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DESCRIPTION

MULTIBEAM OPTICAL DISK READOUT METHOD AND APPARATUS

Technical Field of the Invention

The present invention relates to an optical disk readout method and optical disk readout system, and in particular, to an optical disk readout method and optical disk readout system configured such that separate light beams simultaneously illuminate each of the multiple adjacent tracks of an optical disk in which tracks are formed in a spiral (e.g. CD-ROM, CD-WO, DVD, DVD-ROM, or DVD-RAM disk), and wherein data recorded in the tracks being illuminated by the beams is read from the detected output of each returned beam by a record data readout system.

Related art

One technique available as a method for reading recorded data from CD-ROM at high speed is the multi-beam technique. This multi-beam technique is disclosed in U.S. Patent No. 5,457,670 and International Application WO-A-9419797 (PCT/US94/01790). In this technique, separate light beams simultaneously illuminate each of the multiple adjacent tracks of an optical disk on which the tracks are formed in a spiral. Data recorded in the tracks illuminated by the beams is simultaneously read-back from the detected output of each returned beam by a record data readout system in a manner such that there will be no

duplications or gaps in the data being read back, and such that the data will be output in the sequence in which it was recorded.

Such a multi-beam optical disk (CD-ROM) readout method will be described with reference to Fig. 20. Item 5 1 is a CD-ROM as seen from the signal side (optical pickup side), on which tracks in which data has been recorded are formed in a spiral with the outside diameter (outer circumference) of the tracks shown at the top of 10 Fig. 20, and the inside diameter (inner circumference) at the bottom. Item 2 is an optical pickup capable of emitting five light beams. When reading, the optical pickup 2 is in a state of relative rotation with respect to the CD-ROM 1, gradually moving from the inside of the 15 disk toward the circumference as it advances, reading the recorded data as proceeds. Now, when the optical pickup 2 arrives at position I and starts reading data, the tracks x through $(x + 4)$ are separately illuminated simultaneously by the light beams $3_1 - 3_5$, respectively. 20 The data recorded in each of the tracks illuminated by the beams $3_1 - 3_5$ is simultaneously read from the detected output of each of the returned beams by the prescribed record data readout system, and the data recorded on the CD-ROM 1 is output serially in the sequence in which it 25 was recorded, with no duplications or gaps.

The recorded data of CD-ROM 1 is structured in accordance with a CD signal format in sub-code Q-channel A-time (absolute time) frame units, where one frame = 1/75 second. Hereinafter, A-times are expressed in the form aa:bb:cc, where aa = seconds, bb = minutes, and cc = frames. If the optical pickup 2 were to start reading data from position I of Fig. 20, then

- the light beam 3₁ channel would start reading recorded data correctly from the A-time = 23:40:60 portion;
- the light beam 3₂ channel would start reading recorded data correctly from the A-time = 23:41:00 portion;
- the light beam 3₃ channel would start reading recorded data correctly from the A-time = 23:41:15 portion;
- the light beam 3₄ channel would start reading recorded data correctly from the A-time = 23:41:30 portion; and
- the light beam 3₅ channel would start reading recorded data correctly from the A-time = 23:41:45 portion.

By the time the CD-ROM 1 completes approximately (slightly more than) one revolution, advancing the optical pickup 2 to position II of Fig. 20 (where tracks

($x + 1$) - ($x + 5$) are illuminated by light beams 3_1 - 3_5 respectively,

- the light beam 3_1 channel will have read the recorded data correctly up to A-time = 23:40:74;
 - 5 • the light beam 3_2 channel will have read the recorded data correctly up to A-time = 23:41:14;
 - the light beam 3_3 channel will have read the recorded data correctly up to A-time = 23:41:29; and
 - the light beam 3_4 channel will have read the
 - 10 recorded data correctly up to A-time = 23:41:44;
- with the gaps between the data read separately by the light beams 3_1 - 3_5 now filled. (By this time, light beam 3_5 will have read the recorded data correctly up to A-time = 23:41:59.) The data read by light beams 3_1 - 3_5
- 15 is then output from the system in the sequence in which it was recorded, such that no duplications occur. (No frame is output more than once.)

When the optical pickup 2 has read data as far as position II in Fig. 20, the light pickup 2 is "track-jumped" forward (outward from the center of the CD-ROM 1) by three tracks. This puts the light pickup 2 in position III of Fig. 20 (where light beams 3_1 through 3_5 now illuminate tracks ($x + 4$) through ($x + 8$), respectively). At that point, the read operation then

25 begins again, with

- the light beam 3_1 channel reading recorded data correctly from the A-time = 23:41:48 portion;
- the light beam 3_2 channel reading recorded data correctly from the A-time = 23:41:63 portion;
- 5 • the light beam 3_3 channel reading recorded data correctly from the A-time = 23:42:03 portion;
- the light beam 3_4 channel reading recorded data correctly from the A-time = 23:42:18 portion; and
- the light beam 3_5 channel reading recorded data
- 10 correctly from the A-time = 23:42:33 portion.

By the time the CD-ROM 1 turns approximately (slightly more than) one revolution, advancing the optical pickup 2 to position IV of Fig. 20 (where tracks $(x + 5) - (x + 9)$ are illuminated by light beams $3_1 - 3_5$ respectively)

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- the light beam 3_1 channel will have read the recorded data correctly up to A-time = 23:41:62;
- the light beam 3_2 channel will have read the recorded data correctly up to A-time = 23:42:02;
- 20 • the light beam 3_3 channel will have read the recorded data correctly up to A-time = 23:42:17; and
- the light beam 3_4 channel will have read the recorded data correctly up to A-time = 23:42:32: and
- with all gaps between the data read by light beams $3_1 -$
- 25 3_5 now closed. (By this time, light beam 3_5 will have

read the recorded data correctly up to A-time = 23:42:47.) The data read by light beams 3_1 - 3_5 is then output from the system in the sequence in which it was recorded, and such that no duplications occur.

5 As the optical pickup 2 advances from position I to position II (one revolution of the CD-ROM 1), the optical beam 3_5 channel reads recorded data from A-time 23:41:45 through 23:41:59. As the optical pickup 2 advances from position III to position IV (one revolution of the CD-ROM
10 1), the optical beam 3_1 channel reads recorded data from A-time 23:41:48 through 23:41:62. In other words, there is an overlap between A-times 23:41:48 and 23:41:59, which was read by both channels. To avoid outputting these 12 frames twice, the system outputs only the copy
15 of this data that was read by the 3_5 channel (which read it first) and discards the duplicate data read by channel 3_1 .

Moreover, when the track jump from position II of Fig. 20 is executed, instead of a four-track jump, a
20 three-track jump is executed. Thus the data in track ($x + 4$), which was being read by the light beam 3_5 channel before the jump, is now illuminated by light beam 3_1 . The reason for doing this is that a four-track jump would have put the optical pickup 2 in position III of Fig. 20.
25 The light beam 3_1 channel would then have resumed reading

recorded data from A-time 23:41:63. This would have left a gap in the data between 23:41:60 and 23:41:62, which had not yet been read by the light beam 3₅ channel prior to the track jump.

5 Stated in general terms, for a system with n light beams, where n is an integer of 3 or greater, each light beam channel reads data for approximately one revolution. At that point, a forward track jump of $(n - 2)$ tracks is executed, after recorded data is again read for
10 approximately one revolution. This operation repeats continuously to perform high-speed readout of the CD-ROM 1.

Due to factors such as track pitch variance, surface flutter, and eccentric wobble of the CD-ROM 1, however,
15 some of the recorded data may not be readable by the light beam circuits. Consider a disk readout system such as the prior art method described above, where n light beam channels read approximately one revolution-worth of data, then a forward track jump of $(n - 2)$ tracks is
20 executed, after which approximately one revolution of recorded data is again read, and this operation is repeated. In this method, for the case illustrated in Fig. 20, if the recorded data in the light beam channel 3₂, for example, became unreadable during the
25 approximately one revolution of optical pickup 2 reading

from the position I of Fig. 20, the data from A-time 23:41:00 through 23:41:14 would be lost.

When the optical pickup 2 reaches position II, it jumps three tracks to position III; therefore, this data
5 between A-time = 23:41:00 and A-time = 23:41:14 is never read. Next, as the recorded data read continues for approximately one revolution from position III, the recorded data between A-time = 23:41:63 and A-time = 23:42:02 fails to be read.

10 In this method, then, there was a problem in that some data required by the user could not be retrieved.

In consideration of the above problem of the prior art, it is an object of the present invention to provide an optical disk readout method and optical disk readout
15 system in which, even if recorded data cannot be read by some of the light beams, the required data can still be obtained.

It is also an object of the present invention to provide an optical disk readout method and optical disk
20 readout system capable of reading data from an optical disk more efficiently.

Summary of the Invention

In an optical disk readout method according to the
25 present invention, n adjacent tracks (n being an integer

of 3 or greater) of an optical disk are illuminated simultaneously by separate n light beams arranged in the radial direction of the optical disk in order to read recorded data in the tracks illuminated by the n light beams, from output obtained by detecting returned ones of the n light beams through n light beam-read channels, and the reading of the optical disk is performed by alternating between a continuous reading and a track jump in the forward direction.

The method is characterized by steps of detecting the alignment status in the radial direction for the light beam-read channels incapable of reading recorded data from the optical disk; designating of light beam-read channels to be used for reading and determining the number of tracks to be jumped, according to the detection for the alignment status in the radial direction of the capable light beam-read channels; storing the readout data and corresponding frame addresses of the optical disk during the continuous reading by the light beam-read channels designated for reading; and executing the track jump by the determined number of tracks when the stored corresponding frame addresses become successive for data from the designated light beam-read channels during the continuous reading.

In the embodiment, when detecting that one or

adjacent two light beam-read channels only are capable of reading the recorded data, a single light beam-read channel is designated for reading and the continuous reading is successively conducted without executing the track jump.

M is the number of beams in the most populous contiguous group of light beam-read channels from which data can be read, said M light beam-read channels are designated as the valid ones, and the optical disk is read by alternating between performing continuous reading through said M designated valid light beam-read channels, for approximately one revolution of the optical disk, and executing a track jump of $(M - 2)$ tracks in the forward direction.

If Q is the distance, in number of tracks, between the innermost and outermost beams of light beam-read channels capable of reading recorded data, R is the number of beams in the most populous contiguous group of light beam-read channel incapable of reading recorded data, whose beams lie between said innermost and outermost light beams, and also if Q is at least 2, and R is at least 1, then the optical disk is read by alternating between performing continuous reading of the optical disk through the light beam-read channels that are capable of reading recorded data for approximately (R

+ 1) revolutions of the optical disk, and executing a track jump of $(Q - 1)$ tracks in the forward direction.

When $(Q - 1)$ is equal or less than zero, a single light beam-read channel only is designated for reading
5 and the continuous reading is successively performed without executing the track jump.

In an optical disk readout apparatus according to the present invention, n adjacent tracks (n being an integer of 3 or greater) of an optical disk are
10 illuminated simultaneously by separate n light beams arranged in the radial direction of the optical disk, comprising optical detection means for reading recorded data in the tracks illuminated by the n light beams, from
output obtained by detecting returned ones of the n light
15 beams through n light beam-read channels, and readout control means for reading the optical disk by alternating between a continuous reading and a track jump in the forward direction.

The apparatus is characterized by means for
20 detecting the alignment status in the radial direction for the light beam-read channels incapable of reading recorded data from the optical disk; means for designating of light beam-read channels to be used for reading and for determining the number of tracks to be
25 jumped, according to the detection for the alignment

status in the radial direction of the capable light beam-read channels; and means for storing the readout data and corresponding frame addresses of the optical disk during the continuous reading by the light beam-read channels
5 designated for reading; wherein the readout control means executes the track jump by the determined number of tracks when the stored corresponding frame addresses become successive for data from the designated light beam-read channels during the continuous reading.

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Brief Description of the Drawings

Fig. 1 is a block diagram of a CD-ROM readout system in which a first embodiment of the optical disk readout method and optical disk readout system of the present
15 invention is embodied.

Fig. 2 is a block diagram of the parallel-to-serial converter of Fig. 1.

Fig. 3 shows an example of the contents of the memories of Fig. 2.

20 Fig. 4 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

Fig. 5 shows an example of the contents of the memories of Fig. 2.

25 Fig. 6 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

Fig. 7 shows an example of the contents of the memories of Fig. 2.

Fig. 8 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

5 Fig. 9 shows an example of the contents of the memories of Fig. 2.

Fig. 10 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

10 Fig. 11 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

Fig. 12 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

Fig. 13 shows an example of the contents of the memories of Fig. 2.

15 Fig. 14 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

Fig. 15 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

20 Fig. 16 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

Fig. 17 shows an example of the contents of the memories of Fig. 2.

Fig. 18 shows an example of a data read operation in the CD-ROM readout system of Fig. 1.

25 Fig. 19 shows the configuration of an optical pickup

for another embodiment [of the present invention].

Fig. 20 is a drawing to explain the multi-beam optical disk readout technique.

5 Detailed Description of Embodiments

 An embodiment of the invention will be described with reference to Fig. 1. Fig. 1 is a block diagram of a CD-ROM readout system for implementing the optical disk readout method of the present invention. Items in Fig.
10 1 that are the same as items in Fig. 20 bear the same reference numbers.

 In Fig. 1, item 1 is a CD-ROM, on which tracks on which data is recorded are formed in a spiral (the left side in Fig. 1 corresponding to the inside of the disk,
15 and the right side in Fig. 1 corresponding to its outer edge). A spindle motor (not illustrated) spins the CD-ROM 1 at constant linear velocity. Item 2 is a multibeam optical pickup that simultaneously illuminates each of $n = 5$ adjacent tracks of the CD-ROM 1 with the separate
20 light beams $3_1 - 3_5$. The intercepted light of the returned beam is detected (received) by individual photodetectors $PD_1 - PD_5$, which output photoelectric currents as detected signals.

 Within the optical pickup 2 are

- 25 • a laser diode 4 that emits a laser beam 3;

- a diffraction grating 5, which is placed perpendicular to the optical axis of the laser diode 4, to form the following light beams:
 - light beam 3_1 , of -2nd order diffracted light,
 - 5 • light beam 3_2 , of -1st order diffracted light,
 - light beam 3_3 , of 0th order diffracted light,
 - light beam 3_4 , of +1st order diffracted light, and
 - light beam 3_5 , of +2nd order diffracted light,
- 10 • a beam splitter 6, made of two rectangular prisms, pasted together;
- a collimator lens 7 that collimates the diverging light to form parallel light rays;
- an objective lens 8 that focuses the light beams 3_1 - 3_5 that have passed through beam splitter 6 and the collimator lens 7 onto the signal surface 1A of the CD-ROM 1,
- 15 • a focus actuator 9, for moving the objective lens 8 in a direction perpendicular to the CD-ROM 1 so as to follow the surface flutter thereof, to thereby keep the light beams 3_1 - 3_5 in focus at the signal surface 1A, regardless of surface flutter of the CD-ROM 1;
- 20 • a tracking actuator 10, which moves the objective lens 8 radially with respect to the CD-ROM 1 so as
- 25

to follow the eccentric wobble thereof such that the beams $3_1 - 3_5$ will properly trace their tracks, regardless of the eccentric wobble of the CD-ROM 1.

Focus actuator 9 and tracking actuator 10 are separately driven by a servo circuit, to be discussed later.

Each of the separate photodetectors $PD_1 - PD_5$, provided to detect light beams $3_1 - 3_5$, respectively, output photoelectric currents proportional to the amount of received light. The returned beams of the light beams $3_1 - 3_5$, having been reflected from the signal surface 1A of the CD-ROM 1, pass through the objective lens 8 and collimator lens 7, are reflected by the beam splitter 6, and pass through optics (cylindrical and detector lenses, etc, that are not shown in the drawing), to become separately incident to the photodetectors $PD_1 - PD_5$. The photodetectors PD_1 , PD_2 , PD_4 , and PD_5 output photoelectric currents I_1 , I_2 , I_4 , and I_5 proportional to the amount of light received, as the detected signals of the returned beams of the light beams 3_1 , 3_2 , 3_4 , and 3_5 . The photodetector PD_3 is a quarter-split photodiode of the type used in common single-beam optical pickups. The four diode quadrants A, B, C, and D of photodetector PD_3 output the photoelectric currents I_{3-A} , I_{3-B} , I_{3-C} , and I_{3-D} , respectively, proportional to the amount of light

received.

During search of readout, a sled motor 11 moves the optical pickup 2 in the radial direction of the CD-ROM 1. During search, this sled motor 11 is driven by a servo
5 circuit to move the optical pickup 2 in either the forward or reverse direction to position it in a desired location. During readout, it moves the optical pickup 2 gradually in the forward direction as the reading of CD-ROM 1 proceeds.

10 From the outputs of the photodetectors $PD_1 - PD_5$, of the optical pickup 2, a recorded data readout system 20 simultaneously reads the data that is recorded in the tracks being illuminated by light beams $3_1 - 3_5$, and outputs the CD-ROM 1 recorded data in serial form, in the
15 sequence in which it was recorded, with no duplications or gaps in the data. Within this recorded data readout system 20, current-to-voltage (I/V) converters $21_1, 21_2, 21_4$ and 21_5 convert the photoelectric currents I_1, I_2, I_4 and I_5 output by the photodetectors PD_1, PD_2, PD_4 and PD_5 ,
20 respectively, to voltages, which are output as the RF signals RF_1, RF_2, RF_4 and RF_5 , corresponding to the light beams $3_1, 3_2, 3_4$ and 3_5 . The current-to-voltage (I/V) converters $21_3-A, 21_3-B, 21_3-C$, and 21_3-D convert the photoelectric currents I_3-A, I_3-B, I_3-C and I_3-D output by
25 the photodetector PD_3 , to voltages, which it outputs as

the voltage values V_A , V_B , V_C , and V_D .

The computation section 22 performs the computation $(V_A + V_B + V_C + V_D)$, to output an RF signal RF_3 corresponding to light beam 3_3 , performs the computation
5 $(V_A + V_C) - (V_B + V_D)$ to output the focus error signal FE, and the performs computation $(V_A + V_B) - (V_C + V_D)$ to output the tracking error signal TE. The servo circuit 23 performs focus servo control, tracking servo control, and sled servo control: It drives the focus actuator 9,
10 based on the focus error signal FE, so as to reduce the focus error to zero, to thereby focus the light beams $3_1 - 3_5$ at the signal surface 1A; and drives the tracking actuator 10, based on the tracking error signal TE, so as to reduce the tracking error signal to zero, to thereby
15 keep the light beams $3_1 - 3_5$ on their respective tracks.

Waveshape equalization circuits $24_1 - 24_5$ modify the waveshapes of the RF signals $RF_1 - RF_5$ to enhance their high frequency components to compensate for high band attenuation due to the modulation transfer functions
20 (MTF) of light beams $3_1 - 3_5$, and suppress intersymbol interference. Also, either the RF signal RF_3 , input to waveshape equalization circuit 24_3 , or the [waveshape-equalized version of the] RF signal RF_3 , output from waveshape equalization circuit 24_3 , is input to the servo
25 circuit 23 (not shown in Fig. 2). When turning on the

focus servo, the servo circuit 23 activates a focus search operation, timing the focus servo turn-on point to occur while the value of the focus error signal FE is in the negative feedback region of the focus servo loop.

5 Also, when turning the tracking servo on, [the servo circuit 23] uses the RF signal RF_3 to time the tracking servo turn-on point to occur with the light beam 3₃ in the negative feedback region of the tracking servo loop.

The RF signals $RF_1 - RF_5$ are input to the "first
10 signal processing circuits" 26₁ - 26₅, respectively, where digitization, clock extraction (using a PLL), bit demodulation, frame sync detection, EFM demodulation, and subcode demodulation processes are performed. The EFM demodulated data signals DATA₁ - DATA₅ (which include P
15 and Q parity) are output along with their corresponding subcode Q-channel A-time data signals AT₁ - AT₅. DATA₁ - DATA₅ are output in blocks (98-frame units concluding with one subcode frame). The first signal processing
circuits 26₁ - 26₅ output the demodulated data signals
20 DATA₁ - DATA₅, one symbol (8 bits) at a time. When the first signal processing circuits 26₁ - 26₅ detect frame sync, they output the "frame sync detect" signals FS₁ - FS₅, respectively, as a HIGH level, to a system controller, to be described later. The system controller
25 uses these frame sync detect signals FS₁ - FS₅ to

determine separately for each of the light beam $3_1 - 3_5$ channels, whether data can or cannot be read from the channel. The first signal processing circuit 26_3 also sends the AT_3 A-time data signal to the system
5 controller. The first signal processing circuit 26_3 , the signal processing circuit for the RF_3 RF signal channel has an internal CLV control circuit (not illustrated), the purpose of which is to cause the frame sync signal to be detected at constant time intervals, performing CLV
10 control for a spindle motor drive circuit (not illustrated) to cause the CD-ROM 1 to spin at constant linear velocity.

Parallel-to-serial (P/S) converter 30 inputs the 8-bit parallel data output by each of the first signal
15 processing circuits $26_1 - 26_5$ one block at time. The P/S converter 30 converts the parallel data to serial data, ensures that there are no duplications or gaps in the data, and outputs it, in the order in which it was recorded, as serial data. Fig. 2 is a block diagram
20 showing a specific configuration for this parallel-to-serial converter 30. In Fig. 2, one of each of the memory circuits $32_1 - 32_5$ is provided for the corresponding one of the first signal processing circuits $26_1 - 26_5$. Each memory circuit has two memory areas: a
25 first area and a second area. The $DATA_1 - DATA_5$ data

output from first signal processing circuits $26_1 - 26_5$, is stored in one or the other of the two storage areas [of the associated memory circuit]. The first and second areas have sufficient storage capacity to store the required number of blocks of $DATA_1 - DATA_5$ data. One of each of the memory circuits $33_1 - 33_5$ is also provided for each of the first signal processing circuits $26_1 - 26_5$, respectively. Each of these memory circuit also has a first area and second area. The $AT_1 - AT_5$ A-time data output from first signal processing circuits $26_1 - 26_5$, is stored in one or the other of these areas, along with the start address $A_{1s} - A_{5s}$ (or $a_{1s} - a_{5s}$) and end address $A_{1e} - A_{5e}$ (or $a_{1e} - a_{5e}$), marking the memory locations of the $DATA_1 - DATA_5$ data stored in the corresponding $32_1 - 32_5$ memories. The first and second areas have sufficient storage capacity to store [the required] number of [sets of] $AT_1 - AT_5$ A-time data.

One of the five write controllers $31_1 - 31_5$ is provided for the corresponding one of the first signal processing circuits $26_1 - 26_5$. The write controllers write the $DATA_1 - DATA_5$ data output from first signal processing circuits $26_1 - 26_5$ into the first or second areas of memory circuits $32_1 - 32_5$, and write the $AT_1 - AT_5$ A-time data, along with the start address $A_{1s} - A_{5s}$ (or $a_{1s} - a_{5s}$) and end address $A_{1e} - A_{5e}$ (or $a_{1e} - a_{5e}$), marking

the memory locations of the $DATA_1 - DATA_5$ data stored in the corresponding $32_1 - 32_5$ memories, in the first or second areas of memories $33_1 - 33_5$.

If, for example, the write controller 32_f (where $f = 1 - 5$) writes the 15 blocks of data $DATA_f(1) - DATA_f(15)$ to the first area, and the 15 blocks $DATA_f(16) - DATA_f(30)$ to the second area of memory 32_f , then the contents of memories 32_f and 33_f will be as shown in Fig. 3. That is, written to the first area of memory 33_f is the A-time data for each block of $DATA_f(1) - DATA_f(15)$ (e.g. 23:40:60 - 23:40:74), and the start address $A_{fs}(1)$ and end address $A_{fe}(1)$ through start address $A_{fs}(15)$ and end address $A_{fe}(15)$, which indicate the storage locations in the first area of memory 32_f of $DATA_f(1) - DATA_f(15)$. Written to the second area of memory 33_f are the A-time data for each block of $DATA_f(16) - DATA_f(30)$ (e.g. 23:41:48 to 23:41:62), and the start address $a_{fs}(1)$ and end address $a_{fe}(1)$ through start address $a_{fs}(15)$ and end address $a_{fe}(15)$, which indicate the storage locations in the second area of memory 32_f of $DATA_f(16) - DATA_f(30)$.

Read controller 34 accesses the A-time data $AT_1 - AT_5$ stored in memories $33_1 - 33_5$ at the start addresses $A_{1s} - A_{5s}$ (or $a_{1s} - a_{5s}$) and end addresses $A_{1e} - A_{5e}$ (or $a_{1e} - a_{5e}$), to read out the $DATA_1 - DATA_5$ data stored in memories $32_1 - 32_5$, without duplication or gaps, and in the same

sequence as it was recorded on CD-ROM (i.e., A-time sequence), and output it serially, a symbol at a time. The operation of the write controllers 31₁ - 31₅ and the read controller 34 will be described in more specific
5 terms later.

Returning now to Fig. 1, second signal processing circuit 40 inputs the serial data output by parallel-to-serial converter 30. After descrambling this data a block at a time, it performs error detection/correction
10 based on CIRC code (P parity error detection/correction, de-interleaving, and Q parity error detection/correction). It then demodulates L and R channel data in accordance with the CD-DA standard; and from the resulting L and R channel data, performs
15 additional sync detection, descrambling, header detection, and EDC and ECC code error correction, in order to demodulate the CD-ROM data and output it to an external host computer.

A microcontroller circuit is used for the system
20 controller 50. In search operation, it issues a search command to servo circuit 23, which responds by applying drive to sled motor 11 as required to move the optical pickup 2 in either the forward or reverse direction of the CD-ROM 1 to position it in the desired location.
25 During read operations, the system controller 50 issues

"servo on" commands as required to focus the light beam
3₁ - 3₅ spots at the signal surface 1A, and to keep the
beams "on-track" (autotrack locked) on five adjacent
tracks of the CD-ROM 1. Also, after reading the data
5 recorded in these tracks for an appropriate number of
revolutions of the disk (at least one or two), a "track
jump" command is issued to jump [the sled] forward a
prescribed number of tracks.

At the start of each read operation, for one
10 revolution of the CD-ROM 1, the system controller 50
monitors the states of the frame sync detect signals FS₁
- FS₅ received from the first signal processing circuits
26₁ - 26₅, to determine whether the data from any of the
3₁ - 3₅ light beam channels is unreadable (due to CD-ROM
15 1 track pitch variance, disk flutter, wobble, etc.). If
all of the frame sync detect signals FS₁ - FS₅ are HIGH
(i.e., if there are no unreadable channels) the
controller sends a normal write/read command to parallel-
to-serial converter 30, to write/read the DATA₁ - DATA₅
20 data outputs of all of the first signal processing
circuits 26₁ - 26₅ to/from memory (32₁ - 32₅).

However, if one or more of the light beam channel
frame sync detect signals FS₁ - FS₅ stays LOW for a set
minimum time (e.g., 1/75 second), indicating that the
25 data in that channel (or channels) is unreadable, those

light beams (from among the beams $3_1 - 3_5$) that are to be used for reading data are determined (these light beams will be designated $3_i, 3_j, 3_k \dots$), and special write/read commands, which contain information as to the light beam channels to be used for reading data ($i, j, k, \dots$), are sent to the serial-to-parallel converter 30. The data outputs of those of the first signal processing circuits $26_1 - 26_5$, that are in the channels being used to read the data outputs (the $DATA_1, DATA_j, DATA_k, \dots$ outputs of first signal processing circuits $26_1, 26_j, 26_k, \dots$) are then written to and read from the memory circuits $32_1 - 32_5$.

These "normal" and "special" read/write commands output by the system controller 50 are input to the read controller 34 of parallel-to-serial converter 30, and are also passed on from the read controller 34 to the write controllers $31_1 - 31_5$. At the start of a read operation, if the write controllers $31_1 - 31_5$ receive a normal write/read command, they first write the $DATA_1 - DATA_5$ data outputs of all of the first signal processing circuits $26_1 - 26_5$ to the first areas of the memories $32_1 - 32_5$, respectively. When a "stop" command is received from the read controller 34, the write controllers stop writing, and next, when a resume command is received, they write to the second area (the area other than the

one they wrote to last time). After that, when the controllers receive a halt command followed by a resume command, they stop writing, and when they resume, they write to the area (first or second) other than the one
5 they were writing to when they received the halt command.

At the start of a read operation, if the write controllers $31_1 - 31_5$ receive a special write/read command, however, only those write controllers of the readable channels identified by the special write command
10 write the data outputs of the first signal processing circuits for those channels to the first areas of the applicable memory circuits for those channels. That is, if the readable channels are i, j , and k , ... the write controllers $31_i, 31_j, 31_k$, ... write the $DATA_i, DATA_j,$
15 $DATA_k$ outputs of the first signal processing circuits $26_i, 26_j, 26_k$, ... to the first areas of the $32_i, 32_j, 32_k$, ... memories. When the halt command is received from the read controller 34, the write controllers stop writing, and next, when a "resume" command is received, they write
20 to the second area (the area other than the one they wrote to last time). After that, the operation proceeds in the same manner: when the controllers receive a halt command, they stop writing; and when they receive a resume command, they write to the area (first or second)
25 other than the one they wrote to the previous time.

When the read controller 34 receives a normal write/read command (special write/read command) from the system controller 50, if a "stop" command is sent to the write controllers $31_1 - 31_5$ ($31_i, 31_j, 31_k, \dots$), when the
5 A-times indicated by the A-time data stored in those areas (first or second) of the memories $33_1 - 33_5$ ($33_i, 33_j, 33_k, \dots$) that were written to during this operation by the write controllers $31_1 - 31_5$ ($31_i, 31_j, 31_k, \dots$) are all consecutive times, with no gaps, a track-jump command
10 is sent to the system controller 50, and the read controller 34 itself then accesses the A-time data and the start and end addresses stored in the areas (first or second) of memories $33_1 - 33_5$ ($33_i, 33_j, 33_k$) that were written to this time, and reads out the corresponding
15 recorded data stored in those areas (first or second) of memories $32_1 - 32_5$ ($32_i, 32_j, 32_k, \dots$) that were written to this time, outputting the data in A-time sequence, starting with the data corresponding to the most recent A-time.

20 Later, when the "jump completed" notification input is received from the system controller 50, a resume command is sent to the write controllers $31_1 - 31_5$ ($31_i, 31_j, 31_k, \dots$). This time, when the A-times, as indicated by the A-time data written to those areas (first or
25 second) of the memories $33_1 - 33_5$ ($33_i, 33_j, 33_k, \dots$)

other than the ones written to the previous time are all consecutive A-times, without gaps, the read controller 34 itself sends a halt command to the write controllers 31_1 - 31_5 (31_1 , 31_j , 31_k), and sends a jump command to the
5 system controller 50. The read controller 34 also accesses the A-time data and the start and end addresses stored in those areas (first or second) of memories 33_1 - 33_5 (33_1 , 33_j , 33_k) other than the ones written to last time, and reads out the corresponding recorded data
10 stored in the areas (first or second) of memories 32_1 - 32_5 (32_1 , 32_j , 32_k) other than the ones written to the previous time, outputting the data in A-time sequence, starting with the data corresponding to the A-time immediately following the A-time for to the last block of
15 data output to the second signal processing circuit 40. From that point on, the process repeats.

Next, the operation of the above embodiment will be described, with reference to Figures 4 through 18. For this description, it is assumed that the CD-ROM 1 is
20 already spinning at constant linear velocity under CLV control, and that the focus servo is on. It is also assumed that the optical pickup 2 is simultaneously illuminating five adjacent tracks of the CD-ROM 1 separately with $n = 5$ light beams 3_1 - 3_5 .

25 (1) Identifying Unreadable Channels

The host computer (not illustrated) generates an input to the system controller 50 to specify a "read start point" on the CD-ROM 1, in A-time (e.g. 23:41:00). For this discussion, the track that includes this read start point shall be designated "track x" (see Fig. 4, 6, 8, 10, 11, 12, 14, 15, 16, and 18). In response to this input, the system controller 50 first sends a "search" command to servo circuit 23. This causes optical pickup 2 to be moved so as to position beam 3_1 at track $(x - 6)$. Then, "tracking servo on" and "sled servo on" commands are sent to the servo circuit 23 to activate the tracking and sled search functions. This results in beams 3_1 through 3_5 that are being emitted from optical pickup 2 being focused and on-track on tracks $(x - 6)$ through $(x - 2)$ (position I in Fig. 4, 6, 8, 10, 11, 12, 14, 15, 16, and 18).

The beams $3_1 - 3_5$ are reflected by the signal surface 1A, and the returned beams intercepted by the photodetectors $PD_1 - PD_5$, which output photoelectric currents $I_1 - I_5$. The photoelectric currents I_1, I_2, I_4 and I_5 , output by the photodetectors PD_1, PD_2, PD_4 and PD_5 are converted to RF signals RF_1, RF_2, RF_4 and RF_5 by the I/V converters $21_1, 21_2, 21_4$ and 21_5 . After waveshaping by waveshape equalization circuits $24_1, 24_2, 24_4$, and 24_5 , these RF signals are input to the first signal processing

circuits 26_1 , 26_2 , 26_4 and 26_5 . The photoelectric currents I_3 -A - I_3 -D from photodetector PD_3 are converted to the voltage values V_A - V_D by the I/V converters 21_3 -A - 21_3 -D, which are summed in the computation section 22 to generate the RF signal RF_3 . After waveshaping by the waveshape equalization circuit 24_3 , this signal is input to the first signal processing circuit 26_3 .

The RF signals RF_1 - RF_5 are input to the "first signal processing circuits" 26_1 - 26_5 , respectively, where digitization, clock extraction (using a PLL), bit demodulation, frame sync detection, EFM demodulation, and subcode demodulation are performed. The EFM demodulated data signals $DATA_1$ - $DATA_5$ (which include P and Q parity) are output along with their corresponding subcode Q-channel A-time data signals AT_1 - AT_5 . $DATA_1$ - $DATA_5$ are output in block units. The first signal processing circuits 26_1 - 26_5 output the demodulated data signals $DATA_1$ - $DATA_5$, one symbol (8 bits) at a time. When the first signal processing circuits 26_1 - 26_5 detect frame sync, they output the "frame sync detect" signals FS_1 - FS_5 , respectively, as a HIGH level to the system controller 50.

After executing a search operation to put the light beams 3_1 - 3_5 of optical pickup 2 on-track, at tracks (x - 6) through (x - 2), the system controller 50 monitors

the frame sync detect signals $FS_1 - FS_5$ received from the first signal processors $26_1 - 26_5$. The decision as to whether the data from a particular channels is readable is made as follows: If, during one revolution of the CD-ROM 1, a frame sync signal stays LOW for at least one block (for our purposes, 1/75 seconds), it is determined that data from that channel is unreadable.

(2) Normal Write/Read Operation (Figures 4 and 5)

First operation will be explained for the case in which the recorded data is readable in all five of the light beam channels ($3_1 - 3_5$).

When it is determined, as described above, that there are no unreadable channels, all five light beam channels ($3_1 - 3_5$) are allocated to h (the number of "valid" beam (or channels), i.e., beams to be used for reading data. Also, the values "I" and "J" are set to $I = 1$, and $J = (n - 2) = 3$, where I is the number of disk revolutions in a continuous data read (without track-jumping), J is the number of tracks jumped in a track jump, and n is the total number of beams (five in this case). Also, from the newest (latest) A-time in the A-time data AT_3 input from the first signal processing circuit 26_3 , and the A-time of the "read start point" specified by the host computer, [the system controller 50] determines the jump direction and number of tracks

for a track jump that will put beam 3_1 , the innermost of the $h = 5$ valid beams (the beam nearest the center of the disk), on-track, one track inside of track "x," the track that includes the A-time of the read start point (i.e.,
5 the jump that will put 3_1 on track at track $(x - 1)$) and executes that track jump.

With the h valid light beam channels allocated, and the values of I (the number of disk revolutions in a continuous data read) and J (the number of tracks jumped
10 in a track jump) set, if the optical pickup 2 is located at position II of Fig. 4, it will be jumped forward from position II by four tracks, to put beams $3_1 - 3_5$ on-track at tracks $(x - 1) - (x + 3)$ (position III in Fig. 4). Simultaneous reading of the recorded data in tracks $(x -$
15 $1)$ through $(x + 3)$ begins at that point through the five channels (circuits) made up of photodetector PD_1 through first signal processing circuit 26_1 , photodetector PD_2 through first signal processing circuit 26_2 , photodetector PD_3 through first signal processing circuit
20 26_3 , photodetector PD_4 through first signal processing circuit 26_4 , and photodetector PD_5 through first signal processing circuit 26_5 . Also, when HIGH level frame sync detect signals $FS_1 - FS_5$ are received from all five of the first signal processing circuits $26_1 - 26_5$, a "normal
25 write/read" command is sent to parallel-to-serial

converter 30.

The normal write/read command is fed through read controller 34 to the write controllers $31_1 - 31_5$, which then write the data $DATA_1 - DATA_5$, received from first
5 signal processor circuits $26_1 - 26_5$, respectively, a block at a time, to the first areas of the memories $26_1 - 26_5$, in sequence [(the sequence in which it was recorded)]. The write controllers also write the A-time data corresponding to the above data to memory, along with the
10 memory addresses at which that data is located, as follows: Referring to Fig. 3, $AT_1 - AT_5$ (the A-time data for $DATA_1 - DATA_5$) is written to the first areas of memories $33_1 - 33_5$, along with the memory $32_1 - 32_5$ start/end address pairs (start addresses $A_{1s} - A_{5s}$ and end
15 addresses $A_{1e} - A_{5e}$) at which the corresponding data is stored. For the case illustrated in Fig. 4, the data written as A-time data in the first areas of each of the memories $33_1 - 33_5$, would be 23:40:60, 23:41:00, 23:41:15, 23:41:30, 23:41:45, and so on, as shown in Fig. 5.

20 Having received a normal write/read command, read controller 34 accesses the data just written to the first areas of memory $33_1 - 33_5$, as described above, to verify that the state of the stored data is such that

the A-time immediately prior to the A-time data
-
25 stored at the top address in the first area of

memory 33₅ is in the first area of memory 33₄,
the A-time immediately prior to A-time data stored
at the top address in the first area of memory 33₄
is in the first area of memory 33₃,
5 the A-time immediately prior to the A-time data
stored at the top address in the first area of
memory 33₃ is in the first area of memory 33₂, and
the A-time immediately prior to the A-time data
stored at the top address in the first area of
10 memory 33₂ is in the first area of memory 33₁,
thus verifying that there are no gaps in the data
read from the five valid channels.

When reading performed by optical pickup 2 for
approximately $I = 1$ revolution (actually slightly more
15 than one revolution) advances to position IV in Fig. 4,
the contents of memories 33₁ - 33₅ will be as shown in
Fig. 5. Since it finds no gaps in the data read from the
valid channels, the read controller 34 sends a halt
command to the write controllers 31₁ - 31₅ to halt the
20 write operation, and a track jump command to the system
controller 50. The read controller 34 then accesses the
A-time data and the start and end addresses stored in the
first areas of memories 33₁ - 33₅, and starts reading the
corresponding DATA₁ - DATA₅ data from the first areas of
25 memories 32₁ - 32₅ (to which it was written this time).

The read controller 34 outputs this data to the second signal processing circuit 40 in A-time sequence, starting with the data corresponding to the most recent A-time. In this case, it outputs the data corresponding to A-
5 times 23:40:60 through 23:41:59. The A-time of the start read point originally specified by the host computer was 23:41:00. Therefore this data is output from the frame just prior to the start read point.

The second signal processing circuit 40 inputs the
10 serial data output by parallel-to-serial converter 30. After descrambling this data block by block it performs error detection/correction based on the CIRC code (P parity error detection/correction, de-interleaving, and Q parity error detection/correction). It then
15 demodulates L and R channel data in accordance with the CD-DA standard; and from the resulting L and R channel data, performs additional sync detection, descrambling, header detection, and EDC and ECC code error correction based on the CD-ROM standard, in order to demodulate the
20 CD-ROM data and output it to the external host computer.

When the write controllers $31_1 - 31_5$ receive the halt command they stop writing to memories $32_1 - 32_5$ and $33_1 - 33_5$. When the system controller 50 receives the track jump command, it sends commands to the servo circuit 23
25 to execute a track jump of $J = 3$ tracks in the forward

direction, causing the optical pickup 2 to jump from position IV of Fig. 4 to position V, and positioning the beams $3_1 - 3_5$ on-track to start reading data at tracks $(x + 3) - (x + 7)$. Then, when the frame sync signals $FS_1 -$
5 FS_5 outputs of all of the first signal processing circuits $26_1 - 26_5$ go HIGH, the system controller 50 sends a "track jump completed" notification to the read controller 34.

Upon receiving the "track jump completed" notification, the read controller 34 sends a "resume"
10 command to write controllers $31_1 - 31_5$, causing them to start writing to memory, the data output by the first signal processing circuits $26_1 - 26_5$ after the track jump. This time (after the track jump) the write controllers
15 write the $DATA_1 - DATA_5$ outputs to the second areas of the memories $32_1 - 32_5$, and write the corresponding A-time data ($AT_1 - AT_5$) along with the memory $32_1 - 32_5$ start addresses ($a_{1s} - a_{5s}$) and end addresses ($a_{1e} - a_{5e}$) of the $DATA_1 - DATA_5$ data currently being stored, to the second
20 areas of memories $33_1 - 33_5$. (See Fig. 3.) For the case illustrated in Fig. 4, the data written as A-time data in the second areas of the memories $33_1 - 33_5$ would be 23:41:48, 23:41:63, 23:42:03, 23:42:18, 23:42:33, and so on, as shown in Fig. 5.

25 After issuing the "resume" command, the read

controller 34 accesses the second areas of memories 33_1 - 33_5 (the areas just written to) to verify that there are no gaps in the data read by the valid ($h = 5$) beam 3_1 - 3_5 channels as described above. It does this by

5 verifying that the state of the stored data is such that the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_5 is in the second area of memory 33_4 , the A-time immediately prior to the A-time data

10 stored at the top address in the second area of memory 33_4 is in the second area of memory 33_3 , the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_3 is in the second area of memory 33_2 , and

15 the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_2 is in the second area of memory 33_1 .

When the reading performed by optical pickup 2 for approximately $I = 1$ revolution (actually slightly more

20 than one revolution) advances to position VI in Fig. 4, the contents of the second areas of memories 33_1 - 33_5 will be as shown in Fig. 5. Since it finds no gaps in the data read from the valid channels, the read controller 34 sends a halt command to the write

25 controllers 31_1 - 31_5 to halt the write operation, and a

track jump command to the system controller 50. The read controller 34 then accesses the A-time data and the start and end addresses stored in the second areas of memories $33_1 - 33_5$ (the areas to which it was written this time) and starts reading the corresponding $DATA_1 - DATA_5$ data from the second areas of memories $32_1 - 32_5$ (to which it was written this time). The read controller 34 outputs this data to the second signal processing circuit 40 in A-time sequence, starting with the data corresponding to the A-time immediately following the last A-time of the block of data last output to the second signal processing circuit 40 the previous time (before the last track jump). In this case, it outputs the data corresponding to A-times 23:41:60 through 23:42:47.

When the write controllers $31_1 - 31_5$ receive the halt command they stop writing to memories $32_1 - 32_5$ and $33_1 - 33_5$. When the system controller 50 receives the track jump command, it jumps the optical pickup 2 from position V_i of Fig. 4 to position V_{II} , positioning the beams $3_1 - 3_5$ on-track to start reading data at tracks $(x + 7) - (x + 11)$. Then, when the frame sync signal $FS_1 - FS_5$ outputs of all of the first signal processing circuits $26_1 - 26_5$ go HIGH, the system controller 50 sends a "track jump completed" notification to the read controller 34.

Upon receiving the "track jump completed"

notification through the read controller 34, write controllers 31₁ - 31₅, start writing to memory, the data output by the first signal processing circuits 26₁ - 26₅ after last the track jump. This time the write
5 controllers write the DATA₁ - DATA₅ outputs to the first areas of the memories 32₁ - 32₅, and write the corresponding A-time data (AT₁ - AT₅) along with the memory 32₁ - 32₅ start addresses (A_{1s} - A_{5s}) and end addresses (A_{1e} - A_{5e}) of the DATA₁ - DATA₅ data currently
10 being stored, to the first areas of memories 33₁ - 33₅. If the A-times stored in the first areas of memories 33₁ - 33₅ are all consecutive times, with no gaps, the read controller 34 reads out the contents of the first areas of memories 32₁ - 32₅ for output in A-time sequence,
15 starting with the data corresponding to the A-time immediately following the last A-time of the block of data last output to the second signal processing circuit 40 the previous time. From this point on, the above operations are repeated as required to read the desired
20 data from CD-ROM 1 in the sequence in which it was recorded, at high speed, without duplications or gaps.

(3) Special Write/Read Operation, Part 1 (Beam 3₅ Channel Unreadable) (Figures 6 and 7)

If the system controller 50 determines, during one
25 revolution of relative motion between the optical pickup

2 and CD-ROM 1, starting from position I of Fig. 6, that recorded data cannot be read from the outermost beam (3_5) channel, then the largest contiguous group of beam channels from which data can be read would be made up of the four beams $3_1 - 3_4$. Thus $M \geq 3$, where M is the number of beams in the largest contiguous group of beam channels from which data can be read. Accordingly, the channels of the M beams $3_1 - 3_4$ are designated as the h valid beam channels. Also, values I and J are set to $I = 1$, and $J = (M - 2) = 2$, where I is the number of disk revolutions in a continuous data read (without track-jumping), and J is the number of tracks jumped in a track jump.

Also, from the newest A-time in the A-time data AT_3 , input from the first signal processing circuit 26₃, and the "read start point" A-time specified by the host computer, the system controller 50 determines the jump direction and number of tracks for a track jump that will put beam 3_1 , the innermost of the $h = 4$ valid beams (the beam nearest the center of the disk), on-track, one track inside of track "x," the track that includes the A-time of the read start point (i.e., the jump that will put 3_1 at track $(x - 1)$), and executes that track jump.

When the h valid light beam channels are designated, and the values of I (the number of disk revolutions in a continuous data read) and J (the number of tracks jumped

in a track jump) set, if the optical pickup 2 is located at position II of Fig. 6, it will be jumped forward from position II by four tracks, to put beams $3_1 - 3_4$ on-track at tracks $(x - 1) - (x + 2)$ (position III in Fig. 6).

5 Simultaneous reading of the recorded data in tracks $(x - 1)$ through $(x + 2)$ will then begin at that point through the four channels (circuits) made up of photodetector PD_1 through first signal processing circuit 26_1 , photodetector PD_2 through first signal processing circuit

10 26_2 , photodetector PD_3 through first signal processing circuit 26_3 , and photodetector PD_4 through first signal processing circuit 26_4 . Also, when HIGH level frame sync detect signals $FS_1 - FS_4$ are received from all four of the first signal processing circuits $26_1 - 26_4$, a special

15 write/read command including valid channel information "1, 2, 3, 4" is sent to parallel-to-serial converter 30.

The special write/read command is fed through read controller 34 to the write controllers. After that, only the write controllers $31_1 - 31_4$, identified in the valid

20 channel information "1, 2, 3, 4" write the data $DATA_1 - DATA_4$, received from first signal processor circuits $32_1 - 32_4$, respectively, a block at a time, to the first areas of the memories $26_1 - 26_4$, in sequence (the sequence in which it was recorded). The write controllers also write

25 the A-time data corresponding to the above data to

memory, along with the memory addresses at which that data is located, as follows: $AT_1 - AT_4$ (the A-time data for $DATA_1 - DATA_4$) is written to the first areas of memories $33_1 - 33_4$, along with start addresses $A_{1s} - A_{4s}$ and end addresses $A_{1e} - A_{4e}$ (as start/end address pairs) in memories $32_1 - 33_4$ at which the corresponding data is stored. For the case illustrated in Fig. 6, the data written as A-time data in the first areas of each of the memories $33_1 - 33_4$, would be 23:40:60, 23:41:00, 23:41:15, 23:41:30, and so on, as shown in Fig. 7.

Having received a special write/read command, read controller 34 checks only the data written to the memories in the indicated valid channel information "1, 2, 3, 4". Thus it accesses the data just written to the first areas of memories $33_1 - 33_4$, to verify that the state of the stored data is such that

the A-time immediately prior to the A-time data stored at the top address in the first area of memory 33_4 is included in the first area of memory 33_3 ,

the A-time immediately prior to the A-time data stored at the top address in the first area of memory 33_3 is included in the first area of memory 33_2 , and

the A-time immediately prior to the A-time data

stored at the top address in the first area of
memory 33₂ is included in the first area of memory
33₁,

thus verifying that there are no gaps in the data read
5 from the valid channels.

When reading performed by optical pickup 2 for
approximately $I = 1$ revolutions (actually slightly more
than one revolution) advances to position IV in Fig. 6,
the contents of memories 33₁ - 33₄ will be as shown in
10 Fig. 7. Because it finds no gaps in the data read from
the valid channels, the read controller 34 sends a halt
command to the write controllers 31₁ - 31₄ to halt the
write operation, and a track jump command to the system
controller 50. The read controller 34 then accesses the
15 A-time data and the start and end addresses stored in the
first areas of memories 33₁ - 33₄, and starts reading the
corresponding DATA₁ - DATA₄ data from the first areas of
memories 32₁ - 32₄ (to which it was written this time).
The read controller 34 outputs this data to the signal
20 processing circuit 40 in A-time sequence, starting with
the data corresponding to the newest A-time. In this
case, it outputs the data corresponding to A-times
23:40:60 through 23:41:44.

When the write controllers 31₁ - 31₄ receive the halt
25 command they stop writing to memories 32₁ - 32₄ and 33₁ -

33₄. When the system controller 50 receives the track jump command, it sends commands to the servo circuit 23 to execute a track jump of $J = 2$ tracks in the forward direction, causing the optical pickup 2 to jump from position IV of Fig. 6 to position V, and positioning the beams 3₁ - 3₄ on-track to start reading recorded data at tracks $(x + 2) - (x + 5)$. Then, when the frame sync detect signal outputs (FS₁ - FS₄) of all of the first signal processing circuits 26₁ - 26₄ go HIGH, the system controller 50 sends a "track jump completed" notification to the read controller 34.

Upon receiving the "track jump completed" notification, the read controller 34 sends a "resume" command to write controllers 31₁ - 31₄, causing them to start writing to memory, the data output by the first signal processing circuits 26₁ - 26₄ after the track jump. This time, the write controllers write the DATA₁ - DATA₄ outputs to the second areas of the memories 32₁ - 32₄, and write the corresponding A-time data (AT₁ - AT₄) along with the memory 32₁ - 32₄ start addresses (a_{1s} - a_{4s}) and end addresses (a_{1e} - a_{4e}) of the DATA₁ - DATA₄ data currently being stored, to the second areas of memories 33₁ - 33₄. For the case illustrated in Fig. 6, the data written as A-time data in the second areas of the memories 33₁ - 33₄, would be 23:41:33, 23:41:48, 23:41:63, 23:42:03, and so

on, as shown in Fig. 7.

After issuing the "resume" command, the read controller 34 accesses the second areas of memories 33_1 - 33_4 (the areas just written to) to verify that there are
5 no gaps in the data read by the valid channels. It does this by verifying that the state of the stored data is such that

the A-time immediately prior to the A-time data stored at the top address in the second area of
10 memory 33_4 is included in the second area of memory 33_3 ,

the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_3 is included in the second area of
15 memory 33_2 , and

the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_2 is in the second area of memory 33_1 .

When the reading performed by optical pickup 2 for
20 approximately $I = 1$ revolution (actually slightly more than one revolution) advances to position VI in Fig. 6, the contents of the second areas of memories 33_1 - 33_4 will be as shown in Fig. 7. Because it finds no gaps in the data read from the valid channels (1, 2, 3, and 4),
25 the read controller 34 sends a halt command to the write

controllers $31_1 - 31_4$ to halt the write operation, and a track jump command to the system controller 50. The read controller 34 then accesses the A-time data and the start and end addresses stored in the second areas of memories $33_1 - 33_4$, and starts reading the corresponding $DATA_1 - DATA_4$ data from the second areas of memories $32_1 - 32_4$ (the areas to which it was written this time). The read controller 34 outputs this data to the second signal processing circuit 40 in A-time sequence, starting with the data corresponding to the A-time immediately following the last A-time of the block of data last output to the second signal processing circuit 40 the previous time (before the last track jump). In this case, it outputs the data corresponding to A-times 23:41:45 through 23:42:17.

When the write controllers $31_1 - 31_4$ receive the halt command they stop writing. When the system controller 50 receives the track jump command, it jumps the optical pickup 2 from position VI of Fig. 6 to position VII, positioning the beams $3_1 - 3_4$ on-track to start reading data at tracks $(x + 5) - (x + 8)$. Then, when the frame sync detect signal $FS_1 - FS_4$ outputs of all of the first signal processing circuits $26_1 - 26_4$ go HIGH, the system controller 50 sends a "track jump completed" notification to the read controller 34.

From this point on, the above operations repeat until the desired recorded data has been read from the CD-ROM 1 in the sequence in which it was recorded, using the four valid beams $3_1 - 3_4$, operating at high speed, and
5 with no duplications or gaps in the data.

(4) Special Write/Read Operation, Part 2 (Beam 3_4 Channel Unreadable) (Figures 8 and 9)

If the system controller 50 determines, during one revolution of relative motion between the optical pickup
10 2 and CD-ROM 1, starting from position I of Fig. 8, that recorded data cannot be read from the beam (3_4) channel, then the largest contiguous group of remaining beam channels from which data can be read would be made up of the three beams $3_1 - 3_3$. Thus ≥ 3 , where M is the number
15 of beams in the largest contiguous group of beam channels from which data can be read. Accordingly, the channels of the M beams $3_1 - 3_3$ are designated as the h valid beam channels. Also, values I and J are set to $I = 1$, and $J = (M - 2) = 1$, where I is the number of disk revolutions
20 in a continuous data read (without track-jumping), and J is the number of tracks jumped in a track jump. Also, from the newest [(latest)] A-time in the A-time data AT_3 input from the first signal processing circuit 26₃, and the "read start point" A-time specified by the host
25 computer, [the system controller 50] determines the jump

direction and number of tracks for a track jump that will put beam 3_1 , the innermost of the $h = 3$ valid beams (the beam nearest the center of the disk), on-track, one track inside of track "x," the track that includes the A-time of the read start point (i.e., the jump that will put 3_1 at track $(x - 1)$), and executes that track jump.

When the h valid light beam channels are designated, and the values of I (the number of disk revolutions in a continuous data read) and J (the number of tracks jumped in a track jump) set, if the optical pickup 2 is located at position II of Fig. 8, it will be jumped forward from position II by four tracks, to put beams $3_1 - 3_3$ on-track at tracks $(x - 1) - (x + 1)$ (position III in Fig. 8). Simultaneous reading of the recorded data in tracks $(x - 1)$ through $(x + 1)$ will then begin at that point, through the three channels (circuits) made up of photodetector PD_1 through first signal processing circuit 26_1 , photodetector PD_2 through first signal processing circuit 26_2 , and photodetector PD_3 through first signal processing circuit 26_3 . Also, when HIGH level frame sync detect signals $FS_1 - FS_3$ are received from all three of the first signal processing circuits $26_1 - 26_3$, a special write/read command including valid channel information "1, 2, 3" is sent to parallel-to-serial converter 30.

The special write/read command is fed through read

controller 34 to the write controllers. After that, only the write controllers $31_1 - 31_3$, identified in the valid channel information "1, 2, 3" write the data $DATA_1 - DATA_3$, received from first signal processor circuits $26_1 - 26_3$, respectively, a block at a time, to the first areas of the memories $26_1 - 26_3$, in sequence [(the sequence in which it was recorded)]. The write controllers also write the A-time data corresponding to the above data to memory, along with the memory addresses at which that data is located, as follows: $AT_1 - AT_3$ (the A-time data for $DATA_1 - DATA_3$) is written to the first areas of memories $33_1 - 33_3$, along with the start/end address pairs made up of start addresses $A_{1s} - A_{3s}$ and end addresses $A_{1e} - A_{3e}$ in memories $32_1 - 33_3$ at which the corresponding data is stored. For the case illustrated in Fig. 8, the data written as A-time data in the first areas of each of the memories $33_1 - 33_3$, would be 23:40:60, 23:41:00, 23:41:15, and so on, as shown in Fig. 9.

Having received a special write/read command, read controller 34 checks only the data written to the memories in the indicated valid channels "1, 2, 3". Thus it accesses the data just written to the first areas of memories $33_1 - 33_3$, to verify that the state of the stored data is such that

the A-time immediately prior to the A-time data

stored at the top address in the first area of
memory 33₃ is included in the first area of memory
33₂, and
the A-time immediately prior to the A-time data
5 stored at the top address in the first area of
memory 33₂ is included in the first area of memory
33₁,
thus verifying that there are no gaps in the data read
from the valid channels.

10 When reading performed by optical pickup 2 at
approximately $I = 1$ revolution (actually slightly more
than one revolution) advances to position IV in Fig. 8,
the contents of the first areas of memories 33₁ - 33₃ will
be as shown in Fig. 9. Because it finds no gaps in the
15 data read from the valid channels, the read controller 34
sends a halt command to the write controllers 31₁ - 31₃
to halt the write operation, and a track jump command to
the system controller 50. The read controller 34 then
accesses the A-time data and the start and end addresses
20 stored in the first areas of memories 33₁ - 33₃, and
starts reading the corresponding DATA₁ - DATA₃ data from
the first areas of memories 32₁ - 32₃ (to which it was
written this time). The read controller 34 outputs this
data to the signal processing circuit 40 in A-time
25 sequence, starting with the data corresponding to the

newest A-time. In this case, it outputs the data corresponding to A-times 23:40:60 through 23:41:29.

When the write controllers $31_1 - 31_3$ receive the halt command, they stop writing. When the system controller
5 50 receives the track jump command, it sends commands to the servo circuit 23 to execute a track jump of $J = 1$ tracks in the forward direction, causing the optical pickup 2 to jump from position IV of Fig. 8 to position V, and positioning the beams $3_1 - 3_3$ on-track to start
10 reading recorded data at tracks $(x + 1) - (x + 3)$. Then, when the frame sync detect signal $FS_1 - FS_3$ outputs of all of the first signal processing circuits $26_1 - 26_3$ go HIGH, the system controller 50 sends a "track jump completed" notification to the read controller 34.

15 Upon receiving the "track jump completed" notification, the read controller 34 sends a "resume" command to write controllers $31_1 - 31_3$, causing them to start writing to memory, the data output by the first signal processing circuits $26_1 - 26_3$ after the track jump.
20 This time, the write controllers write the $DATA_1 - DATA_3$ outputs to the second areas of the memories $32_1 - 32_3$, and write the corresponding A-time data ($AT_1 - AT_3$) along with the memory $32_1 - 32_3$ start addresses ($a_{1s} - a_{3s}$) and end addresses ($a_{1e} - a_{3e}$) of the $DATA_1 - DATA_3$ data currently
25 being stored, to the second areas of memories $33_1 - 33_3$.

For the case illustrated in Fig. 8, the data written as A-time data in the second areas of the memories $33_1 - 33_3$, would be 23:41:18, 23:41:33, 23:41:48, and so on, as shown in Fig. 9.

5 After issuing the "resume" command, the read controller 34 accesses the second areas of memories $33_1 - 33_3$ (the areas just written to) to verify that there are no gaps in the data read by the valid channels. It does this by verifying that the state of the stored data is
10 such that

the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_3 is included in the second area of memory 33_2 , and

15 the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33_2 is included in the second area of memory 33_1 .

When the reading performed by optical pickup 2 at
20 approximately $I = 1$ revolution (actually slightly greater than one revolution) advances to position VI in Fig. 8, the contents of the second areas of memories $33_1 - 33_3$ will be as shown in Fig. 9. Because it finds no gaps in the data read from the valid channels (1, 2 and 3), the
25 read controller 34 sends a halt command to the write

controllers $31_1 - 31_3$ to halt the write operation, and a track jump command to the system controller 50. The read controller 34 then accesses the A-time data and the start and end addresses stored in the second areas of memories $33_1 - 33_3$, and starts reading the corresponding $DATA_1 - DATA_3$ data from the second areas of memories $32_1 - 32_3$ (the areas to which it was written this time). The read controller 34 outputs this data to the second signal processing circuit 40 in A-time sequence, starting with the data corresponding to the A-time immediately following the A-time of the block of data last output to the second signal processing circuit 40 the previous time (before the last track jump). In this case, it outputs the data corresponding to A-times 23:41:30 through 23:41:62.

When the write controllers $31_1 - 31_3$ receive the halt command, they stop writing. When the system controller 50 receives the track jump command, it jumps the optical pickup 2 by one track from position VI of Fig. 8 to position VII, positioning the beams $3_1 - 3_3$ on-track to start reading data at tracks $(x + 3) - (x + 5)$.

From this point on, the above operations repeat until the desired recorded data has been read from the CD-ROM₁ in the sequence in which it was recorded, using the three valid beams $3_1 - 3_3$, operating at high speed,

and with no duplications or gaps in the data.

(5) Special Write/Read Operation, Part 3 (Beam Channel 3₄ and 3₅ Unreadable) (Figures 9 and 10)

If [the system controller 50] determines, during one
5 revolution, with the optical pickup 2 starting from
position I of Fig. 10, that recorded data cannot be read
from the beam 3₄ and 3₅ channels, then the largest
contiguous group of remaining beam channels from which
data can be read would be made up of the three beams 3₁ -
10 3₃. Thus $M \geq 3$, where M is the number of beams in the
largest contiguous group of beam channels from which data
can be read. Accordingly, the channels of the M beams 3₁
- 3₃ are designated as the h valid beam channels. Also,
values I and J are set to $I = 1$, and $J = (M - 2) = 1$,
15 where I is the number of disk revolutions in a continuous
data read (without track-jumping), and J is the number of
tracks jumped in a track jump. Also, from the newest A-
time in the A-time data AT₃ input from the first signal
processing circuit 26₃, and the "read start point" A-time
20 specified by the host computer, the system controller 50
determines the jump direction and number of tracks for a
track jump that will put beam 3₁, the innermost of the h
= 3 valid beams (the beam nearest the center of the
disk), on-track, one track inside of track "x," the track
25 that includes the A-time of the read start point (i.e.,

the jump that will put beam 3_1 at track $(x - 1)$, and executes that track jump.

When the h valid light beam channels are designated, and the values of I (the number of disk revolutions in a continuous data read) and J (the number of tracks jumped in a track jump) set, if the optical pickup 2 is located at position II of Fig. 10 [sic], it will be jumped forward from position II by four tracks, to put beams $3_1 - 3_3$ on-track at tracks $(x - 1) - (x + 1)$. Simultaneous reading of the recorded data in tracks $(x - 1)$ through $(x + 1)$ will then begin at that point, through the three channels (circuits) made up of photodetector PD_1 through first signal processing circuit 26₁, photodetector PD_2 through first signal processing circuit 26₂, and photodetector PD_3 through first signal processing circuit 26₃. Also, when HIGH level frame sync detect signals $FS_1 - FS_3$ are received from all three of the first signal processing circuits 26₁ - 26₃, a special write/read command including valid channel information "1, 2, 3" is sent to parallel-to-serial converter 30.

From this point on, the operation is exactly the same as the case shown in Fig. 8: At the spot where the data has been read for approximately one revolution of CD-ROM 1, a forward jump of $J = 1$ is executed, and at the spot where approximately another revolution of recorded

data has been read, another forward jump of $J = 1$ is executed, and so on. This is repeated (positions III - VII in Fig. 10) to continue to read out the recorded data, in the sequence in which it was recorded, at high speed, with no duplications or gaps in the data.

(6) Special Write/Read Operation, Part 4 (Beam Channel 3_1 and 3_5 Unreadable) (Figure 11)

If [the system controller 50] determines, during one revolution of relative motion between the optical pickup 2 and CD-ROM 1, starting from position I of Fig. 11, that recorded data cannot be read from the beam 3_1 and 3_5 channels, then the largest contiguous group of remaining beam channels from which data can be read would be made up of the three beams $3_2 - 3_4$. Thus $M \geq 3$, where M is the number of beams in the largest contiguous group of beam channels from which data can be read. Accordingly, the channels of the M beams $3_2 - 3_4$ are designated as the h valid beam channels. Also, values I and J are set to $I = 1$, and $J = (M - 2) = 1$, where I is the number of disk revolutions in a continuous data read [(without track-jumping)], and J is the number of tracks jumped in a track jump. Also, from the newest A-time in the A-time data AT_3 input from the first signal processing circuit 26₃, and the "read start point" A-time specified by the host computer, the system controller 50 determines the

jump direction and number of tracks for a track jump that will put beam 3_2 , the innermost of the $h = 3$ valid beams (the valid beam nearest the center of the disk), on-track, one track inside of track "x," the track that includes the A-time of the read start point (i.e., the jump that will put beam 3_2 on-track at track $(x - 1)$), and executes that track jump.

When the $h = 3$ valid light beam channels are designated, and the values of I (the number of disk revolutions in a continuous data read) and J (the number of tracks jumped in a track jump) set, if the optical pickup 2 is located at position II of Fig. 11, it will be jumped forward from position II by three tracks, to put beams $3_3 - 3_4$ on-track at tracks $(x - 1) - (x + 1)$ (position III in Fig. 8). Simultaneous reading of the recorded data in tracks $(x - 1)$ through $(x + 1)$ will then begin at that point, through the three channels (circuits) made up of photodetector PD_2 through first signal processing circuit 26₂, photodetector PD_3 through first signal processing circuit 26₃, and photodetector PD_4 through first signal processing circuit 26₄. Also, when HIGH level frame sync detect signals $FS_2 - FS_4$ are received from all three of the first signal processing circuits 26₂ - 26₄, a special write/read command including valid channel information "2, 3, 4" is sent to parallel-

to-serial converter 30.

From that point on, operation is almost the same as for the case illustrated in Fig. 8. (In the Fig. 11 case, the write controllers $31_2 - 31_4$ write the data $DATA_2 - DATA_4$, from first signal processor circuits $26_2 - 26_4$, and the A-time data $AT_1 - AT_3$ to memories $32_2 - 32_4$, and $33_1 - 33_3$. Also, the read controller 34 checks the A-time and start and end address data stored in memories $33_2 - 33_4$, and then reads out the data stored in memories $32_2 - 32_4$ [sic] so that it will be in A-time sequence, and will have no duplications or gaps in it.) At the location where recorded data has been read for approximately one revolution of the CD-ROM 1, a forward jump of $J = 1$ track is executed, and after reading data for another turn, another jump is executed, and so on, continuing, in this manner, to read the recorded data at high speed, in the sequence in which it was recorded, with no duplications or gaps in the output data.

(7) Special Write/Read Operation, Part 5 (Beam Channel 3_2 and 3_5 Unreadable) (Figures 12 and 13)

If the system controller 50 determines, during one revolution of relative motion between the optical pickup 2 and CD-ROM 1, starting from position I of Fig. 12, that recorded data cannot be read from the beam 3_2 and 3_5 channels, the largest contiguous group within the

remaining three beam channels from which data can be read
(3_1 , 3_3 , and 3_4) would then consist of only the two beams
 3_3 and 3_4 . If we try to read data at high speed [as
described earlier], by repeatedly alternating between
5 reading for approximately one turn of the CD-ROM 1, then
performing track jumps, we will find that it cannot be
done: To read data in this manner, there must be at least
three readable light beam channels in a contiguous group.
Even when this condition ($M \geq 3$) is not met, however,
10 high speed reading of data can still be performed by
combining readable channels and performing repeated
operations wherein data is read by the combined channels
over multiple revolutions of CD-ROM 1, followed by track
jumps of a prescribed number of tracks.

15 Specifically, in repeated cycles of continuous
reading and track jump operations, the number of disk
revolutions of continuous reading, and the number of
tracks to be jumped, may be determined as follows
with

20 Q as the distance, in number of tracks, between
the innermost and outermost beams of light beam
channels capable of reading recorded data, and
R as the number of beams in the most populous
contiguous group of light beam channels incapable
25 of reading recorded data, whose beams lie between

the above innermost and outermost light beams,

then

if Q is at least 2, and R is at least 1,

$(R + 1)$ is the number of disk revolutions of

5 continuous reading by the beams capable of reading
recorded data (I), and

$(Q - 1)$ is the number of tracks to be jumped
forward (J).

In the present case, the innermost and outermost
10 beams of light beam channels capable of reading recorded
data, are beams 3_1 and 3_4 . Therefore, the distance
between them, in number of tracks would be $Q = (4 - 1) =$
3. Also, the most populous contiguous group of light
beam channels incapable of reading recorded data, whose
15 beams lie between beams 3_1 and 3_4 , consists of only one
light beam: beam 3_2 . Therefore, $R = 1$. All three beams
that are capable of reading recorded data, 3_1 , 3_3 , and 3_4 ,
are designated as the $h = 3$ light beam channels. The
number of disk revolutions of continuous reading = $I = (R$
20 $+ 1) = 2$. The number of tracks to be jumped in track
jumps performed during read = $J = (Q - 1) = 2$. Thus I
and J are both set to 2.

When the $h = 3$ valid light beam channels are
designated, and the values of I (the number of disk
25 revolutions in a continuous data read) and J (the number

of tracks jumped in a track jump) are set to $I = 2$ and $J = 2$, if the optical pickup 2 is located at position II of Fig. 12, it will be jumped forward from position II by four tracks, to put beams 3_1 , 3_3 , and 3_4 on-track at
5 tracks $(x - 1)$, $(x + 1)$, and $(x + 2)$ (position III in Fig. 12). Simultaneous reading of the recorded data in tracks $(x - 1)$, $(x + 1)$, and $(x + 2)$ will then begin at that point, through the three channels (circuits) made up of photodetector PD_1 through first signal processing
10 circuit 26₁, photodetector PD_3 through first signal processing circuit 26₃, and photodetector PD_4 through first signal processing circuit 26₄. Also, when HIGH level frame sync detect signals FS_1 , FS_3 , and FS_4 are received from all three of the first signal processing
15 circuits 26₁, 26₃, and 26₄, a special write/read command including valid channel information "1, 3, 4" is sent to parallel-to-serial converter 30.

The special write/read command is fed through read controller 34 to the write controllers. After that, only
20 the write controllers 31₁, 31₃, and 31₄ identified in the valid channel information "1, 3, 4" write the data $DATA_1$, $DATA_3$, and $DATA_4$, received from first signal processor circuits 26₁, 26₃, and 26₄, respectively, a block at a time, to the first areas of the memories 32₁, 32₃, and
25 32₄, in sequence (the sequence in which it was recorded).

The write controllers also write the A-time data corresponding to the above data to memory, along with the memory addresses at which that data is located, as follows: AT_1 , AT_3 , and AT_4 (the A-time data for $DATA_1$,
5 $DATA_3$, and $DATA_4$) is written to the first areas of memories 33_1 , 33_3 , and 33_4 along with the start addresses A_{1s} , A_{3s} and A_{4s} and end addresses A_{1e} , A_{3e} , and A_{4e} of memories 32_1 , 33_3 , and 33_4 , [at which the corresponding data is stored]. For the case illustrated in Fig. 12,
10 the data written as A-time data in the first areas of each of the memories 33_1 , 33_3 , and 33_4 would be 23:40:60, 23:41:15, 23:41:30, and so on, as shown in Fig. 13.

Having received a special write/read command, read controller 34 checks only the data written to the
15 memories in the indicated valid channels "1, 3, 4". Thus it accesses the data just written to the first areas of memories 33_1 , 33_3 , and 33_4 to verify that the state of the stored data is such that

the A-time immediately prior to the A-time data
20 stored at the top address in the first area of memory 33_4 is included in the first area of memory 33_3 , and
the A-time immediately prior to the A-time data stored at the top address in the first area of
25 memory 33_3 is included in the first area of memory

33₁,

thus verifying that there are no gaps in the data read from the valid channels.

When reading performed by optical pickup 2 at approximately $I = 2$ (actually slightly greater than 2) advances to position IV in Fig. 12, the contents of memories 33₁, 33₃, and 33₄ will be as shown in Fig. 13. Because it finds no gaps in the data read from the valid channels, the read controller 34 sends a halt command to the write controllers 31₁, 31₃, and 31₄ to halt the write operation, and sends a track jump command to the system controller 50. The read controller 34 then accesses the A-time data and the start and end addresses stored in the first areas of memories 33₁, 33₃, and 33₄, and starts reading the corresponding data from the first areas of memories 32₁, 32₃, and 32₄ (to which it was written this time). The read controller 34 outputs this data to the signal processing circuit 40 in A-time sequence, starting with the data corresponding to the newest A-time. In this case, it outputs the data corresponding to A-times 23:40:60 through 23:41:59.

When the write controllers 31₁, 31₃, and 31₄ receive the halt command, they stop writing. When the system controller 50 receives the track jump command, it sends commands to the servo circuit 23 to execute a track jump

of $J = 2$ tracks in the forward direction, causing the optical pickup 2 to jump from position IV of Fig. 12 to position V, and positioning the beams 3_1 , 3_3 , and 3_4 on-track to start reading data at tracks $(x + 3)$, $(x + 5)$, and $(x + 6)$. Then, when the frame sync detect signal FS_1 , FS_3 , and FS_4 outputs of all of the first signal processing circuits 26_1 , 26_3 , and 26_4 go HIGH, the system controller sends a "track jump completed" notification to the read controller 34.

Upon receiving the "track jump completed" notification, the read controller 34 sends a "resume" command to write controllers 31_1 , 31_3 , and 31_4 , causing them to start writing to memory, the data output by the first signal processing circuits 26_1 , 26_3 , and 26_4 after the track jump. This time, the write controllers write these $DATA_1$, $DATA_3$, and $DATA_4$ outputs to the second areas of the memories 32_1 , 32_3 , and 32_4 , and write the corresponding A-time data (AT_1 , AT_3 , and AT_4) along with the memory 32_1 , 32_3 , and 32_4 start addresses (a_{1s} , a_{3s} , and a_{4s}) and end addresses (a_{1e} , a_{3e} , and a_{4e}) of the $DATA_1$, $DATA_3$, and $DATA_4$ data currently being stored, to the second areas of memories 33_1 , 33_3 , and 33_4 . For the case illustrated in Fig. 12, the data written as A-time data in the second areas of the memories 33_1 , 33_3 , and 33_4 would be 23:41:48, 23:42:03, 23:42:18, and so on, as

shown in Fig. 13.

After issuing the "resume" command, the read controller 34 accesses the second areas of memories 33₁, 33₃, and 33₄ (the areas just written to) to verify that
5 there are no gaps in the data read by the valid channels. It does this by verifying that the state of the stored data is such that

the A-time immediately prior to the A-time data stored at the top address in the second area of
10 memory 33₄ is included in the second area of memory 33₃, and

the A-time immediately prior to the A-time data stored at the top address in the second area of memory 33₃ is included in the second area of
15 memory 33₁.

When the reading performed by optical pickup 2 at approximately $I = 2$ revolutions (actually slightly greater more than two revolutions) advances to position VI in Fig. 12, the contents of the second areas of
20 memories 33₁, 33₃, and 33₄ will be as shown in Fig. 13. Because it finds no gaps in the data read from the valid channels (1, 3, and 4), the read controller 34 sends a halt command to the write controllers 31₁, 31₃, and 31₄ to halt the write operation, and a track jump command to the
25 system controller 50. The read controller 34 then

accesses the A-time data and the start and end addresses stored in the second areas of memories 33_1 , 33_3 , and 33_4 , and starts reading the corresponding data from the second areas of memories 32_1 , 32_3 , and 32_4 (the areas to which it was written this time). The read controller 34 outputs this data to the second signal processing circuit 40 in A-time sequence, starting with the data corresponding to the A-time immediately following the A-time of the block of data last output to the second signal processing circuit 40 the previous time (before the last track jump). In this case, it outputs the data corresponding to A-times 23:41:60 through 23:42:47.

When the write controllers 31_1 , 31_3 , and 31_4 receive the halt command, they stop writing. When the system controller 50 receives the track jump command, it jumps the optical pickup 2 by $J = 2$ tracks, from position VI of Fig. 12 to position VII, positioning the beams 3_1 , 3_3 , and 3_4 on-track to start reading data at tracks $(x + 7)$, $(x + 9)$, and $(x + 10)$. From this point on, the above operations repeat until the desired recorded data has been read from the CD-ROM 1 in the sequence in which it was recorded, using the three valid beams 3_1 , 3_3 , and 3_4 , operating at high speed, and with no duplications or gaps in the data.

In this method, for example, it takes the time of

four revolutions of CD-ROM 1 to read the data in the nine tracks between $(x - 1)$ and $(x + 7)$ and complete the one track jump, as indicated in Fig. 12. The data read time using this method, then, is a major improvement over the
5 time of nine revolutions of CD-ROM 1 that would be required read the same data with only one beam.

(8) Special Write/Read Operation, Part 6 (Beam Channel 3_1 , 3_2 and 3_4 Unreadable) (Figure 14)

If the system controller 50 determines, during one
10 revolution of relative motion between the optical pickup 2 and CD-ROM 1, starting from position I of Fig. 14, that recorded data cannot be read from the beam 3_1 , 3_2 and 3_4 channels, then there are not three adjacent channels from which data can be read (the $M \geq 3$ condition is not
15 satisfied). As in the case illustrated in Fig. 12, however, in repeated cycles of continuous reading and track jump operations, the number of disk revolutions of continuous reading, and the number of tracks to be jumped, may be determined as follows:

20 with

Q as the distance, in number of tracks, between the innermost and outermost beams of light beam channels capable of reading recorded data, and
 R as the number of beams in the most populous
25 contiguous group of light beam channels incapable

of reading recorded data, whose beams lie between
the above innermost and outermost light beams,
then

if Q is at least 2, and R is at least 1,

5 $(R + 1)$ is the number of disk revolutions of
continuous reading by the beams capable of reading
recorded data (I), and

$(Q - 1)$ is the number of tracks to be jumped (J).

In the present case, the innermost and outermost
10 beams of light beam channels capable of reading recorded
data, are beams 3_3 and 3_5 . Therefore, $Q = (5 - 3) = 2$.
Also, the most populous contiguous group of light beam
channels incapable of reading recorded data, whose beams
lie between beams 3_3 and 3_5 , consists of only one light
15 beam. Therefore, $R = 1$. The two beams that are capable
of reading recorded data, 3_3 and 3_5 , are designated as the
 h light beam channels. The number of disk revolutions of
continuous reading = $I = (R + 1) = 2$. The number of
tracks to be jumped in track jumps performed during read
20 = $J = (Q - 1) = 1$. These values of I and J are set.

When the $h = 2$ valid light beam channels are
designated, and the values of I (the number of disk
revolutions in a continuous data read) and J (the number
of tracks jumped in a track jump) are set to $I = 2$ and J
25 = 1, if the optical pickup 2 is located at position II of

Fig. 14, it will be jumped forward from position II by two tracks, to put beams 3_3 and 3_5 on-track at tracks $(x - 1)$ and $(x + 1)$ (position III in Fig. 14). Simultaneous reading of the recorded data in tracks $(x - 1)$ and $(x + 1)$ will then begin at that point, through the two channels (circuits) made up of photodetector PD_3 through first signal processing circuit 26_3 , and photodetector PD_5 through first signal processing circuit 26_5 . Also, when HIGH level frame sync detect signals FS_3 , and FS_5 are received from both of the first signal processing circuits 26_3 , and 26_5 , a special write/read command including valid channel information "3, 5" is sent to parallel-to-serial converter 30.

From that point on, operation is almost the same as for the case illustrated in Fig. 12. (In the Fig. 14 case, the write controllers 31_3 and 31_5 write the data $DATA_3$ and $DATA_5$, from first signal processor circuits 26_3 and 26_5 , and the A-time data AT_3 and AT_5 to memories 32_3 and 32_5 , and 33_3 and 33_5 . Also, the read controller 34 checks the A-time and start and end address data stored in memories 33_3 and 33_5 , and then reads out the data stored in memories 32_3 and 32_5 so that it will be in A-time sequence, and will have no duplications or gaps in it.) At the location where recorded data has been read for approximately $I = 2$ revolutions of the CD-ROM 1, a

forward jump of $J = 1$ track is executed, and after reading data for another $I = 2$ turns, another jump of $J = 1$ is executed, and so on, continuing in this manner, to read the recorded data at high speed, in the sequence in which it was recorded, with no duplications or gaps in the output data.

In this method, for example, it takes the time of four revolutions of CD-ROM 1 to read the data in the seven tracks between $(x - 1)$ and $(x + 5)$ and complete the one track jump, as indicated in Fig. 14. With only two good channels, then, the data read time using this method is still a major improvement over the time of seven revolutions of CD-ROM 1 that would be required read the same data with only one beam.

(9) Special Write/Read Operation, Part 7 (Beam Channel 3₄ Unreadable) (Figure 15)

If the system controller 50 determines, during one revolution of relative motion between the optical pickup 2 and CD-ROM 1, starting from position I of Fig. 15, that recorded data cannot be read from the light beam 3₄ channel, the contiguous group of the three beams 3₁ - 3₃ could be used to read data as described in the above section (4) and shown in Fig. 8. The data can be read faster, however, by performing the read operation as shown in Fig. 12.

In the present case, the innermost and outermost beams of the light beam channels capable of reading recorded data are 3_1 and 3_5 , respectively; therefore, $Q = [(5 - 1)] = 4$. Also, the number of beams in the most
5 populous contiguous group of light beam channels incapable of reading recorded data, whose beams lie between the above innermost and outermost light beams (3_1 and 3_5) is the single beam, 3_4 ; therefore, $R = 1$. Accordingly, the beams 3_1 , 3_2 , 3_3 and 3_5 are allocated as
10 the h valid channels; R (the number of disk revolutions of continuous reading) and J (the number of tracks jumped in a track jump), respectively, are set to $I = (R + 1) = 2$, and $J = (Q - 1) = 3$.

When the $h = 4$ valid light beam channels are
15 designated, and the values of $I = 2$ (the number of disk revolutions in continuous data read) and $J = 3$ (the number of tracks jumped in a track jump) are set, if the optical pickup 2 is located at position II of Fig. 15, it will be jumped forward from position II by four tracks,
20 to put beams $3_1 - 3_3$ and 3_5 on-track at tracks $(x - 1) - (x + 1)$, and $(x + 3)$. Simultaneous reading of the recorded data in tracks $(x - 1)$ through $(x + 1)$ and $(x + 3)$ will then begin at that point, through the four channels made up of photodetector PD_1 through first signal processing
25 circuit 26₁, photodetector PD_2 through first signal

processing circuit 26₂, photodetector PD₃ through first
signal processing circuit 26₃, and photodetector PD₅
through first signal processing circuit 26₅. Also, when
HIGH frame sync detect signals FS₁ - FS₃ and FS₅ are
5 received from all four of the first signal processing
circuits 26₁ - 26₃, and 26₅, a special write/read command
including the valid channel information "1, 2, 3, 5" is
sent to parallel-to-serial converter 30.

From that point on, operation is almost the same as
10 for the case illustrated in Fig. 12. (In the Fig. 15
case, the write controllers 31₁ - 31₃ and 31₅ write the
data DATA₁ - DATA₃ and DATA₅ from first signal processor
circuits 26₁ - 26₃ and 26₅, and the A-time data AT₁ - AT₃
and AT₅ to memories 32₁ - 32₃ and 32₅, and 33₁ - 33₃ and
15 33₅. Also, the read controller 34 checks the A-time and
start and end address data stored in memories 33₁ - 33₃
and 33₅, and then reads out the data stored in memories
32₁ - 32₃ and 32₅ so that it will be in A-time sequence,
and will have no duplications or gaps in it.) At the
20 location where recorded data has been read for
approximately I = 2 revolutions of the CD-ROM 1, a
forward jump of J = 3 tracks is executed, and after
reading data for another I = 2 revolutions, another J =
3 jump is executed, and so on, continuing in this manner
25 to read the recorded data, at high speed, in the sequence

in which it was recorded, and with no duplications or gaps in the output data (Fig. 15, positions III - VII).

In this example, it takes the time of four revolutions of CD-ROM 1 to read the data in the eleven
5 tracks between $(x - 1) - (x + 9)$, and to complete the one track jump, as indicated in Fig. 15. In comparison, in Fig. 8, three track jumps are required to read data for the time of four revolutions of the CD-ROM 1.

(10) Special Write/Read Operation, Part 8 (Beam Channels
10 3_1 , 3_4 and 3_5 Unreadable) (Figures 16 and 17)

We will now consider the case where it is determined, during one revolution of relative motion between the optical pickup 2 and CD-ROM 1, starting from position I of Fig. 16, that recorded data cannot be read
15 from the light beam 3_1 , 3_4 , and 3_5 channels. If we try to read as before (by performing repeated cycles alternating between reading for one or more revolutions of CD-ROM 1 and executing a forward track jump) with only the two remaining adjacent channels 3_2 and 3_3 , there will be gaps
20 in the data. In this situation, the data must be read from CD-ROM 1 continuously by only one light beam channel.

Specifically, of the two light beams that can read data, 3_2 and 3_3 , the one nearer the center [of the disk]
25 (3_3) is designated as the valid channel ($h = 1$), the

number of disk revolutions of continuous reading is set to $I = \text{unlimited}$, and the number of tracks jumped in a track jump is set to $J = 0$.

When the $h = 1$ valid light beam channels are designated and the values " $I = \text{unlimited}$ " (the number of disk revolutions in a continuous data read) and " $J = 0$ " (the number of tracks jumped in a track jump) are set, if the optical pickup 2 is located at position II of Fig. 16, it will be jumped forward from position II by two tracks, to put beam 3₃ on-track at track $(x - 1)$. Reading of the recorded data in track $(x - 1)$ then begins at that point, through the single channel made up of photodetector PD₃ through first signal processing circuit 26₃. Also, when a HIGH level frame sync detect signal FS₃ is received from the first signal processing circuit 26₃, a special write/read command including valid channel information "3" is sent to parallel-to-serial converter 30.

A special write/read command is fed through read controller 34 to the write controllers. After that, only the write controller 31₃ (identified by the [special write/read command] valid channel information "3") writes the DATA₃ data received from first signal processor circuit 26₃, a block at a time, to the first area of the memory 32₃, in sequence [(the sequence in which it was

recorded)]. The write controller also writes the A-time data corresponding to the above data to memory, along with the memory addresses at which that data is located, by writing AT_3 (the A-time data for $DATA_3$) to the first
5 area of memory 33_3 along with the start address A_{3s} and end address A_{3e} of memory 32_3 at which $DATA_3$ is stored. For the case illustrated in Fig. 16, the data written as A-time data in the first area of the memory 33_3 , would start with 23:40:60 as shown in Fig. 17. If enough data
10 is written to the first areas of memories 32_3 and 33_3 to fill them, the write controller automatically goes back to the first area and continues writing.

When the read controller 34 receives the special write/read command, if only one channel (3) is indicated
15 in the valid channel information, it accesses only the data written to the first area of the memory for that channel, memory 33_3 , and reads the data from the first area of memory 32_3 in A-time sequence, starting with the data corresponding to the newest A-time, outputting it to
20 the second signal processing circuit 40. It issues no halt or track jump commands. Thus during data read, optical pickup 2 simply reads data from $(x - 1)$ and subsequent tracks through the beam 3_3 channel, reading continuously without jumping tracks as CD-ROM 1 rotates,
25 sending the data to the input of the second signal

processing circuit 40.

(11) Special Write/Read Operation, Part 9 (Beam Channels 3_1 , 3_2 , 3_4 and 3_5 Unreadable) (Figures 18)

If it is determined, during one revolution of
5 relative motion between the optical pickup 2 and CD-ROM
1, starting from position I of Fig. 18, that recorded
data cannot be read from the light beam 3_1 , 3_2 , 3_4 , and 3_5
channels; and if we try to read as before (by performing
repeated cycles alternating between reading for one or
10 more revolutions of CD-ROM 1 and executing a forward
track jump) with only the one remaining adjacent channel
 3_3 , there will be gaps in the data. Here too, the data
must be read from CD-ROM 1 continuously (with no track
jumps) using only one light beam channel.

15 Specifically, the single light beam that can read
data (3_3) is designated as the valid channel (h), the
number of disk revolutions of continuous reading is set
to $I = \text{unlimited}$, and the number of tracks jumped in a
track jump is set to $J = 0$.

20 When the $h = 1$ valid light beam channels are
designated, and the values " $I = \text{unlimited}$ " (the number of
disk revolutions in a continuous data read) and " $J = 0$ "
(the number of tracks jumped in a track jump) are set, if
the optical pickup 2 is located at position II of Fig.
25 18, it will be jumped forward from position II by two

tracks, to put beam 3_3 on-track at track $(x - 1)$.
Reading of the recorded data in track $(x - 1)$ then begins
at that point, through the single channel made up of
photodetector PD_3 through first signal processing circuit
5 26₃. Also, when [a HIGH] frame sync detect signal FS_3 is
received, a special write/read command including valid
channel information "3" is sent to parallel-to-serial
converter 30.

From this point on, operation is exactly the same as
10 for the case illustrated in Fig. 16: Data from $(x - 1)$
and subsequent tracks are all read through the beam 3_3
channel, reading continuously as CD-ROM 1 rotates,
without having optical pickup 2 jump tracks, and
outputting the data with no gaps.

15 Moreover, although the above embodiment was
described for $n = 5$ optical beams, the desired effect can
be achieved as long as there are three or more beams.
With an optical pickup 2A, such as shown in Fig. 19(1),
for example, if data through the channel the center beam
20 (3_2) of beams $3_1 - 3_3$ became unreadable (assuming that the
focus and tracking error signals are generated from the
returned beam of light beam 3_1 or 3_3), then with $Q = 2$ and
 $R = 1$ (as in the case illustrated in Fig. 14), the two
beams 3_1 and 3_3 would be designated as valid channels, and
25 I (the number of disk revolutions in a continuous data

read) and J (the number of tracks jumped in a track jump) set to $I = (R + 1) = 2$ and $J = (Q - 1) = 1$.

With an optical pickup having the seven beams $3_1 - 3_7$, as shown in Fig. 19(2), if data became unreadable through the 3_5 and 3_6 light beam channels (assuming that the focus and tracking error signals are generated from the returned beam of light beam 3_4), then $Q = 6$ and $R = 2$, and all five of the readable beams $3_1 - 3_4$ and 3_7 should be designated as valid channels, and I (the number of disk revolutions in a continuous data read) and J (the number of tracks jumped in a track jump) set to $I = (R + 1) = 3$ and $J = (Q - 1) = 5$.

In addition, as in the case described section (3) and illustrated in Figures 6 and 7, where the beam 3_5 channel was unreadable, " M " (the number of beams in the largest contiguous group of beam channels from which data can be read) was made up of the four beams $3_1 - 3_4$. Therefore, since $M \geq 3$, the channels of the M beams ($3_1 - 3_4$) were designated as the h valid beam channels, and I and J were set to $I = 1$, (where I is the number of disk revolutions in a continuous data read) and $J = (M - 2) = 2$ (where J is the number of tracks jumped in a track jump). However, with beams $3_1 - 3_4$ designated as the h valid beam channels, we have $Q = (4 - 1) = 3$ (where Q is the distance, in number of tracks, between the innermost

and outermost beams of light beam channels capable of reading recorded data, and $R = 0$, (where R is the number of beams in the most populous contiguous group of light beam channels incapable of reading recorded data, whose beams lie between the above innermost and outermost light beams, $3_1 - 3_4$). Therefore, by using Q and R to computer the number of disk revolutions in a continuous data read (I) and the number of tracks in a track jump (J), we can set $I = (R + 1) = 1$, and $J = (Q - 1) = 2$.

Also, in the description of section (4) above (Figures 8 and 9), where the beam 3_4 channel was unreadable, " M " (the number of beams in the largest contiguous group of beam channels from which data can be read) was made up of the three beams $3_1 - 3_3$. Therefore, since $M \geq 3$, the channels of the M beams ($3_1 - 3_3$) were designated as the h valid beam channels, and I and J were set to $I = 1$, (where I is the number of disk revolutions in a continuous data read) and $J = (M - 2) = 1$ (where J is the number of tracks jumped in a track jump). However, with beams $3_1 - 3_3$ designated as the h valid beam channels, we have $Q = (3 - 1) = 2$, where Q is the distance, in number of tracks, between the innermost and outermost beams (3_1 and 3_3) of light beam channels capable of reading recorded data, and $R = 0$, where R is the number of beams in the most populous contiguous group of

light beam channels incapable of reading recorded data,
whose beams lie between the above innermost and outermost
light beams (3_1 and 3_3). Therefore, by using this Q and
 R to compute the number of disk revolutions in a
5 continuous data read (I) and the number of tracks in a
track jump (J), we can set $I = (R + 1) = 1$, and $J = (Q -$
 $1) = 1$.

Similarly, in the case of the above section (5)((6))
as well, if Q is the distance, in number of tracks,
10 between the innermost and outermost beams of the $h = 3$
valid channels $3_1 - 3_3$ ($3_2 - 3_4$), then $Q = 2$; and if R is
the number of beams in the most populous contiguous group
of light beam channels incapable of reading recorded
data, whose beams lie between the innermost and outermost
15 of the $h = 3$ valid channels, $3_1 - 3_3$ ($3_2 - 3_4$), then $R =$
 0 . Therefore, by using this Q and R to compute the
number of disk revolutions in a continuous data read (I)
and the number of tracks in a track jump (J), we can set
 $I = (R + 1) = 1$, and $J = (R - 1) = 1$.

20 Also, in the embodiment described above, the
determination as to whether there were unreadable
channels was made at a track location just before the
"read start point" specified by the host computer. Then,
based on the results of this determination, the h valid
25 light beam channels, and the values of I and J were set

(where I is the number of disk revolutions in a continuous data read and J is the number of tracks to be jumped per track jump), after which a track jump was executed to position the light beams at the read start point specified by the host computer, and the reading of data commenced at that point. Instead of doing it this way, however, the determination as to whether there are channels incapable of reading data may also be made at the track position that contains the read start point, or at the read-in¹³ nearest the center of the CD-ROM 1.

Also, in all of the cases described in sections (3) - (9), and Fig. 19, the system controller 50 made a determination as to the light beam channels (if any) that were incapable of reading data; and if the results of this determination indicated that some of the channels were incapable of reading data, after a combination of the remaining channels capable of reading data were designated as the "h" (number) valid channels (where that combination consisted neither of only one channel nor of only two adjacent channels); the values of I (the number of disk revolutions in a continuous data read) and J (the number of tracks to be jumped in a track jump) were set, based on a prescribed standard. [As an alternative], however, in continuous reading of the CD-ROM 1 using a combination of the h beam channels designated as valid

channels, the number of continuous reading revolutions of the optical disk that are required before there will be no gaps in the data read therefrom can be automatically determined as the constant $(R + 1)$ (where R is the number of beams in the most populous contiguous group of light beam channels incapable of reading recorded data, whose beams lie between the innermost and outermost of the n valid channels); thus requiring only " J ," the number of tracks jumped in a track jump, to be set. In continuous reading of the CD-ROM 1 using the combination of all of the n beam channels (where there are no bad channels), the number of continuous reading revolutions of the optical disk that are required before there will be no gaps in the data read therefrom is also automatically determined as approximately 1.

Also, although in the above described embodiment, it was assumed that the CD-ROM 1 was rotated at a constant linear velocity, it may also be rotated at a constant angular velocity (CAV). The optical disk may be of a type other than CD-ROM. It may be, for example, a CD-WO, DVD, DVD-ROM, or DVD-RAM optical disk having its tracks formed in a spiral.

Through the present invention, even if some of the light beam channels become incapable of reading recorded data because of problems with optical disk such as track

pitch variance, surface flutter, and eccentric wobble, it
is possible to perform accurate high-speed reading of the
desired data from an optical disk with no gaps in the
data, by using all or a portion of the remaining light
5 beam channels that are capable of reading recorded data.

CLAIMS

1. An optical disk readout method wherein n adjacent tracks, n being an integer of 3 or greater, of an optical disk (1) are illuminated simultaneously by separate n light beams ($3_1, 3_2, \dots, 3_n$) arranged in the radial direction of the optical disk in order to read recorded data in the tracks illuminated by the n light beams from outputs obtained by detecting reflected ones of the n light beams through n light beam-read channels ($21_i, 24_i, 26_i, 31_i, 32_i, 33_i$ with $i = 1$ to n), whereby the reading of the optical disk is performed by alternating between the continuous readings and track jumps in the forward direction, CHARACTERIZED BY,

detecting the relative positions in said radial direction of light beams associated with the light beam-read channels capable of reading recorded data from the optical disk;

designating a set of said light beam-read channels which are capable of reading recorded data from the optical disk to be used for reading and determining the number of tracks to be jumped, according to the detected radial positions of the light beams associated with the capable light beam-read channels;

continuously reading data from said disk with said set of light beam-read channels and storing the readout data and corresponding addresses of the optical disk during the continuous reading by said set of light beam-read channels designated for reading; and

if said set comprises more than one light beam-read channel, executing the track jump by the determined number of tracks when the stored corresponding frame addresses show that said stored readout data correspond to a continuous block of data recorded on the optical disk.

2. The optical disk readout method according to Claim 1, wherein when detecting that only one or two adjacent light beam-read channels are capable of reading the recorded data, only a single light beam-read channel is designated for reading and the continuous reading is successively conducted without executing the track jump.

3. The optical disk readout method according to Claim 1, wherein M is the number of beams in the most populous contiguous group of light beam-read channels from which data can be read and $M \geq 3$, said M light beam-read channels are designated as said set of light beam-read channels, and the continuous reading of approximately one revolution of the optical disk and the track jump of M-2 tracks are performed.

4. The optical disk readout method according to Claim 1, wherein

if Q is the distance, in number of tracks, between the innermost and outermost beams of light beam-read channels capable of reading recorded data,

R is the number of beams in the most populous contiguous group of light beam-read channels incapable of reading recorded data, whose beams lie between said innermost and outermost light beams, and also

if Q is at least 2, and R is at least 1, then

the optical disk is read by alternating between

performing continuous reading of the optical disk through the light beam-read channels that are capable of reading recorded data for approximately (R+1) revolutions of the optical disk, and

executing a track jump of (Q-1) tracks in the forward direction.

5. The optical disk readout method according to Claim 4, wherein when (Q-1) is equal or less than zero, a single light beam-read channel only is designated for reading and the continuous reading is successively performed without executing the track jump.

6. An optical disk readout apparatus wherein n adjacent tracks, n being an integer of 3 or greater, of an optical disk (1) are illuminated simultaneously by separate n light beams ($3_1, 3_2, \dots, 3_n$) arranged in the radial direction of the optical disk, comprising optical detection means (4, 5, 6, 7, 8, PD₁ to PD₅) for reading recorded data in the tracks illuminated by the n light beams, from output obtained by detecting reflected ones of the n light beams through n light beam-read channels (21_i, 24_i, 26_i, 31_i, 32_i, 33_i, with i = 1 to n), and readout control means for controlling the optical detection means to read the optical disk, whereby the reading of the optical disk is performed by alternating between the continuous readings and track jumps in the forward direction, CHARACTERIZED BY,

means (26_i, 50) for detecting the relative positions in said radial direction of the light beams associated with the light beam-read channels capable of reading recorded data from the optical disk;

means (50) for designating set of said light beam-read channels which is capable of reading recorded data from the optical disk to be used for reading and for determining the number of tracks to be jumped, according to the detected radial positions of the light beams associated with the capable light beam-read channels;

means (20) for continuously reading data from said disk with said set of light beam-read channels;

means (32_i, 33_i) for storing the readout data and corresponding frame addresses of the optical disk during the continuous reading by said set of light beam-read channels designated for reading; wherein

said readout control means has means (50) for executing the track jump by the determined number of tracks when the stored corresponding frame addresses show that the stored readout data corresponds to a continuous block of data recorded on the optical disk and only if said set comprises more than one light beam-read channel.