.

FIG.4 illustrates a light emitter and input channel waveguide with Bragg grating.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 3, there is a schematically shown a high power laser device in accordance with one embodiment of the present invention. The high power laser source is provided on a single substrate 8, which is typically an InP (indium Phosphate) wafer. It comprises a laser diode array 9 having a plurality of light emitters 10_i ($i = 1, 2, 3, \dots, n$), the arrayed waveguide grating (AWG) 11, having a plurality of input channel waveguides 12_i , and at least one output channel waveguide 13. Bragg grating, 14_i , is written into a portion of each input channel waveguides of the AWG 11 to have a center wavelength, providing optical feedback to the light source, and locking the longitudinal mode wavelength of the light emitter to the center wavelength of the grating. The AWG 11 is formed on a common substrate. In the AWG 11, a plurality of input channel waveguides are connected to a first slab waveguide which is in turn connected to a second slab waveguide through internal channel waveguides. The input channel waveguides are adopted for a plurality of wavelengths ($\lambda_1, \lambda_2, \dots, \lambda_i, \dots, \lambda_n$), being within the bandwidth of the said light emitters of the laser diode array 9. In the present embodiment, the wavelength spacing between the input channel waveguide, $\Delta\lambda_i = \lambda_i - \lambda_{i-1}$, is substantially constant, and is about 0.4 nm. As the wavelength from each emitter 10_i is locked by a Bragg grating 14_i , stability of the laser diode is maintained. Furthermore, Since the lasing wavelength of each emitter is determined by the corresponding wavelength locker enabled by the Bragg grating, the total spectrum width can be preset in a wavelength range from λ_1 to λ_n . The number of the light emitters of the laser diode array can be readily increased in accordance with the requirements for industry

applications. A high power output can be easily obtained through the wavelength combination of the light power from all emitters using AWG based WDM coupler.

Fig. 4 illustrates the details of a light emitter and its AWG input channel waveguide in accordance with preferred embodiments of the present invention. In Fig. 4, reference numerals **16** and **17** designate the metallic layers acting as the electrodes at the top and bottom of the emitter. The numeral **18** in FIG. 4 designates the gain medium sandwiched between the InP layer **19** and InP layer **20**. The gain medium **18** typically comprises of $\text{In}_x\text{Ge}_{x-1}\text{As}_y\text{P}_{1-y}$. The gain medium **18** is an active layer which is a portion where light is produced. The light **21** emitted from the laser diode propagates along the gain medium **18** inside the emitter and the waveguide portion **22** of the input channels for the AWG. The waveguide portion **22** typically comprises of $\text{In}_{x1}\text{Ge}_{1-x1}\text{As}_{y1}\text{P}_{1-y1}$. One of the key factors for achieving the integrated light source is that the band-gap for the waveguide portion **22** is wider than that of the gain medium **18** of the light emitter. The interface **23** between the gain medium **18** and the waveguide portion **22** has a low reflectivity. The reflectivity of the interface between the gain medium **18** and the waveguide portion **22** can be reduced to the minimum possible value by optimizing the device function conditions, e.g. the crystal growth condition in fabricating the interface. In Fig. 4, reference numeral **24** designates the Bragg grating adjacent to the waveguide portion **22**. The Bragg grating can be fabricated typically by the following method:

- Step 1 – Spin coating a photo resistor layer on the substrate,
- Step 2 – Writing the grating pattern using two UV beam by interference method,
- Step 3 – Print coping the grating pattern to the wafer surface by chemical etching method,
- Step 4 – Removing the remains and the crystal re-growth in the surface.

In order to achieve better quality i.e. to lock effectively the wavelength and to allow the sufficiently high output, the reflectivity for the Bragg grating is typically within a range of 3-5%, the band width of the Bragg grating is about 0.2 nm.

A high reflectivity (HR) coating 25 is disposed on the rear facet of the said laser diode array so that the gain medium of the light emitter is directly coupled with the mating waveguide portion.

The methods cited above for producing the integrated semiconductor laser light source only serve as examples; other materials and different sequence of the cited steps can also be used to effect integrated semiconductor laser light source for high power applications according to the present invention.

CLAIMS



What is claimed is:

1. A semiconductor laser source integrated on a single substrate comprises:
 - a laser diode array having a plurality of light emitters;
 - an arrayed waveguide grating (AWG) portion, wherein a plurality of input channel waveguides are connected to a first slab waveguide which is in turn connected to a second slab waveguide through internal channel waveguides, and the said AWG has at least one output channel waveguide connected to the second slab waveguide;
 - wherein the gain medium of said light emitter is directly coupled with the mating input channel waveguide of the said AWG, wherein the band-gap of the said input channel waveguide of the said AWG is wider than the band-gap of the gain medium of the said light emitter;
 - wherein Bragg grating is written into a portion of the said input channel waveguides; said grating having a center wavelength, providing optical feedback to said light source, and locking the longitudinal mode wavelength of the light emitter to the center wavelength of the grating.
2. The pump light laser apparatus of claim 1, wherein a high reflectivity (HR) coating is disposed on the rear facet of said laser diode array.
3. The pump light laser apparatus as claimed in claims 1, a low reflectivity interface is disposed between the grating region and the gain medium of said laser diode array.
4. The pump light laser apparatus as claimed in claim 1, wherein the said input channel waveguides of the AWG are adopted for a plurality of wavelengths ($\lambda_1, \lambda_2, \dots, \lambda_i, \dots, \lambda_n$), being within the bandwidth of the said light emitter of the laser diode array.
5. The pump light laser apparatus as claimed in claim 1, wherein the wavelength spacing between the input channel waveguide, $\Delta\lambda_i = \lambda_i - \lambda_{i-1}$, is substantially constant.
6. The pump light laser apparatus of claim 1, wherein the reflectivity for said Bragg grating is within a range of 3-5%.



7. The pump light laser apparatus of claim 5, wherein the wavelength spacing between the input channel waveguide is about 0.4 nm.
8. The pump light laser apparatus of claim 1, wherein the number of the light emitters of the laser diode array is substantially the same as the number of the input channel waveguides of the AWG.