

DESCRIPTION

METHOD AND APPARATUS OF MULTIBEAM OPTICAL DISC READOUT

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical disc read apparatus and method, and more particularly to an optical disc read apparatus and method in which different light beams are applied at the same time to a plurality of adjacent tracks of an optical disc formed with a spiral track, such CD-ROM, CD-WO, DVD, DVD-ROM, and DVD-RAM, and data recorded on the tracks applied with the light beams are read with a record data read system in accordance with a detected output of each reflected light beam.

2. Description of the Related Art

A multibeam method is one of the methods of reading record data from a CD-ROM at high speed. With this method, different light beams are applied at the same time to a plurality of adjacent tracks of an optical disc formed with a spiral track, data recorded on the tracks applied with the light beams are read with a record data read system in accordance with a detected output of each reflected light beam, and the read data are sequentially output in the

record order by preventing the read data from being duplicated or omitted.

A multibeam method of reading an optical disc (CD-ROM) will be described with reference to Fig. 21. Reference numeral 1 represents an optical disc (CD-ROM) as viewed toward a signal plane (from an optical pickup side), CD-ROM being formed with a spiral track recorded with data (the outer and inner circumference sides of CD-ROM are indicated by arrows in Fig. 21). Reference numeral 2 represents an optical pickup capable of radiating five light beams, the optical pickup 2 being provided with a relative rotation to CD-ROM 1 and moved from the inner circumference to outer circumference as record data read advances. As the optical pickup 2 reaches a position I and starts reading record data, light beams 3_1 to 3_5 are applied at the same time to respective tracks $(x-1)$ to $(x+3)$ and data recorded on the tracks applied with the light beams 3_1 to 3_5 are read with a record data read system in accordance with a detected output of each reflected light beam.

Record data of CD-ROM 1 is formed on the basis of one frame unit (one frame = $1/75$ sec) represented by A-time (Absolute-time) of a sub-code Q channel, in conformity with the CD signal format. As the optical pickup 2 starts reading data from the position I shown in Fig. 21, the optical beam 3_1 system correctly reads record data from the

frame of A-time = 23:40:59 or 23 minutes, 40 seconds, 59 frames, the optical beam 3₂ system correctly reads record data from the frame of A-time = 23:40:74, the optical beam 3₃ system correctly reads record data from the frame of A-time = 23:41:14, the optical beam 3₄ system correctly reads record data from the frame of A-time = 23:41:29, and the optical beam 3₅ system correctly reads record data from the frame of A-time = 23:41:44.

As CD-ROM 1 rotates generally once (slightly more than once) and the read position with the optical pickup 2 reaches a position II shown in Fig. 21 (the light beams 3₁ to 3₅ are applied to the tracks x to (x+4), the optical beam 3₁ correctly reads record data up to the frame of A-time = 23:40:73, the optical beam 3₂ correctly reads record data up to the frame of A-time = 23:41:13, the optical beam 3₃ correctly reads record data up to the frame of A-time = 23:41:28, and the optical beam 3₄ correctly reads record data up to the frame of A-time = 23:41:43. In this manner, there is no omission of read data by the optical beams 3₁ to 3₅ (at this time, the light beam 3₅ has correctly read record data up to the frame of A-time = 23:41:58). The data read by the optical beams 3₁ to 3₅ are output to external circuits in the record order by preventing the read data from being duplicated.

When the read position with the optical pickup 2

reaches the position II shown in Fig. 21, the optical pickup 2 is jumped forward (toward the outer circumference of CD-ROM 1) by three tracks. Namely, the optical pickup 2 is jumped to a position III shown in Fig. 21 (and the light beams 3₁ to 3₅ are applied to tracks (x+3) to (x+7)). Thereafter, data read starts again. Specifically, the optical beam 3₁ system correctly reads record data from the frame of A-time = 23:41:46, the optical beam 3₂ system correctly reads record data from the frame of A-time = 23:41:61, the optical beam 3₃ system correctly reads record data from the frame of A-time = 23:42:01, the optical beam 3₄ system correctly reads record data from the frame of A-time = 23:42:16, and the optical beam 3₅ system correctly reads record data from the frame of A-time = 23:42:31.

As CD-ROM 1 rotates generally once (slightly more than once) and the read position with the optical pickup 2 reaches a position IV shown in Fig. 21 (the light beams 3₁ to 3₅ are applied to the tracks (x+4) to (x+8), the optical beam 3₁ system correctly reads record data up to the frame of A-time = 23:41:60, the optical beam 3₂ system correctly reads record data up to the frame of A-time = 23:42:00, the optical beam 3₃ system correctly reads record data up to the frame of A-time = 23:42:15, and the optical beam 3₄ system correctly reads record data up to the frame of A-time = 23:42:30. In this manner, there is no omission of read

data by the optical beams 3_1 to 3_5 (at this time, the light beam 3_5 has correctly read record data up to the frame of A-time = 23:42:45). The data read by the optical beams 3_1 to 3_5 are output to the external circuits in the record order by preventing the read data from being duplicated.

When the read position with the optical pickup 2 reaches the position IV shown in Fig. 21, the optical pickup 2 is jumped forward (toward the outer circumference of CD-ROM 1) by three tracks. Namely, the optical pickup 2 is jumped to a position V shown in Fig. 21 (and the light beams 3_1 to 3_5 are applied to tracks $(x+7)$ to $(x+11)$). Thereafter, data read starts again. Specifically, the optical beam 3_1 system correctly reads record data from the frame of A-time = 23:42:33, the optical beam 3_2 system correctly reads record data from the frame of A-time = 23:42:48, the optical beam 3_3 system correctly reads record data from the frame of A-time = 23:42:63, the optical beam 3_4 system correctly reads record data from the frame of A-time = 23:43:03, and the optical beam 3_5 system correctly reads record data from the frame of A-time = 23:43:18.

As CD-ROM 1 rotates generally once (slightly more than once) and the read position with the optical pickup 2 reaches a position VI shown in Fig. 21 (the light beams 3_1 to 3_5 are applied to the tracks $(x+8)$ to $(x+12)$), the optical beam 3_1 system correctly reads record data up to the frame

of A-time = 23:42:47, the optical beam 3₂ system correctly reads record data up to the frame of A-time = 23:42:62, the optical beam 3₃ system correctly reads record data up to the frame of A-time = 23:43:02, and the optical beam 3₄ system correctly reads record data up to the frame of A-time = 23:43:17. In this manner, there is no omission of read data by the optical beams 3₁ to 3₅ (at this time, the light beam 3₅ has correctly read record data up to the frame of A-time = 23:43:32). The data read by the optical beams 3₁ to 3₅ are output to the external circuits in the record order by preventing the read data from being duplicated.

When the read position with the optical pickup 2 reaches the position VI shown in Fig. 21, the optical pickup 2 is jumped forward (toward the outer circumference of CD-ROM 1) by three tracks. Namely, the optical pickup 2 is jumped to a position VII shown in Fig. 21 (and the light beams 3₁ to 3₅ are applied to tracks (x+11) to (x+15)). Thereafter, data read starts again. Specifically, the optical beam 3₁ system correctly reads record data from the frame of A-time = 23:43:20, the optical beam 3₂ system correctly reads record data from the frame of A-time = 23:43:35, the optical beam 3₃ system correctly reads record data from the frame of A-time = 23:43:50, the optical beam 3₄ system correctly reads record data from the frame of A-time = 23:43:65, and the optical

beam 3₅ system correctly reads record data from the frame of A-time = 23:44:05.

As CD-ROM 1 rotates generally once (slightly more than once) and the read position with the optical pickup 2 reaches a position VIII shown in Fig. 21 (the light beams 3₁ to 3₅ are applied to the tracks (x+12) to (x+16), the optical beam 3₁ system correctly reads record data up to the frame of A-time = 23:43:34, the optical beam 3₂ system correctly reads record data up to the frame of A-time = 23:43:49, the optical beam 3₃ system correctly reads record data up to the frame of A-time = 23:43:64, and the optical beam 3₄ system correctly reads record data up to the frame of A-time = 23:44:04. In this manner, there is no omission of read data by the optical beams 3₁ to 3₅ (at this time, the light beam 3₅ has correctly read record data up to the frame of A-time = 23:44:19). The data read by the optical beams 3₁ to 3₅ are output to the external circuits in the record order by preventing the read data from being duplicated.

While the optical pickup 2 is given a relative rotation to CD-ROM 1 from the position I to the position II, the light beam 3₅ system reads the record data from the frame of A-time = 23:41:44 to the frame of A-time = 23:41:58, whereas while the optical pickup 2 is given a relative rotation to CD-ROM 1 from the position III to the

position IV, the light beam 3₁ system reads the record data from the frame of A-time = 23:41:46 to the frame of A-time = 23:41:60. Therefore, record data from the frame of A-time = 23:41:46 to the frame of A-time = 23:41:58 is duplicated. Therefore, for the record data from the frame of A-time = 23:41:46 to the frame of A-time = 23:41:58, the record data previously read with the light beam 3₅ is output and the record data read with the light beam 3₁ is discarded.

10 When the track jump is performed from the position II shown in Fig. 21, the optical pickup 2 is jumped not by four tracks, but by three tracks in order to apply the light beam 3₁ to the track (x+3) from which the record data was read with the light beam 3₅ system immediately before the track jump. If the number of jump tracks is "4", the optical pickup 2 is jumped to a position III' shown in Fig. 21, and thereafter the light beam 3₁ system reads record data from the frame of A-time = 23:41:61. Therefore, the record data in the frames of A-time = 23:41:59 and A-time = 23:41:61 still not read with the light beam 3₅ before the track jump are omitted.

Generally, high speed read of CD-ROM 1 is performed by repeating an operation of reading record data with n (n is an integer "3" or larger) light beam systems for one rotation and then making the optical pickup jump forward by

(n-2) tracks.

When a track jump is performed, the focus servo system and tracking servo system are temporarily disturbed so that record data read cannot resume until these servo systems
5 become stable.

With the conventional multibeam optical disc read method described above, if the number n of light beams is "5", it is necessary to perform a continuous read by about four rotations of CD-ROM 1 and three track jumps in order
10 to read record data from the tracks (x-1) to (x+16) shown in Fig. 21. Since a fairly long time is necessary for each track jump, it takes a long time to read data recorded in a number of tracks.

Record data read with some light beam systems may
15 become impossible because of a track pitch variation, surface vibration, center deviation and the like of CD-ROM 1. In such a case, the conventional optical disc read method of repeating an operation of reading record data with n (n is an integer "3" or larger) light beam systems
20 for approximately one rotation and then making the optical pickup jump forward by (n-2) tracks, is associated with some problem. For example, if the light beam 3₂ system shown in Fig. 21 is unable to read record data, the record data in the frames from A-time = 23:40:74 to A-time =
25 23:41:13 cannot be read during the record data read with

the optical pickup 2 by approximately one rotation from the position I shown in Fig. 21.

As the optical pickup 2 reaches the position II, the track jump by three tracks to the position III is performed. Therefore, the record data in the frames from A-time = 23:40:74 to A-time = 23:41:13 cannot be read. Also, the record data in the frames from A-time = 23:41:61 to A-time = 23:42:00 cannot be read during the record data read by approximately one rotation from the position III.

As above, a problem occurs that a user cannot acquire a portion of necessary data.

SUMMARY OF THE INVENTION

It is an object of the present invention to solve the above problem and provide an optical disc read method and apparatus capable of reading data at high speed from an optical disc.

It is another object of the present invention to provide an optical disc read method and apparatus capable of acquiring necessary data even if data read with some light beams is impossible.

It is a further object of the present invention to provide an optical disc read method and apparatus capable of efficiently reading record data from an optical disc even if data read with some light beams is impossible.

In an optical disc read method according to the invention, data recorded on tracks of an optical disc formed with a spiral track is read with a record data read system by applying different light beams $1, \dots, \underline{i}, \dots, \underline{n}$ at
5 the same time to $\underline{n}$ tracks at every $(c+1)$ -th and independently detecting the light beams reflected from the optical disc, where $\underline{c}$ is an integer of 1 or larger and $\underline{n}$ is an integer of 2 or larger, and the record data of the optical disc is read by alternately performing an operation
10 of continuously reading the record data on the tracks of the optical disc with $\underline{n}$ light beam systems and a track jump operation in a forward direction after the continuous reading operation.

The continuous reading operation may be performed
15 during approximately $(c+1)$ rotations of the optical disc, and the track jump operation jumps approximately $\{(c+1) \cdot (n-1) - 1\}$ tracks in the forward direction.

If there is a light beam system unable to read the record data of the optical disc, among the $\underline{n}$ light beam
20 systems, the record data of the optical disc may be read by alternately performing an operation of continuously reading the record data on the tracks of the optical disc with $\underline{n}$ light beam systems during approximately $(c+1)$ rotations and a track jump operation by approximately $\{(c+1) \cdot (M-1) - 1\}$
25 tracks in a forward direction after the continuous reading

operation, by using detection outputs from only M ($M < n$) adjacent record data readable light beam systems.

M is the maximum number of adjacent record data readable light beam systems among record data readable
5 light beam systems.

Alternatively, if there is a light beam system unable to read the record data of the optical disc, among the n light beam systems and if Q is 2 or larger and R is 0 or larger, where Q is the number of tracks representing a
10 distance between the innermost light beam and outermost light beam among record data readable light beam systems and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams, the record data of the
15 optical disc may be read by alternately performing an operation of continuously reading the record data on the tracks of the optical disc with the record data readable light beam systems during approximately $\{(R+1) \cdot (C+1)\}$ and a track jump operation by approximately $(Q-1)$ tracks in a
20 forward direction after the continuous reading operation with a combination of the record data readable light beam systems shows no omission of the record data of the optical disc.

The record data detected from the tracks of the
25 optical disc during the continuous reading operation may be

stored together with frame addresses, and the track jump operation may be performed when a frame address corresponding to the record data read with the i -th light beam becomes continuous with a continuous data read start frame address corresponding to the record data to be read
5 with the adjacent $(i+1)$ -th light beam.

According to another aspect of the optical disc read method of this invention, data recorded on tracks of an optical disc formed with a spiral track is read with a
10 record data read system by applying different light beams at the same time to n tracks at every $(c+1)$ -th and independently detecting the light beams reflected from the optical disc, where c is an integer of 1 or larger and n is an integer of 2 or larger; a system capable of reading the
15 record data from the optical disc is detected from n light beam systems by applying the light beams to predetermined positions of the tracks of the optical disc at a start of a continuous data reading operation and continuously reading the record data; and each light beam is set so that
20 one of the detected record data readable systems is applied to a read start track frame.

After each light beam is set so that one of the detected record data readable systems is applied to a read start track frame, the record data of the optical disc may
25 be read by alternately performing an operation of

continuously reading the record data during a predetermined number of rotations of the optical disc and a track jump operation by a predetermined number of tracks, the rotation number and the track number being determined in accordance with the number and layout of the record data readable systems.

The predetermined positions of the tracks of the optical disc may be positions more in a backward direction than the read start track frame.

10 In an optical disc read apparatus embodying the optical disc read method, record data reading means includes a memory for storing the record data obtained during the continuous reading operation and a corresponding frame address, and read control means performs the track
15 jump operation when a frame address corresponding to the record data read with the i -th light beam becomes continuous with a continuous data read start frame address corresponding to the record data to be read with the adjacent $(i+1)$ -th light beam.

20 According to the invention, since the continuous read of an optical disc is performed approximately during $(c+1)$ rotations, the number of track jumps which take a long process time can be reduced so that record data of the optical disc in a desired area can be read quickly.

25 Even if the record data cannot be read with some light

beam systems because of a track pitch variation, surface vibration, center deviation and the like of an optical disc, desired data of the optical disc can be read reliably and quickly with some or all the remaining record data
5 readable light beam systems by preventing the record data from being omitted.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a CD-ROM read apparatus
10 embodying an optical disc read method according to an embodiment of the invention.

Fig. 2 is a block diagram showing the structure of a parallel-to-serial converter shown in Fig. 1.

Fig. 3 is a diagram illustrating an example of the
15 contents of a memory shown in Fig. 2.

Fig. 4 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 5 is a diagram illustrating an example of the
20 contents of the memory shown in Fig. 2.

Fig. 6 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 7 is a diagram illustrating an example of the
25 contents of the memory shown in Fig. 2.

Fig. 8 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 9 is a diagram illustrating an example of the contents of the memory shown in Fig. 2.

Fig. 10 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 11 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 12 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 13 is a diagram illustrating an example of the contents of the memory shown in Fig. 2.

Fig. 14 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 15 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 16 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 17 is a diagram illustrating an example of the contents of the memory shown in Fig. 2.

Fig. 18 is a diagram illustrating an example of a data read operation of the CD-ROM read apparatus shown in Fig. 1.

Fig. 19 is a diagram illustrating an example of the contents of the memory shown in Fig. 2.

Figs. 20-1 and 20-2 are diagrams showing the structure of optical pickups according to another embodiment of the invention.

Fig. 21 is a diagram illustrating a multibeam optical disc read method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Next, an embodiment of the invention will be described with reference to Fig. 1.

Fig. 1 is a block diagram of a CD-ROM read apparatus embodying an optical disc read method according to an embodiment of the invention. In Fig. 1, like elements to those shown in Fig. 21 are represented by using identical reference numerals and characters.

Referring to Fig. 1, reference numeral 1 represents a CD-ROM formed with a spiral track recorded with data (the outer and inner circumference sides of CD-ROM are indicated by arrows in Fig. 1). CD-ROM 1 is rotated at a constant

linear velocity with an unrepresented spindle motor. Reference numeral 2 represents an optical pickup of a multibeam type. The optical pickup 2 applies light beams 3_1 to 3_n (n is the total number of tracks applied with light beams) at the same time to every $(c+1)$ -th tracks of CD-ROM 1, each reflected light beam is detected (received) with photodetectors PD_1 to PD_n which output photocurrents as detection signals. c is an integer of "1" or larger and n is an integer of "3" or larger. It is assumed here by way of example that $c = 1$ and $n = 5$ (refer to Fig. 4).

In the optical pickup 2, reference numeral 4 represents a laser diode for radiating a laser beam 3. Reference numeral 5 represents a grating (diffraction grating) for diffracting the laser beam to form a -2 order diffraction light beam 3_1 , a -1 order diffraction light beam 3_2 , a 0 order diffraction light beam 3_3 , a +1 order diffraction light beam 3_4 , and a +2 order diffraction light beam 3_5 . Reference numeral 6 represents a beam splitter made of two rectangular prisms glued together. Reference numeral 7 represents a collimator lens for converting each diffused light beam into a collimated light beam. Reference numeral 8 represents an objective lens for focussing the light beams 3_1 to 3_5 passed through the beam splitter 6 and collimator lens 7 onto a signal plane 1A of CD-ROM 1. Reference numeral 9 represents a focus actuator

for moving the objective lens 8 along a direction perpendicular to the signal plane A1 of CD-ROM 1 to follow a surface vibration of CD-ROM 1, in order to maintain an in-focus state of the light beam 3_1 to 3_5 relative to the
5 signal plane 1A irrespective of surface vibrations of CD-ROM 1. Reference numeral 10 represents a tracking actuator for moving the objective lens 8 along a radial direction of the signal plane A1 of CD-ROM 1 to follow a center deviation of CD-ROM 1, in order to make each light beam 3_1
10 to 3_5 correctly trace a corresponding track. The focus actuator 9 and tracking actuator 10 are independently driven by a servo circuit to be described later.

The photodetectors PD_1 to PD_5 are provided in correspondence with the light beams 3_1 to 3_5 , and each
15 outputs a photocurrent proportional to a received light amount. The light beams 3_1 , 3_2 , 3_4 , and 3_5 reflected from the signal plane A of CD-ROM 1 pass through the objective lens 8 and collimator lens 7 and are reflected by the beam splitter 6. Thereafter, they pass through an optical
20 system (not shown) including a cylindrical lens, a detector lens and the like and become incident upon the corresponding photodetectors PD_1 , PD_2 , PD_4 , and PD_5 . The photodetectors PD_1 , PD_2 , PD_4 , and PD_5 output photocurrents I_1 , I_2 , I_4 , and I_5 proportional to received light amounts, as
25 detected outputs of the respective light beams 3_1 , 3_2 , 3_4 ,

and 3₅. The photodetector PD₃ is a four-division photodiode similar to that used for an optical pickup of the ordinary one beam type, and outputs photocurrents I₃-A, I₃-B, I₃-C, and I₃-D proportional to received light amounts of
5 respective division diodes.

Reference numeral 11 represents a sled motor for moving the optical pickup 2 in the radial direction of CD-ROM 1 during a read or search operation. The sled motor is driven with the servo circuit and moves the optical pickup
10 2 to a desired position along a forward or reverse direction during the search operation, or gradually moves the optical pickup 2 along the forward direction during the read operation as the read operation of CD-ROM 1 advances.

Reference numeral 20 represents a record data read
15 system which reads at the same time the record data recorded on the tracks applied with the light beams 3₁ to 3₅, from the light reception outputs of the photodetectors PD₁ to PD₅ of the optical pickup 2, and serially outputs the read record data in the record order of CD-ROM 1 by
20 preventing the read record data from being duplicated or omitted. In the record data read system 20, current/voltage converters (I/V) 21₁, 21₂, 21₄, and 21₅ convert the photocurrents I₁, I₂, I₄, and I₅ output from the photodetectors PD₁, PD₂, PD₄, and PD₅ into RF voltage signals
25 RF₁, RF₂, RF₄, and RF₅ corresponding to the light beams 3₁,

3₂, 3₄, and 3₅ and output them. Current/voltage converters (I/V) 21₃-A, 21₃-B, 21₃-C, and 21₃-D convert the photocurrents I₃-A, I₃-B, I₃-C, and I₃-D output from the photodetector PD₃ into voltage values V_A, V_B, V_C, and V_D and
5 output them.

Reference numeral 22 represents a computation section which performs an arithmetic operation of $(V_A + V_B + V_C + V_D)$ to output an RF signal RF₃ corresponding to the light beam 3₃, an arithmetic operation of $(V_A + V_C) - (V_B + V_D)$ to
10 output a focus error signal FE, and an arithmetic operation of $(V_A + V_B) - (V_C + V_D)$ to output a tracking error signal TE. Reference numeral 23 represents the servo circuit for performing a focus servo control, a tracking servo control, and a sled servo control. In accordance with the focus
15 error signal FE, the focus actuator 9 is driven so as to make FE zero and focus the light beams 3₁ to 3₅ upon the signal plane 1A, and in accordance with the tracking error signal TE, the tracking actuator 10 is driven to make TE zero and make (on-track) the light beams 3₁ to 3₅ trace the
20 corresponding tracks.

Reference numerals 24₁ to 24₅ represent waveshape equalizers for increasing the high frequency components of the RF signals RF₁ to RF₅ to thereby compensate for high frequency attenuation to be caused by the spatial
25 transmission frequency (MTF) characteristics of the light

beams 3_1 to 3_5 and suppress the generation of inter-code interference. The RF signal RF_3 input to the waveshape equalizer 24, or the RF signal RF_3 output from the waveshape equalizer 24, is input to the servo circuit 23. The servo
5 circuit 23 activates the focus servo control upon judgement of a timing when the value of the focus error signal FE enters a negative feedback region of the focus servo control during a focus search operation. The servo circuit 23 activates the tracking servo control upon judgement of
10 a timing by using the RF signal RF_3 when the light beam 3_3 enters the negative region of the tracking servo control.

Reference numerals 26_1 to 26_5 represent first signal processing circuits for performing binarization, clock recovery using PLL circuits, bit demodulation, frame sync
15 detection, EFM demodulation, and sub-code demodulation, by using the RF signals RF_1 to RF_5 , and outputting data $DATA_1$ to $DATA_5$ (inclusive of P, Q parities) after the EFM demodulation on the basis of one block unit (unit of 98 frames completing one sub-code frame), together with
20 corresponding A-time data AT_1 to AT_5 of the sub-code Q channel. The first signal processing circuits 26_1 to 26_5 serially output the demodulated data $DATA_1$ to $DATA_5$ one symbol (8 bits) after another. Upon detection of frame sync, the first signal processing circuits 26_1 to 26_5 output
25 frame sync detection signals FS_1 to FS_5 of H level to a

system controller to be described later. These frame sync detection signals FS_1 to FS_5 are used for judging whether data can be read or not for the respective light beam 3_1 to 3_5 systems. A-time data AT_3 output from the first signal processing circuit 26_3 is also input to the system controller. The first signal processing circuit 26_3 for the RF signal RF_3 system includes a CLV control circuit (not shown) for making the frame sync signal be detected at a predetermined time interval. The CLV control circuit performs a CLV control of an unrepresented spindle motor drive circuit to rotate CD-ROM 1 at a constant linear velocity. Reference numeral 30 represents a parallel-to-serial converter (P/S) for receiving in parallel data of one block unit output from the first signal processing circuits 26_1 to 26_5 and serially outputting them in the record order by preventing the data from being duplicated or omitted. The specific structure of the P/S converter 30 is shown in Fig. 2. In Fig. 2, reference numerals 32_1 to 32_5 represent memories each having two storage areas, a first area and a second area, and provided in correspondence with a corresponding one of the first signal processing circuits 26_1 to 26_5 . The data $DATA_1$ to $DATA_5$ output from the first signal processing circuits 26_1 to 26_5 are stored in ones of the first and second areas. Each of the first and second areas has a capacity allowing the data

DATA₁ to DATA₅ of a sufficient number of block units to be stored therein. Reference numerals 33₁ to 33₅ represent memories each having two storage areas, a first area and a second area, and provided in correspondence with a
5 corresponding one of the first signal processing circuits 26₁ to 26₅. The A-time data AT₁ to AT₅ output from the first signal processing circuits 26₁ to 26₅ are stored in ones of the first and second areas, together with start addresses A_{1s} to A_{5s} (or a_{1s} to a_{5s}) and end addresses A_{1e} to A_{5e} (or a_{1e}
10 to a_{5e}) indicating the location of the corresponding data DATA₁ to DATA₅ in the memories 32₁ to 32₅. Each of the first and second areas has a capacity allowing the A-time data AT₁ to AT₅ of a sufficient number of data sets to be stored therein.

15 Reference numerals 31₁ to 31₅ represent write controllers provided in correspondence with the first signal processing circuits 26₁ to 26₅. The write controllers 31₁ to 31₅ control to write the data DATA₁ to DATA₅ output from the first signal processing circuits 26₁
20 to 26₅ in the first or second areas of the memories 32₁ to 32₅, and to write the A-time data AT₁ to AT₅ in the first or second areas of the memories 32₁ to 32₅, together with the start addresses A_{1s} to A_{5s} (or a_{1s} to a_{5s}) and end addresses A_{1e} to A_{5e} (or a_{1e} to a_{5e}) indicating the location of the
25 corresponding data DATA₁ to DATA₅ in the memories 32₁ to 32₅.

The contents of memories 32_f and 33_f (where $f = 1$ to 5) are shown in Fig. 3. In this example, a write controller 31_f controls to write 15 blocks of each set of data $DATA_f$ (1) to $DATA_f$ (30) in the first area, and to write 15 blocks of each set of data $DATA_f$ (31) to $DATA_f$ (60) in the second area. In the first area of the memory 33_f , the A-time data for each block of the data $DATA_f$ (1) to $DATA_f$ (30) are written as, for example, frames of 23:40:60 to 23:41:14, together with a start address A_{fs} (1) and an end address A_{fe} (1) to a start address A_{fs} (30) and an end address A_{fe} (30) indicating the location of the corresponding data $DATA_f$ (1) to $DATA_f$ (30) in the first area of the memory 32_f . In the second area of the memory 33_f , the A-time data for each block of the data $DATA_f$ (31) to $DATA_f$ (60) are written as, for example, frames of 23:42:48 to 23:43:02, together with a start address A_{fs} (1) and an end address A_{fe} (1) to a start address A_{fs} (30) and an end address A_{fe} (30) indicating the location of the corresponding data $DATA_f$ (31) to $DATA_f$ (60) in the second area of the memory 32_f .

Reference numeral 34 represents a read controller. With reference to the A-time data and the start addresses A_{1s} to A_{5s} (or a_{1s} to a_{5s}) and end addresses A_{1e} to A_{5e} (or a_{1e} to a_{5e}) stored in the memories 33_1 to 33_5 , the read controller 34 reads the data $DATA_1$ to $DATA_5$ stored in the

memories 33₁ to 33₅ by preventing the data from being duplicated or omitted, and serially outputs the data one symbol after another in the record order (A-time order) of CD-ROM 1. Specific operations of the write controllers 31₁ to 31₅ and read controller 34 will be later described.

Returning back to Fig. 1, reference numeral 40 represents a second signal processing circuit. The second signal processing circuit 40 receives the data serially output from the P/S converter 30, descrambles the data in the unit of one block, and thereafter demodulates Lch and Rch data in conformity with the CD-DA specification through error detection/correction based on CIRC codes (error detection/correction with P parities, deinterleaveing, error detection/correction with Q parities). The second signal processing circuit 40 then demodulates the CD-ROM data from the Lch and Rch data by performing sync detection, descrambling, header detection, and error detection/correction with EDC and ECC codes in accordance with the CD-ROM specification, and thereafter outputs the CD-ROM data to an external host computer.

Reference numeral 50 represents a system controller made of a microcomputer. For the search operation, the system controller 50 operates to supply a search command to the servo circuit 23, and to drive the sled motor 11 for the search operation to thereby move the optical pickup 2

along the forward or reverse direction of CD-ROM 1 to a desired position. For the read operation, the system controller 50 operates to supply various servo-on commands to the servo circuit 23, and to focus the light beams 3_1 to 3_5 upon the signal plane 1A of CD-ROM 1 to thereby trace the every $(c+1)$ -th tracks ($n = 5$). Each time record data is read from each track during a proper number of rotations of two or three or more, the system controller 50 supplies the servo circuit 23 with a track jump command of jumping the optical pickup by a predetermined number of tracks in the forward direction.

At the start of a read operation, the system controller 50 monitors the frame sync detection signals FS_1 to FS_5 input from the first signal processing circuits 26_1 to 26_5 , during one rotation of CD-ROM 1, to check whether or not any system of the light beams 3_1 to 3_5 cannot read record data because of a track pitch variation, surface vibration, center deviation and the like of CD-ROM 1. If all the frame sync detection signals FS_1 to FS_5 are H and there is no system unable to read record data, the system controller supplies a general read/write command to the P/S converter 30 to thereby read/write data output from the first signal processing circuit 26_1 to 26_5 to and from the memories 32_1 to 32_5 .

If the frame sync detection signal for one or a

plurality of light beams is L for a predetermined time (e.g., 1/75 sec or longer) and data cannot be read, light beams $3_1, 3_j, 3_k, \dots$ to be used for the data read are selected from the light beams 3_1 to 3_5 , and a specific
5 read/write command including read system information " $i, j, k, \dots$ " indicating the light beam systems to be used for the data read is supplied to the P/S converter 30 to thereby read/write data $DATA_1, DATA_j, DATA_k, \dots$ output from the first signal processing circuit $26_1, 26_j, 26_k, \dots$ among the first
10 signal processing circuits 26_1 to 26_5 to and from the memories 32_1 to 32_5 .

The general read/write command or specific read/write command output from the system controller 50 is input to the read controller 34 of the P/S converter 30 and
15 transferred from the read converter 34 to the write controllers 31_1 to 31_5 . Upon reception of the general read/write command at the start of the data read, the write controllers 31_1 to 31_5 control to write the data $DATA_1$ to $DATA_5$ output from all the first signal processing circuits
20 26_1 to 26_5 first in the first areas of the memories 32_1 to 32_5 . Upon reception of an intercept command from the read controller 34, the read operation is intercepted until a resume command is received, and then the data is written in the second areas. Similarly, when the intercept command is
25 received thereafter, the read operation is intercepted, and

when the resume command is received, data is written in the areas not used at the preceding time.

If the write controllers 31_1 to 31_5 receive the specific read/write command at the start of the data read, only the write controllers 31_i , 31_j , 31_k , ... indicated by the read system information " $i, j, k, \dots$ " operate to write the data $DATA_i$, $DATA_j$, $DATA_k$, ... output from the first signal processing circuits 26_i , 26_j , 26_k , ... first in the first areas of the memories 32_i , 32_j , 32_k , Upon reception of the intercept command from the read controller 34, the read operation is intercepted until the resume command is received, and then the data is written in the second areas. Similarly, when the intercept command is received thereafter, the read operation is intercepted, and when the resume command is received, data is written in the areas not used at the preceding read cycle.

After receiving the general read/write command (specific read/write command) from the system controller 50, the read controller 34 supplies the intercept command to the write controllers 31_1 to 31_5 (31_i , 31_j , 31_k , ...) and a jump command to the system controller 50, when all A-time data become continuous without omission in the areas among the memories 33_1 to 33_5 (33_i , 33_j , 33_k , ...) where data were written by the write controllers 31_1 to 31_5 (31_i , 31_j , 31_k , ...) at the present read cycle. With reference to the

A-time data and the start and end addresses stored in the areas among the memories 33_1 to 33_5 (33_i , 33_j , 33_k , ...) where data were written at the present read cycle, the read controller 34 controls to read and output record data in the order of A-time starting from the oldest A-time, relative to the data stored in the areas among the memories 33_1 to 33_5 (33_i , 33_j , 33_k , ...) where data were written at the present read cycle.

Thereafter, upon reception of a jump completion notice from the system controller 50, the read controller 34 supplies the resume command to the write controllers 31_1 to 31_5 (31_i , 31_j , 31_k , ...). Thereafter, the read controller 34 supplies the intercept command to the write controllers 31_1 to 31_5 (31_i , 31_j , 31_k , ...) and the jump command to the system controller 50, when all A-time data become continuous without omission in the areas among the memories 33_1 to 33_5 (33_i , 33_j , 33_k , ...) not used at the preceding read cycle. With reference to the A-time data and the start and end addresses stored in the areas among the memories 33_1 to 33_5 (33_i , 33_j , 33_k , ...) not used at the preceding read cycle, the read controller 34 controls to read and output record data in the order of A-time starting from the A-time next to the A-time corresponding to the one block data lastly output to the second signal processing circuit at the preceding read cycle, relative to the data stored in the areas among the

memories 33_1 to 32_5 (32_i , 32_j , 32_k , ...) not used at the preceding read cycle. Similar operations are repeated thereafter.

The operation of the embodiment will be described with reference to Figs. 4 to 19. It is herein assumed that CD-ROM 1 rotates at a constant linear velocity under CLV control and the focus servo is turned on, and that different light beams 3_1 to 3_5 are applied at the same time to every $(c+1)$ -th tracks ($n = 5$) of CD-ROM 1.

10

(1) Judgement of Unreadable System

When an unrepresented host computer designates a read start point of CD-ROM 1 as a frame having A-time, for example, 23:41:0, the system controller 50 determines the position of the track containing the read start A-time frame of CD-ROM 1, the read start point being represented by x (refer to Figs. 4, 6, 8, 10-12, 14-16, and 18). The system controller 50 first supplies the search command to the servo circuit 23 to move the optical pickup 2 so that the light beam 3_1 reaches the position of the track $(x-8)$. Thereafter, the system controller 50 supplies a tracking servo-on command and a sled servo-on command to the servo circuit 23 to activate the tracking servo and sled servo. Therefore, the light beams 3_1 to 3_5 radiated from the optical pickup 2 are focussed on the tracks $(x-8)$, $(x-6)$,

25

(x-4), (x-2) and x in an track-on state (refer to I in Figs. 4, 6, 8, 10-12, 14-16, and 18).

The light beams 3_1 to 3_5 reflected by the signal plane 1A are received by the photodetectors PD_1 to PD_5 which
5 output photocurrents I_1 to I_5 . Of these photocurrents, the photocurrents I_1 , I_2 , I_4 , and I_5 output from the photodetectors PD_1 , PD_2 , PD_4 , and PD_5 are converted into RF signals RF_1 , RF_2 , RF_4 , and RF_5 by the current-to-voltage converters 21_1 , 21_2 , 21_4 , and 21_5 which are waveshape
10 equalized by the waveshape equalizers 24_1 , 24_2 , 24_4 , and 24_5 and input to the first signal processing circuits 26_1 , 26_2 , 26_4 , and 26_5 . Photocurrents I_3 -A to I_3 -D from the photodetector PD_3 are converted into voltage values V_A to V_D by the current-to-voltage converters 21_3 -A to 21_3 -D and
15 added together by the computation section 22 to generate an RF signal RF_3 . The RF signal RF_3 is waveshape equalized by the waveshape equalizer 24_3 and input to the first signal processing circuit 26_3 .

The first signal processing circuits 26_1 to 26_5 make
20 the input RF signals RF_1 to RF_5 be subjected to binarization, clock recovery using PLL circuits, bit demodulation, frame sync detection, EFM demodulation, and sub-code demodulation, and outputs data $DATA_1$ to $DATA_5$ (inclusive of P, Q parities) after the EFM demodulation on
25 the basis of one block unit, together with corresponding A-

time data AT_1 to AT_5 of the sub-code Q channel. The first signal processing circuits 26_1 to 26_6 serially output the demodulated data $DATA_1$ to $DATA_5$ one symbol (8 bits) after another. Upon detection of the frame sync signals, the
5 first signal processing circuits 26_1 to 26_6 output the frame sync detection signals FS_1 to FS_6 of H level to the system controller 50.

After the light beams 3_1 to 3_5 from the optical pickup 2 are focussed onto the tracks $(x-8)$, $(x-6)$, $(x-4)$, $(x-2)$,
10 and x in the on-track state by the search operation, the system controller monitors the frame sync detection signals FS_1 to FS_5 input from the first signal processing circuits 26_1 to 26_6 to judge a presence/absence of a record data unreadable system, depending upon whether there is a system
15 taking the L level for a predetermined time (in this example, one block = 1/75 sec or longer) during one rotation of CD-ROM 1.

(2) General Read/write Operation (refer to Figs. 4 and 5).

20 First, the description will be given for the case wherein record data can be read with all the light beam 3_1 to 3_5 systems.

If the judgement of a presence/absence of a record data unreadable system shows that there is no record data
25 unreadable system, as the read systems of h light beams,

all the five light beams 3_1 to 3_5 are allocated. A continuous read rotation number I is set as $I = (c + 1) = 2$, and a read track jump number J is set to $J = \{(c+1) \cdot (c-1) - 1\} = 7$. In accordance with the A-time data representative of the latest A-time data AT_3 , input from the first signal processing circuit 26₃, and the read start point A-time designated by the host computer, the track jump direction and number are determined so that the light beam 3_1 at the innermost circumference among the $h = 5$ read light beams is focussed in the track-on state on the track $(x-1)$ one track inner than the track x containing the read start point of the A-time.

If the optical pickup 2 is at a position II shown in Fig. 4 after the h read light beam systems are allocated and the continuous read number I and read track jump number J are set, the optical pickup 2 is jumped from the position II by six tracks in the forward direction so that the light beams 3_1 to 3_5 are focussed in the track-on state on the tracks $(x-1)$, $(x+1)$, $(x+3)$, $(x+5)$, and $(x+7)$ (refer to III in Fig. 4). Then, reading the record data on the tracks $(x-1)$, $(x+1)$, $(x+3)$, $(x+5)$, and $(x+7)$ at the same time starts, by using five systems including the photodetector PD_1 to first signal processing circuit 26₁, photodetector PD_2 to first signal processing circuit 26₂, photodetector PD_3 to first signal processing circuit 26₃, photodetector PD_4 to

first signal processing circuit 26₄, and photodetector PD₅ to first signal processing circuit 26₅. When all the frame sync detection signals FS₁ to FS₅ are input from the first signal processing circuits 26₁ to 26₅, the general read/write command is supplied to the P/S converter 30.

Upon reception of the general read/write command via the read controller 34, the write controllers 31₁ to 31₅ write one block after another the data DATA₁ to DATA₅ output from the first signal processing circuits 26₁ to 26₅, into the first areas of the memories 32₁ to 32₅, and writes the A-time data AT₁ to AT₅ corresponding to the data DATA₁ to DATA₅ and the pairs of start addresses A_{1s} to A_{5s} and end addresses A_{1e} to A_{5e} in the memories 32₁ to 32₅, into the first areas of the memories 33₁ to 33₅ (refer to Fig. 3). In the example shown in Fig. 4, in the first areas of the memories 33₁ to 33₅, the A-time data is written from the frames of 23:40:60, 23:41:15, 23:41:45, 23:42:00, and 23:42:30 (refer to Fig. 5).

The read controller 34 received the general read/write command checks whether there is no omission of record data read with each read system, by referring to the first areas of the memories 33₁ to 33₅ used at the present read cycle to confirm that the A-time one frame before the start A-time data in the first area of the memory 33₅ is contained in the first area of the memory 33₄, that the A-time one frame

before the start A-time data in the first area of the memory 33₄ is contained in the first area of the memory 33₃, that the A-time one frame before the start A-time data in the first area of the memory 33₃ is contained in the first
5 area of the memory 33₂, and that the A-time one frame before the start A-time data in the first area of the memory 33₂ is contained in the first area of the memory 33₁.

After the read operation by the optical pickup 2 is performed approximately I = two rotations (in actual,
10 slightly more than two rotations) and the optical pickup 2 reaches a position IV shown in Fig. 4, the contents of the first areas of the memories 33₁ to 33₅ become as shown in Fig. 5 and there is no omission of record data read with the read systems. Therefore, the read controller 34
15 supplies the intercept command to the write controllers 31₁ to 31₅ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the first areas among the memories 33₁
20 to 33₅ where data were written at the present read cycle, the read controller 34 controls to read record data in the order of A-time starting from the oldest A-time, relative to the data stored in the first areas among the memories 33₁ to 33₅ where data DATA₁ to DATA₅ were written at the present
25 read cycle, and outputs the read data to the second signal

processing circuit 40. In this example, the data from the frame 23:40:60 to the frame 23:42:59 is output. Since the read start point designated by the host computer has the A-time at the frame of 23:41:00, the data is output starting
5 from the frame immediately before the read start point.

The second signal processing circuit 40 receives the data serially output from the P/S converter 30, descrambles the data in the unit of one block, and thereafter demodulates Lch and Rch data in conformity with the CD-DA
10 specification through error detection/correction based on CIRC codes (error detection/correction with P parities, deinterleaveing, error detection/correction with Q parities). The second signal processing circuit 40 then demodulates the CD-ROM data from the Lch and Rch data by
15 performing sync detection, descrambling, header detection, and error detection/correction with EDC and ECC codes in accordance with the CD-ROM specification, and thereafter outputs the CD-ROM data to an external host computer.

The write controllers 31₁ to 31₅ received the intercept
20 command intercepts the read operation of the memories 32₁ to 32₅ and 33₁ to 33₅. The system controller 50 received the track jump command supplies the servo circuit 23 with the track jump command indicating a track jump by J = 7 tracks in the forward direction to thereby jump the optical pickup
25 2 from the position IV to a position V shown in Fig. 4.

After the light beams 3_1 to 3_5 are focussed in the track-on state on the tracks $(x+8)$, $(x+10)$, $(x+12)$, $(x+14)$, and $(x+16)$, reading record data resumes. When all the frame sync detection signals FS_1 to FS_5 of H level are output from the first signal processing circuits 26_1 to 26_5 , the track jump completion notice is read and supplied to the controller 34.

The controller 34 received the track jump completion notice supplies the resume command to the write controllers 31_1 to 31_5 , and the write controllers 31_1 to 31_5 received the resume command write the data $DATA_1$ to $DATA_5$ output from the first signal processing circuits 26_1 to 26_5 after the track jump, this time into the second areas of the memories 32_1 to 32_5 , and writes the A-time data AT_1 to AT_5 corresponding to the data $DATA_1$ to $DATA_5$ and the pairs of start addresses a_{1s} to a_{5s} and end addresses a_{1e} to a_{5e} in the memories 32_1 to 32_5 , into the second areas of the memories 33_1 to 33_5 (refer to Fig. 3). In the example shown in Fig. 4, in the second areas of the memories 33_1 to 33_5 , the A-time data is written from the frames of 23:42:48, 23:43:03, 23:43:33, 23:43:63, and 23:44:18 (refer to Fig. 5).

After the read controller 34 supplies the resume command, the read controller 34 checks whether there is no omission of record data read with each read system of the $h = 5$ read light beams, by referring to the second areas of

the memories 33₁ to 33₅ used at the present read cycle to confirm that the A-time one frame before the start A-time data in the second area of the memory 33₅ is contained in the second area of the memory 33₄, that the A-time one frame
5 before the start A-time data in the second area of the memory 33₄ is contained in the second area of the memory 33₃, that the A-time one frame before the start A-time data in the second area of the memory 33₃ is contained in the second area of the memory 33₂, and that the A-time one frame
10 before the start A-time data in the second area of the memory 33₂ is contained in the second area of the memory 33₁.

After the read operation by the optical pickup 2 is performed approximately I = two rotations (in actual,
15 slightly more than two rotations) and the optical pickup 2 reaches a position VI shown in Fig. 4, the contents of the second areas of the memories 33₁ to 33₅ become as shown in Fig. 5 and there is no omission of record data read with the read systems. Therefore, the read controller 34
20 supplies the intercept command to the write controllers 31₁ to 31₅ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the second areas among the memories 33₁
25 to 33₅ where data were written at the present read cycle,

the read controller 34 controls to read record data in the order of A-time starting from the A-time next to the one block data lastly output to the second signal processing circuit 40 at the preceding read cycle, relative to the data stored in the second areas among the memories 32₁ to 32₅, where data DATA₁ to DATA₅ were written at the present read cycle, and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:42:60 to the frame 23:44:47 is output.

10 The write controllers 31₁ to 31₅ received the intercept command intercepts the read operation of the memories 32₁ to 32₅ and 33₁ to 33₅. The system controller 50 received the track jump command controls to jump the optical pickup 2 from the position VI to a position VII shown in Fig. 4.

15 After the light beams 3₁ to 3₅ are focussed in the track-on state on the tracks (x+17), (x+19), (x+21), (x+23), and (x+25), reading record data resumes. When all the frame sync detection signals FS₁ to FS₅ of H level are output from the first signal processing circuits 26₁ to 26₅, the track

20 jump completion notice is read and supplied to the controller 34.

 The controller 34 received the track jump completion notice via the read controller 34 controls to write the data DATA₁ to DATA₅ output from the first signal processing

25 circuits 26₁ to 26₅ after the track jump, this time into the

first areas of the memories 32_1 to 32_5 , and writes the A-time data AT_1 to AT_5 corresponding to the data $DATA_1$ to $DATA_5$ and the pairs of start addresses A_{1s} to A_{5s} and end addresses A_{1e} to A_{5e} in the memories 32_1 to 32_5 , into the first areas of the memories 33_1 to 33_5 . When all A-time data stored in the first areas of the memories 33_1 to 33_5 become continuous without omission, the read controller 34 controls to read and output record data in the A-time order starting from the A-time next to the A-time corresponding to the one block data lastly output to the second signal processing circuit 40 at the preceding read cycle, relative to the first areas of the memories 32_1 to 32_5 . Thereafter, similar operations are repeated to read at high speed desired record data from CD-ROM 1 by preventing the record data from being duplicated and omitted.

Reading the tracks $(x-1)$ to $(x+17)$ shown in Fig. 4 requires a continuous read of CD-ROM by about two rotations and one track jump and can be executed at much more higher speed than the case illustrated in Fig. 20.

(3) First Specific Read/write Operation (read unable by the light beam system 3_5 , refer to Figs. 6 and 7)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 6 relative

to CD-ROM 1, shows that there is one record data unreadable system of the light beam 3₅ at the outermost circumference, M = 4 light beams 3₁ to 3₄ are allocated as the read systems of h light beams, where M is the maximum number of adjacent
5 light beam systems usable, which is "4" or a combination of light beams 3₁ to 3₄ and $M \geq 2$. The continuous read rotation number I is set as $I = (c + 1) = 2$, and the read track jump number J is set to $J = \{(c+1) \cdot (M-1) - 1\} = 5$.

In accordance with the A-time data representative of
10 the latest A-time data AT₃ input from the first signal processing circuit 26₃ and the read start point A-time designated by the host computer, the track jump direction and number are determined so that the light beam 3₁ at the innermost circumference among the h = 4 read light beams is
15 focussed in the track-on state on the track (x-1) one track inner than the track x containing the read start point of the A-time.

If the optical pickup 2 is at a position II shown in Fig. 6 after the h read light beam systems are allocated
20 and the continuous read number I and read track jump number J are set, the optical pickup 2 is jumped from the position II by six tracks in the forward direction so that the light beams 3₁ to 3₄ are focussed in the track-on state on the tracks (x-1), (x+1), (x+3), and (x+5). Then, reading the
25 record data on the tracks (x-1), (x+1), (x+3), and (x+5) at

the same time starts, by using four systems including the photodetector PD_1 to first signal processing circuit 26_1 , photodetector PD_2 to first signal processing circuit 26_2 , photodetector PD_3 to first signal processing circuit 26_3 ,
5 and photodetector PD_4 to first signal processing circuit 26_4 . When all the frame sync detection signals FS_1 to FS_4 are input from the first signal processing circuits 26_1 to 26_4 , the specific read/write command including the read system information "1, 2, 3, 4" is supplied to the P/S
10 converter 30.

Upon reception of the specific read/write command via the read controller 34, only the write controllers 31_1 to 31_4 indicated by the read system information "1, 2, 3, 4" write one block after another the data $DATA_1$ to $DATA_4$ output
15 from the first signal processing circuits 26_1 to 26_4 , into the first areas of the memories 32_1 to 32_4 , and writes the A-time data AT_1 to AT_4 corresponding to the data $DATA_1$ to $DATA_4$ and the pairs of start addresses A_{1s} to A_{4s} and end addresses A_{1e} to A_{4e} in the memories 32_1 to 32_4 , into the
20 first areas of the memories 33_1 to 33_4 . In the example shown in Fig. 6, in the first areas of the memories 33_1 to 33_4 , the A-time data is written from the frames of 23:40:60, 23:41:15, 23:41:45, and 23:42:00 (refer to Fig. 7).

The read controller 34 received the specific
25 read/write command checks whether there is no omission of

record data read with each read system, by referring to the first areas of the memories 33₁ to 33₄ indicated by the read system information "1, 2, 3, 4" and used at the present read cycle to confirm that the A-time one frame before the start A-time data in the first area of the memory 33₄ is contained in the first area of the memory 33₃, that the A-time one frame before the start A-time data in the first area of the memory 33₃ is contained in the first area of the memory 33₂, and that the A-time one frame before the start A-time data in the first area of the memory 33₂ is contained in the first area of the memory 33₁.

After the read operation by the optical pickup 2 is performed approximately I = two rotations (in actual, slightly more than two rotations) and the optical pickup 2 reaches a position IV shown in Fig. 6, the contents of the first areas of the memories 33₁ to 33₄ become as shown in Fig. 7 and there is no omission of record data read with the read systems. Therefore, the read controller 34 supplies the intercept command to the write controllers 31₁ to 31₄ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the first areas among the memories 33₁ to 33₄ where data were written at the present read cycle, the read controller 34 controls to read record data in the

order of A-time starting from the oldest A-time, relative to the data stored in the first areas among the memories 33₁ to 33₄, where data DATA₁ to DATA₄ were written at the present read cycle, and outputs the read data to the second
5 signal processing circuit 40. In this example, the data from the frame 23:40:60 to the frame 23:42:29 is output.

The write controllers 31₁ to 31₄ received the intercept command intercepts the read operation of the memories 32₁ to 32₄ and 33₁ to 33₄. The system controller 50 received the
10 track jump command supplies the servo circuit 23 with the track jump command indicating a track jump by $J = 5$ tracks in the forward direction to thereby jump the optical pickup 2 from the position IV to a position V shown in Fig. 6. After the light beams 3₁ to 3₄ are focussed in the track-on
15 state on the tracks $(x+6)$, $(x+8)$, $(x+10)$, and $(x+12)$, reading record data resumes. When all the frame sync detection signals FS₁ to FS₅ of H level are output from the first signal processing circuits 26₁ to 26₄, the track jump completion notice is read and supplied to the controller
20 34.

The controller 34 received the track jump completion notice supplies the resume command to the write controllers 31₁ to 31₄, and the write controllers 31₁ to 31₄ received the resume command write the data DATA₁ to DATA₄ output from the
25 first signal processing circuits 26₁ to 26₄ after the track

jump, this time into the second areas of the memories 32₁ to 32₄, and writes the A-time data AT₁ to AT₄ corresponding to the data DATA₁ to DATA₄ and the pairs of start addresses a_{1s} to a_{4s} and end addresses a_{1e} to a_{4e} in the memories 32₁ to 32₄,
5 into the second areas of the memories 33₁ to 33₄. In the example shown in Fig. 6, in the second areas of the memories 33₁ to 33₄, the A-time data is written from the frames of 23:42:18, 23:42:48, 23:43:03, and 23:43:33 (refer to Fig. 7).

10 After the read controller 34 supplies the resume command, the read controller 34 checks whether there is no omission of record data read with each read system, by referring to the second areas of the memories 33₁ to 33₄ used at the present read cycle to confirm that the A-time
15 one frame before the start A-time data in the second area of the memory 33₄ is contained in the second area of the memory 33₃, that the A-time one frame before the start A-time data in the second area of the memory 33₃ is contained in the second area of the memory 33₂, and that the A-time
20 one frame before the start A-time data in the second area of the memory 33₂ is contained in the second area of the memory 33₁. After the read operation by the optical pickup 2 is performed approximately I = two rotations (in actual, slightly more than two rotations) and the optical
25 pickup 2 reaches a position VI shown in Fig. 6, the

contents of the second areas of the memories 33₁ to 33₄ become as shown in Fig. 7 and there is no omission of record data read with the read systems "1, 2, 3, 4". Therefore, the read controller 34 supplies the intercept
5 command to the write controllers 31₁ to 31₄ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the second areas among the memories 33₁ to 33₄, where data were written at the
10 present read cycle, the read controller 34 controls to read record data in the order of A-time starting from the A-time next to the one block data lastly output to the second signal processing circuit 40 at the preceding read cycle, relative to the data stored in the second areas among the
15 memories 32₁ to 32₄, where data DATA₁ to DATA₄ were written at the present read cycle, and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:42:30 to the frame 23:43:62 is output.

20 The write controllers 31₁ to 31₄ received the intercept command intercepts the read operation. The system controller 50 received the track jump command controls to jump the optical pickup 2 from the position VI to a position VII shown in Fig. 6. After the light beams 3₁ to
25 3₄ are focussed in the track-on state on the tracks (x+13),

(x+15), (x+17), and (x+19), reading record data resumes. When all the frame sync detection signals FS_1 to FS_4 of H level are output from the first signal processing circuits 26_1 to 26_4 , the track jump completion notice is read and
5 supplied to the controller 34. Thereafter, similar operations are repeated to read at high speed desired record data from CD-ROM 1 by using the four beams 3_1 to 3_4 and by preventing the record data from being duplicated and omitted.

10

(4) Second Specific Read/write Operation (read unable by the light beam system 3_4 , refer to Figs. 8 and 9)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the
15 optical pickup 2 from a position I shown in Fig. 8 relative to CD-ROM 1, shows that there is one record data unreadable system of the light beam 3_4 , $M = 3$ light beams 3_1 to 3_3 are allocated as the read systems of h light beams, where M is the maximum number of adjacent light beam systems usable,
20 which is "3" or a combination of light beams 3_1 to 3_3 and $M \geq 2$. The continuous read rotation number I is set as $I = (c + 1) = 2$, and the read track jump number J is set to $J = \{(c+1) \cdot (M-1) - 1\} = 3$. In accordance with the A-time data representative of the latest A-time data AT_3 input from
25 the first signal processing circuit 26_3 and the read start

point A-time designated by the host computer, the track jump direction and number are determined so that the light beam 3_1 at the innermost circumference among the $h = 3$ read light beams is focussed in the track-on state on the track
5 $(x-1)$ one track inner than the track x containing the read start point of the A-time.

If the optical pickup 2 is at a position II shown in Fig. 8 after the h read light beam systems are allocated and the continuous read number I and read track jump number
10 J are set, the optical pickup 2 is jumped from the position II by six tracks in the forward direction so that the light beams 3_1 to 3_4 are focussed in the track-on state on the tracks $(x-1)$, $(x+1)$, and $(x+3)$. Then, reading the record data on the tracks $(x-1)$, $(x+1)$ and $(x+3)$ at the same time
15 starts, by using three systems including the photodetector PD_1 to first signal processing circuit 26_1 , photodetector PD_2 to first signal processing circuit 26_2 , and photodetector PD_3 to first signal processing circuit 26_3 . When all the frame sync detection signals FS_1 to FS_3 are input from the
20 first signal processing circuits 26_1 to 26_3 , the specific read/write command including the read system information "1, 2, 3" is supplied to the P/S converter 30.

Upon reception of the specific read/write command via the read controller 34, only the write controllers 31_1 to
25 31_3 indicated by the read system information "1, 2, 3" write

one block after another the data $DATA_1$ to $DATA_3$ output from the first signal processing circuits 26_1 to 26_3 , into the first areas of the memories 32_1 to 32_3 , and writes the A-time data AT_1 to AT_3 corresponding to the data $DATA_1$ to $DATA_3$ and the pairs of start addresses A_{1s} to A_{3s} and end addresses A_{1e} to A_{3e} in the memories 32_1 to 32_3 , into the first areas of the memories 33_1 to 33_3 . In the example shown in Fig. 8, in the first areas of the memories 33_1 to 33_3 , the A-time data is written from the frames of 23:40:60, 23:41:15, and 23:41:45 (refer to Fig. 9).

The read controller 34 received the specific read/write command checks whether there is no omission of record data read with each read system, by referring to the first areas of the memories 33_1 to 33_3 indicated by the read system information "1, 2, 3" and used at the present read cycle to confirm that the A-time one frame before the start A-time data in the first area of the memory 33_3 is contained in the first area of the memory 33_2 , and that the A-time one frame before the start A-time data in the first area of the memory 33_2 is contained in the first area of the memory 33_1 .

After the read operation by the optical pickup 2 is performed approximately $I = \text{two rotations}$ (in actual, slightly more than two rotations) and the optical pickup 2 reaches a position IV shown in Fig. 8, the contents of the first areas of the memories 33_1 to 33_3 become as shown in

Fig. 9 and there is no omission of record data read with the read systems. Therefore, the read controller 34 supplies the intercept command to the write controllers 31₁ to 31₃ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the first areas among the memories 33₁ to 33₃ where data were written at the present read cycle, the read controller 34 controls to read record data in the order of A-time starting from the oldest A-time, relative to the data stored in the first areas among the memories 33₁ to 33₃ where data DATA₁ to DATA₃ were written at the present read cycle, and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:40:60 to the frame 23:41:74 is output.

The write controllers 31₁ to 31₄ received the intercept command intercepts the read operation, and the system controller 50 received the track jump command supplies the servo circuit 23 with the track jump command indicating a track jump by $J = 3$ tracks in the forward direction to thereby jump the optical pickup 2 from the position IV to a position V shown in Fig. 8. After the light beams 3₁ to 3₃ are focussed in the track-on state on the tracks (x+4), (x+6), and (x+8), reading record data resumes. When all the frame sync detection signals FS₁ to FS₃ of H level are

output from the first signal processing circuits 26₁ to 26₃, the track jump completion notice is read and supplied to the controller 34.

The controller 34 received the track jump completion notice supplies the resume command to the write controllers 31₁ to 31₃, and the write controllers 31₁ to 31₃ received the resume command write the data DATA₁ to DATA₃ output from the first signal processing circuits 26₁ to 26₃ after the track jump, this time into the second areas of the memories 32₁ to 32₃, and writes the A-time data AT₁ to AT₃ corresponding to the data DATA₁ to DATA₃ and the pairs of start addresses a_{1s} to a_{3s} and end addresses a_{1e} to a_{3e} in the memories 32₁ to 32₃, into the second areas of the memories 33₁ to 33₃. In the example shown in Fig. 8, in the second areas of the memories 33₁ to 33₃, the A-time data is written from the frames of 23:41:63, 23:42:18, and 23:42:48 (refer to Fig. 9).

After the read controller 34 supplies the resume command, the read controller 34 checks whether there is no omission of record data read with each read system, by referring to the second areas of the memories 33₁ to 33₃ used at the present read cycle to confirm that the A-time one frame before the start A-time data in the second area of the memory 33₃ is contained in the second area of the memory 33₂, and that the A-time one frame before the start

A-time data in the second area of the memory 33_2 is contained in the second area of the memory 33_1 .

After the read operation by the optical pickup 2 is performed approximately $I = \text{two rotations}$ (in actual, slightly more than two rotations) and the optical pickup 2 reaches a position VI shown in Fig. 8, the contents of the second areas of the memories 33_1 to 33_3 become as shown in Fig. 9 and there is no omission of record data read with the read systems "1, 2, 3". Therefore, the read controller 34 supplies the intercept command to the write controllers 31_1 to 31_3 to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the second areas among the memories 33_1 to 33_3 , where data were written at the present read cycle, the read controller 34 controls to read record data in the order of A-time starting from the A-time next to the one block data lastly output to the second signal processing circuit 40 at the preceding read cycle, relative to the data stored in the second areas among the memories 32_1 to 32_3 , where data DATA_1 to DATA_3 were written at the present read cycle, and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:42:00 to the frame 23:43:02 is output.

The write controllers 31_1 to 31_3 received the intercept

command intercepts the read operation. The system controller 50 received the track jump command controls to jump the optical pickup 2 from the position VI to a position VII shown in Fig. 8. After the light beams 3_1 to 3_3 are focussed in the track-on state on the tracks $(x+9)$, $(x+11)$, and $(x+13)$, reading record data resumes. Thereafter, similar operations are repeated to read at high speed desired record data from CD-ROM 1 by using the four beams 3_1 to 3_3 and by preventing the record data from being duplicated and omitted.

(5) Third Specific Read/write Operation (read unable by the light beam systems 3_4 and 3_5 , refer to Figs. 10 and 9)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 10 relative to CD-ROM 1, shows that there are two record data unreadable systems of the light beams 3_4 and 3_5 , $M = 3$ light beams 3_1 to 3_3 are allocated as the read systems of h light beams, where M is the maximum number of adjacent light beam systems usable, which is "3" or a combination of light beams 3_1 to 3_3 and $M \geq 2$. The continuous read rotation number I is set as $I = (c + 1) = 2$, and the read track jump number J is set to $J = \{(c+1) \cdot (M-1) - 1\} = 3$. In accordance with the A-time data representative of the

latest A-time data AT_3 input from the first signal processing circuit 26₃ and the read start point A-time designated by the host computer, the track jump direction and number are determined so that the light beam 3₁ at the
5 innermost circumference among the $h = 3$ read light beams is focussed in the track-on state on the track $(x-1)$ one track inner than the track x containing the read start point of the A-time.

If the optical pickup 2 is at a position II shown in
10 Fig. 8 after the h read light beam systems are allocated and the continuous read number I and read track jump number J are set, the optical pickup 2 is jumped from the position II by six tracks in the forward direction so that the light beams 3₁ to 3₃ are focussed in the track-on state on the
15 tracks $(x-1)$, $(x+1)$, and $(x+3)$. Then, reading the record data on the tracks $(x-1)$, $(x+1)$ and $(x+3)$ at the same time starts, by using three systems including the photodetector PD₁ to first signal processing circuit 26₁, photodetector PD₂ to first signal processing circuit 26₂, and photodetector
20 PD₃ to first signal processing circuit 26₃. When all the frame sync detection signals FS₁ to FS₃ are input from the first signal processing circuits 26₁ to 26₃, the specific read/write command including the read system information "1, 2, 3" is supplied to the P/S converter 30.

25 Thereafter, quite similar to the case shown in Fig. 8,

an operation of reading record data from CD-ROM 1 by approximately two rotations, jumping the optical pickup by the track jump number $J = 3$, again reading record data from CD-ROM 1 by approximately two rotations, and jumping the optical pickup by the track jump number $J = 3$ is repeated (refer to III to VII in Fig. 10) to read record data at high speed in the record order by preventing the record data from being duplicated and omitted.

- 10 (6) Fourth Specific Read/write Operation (read unable by the light beam systems 3_1 and 3_5 , refer to Fig. 11)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 11 relative to CD-ROM 1, shows that there are two record data unreadable systems of the light beams 3_1 and 3_5 , $M = 3$ light beams 3_2 to 3_4 are allocated as the read systems of h light beams, where M is the maximum number of adjacent light beam systems usable, which is "3" or a combination of light beams 3_2 to 3_4 and $M \geq 2$. The continuous read rotation number I is set as $I = (c + 1) = 2$, and the read track jump number J is set to $J = \{(c+1) \cdot (M-1) - 1\} = 3$. In accordance with the A-time data representative of the latest A-time data AT_3 input from the first signal processing circuit 26₃ and the read start point A-time

designated by the host computer, the track jump direction and number are determined so that the light beam 3_2 at the innermost circumference among the $h = 3$ read light beams is focussed in the track-on state on the track $(x-1)$ one track
5 inner than the track x containing the read start point of the A-time.

If the optical pickup 2 is at a position II shown in Fig. 11 after the $h = 3$ read light beam systems are allocated and the continuous read number I and read track
10 jump number J are set, the optical pickup 2 is jumped from the position II shown in Fig. 11 by four tracks in the forward direction so that the light beams 3_2 to 3_4 are focussed in the track-on state on the tracks $(x-1)$, $(x+1)$, and $(x+3)$. Then, reading the record data on the tracks $(x-1)$, $(x+1)$ and $(x+3)$ at the same time starts, by using three
15 systems including the photodetector PD_2 to first signal processing circuit 26₂, photodetector PD_3 to first signal processing circuit 26₃, and photodetector PD_4 to first signal processing circuit 26₄. When all the frame sync
20 detection signals FS_2 to FS_4 are input from the first signal processing circuits 26₂ to 26₄, the specific read/write command including the read system information "2, 3, 4" is supplied to the P/S converter 30.

Thereafter, nearly similar to the case shown in Fig.
25 8 (in the case shown in Fig. 11, the write controllers 31₂

to 31₄ control to write the data DATA₂ to DATA₄ and A-time data AT₂ to AT₄ output from the first signal processing circuit 26₂ to 26₄, into the memories 32₂ to 32₄ and 33₂ to 33₄, and with reference to the the A-time data and start and end addresses stored in the memories 33₂ to 33₄, the read controller 34 controls to read record data stored in the memories 33₂ to 33₄ in the order of At-time by preventing the record data from being duplicated and omitted), an operation of reading record data from CD-ROM 1 by approximately two rotations, jumping the optical pickup by the track jump number J = 3, again reading record data from CD-ROM 1 by approximately two rotations, and jumping the optical pickup by the track jump number J = 3 is repeated (refer to III to VII in Fig. 11) to sequentially read record data at high speed in the record order by preventing the record data from being duplicated and omitted.

(7) Fifth Specific Read/write Operation (read unable by the light beams 3₂ and 3₅, refer to Figs. 12 and 13)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 12 relative to CD-ROM 1, shows that there are two record data unreadable systems of the light beams 3₂ and 3₅, then only two light beams 3₃ and 3₄ are adjacent each other among the

remaining three light beams 3_1 , 3_3 , and 3_4 . In reading at high speed record data of CD-ROM 1 by repetitively performing continuous record data read by approximately two rotations and track jump, it is necessary to read record data only with adjacent light beams. High speed read is possible even for a combination of read light beams not completely adjacent each other, if continuous record data read of CD-ROM 1 by three or more rotations and track jump by predetermined tracks are repeated.

Specifically, continuously reading record data with data readable light beams during approximately $\{(R+1) \cdot (c+1)\}$ rotations and track jump by $(Q-1)$ track can be repeated if Q is 2 or larger and R is 0 or larger, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among the record data readable light beam systems, and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams.

In the example shown in Figs. 12 and 13, of the record data readable light beam systems, the innermost light beam is the light beam 3_1 and the outermost light beam is the light beam 3_4 , so that $Q = 6$. In the adjacent record data unreadable light beams between the light beams 3_1 and 3_4 , the maximum number of adjacent record data unreadable light

beams is "1" because there is only the light beam 3_2 . As the h read light beam systems, all the three record data readable light beam systems 3_1 , 3_3 , and 3_4 are allocated. The continuous read rotation number I is set as $I = \{(R + 1) \cdot (c + 1)\} = 4$, and the read track jump number J is set to $J = (Q - 1) = 5$.

If the optical pickup 2 is at a position II shown in Fig. 12 after the $h = 3$ read light beam systems are allocated and the continuous read number $I = 2$ and read track jump number $J = 5$ are set, the optical pickup 2 is jumped from the position II by six tracks in the forward direction so that the light beams 3_1 , 3_3 , and 3_4 are focussed in the track-on state on the tracks $(x-1)$, $(x+3)$, and $(x+5)$. Then, reading the record data on the tracks $(x-1)$, $(x+3)$, and $(x+5)$ at the same time starts, by using three systems including the photodetector PD_1 to first signal processing circuit 26₁, photodetector PD_3 to first signal processing circuit 26₃, and photodetector PD_4 to first signal processing circuit 26₄. When all the frame sync detection signals FS_1 , FS_3 , and FS_4 are input from the first signal processing circuits 26₁, 26₃, and 26₄, the specific read/write command including the read system information "1, 3, 4" is supplied to the P/S converter 30.

Upon reception of the specific read/write command via the read controller 34, only the write controllers 31_1 , 31_3 ,

and 31₄ indicated by the read system information "1, 3, 4" write one block after another the data DATA₁, DATA₃, and DATA₄ output from the first signal processing circuits 26₁, 26₃, and 26₄, into the first areas of the memories 32₁, 32₃, 5 and 32₄, and writes the A-time data AT₁, AT₃, and AT₄ corresponding to the data DATA₁, DATA₃, and DATA₄ and the pairs of start addresses A_{1s}, A_{3s}, and A_{4s} and end addresses A_{1e}, A_{3e}, and A_{4e} in the memories 32₁, 32₃, and 32₄, into the first areas of the memories 33₁, 33₃, and 33₄. In the 10 example shown in Fig. 12, in the first areas of the memories 33₁, 33₃, and 33₄, the A-time data is written from the frames of 23:40:60, 23:41:15, and 23:42:00 (refer to Fig. 13).

The read controller 34 received the specific 15 read/write command checks whether there is no omission of record data read with each read system, by referring to the first areas of the memories 33₁, 33₃, and 33₄ indicated by the read system information "1, 3, 4" and used at the present read cycle to confirm that the A-time one frame 20 before the start A-time data in the first area of the memory 33₄ is contained in the first area of the memory 33₃, and that the A-time one frame before the start A-time data in the first area of the memory 33₃ is contained in the first area of the memory 33₁.

25 After the read operation by the optical pickup 2 is

performed approximately $I = \text{four rotations}$ (in actual, slightly more than four rotations) and the optical pickup 2 reaches a position IV shown in Fig. 12, the contents of the first areas of the memories 33_1 , 33_3 , and 33_4 become as shown in Fig. 13 and there is no omission of record data read with the read systems. Therefore, the read controller 34 supplies the intercept command to the write controllers 31_1 , 31_3 , and 31_4 to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the first areas among the memories 33_1 , 33_3 , and 33_4 , the read controller 34 controls to read record data in the order of A-time starting from the oldest A-time, relative to the data stored in the first areas among the memories 33_1 , 33_3 , and 33_4 , and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:40:60 to the frame 23:42:50 is output.

The write controllers 31_1 , 31_3 , and 31_4 received the intercept command intercepts the read operation, and the system controller 50 received the track jump command supplies the servo circuit 23 with the track jump command indicating a track jump by $J = 5$ tracks in the forward direction to thereby jump the optical pickup 2 from the position IV to a position V shown in Fig. 12. After the

light beams 3_1 , 3_3 and 3_4 are focussed in the track-on state on the tracks $(x+8)$, $(x+12)$, and $(x+14)$, reading record data resumes. When all the frame sync detection signals FS_1 , FS_3 , and FS_5 of H level are output from the first signal processing circuits 26_1 , 26_3 , and 26_4 , the track jump completion notice is read and supplied to the controller 34.

The controller 34 received the track jump completion notice supplies the resume command to the write controllers 31_1 , 31_3 , and 31_4 , and the write controllers 31_1 , 31_3 , and 31_4 received the resume command write the data $DATA_1$, $DATA_3$, and $DATA_4$ output from the first signal processing circuits 26_1 , 26_3 , and 26_4 after the track jump, this time into the second areas of the memories 32_1 , 32_3 , and 32_4 , and writes the A-time data AT_1 , AT_3 , and AT_4 corresponding to the data $DATA_1$, $DATA_3$, and $DATA_4$ and the pairs of start addresses a_{1s} , a_{3s} , and a_{4s} and end addresses a_{1e} , a_{3e} , and a_{4e} in the memories 32_1 , 32_3 , and 32_4 , into the second areas of the memories 33_1 , 33_3 , and 33_4 . In the example shown in Fig. 12, in the second areas of the memories 33_1 , 33_3 , and 33_4 , the A-time data is written from the frames of 23:42:48, 23:43:33, and 23:43:63 (refer to Fig. 13).

After the read controller 34 supplies the resume command, the read controller 34 checks whether there is no omission of record data read with each read system, by

referring to the second areas of the memories 33₁, 33₃, and 33₄, used at the present read cycle to confirm that the A-time one frame before the start A-time data in the second area of the memory 33₄ is contained in the second area of the memory 33₃, and that the A-time one frame before the start A-time data in the second area of the memory 33₃ is contained in the second area of the memory 33₁.

After the read operation by the optical pickup 2 is performed approximately I = four rotations (in actual, slightly more than four rotations) and the optical pickup 2 reaches a position VI shown in Fig. 12, the contents of the second areas of the memories 33₁, 33₃, and 33₄ become as shown in Fig. 13 and there is no omission of record data read with the read systems "1, 3, 4". Therefore, the read controller 34 supplies the intercept command to the write controllers 31₁, 31₃, and 31₄ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the second areas among the memories 33₁, 33₃, and 33₄ where data were written at the present read cycle, the read controller 34 controls to read record data in the order of A-time starting from the A-time next to the one block data lastly output to the second signal processing circuit 40 at the preceding read cycle, relative to the data stored in the second areas

among the memories 32_1 , 32_3 , and 32_4 where data were written at the present read cycle, and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:42:60 to the frame 23:44:62 is
5 output.

The write controllers 31_1 , 31_3 , and 31_4 received the intercept command intercepts the read operation. The system controller 50 received the track jump command controls to jump the optical pickup 2 by the track jump
10 number $J = 5$ from the position VI to a position VII shown in Fig. 12. Thereafter, reading record data resumes. Thereafter, similar operations are repeated to read at high speed desired record data from CD-ROM 1 by using the three beams 3_1 , 3_3 , and 3_4 and by preventing the record data from
15 being duplicated and omitted.

For example, in order to read the record data from the 19 tracks from the track $(x-1)$ to the track $(x+17)$ shown in Fig. 12, only reading the record data of CD-ROM 1 during eight rotations and one track jump are required.
20 Therefore, the record data can be read more rapidly than data is read with one light beam from CD-ROM 1 during 19 rotations.

(8) Sixth Specific Read/write Operation (read unable by the
25 light beams 3_1 , 3_2 , and 3_4 , refer to Fig. 14)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 14 relative to CD-ROM 1, shows that there are three record data unreadable systems of the light beams 3_1 , 3_2 , and 3_4 , then reading record data with adjacent two light beam systems is impossible. However, similar to the case shown in Fig. 12, continuously reading record data with data readable light beams during approximately $\{(R+1) \cdot (c+1)\}$ rotations and track jump by $(Q-1)$ track can be repeated if Q is 2 or larger and R is 0 or larger, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among the record data readable light beam systems, and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams.

In the example shown in Fig. 14, of the record data readable light beam systems, the innermost light beam is the light beam 3_3 and the outermost light beam is the light beam 3_5 , so that $Q = 4$. In the adjacent record data unreadable light beams between the light beams 3_3 and 3_5 , the maximum number of adjacent record data unreadable light beams is "1" because there is only the light beam 3_4 . As the h read light beam systems, all the two record data

readable light beam systems 3_3 and 3_5 are allocated. The continuous read rotation number I is set as $I = \{(R + 1) \cdot (c + 1)\} = 4$, and the read track jump number J is set to $J = (Q - 1) = 3$.

5 If the optical pickup 2 is at a position II shown in Fig. 14 after the $h = 2$ read light beam systems are allocated and the continuous read number $I = 4$ and read track jump number $J = 3$ are set, the optical pickup 2 is jumped from the position II by two tracks in the forward
10 direction so that the light beams 3_1 , 3_3 , and 3_4 are focussed in the track-on state on the tracks $(x-1)$, and $(x+3)$. Then, reading the record data on the tracks $(x-1)$, and $(x+3)$ at the same time starts, by using two systems including the photodetector PD_3 to first signal processing
15 circuit 26_3 , and photodetector PD_5 to first signal processing circuit 26_5 . When all the frame sync detection signals FS_3 and FS_5 are input from the first signal processing circuits 26_3 and 26_5 , the specific read/write command including the read system information "3, 5" is
20 supplied to the P/S converter 30.

Thereafter, nearly similar to the case shown in Fig. 12 (in the case shown in Fig. 14, the write controllers 31_3 and 31_5 control to write the data $DATA_3$ and $DATA_5$ and A-time data AT_3 and AT_5 output from the first signal processing
25 circuit 26_3 and 26_5 , into the memories 32_3 and 32_5 and 33_3 to

33₅, and with reference to the the A-time data and start and end addresses stored in the memories 33₃ and 33₅, the read controller 34 controls to read record data stored in the memories 33₃ and 33₅ in the order of At-time by preventing
5 the record data from being duplicated and omitted), an operation of reading record data from CD-ROM 1 by approximately I = 4 rotations, jumping the optical pickup by the track jump number J = 3, again reading record data from CD-ROM 1 by approximately I = 4 rotations, and jumping
10 the optical pickup by the track jump number J = 3 is repeated (refer to III to VII in Fig. 14) to sequentially read record data at high speed in the record order by preventing the record data from being duplicated and omitted.

15 For example, in order to read the record data from the 16 tracks from the track (x-1) to the track (x+14) shown in Fig. 14, only reading the record data of CD-ROM 1 during eight rotations and one track jump are required. Therefore, the record data can be read more rapidly than
20 data is read with one light beam from CD-ROM 1 during 16 rotations.

(9) Seventh Specific Read/write Operation (read unable by the light beam 3₄, refer to Fig. 15)

25 If the judgement of a presence/absence of a record

data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 15 relative to CD-ROM 1, shows that there is one record data unreadable system of the light beam 3_4 , then reading record data with adjacent three light beam systems is possible as described in the above case (4) (refer to Fig. 8). However, if a similar operation to the case shown in Fig. 12 is incorporated, record data can be read more quickly.

In the example shown in Fig. 15, of the record data readable light beam systems, the innermost light beam is the light beam 3_1 and the outermost light beam is the light beam 3_5 so that $Q = 8$. In the adjacent record data unreadable light beams between the light beams 3_1 and 3_5 , the maximum number of adjacent record data unreadable light beams is $R = 1$ because there is only the light beam 3_4 . As the h read light beam systems, all the four record data readable light beam systems 3_1 to 3_3 , and 3_5 are allocated. The continuous read rotation number I is set as $I = \{(R + 1) \cdot (c + 1)\} = 4$, and the read track jump number J is set to $J = (Q - 1) = 3$.

If the optical pickup 2 is at a position II shown in Fig. 15 after the $h = 4$ read light beam systems are allocated and the continuous read number $I = 4$ and read track jump number $J = 3$ are set, the optical pickup 2 is jumped from the position II shown in Fig. 15 by six tracks

in the forward direction so that the light beams 3_1 to 3_3 , and 3_5 are focussed in the track-on state on the tracks $(x-1)$, $(x+1)$, $(x+3)$, and $(x+7)$. Then, reading the record data on the tracks $(x-1)$, $(x+1)$, $(x+3)$, and $(x+7)$ at the same
5 time starts, by using four systems including the photodetector PD_1 to first signal processing circuit 26_1 , photodetector PD_2 to first signal processing circuit 26_2 , photodetector PD_3 to first signal processing circuit 26_3 , and photodetector PD_5 to first signal processing circuit
10 26_5 . When all the frame sync detection signals FS_1 to FS_3 , and FS_5 are input from the first signal processing circuits 26_1 to 26_3 and 26_5 , the specific read/write command including the read system information "1, 2, 3, 5" is supplied to the P/S converter 30.

15 Thereafter, nearly similar to the case shown in Fig. 12 (in the case shown in Fig. 15, the write controllers 31_1 to 31_3 , and 31_5 control to write the data $DATA_1$ to $DATA_3$, and $DATA_5$ and A-time data AT_1 to AT_3 , and AT_5 output from the first signal processing circuit 26_1 to 26_3 , and 26_5 , into the
20 memories 32_1 to 32_3 , and 32_5 and 33_1 to 33_3 , and 33_5 , and with reference to the the A-time data and start and end addresses stored in the memories 33_1 to 33_3 , and 33_5 , the read controller 34 controls to read record data stored in the memories 33_1 to 33_3 , and 33_5 in the order of At-time by
25 preventing the record data from being duplicated and

omitted), an operation of reading record data from CD-ROM 1 by approximately $I = 4$ rotations, jumping the optical pickup by the track jump number $J = 3$, again reading record data from CD-ROM 1 by approximately $I = 4$ rotations, and
5 jumping the optical pickup by the track jump number $J = 3$ is repeated (refer to III to VII in Fig. 15) to sequentially read record data at high speed in the record order by preventing the record data from being duplicated and omitted.

10 For example, in order to read the record data from the 23 tracks from the track $(x-1)$ to the track $(x+21)$ shown in Fig. 15, only reading the record data of CD-ROM 1 during eight rotations and one track jump are required. In contrast, in the case shown in Fig. 8, reading the record
15 data of CD-ROM 1 during eight rotations and three track jumps.

(10) Eighth Specific Read/write Operation (read unable by the light beams 3_1 , 3_4 , and 3_5 , refer to Figs. 16 and 17)

20 If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 16 relative to CD-ROM 1, shows that there are three record data unreadable systems of the light beams 3_1 , 3_4 , and 3_5 ,
25 even with the remaining two adjacent light beams 3_2 and 3_3 ,

record data can be read by repetitively performing data read of CD-ROM 1 during two rotations and track jump in the forward direction.

Specifically, continuously reading record data with
 5 data readable light beams during approximately $\{(R+1) \cdot (c+1)\}$ rotations and track jump by $(Q-1)$ track can be repeated if Q is 2 or larger and R is 0 or larger, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among the
 10 record data readable light beam systems, and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams.

In the example shown in Figs. 16 and 17, of the record
 15 data readable light beam systems, the innermost light beam is the light beam 3_2 and the outermost light beam is the light beam 3_3 , so that $Q = 2$. In the adjacent record data unreadable light beams between the light beams 3_2 and 3_3 , the maximum number of adjacent record data unreadable light
 20 beams is $R = 0$ because there is no light beam. As the h read light beam systems, all the two record data readable light beam systems 3_2 and 3_3 are allocated. The continuous read rotation number I is set as $I = \{(R + 1) \cdot (c + 1)\} =$
 25 $= 1$, and the read track jump number J is set to $J = (Q - 1)$

If the optical pickup 2 is at a position II shown in Fig. 16 after the $h = 4$ read light beam systems are allocated and the continuous read number $I = 4$ and read track jump number $J = 3$ are set, the optical pickup 2 is
5 jumped from the position II shown in Fig. 16 by four tracks in the forward direction so that the light beams 3_2 and 3_3 are focussed in the track-on state on the tracks $(x-1)$ and $(x+1)$. Then, reading the record data on the tracks $(x-1)$ and $(x+1)$ at the same time starts, by using two systems
10 including the photodetector PD_2 to first signal processing circuit 26_2 , and photodetector PD_3 to first signal processing circuit 26_3 . When all the frame sync detection signals FS_2 and FS_3 are input from the first signal processing circuits 26_2 and 26_3 , the specific read/write
15 command including the read system information "2, 3" is supplied to the P/S converter 30.

Upon reception of the specific read/write command via the read controller 34, only the write controllers 31_2 and 31_3 indicated by the read system information "2, 3" write
20 one block after another the data $DATA_2$ and $DATA_3$ output from the first signal processing circuits 26_2 and 26_3 , into the first areas of the memories 32_2 and 32_3 , and writes the A-time data AT_2 and AT_3 corresponding to the data $DATA_2$ and $DATA_3$ and the pairs of start addresses A_{2s} and A_{3s} and end
25 addresses A_{2e} and A_{3e} in the memories 32_2 and 32_3 , into the

first areas of the memories 33₂ and 33₃. In the example shown in Fig. 16, in the first areas of the memories 33₂ and 33₃, the A-time data is written from the frames of 23:40:60 and 23:41:15 (refer to Fig. 17).

5 The read controller 34 received the specific read/write command checks whether there is no omission of record data read with each read system, by referring to the first areas of the memories 33₂ and 33₃ indicated by the read system information "2, 3" and used at the present read
10 cycle to confirm that the A-time one frame before the start A-time data in the first area of the memory 33₃ is contained in the first area of the memory 33₂.

After the read operation by the optical pickup 2 is performed approximately I = two rotations (in actual,
15 slightly more than two rotations) and the optical pickup 2 reaches a position IV shown in Fig. 16, the contents of the first areas of the memories 33₂ and 33₃ become as shown in Fig. 17 and there is no omission of record data read with the read systems. Therefore, the read controller 34
20 supplies the intercept command to the write controllers 31₂ and 31₃ to intercept the write operation, and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the first areas among the memories 33₂
25 and 33₃, the read controller 34 controls to read record data

in the order of A-time starting from the oldest A-time, relative to the data stored in the first areas among the memories 32_2 and 32_3 , and outputs the read data to the second signal processing circuit 40. In this example, the
5 data from the frame 23:40:60 to the frame 23:41:44 is output.

The write controllers 31_2 and 31_3 received the intercept command intercepts the read operation, and the system controller 50 received the track jump command
10 supplies the servo circuit 23 with the track jump command indicating a track jump by $J = 1$ track in the forward direction to thereby jump the optical pickup 2 from the position IV to a position V shown in Fig. 16. After the light beams 3_2 and 3_3 are focussed in the track-on state on
15 the tracks $(x+2)$ and $(x+4)$, reading record data resumes. When all the frame sync detection signals FS_2 and FS_3 of H level are output from the first signal processing circuits 26_2 and 26_3 , the track jump completion notice is read and supplied to the controller 34.

20 The controller 34 received the track jump completion notice supplies the resume command to the write controllers 31_2 and 31_3 , and the write controllers 31_2 and 31_3 received the resume command write the data $DATA_2$ and $DATA_3$ output from the first signal processing circuits 26_2 and 26_3 after
25 the track jump, this time into the second areas of the

memories 32₂ and 32₃, and writes the A-time data AT₂ and AT₃ corresponding to the data DATA₂ and DATA₃ and the pairs of start addresses a_{2s} and a_{3s} and end addresses a_{2e} and a_{3e} in the memories 32₂ and 32₃, into the second areas of the
5 memories 33₂ and 33₃. In the example shown in Fig. 16, in the second areas of the memories 33₂ and 33₃, the A-time data is written from the frames of 23:41:32 and 23:41:62 (refer to Fig. 17).

After the read controller 34 supplies the resume
10 command, the read controller 34 checks whether there is no omission of record data read with each read system, by referring to the second areas of the memories 33₂ and 33₃ used at the present read cycle to confirm that the A-time one frame before the start A-time data in the second area
15 of the memory 33₃ is contained in the second area of the memory 33₂.

After the read operation by the optical pickup 2 is performed approximately I = two rotations (in actual, slightly more than two rotations) and the optical pickup 2
20 reaches a position VI shown in Fig. 16, the contents of the second areas of the memories 33₁, 33₃, and 33₄ become as shown in Fig. 17 and there is no omission of record data read with the read systems "2, 3". Therefore, the read controller 34 supplies the intercept command to the write
25 controllers 31₂ and 31₃ to intercept the write operation,

and supplies the track jump command to the system controller 50. With reference to the A-time data and the start and end addresses stored in the second areas among the memories 33₂ and 33₃, where data were written at the present read cycle, the read controller 34 controls to read
5 record data in the order of A-time starting from the A-time next to the one block data lastly output to the second signal processing circuit 40 at the preceding read cycle, relative to the data stored in the second areas among the
10 memories 32₂ and 32₃, where data were written at the present read cycle, and outputs the read data to the second signal processing circuit 40. In this example, the data from the frame 23:41:45 to the frame 23:42:16 is output.

The write controllers 31₂ and 31₃ received the
15 intercept command intercepts the read operation. The system controller 50 received the track jump command controls to jump the optical pickup 2 by the track jump number $J = 1$ from the position VI to a position VII shown in Fig. 16. Thereafter, reading record data resumes.
20 Thereafter, similar operations are repeated to read at high speed desired record data from CD-ROM 1 by using the three beams 3₂ and 3₃, and by preventing the record data from being duplicated and omitted.

25 (11) Ninth Specific Read/write Operation (read unable by

the light beams 3_1 , 3_2 , 3_4 , and 3_5 , refer to Figs. 18 and 19)

If the judgement of a presence/absence of a record data unreadable system during one relative rotation of the optical pickup 2 from a position I shown in Fig. 18 relative to CD-ROM 1, shows that there are four record data unreadable systems of the light beams 3_1 , 3_2 , 3_4 , and 3_5 , record data is omitted if it is read with only one light beam 3_3 by repetitively performing data read of CD-ROM 1 during two rotations or more and track jump in the forward direction. In this case, record data is continuously read from CD-ROM 1 by using the record data readable one light beam system.

Specifically, as the h read light beam systems, the record data readable light beam 3_3 is allocated. The continuous read rotation number I is set as infinite, and the read track jump number J is set to $J = 0$.

If the optical pickup 2 is at a position II shown in Fig. 18 after the $h = 1$ read light beam system is allocated and the continuous read number I = infinite and read track jump number $J = 1$ are set, the optical pickup 2 is jumped from the position II shown in Fig. 18 by two tracks in the forward direction so that the light beams 3_3 is focussed in the track-on state on the track (x-1). Then, reading the record data on the track (x-1) starts, by using one system of the photodetector PD_3 to first signal processing circuit

26₃. When the frame sync detection signal FS₃ is input from the first signal processing circuits 26₃, the specific read/write command including the read system information "3" is supplied to the P/S converter 30.

5 Upon reception of the specific read/write command via the read controller 34, only the write controller 31₃ indicated by the read system information "3" writes one block after another the data DATA₃ output from the first signal processing circuits 26₃, into the first area of the
10 memory 32₃, and writes the A-time data AT₃ corresponding to the data DATA₃ and the pairs of start addresses A_{3s} and end addresses A_{3e} in the memory 32₃, into the first area of the memory 33₃. In the example shown in Fig. 18, in the first area of the memory 33₃, the A-time data is written from the
15 frame of 23:40:60 (refer to Fig. 19). After data is written in the end regions of the first areas of the memories 32₃ and 33₃, the start regions of the first areas are automatically reserved for continuing data write.

 Since only one piece of the read system information
20 "3" is used, the read controller 34 received the specific read/write command refers to the first areas of the memories 33₃ indicated by the read system information "3" and used at the present read cycle, and controls to read record data in the order of A-time starting from the oldest
25 A-time, relative to the data stored in the first areas of

the memory 32₃, and outputs the read data to the second signal processing circuit 40, without issuing the intercept command and track jump command. Therefore, during data read, the optical pickup 2 will not jump (refer to III to 5 VI in Fig. 18), and as CD-ROM 1 rotates, the record data after the track (x-1) can be read with the light beam 3₃ system without any omission of record data and supplied to the second signal processing circuit 40.

In the above embodiments, different beams 3₁ to 3_n are 10 applied at the same time to every (c+1)-th tracks of CD-ROM 1, where $c = 1$ and $n = 5$. The invention is not limited only to the above embodiments, other combinations of c and n may also be used if c is an integer "1" or larger and n is an integer "2" or larger. For example, an optical 15 pickup 2B shown in Fig. 20-1 may apply three light beams 3₁ to 3₃ to tracks at every second, or an optical pickup 2C shown in Fig. 20-2 may apply three light beams 3₁ to 3₃ to tracks at every third.

With the optical pickup shown in Fig. 20-1, if there 20 is no record data unreadable light beam system, record data of CD-ROM 1 is read by repeating an operation of continuous read of the record data with three light beam systems 3₁ to 3₃ during approximately $(c+1) = 2$ rotations of CD-ROM 1 and track jump by $\{(c+1) \cdot (n-1) - 1\} = 3$ tracks in the forward 25 direction after it is confirmed that there is no omission

of record data read from CD-ROM 1 with a combination of three light beams 3_1 to 3_3 . Similarly, with the optical pickup shown in Fig. 20-2, if there is no record data unreadable light beam system, record data of CD-ROM 1 is read by repeating an operation of continuous read of the record data with three light beam systems 3_1 to 3_3 during approximately $(c+1) = 3$ rotations of CD-ROM 1 and track jump by $\{(c+1) \cdot (n-1) - 1\} = 5$ tracks in the forward direction after it is confirmed that there is no omission of record data read from CD-ROM 1 with a combination of three light beams 3_1 to 3_3 .

With the optical pickup shown in Fig. 20-1, if there is a record data unreadable light beam system, e.g., the light beam system 3_3 , M is "2" including the two light beams 3_1 and 3_2 where M is the maximum number of adjacent record data readable light beam systems among the remaining light beam systems. The $M = 2$ light beams systems 3_1 and 3_2 are allocated as the read light beam systems. In this case, record data of CD-ROM 1 is read by repeating an operation of continuous read of the record data with the allocated two light beam systems 3_1 and 3_2 during approximately $(c+1) = 2$ rotations of CD-ROM 1 and track jump by $\{(c+1) \cdot (M-1) - 1\} = 1$ track in the forward direction after it is confirmed that there is no omission of record data read from CD-ROM 1 with a combination of two light beams 3_1 and

3₂.

Similarly, with the optical pickup shown in Fig. 20-2, if there is a record data unreadable light beam system, e.g., the light beam system 3₃, M is "2" including the two light beams 3₁ and 3₂ where M is the maximum number of adjacent record data readable light beam systems among the remaining light beam systems. The M = 2 light beams systems 3₁ and 3₂ are allocated as the read light beam systems. In this case, record data of CD-ROM 1 is read by repeating an operation of continuous read of the record data with the allocated two light beam systems 3₁ and 3₂ during approximately (c+1) = 3 rotations of CD-ROM 1 and track jump by {(c+1) · (M-1) - 1} = 2 tracks in the forward direction after it is confirmed that there is no omission of record data read from CD-ROM 1 with a combination of two light beams 3₁ and 3₂.

In the description of the case (3) (refer to Figs. 6 and 7), the light beam system 3₅ is unable to read record data and the maximum number M of adjacent record data readable light beam systems is "4" and M ≥ 2. Therefore, as the h record data light beams systems, the M = 4 light beams 3₁ to 3₄ are allocated, and the continuous read rotation number I is set to I = (c+1) = 2, and the track jump number J is set to J = {(c+1) · (M-1) - 1} = 5. Instead, the continuous read rotation number I may be set

to $I = \{(R+1) \cdot (c+1)\} = 2$ and the track jump number J may be set to $J = (Q-1) = 5$, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among the allocated $h = 4$ record data readable light beam systems 3_1 to 3_4 and in this case $Q = 6$, and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams among the the allocated $h = 4$ record data readable light beam systems 3_1 to 3_4 and in this case $R = 0$.

In the description of the case (4) (refer to Figs. 8 and 9), the light beam system 3_4 is unable to read record data and the maximum number M of adjacent record data readable light beam systems is "3". Therefore, as the h record data light beams systems, the $M = 3$ light beams 3_1 to 3_3 are allocated, and the continuous read rotation number I is set to $I = (C+1) = 2$, and the track jump number J is set to $J = \{(c+1) \cdot (M-1) - 1\} = 3$. Instead, the continuous read rotation number I may be set to $I = \{(R+1) \cdot (c+1)\} = 2$ and the track jump number J may be set to $J = (Q-1) = 3$, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among the allocated h record data readable light beam systems 3_1 to 3_3 and in this case $Q = 4$, and R is the maximum number of adjacent record data unreadable light

beams between the innermost and outermost record data readable light beams among the the allocated h record data readable light beam systems 3_1 to 3_3 and in this case $R = 0$.

5 Similarly, in the cases ((5) or (6), the continuous read rotation number I may be set to $I = \{(R+1) \cdot (c+1)\} = 2$ and the track jump number J may be set to $J = (Q-1) = 3$, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam
10 among the allocated $h = 3$ record data readable light beam systems 3_1 to 3_3 or 3_2 to 3_4 and in this case $Q = 4$, and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams among the the allocated $h = 3$ record
15 data readable light beam systems 3_1 to 3_3 or 3_2 to 3_4 and in this case $R = 0$.

 In the description of the case (10) (refer to Figs. 16 and 17), there are three record data unreadable light beam systems 3_1 , 3_4 , and 3_5 , the continuous read rotation number
20 I is set to $I = \{(R+1) \cdot (c+1)\} = 2$ and the track jump number J may be set to $J = (Q-1) = 1$, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among the record data readable light beam systems 3_2 and 3_3 and in this case $Q =$
25 2 , and R is the maximum number of adjacent record data

unreadable light beams between the innermost and outermost record data readable light beams among the the allocated record data readable light beam systems and in this case $R = 0$. Instead, since the maximum number M of adjacent
5 record data readable light beam systems is "2", as the h record data light beams systems, the $M = 2$ light beams 3_2 and 3_3 may be allocated, and the continuous read rotation number I may be set to $I = (c+1) = 2$, and the track jump number J may be set to $J = \{(c+1) \cdot (M-1) - 1\} = 1$.

10 In the above embodiments, a presence/absence of a record data unreadable light beam system is judged at the track position one track before the read start point designated by the host computer, and in accordance with the judgement result, the h read light beam systems, the
15 continuous read rotation number I , and the track jump number J are set. Thereafter, the optical head is jumped to the track immediately before the read start point to start reading record data. Instead, a presence/absence of a record data unreadable light beam system may be judged at
20 the track position containing the read start point, or at the lead-in of the innermost circumference of CD-ROM 1.

In the cases (3) to (9) and the case shown in Fig. 20, if it is judged that there is some record data unreadable light beam systems, the system controller 50 selects from
25 the remaining record data readable light beam systems a

combination of two or more light beam systems, and allocates the combination as the h read light beam systems, to thereafter set the continuous read rotation number I and the track jump number J in accordance with predetermined rules. However, the continuous read rotation number R when the continuous read of CD-ROM 1 with a combination of the allocated h read light beam systems is performed until omission of the record data becomes none, can be automatically determined as approximately $\{(R+1) \cdot$
5
10 $(c+1)\}$ where R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams among the the h read light beam systems. Therefore, only the track jump number J may be set. The continuous read rotation number
15 when the continuous read of CD-ROM 1 with a combination of all the n optical light beam systems is performed until omission of the record data becomes none, can also be automatically determined as approximately $(c+1)$.

Also in the above embodiments, although CD-ROM is
20 rotated at a constant linear velocity, it may be rotated at a constant angular velocity (CAV). Other optical discs with a spiral track of the type different from CD-ROM may also be used such as CD-WO, DVD, DVD-ROM and DVD-RAM.

CLAIMS

1. An optical disc read method of reading data recorded on tracks of an optical disc formed with a spiral track with a record data read system by applying different light beams
5 1, ..., i, ..., n at the same time to n tracks at every (c+1)-th and independently detecting the light beams reflected from the optical disc, where c is an integer of 1 or larger and n is an integer of 2 or larger, wherein:
the record data of the optical disc is read by
10 alternately performing an operation of continuously reading the record data on the tracks of the optical disc with n light beam systems and a track jump operation in a forward direction after said continuous reading operation.
- 15 2. An optical disc read method according to claim 1, wherein said continuous reading operation is performed during approximately (c+1) rotations of the optical disc, and said track jump operation jumps approximately {(c+1) · (n-1) - 1} tracks in the forward direction.
- 20 3. An optical disc read method according to claim 1, wherein if there is a light beam system unable to read the record data of the optical disc, among the n light beam systems, the record data of the optical disc is read by
25 alternately performing an operation of continuously reading

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the record data on the tracks of the optical disc with n light beam systems during approximately $(c+1)$ rotations $\{(c+1) \cdot (n-1) - 1\}$ and a track jump operation by approximately $\{(c+1) \cdot (n-1) - 1\}$ tracks in a forward direction after said continuous reading operation, by using detection outputs from only M ($M < n$) adjacent record data readable light beam systems.

4. An optical disc read method according to claim 1, wherein M is the maximum number of adjacent record data readable light beam systems among record data readable light beam systems.

5. An optical disc read method according to claim 1, wherein if there is a light beam system unable to read the record data of the optical disc, among the n light beam systems and if Q is 2 or larger and R is 0 or larger, where Q is the number of tracks representing a distance between the innermost light beam and outermost light beam among record data readable light beam systems and R is the maximum number of adjacent record data unreadable light beams between the innermost and outermost record data readable light beams, the record data of the optical disc is read by alternately performing an operation of continuously reading the record data on the tracks of the



optical disc with the record data readable light beam systems during approximately $\{(R+1) \cdot (c+1)\}$ and a track jump operation by approximately $(Q-1)$ tracks in a forward direction after said continuous reading operation with a
5 combination of the record data readable light beam systems shows no omission of the record data of the optical disc.

6. An optical disc read method according to claim 1, wherein the record data detected from the tracks of the
10 optical disc during said continuous reading operation is stored together with frame addresses, and said track jump operation is performed when a frame address corresponding to the record data read with the i -th light beam becomes continuous with a continuous data read start frame address
15 corresponding to the record data to be read with the adjacent $(i+1)$ -th light beam.

7. An optical disc read method of reading data recorded on tracks of an optical disc formed with a spiral track with
20 a record data read system by applying different light beams at the same time to n tracks at every $(c+1)$ -th and independently detecting the light beams reflected from the optical disc, where c is an integer of 1 or larger and n is an integer of 2 or larger, the optical disc read method
25 comprising the steps of:

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detecting a system capable of reading the record data from the optical disc from n light beam systems by applying the light beams to predetermined positions of the tracks of the optical disc at a start of a continuous data reading operation and continuously reading the record data; and

setting each light beam so that one of the detected record data readable systems is applied to a read start track frame.

8. An optical disc read method according to claim 7, wherein after said step of setting each light beam so that one of the detected record data readable systems is applied to a read start track frame, the record data of the optical disc is read by alternately performing an operation of continuously reading the record data during a predetermined number of rotations of the optical disc and a track jump operation by a predetermined number of tracks, the rotation number and the track number being determined in accordance with the number and layout of the record data readable systems.

9. An optical disc read method according to claim 7, wherein the predetermined positions of the tracks of the optical disc are positions more in a backward direction than the read start track frame.

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10. An optical disc read apparatus comprising:

optical detecting means for applying different light beams $1, \dots, \underline{i}, \dots, \underline{n}$ at the same time to $\underline{n}$ tracks at every $(c+1)$ -th of an optical disc with a spiral track and
5 independently detecting and outputting the light beams reflected from the optical disc, where $\underline{c}$ is an integer of 1 or larger and $\underline{n}$ is an integer of 2 or larger;

record data reading means for reading record data recorded on the optical disc independently for each of $\underline{n}$
10 light beam systems, in accordance with the detection outputs from said optical detecting means; and

read control means for controlling said optical detecting means and said record data reading means to read the record data of the optical disc by alternately
15 performing an operation of continuously reading the record data on the tracks of the optical disc with the $\underline{n}$ light beam systems and a track jump operation in a forward direction after the continuous reading operation.

20 11. An optical disc read apparatus according to claim 10, wherein:

said record data reading means includes a memory for storing the record data obtained during the continuous reading operation and a corresponding frame address; and

25 said read control means performs the track jump



operation when a frame address corresponding to the record data read with the i -th light beam becomes continuous with a continuous data read start frame address corresponding to the record data to be read with the adjacent $(i+1)$ -th light beam.

12. An optical disc read apparatus according to claim 10, wherein the continuous reading operation is performed during approximately $(c+1)$ rotations of the optical disc, and the track jump operation jumps approximately $\{(c+1) \cdot (n-1) - 1\}$ tracks in the forward direction.

