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This invention relates to optical disc recording apparatus.

An optical disc may have a recording capacity larger by two or three orders than that of a magnetic disc, while enabling accessing at a higher speed than that for a tape recording medium. An optical disc also has the advantage of contactless data recording and reproduction, so has good durability. A well known form of optical disc is the so-called compact disc (CD).

To provide a portable and, above all, a pocketable headphone stereo or similar recording/reproducing apparatus using an optical disc, a CD with a diameter of 12 cm and a CD with a diameter of 8 cm (so-called CD single) have been proposed. However, with a disc diameter of 12 cm, the recording/reproducing apparatus is too bulky to be readily portable. Therefore, a disc 8 cm or less in diameter would be preferred. However, in attempting to construct a portable or pocket size recording and/or reproducing apparatus for an optical disc 8 cm or less in diameter, the following problems arise.

In the case of a standard CD format optical disc, on which are recorded stereophonic digital PCM audio signals sampled with a sampling frequency of 44.1 kHz and quantized with 16 bits, and where these signals are exclusively reproduced by the user (CD-DA format), the playback time (recording time) of a disc 8 cm in diameter is 20 to 22 minutes at most, meaning that a symphony, for example, cannot be recorded on one disc side. A playback time of 74 minutes or longer, which is approximately equal to that of a 12 cm CD is preferred. In addition, with this CD-DA format, recording by the user is not feasible. In addition, a contactless type optical pick-up device is vulnerable to mechanical vibrations and subject to detracking or defocusing. Thus, when the apparatus is to be portable, some positive measures need to be taken to prevent adverse effects of detracking or defocusing on the reproducing operation.

With the CD-I (CD-interactive) format, the levels A to C as shown in the following Table 1 are prescribed as modes for recording/reproducing bit-compressed digital audio signals.

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Table 1

levels	sampling frequency	number of bits for quantization	bandwidth	playback time (stereo/ monaural)
A	37.8 kHz	8	17 kHz	2/4
B	37.8 kHz	4	17 kHz	4/8
C	18.9 kHz	4	8.5 kHz	8/16

When reproducing a disc recorded with, for example, the level B mode, signals obtained by 4-fold bit compression of standard CD-DA format digital signals are reproduced. Thus, if all of the recorded data are stereophonic audio compressed data, playback time increases 4-fold, or reproduction of 4-channel data, becomes feasible, so that reproduction for 70 minutes or longer becomes possible with an optical disc of about 6 cm in diameter.

Meanwhile, with the CD-I format, the disc is rotationally driven at the same linear velocity as that for the standard CD-DA format, so that continuous audio compressed data are reproduced at a rate of one unit to n recorded units on the disc, where n is a figure corresponding to the playback time or the bit compression rate of data, and is equal to 4 with the level B stereo mode. This unit is termed a block or sector, which is made up of 98 frames and has a period of 1/75 second. Therefore, with this level B stereo mode, a data string in which one of 4 sectors is an audio sector, such as:

S D D D S D D D ...

where S is an audio sector and D is another sector or sectors, is recorded on a sector-by-sector basis on the disc. However, for actual recording, since the above data string undergoes a predetermined encoding similar to that for ordinary CD format audio data, such as error correction coding and interleaving, data of the audio sector S and data of the data sector D are arranged in a scrambled fashion in the recording sectors on the disc. The other data sectors D may, for example, be video or computer data. When the bit-compressed audio signals are also used for the data sector D, a data string in which 4-channel audio sectors S1 to S4 are cyclically arranged; that is a data

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string:

S1 S2 S3 S4 S1 S2 S3 S4 ...

is encoded and recorded on the disc. When recording and reproducing continuous audio signals, the above-mentioned 4-channel audio signals are linked sequentially beginning at the first channel and terminating at the fourth channel. More specifically, channel 1 data corresponding to the audio sector S1 are reproduced from the innermost to the outermost areas of the disc. Channel 2 data corresponding to the audio sector S2 are reproduced from the innermost to the outermost areas of the disc. Channel 3 data corresponding to the next audio sector S3 are reproduced from the innermost to the outermost areas of the disc. Finally, channel 4 data corresponding to the audio sector S4 are reproduced from the innermost to the outermost areas of the disc to enable data reproduction for a continuous 4-fold time duration.

However, for the above-mentioned continuous reproduction, several track jump operations spanning the inner and outer disc peripheries are necessitated. Since a track jump cannot be achieved instantaneously, playback data are interrupted for a short time period, meaning that the playback sound is momentarily interrupted. On the other hand, when continuous audio signals are to be recorded, it is not possible to record only the sector 2 signals, as an example, because the data need to undergo interleaving at the time of recording. That is, sector 2 data need to be interleaved with adjoining and even near-by sectors, such as sectors S1 and S3, such that it becomes necessary to rewrite signals of previously recorded sectors. Thus it is extremely difficult to record continuous compressed audio data, while real-time processing is virtually impossible.

According to the present invention there is provided an optical disc recording apparatus for recording digital data on a disc-shaped recording medium by optical means, the apparatus comprising:

memory means for temporarily storing input digital data compressed from a continuous signal;

signal processing means for arranging digital data read out from said memory means into a plurality of clusters at an interval of a predetermined number of sectors, annexing to each of said clusters a

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cluster-linking sector so that a linking portion to each cluster is longer than an interleaving length of an interleaving operation for said digital data, and for processing the digital data of said cluster by the interleaving operation;

recording means for recording digital data obtained from said signal processing means on said medium;

abnormality detection means for detecting abnormalities in the recording operation in said recording means;

resetting control means for inhibiting said recording operation and for resetting said recording means from an abnormal state to a normal state in dependence upon detection of an abnormality by said abnormality detection means;

memory control means for performing a read-out control of said memory means for reading a predetermined amount of said recording data on a cluster-by-cluster basis when an amount of said input digital data stored in said memory means exceeds a present first predetermined amount of data to maintain a writable space larger than a second predetermined amount of data in said memory means; and

recording control means for performing a recording position control for continuously recording the digital data intermittently read out cluster by cluster from said memory means by said memory control means on a recording track of said medium.

According to the present invention there is also provided an optical disc recording apparatus for recording digital data on a disc-shaped recording medium by optical means, the apparatus comprising:

memory means in which input data digitized from continuous signals are sequentially written and from which the input data thus written are read out as record data having a transfer rate higher than the transfer rate of said digital data;

signal processing means for arranging digital data read out from said memory means into a plurality of clusters at an interval of a predetermined number of sectors, annexing to each of said clusters a cluster-linking sector so that a linking portion to each cluster is longer than an interleaving length of an interleaving operation for said digital data, and for processing the digital data of said cluster by the interleaving operation;

recording means for recording digital data obtained by said signal

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processing means on said medium;

abnormality detection means for detecting abnormalities in the recording operation in said recording means;

resetting control means for inhibiting said recording operation and for resetting said recording means from an abnormal state to a normal state in dependence upon detection of an abnormality by said abnormality detection means;

memory control means for performing a read-out control of said memory means for reading a predetermined amount of said recording data on a cluster-by-cluster basis when an amount of data of said input digital data stored in said memory means exceeds a preset first predetermined amount of data to maintain a writable space larger than a second predetermined amount of data in said memory means; and

recording control means for performing a recording position control for continuously recording the digital data intermittently read out cluster by cluster from said memory means by said memory control means on a recording track of said medium.

According to the present invention there is also provided an optical disc recording apparatus for recording digital data on a disc-shaped recording medium by optical means, the apparatus comprising:

memory means for temporarily storing input digital data compressed from a continuous signal;

signal processing means for arranging digital data read out from said memory means into a plurality of clusters at an interval of a predetermined number of sectors, annexing to each of said clusters a cluster-linking sector so that a linking portion to each cluster is longer than an interleaving length of an interleaving operation for said digital data, and for processing digital data of said cluster by the interleaving operation;

recording means for recording digital data obtained by said signal processing means on said medium;

abnormality detection means for detecting abnormalities in the recording operation in said recording means;

resetting control means for lowering a laser power of said recording means and for resetting said recording means from an abnormal state to a normal state upon detection of an abnormality by said abnormality detection means;

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memory control means for performing a read-out control of said memory means for reading one-cluster data on a cluster-by-cluster basis when an amount of data of said input digital data stored in said memory means exceeds the amount of said one-cluster-by-cluster data to maintain a writable space larger than a second predetermined amount of data in said memory means;

recording control means for performing a recording position control for continuously recording the digital data intermittently read out cluster by cluster from said memory means by said memory control means on a recording track of said medium; and

control means for performing control of again reading out from said memory means those record data which could not be read out due to an abnormality of the recording operation, after resetting of said recording state to a normal state by a resetting control by said resetting control means, said control means also performing a control of recording said record data again read out in recording positions contiguous to the record data preceding said record data which could not be recorded.

With an embodiment of optical disc recording apparatus according to the present invention, input data digitized from continuous signals are written in memory means, the data thus written in the memory means are sequentially read out as record data having a transfer rate faster than the transfer rate of said input data so as to be interleaved by record means for recording on a cluster-by-cluster basis on said optical disc.

Cluster-linking sectors longer than an interleaving length may be arrayed between the clusters, such that, by recording the clusters and the cluster-linking sectors simultaneously, it becomes possible to eliminate the effects of interleaving on adjoining clusters. With the cluster and cluster-linking sector as a recording unit, recording may be made independently cluster-by-cluster without taking account of the effects of interleaving on other clusters, such that recording data discontinuously read out on the cluster-by-cluster basis from the memory means by the memory control means may be continuously recorded on a recording track of the optical disc by controlling the recording positions by recording control means.

When the abnormality detection means detects an abnormality

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in the recording operation, the laser power of the recording means may be lowered by resetting control means, while the recording means are controlled so as to be reset from the abnormal state to the normal state to maintain continuity of the recording data.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is a block diagram showing an optical disc recording/reproducing apparatus embodying the present invention;

Figure 2 is a block diagram showing an abnormality detection circuit provided in the apparatus of Figure 1;

Figure 3 shows the format of a cluster;

Figure 4 is a flow chart showing a control operation of a recording mode of a system controller in the apparatus of Figure 1;

Figure 5 shows an example of a data structure of one sector or block;

Figure 6 shows the contents of a sub-header;

Figure 7 shows an example of a data structure in one sector of a so-called CD-I;

Figure 8 shows a format of a frame and a block (sector) in the CD standard;

Figure 9 shows a data format employed in the apparatus of Figure 1;

Figure 10 shows the status of a memory-controlled memory in a recording system of the apparatus of Figure 1; and

Figure 11 shows the status of a memory-controlled memory in a reproducing system of the apparatus of Figure 1.

Figure 1 is a block circuit diagram showing a schematic construction of an optical disc recording/reproducing apparatus according to an embodiment of the present invention.

In the disc recording/reproducing apparatus of Figure 1, a magneto-optical disc 2 rotationally driven by a spindle motor 1 is employed as a recording medium. While a laser light is irradiated by an optical head 3 on the disc 2, a modulating magnetic field corresponding to recording data is applied by a magnetic head 4 to the disc 2 for recording data along a recording track of the disc 2. On the other hand, the recording track of the disc 2 is traced with a

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laser light by the optical head 3 for photomagnetically reproducing the recorded data.

The optical head 3 comprises a laser light source, such as a laser diode, optical components, such as a collimator lens, an objective lens, a polarization beam splitter or a cylindrical lens, and a split photodetector, although these device are not shown, and is arranged to face the magnetic head 4 with the disc 2 in-between. For recording data on the disc 2, the optical head 3 irradiates a laser light on a target track on the disc 2 for recording data by thermomagnetic recording. The modulating magnetic field corresponding to the recording data is applied to the target track by the magnetic head 4, which is driven by a head driving circuit 16 of the recording system which will be explained subsequently. The optical head 3 detects a laser light irradiated on and reflected by the target track for detecting the focusing error by a so-called astigmatic method, as well as detecting the tracking error by a so-called push-pull method. When reproducing data from the disc 2, the optical head 3 detects the difference of a polarization angle (Kerr rotation angle) of the reflected laser light from the target track to produce playback signals.

The output of the optical head 3 is supplied to an RF circuit 5. The RF circuit 5 extracts the focusing error signal and the tracking error signal from the output of the optical head 3 and transmits the extracted signals to a servo control circuit 6 while converting the reproduced signals into corresponding binary signals and supplying the binary signals to a decoder 21 of the reproducing system, which will be explained subsequently, and supplying these to an abnormality detection circuit 30.

The servo control circuit 6 comprises a focusing servo circuit, a tracking servo circuit, a spindle motor servo control circuit and a thread servo control circuit, although these circuits are not shown. The focusing servo control circuit executes focusing control of an optical system of the optical head 3 so that the focusing error signal will be reduced to zero. The tracking servo control circuit executes tracking control of the optical system of the optical head 3 so that the tracking error signal will be reduced to zero. The spindle motor servo control circuit controls the motor 1

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for rotationally driving the disc 2 at a predetermined rotational velocity, such as at a constant linear velocity. The thread servo control circuit causes the optical head 3 and the magnetic head 4 to be moved to a target track position on the disc 2 designated by the system controller 7. The servo control circuit 6, which performs these various control operations, transmits an information indicating operating states of components controlled by the servo control circuit 6 to a system controller 7.

Referring to Figure 2, the abnormality detection circuit 30 includes a focusing monitoring circuit 31 for monitoring the focusing state of the optical head 3 based on the focusing error signals supplied from the RF circuit 5 for detecting the focusing state of the optical head 3, a track jump detection circuit 32 for detecting an occurrence of a track jump based on the tracking error signal, and a discontinuity detection circuit 33 for detecting discontinuities in the sub-code 2 data or header time, and supplies a detection output of these circuits as an abnormality detection output signal to the system controller 7.

To the system controller 7 are connected a key input operating unit 8 and a display 9. The system controller 7 controls the recording system and the reproducing system with the operating mode designated by operating input information from the key unit 8. The system controller 7 supervises, on the basis of a sector-by-sector address information reproduced from the recording track of the disc 2 by the header time or sub-Q data, the recording position as well as the reproducing position on the recording track traced by the optical head 3 and the magnetic head 4. The system controller 7 causes a bit compression mode to be displayed on the display 9 on the basis of bit compression mode data in the reproduced data obtained from the RF circuit 5 by means of a reproducing system as later described, or of bit compression mode data in an adaptive differential PCM (ADPCM) encoder 13 switchingly selected by the key unit 8. The system controller 7 also causes the playback time to be displayed on the display 9 on the basis of a data compression ratio and the reproducing position data on the recording track in the bit compression mode.

For displaying the playback time, the sector-by-sector address information (absolute time information), reproduced from the

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recording track of the disc 2 with the head time or sub-Q data, is multiplied by a reciprocal of the data compression ratio in the bit compression mode (4 in the case of 1/4 compression) to find an actual time information for display on the display 9. It is noted that, if absolute time information has been recorded (preformatted) on a recording track of a magneto-optical disc, the preformatted absolute time information may be read during recording and multiplied by the reciprocal of the data compression ratio to cause display of the current position in the form of the actual recording time.

The apparatus also comprises an A/D converter 12 to which an analogue audio signal A_{IN} is supplied from an input terminal 10 by way of a low-pass filter 11.

The A/D converter 12 quantizes the audio signal A_{IN}. The digital audio data obtained at the A/D converter 12 is transmitted to the ADPCM encoder 13. The ADPCM encoder 13 processes the standard transfer rate digital audio data quantized from the audio signal A_{IN} by the A/D converter 12 by a data compressing operation in conformity with the various modes in the CD-I system shown in Table 1, and has its operating mode designated by the system controller 7. For example, in the B-level mode of Table 1, the digital audio data are processed into compressed data (ADPCM) audio data) having a sampling frequency of 37.8 kHz, with the number of bits per sample equal to 4 before being supplied to a memory 14. The data transfer rate with the B-level stereo mode is reduced to 1/4 of the standard data transfer rate of 75 sectors/second, or 18.75 sectors/second.

In the embodiment of Figure 1, it is assumed that the sampling frequency of the A/D converter 12 is fixed at the sampling frequency of the standard CD-DA format, or 44.1 kHz, and that, in the ADPCM encoder 13, bit compression from 16 bits to 4 bits is performed after conversion of the sampling rate in conformity with the compression mode, for example, from 44.1 kHz to 37.8 kHz for level B. Alternatively, the sampling frequency of the A/D converter 12 itself may be switchingly controlled as a function of the compression modes. In this case, the cut-off frequency of the low-pass filter 11 is also switchingly controlled as a function of the switchingly controlled sampling frequencies of the A/D converter 12. That is, the sampling

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frequency of the A/D converter 12 and the cut-off frequency of the low-pass filter 11 may be simultaneously controlled in dependence upon the compression modes.

The memory 14 is used as a buffer memory in which data writing and read-out are controlled by the system controller 7, and which transiently stores ADPCM audio data supplied from the ADPCM encoder 13 for recording on the disc 1 as the occasion may demand. That is, in the B-level stereo mode, the compressed audio data supplied from the ADPCM encoder 13 has its transfer rate reduced to 1/4 of the standard data transfer rate of 75 sectors/second, or to 18.75 sectors/second, these compressed data being continuously written in the memory 14. Although it suffices to record the compressed data (ADPCM data) at a rate of every 4 sectors, as explained above, it is practically impossible to record the data at this rate in view of the interleaving operation, and hence the sectors are recorded continuously as later explained. Such recording is performed in a burst fashion (discontinuously) at a standard data transfer rate of 75 sectors/second, by taking advantage of a quiescent period of the time-compressed data, with a cluster, composed of a predetermined number of, for example, 32 plus a few sectors, as a recording unit. That is, in the memory 14, the B-level stereo mode ADPCM audio data which has been continuously written at the lower transfer rate of 18.75 (= 75/4) sectors/second conforming to the data compression ratio, is read out as record data in a burst fashion at the above-mentioned transfer rate of 75 sectors/second. The overall data transfer rate of the data read out and recorded in this way, inclusive of the non-recording period, is a lower rate of 18.75 sectors/second. However, an instantaneous data transfer rate within the time of the burst-like recording operation is equal to the above-mentioned standard rate of 75 sectors/second. Therefore, if the rotational velocity of the disc is the same as that of the standard CD-DA format, that is, a constant linear velocity, recording is made at the same recording density and with the same recording pattern as those of the CD-DA format.

The ADPCM audio data read out from memory 14 in a burst fashion at the transfer rate of 75 sectors/second, that is, the record data, is supplied to an encoder 15. With a data string supplied from the memory 14 to the encoder 15, a data unit continuously recorded

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with each recording is composed of a plurality of, for example 32 sectors, and a few cluster-linking sectors arrayed before and after the cluster. The cluster-linking sector has a length longer than the interleaving length at the encoder 13, so that, even when the sector undergoes interleaving, data of other clusters remain unaffected. Details of the recording on the cluster-by-cluster basis will be discussed later referring to Figure 3.

The encoder 15 processes the record data supplied in a burst fashion from the memory 14 with an error correcting coding operation, such as by parity addition or interleaving, or 8-to-14 modulation (EFM). The recording data, thus encoded by the encoder 15, is supplied to the magnetic head driving circuit 16.

To the head driving circuit 16 is connected the magnetic head 4 and drives it to apply a modulating magnetic field conforming to the record data to the disc 2.

On the other hand, the system controller 7 performs writing and read-out control for the memory 14 and, based on the memory control, performs a disc recording position control so that the above-mentioned record data read out in a burst fashion from memory 14 will be recorded continuously on the recording track of the disc 2. For the recording position control, the record position on the disc 1 of the record data read out in a burst fashion from the memory 14 is supervised by the system controller 7, and controls signals designating the record position on the recording track of the disc 2 are supplied to the servo control circuit 6.

If an abnormality, such as track jump or defocusing, should have occurred during the recording operation, the system controller 7 performs a control operation of immediately lowering the laser power of the optical head 3 based on the abnormality detection signal from the abnormality detection circuit 30, to prevent mistaken recording, and of resetting the recording system under this condition from the abnormal state to the normal state.

The reproducing system in the disc recording/reproducing apparatus will now be explained.

The reproducing system reproduces the record data continuously recorded by the above-described recording system on the recording track of the disc 2, and is provided with the decoder 21, to

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which is supplied a playback output, which has been generated by the optical head 3 tracing the recording track on the disc 3 with a laser light and converted into binary format signals by the RF circuit 5.

The decoder 21 is associated with the encoder 15 in the above-described recording system, and processes the playback output, converted into the binary format signals by the RF circuit 5, with the above-mentioned decoding for error correction and EFM decoding, and reproduces the above-mentioned B level stereo mode ADPCM audio data at a transfer rate of 75 sectors/second, which is faster than the normal transfer rate in the above-mentioned B level stereo mode. The reproduced data, produced by the decoder 21, are supplied to a memory 22.

The memory 22 has its data writing and read-out controlled by the system controller 7 so that the playback data supplied from decoder 21 at a transfer rate of 75 sectors/second are sequentially written in a burst fashion at the transfer rate of 75 sectors/second. Also the playback data intermittently written at the transfer rate of 75 sectors/second in the memory 22 are continuously read out therefrom at the regular B-level stereo mode of 18.75 sectors/second.

The system controller 7 also performs a memory control of writing the reproduced data in the memory 22 at the transfer rate of 75 sectors/second, continuously reading out the playback data from the memory 22 at the transfer rate of 18.75 sectors/second.

The system controller 7 performs, besides the above-mentioned memory control operation for the memory 22, a reproducing position control from the recording track of the disc 2, in such a manner that the playback data written in a burst fashion by the above-mentioned memory control in the memory 22 is reproduced continuously from the recording track of the disc 2. The reproducing position control is performed by supervising a reproducing position on the disc of the above-mentioned playback data written in a burst fashion in the memory 22 by the system controller 7, and by supplying a control signal designating the reproducing position on the recording track of the disc 2 to the servo control circuit 6.

The B-level stereo mode ADPCM audio data, obtained as playback data read out continuously from the memory 22 at a transfer rate of 18.75 sectors/second, are supplied to the ADPCM decoder 23.

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This ADPCM decoder 23 is associated with the ADPCM encoder 13 of the recording system, and has its operation mode designated by the system controller 7. With the present disc recording/reproducing apparatus, the B-level stereo mode ADPCM audio data are expanded by a factor of 4 for reproducing the digital audio data. The reproduced digital audio data are transmitted by the ADPCM decoder 23 to a D/A converter 24.

The D/A converter 24 causes the digital audio data supplied from the ADPCM decoder 23 to be converted into an analogue audio signal A_{OUT} which is outputted via a low-pass filter 25 at an output terminal 26.

The reproducing system of the disc recording/reproducing apparatus is provided with a digital outputting function so that the digital audio data at the output of the ADPCM decoder 23 is outputted at a data output terminal 28 via a digital output encoder 27 as a digital output signal D_{OUT}.

The recording/reproducing operation by the above-described apparatus will now be explained in more detail.

The record data, that is data read out from the memory 14, is arranged into a cluster at an interval of a predetermined number of, for example 32, sectors or blocks, and several cluster-linking sectors are arrayed between adjoining clusters. In more detail, each cluster C_n consists of 32 sectors or blocks B0 to B31, and 5 linking sectors L1 to L5 are arranged between these clusters C_n for linking the adjoining clusters. For recording a cluster, such as a k'th cluster C_k, the 32 sectors B0 to B31 of the cluster C_k and the linking clusters ahead of and following the cluster C_k, namely the 3 sectors L3 to L5 towards the cluster C_{k-1} (run-in blocks) and the 3 blocks L1 to L3 towards the cluster C_{k+1}, making a total of 38 sectors, are recorded as one unit. The 38-sector record data are transmitted from the memory 14 to the encoder 15 where interleaving is carried out for data rearrangement over a distance of up to 108 frames corresponding to ca. 1.1 sector. However, the data within the cluster C_k are safely contained within a range of from the run-in blocks L3 to L5 to the run-out blocks L1 to L3 without affecting the remaining clusters C_{k-1} or C_{k+1}. Meanwhile, dummy data, such as 0, are arrayed in the linking

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sectors L1 to L5 to avoid adverse effects which interleaving might have on the data per se. When recording the next cluster C_{k+1}, 3 sectors L3 to L5 of the 5 linking sectors L1 to L5 between the current cluster and the next cluster C_{k+1} are used as the run-in blocks, so that the sector L3 is recorded superfluously without causing any inconvenience. The sector L3 of the run-in block or the sector L3 of the run-out block may be omitted, so that recording may be performed with the remaining 37 sectors as a unit.

By recording on the cluster-by-cluster basis, there is no necessity of taking account of interference with the adjoining clusters by interleaving, so that data processing may be significantly simplified. On the other hand, if the record data cannot be recorded normally due to malfunctions, such as defocusing, detracking etc, re-recording may be done on the cluster-by-cluster basis and, if the record data cannot be reproduced effectively, re-reading may be done on the cluster-by-cluster basis.

With the present embodiment, the system controller 7 performs, during the recording mode, a record control operation shown for example in the flow chart of Figure 4.

During the recording mode, the system controller 7 waits at step S_1 until one-cluster recording data are available. When the one-cluster recording data are in order, the system controller 7 proceeds to step S_2 to access the optical head 3 and the magnetic head 4 to record one-cluster recording data on the disc 2. At the next step S_3, the system controller 7 monitors the end of recording of the one-cluster recording data. When the recording of the one-cluster recording data comes to an end, the system controller 7 proceeds to step S_4 to set the laser power of the optical head 3 to a reproducing level. At the next step S_5, it is checked if recording of all of the record data has come to an end and, if there is any record data, the system controller 7 reverts to step S_1 to continue the recording operation. If the recording has come to an end, the control operation of the record mode is terminated. During monitoring of the end of recording of the one-cluster record data during step S_3, it is checked at step S_6 if an abnormality has been detected by the abnormality detection circuit 30. Unless an abnormality is detected, the system

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controller 7 reverts to step S_3 to continue the monitoring operation and, if an abnormality is detected, the system controller 7 reverts to step S_7 to set the laser power of the optical head 3 to the reproducing level immediately. At step S_8, the recording system is reset from the abnormal state and, after again setting at step S_8 the record data at the leading end of the cluster where the abnormality has been detected, the system controller 7 reverts to step S_2 to re-start the recording operation.

In this manner, the recording operation is performed on a cluster-by-cluster basis and, if an abnormality is detected by the abnormality detection circuit 30, recording is re-started at the leading end of the cluster to maintain continuity of record data.

Each sector or block consists of 12 synchronizing bits, 4 header bytes and 2336 bytes of data per se D0001 to D2336, arrayed in this order, making a total of 2352 bytes. This sector or block array is represented as a two-dimensional array, as shown in Figure 5, wherein the 12 synchronization bits consist of the first byte 00H, 10 bytes FFH and the last byte 00H in the hexadecimal system (H is a hexadecimal number). The next 4-byte header consists of address parts for minute, second and bloc, each one byte, and a mode data byte. These mode data mainly indicate a CD-ROM mode, while a sector structure shown in Figures 3 or 5 correspond to the mode 2 of the CD-ROM format. The CD-I is a standard employing the mode 2 and the contents of the data D0001 to D0001 are prescribed as shown in Figure 6.

Figure 5 shows forms 1 and 2 of the CD-I standard, in which 12 synchronizing bits and 4 header bytes are the same as those of the CD-ROM mode 2 shown in Figures 3 and 5. The next 8 sub-header bytes are prescribed as shown in Figure 4 wherein data D0001 and D0005 are file numbers, data D0002 and D0006 are channel numbers, data D0003 and D0007 are sub-code data and data D0004 and D0008 are data type data. The data D0001 to D0004 and data D0005 to D0008 are the same data written in duplicate. The next 2328 bytes consist of 2048 user data bytes, 4 error-detecting bytes, 172 P parity byte and 104 Q parity bytes, for form 1 of Figure 7A. This form 1 is used for recording letter data, binary data and high compression video data. The 2328

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bytes for form 2 of Figure 7B consist of 2324 user data bytes, downstream of the sub-header data, and the remaining 4 reserve data bytes. This form 2 is used for recording compressed audio data or video data. In the case of compressed audio data, 18 128-byte sound groups (2304 bytes) are arrayed in the 2324 user data bytes, with the remaining 20 bytes representing a vacant space.

When recording the above-described sector-based data on a disc, a coding operation such as parity addition or interleaving or EFM encoding is carried out by the encoder 15, so that recording is performed with a recording format shown in Figure 8.

Referring to Figure 8, each block or sector consists of 98 frames of 1st to 98th frames, with each frame being 588 times a channel clock period T (588T). Within each frame, there are a frame synchronizing pattern part of 24T (plus 3T for linking), a sub-code part of 14T (plus 3T for linking) and data part of 544T (for audio data and parity data). The 544 T data part consists of 12 bytes or symbols of audio data, 4 bytes of parity data, 12 bytes of audio data and 4 bytes of parity data, which have been processed by EFM. Audio data in each frame are constituted by 24 bytes or 12 words because each word of the audio sample data consists of 16 bites. The sub-code part is the 8-bit sub-code data which has undergone EFM and is arrayed in a block with 98 frames as a unit, each bit constituting one of 8 sub-code channels P to W. The sub-code parts of the first and second frames are block synch patterns S_0 and S_1 which violate the EFM rule, each of the sub-code channels P to W being constituted by 96 bits for the 3rd to 98th frames.

The above audio data, recorded after interleaving, are deinterleaved during reproduction into audio data of a data array conforming to the regular time sequence. The CD-I data, such as are shown in Figures 3 and 5, may be recorded in place of the audio data.

Digital data obtained at the A/D converter 12 in the apparatus of Figure 1, are similar to those of the CD-DA format, that is audio PCM data with a sampling frequency of 44.1 kHz, the number of quantization bits equal to 16 and a data transfer rate of 75 sectors/second, as shown in Figure 9. When the data are transmitted to the ADPCM encoder 13 so as to be bit-compressed to the above-mentioned stereo mode, the digital data are converted into data with

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a sampling frequency of 37.8 kHz and the number of quantization bits is compressed to 4 bits. Thus the output data are the ADPCM audio data having the data transfer rate reduced to 1/4, or to 18.75 sectors/second. The B level stereo mode ADPCM audio data, continuously outputted at a transfer rate of 18.75 sectors/second from the ADPCM encoder 13, are supplied to the memory 14.

Referring to Figure 10, the system controller 7 controls the memory 14 in such a manner that a write pointer W of the memory 14 is continuously incremented at a transfer rate of 18.75 sectors/second continuously to write the ADPCM audio data in the memory 14 at a transfer rate of 18.75 sectors/second and, when the amount of data of the ADPCM audio data stored in the memory 14 exceeds a predetermined amount K, a read pointer R of the memory 14 is incremented in a burst fashion at the transfer rate of 75 sectors/second to read out a predetermined amount of K of the ADPCM data in a burst fashion from the memory 14 as record data at the above mentioned transfer rate of 75 sectors/second. It is noted that the above predetermined amount K has one-cluster data as a unit.

That is, in the recording system of the apparatus of Figure 1, the ADPCM audio data continuously outputted at the transfer rate of, for example 18.75 sectors per second, from the ADPCM encoder 13 are written in the memory 14 at the above-mentioned transfer rate of 18.75 sectors/second. When the amount of data of the ADPCM data stored in the memory 14 exceeds the predetermined amount of data K, the amount of data K of the ADPCM audio data is read out in a burst fashion from memory 14 at the transfer rate of 75 sectors/second as record data, so that input data can be continuously written in the memory 14 while a data write region K' in excess of a predetermined amount is perpetually maintained within the memory 14. By recording the recording positions on the recording track of the disc 2 under control by the system controller 7, the record data read out in a burst fashion from the memory 14 can be recorded consecutively on the recording track on the disc 2. Since a data-depleted region in excess of a predetermined amount is maintained in the memory 14, data can be continuously written in the data-depleted region in excess of the predetermined amount even if the system controller 7 detects that a track jump etc has occurred due to disturbances or the like to

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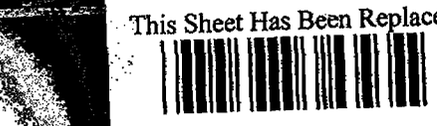
discontinue a recording operation on the disc 2, and the resetting operation may be carried out in the interim. Thus, input data can be continuously recorded without drop-out on the recording track of the disc 2.

Meanwhile, header time data corresponding to the physical address of the sectors are annexed to the ADPCM audio data on the sector-by-sector basis, and recorded on the sector-by-sector basis on the disc 2. Table of contents data indicating the record region and the recording mode are recorded in a table-of-contents region.

In the reproducing system of the apparatus of Figure 1, the system controller 7 controls the memory 22 in such a manner that, as shown in Figure 11, the write pointer W of the memory 22 is incremented at a transfer rate of 75 sectors/second to write the reproduced data in the memory 22 at the transfer rate of 75 sectors/second, the read pointer R of the memory 22 is continuously incremented at a transfer rate of 18.75 sectors/second continuously to read out the playback data from the memory 22 at the transfer rate of 18.75 sectors/second, and the write pointer W of the memory 22 is intermittently incremented at the transfer rate of 75 sectors/second in a burst fashion, so that, when the write pointer W catches up with the read pointer R, writing is discontinued. When the amount of data of the playback data stored in the memory 22 is lower than the predetermined amount L, writing is started again.

Thus, with the above-described reproducing system of the apparatus, the system controller 7 controls the memory 22 in such a manner that the B-level stereo mode ADPCM audio data reproduced from the recording track of the disc 2 is written in a burst fashion in the memory 22 at a transfer rate of 75 sectors/second, and read out continuously from the memory 22 as playback data at the transfer rate of 18.75 sectors/second, so that the playback data may be continuously read out from the memory 22 while the data-depleted region in excess of the predetermined amount L is perpetually maintained within memory 22. Also the playback data intermittently read out from the disc 2 may be continuously reproduced from the recording track on the disc 2 by controlling the reproducing position on the recording track of the disc 2 by the system controller 7. In addition, the data read-out region in excess of the predetermined amount L is perpetually

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maintained in the memory 22, as described previously, so that, even when the system controller 7 should detect the occurrence of a track jump etc due to, for example, disturbances, and the operation of reproducing the disc 2 is discontinued, the playback data may be read out from the data read-out region having a space in excess of the predetermined amount of data to continue the outputting of the analogue audio signals. Since the resetting operation may be executed in the interim, there is no risk of interruption in the reproduced sound.

With the above optical disc recording/reproducing apparatus, a description has been given of the recording and reproduction of B-level stereo mode ADPCM audio data. Recording and reproduction may similarly be made of ADPCM audio data of other modes of the other CD-I systems. As long as PCM audio data of the CD-DA mode is stored, a time compression may be made in the memory 14 in the recording system while the record data may be recorded during the time when the disc 2 is rotationally driven at a velocity conforming to the compression ratio of time compression. In the reproducing system, time expansion may be performed in the memory 22.

With the above-described optical disc recording apparatus, input data digitized from continuous signals are written in memory means and the input area thus written in the memory means are sequentially read out as record data having a transfer rate faster than the transfer rate of the input data so as to be processed by interleaving by recording means. A cluster-linking sector longer than the interleaving length is arrayed between the clusters, and data are recorded simultaneously with the cluster-linking sectors on a cluster-by-cluster basis to eliminate the effects of interleaving on adjoining clusters. With the cluster and the cluster-linking sector as one recording unit, data may be recorded independently on the cluster-by-cluster basis without the necessity of taking account of the effects of interleaving on other clusters, so that the record data read out discretely on the cluster-by-cluster basis from the memory means by memory control means may be continuously recorded on the recording track of the optical disc by controlling the recording positions by the recording control means. If an abnormality of the recording operation is detected by abnormality detection means, resetting

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control means lowers the laser power of the recording means to prevent mistaken recording. In this state, the recording means is reset from the abnormal state to the normal state and recording is again performed at the leading end f the cluster where the abnormality was detected, to maintain continuity of the record data.

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CLAIMS

1. An optical disc recording apparatus for recording digital data on a disc-shaped recording medium (2) by optical means, the apparatus comprising:

memory means (14) for temporarily storing input digital data compressed from a continuous signal;

signal processing means (15) for arranging digital data read out from said memory means (14) into a plurality of clusters at an interval of a predetermined number of sectors, annexing to each of said clusters a cluster-linking sector so that a linking portion to each cluster is longer than an interleaving length of an interleaving operation for said digital data, and for processing the digital data of said cluster by the interleaving operation;

recording means (3, 4) for recording digital data obtained from said signal processing means (15) on said medium (2);

abnormality detection means (30) for detecting abnormalities in the recording operation in said recording means (3, 4);

resetting control means (7) for inhibiting said recording operation and for resetting said recording means (3, 4) from an abnormal state to a normal state in dependence upon detection of an abnormality by said abnormality detection means (30);

memory control means (7) for performing a read-out control of said memory means (14) for reading a predetermined amount of said recording data on a cluster-by-cluster basis when an amount of said input digital data stored in said memory means (14) exceeds a present first predetermined amount of data to maintain a writable space larger than a second predetermined amount of data in said memory means (14); and

recording control means (7) for performing a recording position control for continuously recording the digital data intermittently read out cluster by cluster from said memory means (14) by said memory control means (7) on a recording track of said medium (2).

2. Apparatus according to claim 1 wherein said memory control means (7) performs a control operation for again reading out from said memory means (14) those record data which could not be recorded, after resetting of said recording means (3, 4) by a resetting control

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from said resetting control means (7).

3. Apparatus according to claim 1 wherein said second predetermined amount of data is in excess of an amount of input data inputted to said memory means (14) during the time of resetting from the non-recording state to the recording state.

4. Apparatus according to claim 3 wherein said first predetermined amount of digital data corresponds to one cluster.

5. Apparatus according to claim 1 wherein said cluster-linking sector is formed by dummy data not affecting the digital data in said cluster.

6. Apparatus according to claim 1 wherein said one sector corresponds to one block (98 EFM frames) of a compact disc.

7. Apparatus according to claim 1 wherein said abnormality detection means (30) detects detracking and/or defocusing to check for an abnormality in the recording operation.

8. An optical disc recording apparatus for recording digital data on a disc-shaped recording medium (2) by optical means, the apparatus comprising:

memory means (14) in which input data digitized from continuous signals are sequentially written and from which the input data thus written are read out as record data having a transfer rate higher than the transfer rate of said digital data;

signal processing means (15) for arranging digital data read out from said memory means (14) into a plurality of clusters at an interval of a predetermined number of sectors, annexing to each of said clusters a cluster-linking sector so that a linking portion to each cluster is longer than an interleaving length of an interleaving operation for said digital data, and for processing the digital data of said cluster by the interleaving operation;

recording means (3, 4) for recording digital data obtained by said signal processing means (15) on said medium (2);

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abnormality detection means (30) for detecting abnormalities in the recording operation in said recording means (3, 4);
resetting control means (7) for inhibiting said recording operation and for resetting said recording means (3, 4) from an abnormal state to a normal state in dependence upon detection of an abnormality by said abnormality detection means (30);
memory control means (7) for performing a read-out control of said memory means (14) for reading a predetermined amount of said recording data on a cluster-by-cluster basis when an amount of data of said input digital data stored in said memory means (14) exceeds a preset first predetermined amount of data to maintain a writable space larger than a second predetermined amount of data in said memory means (14); and
recording control means (7) for performing a recording position control for continuously recording the digital data intermittently read out cluster by cluster from said memory means (14) by said memory control means (7) on a recording track of said medium (2).

9. Apparatus according to claim 8 wherein said memory control means (7) performs a control operation for again reading out from said memory means (14) those record data which could not be recorded, after resetting of said recording means (3, 4) by a resetting control by said resetting control means (7), and wherein said memory control means (7) performs a control operation for recording the record data thus again read out at recording positions contiguous to the previously recorded said record data.

10. Apparatus according to claim 8 wherein said second predetermined amount of data is in excess of an amount of input data inputted to said memory means (14) during the time of resetting from the non-recording state to the recording state.

11. Apparatus according to claim 10 wherein said first predetermined amount of digital data corresponds to one cluster.

12. Apparatus according to claim 8 wherein said cluster-linking sector is formed by dummy data not affecting the digital data in said

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cluster.

13. Apparatus according to claim 8 wherein said abnormality detection means (30) detects detracking and/or defocusing to check for any abnormality in the recording operation.

14. Apparatus according to claim 8 wherein the recording operation is inhibited on detection of the abnormality in the recording operation by lowering the laser power of said recording means (3, 4).

15. An optical disc recording apparatus for recording digital data on a disc-shaped recording medium (2) by optical means, the apparatus comprising:

memory means (14) for temporarily storing input digital data compressed from a continuous signal;

signal processing means (15) for arranging digital data read out from said memory means (14) into a plurality of clusters at an interval of a predetermined number of sectors, annexing to each of said clusters a cluster-linking sector so that a linking portion to each cluster is longer than an interleaving length of an interleaving operation for said digital data, and for processing digital data of said cluster by the interleaving operation;

recording means (3, 4) for recording digital data obtained by said signal processing means (15) on said medium (2);

abnormality detection means (30) for detecting abnormalities in the recording operation in said recording means (3, 4);

resetting control means (7) for lowering a laser power of said recording means (3, 4) and for resetting said recording means (3, 4) from an abnormal state to a normal state upon detection of an abnormality by said abnormality detection means (30);

memory control means (7) for performing a read-out control of said memory means (14) for reading one-cluster data on a cluster-by-cluster basis when an amount of data of said input digital data stored in said memory means (14) exceeds the amount of said one-cluster-by-cluster data to maintain a writable space larger than a second predetermined amount of data in said memory means (14);

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recording control means (7) for performing a recording position control for continuously recording the digital data intermittently read out cluster by cluster from said memory means (14) by said memory control means (7) on a recording track of said medium (2); and

control means (7) for performing control of again reading out from said memory means (14) those record data which could not be read out due to an abnormality of the recording operation, after resetting of said recording state (3, 4) to a normal state by a resetting control by said resetting control means (7), said control means (7) also performing a control of recording said record data again read out in recording positions contiguous to the record data preceding said record data which could not be recorded.

16. Apparatus according to claim 15 wherein said cluster-linking sector is formed by dummy data not affecting the digital data of said cluster.