

Description

BACKGROUND

1. Field of the Invention

The present invention relates to a laser light beam generating apparatus. More particularly, the present invention relates to a laser light beam generating apparatus including a light source which generates a second harmonic laser light beam using a non-linear optical crystal element.

2. Background of the invention

It has hitherto been proposed to effect efficient wavelength conversion by taking advantage of a high power density in a resonator. For example, investigations are conducted in an external resonation type second harmonic generation or second harmonic generation (SHG) by a non-linear optical element within a laser resonator.

As an example of a laser light beam generating apparatus as a solid state laser generating the second harmonics within a resonator, it has been known a resonator including a pair of reflective mirrors, a laser medium provided between the reflective mirrors and a non-linear optical crystal element provided between one of the mirrors and the laser light medium. In this apparatus, the second harmonic laser light beam may be generated efficiently by phase-matching the second harmonic laser light beam with respect to the laser light beam having the fundamental wavelength.

For realizing the phase matching, type I or type II phase matching conditions need to be established between the laser light beam having the fundamental wavelength and the second harmonic laser light beam. The type I phase matching is based on the principle of producing a phenomenon in which a sole photon having a double frequency is created from two photons polarized in the same direction by taking advantage of the ordinary light of the laser light beam having the fundamental wavelength. On the other hand, the type II phase matching is based on the principle of causing the eigen polarization of the two perpendicular fundamental wavelengths to fall on a non-linear optical crystal element to establish phase matching conditions for each of the two eigen polarization light beams. The laser light beam of the fundamental wavelength is divided into an ordinary light beam and an extraordinary light beam within the non-linear optical crystal element. As a result, the phase matching is carried out the ordinary light and the extraordinary light beam with the extraordinary light of the second harmonic laser light beam.

However, if it is desired to generate second harmonic laser light beam using type II phase matching

conditions, there is the risk that generation of the laser light of the second harmonics cannot be maintained stably. Because, the eigen polarization is changed in phase each time the laser light beam of the fundamental wavelength traverse the non-linear optical crystal element.

If two perpendicular eigen polarizations, that is p- and s-waves, are deviated in phase each time the laser light beam having the fundamental wavelength produced in the laser medium traverses the non-linear optical crystal element repeatedly by a resonant operation, a strong resonant state, that is strong standing wave, cannot be produced. Because, the steady-state operation in which the two eigen polarizations of the laser light beam of the fundamental wavelength strengthen each other efficiently in each part of the resonator cannot be produced. As a result of which the conversion efficiency of the laser light beam of the fundamental wavelength into the laser light beam of the second harmonics is deteriorated with the risk of noise generation in the second harmonics laser light beam.

The present Assignee has already proposed in Japanese Patent KOKAI Publication No. 1-220879 (JP-A-01 220879) a laser light beam generating apparatus to resolve the above-described problem. This laser light beam generating apparatus generating a second harmonic laser light beam using a non-linear optical crystal element has a birefringent element as a quarter wave plate arranged in a resonant optical path of the laser light beam of the fundamental wavelength. In this type laser light beam generating apparatus, the second harmonic laser light beam as a output laser light beam is radiated in a stable condition.

FIGURE 1 shows an example of a laser light beam generating apparatus disclosed in the above-mentioned Japanese Patent KOKAI publication No. 1-220879 (JP-A- 01 220879). The laser light beam generating apparatus shown in FIGURE 1 includes a resonator 101 which has a laser medium 102 a pair of reflecting surfaces 103, 105, a non-linear optical crystal element 106 and a birefringent element 107 as a quarter wave plate. The laser medium as a Nd:YAG is formed into rod-shaped. One of the reflecting surfaces 103 as a dichroic mirror is formed on the incident surface of the laser medium 102. The other of reflecting surface 105 as a dichroic mirror is formed on the inside surface of an output concave mirror 104. The non-linear optical crystal element 106 is made of KTP (KTIPO₄). The birefringent element 107 is made of a quartz plate. The laser medium 102, the non-linear optical crystal element 106 and the birefringent element 107 are provided between the pair of reflecting surfaces 103, 105.

The incident surface of the laser medium 102 arranged in the resonator 101 is irradiated a pumping laser light beam emitted from a semiconductor laser 111 as a pumping light source via a collimator lens 112

and an objective lens 113. As a result, the laser medium 102 generates a laser light beam of a fundamental wavelength $\text{LA}(\omega)$. The laser light beam of the fundamental wavelength $\text{LA}(\omega)$ is transmitted through the non-linear optical crystal element 106 and the birefringent element 107 and reflected back at the reflective surface 105 of the concave mirror 104 so as to be transmitted again through the birefringent element 107, the non-linear optical crystal element 106 and the laser medium 102 in this order before being reflected by the incident surface of the laser medium 102. Consequently, the laser light beam of the fundamental wavelength $\text{LA}(\omega)$ performs a resonating operation by being propagated back and forth between the reflective surface 103 of the laser medium 102 and the reflective surface 105 of the concave mirror 104 of the resonator 101.

The birefringent element 107, such as the quarter wave plate, has its optical axes so set that, within a plane perpendicular to the direction of light propagation, the direction of the refractive index $n_{o(7)}$ of an extraordinary light is inclined by a predetermined azimuth angle θ shown in FIGURE 2, for example $\theta = 45^\circ$, with respect to the direction of the refractive index of the extraordinary light beam $n_{o(6)}$ of the non-linear optical crystal element 106.

In the above-described laser light beam generating apparatus, a laser light beam of second harmonics $\text{LA}(2\omega)$ is generated by the laser light beam of fundamental wavelength when the laser light beam of the fundamental wavelength through the non-linear optical crystal element 106. The laser light beam of the second harmonics $\text{LA}(2\omega)$ is transmitted through the concave mirror 104 and outputted as an output laser light beam.

In this state, the ordinary light and the extraordinary light beam of the laser light of the fundamental wavelength $\text{LA}(\omega)$ are passed through the birefringent element 107, a quarter wave plate as a birefringent element has a wavelength equal to one-fourth of the wavelength of the laser light beam of the fundamental wavelength, which is set in an azimuth angle θ of 45° with respect to the non-linear optical crystal element 106. As a result, the power of the laser light beam in each region of the resonator 101 is stabilized at a predetermined level. For the birefringent element 107 inhibits coupling between two perpendicular intrinsic polarization modes of the laser light beam of the fundamental wavelength $\text{LA}(\omega)$ caused by generation of the sum frequency, when the laser light beam of fundamental wave length $\text{LA}(\omega)$ generated in the laser medium 102 is passed through the non-linear optical crystal element 106 in resonance for generating the type II laser light beam of the second harmonics, thereby stabilizing the oscillation.

If an optical system is employed which converges the generated SHG laser light beam on an optical conjugate point to a virtual luminance point of the reso-

nator, for example, a point on an optical disc, for applying the above-described type II SHG laser light beam generating apparatus, a return light beam to the resonator is produced. Although it is possible to reduce the return laser light beam by an optical system using a Faraday element or a quarter wave plate and a polarization prism. However, it is difficult to reduce the return light beam to zero due to manufacturing tolerances of the optical components and to birefringence produced at the optical disc.

In the case of the above-described SHG laser light beam generating apparatus only the SHG laser light beam is returned, so that there is no problem of a mode hop noise due to only a minor amount of the light beam being returned as in the case of the conventional semiconductor laser light source. However, the return light beam interferes with the light beam generated at the SHG laser light beam generating apparatus, so that interference noise is produced if the length of the light path is fluctuated on the order of a wavelength.

If the reflectivity of intensity of the return laser light beam of the SHG laser light beam from the optical disc is R_d and the reflectivity of intensity of the mirror within the laser light beam generating apparatus is R_m , the peak-to-peak value N_{pp} of the interference noise is given by the formula

$$\begin{aligned} & (1 \pm (R_d R_m)^{1/2})^2 \\ & = 1 \pm 2(R_d R_m)^{1/2} + R_d R_m \\ & \therefore N_{pp} = 4(R_d R_m)^{1/2} \end{aligned}$$

Consequently, even if R_d and R_m are each 1 %, the peak-to-peak value N_{pp} produces an interference noise of 4 %, which in turn deteriorates signal characteristics. An interference noise with a backward output is the same as that for $R_m = 1$, that is 100 %, reflectivity so that, even if the return light beam is 1 %, the peak-to-peak value N_{pp} produces an interference noise even reaching 40 %, thus tending to modify a laser output.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a laser light beam generating apparatus which resolves the above-described problem.

It is another object of the present invention to provide a laser light beam generating apparatus generating a type II second harmonic laser light beam to prevent fluctuations of the laser output or deterioration in signal characteristics due to the interference noise.

According to this invention as defined in claim 1, there is provided a laser light beam generating apparatus including at least one light source, a resonator and an optical system. The resonator generates a type II second harmonic laser light beam. The resonator has a first reflector, a second reflector, a laser medium provided between the first and second re-

flectors and irradiated a light beam emitted from the light source through the first reflector and a non-linear optical crystal element provided between the laser medium and the second reflector. The optical system radiates the type II second harmonic laser light beam emitted from a virtual luminance point of the resonator to a conjugate point. In the laser light beam generating apparatus, with an effective length of the resonator L , an effective distance L_e from the resonator to the conjugate point is set so that

$$L_e = (m + 1/2)L$$

where m is an integer.

According to this invention as defined in claim 4, there is provided an optical pickup apparatus for an optical recording medium having at least one light source, a resonator, a deflector and an optical system. The resonator generates a type II second harmonic laser light beam and is radiated a light beam emitted from the light source. The deflector deflects the type II second harmonic laser light beam emitted from the resonator. The optical system includes an objective lens for focusing the type II second harmonic laser light beam emitted from the resonator on the optical recording medium. In the optical pickup apparatus, with an effective length of the resonator L , an effective distance L_e from the resonator to the focusing point of the type II second harmonic laser light beam on the optical recording medium is set so that

$$L_e = (m + 1/2)L$$

where m is an integer.

In the present invention, the interference of the laser light beam of the second harmonics generated in the resonator and the return light beam from the conjugate point is inhibited, the interference noise may be reduced to prevent deterioration in signal characteristics and fluctuations in the laser output. On the other hand, the allowable range of deviations from the design dimensional values of the optical components employed in the optical system, such as the Faraday element, the quarter wave plate or polarization prism, may be enlarged to render it possible to implement an inexpensive system.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be more readily understood with reference to the accompanying, wherein:

FIGURE 1 is a schematic view showing an arrangement of a conventional laser light beam generating apparatus.

FIGURE 2 is a diagrammatic view for illustrating the angle of orientation of the birefringent element employed in the conventional system shown in FIGURE 1.

FIGURE 3 shows a schematic basic arrangement of a laser light beam generating apparatus according to an embodiment of the present invention.

FIGURE 4 is a graph showing frequency charac-

teristics for illustrating the embodiment shown in FIGURE 3.

FIGURE 5 is a perspective view showing a schematic arrangement of an embodiment in which the laser light beam generating apparatus is applied to an optical pickup apparatus.

FIGURE 6 is a cross-sectional view showing a schematic arrangement of an SHG laser light beam source employed in the optical pickup apparatus shown in FIGURE 5.

FIGURE 7 is a front view showing a schematic arrangement of the apparatus shown in FIGURE 5.

DESCRIPTION OF THE INVENTION

Referring to the drawings, the referred embodiments of the present invention will be explained in detail. FIGURE 3 shows a schematic view of an embodiment of a laser light beam generating apparatus according to the present invention.

In FIGURE 3, the laser light beam generating apparatus includes a laser diode 11, such as a semiconductor laser element, a lens 12, a resonator 13, an optical system 20 and an objective lens 21. The laser diode 11 as a pumping light source radiates a pumping light beam. The resonator 13 has a concave mirror 14, a quarter wave plate 15 as a birefringent element, a rod-shaped laser medium 16, such as a Nd:YAG, a non-linear optical crystal element 17, such as a KTP (KTiOPO₄) and a plane mirror 18. A reflective surface 14R is formed on an inner concave surface of the concave mirror 14. A reflective surface 18R is formed on one surface of the plane mirror 18. These reflective surfaces 14R, 18R are dichroic mirrors. The pumping light beam radiated from the laser diode 11 is converged by the lens 12 and is incident the laser medium 16 through the concave mirror 14 and the quarter wave plate 15. A laser light beam of a fundamental wavelength $\lambda_A(\omega)$ is generated by the laser medium 16 responding to the radiated pumping light beam. The laser light beam of the fundamental wave length $\lambda_A(\omega)$ reaches the plane mirror 18 through the non-linear optical crystal element 17 and is reflected by the reflective surface 18R.

As the laser medium 16, Nd:YVO₄, LNP, Nd:BEL etc. are employed, whereas, as the non-linear optical crystal element 17, LiNbO₃, BBO or LBO etc. may be employed.

By type II phase matching, the non-linear optical crystal element 17 as KTP 17 generates a laser light beam of second harmonics $\lambda_A(2\omega)$ having the frequency twice that of the laser light beam $\lambda_A(\omega)$. If the wavelength λ of the laser light beam $\lambda_A(\omega)$ is 1064 nm, the wavelength of the laser light beam $\lambda_A(2\omega)$ is $\lambda/2$ or 532 nm. The reflective surface 14R of the concave mirror 14 has such properties as will transmit the pumping light beam with a wavelength of e.g. 808 nm but will reflect the laser light beam $\lambda_A(\omega)$ generated

in the laser medium 16, while the reflective surface 18R of the plane mirror 18 has such properties as will reflect the laser light beam LA(ω) but will transmit the laser light beam LA(2ω) of the second harmonics laser light beam. These reflective surfaces 14R, 18R may be used by dichroic mirrors. Thus the laser light beam of the fundamental wavelength LA(ω), generated in the laser medium 16, is propagated back and forth between the reflective surface 14R and the reflective surface 18R of the resonator 13 for emitting the laser light beam. It is noted that the quarter wave plate 15 is set at an orientation inclined by an azimuth angle θ of 45° with respect to the non-linear optical crystal element 17 and is used for stabilizing the laser light power in various parts of the resonator 13.

The SHG (second harmonic generation) laser light beam LA(2ω) emitted from a virtual luminance point of the resonator 13 is converged on an optical conjugate point, such as a point on recording layer (reflective layer) of an optical disc 22 through the optical system 20 and the objective lens 21. In this resonator, the virtual point of the resonator is positioned at a point O shown in FIGURE 3. The point O is arranged on the reflective surface 18R and the optical axis of the outputting second harmonic laser light beam. With the length L of the light path of the resonator 13, that is the distance between the reflective surface 14R and the reflective surface 18R, calculated in terms of air, or the effective length of the resonator 13, the effective length Le in terms of air from the outgoing reflective surface 18R of the resonator 13 to the conjugate point satisfies a relation

$$Le = (m + 1/2)L \quad (1)$$

where m is an integer.

If the relation of the formula (1) is satisfied, it becomes possible to reduce the interference noise and to prevent fluctuations in the laser output or deterioration of signal characteristics to implement a high performance system. On the other hand, the manufacture tolerance of the Faraday elements employed in the optical system 20, quarter wave plate 15 or other optical components for reducing the return laser light beam may be increased to render it possible to implement an inexpensive system.

The quarter wave plate 15 is a birefringent element which is employed in accordance with the art disclosed by the present Assignee in the Japanese Patent KOKAI Publication No. 1-220879 (JP-A-01 220879) and in the specification and drawings of the Japanese Patent Application Nos. 2-125854 (JP-A-04 025 087) and 3-17068 (JP-A-04 243 177). The laser light beam is passed through the quarter wave plate 15 set at the azimuth angle of $\theta = 45^\circ$ with respect to the non-linear optical crystal element 17 for stabilizing the laser light power in various parts of the resonator 13.

That is, by inserting the quarter wave plate 15 into the resonator 13,

(i) non-linear coupling between the polarization modes due to sum frequency generation is eliminated to inhibit competition between the polarization modes; and

(ii) the spatial phase difference caused by the quarter wave plate becomes equal to 90° , so that the spatial hole burning effect due to emission of two polarization modes may be inhibited to produce stable oscillation of two longitudinal modes (two polarization modes).

In general, in a laser light beam resonated in a resonator, the distance between longitudinal modes, that is the frequency difference between adjacent longitudinal modes for the same transverse mode, is $c/2L$, where L is the length of the resonator 13 and c the light velocity. In the resonator 13 employing the non-linear optical crystal element 17 performing the above-described type II phase matching and having the quarter wave plate 17 inserted on its light path, the mode frequency distance Δf_B is given by

$$\Delta f_B = c/4L \quad (2)$$

if the laser light beam of the fundamental wavelength LA(ω) having a wavelength λ of e.g. 1064 nm is oscillated with the two longitudinal modes (two polarization modes), and L is the light path length between the opposite reflecting surfaces 14R and 18R (effective resonator length in terms of air). Since the SHG laser light beam is taken out as a polarization in one direction, the frequency of each of the longitudinal modes of these eigen polarization modes is doubled so that the frequency distance between-adjacent longitudinal modes Δf_{SH} is given by

$$\Delta f_{SH} = c/2L \quad (3)$$

An electrical field E(z) in the SHG laser light beam when the above-described two longitudinal modes are resonated with the same intensity is found. If ω_1 , ω_2 are angular frequencies of the respective modes, and $k_1 (= \omega_1/c)$ and $k_2 (= \omega_2/c)$ are the numbers of waves in each mode, the electrical field E(z) in the SHG laser light beam is given by

$$\begin{aligned} E(z) &= E_0 e^{i(\omega_1 t - k_1 z)} + E_0 e^{i(\omega_2 t - k_2 z)} \\ &= E_0 e^{i(\omega_1 + \omega_2)t/2 - (k_1 + k_2)z/2} 2 \cos \left((\omega_1 - \omega_2) \frac{t}{2} - (k_1 - k_2) \frac{z}{2} \right) \quad (4) \end{aligned}$$

From the above formula (3), the angular frequency between the modes is

$$\omega_1 - \omega_2 = 2\pi \Delta f_{SH} = \pi c/L \quad (5)$$

so that the formula (4) may be simplified to

$$\begin{aligned} E(z) &= E_0 e^{i(\omega_1 + \omega_2)t/2 - (k_1 + k_2)z/2} 2 \cos \left(2\pi \Delta f_{SH} \frac{t}{2} - \frac{\pi z}{2L} \right) \quad (6) \end{aligned}$$

In the optical system employing the laser light beam generating apparatus, if the reflectivity of intensity of the return light beam from the conjugate point is R_d , the reflectivity of the intensity of the SHG laser light beam at the reflective surface 18R of the

resonator 13 is R_m , these reflectivity R_d , R_m , which in effect are on the order of several percent, are assumed to be small, and if multiple reflection is disregarded, the forward interference noise intensity I_1 and rear interference noise intensity I_2 are given by

$$I_1 = |E(0) + \sqrt{R_m R_d} E(2L_e)|^2 \quad (7)$$

$$I_2 = |E(0) + \sqrt{R_d} E(2L_e)|^2 \quad (8)$$

where L_e is the effective distance as far as the conjugate point.

If the formulas (7) and (8) are expanded and a term $(\omega_1 + \omega_2)$ oscillated at a high velocity is time-averaged,

$$\langle I_1 \rangle = \langle E(0)E^*(0) \rangle + \sqrt{R_m R_d} \langle E(0)E^*(2L_e) + E^*(0)E(2L_e) \rangle + R_m R_d \langle E(2L_e)E^*(2L_e) \rangle \quad (9)$$

is obtained.

The first term of the formula (9) is

$$E_0^2 4 \langle \cos(2\pi \Delta f_{SH}) \rangle = 2E_0^2 \quad (10)$$

The second term of the formula (9) is

$$\begin{aligned} & \sqrt{R_m R_d} E_0^2 4 \langle (e^{-i(k_1 + k_2)L_e} + e^{i(k_1 + k_2)L_e}) \cos \\ & \quad \left(\frac{2\pi \Delta f_{SH}}{2} \frac{t}{2} \right) \cos \left(2\pi \Delta f_{SH} \frac{t}{2} \frac{\pi L_e}{L} \right) \rangle \\ & = \sqrt{R_m R_d} E_0^2 8 \cos((k_1 + k_2)L_e) \\ & \times \langle \cos^2 \left(2\pi \Delta f_{SH} \frac{t}{2} \right) \cos \left(\frac{\pi L_e}{L} \right) + \cos \left(2\pi \Delta f_{SH} \frac{t}{2} \right) \sin \left(2\pi \Delta f_{SH} \right. \\ & \quad \left. \frac{t}{2} \right) \sin \left(\frac{\pi L_e}{L} \right) \rangle \\ & = \sqrt{R_m R_d} E_0^2 4 \cos((k_1 + k_2)L_e) \cos \left(\frac{\pi L_e}{L} \right) \quad (11) \end{aligned}$$

The third term of the formula (9) is

$$R_m R_d E_0^2 4 \langle \cos^2 \left(2\pi \Delta f_{SH} \frac{t}{2} - \frac{\pi L_e}{L} \right) \rangle = 2R_m R_d E_0^2 \quad (12)$$

Therefore, the forward interference noise intensity I_1 and the rearward interference noise intensity I_2 are given by

$$I_1 = 2E_0^2 (1 + 2\sqrt{R_m R_d} \cos((k_1 + k_2)L_e) \cos \left(\frac{\pi L_e}{L} \right) + R_m R_d) \quad (13)$$

$$I_2 = 2E_0^2 (1 + 2\sqrt{R_d} \cos((k_1 + k_2)L_e) \cos \left(\frac{\pi L_e}{L} \right) + R_d) \quad (14)$$

In these formulas (13), (14), it is the second term which produces the interference noise. Specifically, the first cosine term that is term, that is

$$\cos((k_1 + k_2)L_e) = \cos \left(\frac{2\pi L_e}{\lambda/2} \right) \quad (15)$$

represents a term which oscillates at a half wavelength period when the distance to the conjugate point L_e in terms of air undergoes extremely small oscillations of the order of the wavelength of light and hence is responsible for the interference noise.

The second cosine term $\cos(\pi L_e/L)$ in the second term of the formulas (13), (14) is a term which undergoes moderate oscillations with $2L$ (L being the length of the resonator of the laser light source) as a period.

If the condition of formula (1), that is $L_e = (m + 1/2)L$, m being an integer, is satisfied, $\cos(\pi L_e/L)$ becomes zero. In other words, if the distance as far as the conjugate point L_e is (integer + half integer) times the length in terms of air of the resonator, the interference noise in the forward and rearward directions becomes zero. Even if the formula (1) is not satisfied completely, that is if the distance L_e is approximately equal to (integer + half integer) times the resonator length L , the interference noise is significantly reduced, as may be seen from FIGURE 4.

FIGURES 5 to 7 show concrete embodiments in which the present invention is applied to an optical pickup apparatus for an optical recording disc. FIGURE 5 shows a schematic overall perspective view. FIGURE 6 shows a schematic cross-sectional view of an SHG light source. FIGURE 7 shows a schematic overall front view. In FIGURES 5 to 7, like elements corresponding to those in FIGURE 3 are identified by the same reference numerals and will not be described.

In the optical pickup apparatus shown in FIGURES 5 to 7, the SHG light source having a small-sized and compact design as shown in FIGURE 6 is adopted. The pumping light beam emitted from the laser diode 11 is converged by the lens 12 and is incident the laser medium 16 through an incident surface of the quarter wave plate 15. A reflective surface 15 is formed on the incident surface of the quarter wave plate 15 by a coating method and has a wavelength selectivity as a dichroic mirror. The reflective surface 15R transmits the pumping light beam, in which a wavelength is, for example, 810 nm and reflects a laser light beam of the fundamental wavelength, in which a wavelength is, for example, 1064 nm, generated by the laser medium 16. The reflective surface 15R is a concave mirror when seen from the laser medium 16. The laser light beam of fundamental wavelength generating the laser medium 16 is irradiated to the non-linear optical crystal element 17 as KTP (KTiPO₄). The second harmonic generation is generated at the non-linear optical crystal element 17 corresponding to the irradiated laser light beam of fundamental wavelength. A reflective surface 17R is formed on the outgoing surface of the non-linear optical crystal element 17. The reflective surface 17R transmits the laser light beam of the fundamental wavelength and reflects a second harmonic laser light beam, in which a wavelength is, for example, 532 nm. The resonator is formed between the reflective surface 15R and the reflective surface 17R.

In the resonator adopted in the optical pickup apparatus shown in FIGURES 5 to 7, the concave mirror 14 and the plane mirror 18 of the resonator 13 shown in FIGURE 3 is omitted, and the wavelength selectivity reflective surfaces 15R and 17R are formed on the incident surface of the quarter wave plate 15 and the outgoing surface of the non-linear optical crystal ele-

ment 17. The quarter wave plate 15, the laser medium 16 and the non-linear optical crystal element 17 are intimately connected with one another. The resonator is accommodated in a V-shaped groove in a resonator securing block 31 in a direction along the Z-axis shown in FIGURE 5.

The SHG laser light beam outputted from the reflective surface 17R of the resonator in the Z-axis direction is deflected by a vertically deflecting mirror 19 in a vertical direction, Y-axis direction, shown in FIGURE 5 and led to an optical system of the optical pickup apparatus. The SHG laser light beam is irradiated to the optical disc 22.

In the optical pickup apparatus, a mounting block of the laser diode 11, the resonator securing block 31 and a mounting block of the deflecting mirror 19 are mounted on a base 33. The base 33 is temperature-controlled by a sole temperature control device 34, such as a so-called thermoelectric (TE) cooler. These blocks and the base 33 are accommodated in a package 35.

The SHG laser light beam emitted in the Y-axis by the deflecting mirror 19 is transmitted through a concave lens 23 and a grating 24 a polarization beam splitter 25. The SHG laser light beam further is led to the objective lens 21 via a lens 26 and a quarter wave plate 27. The SHG laser light beam is focused on the point of the recording surface of the optical disc 22 as the optical conjugate point. In this case, the sum l_e of the distance in terms of air l_{e1} from the reflective surface 17R as the outgoing surface to the deflecting mirror 19 of the resonator and the distance in terms of air l_{e2} from the mirror 19 to the recording surface of the optical disc 22 as the optical conjugate point is an (integer plus half integer) times the length in terms of air L between the reflective surfaces 15R and 17R of the resonator, that is the effective resonator length, that is,

$$l_e = l_{e1} + l_{e2} = (m + 1/2)L.$$

In this manner, it becomes possible to reduce the interference noise and to prevent deterioration in signal characteristics or fluctuations in the laser output otherwise caused by the interference noise. On the other hand, the manufacture tolerances of the optical components employed the optical system of the optical pickup apparatus, such as the polarization beam splitter 25 or the quarter wave plate 27 may be enlarged to enable implementation of an inexpensive system.

The return light beam from the recording surface of the optical disc 22 is irradiated to the polarization beam splitter 25 through the objective lens 21, the quarter wave plate 27 and the lens 26 and reflected by a boundary surface of the polarization beam splitter 25. The return laser light beam reflected by the polarization beam splitter 25 is received by a photodetector 29 via a multi lens 28, and the recording signals are reproduced.

It is to be noted that, although not claimed, the present invention may be applied not only to the above-described optical pickup apparatus but to generation of fourth and higher harmonics, with the use of an external resonator, laser scanning microscope, laser lithography or coupling to optical fibers. The above-described effect may be derived by designing the distance l_e to the optical conjugate points of these optical systems in terms of air so as to be equal to substantially (integer + half integer) times the effective resonator length L , that is, by designing the distances so that

$$l_e = (m + 1/2)L.$$

The present invention is not limited to the above-described embodiments. For example, a resonator including an optical path folding type reflective mirror in the optical path in addition to a pair of reflective mirrors on both ends along the resonator optical path may be employed. The laser medium or the non-linear optical crystal element are naturally not limited to Nd:YAG or KTP.

Claims

1. A laser light beam generating apparatus comprising:
 - at least one light source (11);
 - a resonator (13) for generating a type II second harmonic laser light beam and comprising a first reflector (14R), a second reflector (18R), a laser medium (16) provided between said first (14R) and second (18R) reflectors and irradiated a light beam emitted from said light source (11) through said first reflector (14R) and a non-linear optical crystal element (17) provided between said laser medium (16) and said second reflector (18R); and
 - an optical system (20) for radiating the type II second harmonic laser light beam emitted from a virtual luminance point (O) of said resonator (13) to a conjugate point,
 - wherein with an effective length L of said resonator (13), an effective distance l_e from said resonator (13) to the conjugate point is set to that

$$l_e = (m + 1/2)L$$
 where m is an integer.
2. A laser light beam generating apparatus according to claim 1, wherein said resonator (13) further comprises a birefringent element (15) provided between said first (14R) and second (18R) reflectors.
3. A laser light beam generating apparatus according to claim 1, wherein said optical system (20) comprises a convergent lens (21) for focusing the type II second harmonic laser light beam on the



ment 17. The quarter wave plate 15, the laser medium 16 and the non-linear optical crystal element 17 are intimately connected with one another. The resonator is accommodated in a V-shaped groove in a resonator securing block 31 in a direction along the Z-axis shown in FIGURE 5.

The SHG laser light beam outputted from the reflective surface 17R of the resonator in the Z-axis direction is deflected by a vertically deflecting mirror 19 in a vertical direction, Y-axis direction, shown in FIGURE 5 and led to an optical system of the optical pickup apparatus. The SHG laser light beam is irradiated to the optical disc 22.

In the optical pickup apparatus, a mounting block of the laser diode 11, the resonator securing block 31 and a mounting block of the deflecting mirror 19 are mounted on a base 33. The base 33 is temperature-controlled by a sole temperature control device 34, such as a so-called thermoelectric (TE) cooler. These blocks and the base 33 are accommodated in a package 35.

The SHG laser light beam emitted in the Y-axis by the deflecting mirror 19 is transmitted through a concave lens 23 and a grating 24 a polarization beam splitter 25. The SHG laser light beam further is led to the objective lens 21 via a lens 26 and a quarter wave plate 27. The SHG laser light beam is focused on the point of the recording surface of the optical disc 22 as the optical conjugate point. In this case, the sum is of the distance in terms of air Le_1 from the reflective surface 17R as the outgoing surface to the deflecting mirror 19 of the resonator and the distance in terms of air Le_2 from the mirror 19 to the recording surface of the optical disc 22 as the optical conjugate point is an (integer plus half integer) times the length in terms of air L between the reflective surfaces 15R and 17R of the resonator, that is the effective resonator length, that is,

$$Le = Le_1 + Le_2 = (m + 1/2)L.$$

In this manner, it becomes possible to reduce the interference noise and to prevent deterioration in signal characteristics or fluctuations in the laser output otherwise caused by the interference noise. On the other hand, the manufacture tolerances of the optical components employed the optical system of the optical pickup apparatus, such as the polarization beam splitter 25 or the quarter wave plate 27 may be enlarged to enable implementation of an inexpensive system.

The return light beam from the recording surface of the optical disc 22 is irradiated to the polarization beam splitter 25 through the objective lens 21, the quarter wave plate 27 and the lens 26 and reflected by a boundary surface of the polarization beam splitter 25. The return laser light beam reflected by the polarization beam splitter 25 is received by a photodetector 29 via a multi lens 28, and the recording signals are reproduced.

It is to be noted that, although not claimed, the present invention may be applied not only to the above-described optical pickup apparatus but to generation of fourth and higher harmonics, with the use of an external resonator, laser scanning microscope, laser lithography or coupling to optical fibers. The above-described effect may be derived by designing the distance Le to the optical conjugate points of these optical systems in terms of air so as to be equal to substantially (integer + half integer) times the effective resonator length L, that is, by designing the distances so that

$$Le = (m + 1/2)L.$$

The present invention is not limited to the above-described embodiments. For example, a resonator including an optical path folding type reflective mirror in the optical path in addition to a pair of reflective mirrors on both ends along the resonator optical path may be employed. The laser medium or the non-linear optical crystal element are naturally not limited to Nd:YAG or KTP.

Claims

1. A laser light beam generating apparatus comprising:
 - at least one light source (11);
 - a resonator (13) for generating a type II second harmonic laser light beam and comprising a first reflector (14R), a second reflector (18R), a laser medium (16) provided between said first (14R) and second (18R) reflectors and irradiated a light beam emitted from said light source (11) through said first reflector (14R) and a non-linear optical crystal element (17) provided between said laser medium (16) and said second reflector (18R); and
 - an optical system (20) for radiating the type II second harmonic laser light beam emitted from a virtual luminance point (O) of said resonator (13) to a conjugate point,
 - wherein with an effective length L of said resonator (13), an effective distance Le from said resonator (13) to the conjugate point is set to that

$$Le = (m + 1/2)L$$
 where m is an integer.
2. A laser light beam generating apparatus according to claim 1, wherein said resonator (13) further comprises a birefringent element (15) provided between said first (14R) and second (18R) reflectors.
3. A laser light beam generating apparatus according to claim 1, wherein said optical system (20) comprises a convergent lens (21) for focusing the type II second harmonic laser light beam on the



conjugate point.

4. An optical pickup apparatus for an optical recording medium comprising:

at least one light source (11);

a resonator (15R, 17R) for generating a type II second harmonic laser light beam and comprising a first reflector (14R), a second reflector (18R), a laser medium (16) provided between said first (14R) and second (18R) reflectors and irradiated a light beam emitted from said light source (11) through said first reflector (14R) and a non-linear optical crystal element (17) provided between said laser medium (16) and said second reflector (18R);

a deflector (19) for deflecting the type II second harmonic laser light beam; and

an optical system (20) comprising an objective lens (21) for focusing the type II second harmonic laser light beam emitted from a virtual luminance point (O) of said resonator (15R, 17R) to a focusing point on the optical recording medium (22),

wherein with an effective length L of said resonator (15R, 17R), an effective distance L_e from said resonator (17R) to said focusing point of the type II second harmonic laser light beam by said objective lens (21) is set so that

$$L_e = (m + 1/2)L$$

where m is an integer.

5. An optical pickup apparatus according to claim 4, wherein said resonator (15R, 17R) comprises a first reflector (15R), a second reflector (17R), a laser medium (16) provided between said first (15R) and second (17R) reflectors and irradiated a light beam emitted from said light beam source (11) through said first reflector (15R), a non-linear optical crystal element (17) provided between said laser medium (16) and said second reflector (17R) and a birefringent element (15) provided between said first (15R) and second (17R) reflectors.

Patentansprüche

1. Laserstrahlerzeugende Vorrichtung aufweisend: wenigstens eine Lichtquelle (11); einen Resonator (13) zur Erzeugung eines Laserstrahls der zweiten Harmonischen vom Typ II und aufweisend einen ersten Reflektor (14R), einen zweiten Reflektor (18R), ein Lasermedium (16) zwischen dem ersten (14R) und dem zweiten (18R) Reflektor, auf welches ein von der Lichtquelle (11) emittierter Lichtstrahl über den ersten Reflektor (14R) eingestrahlt wird, und ein nichtlineares optisches Kristallelement (17), das zwischen dem Lasermedium (16) und dem zweiten Reflektor (18R) vorgesehen ist; und ein optisches System (20) aufweisend eine Sammellinse (21) zur Fokussierung des Laserstrahls der zweiten Harmonischen des Typs II auf den Konjugationspunkt aufweist.

schen dem Lasermedium (16) und dem zweiten Reflektor (18R) vorgesehen ist; und ein optisches System (20), um den von einem virtuellen Luminanzpunkt (O) emittierten Laserstrahl der zweiten Harmonischen vom Typ II auf einen Konjugationspunkt zu strahlen, wobei die effektive Länge L des Resonators (13), der effektive Abstand L_e von dem Resonator (13) zu dem Konjugationspunkt so festgelegt ist, daß $L_e = (m + 1/2)L$, wobei m ganzzahlig ist.

2. Laserstrahlerzeugende Vorrichtung gemäß Anspruch 1, wobei der Resonator (13) ferner ein zwischen dem ersten (14R) und dem zweiten (18R) Reflektor vorgesehenes doppelbrechendes Element (15) aufweist.
3. Laserstrahlerzeugende Vorrichtung gemäß Anspruch 1, wobei das optische System (20) eine Sammellinse (21) zur Fokussierung des Laserstrahls der zweiten Harmonischen des Typs II auf den Konjugationspunkt aufweist.
4. Optische Aufnahmevorrichtung für ein optisches Aufzeichnungsmedium aufweisend: wenigstens eine Lichtquelle (11); einen Resonator (13) zur Erzeugung eines Laserstrahls der zweiten Harmonischen vom Typ II und aufweisend einen ersten Reflektor (14R), einen zweiten Reflektor (18R), ein Lasermedium (16) zwischen dem ersten (14R) und dem zweiten (18R) Reflektor, auf welches ein von der Lichtquelle (11) emittierter Lichtstrahl über den ersten Reflektor (14R) eingestrahlt wird und ein nichtlineares optisches Kristallelement (17), das zwischen dem Lasermedium (16) und dem zweiten Reflektor (18R) vorgesehen ist; eine Ablenkeinrichtung (19) zur Ablenkung des Laserstrahls der zweiten Harmonischen vom Typ II; und ein optisches System (20) aufweisend eine Objektivlinse (21) zur Fokussierung des von einem virtuellen Luminanzpunkt (O) des Resonators (15R, 17R) emittierten Laserstrahls der zweiten Harmonischen vom Typ II auf einen Brennpunkt auf dem optischen Aufzeichnungsmedium (22), wobei die effektive Länge L des Resonators (15R, 17R), der effektive Abstand L_e von dem Resonator (17R) zu dem Brennpunkt des Laserstrahls der zweiten Harmonischen vom Typ II durch die Objektivlinse (21) so festgelegt ist, daß $L_e = (m + 1/2)L$ wobei m ganzzahlig ist.
5. Optische Aufnahmevorrichtung gemäß Anspruch 4, wobei der Resonator (15R, 17R) einen ersten Re-



flektor (15R), einen zweiten Reflektor (17R), ein zwischen dem ersten (15R) und dem zweiten (17R) Reflektor vorgesehenes Lasermedium aufweist, auf das ein von der Lichtquelle (11) emittierter Lichtstrahl über den ersten Reflektor (15R) eingestrahlt wird, und ein nichtlineares optisches Kristallelement (17) zwischen dem Lasermedium (16) und dem zweiten Reflektor (17R) vorgesehen ist und ein doppelbrechendes Element (15) zwischen dem ersten (15R) und dem zweiten (17R) Reflektor vorgesehen ist.

Revendications

1. Dispositif générateur de faisceau de lumière laser comprenant :

au moins une source de lumière (11) ;

un résonateur (13) pour produire un faisceau de lumière laser du second harmonique de type II et comprenant un premier réflecteur (14R), un second réflecteur (18R), un milieu laser (16) disposé entre lesdits premier (14R) et second (18R) réflecteurs et éclairé par un faisceau de lumière émis par ladite source de lumière (11) par l'intermédiaire dudit premier réflecteur (14R), et un élément de cristal optique non linéaire (17) disposé entre ledit milieu laser (16) et ledit second réflecteur (18R) ; et

un système optique (20) pour projeter le faisceau de lumière laser du second harmonique de type II, émis à partir d'un point de luminance virtuel (O) dudit résonateur (13) vers un point conjugué ;

dans lequel, pour une longueur efficace L dudit résonateur (13), la distance efficace L_e dudit résonateur (13) au point conjugué est déterminée de sorte que :

$$L_e = (m + 1/2)L$$

où m est un nombre entier.

2. Dispositif générateur de faisceau de lumière laser selon la revendication 1, dans lequel ledit résonateur (13) comprend un outre un élément biréfringent (15) disposé entre lesdits premier (14R) et second (18R) réflecteurs.

3. Dispositif générateur de faisceau de lumière laser selon la revendication 1, dans lequel ledit système optique (20) comprend une lentille convergente (21) pour focaliser le faisceau de lumière laser du second harmonique de type II sur le point conjugué.

4. Dispositif de tête de lecture optique pour un support d'enregistrement optique comprenant :

au moins une source de lumière (11) ;

un résonateur (15R, 17R) pour produire un

faisceau de lumière laser du second harmonique de type II et comprenant un premier réflecteur (14R), un second réflecteur (18R), un milieu laser (16) disposé entre lesdits premier (14R) et second (18R) réflecteurs et éclairé par un faisceau de lumière émis par ladite source de lumière (11) par l'intermédiaire dudit premier réflecteur (14R), et un élément de cristal optique non linéaire (17) disposé entre ledit milieu laser (16) et ledit second réflecteur (18R) ;

un déflecteur (19) pour dévier le faisceau de lumière laser du second harmonique de type II ; et

un système optique (20) comprenant une lentille objectif (21) pour focaliser le faisceau de lumière laser du second harmonique de type II, émis à partir d'un point de luminance virtuel (O) dudit résonateur (15R, 17R) vers un point de focalisation sur le support d'enregistrement optique (22) ;

dans lequel, pour une longueur efficace L dudit résonateur (15R, 17R), la distance efficace L_e dudit résonateur (17R) audit point de focalisation du faisceau de lumière laser du second harmonique de type II par ladite lentille objectif (21) est déterminée de sorte que :

$$L_e = (m + 1/2)L$$

où m est un nombre entier.

5. Dispositif de tête de lecture optique selon la revendication 4, dans lequel ledit résonateur (15R, 17R) comprend un premier réflecteur (15R), un second réflecteur (17R), un milieu laser (16) disposé entre lesdits premier (15R) et second (17R) réflecteurs et éclairé par un faisceau de lumière émis par ladite source de lumière (11) par l'intermédiaire dudit premier réflecteur (15R), un élément de cristal optique non linéaire (17) disposé entre ledit milieu laser (16) et ledit second réflecteur (17R), et un élément biréfringent (15) disposé entre lesdits premier (15R) et second (17R) réflecteurs.