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OPTICAL PICKUP DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical pickup device, and more particularly, to an optical pickup device which can record/reproduce information at high density by employing a solid immersion lens (SIL).

2. Description of the Related Art

Referring to FIG. 1 showing a conventional optical pickup device for recording/reproducing information at high density, light emitted from a light module 1 is incident onto a SIL 10 by a reflection member 5 and is focused by the SIL 10 to form a beam spot on a recording plane of a disk 19.

The light module 1 includes a light source, means for converting a traveling path of incident light and a photodetector for receiving the light reflected from the recording plane of the disk 19.

The reflection member 5 makes fine changes to the incidence angle of incident light so as to perform minute tracking by moving the position of the beam spot formed on the disk 19 little by little.

The SIL 10 is supported to a slider 15 lifting from the disk 19 in the range of several tens of nanometers by an air bearing effect when the disk 19 rotates. An incident surface 10a of the SIL 10 is curved to thus focus incident light whereas a surface 10b of the SIL 10, facing the disk 19, is planar.

The size of the beam spot formed on the disk 19 can be substantially represented as:

$$\frac{\lambda}{2NA} \qquad (1)$$

where λ is the wavelength of light emitted from a light source, and NA is the numerical aperture of the light focusing means. Thus, in order to reduce the size of

a beam spot for high-density recording/reproduction, the wavelength of light must be reduced or the numerical aperture must be increased. However, the maximum numerical aperture theoretically available in air is approximately 1.

Since the surface 10b of the SIL 10 is very close to the disk 19, when the refractive index of the SIL 10 is n_{SIL}, the wavelength of light in the SIL 10 and the disk 19 equals $\frac{\lambda}{n_{SIL}}$, which is compared to equation (1), so that the numerical aperture of the SIL 10 with respect to the wavelength of light emitted from a light source, i.e., λ, is greater than or equal to 1, thereby reducing the size of the beam spot. Here, the SIL 10 has a refractive index which is substantially the same as that of a protective film for protecting the recording plane of the disk 19.

As described above, if the SIL 10 is employed, since the distance between the SIL 10 and the disk 19 is maintained in the range of several tens of nanometers due to an air bearing effect while the disk 19 rotates, the beam spot is not exposed to the air and thus the numerical aperture is greater than or equal to 1, thereby reducing the size of the beam spot.

However, as described above, the SIL 10 having one curved surface cannot remove both spherical aberration and coma aberration. In other words, if the incident surface 10a of the SIL 10 is elliptically curved, as shown in FIG. 2, the spherical aberration can be removed. However, the elliptically curved surface 10a from which the spherical aberration is removed does not satisfy Abbe's sine condition so that it becomes very sensitive to the tilt of incident light. Thus, the coma aberration is generated at the light S1 which is incident obliquely and is focused by the SIL 10, as shown in FIGs. 2 and 3. If the incident surface 10a of the SIL 10 is curved hemispherically, the coma aberration is removed but defocusing and spherical aberration still exist.

As described above, since an optical recording/reproducing apparatus employing the SIL 10 is very sensitive to tilt to thus generate coma aberration, it is very difficult to fabricate the same.

Conventionally, as shown in FIG. 4, an optical pickup device having a focusing objective lens 7 separately installed between the light module 1 and the SIL

10 has been proposed. In this case, spherical aberration and coma aberration are removed by the objective lens 7 and the SIL 10 serves to increase the numerical aperture. However, since the optical pickup device having the aforementioned configuration must employ two lenses, that is, the objective lens 7 and the SIL 10, the system becomes complex and bulky.

SUMMARY OF THE INVENTION

To solve the above problems, it is an objective of the present invention to provide an optical pickup device which is not sensitive to a tilt of incident light and has a high numerical aperture so as to be capable of high-density recording/reproduction, while being simple and compact by employing a single lens.

Accordingly, to achieve the above objective, there is provided an optical pickup device including a light module for emitting light and receiving light reflected from a recording medium, and a solid immersion lens (SIL) member disposed in an optical path between the light module and the recording medium, and having a planar surface facing the recording medium and a plurality of elliptically curved surfaces having different radii of curvature so as to be symmetrical with respect to a central axis on its incident surface to which the light is incident from the light module, for focusing the incident light to form a beam spot on a recording plane of the recording medium.

The radius of curvature of an ellipse positioned farther than the central axis is larger than that of an ellipse positioned nearer than the central axis.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objective and advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings in which:

FIG. 1 is a schematic diagram illustrating a conventional optical pickup device capable of high-density recording/reproduction;

FIG. 2 is a diagram illustrating a solid immersion lens (SIL) employed in the optical pickup device shown in FIG. 1;

FIG. 3 is a diagram schematically illustrating a beam spot focused by the SIL employed in the optical pickup device shown in FIG. 1;

FIG. 4 is a schematic diagram illustrating another example of a conventional optical pickup device capable of high-density recording/reproduction;

FIG. 5 is a schematic diagram illustrating an optical pickup device capable of high-density recording/reproduction according to an embodiment of the present invention;

FIG. 6 is a diagram illustrating a solid immersion lens (SIL) employed in the optical pickup device shown in FIG. 5;

FIG. 7 is a diagram schematically illustrating a beam spot focused by the SIL employed in the optical pickup device shown in FIG. 5; and

FIG. 8 is a schematic diagram illustrating an optical pickup device capable of high-density recording/reproduction according to another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 5, an optical pickup device according to an embodiment of the present invention includes a light module 21 for emitting light and receiving light reflected from a recording medium 19, and a solid immersion lens (SIL) member 30 disposed in an optical path between the light module 21 and the recording medium 19.

The light module 21 can be a light module employed in a conventional optical pickup device and includes a light source (not shown), means (not shown) for converting the traveling path of incident light, and a photodetector (not shown) for receiving light reflected from the recording medium 19 and having passed through the optical path converting means. The optical path converting means may be a beam splitter or a hologram device.

The SIL member 30 focuses incident light and forms a beam spot on the recording plane of the recording medium 19. An incident surface 33 of the SIL member 30 is formed to be curved for focusing incident light from the light module 21 to land on the recording plane of the recording medium 19. Also, another surface 31 facing the recording medium 19 is made plane.

In this embodiment, the incident surface 33, as shown in FIG. 6, has a plurality of elliptically curved surfaces 33a and 33b having different radii of curvature so as to be symmetrical with respect to a central axis (c). Preferably, the radii of curvature of the elliptically curved surfaces 33a and 33b become larger as the central axis (c) gets farther.

The SIL member 30 having the elliptically curved surface as described above generates little spherical aberration and offsets coma aberration due to a tilt of incident light. Therefore, as shown in FIG. 6, the light which is incident obliquely with respect to the SIL member 30 is focused to form a beam spot S2, as shown in FIG. 7.

The SIL member 30 is supported by a slider 35, as shown in FIG. 5. The SIL member 30 and the slider 35 are lifted slightly from the recording medium 19 by an air bearing effect when the disk-shaped recording medium 19 rotates. The SIL member 30 has substantially the same refractive index as that of a protective film for protecting the recording plane of the recording medium 19, and the principle of increasing the numerical aperture by employing the SIL member 30 has been described above with reference to FIG. 1 and an explanation thereof will be omitted.

Preferably, a reflection member 25 for adjusting a tilt of incident light is additionally provided on an optical path between the light module 21 and the SIL member 30. An incidence angle of light incident onto the SIL member 30 can be changed minutely by rotating the reflection member 25. Thus, minute tracking can be performed by changing the position of the beam spot formed on the recording medium 19 little by little.

According to the present invention, by employing the SIL member 30 having a plurality of elliptically curved surfaces, occurrence of coma aberration can be suppressed by about 1/3, compared to the optical pickup device employing a conventional SIL (10 of FIG. 1).

Referring to FIG. 8, an optical pickup device according to another embodiment of the present invention further includes an optical fiber 40 installed on an optical path between the light module 21 and the SIL member 30, for transmitting light. The optical fiber 40 is a channel for transmitting light from the light module 21 to the SIL member 30 and from the SIL member 30 to the light module 21. By

providing the optical fiber 40, fabrication of an optical recording/reproducing apparatus is facilitated and minute tracking area can be widened.

Since the optical pickup device according to the present invention employs a single SIL member having a plurality of elliptically curved surfaces, the overall device is simplified and compact. Also, the optical pickup device is considerably less affected by coma aberration so that it is not sensitive to a tilt of incident light and minute tracking area is increased. Also, since the numeral aperture is greater than or equal to 1, the size of a beam spot can be reduced, thereby enabling high-density recording/reproduction of an information signal.

What is claimed is:

1. An optical pickup device comprising:

a light module for emitting light and receiving light reflected from a recording medium; and

a solid immersion lens (SIL) member disposed in an optical path between the light module and the recording medium, and having a planar surface facing the recording medium and a plurality of elliptically curved surfaces having different radii of curvature so as to be symmetrical with respect to a central axis on its incident surface to which the light is incident from the light module, for focusing the incident light to form a beam spot on a recording plane of the recording medium.

2. The optical pickup device according to claim 1, wherein the radius of curvature of an ellipse positioned farther than the central axis is larger than that of an ellipse positioned nearer than the central axis.

3. The optical pickup device according to claim 1, further comprising a reflection member installed on the optical path between the light module and the SIL member, for adjusting a tilt of incident light.

4. The optical pickup device according to claim 1, further comprising an optical fiber installed on the optical path between the light module and the SIL member, for transmitting light therebetween.