

TITLE OF THE INVENTION

Inspection Device for optical Pickup and Method for Detecting Sensitivity of Focussing Actuator

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an inspection device for detecting the sensitivity of a focussing actuator and a method for detecting the sensitivity of the focussing actuator.

Description of the Related Art

There has hitherto been known an inspection device for an optical pickup used in an optical disc drive. The inspection device for an optical pickup is used in, for example, an optical pickup shipment inspection or acceptance inspection and is conducted for inspecting whether or not the optical pickup meets the prescribed specifications.

Among inspection items for the inspection device for an optical pickup, there is an inspection item of detecting the sensitivity of a so-called focussing actuator of an optical pickup.

An optical disc drive performs focussing servo control so that the laser light radiated from the optical pickup will form a minimum spot on a recording track. For example, the optical disc drive detects the reflected light from the optical disc by an optical pickup and converts the detected reflected light by a photoelectric converter into electrical signals from which focussing error signals are generated. The optical

disc drive drives the focussing actuator based on the focussing error signals to control the movement of the objective lens of the optical pickup so that the focussing error signals will be reduced to zero.

In the conventional inspection device for an optical pickup, the dc or ac driving voltage is applied from outside to the focussing actuator and the displacement of the objective lens at this time is detected to detect the sensitivity of the focussing actuator.

Meanwhile, in a conventional inspection device for an optical pickup, the displacement of the objective lens needs to be detected in a contact-free manner, so that the objective lens displacement needs to be detected using an external device such as a laser Doppler displacement meter to render facilitated inspection impossible.

Moreover, if a laser Doppler displacement meter is used, a reflective sheet for reflecting the laser light radiated from the laser Doppler displacement meter needs to be stuck to the objective lens, again to render it impossible to perform facilitated inspection.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an inspection device for an optical pickup and a method for detecting the sensitivity of the focussing actuator whereby the sensitivity of the focussing actuator can be measured without employing an external measurement device.

In one aspect, the present invention provides an inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by an optical

pickup including first light reflecting means provided facing an objective lens so as to be in a perpendicular state with respect to the direction of the optical axis of the laser light radiated from the optical pickup, the first light reflecting means having a reflecting surface for reflecting the laser light in the direction of the optical axis of the laser light, second light reflecting means provided facing the objective lens at a distance d in the direction of the optical axis from the first light reflecting means parallel thereto, the second light reflecting means having a reflecting surface for reflecting the laser light, radiated from the optical pickup, in a direction of the optical axis of the laser light, the second light reflecting means being offset in a parallel state to the first light reflecting means so that the second light reflecting means is not overlapped with the first light reflecting means with respect to the laser light, focussing servo control means for applying a focussing actuator driving voltage derived from the reflected light from the first or second light reflecting means to the focussing actuator to cause movement of the objective lens to bring the focussing point of the laser light converged by the objective lens into coincidence with the first or second light reflecting means, position control means for controlling the position of the optical pickup facing the first or second light reflecting means by displacing the optical pickup in a direction perpendicular to the optical axis direction so that the laser light converged by the objective lens will be focussed from the first light reflecting means to the second light reflecting means or from the second light reflecting means to the first light reflecting means, and calculating means for calculating the sensitivity of the

focussing actuator from a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the first light reflecting means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the second light reflecting means and the distance d .

In the inspection apparatus, the optical pickup is displaced in a direction perpendicular to the optical axis direction to control the position of the optical pickup facing the first or second light reflecting means so that the focussing point of the laser light converged by the objective lens will be from the first light reflecting means on the second light reflecting means or vice versa. The sensitivity of the focussing actuator is controlled based on a focussing actuator driving voltage derived from the reflected laser light illuminated on the first light reflecting means, a focussing actuator driving voltage derived from the reflected laser light illuminated on the second light reflecting means and on the distance d .

In another aspect, the present invention provides an inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by the optical pickup including light reflecting means provided facing an objective lens in an inclined state at a pre-set angle along the direction of movement of the optical pickup from a state in which the light reflecting means is inclined at a right angle relative to the optical axis direction of the laser light radiated from the optical pickup, the light reflecting means including a first light reflecting portion provided in a reflecting surface reflecting the laser light along the optical axis direction of the laser light and

a second light reflecting portion provided in the reflecting surface, the second light reflecting portion being offset in a direction perpendicular to the optical axis so that it is not overlapped with the first light reflecting portion with respect to the laser light, the second light reflecting portion being positioned at a distance d along the optical axis direction from the first light reflecting portion, focussing servo control means for bringing the focussing point of the laser light converged by the objective lens into coincidence with the first or second light reflecting portion by displacing the objective lens by applying a focussing actuator driving voltage derived from the reflected light from the first or second light reflecting portion to the focussing actuator, position control means for controlling the position of the optical pickup facing the first or second light reflecting portion by displacing the optical pickup at right angles to the optical axis direction so that the laser light converged by the objective lens will be focussed from the first light reflecting portion to the second light reflecting portion or vice versa and calculating means for calculating the sensitivity of the focussing actuator from a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the first light reflecting means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the second light reflecting means, and the distance d .

In the inspection apparatus, the optical pickup is displaced in a direction perpendicular to the optical axis direction to control the position of the optical pickup facing the first or second light reflecting means so that the focussing point of the laser

light converged by the objective lens will be from the first light reflecting means on the second light reflecting means or vice versa. The sensitivity of the focussing actuator is controlled based on a focussing actuator driving voltage derived from the reflected laser light illuminated on the first light reflecting means, a focussing actuator driving voltage derived from the reflected laser light illuminated on the second light reflecting means, and on the distance d .

In a still another aspect, the present invention provides an inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by the optical pickup including light reflecting means including a first light reflecting portion provided facing the objective lens so that, by producing deviation in planarity, the first light reflecting portion is inclined at a pre-set angle of inclination from the state of the perpendicular inclined angle with respect to the optical axis direction of the laser light radiated from the optical pickup, the first light reflecting portion being provided in a reflecting surface reflecting the laser light along the optical axis direction of the laser light, and a second light reflecting portion provided in the reflecting surface, the second light reflecting portion being positioned at a distance d along the optical axis direction from the first light reflecting portion so that the second light reflecting portion will be overlapped with the first light reflecting portion with respect to the laser light, focussing servo control means for bringing the focussing point of the laser light converged by the objective lens into coincidence with the first or second light reflecting portion by displacing the objective lens by applying a focussing actuator

driving voltage derived from the reflected light from the first or second light reflecting portion to the focussing actuator, rotation means for rotating the light reflecting means relative to a point of origin for producing the deviation from planarity and calculating means for calculating the sensitivity of the focussing actuator from a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the first light reflecting means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the second light reflecting means and the distance d . The distance d is found by producing deviations in planarity on rotating the light reflecting means.

In this optical pickup inspection apparatus, the light reflecting means is rotated relative to a point of origin for producing deviations in planarity. The sensitivity of the focussing actuator is found based on a focussing actuator driving voltage derived from the reflected laser light illuminated on the first light reflecting portion, a focussing actuator driving voltage derived from the reflected laser light illuminated on the second light reflecting portion and the distance d as found by producing the deviations in planarity on rotating the light reflecting means.

In still another aspect, the present invention provides an inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by an optical pickup including light reflecting means provided facing an objective lens so as to be in a perpendicular state with respect to the direction of the optical axis of the laser light radiated from the optical pickup, the light reflecting means having a

reflecting surface for reflecting the laser light in the direction of the optical axis of the laser light, focussing servo control means for applying a focussing actuator driving voltage derived from the reflected light from the light reflecting means to the focussing actuator to cause movement of the objective lens to bring the focussing point of the laser light converged by the objective lens into coincidence with the first or second light reflecting means, position control means for controlling the position of the light reflecting means relative to the optical pickup along the optical axis direction or the position of the optical pickup relative to the light reflecting means along the optical axis direction, and calculation means for calculating the sensitivity of the focussing actuator based on a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the light reflecting means before the relative position between the optical pickup and the light reflecting means is changed by the position control means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the light reflecting means after the relative position between the optical pickup and the light reflecting means is changed by the position control means, and on the distance d .

In this optical pickup inspection apparatus, the position of the light reflecting means relative to the optical pickup along the optical axis direction or the position of the optical pickup relative to the light reflecting means along the optical axis direction is controlled. The sensitivity of the focussing actuator is found based on a focussing actuator driving voltage derived from the reflected light of the laser light illuminated

on the light reflecting means before the relative position between the optical pickup and the light reflecting means is changed, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on the light reflecting means after the relative position between the optical pickup and the light reflecting means is changed, and on the distance d .

In yet another aspect, the present invention provides an inspection method for a focussing actuator for detecting the sensitivity of the focussing actuator owned by an optical pickup including detecting the sensitivity of the focussing actuator based on a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on a first light reflecting portion having a reflecting surface reflecting the laser light along the direction of the optical axis of the laser light radiated from the optical pickup, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on second light reflecting means removed a distance d from the first light reflecting portion along the optical axis, and on the distance d .

In the inspection device for detecting the sensitivity of a focussing actuator and a method for detecting the sensitivity of the focussing actuator, according to the present invention, the sensitivity of the focussing actuator can be detected easily since the distance between at least two reflecting surfaces on which the laser light converged by the objective lens is focussed is known from the outset.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a block diagram showing an inspection device for an optical pickup

embodying the present invention.

Fig.2 shows a typical photodetector provided in an optical pickup of the optical pickup device under inspection.

Fig.3 shows the relative positions of the optical pickup and a light reflecting portion inclined relative to the optical axis.

Fig.4 shows the relative positions of the optical pickup and the light reflecting portion exhibiting surface offset.

Fig.5 shows the relative position between the optical pickup and the light reflecting portion when the optical pickup or the light reflecting portion is moved.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, preferred embodiments of the present invention will be explained in detail.

An inspection device for an optical pickup, embodying the present invention, inspects characteristics of an optical pickup used in an optical disc drive. This inspection device is used for inspecting the specifications of the optical pickup or investigating into characteristics of the optical pickup and is a tool useful in the shipment inspection or acceptance inspection of the optical pickup. The optical pickup inspection device embodying the present invention is shown in Fig. 1.

Referring to Fig.1, an optical pickup inspection device 1 includes a light reflecting portion 3 formed by two planar plates of a light reflecting material and adapted for reflecting the laser light illuminated from the optical pickup 2, a matrix

circuit 4 fed with an output of a photodetector 2d as later explained and adapted for outputting focussing error signals (FE signals) and playback signals (RF signals), a focussing servo circuit 5 for performing servo control for focussing driving of the light reflecting portion 3 based on an output of the matrix circuit 4, a driver 6 for driving a focussing actuator 2e owned by an optical pickup 2 as later explained and a calculation circuit 7 for finding the sensitivity of the focussing actuator 2e. The optical pickup inspection device 1 also includes a position control circuit 8 for causing relative movement of the optical pickup 2 with respect to the light reflecting portion 3.

The optical pickup 2 is an object of inspection by the present optical pickup inspection device 1. This optical pickup 2 can be attached to or detached from the inspection device 1. The optical pickup 2 includes a laser diode 2a for outputting the laser light by exploiting light emission by recombination of electrons and positive holes produced in a semiconductor crystal, a beam splitter 2b formed by a prism etc having a multi-layered coating film thereon and adapted for separating the laser light into the transmitting light and the reflected light, an objective lens 2c for converging the laser light outputted by the laser diode 2a, and a photodetector 2d for exciting electron-positive hole pairs by light absorption in a semiconductor and for transporting the pairs in an electric field of a depletion layer for recuperation as eclectic current. The optical pickup 2 also includes a focussing actuator 2e for moving the objective lens 2c along the optical axis direction for bringing the focussing point of the laser light converged by the objective lens 2c into coincidence with the reflecting surface

of the light reflecting portion 3.

This optical pickup 2 converges the laser light radiated from the laser diode 2a via the beam splitter 2b and the objective lens 2c to the light reflecting portion 3. The optical pickup 2 forms an image of the reflected light from the light reflecting portion 3 via the objective lens 2c and the beam splitter 2b on the photodetector 2d. The photodetector 2d is the photo-electric transducer as described above and converts the imaged reflected light into electrical signals.

The optical pickup 2 includes plural photodetectors, an example of which is shown in Fig.2.

The optical pickup 2 includes four photodetectors A to D, arrayed in a 2-by-2 matrix configuration, and photodetector E, F for side spot detection on both sides of the photodetector A to D, as shown in Fig.2. These photodetector A to F are used in, for example, an optical pickup of the so-called three-spot system adapted for radiating three laser light beams to the light reflecting portion 3. On the photodetectors A to D is illuminated a main beam as a center light beam in the three-spot system. That is, the reflected light with respect to the light reflecting portion 3 is illuminated on the photodetectors A to D. Also, the photodetectors E, F are provided on both radial sides of the light reflecting portion 3 with respect to the photodetector A to D. The photodetectors are illuminated with side beams in the three-spot system. The photodetectors E, F are illuminated by the light reflected from the track edge of the light reflecting portion 3.

The photodetectors A to F convert the light volumes of the reflected light into signals A to F, respectively. The optical pickup 2 routes these signals A to F to the matrix circuit 4.

The light reflecting portion 3 is made up of a first light reflecting portion 3a and a second light reflecting portion 3b, both being flat-shaped for reflecting the light, as shown in Fig.1. The reflecting surfaces of the first light reflecting portion 3a and the second light reflecting portion 3b are parallel to each other and are separated a distance d in a direction normal to the reflecting surfaces. Also, the first light reflecting portion 3a and the second light reflecting portion 3b are offset from each other in a direction parallel to the respective reflecting surfaces to avoid overlapping of the respective reflecting surfaces. The first light reflecting portion 3a and the second light reflecting portion 3b reflect the laser light radiated from the optical pickup 2 which is an object of inspection of the optical pickup inspection device 1.

The matrix circuit 4 is fed with signals A to F outputted by the photodetectors A to F of the optical pickup 2, and generates FE and RF signals based on these signals A to F. For example, the matrix circuit 4 calculates $(A+C) - (B+D)$, based on signals A to D, to generate FE signals, and routes the generated FE signals to the focussing servo circuit 5. That is, the matrix circuit 4 generates the FE signals based on the astigmatic method, and routes the generated FE signals to the focussing servo circuit 5. Also, the matrix circuit 4 calculates $(A+B+C+D)$ to generate RE signals, which are routed to a signal processing circuit, not shown.

The focussing servo circuit 5 servo-controls the light reflecting portion 3 based on the FE signals. Specifically, the focussing servo circuit 5 drives the focussing actuator 2e, adapted for actuating the objective lens 2c of the optical pickup 2, based on the FE signals, so that the FE signals will be reduced to zero, by way of performing focussing servo control.

The driver 6 generates a focussing actuator driving voltage, adapted for driving the focussing actuator 2e, based on the FE signals routed from the focussing servo circuit 5, and routes the generated focussing actuator driving voltage to the focussing actuator 2e. The driver 6 also routes the generated focussing actuator driving voltage to the calculation circuit 7.

The calculation circuit 7 includes a controller 7a for supplying control signals to a memory 7b and to a calculation processor 7c, a storage unit 7b for holding on memory the focussing actuator driving voltage etc, and the calculation processor 7c for detecting the sensitivity of the focussing actuator based on the focussing actuator driving voltage etc stored in the memory 7b. The calculation circuit 7 calculates the sensitivity of the focussing actuator based on plural focussing actuator driving voltages routed from the driver 6 and the pre-stored distance d between the first light reflecting portion 3a and the second light reflecting portion 3b. The detailed operation of the calculation circuit 7 will be explained subsequently.

The position control circuit 8 displaces the optical pickup 2 in a direction parallel to the reflecting surfaces of the first light reflecting portion 3a and the second

light reflecting portion 3b, that is in a direction normal to the direction of the optical axis of the outgoing laser light, to illuminate the laser light radiated from the optical pickup 2 on the first and second light reflecting portions 3a, 3b. For example, the position control circuit 8 displaces the optical pickup 2 from the laser light illuminating position on the first light reflecting portion 3a in a direction X1 in Fig.1 to set the optical pickup 2 at a laser light illuminating position on the second light reflecting portion 3b. The position control circuit 8 also displaces the optical pickup 2 from the laser light illuminating position on the second light reflecting portion 3b in a direction X2 in Fig.1 to set the optical pickup 2 at a laser light illuminating position on the first light reflecting portion 3a.

Meanwhile, since it suffices if the position control circuit 8 displaces the optical pickup 2 and the first and second light reflecting portions 3a, 3b relative to each other in a direction parallel to the reflecting surface, the first light reflecting portion 3a and the second light reflecting portion 3b may be moved, with the optical pickup 2 remaining fixed.

The optical pickup inspection device 1, having the focussing position accuracy of $\pm 1 \mu\text{m}$, in the case of a CD, has equivalent or even higher focussing position accuracy for e.g., a DVD.

The method of calculating sensitivity of the focussing actuator, employing the above-described optical pickup inspection device 1, is hereinafter explained.

The calculation circuit 7 performs the following processing to calculate the

sensitivity of the focussing actuator:

First, the focussing actuator driving voltage V_1 when the focussing point of the laser light converged on the objective lens 2c is coincident with the reflecting surface of the first light reflecting portion 3a is found.

The position control circuit 8 sets the optical pickup 2 at a position such that the laser light converged by the objective lens 2c can be illuminated on the reflecting surface of the first light reflecting portion 3a.

With the focussing servo loop turned on, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the reflecting surface of the first light reflecting portion 3a.

The matrix circuit 4 generates FE signals for V_1 , based on the reflected light from the reflecting surface of the first light reflecting portion 3a, to route the generated FE signals for V_1 to the focussing servo circuit 5.

The focussing servo circuit 5 generates driver control signals for V_1 , for controlling the driving of the focussing actuator 2e, based on the FE signals for V_1 routed from the matrix circuit 4, to route the generated driver control signals for V_1 to the driver 6. That is, the focussing servo circuit 5 drives the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the reflecting surface of the first light reflecting portion 3a.

The driver 6 generates V_1 , based on the driver control signals for V_1 routed

from the focussing servo circuit 5; to route the generated V1 to the focussing actuator 2e. The driver 6 also routes the generated V1 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 stores the V1 routed from the driver 6 in the memory 7b.

The position control circuit 8 moves the optical pickup 2 from the laser light illuminating position for the first light reflecting portion 3a in the direction indicated by arrow X1 in Fig.1 to set the optical pickup 2 at the laser light illuminating position for the second light reflecting portion 3b.

The focussing actuator driving voltage V2, when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the reflecting surface of the second light reflecting portion 3b then is found.

With the focussing servo loop again turned on, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the reflecting surface of the second light reflecting portion 3b.

The matrix circuit 4 generates FE signals for V2, based on the reflected light form the reflecting surface of the second light reflecting portion 3b, to route the generated FE signals for V2 to the focussing servo circuit 5.

The focussing servo circuit 5 generates driver control signals for V2, for controlling the driving of the focussing actuator 2e, based on the FE signals for V2 routed form the matrix circuit 4, to route the generated driver control signals for V2 to the driver 6. That is, the focussing servo circuit 5 drives the objective lens 2c by

driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the reflecting surface of the first light reflecting portion 3a.

The driver 6 generates V2, based on the driver control signals for V2 routed from the focussing servo circuit 5, to route the generated V2 to the focussing actuator 2e. The driver 6 also routes the generated V2 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 stores the V2 routed from the driver 6 in the memory 7b.

The memory 7b holds on memory the distance d between the first light reflecting portion 3a and the second light reflecting portion 3b, having parallel reflecting surfaces, one of which is separated in a perpendicular direction from the other.

Based on the distance d, V1 and V2, stored in the memory 7b, the calculation circuit 7 performs the following processing to calculate the sensitivity of the focussing actuator:

Specifically, the controller 7a acquires the distance d, V1 and V2 from the memory 7b to route the acquired distance d, V1 and V2 to the calculation processor 7c, which then calculates the sensitivity S1 of the focussing actuator when the distance d between the optical pickup 2 and the light reflecting portion 3 is changed, in accordance with the following equation (1):

$$S1 = d/(V2 - V1)$$

...(1).

Meanwhile, the sensitivity S1 of the focussing actuator in this case is the sensitivity of the focussing actuator when the focussing point of the laser light converged by the objective lens 2c is moved from the reflecting surface of the first light reflecting portion 3a to the reflecting surface of the second light reflecting portion 3b, that is when the optical pickup 2 is separated a distance d from the light reflecting surface of the light reflecting portion 3.

The driver 6 then applies to the focussing actuator 2e a voltage of an opposite polarity to that when finding S1 to find the focussing actuator driving voltages V4 and V3 on the first light reflecting portion 3a and the second light reflecting portion 3b for the voltage of the opposite polarity in the same manner as when finding S1. Based on this focussing actuator driving voltages V4 and V3, thus found, the focussing actuator sensitivity S2 is found by the same method as that used in finding S1.

The reason the focussing actuator sensitivity when applying the voltage of the opposite polarity is found is that the objective lens 2c driven by the focussing actuator 2e is also moved in the reverse direction due to application of the opposite polarity voltage, and that the focussing actuator sensitivity on application of the voltage of the same polarity differs from that on application of the voltage of the opposite polarity.

It is noted however that the sequence of finding the focussing actuator driving voltage and the equation used for calculating the sensitivity of the focussing actuator differ from those in finding S1 described above.

First, the focussing actuator driving voltage $V3$ when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the reflecting surface of the second light reflecting portion 3b is found.

The position control circuit 8 then moves the optical pickup 2 from the laser light illuminating position for the second light reflecting portion 3b in the direction indicated by arrow X2 in Fig. 1 to set the optical pickup 2 at the laser light illuminating position for the first light reflecting portion 3a.

The focussing actuator driving voltage $V4$ when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the reflecting surface of the first light reflecting portion 3a then is found.

Finally, the calculation circuit 7 calculates the sensitivity $S2$ of the focussing actuator when the distance d between the optical pickup 2 and the light reflecting portion 3 is changed, from the values $V3$ and $V4$, as found by these methods, and the pre-stored distance d , in accordance with the following equation(2):

$$S2 = d(V4 - V3)$$

...(2).

It should be noted that the sensitivity $S2$ of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the reflecting surface of the second light reflecting portion 3b to that of the first light reflecting portion 3a, that is when the optical pickup 2 approaches to the reflecting surface of the light reflecting

portion 3 by the distance d .

As discussed above, the optical pickup inspection device 1 calculates the sensitivity of the focussing actuator based on the distance d between the first light reflecting portion 3a and the second light reflecting portion 3b, having parallel reflecting surfaces, on of which is separated from the other in a perpendicular direction, and on the focussing actuator driving voltage at the respective positions of the first and second light reflecting portions 3a, 3b. Thus, the inspection of the optical pickup can be carried out easily.

Also, the optical pickup inspection device 1 can obtain the noise-free stable focussing actuator driving voltage in the servo-on state. Thus, the sensitivity of the focussing actuator can be calculated to high accuracy.

Moreover, if, in the optical pickup inspection device 1, the inspection of the optical pickup is carried out at plural relative positions between the optical pickup 2 and the light reflecting portion 3, it is possible to measure linearity characteristics between the focussing actuator sensitivity calculating position and the focussing actuator sensitivity.

In Fig.1, the focussing actuator driving voltage is measured by displacing the optical pickup 2, with the first light reflecting portion 3a and the second light reflecting portion 3b remaining fixed. Alternatively, the optical pickup 2 may be fixed, with the first light reflecting portion 3a and the second light reflecting portion 3b being moved, or all of the optical pickup 2 and the first and second light reflecting portions 3a, 3b

may be moved in measuring the focussing actuator driving voltage, it being sufficient if the relative positions between the optical pickup 2 and the first and second light reflecting portions 3a, 3b are varied.

The focussing actuator sensitivity can be measured with the optical pickup inspection device by methods other than the above-described method, as hereinafter explained.

In Fig.3, the calculation circuit 7 calculates the focussing actuator sensitivity by the following processing operations:

In the optical pickup inspection device 1, the first light reflecting portion 3a and the second light reflecting portion 3b shown in Fig.1 may be replaced by a light reflecting portion 11 inclined relative to the movement direction of the optical pickup 2 at an angle other than a right angle with respect to the optical axis of the laser light shown in Fig.3. In Fig.3, only the optical pickup 2 and the light reflecting portion 11 of the optical pickup inspection device 1 are shown.

The light reflecting portion 11 is positioned with respect to the optical pickup 2 at an angle of inclination other than a right angle relative to the optical axis of the laser light converged by the objective lens 2c along the direction of movement of the optical pickup 2, that is in a state in which the light reflecting portion 11 is inclined at a pre-set angle from the perpendicular state along the direction of movement of the optical pickup 2. The light reflecting portion 11 is formed by a planar shaped member of a light reflecting material and, similarly to the above-described light reflecting

portion 3, reflects the laser light illuminated from the optical pickup 2 being inspected by the optical pickup inspection device 1.

If, in the direction parallel to the optical axis of the laser light converged by the objective lens 2c, the focussing point of the laser light coincides with a first illuminating point f on the reflecting surface of the light reflecting portion 11, and the focussing point of the laser light coincides with a second illuminating point g on the reflecting surface of the light reflecting portion 11, the distance between the first illuminating point f and the second illuminating point g is d1. This distance d1 is calculated from the angle by which the light reflecting portion 11 is inclined from the perpendicular position to the optical axis in a direction of movement of the optical pickup 2 and the distance of movement of the optical pickup from the laser light illuminating position on the first illuminating position f on the reflecting surface of the light reflecting portion 11 along the direction X3 in Fig.3 to the laser light illuminating position on the second illuminating position g on the reflecting surface of the light reflecting portion 11. The distance d1 may also be found from the angle by which the light reflecting portion 11 is inclined from the perpendicular position to the optical axis in a direction of movement of the optical pickup 2 and the distance of movement of the optical pickup from the laser light illuminating position on the second illuminating position g on the reflecting surface of the light reflecting portion 11 along the direction X4 in Fig.3 to the laser light illuminating position on the first illuminating position f on the reflecting surface of the light reflecting portion 11.

First, the focussing actuator driving voltage V11 in case the focussing point of the laser light converged by the objective lens 2c coincides with the first illuminating point f on the reflecting surface of the light reflecting portion 11 is found.

The position control circuit 8 moves the optical pickup 2 to an illuminating position at which the laser light converged by the objective lens 2c is able to illuminate the first illuminating position f on the reflecting surface of the light reflecting portion 11. With the focussing servo loop turned on, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the first illuminating position f.

The matrix circuit 4 generates the FE signals for V11, based on the reflected light from the first illuminating position f, to route the generated FE signals for V11 to the focussing servo circuit 5.

The focussing servo circuit 5 generates a driver control signal for V11 for controlling the driving of the focussing actuator 2e via driver 6, based on the FE signals for V11, routed from the matrix circuit 4, to route the driver control signals for V11 to the driver 6. That is, the focussing servo circuit 5 displaces the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the first illuminating position f.

The driver 6 generates V11, based on the driver control signals for V11 routed from the focussing servo circuit 5, to route the generated V11 to the focussing actuator 2e. The driver 6 also routes the generated V11 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes V11 routed from the focussing servo circuit 5 to be stored in the memory 7b.

The position control circuit 8 then displaces the optical pickup 2 from the laser light illuminating position at the first illuminating position f on the reflecting surface of the light reflecting portion 11 along the direction of the inclination of the light reflecting portion 11, for displacing the optical pickup 2 in a direction in which the optical pickup is progressively removed from the light reflecting portion 11, that is in the direction indicated by arrow X3 in Fig.3, until the optical pickup is positioned at the laser light illuminating position corresponding to the second illuminating position g on the reflecting surface of the light reflecting portion 11.

The focussing actuator driving voltage V12 when the focussing point of the laser light converged by the objective lens 2c coincides with the second illuminating position g on the reflecting surface of the light reflecting portion 11 then is found.

With the focussing servo loop turned on, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the first illuminating position f.

The matrix circuit 4 generates the FE signals for V12, based on the reflected light from the second illuminating position g, to route the generated FE signals for V12 to the focussing servo circuit 5.

The focussing servo circuit 5 generates driver control signals for V12 for controlling the driving of the focussing actuator 2e via driver 6, based on the FE signals for V12, routed from the matrix circuit 4, to route the driver control signals for

V11 to the driver 6. That is, the focussing servo circuit 5 displaces the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the second illuminating position g.

The driver 6 generates V11, based on the driver control signals for V12 routed from the focussing servo circuit 5, to route the generated V12 to the focussing actuator 2e. The driver 6 also routes the generated V12 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes V12 routed from the focussing servo circuit 5 to be stored in the memory 7b.

The memory 7b holds the above-mentioned distance d1 on memory from the outset.

The calculation circuit 7 performs the following processing, based on the distance d1, V11 and V12, stored in the memory 7b, to calculate the sensitivity of the focussing actuator shown in Fig.3.

Specifically, the controller 7a acquires the above distance d1, V11 and V12 from the memory 7b to route the acquired distance d1, V11 and V12 to the calculation processor 7c. From the values of the distance d1, V11 and V12, the calculation processor 7c calculates the sensitivity S3 of the focussing actuator when the distance d1 between the optical pickup 2 and the illuminating point on the reflecting surface of the light reflecting portion 11 is changed by d1, in accordance with the following equation (3):

$$S3 = d1/(V12 - V11)$$

...(3).

Meanwhile, the sensitivity S3 of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the first illuminating position f on the reflecting surface of the light reflecting portion 11 to the second illuminating position g on the reflecting surface of the light reflecting portion 11, that is when the optical pickup 2 is removed from the illuminating point on the reflecting surface of the light reflecting portion 11 by the distance d1.

The driver 6 then applies to the focussing actuator 2e a voltage of an opposite polarity to that when finding S3 to find the focussing actuator driving voltages V14 and V13 at the first illuminating position f and second illuminating position g on the reflecting surface of the light reflecting portion 11 for the voltage of the opposite polarity in the same manner as when finding S3. Based on this focussing actuator driving voltages V14 and V13, thus found, the focussing actuator sensitivity S4 is found by the same method as that used in finding S3.

It is noted however that the sequence of finding the focussing actuator driving voltage and the equation used for calculating the sensitivity of the focussing actuator differ from those in finding S3 described above.

First, the focussing actuator driving voltage V13 when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the

second illuminating position g on the reflecting surface of the light reflecting portion 11 is found.

The position control circuit 8 then moves the optical pickup 2 from the laser light illuminating position at the second illuminating position g on the reflecting surface of the light reflecting portion 11 in the direction indicated by arrow X4 in Fig.3 to set the optical pickup 2 at the laser light illuminating position for the first illuminating position f on the reflecting surface of the light reflecting portion 11.

The focussing actuator driving voltage V14 when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the first illuminating position f on the reflecting surface of the light reflecting portion 11 then is found.

Finally, the calculation processor 7c calculates the sensitivity S4 of the focussing actuator when the distance d1 between the optical pickup 2 and the light reflecting portion 3 is changed, from the values V13 and V14, as found by these methods, and the pre-stored distance d1, in accordance with the following equation(4):

$$S4 = d1(V14 - V13)$$

...(4).

It should be noted that the sensitivity S4 of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the second illuminating position g on the reflecting surface of the light reflecting portion 11 to the first

illuminating position f on the reflecting surface of the light reflecting portion 11, that is when the optical pickup 2 approaches to the reflecting surface of the light reflecting portion 3 by the distance $d1$.

As discussed above, the optical pickup inspection device 1 calculates the sensitivity of the focussing actuator based on the distance $d1$ between the first illuminating position f and the second illuminating position g , and on the focussing actuator driving voltage at the respective positions of the first illuminating position f and second illuminating position g on the reflecting surface of the light reflecting portion 11. Thus, the inspection of the optical pickup can be carried out easily.

Also, the optical pickup inspection device 1 can obtain the noise-free stable focussing actuator driving voltage in the servo-on state. Thus, the sensitivity of the focussing actuator can be calculated to high accuracy.

Moreover, if, in the optical pickup inspection device 1, the inspection of the optical pickup is carried out at plural relative positions between the optical pickup 2 and the light reflecting portion 3, it is possible to measure linearity characteristics between the focussing actuator sensitivity calculating position and the focussing actuator sensitivity.

In Fig.3, the focussing actuator driving voltage is measured by displacing the optical pickup 2, with the light reflecting portion 11 remaining fixed. Alternatively, the optical pickup 2 may be fixed, with the light reflecting portion 11 being moved, or both the optical pickup 2 and the light reflecting portion 11 may be moved in

measuring the focussing actuator driving voltage, it being sufficient if the relative positions between the optical pickup 2 and the light reflecting portion 11 are varied.

The method of calculating the focussing actuator sensitivity by rotating a disc-shaped light reflecting portion 21 of an optical disc by a pre-set angle relative to the point of origin of the light reflecting portion 21 to measure the focussing actuator driving voltage, and the method of calculating the focussing actuator sensitivity by measuring the focussing actuator driving voltage with the disc-shaped light reflecting portion 21, such as an optical disc, kept in a rotating state, are now explained.

Referring to Fig.4, the calculation circuit 7 calculates the focussing actuator sensitivity by performing the following processing:

With the optical pickup inspection device 1, the first light reflecting portion 3a and the second light reflecting portion 3b shown in Fig.1 may be modified to a light reflecting portion 21 lying substantially at right angles to the optical axis of the laser light shown in Fig.4. It should be noted that only the optical pickup 2 and the light reflecting portion 21 are shown in Fig.4. The optical pickup is fixed against position deviation.

The light reflecting portion 21 is positioned substantially in a perpendicular position relative to the optical axis of the laser light converged by the objective lens 2c. This light reflecting portion 21 is e.g., an optical disc having known deviation from planarity and, similarly to the light reflecting portion 3, described above, reflects the laser light illuminated from the optical pickup 2 being inspected by the optical pickup

inspection device 1.

When the focussing point of the laser light coincides with a first illuminating position h on the reflecting surface of the light reflecting portion 21 and with a second illuminating position g on the reflecting surface of the light reflecting portion 21, in the direction parallel to the optical axis of the laser light converged by the objective lens 2c, the distance between the first illuminating position h and the second illuminating position g is $d2$. This distance $d2$ is previously calculated because the deviation from planarity of the light reflecting portion 21 is previously known.

First, the method of calculating the sensitivity of the focussing actuator by rotating the disc-shaped light reflecting portion 21 of, for example, an optical disc, a pre-set angle relative to the point of origin of the light reflecting portion 21 to measure the driving voltage of the focussing actuator is explained.

Initially, the focussing actuator driving voltage $V21$ in case the focussing point of the laser light converged by the objective lens 2c coincides with the first illuminating position h on the reflecting surface of the light reflecting portion 21 is found.

With the focussing servo loop turned on, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the first illuminating position h .

The matrix circuit 4 generates the FE signals for $V21$, based on the reflected light from the first illuminating position h , to route the generated FE signals for $V11$ to the focussing servo circuit 5.

The focussing servo circuit 5 generates driver control signals for V21 for controlling the driving of the focussing actuator 2e via driver 6, based on the FE signals for V21, routed from the matrix circuit 4, to route the driver control signals for V21 to the driver 6. That is, the focussing servo circuit 5 displaces the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the first illuminating position h.

The driver 6 generates V21, based on the driver control signals for V21 routed from the focussing servo circuit 5, to route the generated V21 to the focussing actuator 2e. The driver 6 also routes the generated V21 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes V21 routed from the driver 6 to be stored in the memory 7b.

Then, a light reflecting portion rotation control circuit, not shown, rotates the light reflecting portion 21, presenting deviation from planarity, clockwise through 180° to a position at which the laser light can be illuminated on the second illuminating position i on the reflecting surface of the light reflecting portion 21.

The focussing actuator driving voltage V22 when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the second illuminating position i on the reflecting surface of the light reflecting portion 21 then is found.

With the focussing servo loop turned on, as before, the optical pickup 2

illuminates the laser light converged by the objective lens 2c on the second illuminating position i on the reflecting surface of the light reflecting portion 21.

The matrix circuit 4 generates the FE signals for V22, based on the reflected light from the second illuminating position i, to route the generated FE signals for V22 to the focussing servo circuit 5.

The focussing servo circuit 5 generates a driver control signals for V22 for controlling the driving of the focussing actuator 2e via driver 6, based on the FE signals for V22, routed from the matrix circuit 4, to route the driver control signals for V22 to the driver 6. That is, the focussing servo circuit 5 displaces the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by objective lens 2c into coincidence with the second illuminating position i.

The driver 6 generates V22, based on the driver control signals for V22 routed from the focussing servo circuit 5, to route the generated V22 to the focussing actuator 2e. The driver 6 also routes the generated V22 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes V22 routed from the focussing servo circuit 5 to be stored in the memory 7b.

The memory 7b holds the above-mentioned distance d2 on memory from the outset.

The calculation circuit 7 performs the following processing, based on the distance d2, V21 and V22, stored in the memory 7b, to calculate the sensitivity of the

focussing actuator shown in Fig.4.

Specifically, the controller 7a acquires the above distance d2, V21 and V22 from the memory 7b to route the acquired distance d2, V21 and V22 to the calculation processor 7c. From the values of the distance d2, V21 and V22, the calculation processor 7c calculates the sensitivity S5 of the focussing actuator when the distance d2 between the optical pickup 2 and the illuminating point on the reflecting surface of the light reflecting portion 21 is changed, in accordance with the following equation (5):

$$S5 = d2/(V22 - V21)$$

...(5).

Meanwhile, the sensitivity S5 of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the first illuminating position h on the reflecting surface of the light reflecting portion 11 to the second illuminating position i on the reflecting surface of the light reflecting portion 21, that is when the optical pickup 2 is removed from the illuminating point on the reflecting surface of the light reflecting portion 21 by the distance d2.

The driver 6 then applies to the focussing actuator 2e a voltage of an opposite polarity to that when finding S3 to find focussing actuator driving voltages V24 and V23 at the first illuminating position h and second illuminating position i on the reflecting surface of the light reflecting portion 21 for the voltage of the opposite

polarity in the same manner as when finding S5. Based on these focussing actuator driving voltages V24 and V23, thus found, the focussing actuator sensitivity S6 is found by the same method as that used in finding S5.

It is noted however that the sequence of finding the focussing actuator driving voltage and the equation used for calculating the sensitivity of the focussing actuator differ from those in finding S5 described above.

First, the focussing actuator driving voltage V23 when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the second illuminating position i on the reflecting surface of the light reflecting portion 11 is found.

The position control circuit 8 then moves the optical pickup 2 from the laser light illuminating position at the second illuminating position i on the reflecting surface of the light reflecting portion 11 in the direction indicated by arrow X6 in Fig.4 to set the optical pickup 2 at the laser light illuminating position for the first illuminating position h on the reflecting surface of the light reflecting portion 21.

The focussing actuator driving voltage V24 in the case when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the first illuminating position h on the reflecting surface of the light reflecting portion 21 then is found.

Finally, the calculation processor 7c calculates the sensitivity S6 of the focussing actuator when the distance d2 between the optical pickup 2 and the light

reflecting portion 3 is changed, from the values V_{23} and V_{24} , as found by these methods, and the pre-stored distance d_2 , in accordance with the following equation(6):

$$S_6 = d_2(V_{24} - V_{23})$$

...(6).

It should be noted that the sensitivity S_6 of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the second illuminating position i on the reflecting surface of the light reflecting portion 11 to the first illuminating position h on the reflecting surface of the light reflecting portion 11, that is when the optical pickup 2 approaches to the reflecting surface of the light reflecting portion 3 by the distance d_2 .

The method of calculating the sensitivity of the focussing actuator by measuring the driving voltage of the focussing actuator with the disc-shaped light reflecting portion 21 of, for example, an optical disc, is hereinafter explained.

The driving voltage etc of the focussing actuator is similarly measured in the same way as when calculating the sensitivities S_5 and S_6 of the focussing actuator described above. However, in this method, since the light reflecting portion 21, such as an optical disc, suffering from deviations from planarity, is rotating, and hence the driving voltage peak value of the focussing actuator corresponds to the maximum displacement position of the light reflecting portion 21, such as the optical disc, the sensitivity of the focussing actuator is calculated by measuring the driving voltage of

the focussing actuator, as explained below in detail.

The light reflecting portion 21, suffering from deviations from planarity, is kept rotating at a constant velocity by a light reflecting portion rotation control circuit, not shown.

Then, with the focussing servo loop turned on, the driver 6 perpetually generates the focussing actuator driving voltage of the rotating light reflecting portion 21, using the method similar to that used for finding V21 and V22. That is, the driver 6, perpetually generating the focussing actuator driving voltage of the rotating light reflecting portion 21, produces an ac signal, as a value of the continuous focussing actuator driving voltage, to route the so-formed ac signal to the focussing actuator 2e and to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes the ac signals routed from the driver 6 to be stored in the memory 7b.

The memory 7b holds the above-mentioned distance d2 on memory.

Based on the distance d2 and the ac signal, stored in the memory 7b, the calculation circuit 7 performs the following processing to calculate the sensitivity of the focussing actuator in Fig.4.

Specifically, the controller 7a is fed from the memory 7b with the above-mentioned ac signals to acquire the peak values, namely the maximum value V26 and the minimum value V25, of the focussing actuator driving voltage of the rotating light reflecting portion 21, and routes the maximum value V26 and the minimum value V25

of the focussing actuator driving voltage to the calculation processor 7c. The controller 7a also acquires the above distance d2 from the memory 7b to route the acquired distance d2 to the calculation processor 7c.

From the distance d2 and V25, V26, the calculation processor 7c calculates the sensitivity S7 of the focussing actuator when the distance between the optical pickup 2 and the light illuminating point on the reflecting surface of the light reflecting portion 21 is changed by d2, in accordance with the following equation (7):

$$S7 = d2/(V26 - V25)$$

...(7).

As discussed above, the optical pickup inspection device 1 calculates the sensitivity of the focussing actuator based on the distance d2 between the first illuminating position h and the second illuminating position i, along the direction parallel to the optical axis of the laser light, and on the focussing actuator driving voltage at the respective positions of the first illuminating position h and second illuminating position i on the reflecting surface of the light reflecting portion 21, thus facilitating the inspection of the optical pickup.

Also, the optical pickup inspection device 1 can obtain the noise-free stable focussing actuator driving voltage in the servo-on state, thus allowing to calculate the sensitivity of the focussing actuator to high accuracy.

Moreover, if, in the optical pickup inspection device 1, the inspection of the optical pickup is carried out at plural relative positions between the optical pickup 2

and the light reflecting portion 3, it is possible to measure linearity characteristics between the focussing actuator sensitivity calculating position and the focussing actuator sensitivity.

In Fig.4, the focussing actuator driving voltage is measured by rotating the light reflecting portion 11, with the optical pickup 2 remaining fixed. Alternatively, the optical pickup 2 may be fixed, with the light reflecting portion 11 being rotated relative to the point of origin of the light reflecting portion 21, for measuring the focussing actuator driving voltage, it being sufficient if the relative positions between the optical pickup 2 and the light reflecting portion 21 are varied.

The method of calculating the focussing actuator sensitivity by varying the relative distance between the optical pickup 2 and the light reflecting portion 31, using an external position varying device, such as a Z-stage, and by measuring the focussing actuator driving voltage at the respective relative positions, is now explained.

Referring to Fig.5, the calculation circuit 7 calculates the focussing actuator sensitivity by performing the following processing:

In the processing shown in Fig.5, the sensitivity of the focussing actuator is calculated by the processing operations which are similar to those explained in Fig.4 except that the relative positions between the optical pickup 2 and the light reflecting portion 31 is varied by causing movement of the optical pickup 2 or the light reflecting portion 31 by the external position varying device, such as a Z-stage. It should be noted that the light reflecting portion 31 shown in Fig.5 is free from deviations in

planarity.

The relative position between the optical pickup 2 and the light reflecting portion 31 is calculated from graduations on the Z-stage or the amount of rotation of a feed shaft.

With the optical pickup inspection device 1, the first light reflecting portion 3a and the second light reflecting portion 3b shown in Fig.1 may be modified to a light reflecting portion 31 lying substantially at right angles to the optical axis of the laser light shown in Fig.5. It should be noted that only the optical pickup 2 and the light reflecting portion 31 are shown in Fig.5. The optical pickup is fixed against position deviation.

The light reflecting portion 31 is positioned relative to the optical pickup 2 at a substantially perpendicular position relative to the optical axis of the laser light converged by the objective lens 2c. This light reflecting portion 31 is formed by a planar shaped member of a light reflecting material and, similarly to the above-described light reflecting portion 3, reflects the laser light illuminated from the optical pickup 2 being inspected by the optical pickup inspection device 1.

If, in the direction parallel to the optical axis of the laser light converged by the objective lens 2c, the focussing point of the laser light coincides with a first illuminating point j on the reflecting surface of the light reflecting portion 11, and the focussing point of the laser light coincides with a second illuminating point k on the reflecting surface of the light reflecting portion 11, the distance between the first

illuminating point j and the second illuminating point k is d_3 . This distance d_3 is calculated from graduations on the Z-stage or from the amount of rotation of a feed shaft.

In the following explanation, it is assumed that the focussing point of the laser light is brought into coincidence with the illuminating point on the reflecting surface of the light reflecting portion 31 by moving the light reflecting portion 31 using the external position varying device, such as a Z-stage, not shown, so that the light reflecting portion 31 is moved into and out of contact with the optical axis of the laser light converged by the objective lens 2c, with the optical pickup 2 being fixed.

First, the focussing actuator driving voltage V31 for the case when the focussing point of the laser light converged by objective lens 2c is brought into coincidence with the first illuminating position j on the reflecting surface of the light reflecting portion 31, is found.

With the focussing servo loop turned on, as before, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the first illuminating position j.

The matrix circuit 4 generates the FE signal for V31, based on the reflected light from the second illuminating position j, to route the generated FE signals for V31 to the focussing servo circuit 5.

The focussing servo circuit 5 generates a driver control signals for V31 for controlling the driving of the focussing actuator 2e via driver 6, based on the FE

signals for V31, routed from the matrix circuit 4, to route the driver control signals for V31 to the driver 6. That is, the focussing servo circuit 5 displaces the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the first illuminating position j.

The driver 6 generates V31, based on the driver control signals for V31 routed from the focussing servo circuit 5, to route the generated V31 to the focussing actuator 2e. The driver 6 also routes the generated V31 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes V31 routed from the focussing servo circuit 5 to be stored in the memory 7b.

The external position varying device, not shown, causes movement of the light reflecting portion 31, from the position of illumination of the laser light on the first illuminating position j on the reflecting surface of the light reflecting portion 31, in a direction in which the light reflecting portion 31 is moved away from the optical pickup along the optical axis, that is in a direction indicated X5 in Fig.5, until the light reflecting portion 31 is positioned at the position of illumination of the laser light on the second illuminating position g on the reflecting surface of the light reflecting portion 31.

The focussing actuator driving voltage V32 in case the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the second illuminating position k on the reflecting surface of the light reflecting portion

31 then is found.

With the focussing servo loop turned on, as before, the optical pickup 2 illuminates the laser light converged by the objective lens 2c on the second illuminating position k on the reflecting surface of the light reflecting portion 31.

The matrix circuit 4 generates the FE signals for V32, based on the reflected light from the second illuminating position k, to route the generated FE signals for V32 to the focussing servo circuit 5.

The focussing servo circuit 5 generates a driver control signal for V32 for controlling the driving of the focussing actuator 2e via driver 6, based on the FE signals for V32, routed from the matrix circuit 4, to route the driver control signals for V32 to the driver 6. That is, the focussing servo circuit 5 displaces the objective lens 2c by driving the focussing actuator 2e via driver 6 to bring the focussing point of the laser light converged by the objective lens 2c into coincidence with the second illuminating position k.

The driver 6 generates V32, based on the driver control signals for V32 routed from the focussing servo circuit 5, to route the generated V32 to the focussing actuator 2e. The driver 6 also routes the generated V32 to the calculation circuit 7.

The controller 7a of the calculation circuit 7 causes V32 routed from the driver 6 to be stored in the memory 7b.

The memory 7b holds the above-mentioned distance d3 on memory from the outset.

The calculation circuit 7 performs the following processing, based on the distance d3, V31 and V32, stored in the memory 7b, to calculate the sensitivity of the focussing actuator shown in Fig.5.

Specifically, the controller 7a acquires the above distance d3, V31 and V32 from the memory 7b to route the acquired distance d3, V31 and V32 to the calculation processor 7c. From the values of the distance d3, V31 and V32, the calculation processor 7c calculates the sensitivity S8 of the focussing actuator when the distance d3 between the optical pickup 2 and the illuminating point on the reflecting surface of the light reflecting portion 31 is changed, in accordance with the following equation (8):

$$S8 = d3/(V32 - V31)$$

...(8).

Meanwhile, the sensitivity S8 of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the first illuminating position j on the reflecting surface of the light reflecting portion 11 to the second illuminating position k on the reflecting surface of the light reflecting portion 21, that is when the optical pickup 2 approaches to the illuminating point on the reflecting surface of the light reflecting portion 21 by the distance d3.

The driver 6 then applies to the focussing actuator 2e a voltage of an opposite polarity to that when finding S8 to find focussing actuator driving voltages V34 and

V33 at the first illuminating position j and second illuminating position k on the reflecting surface of the light reflecting portion 31 for the voltage of the opposite polarity in the same manner as when finding S8. Based on these focussing actuator driving voltages V34 and V33, thus found, the focussing actuator sensitivity S9 is found by the same method as that used in finding S8.

It is noted however that the sequence of finding the focussing actuator driving voltage and the equation used for calculating the sensitivity of the focussing actuator differ from those in finding S8 described above.

First, the focussing actuator driving voltage V33 when the focussing point of the laser light converged by the objective lens 2c is brought into coincidence with the second illuminating position k on the reflecting surface of the light reflecting portion 31 is found.

The external position varying device, not shown, such as a Z-stage, causes movement of the light reflecting portion 31, from the position of illumination of the laser light on the first illuminating position j on the reflecting surface of the light reflecting portion 31, in a direction in which the light reflecting portion 31 approaches to the optical pickup along the optical axis, that is in a direction indicated X6 in Fig.5, until the light reflecting portion 31 is positioned at the position of illumination of the laser light on the first illuminating position j on the reflecting surface of the light reflecting portion 31.

The focussing actuator driving voltage V24 in the case when the focussing

point of the laser light converged by the objective lens 2c is brought into coincidence with the first illuminating position h on the reflecting surface of the light reflecting portion 21 then is found.

Finally, the calculation processor 7c calculates the sensitivity S6 of the focussing actuator when the distance d2 between the optical pickup 2 and the light reflecting portion 3 is changed, from the values V23 and V24, as found by these methods, and the pre-stored distance d2, in accordance with the following equation(9):

$$S9 = d3/(V34 - V33)$$

...(9).

It should be noted that the sensitivity S9 of the focussing actuator is the value of the focussing actuator sensitivity for the case in which the focussing point of the laser light converged by the objective lens 2c is moved from the second illuminating position k on the reflecting surface of the light reflecting portion 31 to the first illuminating position j on the reflecting surface of the light reflecting portion 31, that is when the optical pickup 2 approaches to the reflecting surface of the light reflecting portion 31 by the distance d3.

In the above-described method for calculating the sensitivity of the focussing actuator in Fig.5, the driving voltage for the focussing actuator is measured by causing the light reflecting portion 31 to be moved by an external position varying device, such as a Z-stage, with the optical pickup 2 remaining fixed. Alternatively, the optical pickup may be moved using an external position varying device, such as a Z-stage,

with the light reflecting portion 31 remaining fixed, for measuring the driving voltage for the focussing actuator.

In the optical pickup inspection device 1, as described above, the sensitivity of the focussing actuator is calculated based on the distance d_3 between the first illuminating position j and the second illuminating position k in the direction parallel to the optical axis of the laser light, and on the focussing actuator driving voltages in the first illuminating position j and the second illuminating position k in the direction parallel to the optical axis of the laser light, thus facilitating the inspection of the optical pickup.

Also, with the present optical pickup inspection device 1, the noise-free stable focussing actuator driving voltage is obtained in the servo-on state, thus enabling the sensitivity of the focussing actuator to be calculated to high accuracy.

If, in the optical pickup inspection device 1, the optical pickup is inspected at plural relative positions between the optical pickup 2 and the illuminating positions on the reflecting surface of the light reflecting portion 31, it is possible to measure linearity characteristics between the focussing actuator sensitivity calculating positions and the sensitivity of the focussing actuator.

Although a plate-shaped light reflecting material is used in the above-described embodiments as the light reflecting portion, it is of course possible to use materials other than the plate-shaped light reflecting material.



WHAT IS CLAIMED IS:

1. An inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by an optical pickup, comprising:

first light reflecting means provided facing an objective lens so as to be in a perpendicular state with respect to the direction of the optical axis of the laser light radiated from said optical pickup, said first light reflecting means having a reflecting surface for reflecting the laser light in the direction of the optical axis of the laser light;

second light reflecting means provided facing said objective lens at a distance d in the direction of the optical axis from said first light reflecting means parallel thereto, said second light reflecting means having a reflecting surface for reflecting the laser light, radiated from the optical pickup, in a direction of the optical axis of the laser light, said second light reflecting means being offset in a parallel state to said first light reflecting means so that the second light reflecting means is not overlapped with said first light reflecting means with respect to the laser light;

focussing servo control means for applying a focussing actuator driving voltage derived from the reflected light from said first or second light reflecting means to said focussing actuator to cause movement of the objective lens to bring the focussing point of the laser light converged by the objective lens into coincidence with said first or second light reflecting means;

position control means for controlling the position of said optical pickup facing said first or second light reflecting means by displacing said optical pickup in a



direction perpendicular to said optical axis direction so that the laser light converged by said objective lens will be focussed from said first light reflecting means to said second light reflecting means or from said second light reflecting means to said first light reflecting means; and

calculating means for calculating the sensitivity of said focussing actuator from a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said first light reflecting means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said second light reflecting means and said distance d.

2. The inspection apparatus for an optical pickup according to claim 1 wherein said calculating means calculates the sensitivity S of the focussing actuator in a case when the distance between said optical pickup and the light reflecting portion is changed by d along the optical axis direction in accordance with the equation:

$$S = d/(V2 - V1)$$

where V1 is a focussing actuator driving voltage before the distance between the optical pickup and the light reflecting portion is changed by d and V2 is a focussing actuator driving voltage after the distance between the optical pickup and the light reflecting portion is changed by d.

3. An inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by said optical pickup, comprising:

light reflecting means provided facing an objective lens in an inclined state at



a pre-set angle along the direction of movement of said optical pickup from a state in which the light reflecting means is inclined at a right angle relative to the optical axis direction of the laser light radiated from the optical pickup, said light reflecting means including a first light reflecting portion provided in a reflecting surface reflecting the laser light along the optical axis direction of the laser light and a second light reflecting portion provided in said reflecting surface, said second light reflecting portion being offset in a direction perpendicular to the optical axis so that it is not overlapped with the first light reflecting portion with respect to the laser light, said second light reflecting portion being positioned at a distance d along the optical axis direction from said first light reflecting portion;

focussing servo control means for bringing the focussing point of the laser light converged by said objective lens into coincidence with the first or second light reflecting portion by displacing said objective lens by applying a focussing actuator driving voltage derived from the reflected light from the first or second light reflecting portion to said focussing actuator;

position control means for controlling the position of said optical pickup facing said first or second light reflecting portion by displacing said optical pickup at right angles to the optical axis direction so that the laser light converged by said objective lens will be focussed from the first light reflecting portion to the second light reflecting portion or vice versa; and

calculating means for calculating the sensitivity of said focussing actuator from



a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said first light reflecting means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said second light reflecting means and said distance d.

4. The inspection apparatus for an optical pickup according to claim 3 wherein said calculating means calculates the sensitivity S of the focussing actuator in a case when the distance between said optical pickup and the light reflecting portion is changed by d along the optical axis direction in accordance with the equation:

$$S = d/(V2 - V1)$$

where V1 is a focussing actuator driving voltage before the distance between the optical pickup and the light reflecting portion is changed by d and V2 is a focussing actuator driving voltage after the distance between the optical pickup and the light reflecting portion is changed by d.

5. An inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by said optical pickup, comprising:

light reflecting means including a first light reflecting portion provided facing said objective lens so that, by producing deviation in planarity, the first light reflecting portion is inclined at a pre-set angle of inclination from the state of the perpendicular inclined angle with respect to the optical axis direction of the laser light radiated from the optical pickup, said first light reflecting portion being provided in a reflecting surface reflecting the laser light along the optical axis direction of the laser light, and



a second light reflecting portion provided in said reflecting surface, said second light reflecting portion being positioned at a distance d along the optical axis direction from the first light reflecting portion so that said second light reflecting portion will be overlapped with said first light reflecting portion with respect to the laser light;

focussing servo control means for bringing the focussing point of the laser light converged by said objective lens into coincidence with the first or second light reflecting portion by displacing said objective lens by applying a focussing actuator driving voltage derived from the reflected light from the first or second light reflecting portion to said focussing actuator;

rotation means for rotating said light reflecting means relative to a point of origin for producing said deviation from planarity; and

calculating means for calculating the sensitivity of said focussing actuator from a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said first light reflecting means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said second light reflecting means and said distance d ;

said distance d being found by producing deviations in planarity on rotating said light reflecting means.

6. The inspection apparatus for an optical pickup according to claim 5 wherein said calculating means calculates the sensitivity S of the focussing actuator in a case when the distance between said optical pickup and the light reflecting portion is changed by



d along the optical axis direction in accordance with the equation:

$$S = d/(V2 - V1)$$

where V1 is a focussing actuator driving voltage before the distance between the optical pickup and the light reflecting portion is varied by d and V2 is a focussing actuator driving voltage after the distance between the optical pickup and the light reflecting portion is varied by d.

7. An inspection apparatus for an optical pickup for detecting the sensitivity of a focussing actuator owned by an optical pickup, comprising:

light reflecting means provided facing an objective lens so as to be in a perpendicular state with respect to the direction of the optical axis of the laser light radiated from said optical pickup, said light reflecting means having a reflecting surface for reflecting the laser light in the direction of the optical axis of the laser light;

focussing servo control means for applying a focussing actuator driving voltage derived from the reflected light from said light reflecting means to said focussing actuator to cause movement of the objective lens to bring the focussing point of the laser light converged by the objective lens into coincidence with said first or second light reflecting means;

position control means for controlling the position of said light reflecting means relative to the optical pickup along the optical axis direction or the position of said optical pickup relative to said light reflecting means along the optical axis direction; and



calculation means for calculating the sensitivity of said focussing actuator based on a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said light reflecting means before the relative position between the optical pickup and the light reflecting means is changed by said position control means, a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on said light reflecting means after the relative position between the optical pickup and the light reflecting means is changed by said position control means, and on said distance d.

8. The inspection apparatus for an optical pickup according to claim 7 wherein said calculating means calculates the sensitivity S of the focussing actuator in a case when the distance between said optical pickup and the light reflecting portion is changed by d along the optical axis direction in accordance with the equation:

$$S = d/(V2 - V1)$$

where V1 is a focussing actuator driving voltage before the distance between the optical pickup and the light reflecting portion is varied by d and V2 is a focussing actuator driving voltage after the distance between the optical pickup and the light reflecting portion is varied by d.

9. An inspection method for a focussing actuator for detecting the sensitivity of the focussing actuator owned by an optical pickup, comprising:

detecting the sensitivity of the focussing actuator based on

a focussing actuator driving voltage derived from the reflected light of the laser



light illuminated on a first light reflecting portion having a reflecting surface reflecting the laser light along the direction of the optical axis of the laser light radiated from said optical pickup; a focussing actuator driving voltage derived from the reflected light of the laser light illuminated on second light reflecting means removed a distance d from the first light reflecting portion along the optical axis; and

on said distance d .

10. The inspection method for a focussing actuator according to claim 9 wherein said calculating means calculates the sensitivity S of the focussing actuator in a case when the distance between said optical pickup and the light reflecting portion is changed by d along the optical axis direction in accordance with the equation:

$$S = d/(V2 - V1)$$

where $V1$ is a focussing actuator driving voltage before the distance between the optical pickup and the light reflecting portion is varied by d and $V2$ is a focussing actuator driving voltage after the distance between the optical pickup and the light reflecting portion is varied by d .