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## SPECIFICATION

### OPTICAL DISC RECORDING AND REPRODUCING APPARATUS

#### Field of the Invention

The present invention relates to an optical disc recording and reproducing apparatus having at least either a function of recording information on an optical disc or a function of reproducing information recorded on the optical disc, and in particular, to an optical disc recording and reproducing apparatus capable of more effective tracking control.

#### Background of the Invention

Tracking control in a conventional optical disc recording and reproducing apparatus will be described with reference to FIG. 7. As shown in FIG. 7, this optical disc recording and reproducing apparatus is comprised of an optical disc 1, a spindle motor 2 for rotating the optical disc 1, an optical pickup 5 having a tracking actuator 4 capable of moving an objective lens 3 in a radial direction of the optical disc 1, to record and reproduce signals on and from the optical disc 1, a tracking drive section 6 for driving the tracking actuator 4, a tracking error signal generating section 7 for generating a tracking error signal a from a photodetector signal from the optical pickup 5, and a tracking control section 8 for determining a gain, a frequency

characteristic, and a phase characteristic required for continuous tracking on the optical disc 1.

Here, a tracking control operation of this optical disc recording and reproducing apparatus will be described below. In the state where the optical disc 1 is rotated by the spindle motor 2, the optical disc 1 is irradiated with laser light for recording/reproduction which is controlled to focus on the optical disc 1. The tracking error signal generating section 7 generates the tracking error signal a based on a photodetector signal from the optical pickup 5. Based on the tracking error signal a, the tracking control section 8 supplies the tracking actuator 4 of the optical pickup 5 with a signal having a gain, a frequency characteristic, and a phase characteristic required for continuous tracking on the optical disc 1, thereby controlling the tracking drive section 6 to perform a tracking operation.

In such an optical disc recording and reproducing apparatus, decentering of the optical disc, decentering occurring when the optical disc is chucked onto a drive motor, an axial offset of the motor, or the like may cause a focus controlled optical spot to trace across different tracks instead of a same track.

The tracking error signal a, which is generated under the above conditions, is shown in FIG. 8(a). As shown in FIG. 8(b), when a center line is an optical spot on the same track, the optical spot traces positions on the disc which are

vertically offset from the center line. FIGS. 8(a) and (b) are interrelated.

With the above eccentricity existing, if the on-the-track target is a spiral track of the optical disc 1, which is rotated by the spindle motor 2, it is disadvantageously impossible to determine with which of the timings in FIG. 8(b) the on-the-track operation is performed. That is, the on-the-track operation is randomly performed, and an on-the-track position on the disc will be an arbitrary one on the disc trace shown in FIG. 8(b). A drive signal received by the tracking actuator 4 immediately before the on-the-track operation is free from control if the disc is placed horizontally, so that operations required to maintain the subsequent tracking control of the tracking actuator 4 significantly vary depending on the on-the-track position on the disc.

If, for example, tracking control is turned on at a central position of an eccentricity range of the optical disc 1, then the on-the-track operation is performed at a point of time corresponding to a shorter period of the tracking error signal a as shown in FIG. 9(a), and the tracking actuator 4 is positioned by using a central portion of its movement range as a reference position, as shown in FIG. 9(b). Then, the tracking actuator 4 is moved depending on the amount of eccentricity of track to maintain the on-the-track state in a fashion following the eccentricity of the optical disc 1. In this case, the tracking actuator 4 moves around the central

position of its movement range over a distance corresponding to the amount of eccentricity, thereby achieving an appropriate tracking state.

If, however, tracking control is turned on at a maximum displacement position of the optical disc 1, then the on-the-track operation is performed at a point of time corresponding to a longer period of the tracking error signal a as shown in FIG. 10(a), and the tracking actuator 4 is positioned using as a reference position a position distant from the center of its movement range, as shown in FIG. 10(b). Then, the tracking actuator 4 is moved around this position depending on the amount of eccentricity, thereby maintaining the on-the-track state in a fashion following the eccentricity of the optical disc 1. In this case, the tracking actuator 4 moves around the position distant from the center of its movement range over a distance corresponding to the amount of eccentricity, so that the tracking actuator 4 is substantially displaced at a point A, shown in FIG. 10(b), resulting in an unstable tracking state to reduce the accuracy of the tracking error signal. In addition, if tracking control is turned on at a minimum displacement position of the optical disc 1, the displacement of the tracking actuator 4 can also be assumed to increase, thereby disadvantageously diminishing the accuracy of the tracking error signal.

Thus, it is contemplated that the movement range of the tracking actuator 4 may be increased to obtain a stable tracking performance, but it is extremely difficult in terms

of optics, mechanics, and assembly accuracy to increase the movement range to the extent that a stable tracking performance can be obtained. Another problem is that the accuracy of the tracking error signal decreases according as  
5 the distance from the center of the movement range increases.

It is an object of the present invention to provide an optical disc recording and reproducing apparatus that improves the accuracy and stability of tracking control for  
10 an eccentric disc.

#### Summary of the Invention

An optical disc recording and reproducing apparatus  
15 according to the present invention is provided with control means for starting tracking control by positioning the center of a movement range of a tracking actuator exactly or substantially at the center of an eccentricity range caused by disc rotations.

Advantageously, a displacement arising from the eccentricity of a tracking actuator is substantially minimized to enable the movement range of the tracking actuator to be placed within a stable tracking control range, thereby improving the accuracy and stability of  
25 tracking control for an eccentric disc.

The present invention provides an optical disc recording and reproducing apparatus comprising:

a tracking actuator for performing a tracking operation for an optical disc;

30 a tracking control section for driving said tracking actuator to perform a tracking operation based on a tracking error signal detected from the optical disc; and

control means for starting tracking control by positioning the center of a movement range of said tracking actuator exactly or substantially at the center of an eccentricity range caused by disc rotations, wherein said  
5 control means measures a period of tracking error signal originating from an eccentric error associated with disc rotations and detects a change timing corresponding to a neighborhood of a minimum value of the measured period to provide such a control as to close a loop of a tracking  
10 control system at a point of time indicated by said detected timing.

Thus, tracking control can be constantly stably turned on at the central position of the disc eccentricity, thereby enabling stable tracking control within a small movement  
15 range of the actuator to improve the accuracy and stability of the tracking control for an eccentric disc.

Advantageously, stable tracking control can be provided within a small movement range of the actuator to improve the accuracy and stability of the tracking control for an  
20 eccentric disc.

Preferably, the control means comprises: a cross-track generating circuit for generating a cross-track signal for a track error signal having a periodicity that provides synchronism with rotation of a motor for rotating the optical disc; measuring means for measuring a period of the cross-track signal; detection means for detecting a neighborhood of a minimum value of the period; and a tracking timing generating circuit for commanding the tracking control section to start the tracking operation at a point of time corresponding to the neighborhood of the minimum value of the period. Thus, the control means is capable of stable tracking control.

Preferably, generation means is provided for generating a rotation synchronizing signal in synchronism with rotation of the motor for rotating the optical disc, and wherein the control means is configured to comprise measuring the period of a tracking error signal arising from an eccentric error associated with disc rotations; detecting correlations between measured positions of maximum and minimum values of the period and a position at which the rotation synchronizing signal is generated, and storing these correlations in a memory; and closing the loop of the tracking control system at a point of time corresponding to the neighborhood of the minimum value of the period, based on a counted number from a measuring reference point of the rotation synchronizing

signal. As described above, the displacement stemming from eccentricity of the tracking actuator is substantially minimized, and tracking control can also be turned on at the central position of disc eccentricity based on the counted number from the measuring reference point of the rotation synchronizing signal, thereby enabling stable tracking control within a small movement range of the actuator. In particular, if the same disc remains installed without being removed, the second and subsequent tracking control operations can be performed by generating and outputting a tracking timing signal based on the stored count value. This configuration can achieve stable tracking control and prevent repeated execution of the process of detecting the correlations between the measured positions of the maximum and minimum values of the period of the tracking error signal and the position at which the rotation synchronizing signal is generated and of storing these correlations in a memory.

#### Brief Description of the Drawings

FIG. 1 is a block diagram showing the configuration of an optical disc recording and reproducing apparatus according to Embodiment 1 of the present invention;

FIG. 2 is a block diagram showing the configuration of a minimum eccentricity detecting section according to Embodiment 1;

FIG. 3 is a diagram showing a signal waveform and data concerning essential parts of tracking control according to Embodiment 1;

FIG. 4 is a flowchart showing a process operation of a minimum eccentricity detecting section according to Embodiment 1;

FIG. 5 is a block diagram showing the configuration of an optical disc recording and reproducing apparatus according to Embodiment 2 of the present invention;

FIG. 6 is a diagram showing a signal waveform and data concerning essential parts of tracking control according to Embodiment 2;

FIG. 7 is a block diagram showing the configuration of a conventional optical disc recording and reproducing apparatus;

FIG. 8 is a diagram showing a trace of an optical spot on a disc observed when rotation of an optical disc is decentered;

FIG. 9 is a diagram showing a movement of an actuator observed when a tracking operation is started at an appropriate position; and

FIG. 10 is a diagram showing a movement of the actuator observed when a tracking operation is started at an unstable position.

Description of the Embodiments

An optical disc recording and reproducing apparatus according to the present invention will be described based on specific embodiments.

(Embodiment 1)

An optical disc recording and reproducing apparatus according to Embodiment 1, shown in FIG. 1, has a tracking actuator 4 for performing a tracking operation for an optical disc 1, and a tracking control section 8 for driving the tracking actuator 4 to perform an tracking operation based on a tracking error signal a detected from the optical disc 1, similarly to the above conventional example, but differs therefrom in that an minimum eccentricity detecting section 9 is provided which controls a central position of a movement range of the tracking actuator 4 exactly or substantially to the center of an eccentricity range caused by disc rotations.

As shown in FIG. 2, the minimum eccentricity detecting section 9 is comprised of a cross-track signal generating circuit 10 for generating a cross-track signal for a tracking error signal a having a periodicity that provides synchronism with rotation of a spindle motor 2 for rotating the optical disc 1, a cross-track period measuring circuit 11 acting as measuring means for measuring a period of the cross-track signal, a measured period minimum value detecting circuit 15 acting as detection means for detecting a neighborhood of a minimum value of the period, and a tracking timing generating circuit 17 for commanding the tracking control section to perform the tracking operation at a point of time

corresponding to a neighborhood of the minimum value of the period.

The operation of this optical disc recording and reproducing apparatus will be described below.

To move an optical spot on the optical disc 1 at a certain linear speed, the optical disc 1 allowing the recording and reproduction of laser light for reproduction/recording which is controlled to focus on the optical disc 1, the spindle motor 2 is used to rotate the optical disc 1. During rotations, the optical disc 1 is irradiated with the focus-controlled laser light. The optical spot on the optical disc 1 is focused on and received by a photodetector of an optical pickup 5.

The tracking error signal generating section 7 generates the tracking error signal a based on a photodetector signal from the optical pickup 5 to output it to the tracking control section 8 and the minimum eccentricity detection section 9. The tracking error signal a has such a waveform as shown in FIG. 3(a) due to disc decentering.

The operation of the minimum eccentricity detecting section 9 will be explained with reference to an eccentricity detecting process flowchart, shown in FIG. 4.

Based on the tracking error signal a, the cross-track generating circuit 10 generates such a cross-track signal as shown in FIG. 3(b), via a comparator or the like at a certain threshold. The cross-track signal has the same period as the tracking error signal a and is composed, for example, of a

binary digital signal represented by "0" and "1" for easy digital processing.

The cross-track period measuring circuit 11 uses a counter to measure a period of the cross-track signal generated by the cross-track signal generating circuit 10. Specifically, a rising and falling edges of the cross-track signal and a reference frequency generator for generating a high frequency sufficient to measure the period of the cross-track signal are used so that the counter or the like is used to determine how many pulses from the reference frequency generator are measured between these edges. This corresponds to step S1, shown in FIG. 4. The period of the cross-track signal is measured as shown in FIG. 3(c). FIGS. 3(a) to (d) are illustrated on the same time scale.

A circuit for determining if a measured period value exceeds a set-value, 12, determines whether the period measured by the cross-track period determining circuit 11 exceeds an externally set value. This corresponds to step S2, shown in FIG. 4. When it is detected at step S2 that the measured period is larger than the set value, the process determines a reference point P1, shown in FIG. 3(c), without branching to step S3.

A measured period equal to a maximum value determining circuit 13 determines whether the period measured by the cross-track period measuring circuit 11 has a maximum value. This corresponds to step S3, shown in FIG. 4.

If it is not detected at step S2 that the measured period exceeds the set value, then at step S3, a maximum value of the measured period is determined to obtain the reference point P1 shown in FIG. 3(c) as described above.

A measured period direction detecting circuit 14 detects whether the period being measured by the cross-track period measuring circuit 11 is increasing or decreasing. This corresponds to step S4, shown in FIG. 4. It is detected whether the period measured after the reference point P1 is decreasing, that is, the frequency is increasing. Specifically, the measured value is stored in a storage device or the like n times to determine, n times, whether the period decreases as the time elapses.

The measured period minimum value detecting circuit 15, determines whether the period measured by the cross-track period measuring circuit 11 has a minimum value. This corresponds to step S5, shown in FIG. 4. It is determined whether the period measured after the reference point P1 exhibits the minimum value. The minimum value of the period corresponds to a maximum value of the frequency, and the start of a decrease in frequency means the passage of the minimum value of the period. Despite a small amount of elapsed time, a point P2 corresponds to the minimum value of the period as shown in FIG. 3.

A measured time managing circuit 16 measures and manages the time after the start of operation of the measuring/determining/detecting circuit in the circuit 12 for

determining if the measured period exceeds the set-value, the measured period maximum value detecting circuit 13, the measured-period direction detecting circuit 14, and the measured period minimum value detecting circuit 15.

The tracking timing generating circuit 17 outputs a tracking timing signal to the tracking control section 8 at a point P2, shown in FIG. 3(c). This corresponds to step S6, shown in FIG. 4.

At the point P2 shown in FIG. 3(c), the tracking control section 8 outputs a signal to the tracking drive section 6 so as to position the tracking actuator 4 for tracking.

Based on the signal from the tracking control section 8, the tracking drive section 6 supplies the tracking actuator 4 of the optical pickup 5 with a signal having a gain, a frequency characteristic, and a phase characteristic required for continuous tracking on the disc. In this manner, a loop of a tracking control system is closed.

In this manner, tracking is carried out for the timing at the point P2 shown in FIG. 3(c), so that tracking control is turned on at a central position of an eccentricity range of the optical disc 1. Thus, a tracking operation is performed at a point of time corresponding to a shorter period of the tracking error signal a as shown in FIG. 9(a), and the tracking actuator 4 is positioned using a central position of its movement range as a reference position as shown in FIG. 9(b) and the tracking actuator 4 is moved depending on the amount of eccentricity of the track, thereby maintaining the

tuned-on state of the track in a fashion following the eccentricity of the optical disc 1. Accordingly, the tracking actuator 4 can maintain an appropriate tracking state because it is moved around the central position of its movement range over a distance corresponding to the amount of the eccentricity.

With this configuration, the tracking control can be constantly stably turned on at the central position of the disc eccentricity, thereby enabling stable tracking control within a small movement range of the actuator to improve the accuracy and stability of the tracking control for an eccentric disc.

(Embodiment 2)

An optical disc recording and reproducing apparatus according to Embodiment 2, shown in FIG. 5, differs from the optical disc recording and reproducing apparatus according to the above Embodiment 1 in that generation means 18 is provided for generating a rotation synchronizing signal  $\phi$  in synchronism with rotation of the spindle motor 2, which acts as a motor for rotating the optical disc 1 and in that a minimum eccentricity detecting section 19, acting as control means, has, in addition to the functions of minimum eccentricity detecting section 9 according to the above Embodiment 1, functions to detect correlations between measured positions of maximum and minimum values of a period of the tracking error signal arising from an eccentric error associated with disc rotations and a position at which the rotation synchronizing

signal b is generated, to store these correlations in a memory and to close the loop of the tracking control system at the point of time corresponding to the neighborhood of the minimum value of the period, based on a count number from the reference point P1, which is used as a measuring reference point of the rotation synchronizing signal b.

The generation means 18 comprises an FG (Frequency Generator) sensor 18a for obtaining a rotation signal for the spindle motor 2 and a spindle rotation synchronizing signal generating section 18b for generating a rotation synchronizing signal b such as that in FIG. 6(e), which synchronizes with rotation of the spindle motor 2 generated by the FG sensor 18a.

The operation of this optical disc recording and reproducing apparatus will be explained.

The tracking error signal a shown in FIG. 6(a), the cross-track signal shown in FIG. 6(b), and the period data shown in FIG. 6(c) are generated as in the above Embodiment 1, and detailed description thereof is thus omitted.

As in the above Embodiment 1, the maximum value of the period of the cross-track signal shown in FIG. 6(b) is detected or the reference point P1 is detected by determining whether the measured period exceeds the set value, thereby detecting the point P2 corresponding to the neighborhood of the minimum value of the period.

This embodiment stores the position of the rotation synchronizing signal b generated by the spindle rotation

synchronizing signal generating section 18b upon the detection of the point P2. In storing the position of the rotation synchronizing signal b, the count value and the disc position can be correlated with each other by setting a pulse position of an arbitrary initial rotation synchronizing signal as a reference point (for example, the reference point P1) and employing for counting a counter that uses the number of pulses per rotation as an upper limit. The storage of the position of the rotation synchronizing signal b corresponds to storage of the count value of the rotation synchronizing signal b up to the position of the point P2 in a storage device such as a RAM (Random Access Memory) which acts as the memory. FIG. 6 shows a waveform of about one rotation period.

Consequently, the period data shown in FIG. 6(c) has two minimum period values. These are the count value of the point P2, which is a minimum period value, and the count value of a point P3 that is the next minimum period value and that is separate from the first minimum period value by 1/2 rotation pulse. The second count value is arithmetically determined and when the determined count value becomes equal to the count value being measured, the tracking timing signal shown in FIG. 6(d) is generated and output to the tracking control section 8. After the tracking timing signal has been output, the tracking operation is performed to close the loop of the tracking control system as in the above Embodiment 1.

With this configuration, similar effects to those in Embodiment 1 described above can be obtained even based on

the counted number from the reference point P1 of the rotation synchronizing signal b, tracking control can be constantly stably turned on at the central position of the disc eccentricity, thereby enabling stable tracking control within a small movement range of the actuator to improve the accuracy and stability of tracking control for the eccentric disc.

Further, since this embodiment stores the count values corresponding to the two minimum period values appearing during one rotation as shown in FIG. 6(c), if the same disc remains installed without being removed, the second and subsequent tracking control operations can be performed by generating and outputting the tracking timing signal shown in FIG. 6(d) based on one of the stored count values without the need to detect the period of the tracking error signal a. This configuration can achieve stable tracking control and prevent repeated execution of the process of detecting the correlations between the measured positions of the maximum and minimum values of the period of the tracking error signal a and the position at which the rotation synchronizing signal b is generated, and of storing these correlations in the memory.

In addition, this optical disc recording and reproducing apparatus according to Embodiment 2 has an excellent effect of accurately carrying out tracking control even under extraneous vibration or the like. Specifically, when this apparatus is vibrated, the tracking actuator 4 is also

vibrated to vary the tracking error signal  $\underline{a}$ ; that is, an element (vibration) other than the eccentric components associated with disc rotations is added to the tracking error signal  $\underline{a}$ , resulting in incorrect tracking control. If, however, the first tracking control has been executed without any adverse effects of vibration and this apparatus is vibrated during the second and subsequent tracking control of the same disc, the tracking operation can be accurately performed without being adversely affected by the vibration.

As described above, the optical disc recording and reproducing apparatus comprises the control means for starting tracking control by positioning the center of the movement range of the tracking actuator exactly or substantially at the center of the eccentricity range caused by disc rotations. Thus, tracking control can be constantly stably turned on at the central position of disc eccentricity, thereby enabling stable tracking control within a small movement range of the actuator to improve the accuracy and stability of tracking control for an eccentric disc.

Similar effects can be obtained if the control means is configured to measure the period of the tracking error signal arising from an eccentric error associated with the disc rotations and to detect the change timing corresponding to the neighborhood of the minimum value of the measured period to provide such control as closes the loop of the tracking control system at the point of time indicated by the detected timing.

In addition, the control means is comprised of the cross-track generating circuit for generating the cross-track signal for the tracking error signal having a periodicity that provides synchronism with rotation of the motor for rotating the optical disc, the measuring means for measuring the period of the cross-track signal, the detection means for detecting the neighborhood of the minimum value of the period, and the tracking timing generating circuit for commanding the tracking control section to start the tracking on operation at the point of time corresponding to the neighborhood of the minimum value of the period. Thus, the control means is capable of stable tracking control.

According to the present invention, the generation means is provided for generating the rotation synchronizing signal in synchronism with rotation of the motor for rotating the optical disc, and the control means is configured to measure the period of the tracking error signal arising from an eccentric error associated with the disc rotations, to detect the correlations between the measured positions of the maximum and minimum values of the period and the position at which the rotation synchronizing signal is generated, to store these correlations in the memory, and to close the loop of the tracking control system at the point of time corresponding to the neighborhood of the minimum value of the period, based on the counted number from the measuring reference point of the rotation synchronizing signal. In this case, even based on the counted number from the measuring

reference point of the rotation synchronizing signal, the tracking control can be constantly stably turned on at the central position of the disc eccentricity, thereby realizing stable tracking control within a small movement range of the actuator. In particular, if the same disc remains installed without being removed, the second and subsequent tracking control operations can be performed by generating and outputting a tracking timing signal based on the stored count value. This configuration can achieve stable tracking control and prevent repeated execution of the process of detecting the correlations between the measured positions of the maximum and minimum values of the period of the tracking error signal and the position at which the rotation synchronizing signal is generated, and of storing these correlations in a memory.

THE CLAIMS:

1. An optical disc recording and reproducing apparatus comprising:

5 a tracking actuator for performing a tracking operation for an optical disc;

a tracking control section for driving said tracking actuator to perform a tracking operation based on a tracking error signal detected from the optical disc; and

10 control means for starting tracking control by positioning the center of a movement range of said tracking actuator exactly or substantially at the center of an eccentricity range caused by disc rotations, wherein said control means measures a period of tracking error signal  
15 originating from an eccentric error associated with disc rotations and detects a change timing corresponding to a neighborhood of a minimum value of the measured period to provide such a control as to close a loop of a tracking control system at a point of time indicated by said detected  
20 timing.

2. An optical disc recording and reproducing apparatus according to claim 1, wherein said control means comprises:

a cross-track generating circuit for generating a cross-  
25 track signal for a track error signal having a periodicity that provides synchronism with rotation of a motor for rotating the optical disc;

measuring means for measuring a period of said cross-track signal;

30 detection means for detecting a neighborhood of a minimum value of said period; and

a tracking timing generating circuit for commanding the

tracking control section to start the tracking operation at a point of time corresponding to the neighborhood of the minimum value of said period.

5 3. The optical disc recording and reproducing apparatus according to claim 1, further comprising generation means for generating a rotation synchronizing signal in synchronism with rotation of the motor for rotating the optical disc,

10 wherein said control means is configured to comprise:  
measuring the period of a tracking error signal arising from an eccentric error associated with disc rotations; detecting correlations between measured positions of maximum and minimum values of said period and a position at which  
15 said rotation synchronizing signal is generated, and storing these correlations in a memory; and closing the loop of the tracking control system at a point of time corresponding to the neighborhood of the minimum value of said period, based on a counted number from a measuring reference point of said  
20 rotation synchronizing signal.