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31 MAR 2003

DESCRIPTION

OPTICAL PICKUP AND OPTICAL REPRODUCING APPARATUS

TECHNICAL FIELD

The present invention relates to an optical pickup, for example, for irradiating an optical recording medium such as an optical disc with a light from a light emitting part and receiving and detecting the returned light reflected by the optical recording medium, and an optical reproducing apparatus.

More specifically, it relates to an optical pickup preferably adopted to the case of detecting a tracking error signal with respect to an optical disc having an optional pit depth, and an optical reproducing apparatus.

BACKGROUND ART

Since optical parts such as gratings and beam splitters are assembled independently in conventional optical pickups, such as optical disc drives including compact disc (CD) players, and magneto-optical disc drives, the configuration of the apparatus as a whole is complicated and large. Moreover, in the case of the assembly on a substrate as a hybrid, a strict alignment accuracy has been required in terms of the optical position setting.

FIG. 8 shows a configuration diagram of an example of an optical pickup dedicated for reproduction of a conventional compact disc (CD). The optical pickup 81 comprises a semiconductor laser 82, a diffraction grating 83, a beam

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splitter plate 84, an objective lens 85, and a light receiving element 86 comprising a photo diode. A laser light L from the semiconductor laser 82 is reflected by the beam splitter plate 84, and converged by the objective lens 85 so as to be irradiated to an optical disc 90. The returned light reflected by the optical disc 90 transmits the beam splitter plate 84 so as to be received and detected by the light receiving element 86.

However, the optical pickup 81 comprises a large number of parts so as to be very bulky as well as a high positioning accuracy is required. As a result, the productivity is low.

As a method for the tracking servo in an optical apparatus such as an optical pickup, in general, the push-pull method, the three beam method, and the heterodyne method, or the like, are used.

Among them, the conventionally executed push-pull method utilizes generation of the strength difference in the ± first order diffracted light generated by the disc in the case the light spot of the incident light is off the track or the pit on a disc so that the far-field image becomes asymmetrical. More specifically, it is a method of detecting the displacement of the optical spot from the track by taking out a signal corresponding to the asymmetry by two detectors and calculating the signals from the two detectors with a calculator.

FIG. 9A and FIG. 9B show schematic configuration

diagrams of a tracking servo using the push-pull method.

As shown in FIG. 9B, a mark or a space is recorded by the ruggedness of the pit on the surface of the disc 52. If the pit is irradiated with a light, the light is diffracted by the ruggedness so as to be divided into the zero-order diffracted light (main beam B) and the ± first-order diffracted lights (sub beams B')/]. In FIG. 9, S_0 and S_1 each denotes the irradiation spots of the zero-order diffracted light and the ± first-order diffracted lights. S_0 is round because of the aperture of the objective lens.

In this case, as shown in FIG. 9A, half-split photo diodes PD_R, PD_L are disposed and formed as the light receiving parts. By the calculation process of a signal received by the photo diodes PD_R, PD_L, for example, of $(PD_L - PD_R)$, with a differential amplifier (not illustrated), or the like, a tracking error signal TE can be obtained as a tracking signal.

In the case the track and the beam are not coincided, since the spot center is off the dividing line of the half-split photo diodes, a positive or negative value is obtained according to the displacement direction without satisfying TE = (PDL - PDR). Accordingly, the displacement direction or amount with respect to the track can be detected.

Since the tracking servo using the push-pull method can be realized with the half-split photo diodes, it can be provided at a low cost.

However, a problem is involved in that the returned light from the disc is shifted perpendicular to the dividing line of the light receiving element on the light receiving surface in the case the objective lens is shifted with respect to the optical axis so that a large offset is generated in the tracking error signal.

As shown in FIG. 10A, in the case the objective lens 51 is shifted in the lateral direction, the spots of the lights received by the photo diodes PD_L, PD_R are shifted accordingly as shown by the broken lines, and thus even if the tracking is made immediately above the track, the tracking error signal does not satisfy TE = 0.

Moreover, as shown in FIG. 10B, also in the case the objective lens 51 is tilted with respect to the disc 52, the spots of the lights to be received are shifted as shown by the broken lines, and thus even if the tracking is made immediately above the track, the tracking error signal does not satisfy TE = 0.

FIG. 11 shows the influence of the above-mentioned lens shift on the tracking error signal in the case of the conventional push-pull signal. The vertical axis denotes a relative value. The calculation was executed with the premise that the disc has a 1.60 μm groove pitch, a wavelength/8 groove depth, and a 65% duty (duty: the ratio between the groove and the track width). Moreover, the laser wavelength was set to be

0.78 μm.

As shown in FIG. 11, in the conventional push-pull signal, the tracking error signal generates the offset according to the shift of the objective lens.

Moreover, in the push-pull method, in the case the pit depth of the disc 52 is $\lambda/4n$ with the premise that the wavelength of the laser for reproduction is λ, and the refractive index of the transparent substrate of the disc 52 is n, since the signal becomes 0 due to the interference between the zero-order diffracted light and the ± first-order diffracted lights, principally, the detection of the tracking error signal is disabled. Therefore, it cannot be used for a disc 52 with a specification of a $\lambda/4n$ pit depth.

For example, the DVD (Digital Versatile Disk)-ROM and DVD-Video have a specification with a pit depth in the vicinity of $\lambda/4n$, the push-pull method cannot be adopted.

Next, the three beam method will be explained.

In the three beam method, a light is divided with a diffraction grating so as to form a main beam and two sub beams on both sides thereof.

FIG. 12 shows spot positions on the disc surface by the three beam method.

The groove or the pit of the disc 52 is irradiated with a spot S_0 by the main beam, and spots S_1, S_2 by the sub beams on

both sides thereof. The reflected lights of the two sub beams are detected, respectively, and a difference signal is obtained so as to execute the tracking servo, using the difference signal.

Here, in the case the spot S_0 of the main beam is off the track center, the reflected lights by the sub beam spots S_1, S_2 become asymmetrical so that the tracking error signal by the difference signal changes from 0. Since the change amount of the tracking error signal changes according to the displacement amount of the spot S_0 of the main beam for the track center, the tracking servo can be executed.

The reflected light of the main beam is used for the detection of a disc recording signal.

In this case, it can cope with the above-mentioned objective lens shift without generating the offset.

However, since it is necessary to pass through a diffraction grating such as a grating, the method has disadvantages in the increase of the number of parts, increase of the power consumption due to the need of increasing the laser light emitting amount according to reduction of the light amount of the main beam, and complication of the adjustment so as to need the production cost.

Next, the phase difference detection method will be explained.

The phase difference detection method is effective, in

particular, for the tracking servo of a disc with a specification of a $\lambda/4n$ pit depth.

The phase difference detection method is realized by a method of heterodyne detection of the diffracted spectrum of a two-dimensional pit with an RF (higher harmonic) signal as the reference, or a method of digital calculation process of each signal detected on an optical detector.

In the phase difference detection method, for example, as shown in FIG. 13, photo diodes PDa, PDb, PDc, and PDd are formed in the four regions of an optical disc as a portion to be irradiated, divided with the optical axis as the center in the longitudinal and lateral directions, for example, in the tangential direction T, which is the pit row direction, and the direction perpendicular to the direction T so as to be disposed in the far-field region. Then, the returned light from the optical disc is detected with the four-split photo diodes PDa to PDd.

In FIG. 13, the circle in the center corresponding to the pupil of the lens corresponds to the spot of the zero-order diffracted light. The eight circles in the vicinity correspond to the spots of the first-order diffracted lights. Moreover, the dot line portion in the center is an image corresponding to the pit P of the disc.

With respect to the configuration of the four-split photo diodes PDa to PDd, for example, the signal process is

executed as follows.

The RF signal, which is the total sum of the detected signal of each photo diode (PDa + PDb + PDc + PDd), and the signal obtained by calculating the detected signal of each photo diode (for example, PDa + PDc - PDb - PDd) are heterodyne-detected in consideration of the phases.

The content of the calculation signal is shown in the following formula (1).

Calculation signal = (PDa + PDc) - (PDb + PDd)

$= C \sin (2\pi V_t/V_p) \sin (2\pi a\omega t/V_p)$ (1),

wherein V_t: detracking amount

V_p: cycle of the pit row

a: radius of the reading position

ω: angular velocity of the optical disc, and

C: constant.

Herein, in consideration that the RF signal (PDa + PDb + PDc + PDd) is $\cos (2\pi a\omega t/V_p)$, the portion of $C \sin(2\pi V_t/V_p)$ in the formula 1 is the signal obtained in the case of the heterodyne detection of the calculation signal having it as the reference. From the signal obtained by the heterodyne detection, the detracking amount V_t can be calculated.

As mentioned above, in the phase difference detection method, the offset of the tracking error signal can hardly be generated by the lens shift, and further, it is effective for a

disc with a specification of a $\lambda/4n$ pit depth.

However, since the phase displacement is generated with respect to a disc having a pit depth other than $\lambda/4n$, consequently, the offset is generated. Therefore, with respect to a disc other than $\lambda/4n$, it is additionally needed to cancel the offset of the low-pass component by providing a phase compensation circuit, or the like.

In contrast, as a means for improving the disadvantages of the above-mentioned conventional optical apparatus, a so-called CLC (confocal laser coupler) configuration, wherein a light emitting part is disposed at the confocal position of a converging means, such as a lens, and forming the light receiving part in the vicinity of the confocal position with the light emitting part is conceivable for the purpose of the simplification and a small size of the apparatus as a whole by enabling the cutback of the number of the optical parts, and simplification of the alignment at the time of the optical position setting.

The present applicant has already proposed an optical apparatus wherein split photo diodes providing a light receiving part are disposed at the above-mentioned confocal position for using the push-pull method, or the like, so as to execute the tracking servo in order to eliminate the offset of the tracking error signal derived from the above-mentioned lens shift or the

tilt of the disc (see "optical apparatus" in Japanese patent Application (JP-A) No. 7-35528).

According to the optical apparatus, since the tracking error signal is detected by the push-pull method (CPP method) by the light receiving part in the vicinity of the confocal position, stable detection of the tracking error signal can be peformed also with respect to the offset of the lens or the warp of the disc, and thus the alignment at the time of assembly can drastically be simplified. Moreover, since the light emitting part and the light receiving part are formed on the same substrate, cutback of the number of parts can be achieved so that the reduction of the production cost or a higher reliability can be realized.

However, the above-mentioned CPP method has a disadvantage peculiar to the confocal optical systems.

In particular, it is revealed directly in the case it is not in just focus, that is, not in the state with a light spot in focus on an optical recording medium, but a slight focal displacement within a focal depth is generated.

FIG. 14 shows an example thereof. FIG. 14 shows an example of a numerical value calculation result, showing the relationship between the tracking error signal and the detracking amount according to the CPP method in the case the defocus is generated. A disc of the model with the same shape as the one used for the calculation in FIG. 11 was used.

From FIG. 14, it is learned that an error is generated in the tracking error detection by the CPP method even in the case of a defocus of ± 1 μm or less, which is almost the same as in the focal depth, or in the focal depth (since the light spot size is not changed in the focal depth, in general, it is not described as the defocus is generated. However, since the focus error signal is changed, it is described so for the convenience).

Moreover, as the case of the defocus = -0.50 μm shown by the curve G in FIG. 14, sometimes it can be a signal having a frequency different from that of the original tracking error signal (the case of the defocus = 0.00 μm shown by the curve E), or, for example, a tracking error signal having a double frequency. Furthermore, like the curve H and the curve I, the positive and the negative of the signal can be reversed.

In contrast, in recording or reproducing a signal in the optical system of an optical disc, in addition to control of tracking, control of the focus is needed. In general, in the focus control, the defocus amount is restrained to the extent of the focal depth of the objective lens or less according to the spot size method, the astigmatism method, the knife edge method, or the like.

However, the defocus amount is not always maintained at 0 μm but a slight fluctuation in the focal depth is always generated. Therefore, in the case of executing the tracking

error detection according to the CPP method, before discussing the pit depth, a compensation method or a detection method in consideration of the influence of the defocus needs to be adopted.

DISCLOSURE OF THE INVENTION

In order to solve the above-mentioned problems, the present invention is for enabling cutback of the number of optical parts and simplification of the alignment in the optical position setting in an optical apparatus such as an optical pickup so as to achieve the simplification and a smaller size of the apparatus as a whole as well as for obtaining a tracking error signal stably with respect to optical recording media with all kinds of pit depths so as to facilitate production in the semiconductor process.

That is, an object of the present invention is to provide an optical pickup characterized in comprising a semiconductor laser, a reflecting means for guiding an outputted light from the semiconductor laser to an optical disc, an objective lens for collecting the outputted light reflected by the reflecting means on the optical disc, a light receiving means disposed in the range substantially in the convergence limit of the returned light from the optical disc, and a tracking error signal generating means for generating a tracking error signal based on the reflected light from the end part of at least one of a mark and a space on the optical disc detected

by the light receiving means.

Furthermore, another object of the present invention is to provide an optical reproducing apparatus comprising a driving means for driving the objective lens in the tracking direction based on the tracking error signal generated by the tracking error signal generating means in reproducing an optical disc medium with a mark or a space formed on the medium.

According to the above-mentioned configuration of the present invention, since the optical detecting element is disposed and formed at a position within the convergence limit of the returned light in the vicinity of the confocal position, the receivable returned light is applied with the band limit, and thus influence of the excessive diffracted light, offset by the lens shift, or the like, can be reduced.

Furthermore, by detecting the tracking error signal by receiving and detecting the returned light generated by the end part of the pit or the region, wherein information is recorded, a stable tracking error signal, which can hardly be influenced by the defocus, or change or irregularity, or the like, of the disc parameters, can be obtained.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic configuration diagram (perspective view) of an embodiment of an optical apparatus according to the present invention. FIG. 2 is an enlarged diagram of the principal part of the optical apparatus of FIG. 1. FIG. 3 is a

plan view of the principal part of the optical apparatus of FIG. 1. FIGS. 4A and 4B are schematic diagrams of a pit edge for explaining the detection at the pit edge. FIG. 5 is a graph showing the tracking error signal characteristics in the case the pit depth of the disc is $\lambda/4n$. Among them, FIG. 5A is a graph showing the change of the tracking error signal by the lens shift in the radial direction. FIG. 5B is a graph showing the change of the tracking error signal by the defocus. FIG. 5C is a graph showing the change of the tracking error signal by the duty of the disc. FIG. 6 is a graph showing the tracking error signal characteristics in the case the pit depth of the disc is $\lambda/6n$. Among them, FIG. 6A is a graph showing the change of the tracking error signal by the lens shift in the radial direction. FIG. 6B is a graph showing the change of the tracking error signal by the defocus. FIG. 6C is a graph showing the change of the tracking error signal by the duty of the disc. FIG. 7 is a graph showing the tracking error signal characteristics in the case the pit depth of the disc is $\lambda/8n$. Among them, FIG. 7A is a graph showing the change of the tracking error signal by the lens shift in the radial direction. FIG. 7B is a graph showing the change of the tracking error signal by the defocus. FIG. 7C is a graph showing the change of the tracking error signal by the duty of the disc. FIG. 8 is a schematic configuration diagram of a conventional optical

apparatus. FIGS. 9A and 9B are diagrams for explaining the tracking servo by the push-pull method. FIG. 10 is a diagram for explaining the problems in the push-pull method. Among them, FIG. 10A is a diagram showing the offset in the case the lens is shifted, and FIG. 10B is a diagram showing the offset in the case the lens is tilted. FIG. 11 is a graph showing the influence of the lens shift to the tracking error signal in the conventional push-pull method. FIG. 12 is a diagram for explaining the tracking servo by the three spot method. FIG. 13 is a diagram for explaining the tracking servo by the phase difference detection method. FIG. 14 is a graph showing the relationship between the tracking error signal and the defocus amount in the CPP method.

BEST MODE FOR CARRYING OUT THE INVENTION

The present invention provides an optical apparatus comprising a semiconductor laser, a light emitting part having a reflecting surface for reflecting a light outputted from the semiconductor laser, a light receiving part comprising a light detecting element, and a converging means for converging and directing the outputted light from the light emitting part onto an optical recording medium, and further, converging the returned light reflected from the optical recording medium, wherein the light emitting part and the light receiving part are formed on the same semiconductor substrate, the confocus of the converging means is set on the semiconductor substrate, the

light detecting element is positioned and formed at a position in the convergence limit of the returned light in the vicinity of the confocal position by the converging means by the returned light and the returned light generated by the end part of the pit or the region, wherein information is recorded, of the optical recording medium is received and detected by the light detecting element so as to detect the tracking error signal.

An embodiment of an optical apparatus according to the present invention is shown in FIGS. 1 to 3.

As shown in FIG. 1, the optical apparatus 10 is the case adopted in an optical pickup having, for example, an optical disc 2 with a recording pit as the optical recording medium at the portion to be irradiated so that a laser light is directed to the optical disc 2 for reading out the record.

Moreover, FIG. 2 is an enlarged perspective view of the optical apparatus, and FIG. 3 is a plan view, respectively.

As shown in FIG. 1, the optical apparatus 10 comprises an optical semiconductor element 7 with a semiconductor laser LD formed, and an objective lens 3 as a converging means for converging and directing the outputted light L_F from the semiconductor laser LD onto the optical disc 2 as a portion to be irradiated.

Moreover, the objective lens 3 is provided such that the returned light L_R of the outputted light L_F reflected by the optical disc 2 is converged and directed to the optical

semiconductor element 7.

That is, the optical apparatus 10 has the so-called CLC (confocal laser coupler) configuration, wherein the light emitting part is disposed at the confocal position of the converging means, such as a lens, and the returned light reflected by the portion to be irradiated is converged and directed in the vicinity of the confocal position having the light emitting part.

At the time, the returned light L_R is converged to the vicinity of the light diffraction limit (that is, the diffraction limit of the lens) by the objective lens 3. The light diffraction limit is described as 1.22 λ/N. A. with the wavelength of the outputted light L_F from the semiconductor laser LD as λ, and the numerical aperture of the objective lens 3 as N. A.

As shown in FIG. 2, the optical semiconductor element 7 comprises a semiconductor laser LD as the light emitting part, having a resonator length direction in the direction along the substrate surface as well as parallel to the tangential direction T of the optical disc 2, a reflecting surface M formed as an oblique surface facing to one of the outputting end faces of the semiconductor laser LD for reflecting the outputted light L_F from the semiconductor laser LD, and a light detecting element comprising two photo diodes PD1, PD2 as the light

receiving part.

Moreover, on the upper surface of the optical semiconductor element 7, as shown in the plan view of FIG. 3, the above-mentioned two photo diodes PD1, PD2 included in the light receiving part are formed in the region in the light diffraction limit of the returned light L_R.

The photo diodes PD1, PD2 are divided in two by the dividing line in the tangential direction T.

Moreover, the optical semiconductor element 7 is disposed such that the pit row direction of the optical disc 2, that is, the tangential direction T of the disc and the stripe direction of the semiconductor laser LD coincide.

Here, for example, in the case the wavelength of the semiconductor laser LD is 780 nm, the semiconductor substrate 1 is formed with GaAs. Then, by forming the reflecting surface M with a {111} crystal plane, a reflecting surface with a 54.7° angle with respect to the substrate surface can be provided.

The optical semiconductor element 7 can be produced by a series of a semiconductor production step according to the so-called wafer batch process, wherein a plurality of the optical semiconductor elements 7 are formed simultaneously on a wafer.

By forming the optical semiconductor element 7 in the semiconductor production step, the optical apparatus 10, such as an optical pickup with a simple adjustment and little aging change, capable of utilizing the advantages of the confocal

optical systems, can be provided.

Moreover, since the reflecting surface M can be formed in the planer state, it can be formed easily.

In the optical apparatus 10, the outputted light L_F reflected by the reflecting surface M is converged and directed by the objective lens 3 to the optical disc 2, and the returned light L_R of the outputted light L_F reflected by the optical disc is converged again by the objective lens 3 so as to be directed to the optical semiconductor element 7.

Furthermore, as shown in FIG. 2, the returned light L_R is in focus (confocus) in the peripheral of the reflecting surface M of the optical semiconductor element 7 so as to be received and detected by the two photo diodes PD1, PD2 formed in the vicinity of the confocus.

Furthermore, since the two photo diodes PD1, PD2 are formed in the light diffraction limit of the returned light L_R, the band limit is applied in terms of the space.

For above-mentioned formation of the two photo diodes PD1, PD2 in the light diffraction limit can be realized specifically by having the area range of two photo detectors within a circle substantially corresponding to the Airy disc size.

The Airy disc size here denotes the size of the returned light corresponding to a circle having a diameter ϕ on

the optical disc, represented by the following formula.

$$\phi = 1.22 \times \lambda/NA$$

The band limit in terms of the space serves for uniformly eliminating the adverse effect to the signal due to extreme reduction of the zero-order diffracted light compared with the ± first-order diffracted light in the region outside the light diffraction limit so as to generate a high wavelength component, or the like, and it is particularly effective in the case the lens shift is generated.

Furthermore, since the half-split photo diodes PD1, PD2 are in the vicinity of the confocal position, even in the case the lens shift is generated, change of the detected signal can be restrained to the extremely small level principally.

However, the push-pull signal, that is, the CPP signal in the half-split photo diodes PD1, PD2 disposed in the vicinity of the confocal position as mentioned above has a disadvantage in that it is easily influenced by the disc parameters such as the displacement of the focus direction in the focal depth and the pit depth.

Here, the push-pull signal to be detected on the half-split photo diodes PD1, PD2 disposed in the vicinity of the confocal position is discussed from the pit formed on the optical disc 2 as a recording signal, or a one corresponding thereto.

The basic signal detection mechanism corresponds to the

above-mentioned proposed optical apparatus.

In the prior proposed optical apparatus, the semiconductor structure is disposed at the confocal position so that the returned light is reflected by the semiconductor structure so as to be propagated to a photo diode away from the confocal position by about several tens to 100 μm for receipt and detection.

In contrast, in the optical apparatus 10 of this embodiment, the returned light L_R is received and detected by the half-split photo diodes disposed in the vicinity of the confocal position.

The difference signal component obtained from the subtraction between the detected signals of the half-split photo diodes PD1, PD2 is substantially same in the case of the present embodiment and the case of the prior proposed optical apparatus configuration, and only the amplitude, or the like, is slightly different.

This is because the state of the superimposition of the diffracted lights from the pit are different in both cases, but in contrast, the components of the diffracted lights as the constituents are the same.

Therefore, in the optical apparatus 10 according to this embodiment, unnecessary signals are eliminated by limiting the size of the half-split photo diodes PD1, PD2 by, for example, the above-mentioned methods into the light diffraction limit in

terms of the space.

Furthermore, in the optical apparatus 10 of this embodiment, the tracking error signal is received and detected, using the returned light L_R at the pit edge of the optical disc 2.

Here, the pit edge denotes the change point from the mark to the space, or from the space to the mark in the case of recording a binarized digital signal onto an optical recording medium as a mark or a space.

According to the calculation described later with respect to a signal obtained from the photo diodes PD1, PD2 by directing the returned light L_R to the photo diodes PD1, PD2, various signals such as the tracking error signal and the RF (higher harmonic) signal can be generated, respectively.

That is, generation of the tracking error signal in the optical apparatus 10 can be realized, for example, as in the following formula (2), with the tracking error signal as STE, the light receiving amounts of the photo diodes PD1, PD2, each as IPD1, IPD2.

$$STE = (IPD1 - IPD2) \text{ *edge 1 (or *edge 2)} \quad (2)$$

*edge 1 or *edge 2 in the formula (2) each denotes detection of the pit edge at rising and falling.

As described later, by using detection at either of the rising pit edge or the falling pit edge, a preferable tracking error signal can be obtained.

Here, with reference to FIG. 4, detection at the pit edge will be explained.

FIG. 4A shows the detecting position of the rising pit edge (1), and FIG. 4B shows the detecting position of the falling pit edge (2), respectively. In the figures, the arrow in the vertical direction denotes the moving direction of the recording medium, and the arrow in the horizontal direction denotes the detecting position.

According to movement of the beam spot S, detection can be executed at each pit edge (1) or pit edge (2).

According to the calculation of the formula (2), that is, by receiving the returned light L_R at the pit edge of either rising or falling and executing the calculation of the formula (2), the tracking error signal STE has a sufficient margin with respect to the lens shift in the radial direction R as later described.

The RF signal can be detected by the addition signal of the two photo diodes PD1, PD2.

Moreover, the focus error signal can be detected, using a well known detection method by receiving and detecting the returned light L_R after being separated halfway.

Furthermore, for the detection of the pit edge, for example, the conventionally used methods, such as the phase difference detection method can be used.

Since the half-split photo diodes PD1 ,PD2 are limited

in terms of the space, the excessive diffracted light is not received as mentioned above, and thus a preferable tracking error signal can be obtained only by detecting the returned light at the pit edge of either falling or rising.

Since the half-split photo diodes PD1, PD2 are formed toward one side (right side in the figure) in the tangential direction T with respect to the optical axis of the returned light L_R as shown in the plan view of FIG. 3, although either one of the rising pit edge or the falling pit edge is more adequate for obtaining a preferable tracking error signal in some cases, basically the tracking error can be detected by using either of the pit edges.

According to the design condition, or the like, of the optical apparatus 10, by which pit edge the signal is detected can be determined.

As mentioned above, since the half-split photo diodes PD1, PD2 are formed in the diffraction limit region of the returned light L_R in the optical apparatus 10 according to this embodiment, the offset (generated in the case of the pit depth other than $\lambda/4n$) in the tracking error signal in the case the lens shift is generated outside the diffraction limit region can be eliminated so that the influence of the lens shift to the tracking error signal can be made extremely small.

Moreover, since the tracking error signal is detected by receiving the returned light L_R by the pit edge of the optical

disc 2 by the half-split photo diodes PD1, PD2, the effect of strengthening the tracking error signal itself can be obtained. Accordingly, the influence to the CPP signal according to the focus state in the focal depth can be made smaller relatively. Therefore, the influence by the defocus observed in the CPP signal (see FIG. 13) can be lowered, and thereby, a preferable tracking error signal can be obtained.

Specifically, as shown in FIG. 2, the tracking error signal can be obtained by binarizing the RF signal, which is the addition signal of the signal of PD1 and the signal of PD2, and sampling the difference signal of the PD1 signal and the PD2 signal at the rising edge or the falling edge.

Furthermore, the reproducing apparatus for an optical recording medium can be realized by applying the tracking error signal accordingly obtained to the above-mentioned actuator coil via a power amplifier for driving an actuator coil, and executing the servo in the tracking direction.

The power amplifier may be provided with a phase compensating circuit according to the actuator characteristics.

Next, in order to show the effectiveness of the optical apparatus of the present invention, the tracking error signal is calculated for the optical apparatus 10 shown in FIGS. 1 to 3.

First, the calculation results of the tracking error signal in consideration of the characteristics including the radial direction lens shift characteristics, the focus

dependency, and the duty dependency with respect to an optical disc having a $\lambda/4n$ pit depth are shown in FIG. 5.

FIG. 5A shows the change of the tracking error signal by the lens shift LS of the disc in the radial direction R, FIG. 5B shows the change of the tracking error signal by the displacement of the focus (hereinafter referred to as defocus) to the extent of the focal depth with a 65% disc pit duty, and FIG. 5C shows the change of the tracking error signal by the change of the disc pit duty.

FIGS. 5A to 5C show the calculation results in the case of detection at the position with the best modulation degree in the vicinity of the rising pit edge.

Similarly, the calculation results for an optical disc having a $\lambda/6n$ pit depth are shown in FIG. 6 (FIGS. 6A, 6B, 6C), and the calculation results for an optical disc having a $\lambda/8$ pit depth are shown in FIG. 7 (FIGS. 7A, 7B, 7C), respectively.

From FIGS. 5 to 7, it is learned that a preferable S-shaped tracking error signal can be obtained with respect to the optical discs with any pit depth with little influence to the tracking error signal even if there is a lens shift in the disc radial direction or a defocus.

Moreover, it is also learned that a preferable tracking error signal can be obtained regardless of the disc duty value.

It is further learned that the tilt of the tracking

error signal is influenced by the sign of the defocus so that the tilt of the tracking error signal is enlarged as the defocus is in the + direction in the case of a pit depth other than $\lambda/4n$.

Moreover, since the tracking error signal can be detected for the discs with any pit depth as mentioned above, if the optical system is adopted in an optical apparatus using a red material in the semiconductor laser LD, for example, it can be used, for example, as the optical pickup common to the DVD-ROM and the DVD-RAM.

According to the above-mentioned optical apparatus 10 of the present embodiment, owing to the characteristics in detection of the tracking error signal, the following advantages can be provided.

(1) The tracking servo can be applied to the optical discs with any pit depth or groove depth.

(2) since the confocal optical system is utilized, the tracking error signal can be durable with respect to the lens shift or the parameter change of the optical system for the optical discs of any pit depth or groove depth.

(3) Since the optical parts added for detection of the tracking error signal are not required, a simple optical system with a reduced number of parts can be provided. Therefore, the assembly step and the adjustment step can be simplified.

(4) According to the cutback of the number of parts and

the simplification of the steps, the production cost can be reduced.

(5) Since optical parts to be added is not required so that the optical loss is small, a low power consumption can be realized.

(6) Since a small size and a light weight can be realized, the improvement of the response speed can be achieved thereby.

(7) Recording and reproduction of an optical disc having a higher linear speed is enabled with the conventional power consumption.

(8) Since the semiconductor laser and the light detecting elements are formed on the same semiconductor substrate, the aging change after assembly is small.

Although the optical disc 2 having a pit has been explained as the optical recording medium in the above-mentioned embodiment, the present invention can be adopted to an optical apparatus using an optical recording medium having another recording region corresponding to the pit.

For example, in an optical apparatus using a phase change type optical disc, utilizing the phase change record in recording a mark or a space representing the digitized binary state, the end part of the region, wherein information is recorded by the phase change is used as the one corresponding to the above-mentioned pit edge so that the returned light

generated by the end part is received and detected by the light detecting element so as to obtain a tracking error signal.

That is, a returned light with a changeable reflection factor with respect to the light outputted from the light emitting part, generated by the vicinity of the boundary (edge part) of the region of the optical recording medium, wherein information is recorded, can be used.

The optical apparatus of the present invention is not limited to the above-mentioned embodiment, but various other configuration can be included within the scope of the gist of the present invention.

INDUSTRIAL APPLICABILITY

According to the above-mentioned optical apparatus of the present invention, since the light detecting element is positioned and formed at a position in the convergence limit of the returned light in the vicinity of the confocal position so that the receivable returned light is applied with the band limit, the excessive diffracted light generated by the lens shift, or the like, is not received, and thus the influence of the change of the converging means, such as an objective lens with respect to the tracking error signal can be made smaller.

Furthermore, by detecting the tracking error signal by receiving and detecting the returned light generated by the end part of the pit or the region with the information recorded, the tracking error signal, which can hardly be influenced by the

defocus, or the like, can be obtained.

Therefore, according to the optical apparatus of the present invention, a stable tracking error signal can be obtained.

Moreover, the tracking error signal can be detected for the optical recording media with any pit depth or groove depth.

Furthermore, since the tracking error signal is detected by the light detecting element and thus optical parts to be added for detection of a signal are not required, a simple optical system with a reduced number of parts can be provided. Therefore, the adjusting step can be simplified.

Accordingly, a low production cost of the optical apparatus can be achieved as well as the light amount loss can be reduced so as to achieve a low power consumption.

Moreover, in the case a confocal optical system is adopted, since the light emitting part and the light detecting element are formed on the same semiconductor substrate, the number of parts can be reduced so as to achieve a small size and a light weight of the optical apparatus. Furthermore, the response speed is improved so as to reduce the aging change after assembly of the optical apparatus.

In the case a confocal optical system is adopted, since it can be formed in the semiconductor process step, production with a high reproductivity and a good yield can be realized.

31 MAR 2003

CLAIMS

1. An optical pickup characterized in comprising:

a semiconductor laser,

a reflecting means for guiding an outputted light from the semiconductor laser to an optical disc,

an objective lens for collecting the outputted light reflected by the reflecting means on the optical disc,

a light receiving means divided at least in two, for receiving only the returned light in the Airy disc size from the optical disc, and

a tracking error signal generating means for generating a tracking error signal based on the reflected light from the end part of at least one of a mark and a space on the optical disc detected by the light receiving means.

2. The optical pickup according to claim 1, characterized in that the semiconductor laser, the reflecting means and the light receiving means are formed on the same semiconductor substrate.

3. The optical pickup according to claim 1, characterized in that the mark or the space is formed by a pit.

4. The optical pickup according to claim 1, characterized in that the mark or the space is formed by the phase change.

5. An optical reproducing apparatus for reproducing a signal from an optical disc medium with a mark or a space formed on the medium, characterized in comprising:

a semiconductor laser,

a reflecting means for guiding an outputted light from the semiconductor laser to an optical disc,

an objective lens for collecting the outputted light reflected by the reflecting means on the optical disc,

a light receiving means divided at least in two, for receiving only the returned light in the Airy disc size from the optical disc,

a tracking error signal generating means for generating a tracking error signal based on the reflected light from the end part of at least one of a mark and a space on the optical disc detected by the light receiving means, and

a driving means for driving the objective lens in the tracking direction based on the tracking error signal.

6. The optical reproducing apparatus according to claim 5, characterized in that the mark or the space is formed by a pit.

7. The optical reproducing apparatus according to claim 5, characterized in that the mark or the space is formed by the phase change.

8. The optical reproducing apparatus according to claim 5, characterized in that the tracking error signal generating means comprises:

at least two light receiving means for receiving the returned light,

a difference signal detecting means for detecting a difference signal from the two light receiving means,

an addition signal detecting means for detecting an addition signal from the two light receiving means,

a binarizing means for obtaining a binary signal from the addition signal,

an edge detecting means for detecting the edge of a rising signal or a falling signal from the binary signal, and

a sample holding means for sample holding the difference signal based on the detection timing of the edge.