

TITLE OF THE INVENTION

Method and Apparatus for Measuring Characteristics of Optical Pickup

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a method and apparatus for measuring characteristics of optical pickup.

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. For example, the present apparatus for measuring characteristics of the optical pickup measures the RF signal level, jitter of the RF signals, TE (EF) signal level, defocussing, TE (EF) signal balance and error rates.

In measuring characteristics of the optical pickup, the apparatus for measuring characteristics of the optical pickup also measures the tolerance of the respective characteristics. The tolerance means the threshold of allowance of variations in the measured values, for example, the range of measured values for which an optical pickup can operate satisfactorily. By measuring the tolerance values, it is possible to estimate characteristics on reproduction of an optical disc that is outside the prescribed range of the relevant standard, or a defective optical disc.

The tolerance values are found by plotting data of measured values on a graph and analyzing the variation in the measured values from the graph, and hence cannot be measured if only routine measurement processing for an optical pickup is resorted to.

Figs.1 to 4 show the plotted measured values of the characteristics data of an optical pickup.

Fig.1 shows changes in the EF level with respect to the gradient in the tangential direction of the optical disc (defocussing). The EF level is the level of the tracking error signals outputted by the photodetector. On analysis from Fig.1, the tolerance of the tilt in the tangential direction, for which the EF level can be detected, is -1.0 to $+1.5^{\circ}$.

Fig.2 shows changes in the EF level with respect to the tilt in the radial direction of the optical disc. On analysis from Fig.2, the tolerance of the tilt in the radial direction, for which the EF level can be detected, is -0.7 to 1.0° .

Fig.3 shows changes in jitter with respect to the tilt in the tangential direction of the optical disc. On analysis from Fig.3, the tolerance of the tilt in the tangential direction of the optical disc with respect to the amount of jitter is -1.7 to $+0.8^{\circ}$.

Fig.4 shows changes in jitter with respect to the tilt in the radial direction of the optical disc. On analysis from Fig.4, the tolerance of the tilt in the radial direction of the optical disc with respect to the amount of jitter is -0.5 to $+1.3^{\circ}$.

The tolerance values of the characteristics of the optical pickup can be analyzed

from the graph showing plotted measured values. The values shown in Figs.1 to 4 are merely typical of measurement of a certain optical pickup.

These tolerance values can be found for all of the measurement items of the apparatus for measuring characteristics of the optical pickup. However, in general, the tolerance values are found for jitter, RF levels, EF levels, EF balance or error rates, by way of examples, because these characteristics are determined on the basis of the tolerance values of different parameters, such as defocussing, lens displacement, tilt in the radial direction or in the tangential direction of the optical disc etc. For example, the jitter amount characteristics are measured by varying the tilt of the optical disc in the radial direction, and the tolerance value in the radial direction of the optical disc is found from the measured jitter.

Meanwhile, in the conventional apparatus for measuring characteristics of the optical pickup, the characteristics of the optical pickup are measured in accordance with the manual system or the automatic system to formulate a graph for finding the above-mentioned tolerance values.

In the manual system, the operator vary pre-set parameters by manual operation or a range for measurement of the pre-set parameters are found to measure the characteristics of the optical pickup. For example, in measuring the amount of jitter of the optical disc in accordance with the manual system, the operator varies the tilt of the optical disc in the radial direction by a manual operation or the range of variation of the tilt is set by a manual operation for each pickup being measured.

In the automatic measurement system, the measurement range of pre-set parameters is previously set to measure characteristics of the optical pickup. For example, in measuring the amount of jitter of the optical disc in accordance with the automatic measurement system, the range of variation of the tilt of the optical disc in the radial direction is previously set, and the optical disc is tilted in the radial direction with the same range of variation for all optical pickups under measurement.

However, in the manual system, the experience or the sense on the part of the operator is required, such that it is difficult to perform efficient measurement.

Also, if, in measuring a defective optical pickup by the automatic measurement system, parameters are varied within a pre-set range of variation, the servo loop of the optical pickup is occasionally disengaged to render it impossible to continue the measurement. For example, if in measuring an optical pickup having poor jitter characteristics, the optical disc is tilted within a pre-set range of variation, the detected light volume is decreased abruptly if the tilt exceeds a certain limit value, thus occasionally disengaging the focussing servo loop. If the measurement cannot be continued in this manner, the operator is obliged to re-set the previously set range of variation of the parameters to render efficient measurement impossible.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method and apparatus for measuring characteristics of optical pickup which enables efficient measurement of optical pickup characteristics.

In one aspect, the present invention provides a apparatus for measuring characteristics of an optical pickup, in which laser light is illuminated on an optical disc to detect the reflected light to detect the information recorded on the optical disc to measure the characteristics of the optical pickup, in which the apparatus includes control means for halting a processing of measurement of the characteristics of the optical pickup that are changed during the measurement in dependence upon pre-set parameters, or for reversing the direction of changes in the pre-set parameters, if, during the measurement, the results of measurement exceed or falls below a pre-set upper limit value.

In another aspect, the present invention provides a method for measuring characteristics of an optical pickup, in which laser light is illuminated on an optical disc to detect the reflected light to detect the information recorded on the optical disc to measure the ch of the optical pickup, in which the method includes halting a processing of measurement of the characteristics of the optical pickup that are changed during the measurement in dependence upon pre-set parameters, or for reversing the direction of changes in the pre-set parameters, if, during the measurement, the results of measurement exceed or falls below a pre-set upper limit value.

According to the present invention, if, during measurement of characteristics of the optical pickup that are changed in dependence upon the pre-set parameters, the results of measurement exceed or falls below a pre-set upper limit value, the measurement processing is halted, or the change of direction of the pre-set parameters

is reversed. This enables efficient measurement of the characteristics of the optical pickup.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 shows changes in the EF level with respect to the tilt in the tangential direction of an optical disc as measured by a conventional apparatus for measuring characteristics of the optical pickup.

Fig.2 shows changes in the EF level with respect to the tilt in the radial direction of an optical disc as measured by a conventional apparatus for measuring characteristics of the optical pickup.

Fig.3 shows changes in the jitter with respect to the tilt in the tangential direction of an optical disc as measured by a conventional apparatus for measuring characteristics of the optical pickup.

Fig.4 shows changes in the jitter with respect to the tilt in the radial direction of an optical disc as measured by a conventional apparatus for measuring characteristics of the optical pickup.

Fig.5 is a block diagram of an apparatus for measuring characteristics of the optical pickup embodying the present invention.

Fig.6 shows an illustrative photodetector provided on an optical pickup being measured by the apparatus for measuring characteristics of the optical pickup shown in Fig.5.

Fig.7 shows the relative position between the optical disc tilted in the radial

direction and the laser light.

Fig.8 shows the relative position between the optical disc tilted in the tangential direction and the laser light.

Fig.9 shows changes in the EF level with respect to the tilt in the tangential direction of the optical disc as measured by the apparatus for measuring characteristics of the optical pickup shown in Fig.5.

Fig.10 shows changes in the EF level with respect to the tilt in the radial direction of the optical disc as measured by the apparatus for measuring characteristics of the optical pickup shown in Fig.5.

Fig.11 shows changes in jitter with respect to the tilt in the tangential direction of the optical disc as measured by the apparatus for measuring characteristics of the optical pickup shown in Fig.5.

Fig.12 shows changes in jitter with respect to the tilt in the radial direction of the optical disc as measured by the apparatus for measuring characteristics of the optical pickup shown in Fig.5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

An apparatus 1 for measuring characteristics of the optical pickup, embodying the present invention, measures characteristics of an optical pickup employed in an optical disc drive. This apparatus for measuring characteristics of the optical pickup

is used for inspecting the specifications of the optical pickup or investigating into optical pickup characteristics and is a useful tool for shipment or acceptance inspection of the optical pickup.

Fig.5 shows a block diagram of an apparatus 1 for measuring characteristics of the optical pickup embodying the present invention.

The apparatus 1 for measuring characteristics of the optical pickup measures characteristics of an optical pickup 2.

The optical pickup 2 is an object for measurement by the apparatus 1 for measuring characteristics of the optical pickup, and includes a laser diode 2a, a beam splitter 2b, an objective lens 2c, a photodetector 2d, a focussing actuator 2e and a tracking actuator 2f etc.

The apparatus 1 for measuring characteristics of the optical pickup includes a photodetector 3, illuminated by the laser light radiated by the optical pickup 2, a rotational driving unit 4 on which the optical disc 3 is set, and a matrix circuit 5 fed with an output of a photodetector owned by the optical pickup 2 and adapted for outputting reproduced signals (RF signals) etc.

The apparatus 1 for measuring characteristics of the optical pickup also includes a focussing servo circuit 6, for performing focussing servo control based on the FE signals from the matrix circuit 5, a focussing driver 7 for amplifying an output of the focussing servo circuit 6 to send the driving voltage to the focussing actuator 2e of the optical pickup 2, and a tracking servo circuit 8 for performing tracking servo control

based on the TE signal from the matrix circuit 5. The apparatus 1 for measuring characteristics of the optical pickup also includes a tracking driver 9 for amplifying an output of the tracking servo circuit 8 to supply a driving voltage to the tracking actuator 2f of the optical pickup 2, and a playback signal processing circuit 10 for performing processing operations, such as binary-coding, demodulation or error correction of the RF signals based on the RF signals from the matrix circuit 5.

The apparatus 1 for measuring characteristics of the optical pickup also includes a control circuit 11 for controlling various circuits, such as rotational driving control of the optical disc 3 or various servo control operations, and for measuring characteristics of the optical disc 2.

The optical pickup 2 may be mounted or dismounted with respect to the apparatus 1 for measuring characteristics of an optical pickup. This optical pickup 2 converges the laser light radiated from the laser diode 2a via the beam splitter 2b and the objective lens 2c on the optical disc 3. The optical pickup 2 forms an image of the reflected light from the optical disc 3 on the photodetector 2d. The photodetector 2d of the optical pickup 2 is the photo-electric transducer as described above and converts the imaged reflected light into electrical signals. The focussing actuator 2e of the optical pickup 2 is responsive to the driving voltage routed from the focussing driver 7 to shift the objective lens 2c along the optical axis of the laser light illuminated on the optical disc 3 in order to bring the focussing point of the laser light into coincidence with the recording surface of the optical disc 3. Also, the tracking

actuator 2f of the optical pickup 2 is responsive to the driving voltage routed from the tracking driver 9 or from the driving voltage generating circuit 10 to shift the objective lens 2c along the radius of the optical disc 3 to shift the laser light to a pre-set track on the optical disc 3.

The optical pickup 2 includes plural photodetectors 2d, an example of which is shown in Fig.6.

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.6. 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 optical pickup. 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 from, for example, recording pits, recorded on the optical disc track, 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 5.

The optical disc 3 is set on the rotationally driving device 4 of the apparatus 1 for measuring characteristics of an optical pickup, and is run in rotation by this rotationally driving device 4. The optical disc 3 is also used as a reference for the apparatus 1 for measuring characteristics of the optical pickup. That is, the apparatus 1 for measuring characteristics of an optical pickup measures the characteristics of the optical pickup 2 based on the information derived from the reflected light from the optical disc 3 used as this reference.

The matrix circuit 5 is fed with signals A to F, outputted by the photodetectors A to F of the optical pickup 2, to generate playback (RF) signals, focussing error (FE) signals and tracking error (TE) signals. The matrix circuit 5 generates the RF, FE and TE signals, from the signals A to D, as described above. That is, the matrix circuit 5 calculates $A+B+C+D$ from the signals A to D to generate RF signals. The matrix circuit 5 also outputs FE signals in accordance with the astigmatic method. That is, the matrix circuit 5 calculates $(A+C) - (B+D)$, from the signals A to D, to output the calculated result as FE signal. On the other hand, the matrix circuit 5 calculates $E - F$ from the signals E and F to output the calculated result as TE signal.

The focussing servo circuit 6 is fed with the FE signals from the matrix circuit 5. After filtering the FE signals in a pre-set manner, the focussing servo circuit 6 routes a control signal of a signal volume which will reduce the FE signals to zero to the focussing actuator 2e of the optical pickup 2 via the focussing driver 7. Thus, the focussing servo circuit 6 controls the laser light radiated from the optical pickup 2 so

that a just-focus state will be reached on the recording surface of the optical disc 3.

The tracking servo circuit 8 is fed with the TE signals from the matrix circuit 5. After filtering the FE signals in a pre-set manner, the tracking servo circuit 8 routes a control signal of a signal volume which will reduce the TE signals to zero to the tracking actuator 2f of the optical pickup 2 via tracking driver 9. Thus, the tracking servo circuit 8 controls the laser light radiated from the optical pickup 2 so that a just-track state will be reached on the recording surface of the optical disc 3.

The playback signal processing circuit 10 is fed with RF signals from the matrix circuit 5. The playback signal processing circuit 10 performs filtering, binary-coding, demodulation and error correction on the supplied Rf signals to output playback data obtained from the optical disc 3.

The control circuit 11 performs rotational driving control of the optical disc 3, controls various circuits, such as servo control circuits, and measures characteristics of the optical pickup 2.

The control circuit 11 performs rotational driving control of the optical disc 3, by controlling the rotational driving unit 4, while performing skew servo control for controlling the tilt of the optical disc 3 in the direction of the optical axis of the radiated laser light, based on the detection signal of a detection mechanism, not shown, adapted for detecting the tilt of the optical disc 3. Meanwhile, the control circuit 11, which usually controls the tilt of the optical disc 3 so as to be perpendicular to the direction of the optical axis of the laser light, is responsive to the contents of

measurement of the optical pickup 2 to cause the reflecting surface of the optical disc 3 to be tilted at a certain angle with respect to the direction of the optical axis of the laser light. For example, the control circuit 11 causes the rotational axis of the optical disc 3 to be tilted in a plane defined by the optical axis x of the laser light and the center o of the optical disc 3, as shown in Fig.7, so that the reflecting surface of the optical disc 3 is tilted at a pre-set angle θ_1 in the radial direction. Also, the rotary axis of the optical disc 3 is tilted in a plane perpendicular to the plane defined by the optical axis x of the laser light and the center o of the optical disc 3, as shown in Fig. 8, so that the reflecting surface of the optical disc 3 is tilted at a pre-set angle θ_2 in the tangential direction. Meanwhile, the laser light shown in Fig.8 is illuminated on a track of the optical disc 3 without being illuminated on the center o of the optical disc 3.

The control circuit 11 is fed with output signals A to F, as outputs of the photodetectors A to F of the optical pickup 2, binary signals of the RF signals, binary-coded by the playback signal processing circuit 10, and with the associated clock signals, to perform measurement of the characteristics of the optical pickup 2 based on these signals. The measured results are fed to an output device, such as a monitor, via a terminal 12.

The processing for measuring characteristics of the optical pickup 2 by the present apparatus 1 for measuring characteristics of the optical pickup is hereinafter explained.

The apparatus 1 for measuring characteristics of the optical pickup measures

the following items to investigate into characteristics of the optical pickup:

- i) RF signal level;
- ii) TE signal level (EF level);
- iii) amount of jitter of the RF signal; and
- iv) difference.

The processing contents of the control circuit 11 in each of the measurement items are as follows:

Measurement of RF Signal Level

The control circuit 11 converts the signals A to D supplied from the optical pickup 2 into digital data. The control circuit 11 then calculates the sum of the signals A to D and calculates the voltage of ac components from the sum to find the RF signal level.

The control circuit 11 sequentially changes the tilt of the optical disc in the radial direction from 0° (tilt with which the optical axis of the laser light intersects the reflecting surface of the optical disc 3 at a right angle) to find the level of the RF signals in each tilt to plot the measured values on a graph.

The control circuit 11 pre-sets the lower limit value of the RF signal level. If the measured RF signal level falls below the lower limit value, the control circuit 11 halts the measurement, or reverses the tilt in the radial direction to continue the measurement.

Measurement of the TE Signal Level

The control circuit 11 converts the signals E and F supplied from the optical pickup 2 into digital data, and then calculates the difference between the signals E and F to calculate the voltage of the ac components to find the TE signal level.

The control circuit 11 sequentially changes the tilt in the tangential direction of the optical disc from 0° (tilt with which the optical axis of the laser light intersects the reflecting surface of the optical disc 3 at a right angle) to find the level of the TE signals in each tilt to plot the measured values on a graph.

The control circuit 11 pre-sets the lower limit value of the TE signal level. If the measured TE signal level falls below the lower limit value, the control circuit 11 halts the measurement, or reverses the tilt in the tangential direction to continue the measurement.

It is assumed that the lower limit value of the TE signal level is 9 mV. If the measured values of the TE signal level of the optical pickup with respect to the tilt in the tangential direction of the optical disc 3 are plotted on a graph, the results are as shown in Fig.9.

It is also possible for the control circuit 11 to change the tilt of the optical disc from 0° in the radial direction to find the level of the TE signal in each tilt to plot the measured values on a graph.

The control circuit 11 also pre-sets the lower limit value of the TE signal level. If the measured TE signal level falls below the lower limit value, the measurement is halted, or the tilt in the radial direction is reversed to continue the measurement.

It is assumed that the lower limit value of the TE signal level is 8 mV. If the measured values of the TE signal level, with respect to the tilt in the radial direction of an optical disc, are plotted on a graph, the result is as shown in Fig.10.

Measurement of Jitter

The control circuit 11 finds the binary-valued signal supplied from the playback signal processing circuit and edge component of the clock signals to find the phase difference between the binary-valued signal and the clock signals. The control circuit 11 then measures the average values and the maximum values of the jitter from the phase difference.

The control circuit 11 sequentially changes the tilt of the optical disc 3 in the tangential direction from 0° (tilt with which the optical axis of the laser light intersects the reflecting surface of the optical disc 3 at a right angle) to find the amount of jitter in each tilt to plot the measured values on a graph.

The control circuit 11 also pre-sets the upper limit value of the amount of jitter. If the measured jitter becomes not less than the upper limit value, the measurement is halted, or the tilt in the tangential direction is reversed to continue the measurement.

It is assumed that the upper limit value of the amount of jitter is 15 ns. If the measured values of the jitter, with respect to the tilt in the radial direction of an optical disc 3, are plotted on a graph, the result is as shown in Fig.11.

It is also possible for the control circuit 11 to change the tilt of the optical disc from 0° in the radial direction to find the jitter in each tilt to plot the measured values

on a graph.

The control circuit 11 also pre-sets the lower limit value of the TE signal level. If the measured TE signal level exceeds the upper limit value, the measurement is halted, or the tilt in the radial direction is reversed to continue the measurement.

It is assumed that the upper limit value of the jitter is 15 ns. If the measured values of the jitter of the optical disc, with respect to the tilt in the radial direction of the optical disc, shown in Table 1, are plotted on a graph, the result is as shown in Fig.12.

Table 1

tilt in radial direction (°)	-1.2	-0.9	-0.6	-0.3	0	0.3	0.6	0.9	1.2
jitter (ns)		17	10	5.5	4	6	11	16.5	

Amount of Difference

It is possible with the control circuit 11 to measure the RF signal level, TE signal level and the difference of the jitter and to provide a limit value for the difference to halt the measurement or continue the measurement in the reverse direction. This difference means the difference between certain measured data and data measured directly before this measured data.

If, in measuring the jitter, the difference of this jitter is to be found, processing is performed in the following manner.

First, the control circuit 11 finds the difference between the jitter measured for a certain tilt of an optical disc and the jitter immediately previous to this tilt.

It is also possible for the control circuit 11 to change the tilt of the optical disc from 0° in the radial direction to find the jitter difference in each tilt to plot the measured values on a graph.

The control circuit 11 also pre-sets the upper limit value of the difference. If the measured TE signal level exceeds the upper limit value, the measurement is halted, or the tilt in the radial direction is reversed to continue the measurement.

It is assumed that the upper limit value of the difference is 5 ns. The measured values of the difference of a certain optical pickup, with respect to the tilt in the radial direction of an optical disc 3, are as shown in the following Table 2.

Table 2

tilt in the radial direction ($^\circ$)	-1.2	-0.9	-0.6	-0.3	0	0.3	0.6	0.9	1.2
jitter (ns)		17	10	5.5	4	6	11	16.5	
difference		7	4.5	1.5		2	5	5.5	

With the apparatus 1 for measuring characteristics of the optical pickup 2, the upper or lower limit values are set to those which will not cause disengagement of the servo loop. This enables the apparatus 1 for measuring characteristics of the optical pickup to measure the characteristics automatically, while there is no risk that the measurement cannot be continued due to disengagement of the servo loop.

It is noted that the values exceeding the limit values are offset significantly from the graph values and are not the information necessary for the apparatus 1 for measuring characteristics of the optical pickup in analyzing the tolerances of the

respective characteristics. Therefore, the tolerance values can be analyzed if these values are precluded.

For example, analysis of Fig.9 indicates that the tolerance of the tilt in the tangential direction of the optical disc which permits detection of the FE level is -1.0 to $+1.5^\circ$, while analysis of Fig.10 indicates that the tolerance of the tilt in the radial direction of the optical disc which permits detection of the FE level is -0.7 to $+1.0^\circ$. Also, analysis of Fig.11 indicates that the tolerance of the tilt in the tangential direction of the optical disc for the amount of jitter is -1.7 to $+0.8^\circ$, while analysis of Fig.12 indicates that the tolerance of the tilt in the radial direction of the optical disc for the amount of jitter is -0.5 to $+1.3^\circ$.

With the apparatus 1 for measuring characteristics of the optical pickup, as described above, there is no risk of disengagement of the optical pickup to permit the range of measurement to be automatically determined to measure the characteristics.



WHAT IS CLAIMED IS:

1. An apparatus for measuring characteristics of an optical pickup, in which laser light is illuminated on an optical disc to detect the reflected light to detect the information recorded on the optical disc to measure the characteristics of the optical pickup, comprising:

control means for halting a processing of measurement of the characteristics of the optical pickup that are changed during the measurement in dependence upon pre-set parameters, or for reversing the direction of changes in said pre-set parameters, if, during said measurement, the results of measurement exceed or falls below a pre-set upper limit value.

2. A method for measuring characteristics of an optical pickup, in which laser light is illuminated on an optical disc to detect the reflected light to detect the information recorded on the optical disc to measure the characteristics of the optical pickup, comprising:

halting a processing of measurement of the characteristics of the optical pickup that are changed during the measurement in dependence upon pre-set parameters, or for reversing the direction of changes in said pre-set parameters, if, during said measurement, the results of measurement exceed or falls below a pre-set upper limit value.