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(54) INFORMATION RECORDING MEDIUM WHICH INDICATES INFORMATION ACCORDING TO THE WOBBLING OF A TRACK AND INFORMATION RECORDING AND REPRODUCING APPARATUS

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Related U.S. Application Data

(60) Continuation of application No. 09/444,994, filed on Nov. 23, 1999, now abandoned, which is a division of application No. 08/955,368, filed on Oct. 21, 1997, now Pat. No. 6,069,870.

(30) **Foreign Application Priority Data**

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Apr. 21, 1997 (JP) 9-102938

Publication Classification

(51) **Int. Cl.**[7] **G11B 7/00**
(52) **U.S. Cl.** **369/111**

(57) **ABSTRACT**

An exposure system and method for an original disk for an information recording medium. A rotating device is provided for driving an original disk and an optical head irradiates a beam for exposure on the original disk. A scanner performs exposure to light in a shape of a track by scanning the beam in a radial direction of the original disk and a controller controls a width of the scanning by the scanner. The controller controls the scanner so that borders on both sides of the track are shifted in phase from each other with a phase difference.

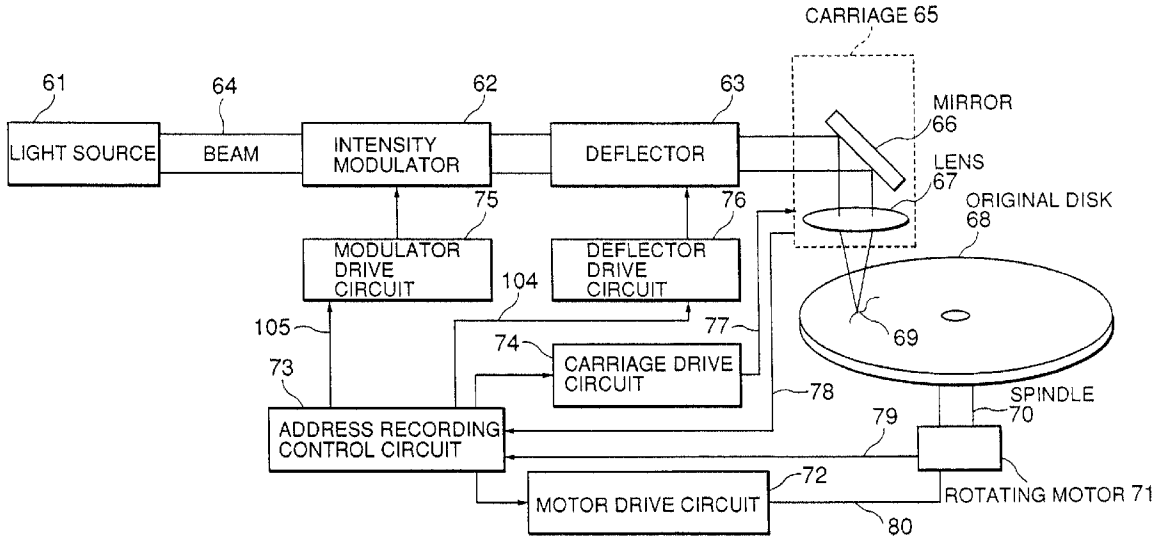

FIG.1

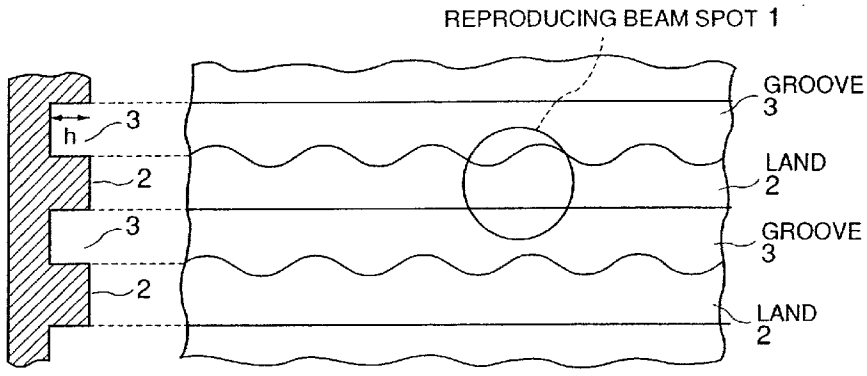

FIG.2

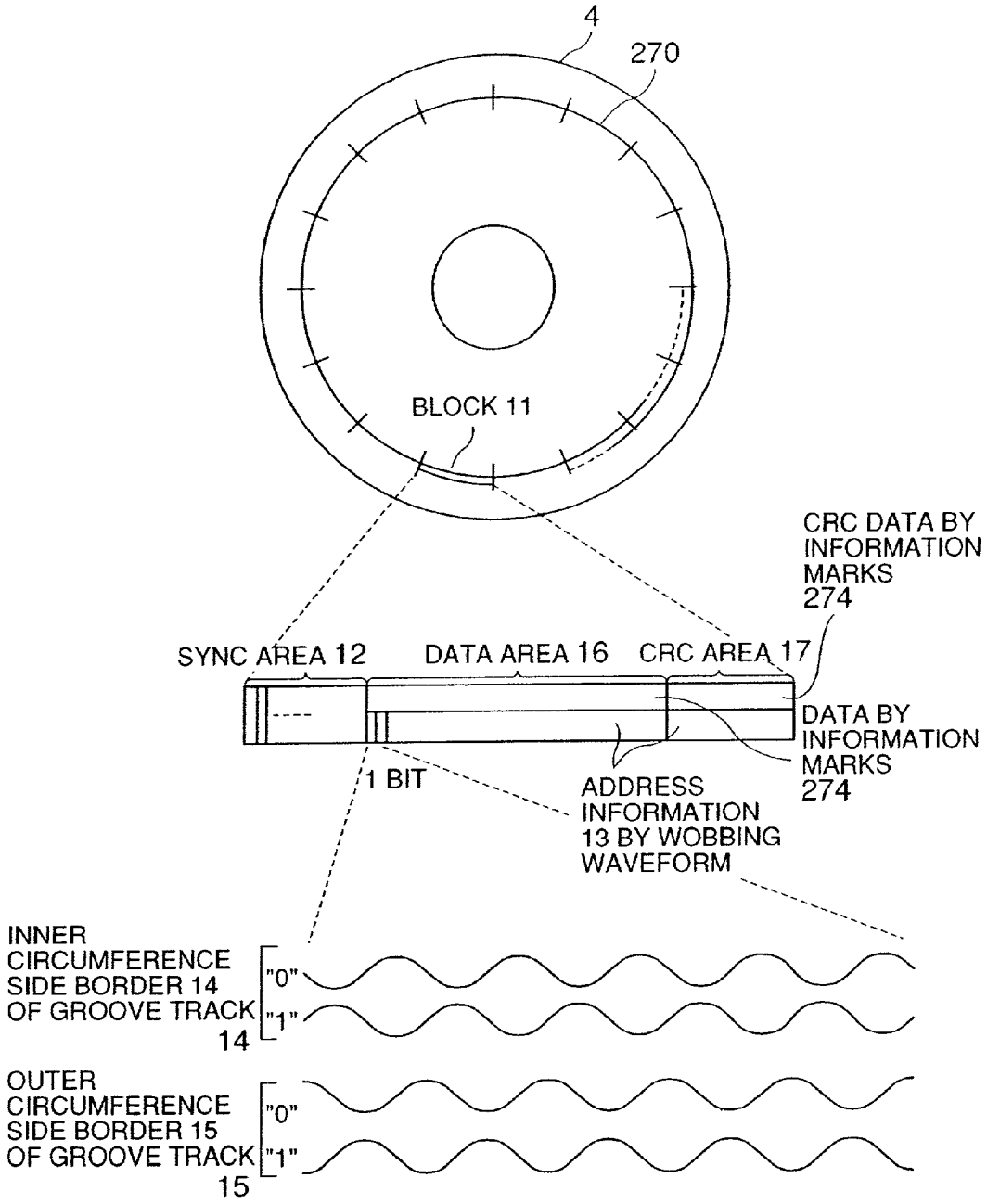
4
270
BLOCK 11
CRC DATA BY INFORMATION MARKS 274
SYNC AREA 12
DATA AREA 16
CRC AREA 17
DATA BY INFORMATION MARKS 274
1 BIT
ADDRESS INFORMATION 13 BY WOBBING WAVEFORM
INNER CIRCUMFERENCE SIDE BORDER 14 OF GROOVE TRACK 14
"0"
"1"
OUTER CIRCUMFERENCE SIDE BORDER 15 OF GROOVE TRACK 15
"0"
"1"

FIG.3

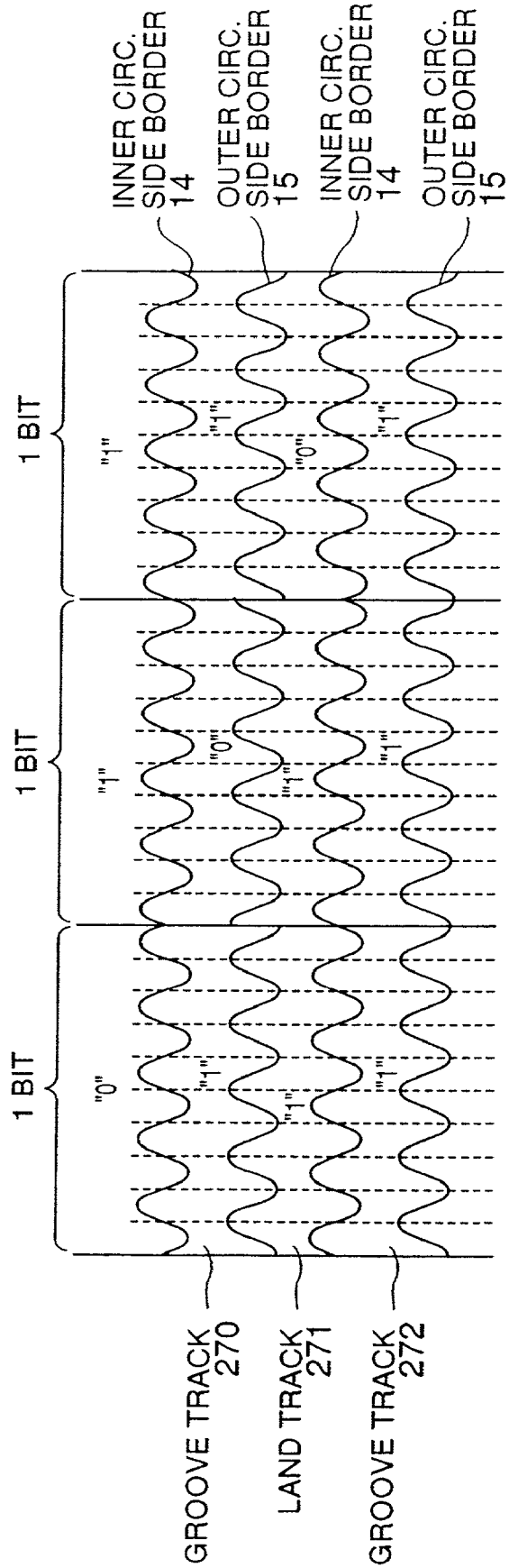
INNER CIRC. SIDE BORDER 14
OUTER CIRC. SIDE BORDER 15
INNER CIRC. SIDE BORDER 14
OUTER CIRC. SIDE BORDER 15
1 BIT
1 BIT
1 BIT
"0"
"1"
"1"
"1"
"0"
"1"
"1"
"0"
"1"
"1"
"1"
GROOVE TRACK 270
LAND TRACK 271
GROOVE TRACK 272

FIG.4

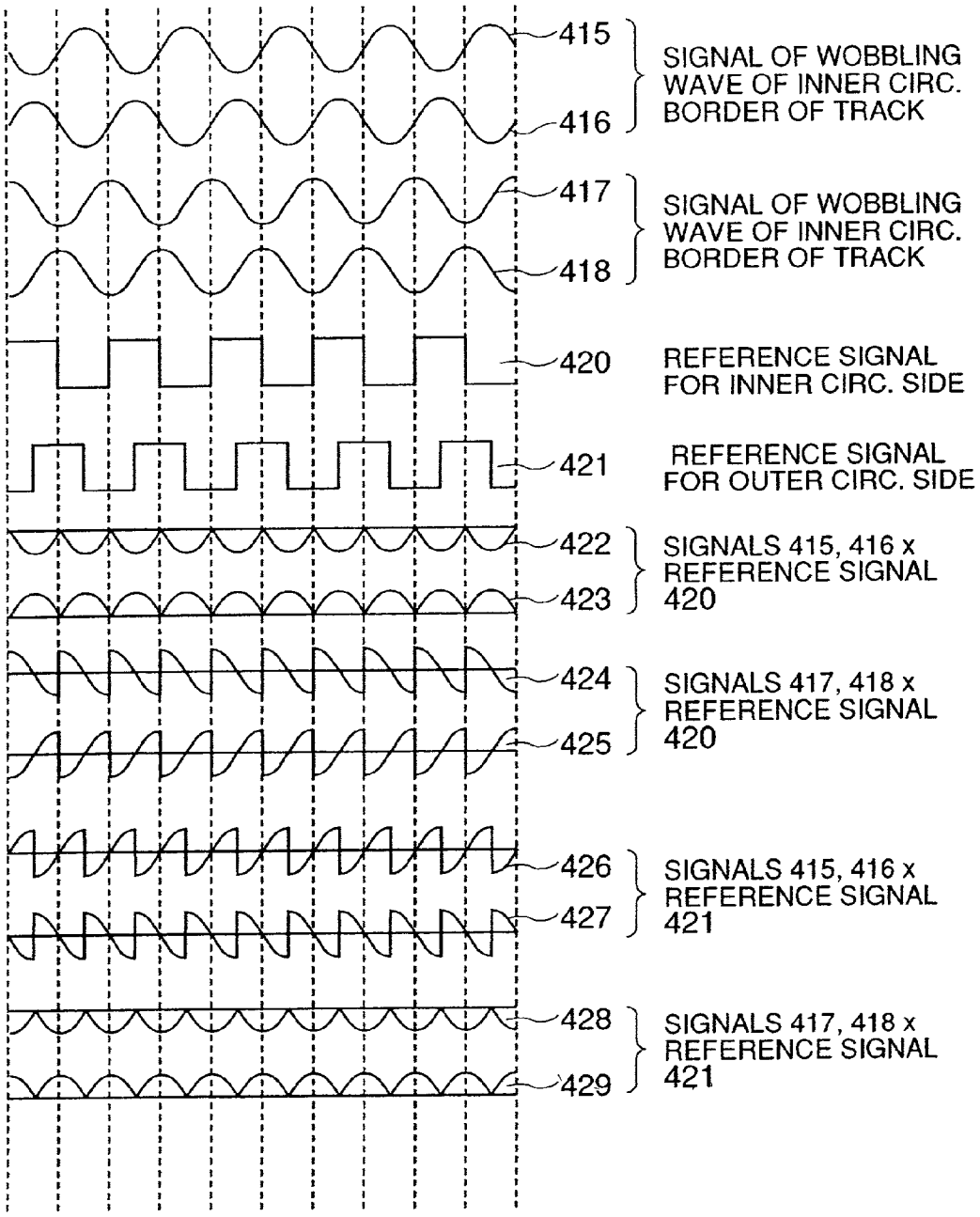
415
416
SIGNAL OF WOBBLING WAVE OF INNER CIRC. BORDER OF TRACK
417
418
SIGNAL OF WOBBLING WAVE OF INNER CIRC. BORDER OF TRACK
420
REFERENCE SIGNAL FOR INNER CIRC. SIDE
421
REFERENCE SIGNAL FOR OUTER CIRC. SIDE
422
423
SIGNALS 415, 416 x REFERENCE SIGNAL 420
424
425
SIGNALS 417, 418 x REFERENCE SIGNAL 420
426
427
SIGNALS 415, 416 x REFERENCE SIGNAL 421
428
429
SIGNALS 417, 418 x REFERENCE SIGNAL 421

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FIG.5A

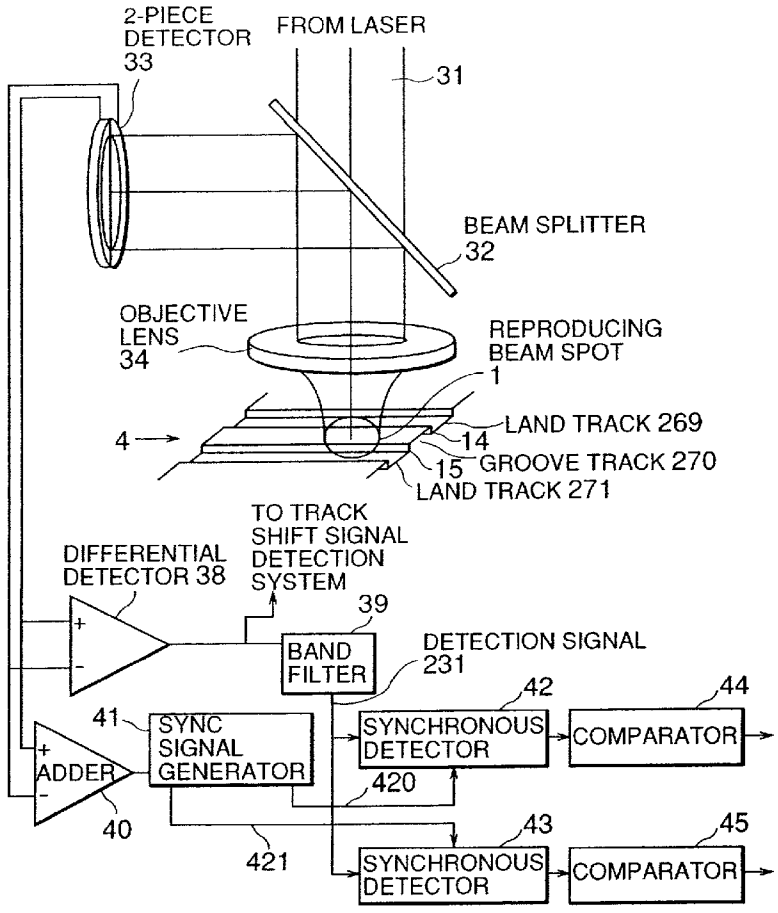


FIG.5B

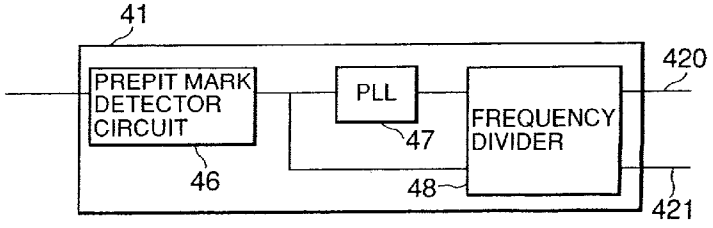


FIG.6

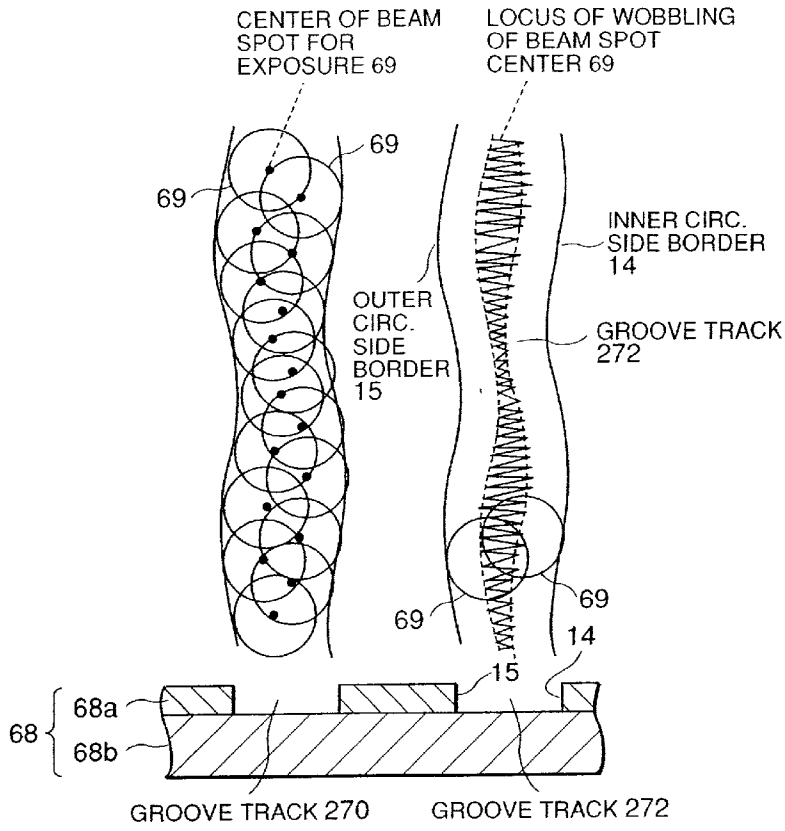

CENTER OF BEAM SPOT FOR EXPOSURE 69
LOCUS OF WOBBLING OF BEAM SPOT CENTER 69
69
69
INNER CIRC. SIDE BORDER 14
OUTER CIRC. SIDE BORDER 15
GROOVE TRACK 272
69
69
14
15
68
68a
68b
GROOVE TRACK 270
GROOVE TRACK 272

FIG.7A

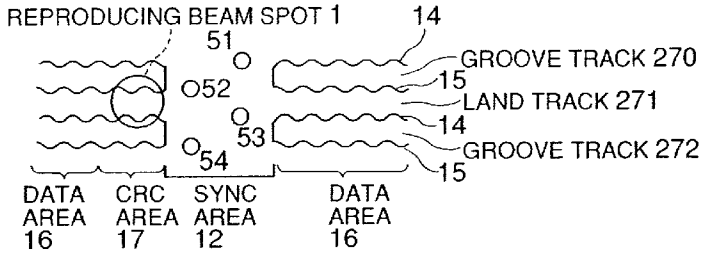


FIG.7B

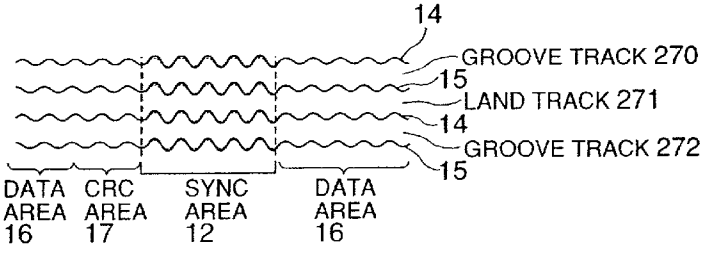


FIG.7C

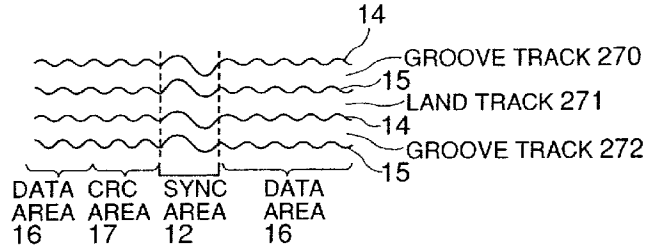
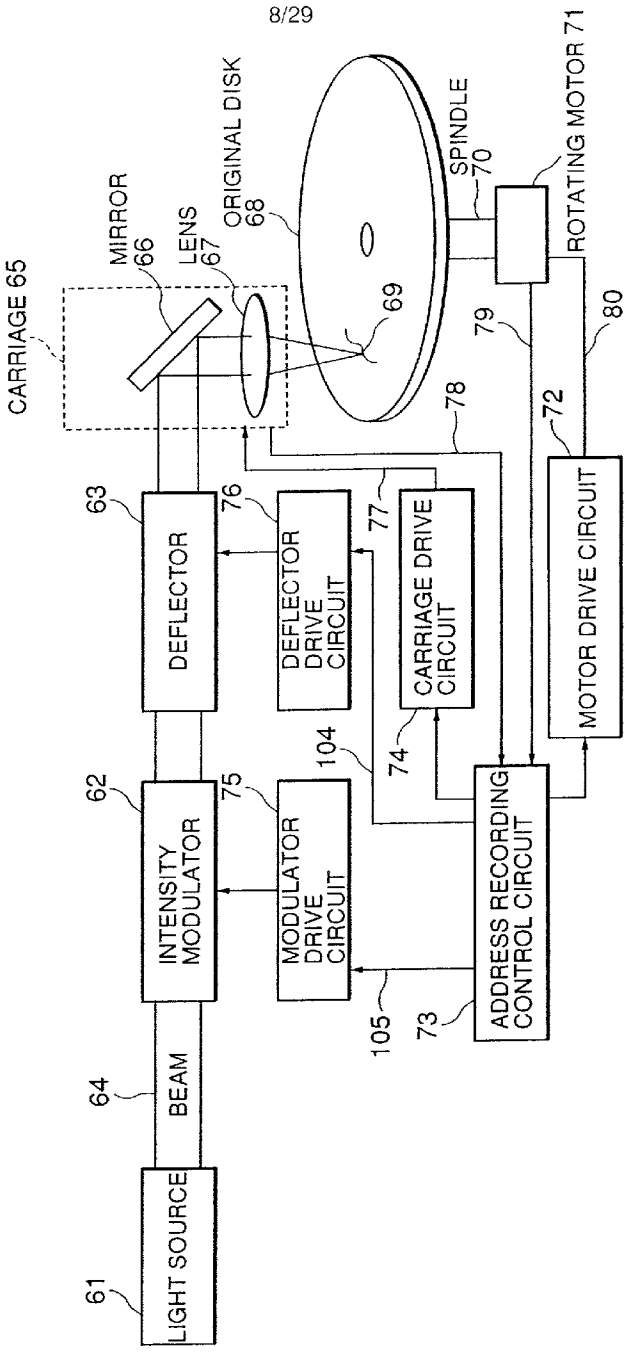


FIG.8


8/29
CARRIAGE 65
MIRROR
66
LENS
67
ORIGINAL DISK
68
69
SPINDLE
70
ROTATING MOTOR 71
79
80
78
72
63
DEFLECTOR
76
DEFLECTOR DRIVE CIRCUIT
77
CARRIAGE DRIVE CIRCUIT
MOTOR DRIVE CIRCUIT
62
INTENSITY MODULATOR
75
MODULATOR DRIVE CIRCUIT
104
74
ADDRESS RECORDING CONTROL CIRCUIT
105
73
64
BEAM
61
LIGHT SOURCE

9/29

FIG.9A

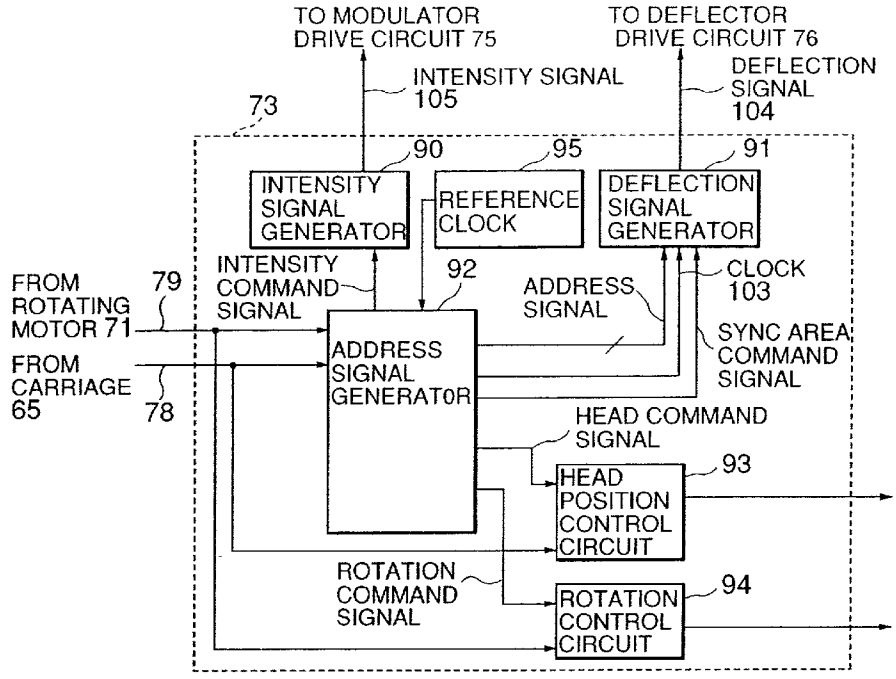


FIG.9B

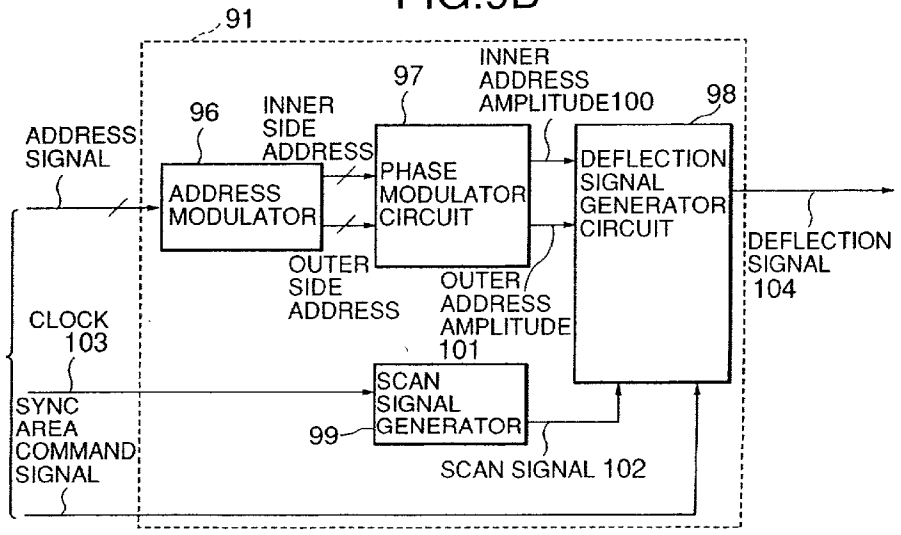
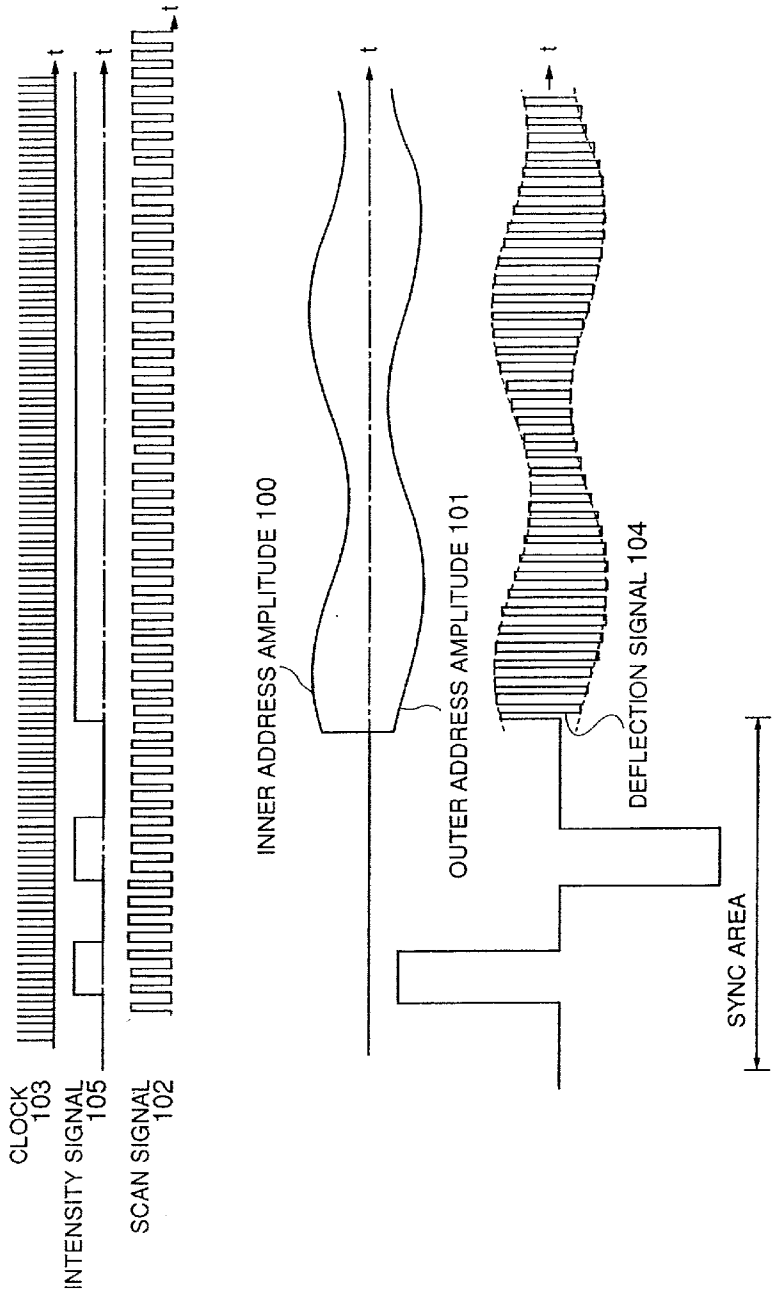


FIG.10


CLOCK 103
INTENSITY SIGNAL 105
SCAN SIGNAL 102
t
INNER ADDRESS AMPLITUDE 100
OUTER ADDRESS AMPLITUDE 101
DEFLECTION SIGNAL 104
SYNC AREA

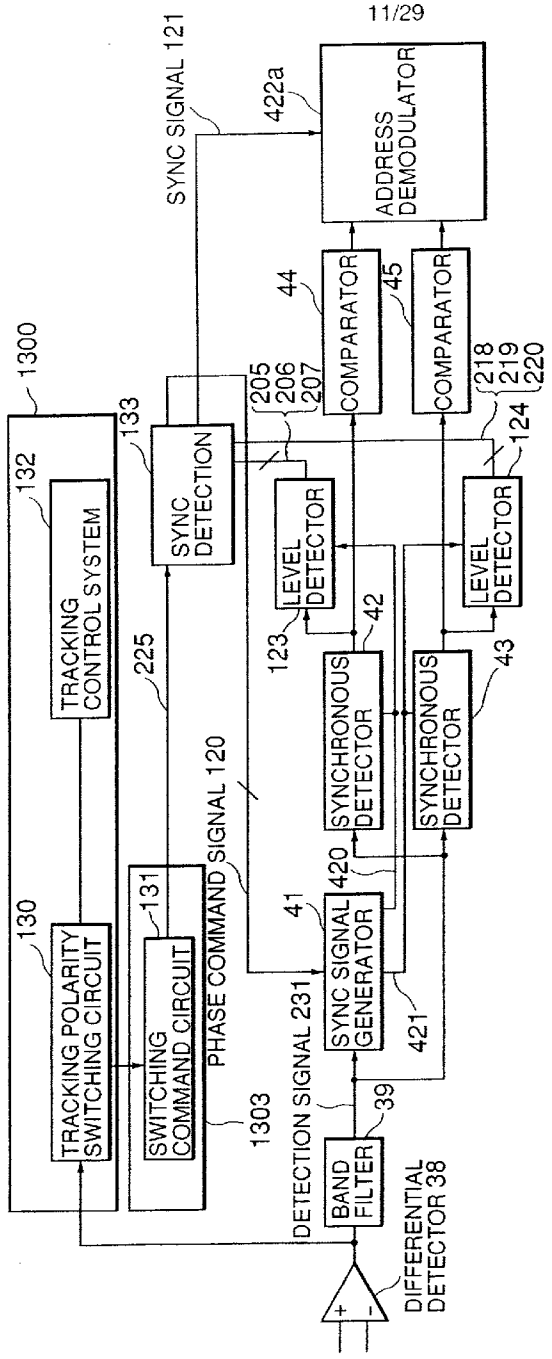


FIG.11A

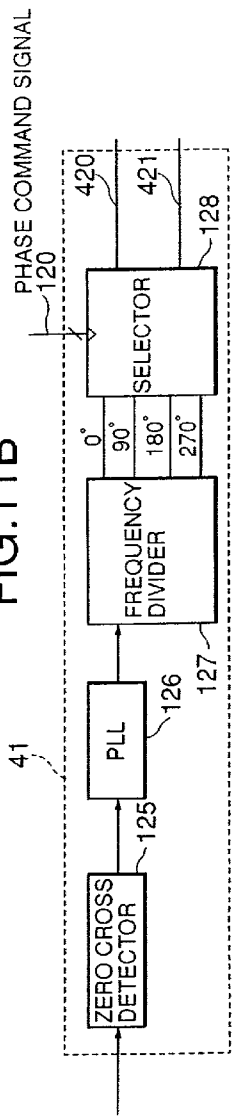


FIG.11B

FIG.12

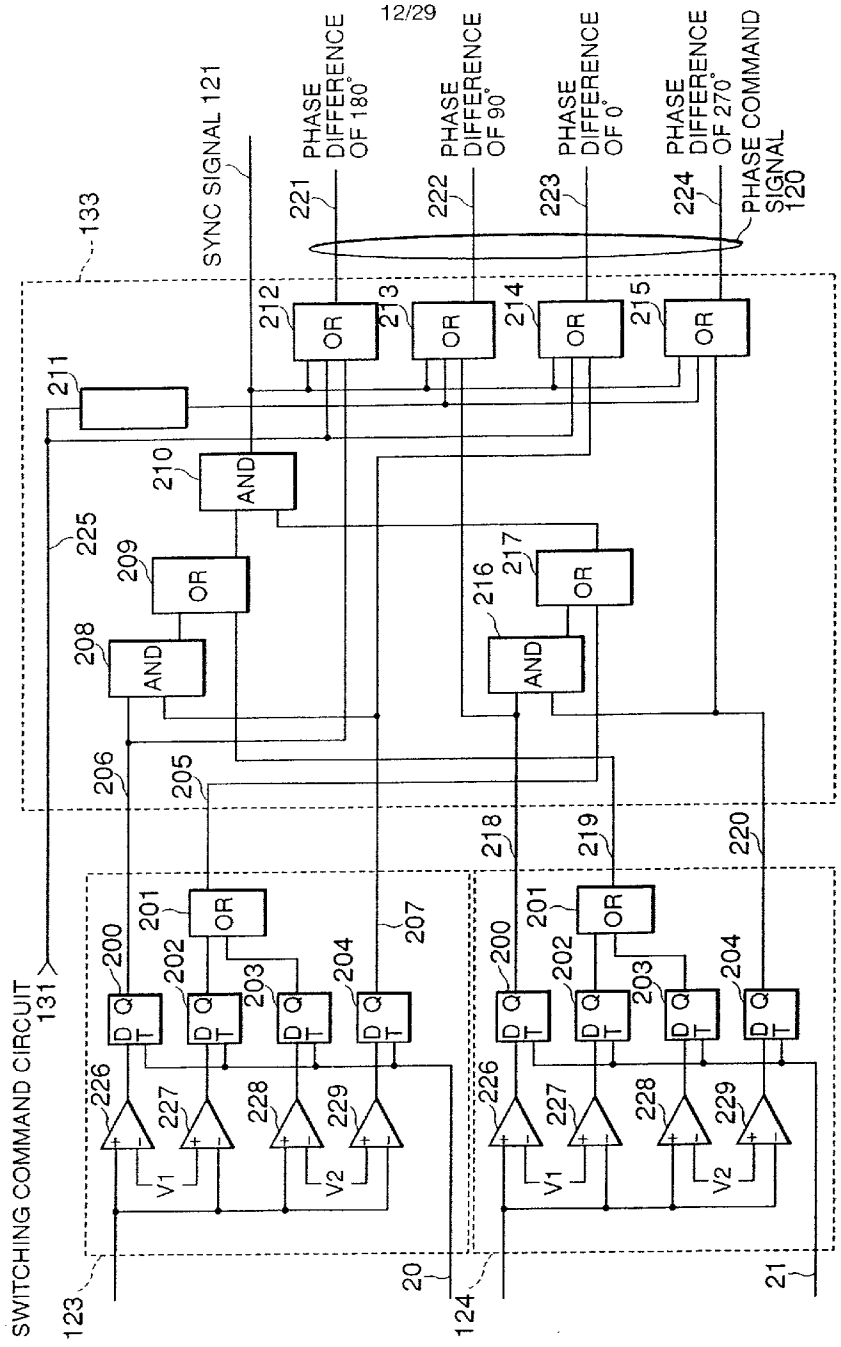

SYNC SIGNAL 121
PHASE DIFFERENCE OF 180°
PHASE DIFFERENCE OF 90°
PHASE DIFFERENCE OF 0°
PHASE DIFFERENCE OF 270°
PHASE COMMAND SIGNAL 120
SWITCHING COMMAND CIRCUIT 131
OR
AND
D Q T
V1
V2

FIG.13

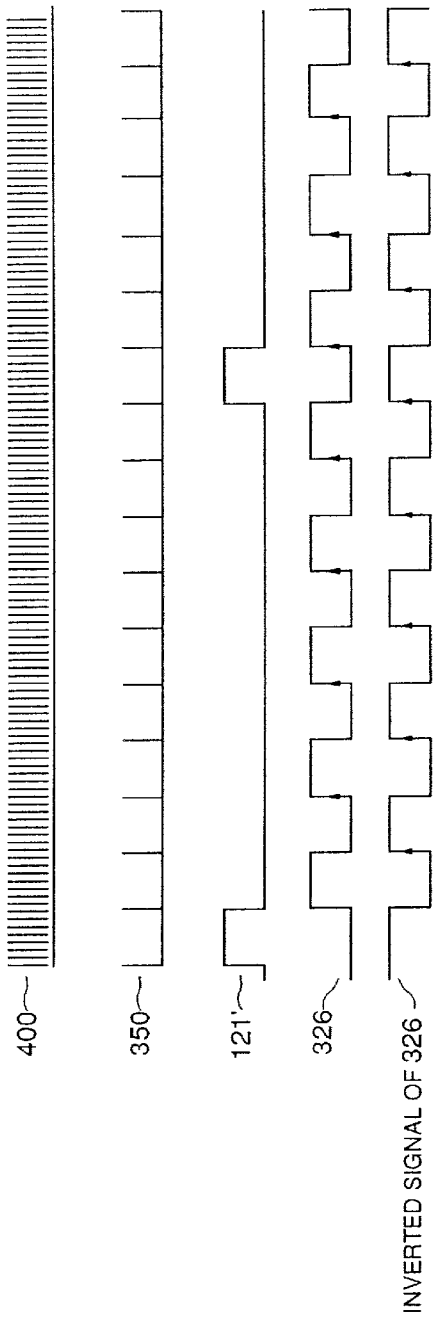


FIG.14A

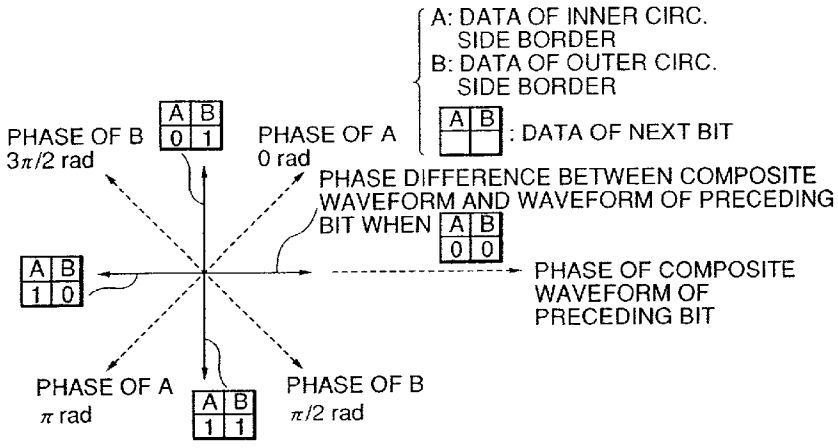


FIG.14B

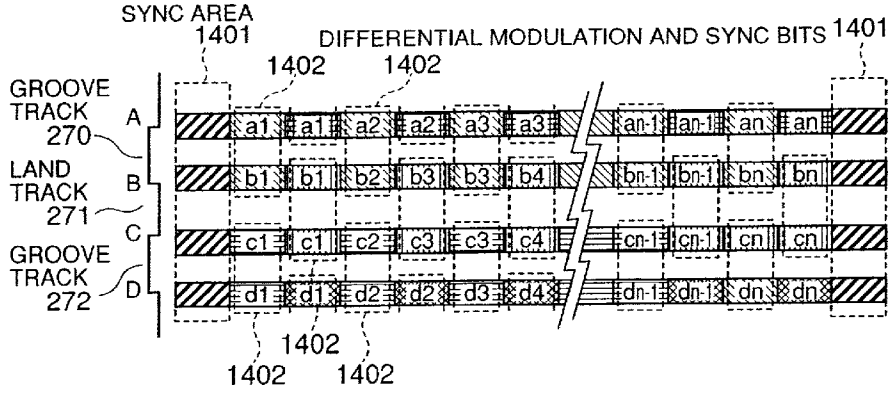


FIG.15A

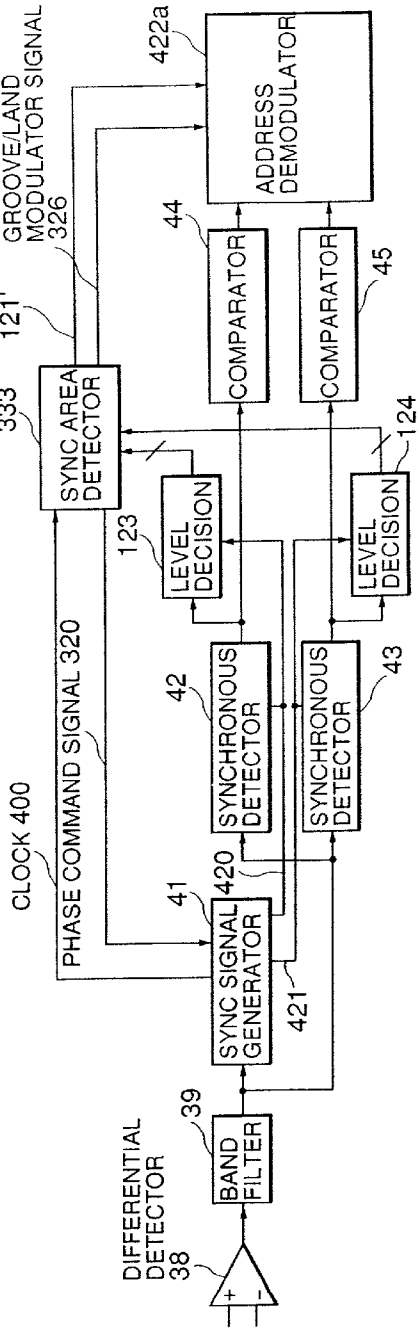
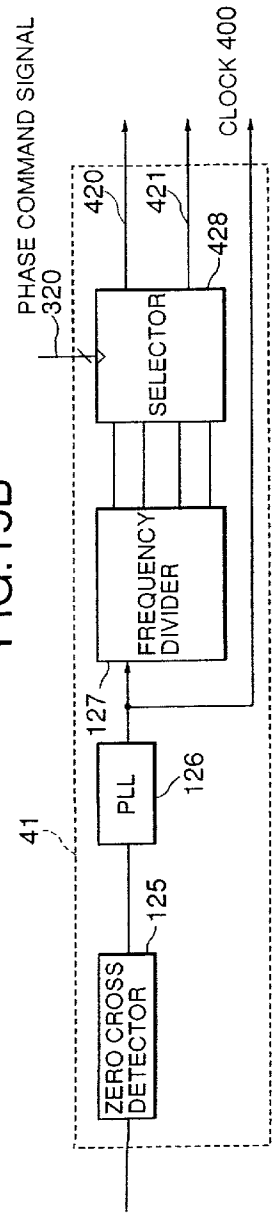


FIG.15B



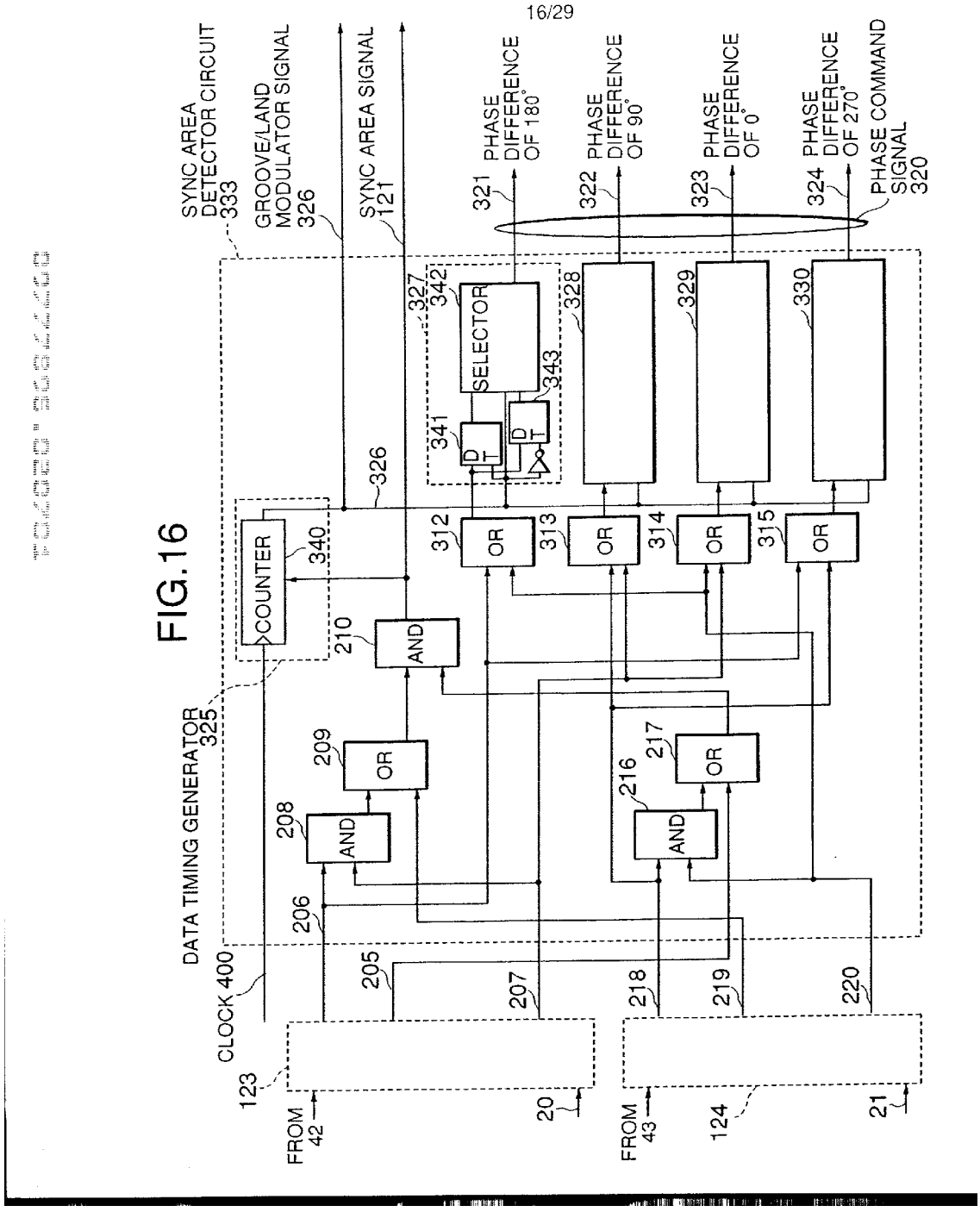

SYNC AREA DETECTOR CIRCUIT 333
GROOVE/LAND MODULATOR SIGNAL 326
SYNC AREA SIGNAL 121
PHASE DIFFERENCE OF 180° 321
PHASE DIFFERENCE OF 90° 322
PHASE DIFFERENCE OF 0° 323
PHASE DIFFERENCE OF 270° 324
PHASE COMMAND SIGNAL 320
DATA TIMING GENERATOR 325
CLOCK 400
COUNTER 340
SELECTOR 342
327
328
329
330
341
343
D
T
OR 312
OR 313
OR 314
OR 315
AND 210
OR 209
AND 208
206
205
207
OR 217
AND 216
218
219
220
123
FROM 42
20
FROM 43
124
21

FIG.16

FIG.17A

PRECEDING BIT	NEXT BIT	PHASE DIFFERENCE
1/0	0	0
	1	π

INNER SIDE OF GROOVE	0 rad	π rad
OUTER SIDE GROOVE	π /2 rad	3 π /2 rad

FIG.17B

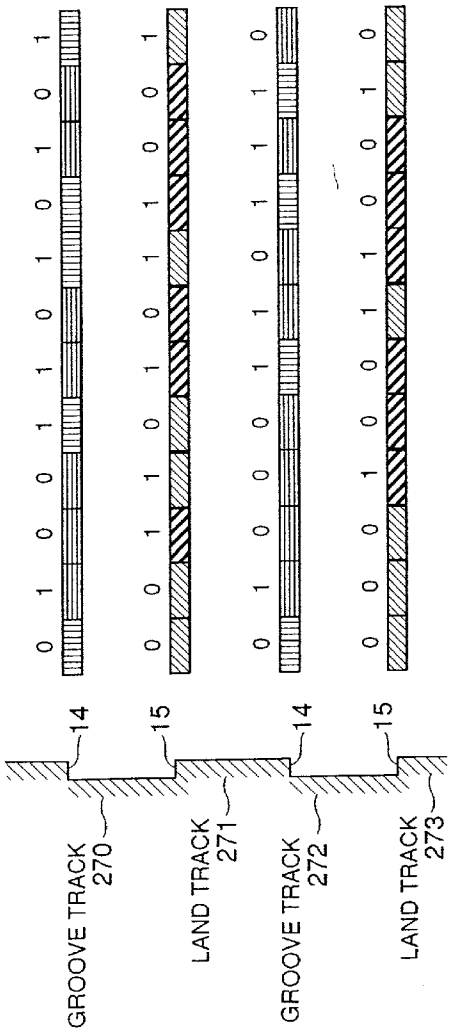


FIG.18A

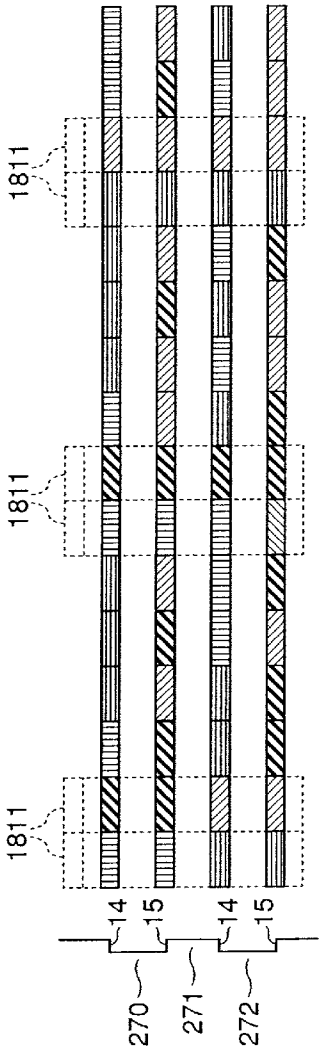
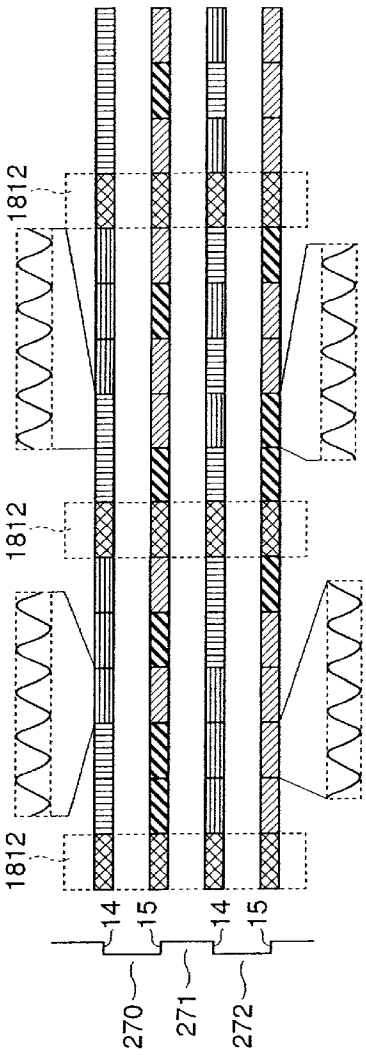


FIG.18B



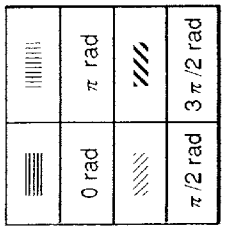


FIG.19

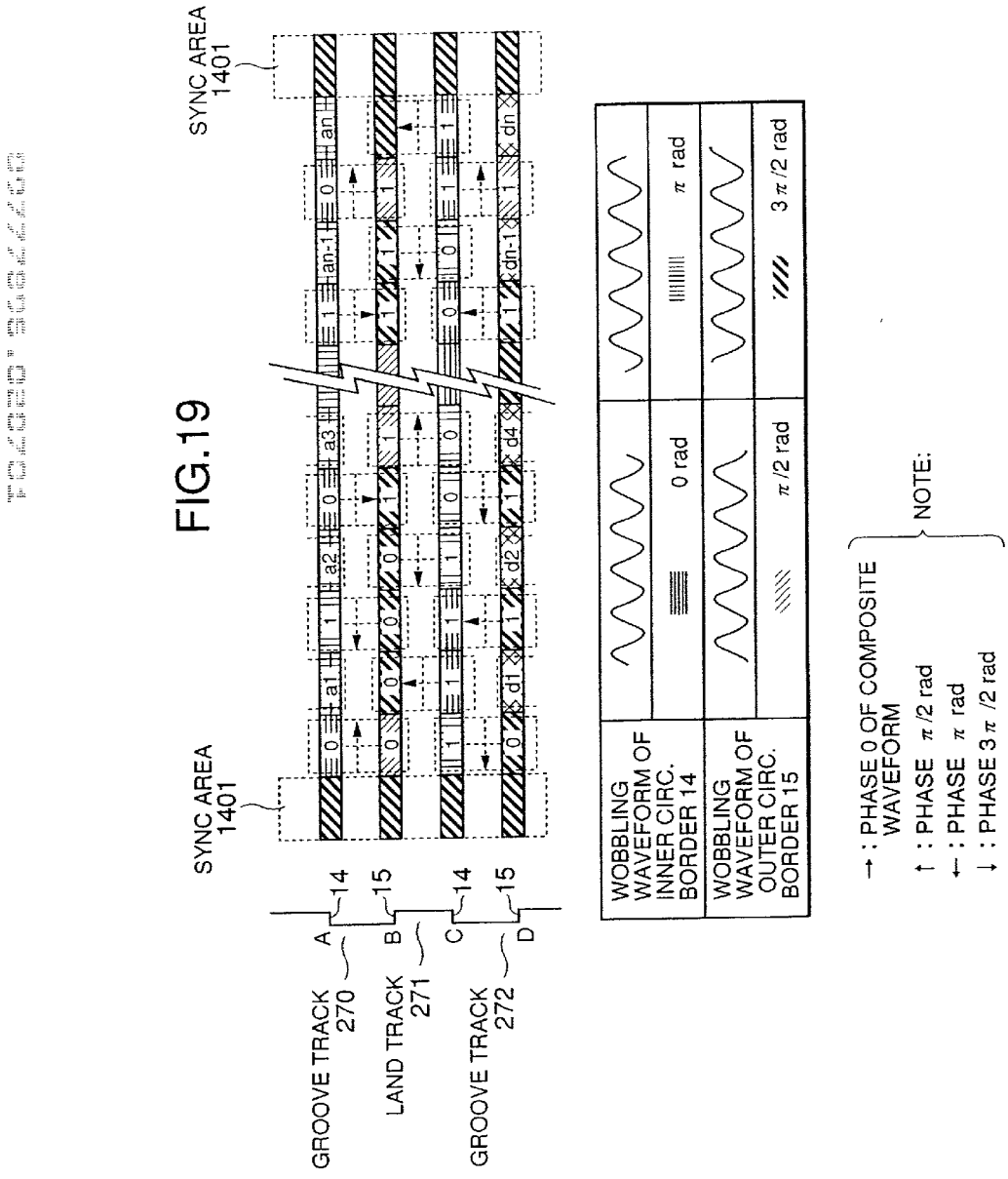

SYNC AREA 1401
SYNC AREA 1401
GROOVE TRACK 270
LAND TRACK 271
GROOVE TRACK 272
A
B
C
D
14
15
14
15
WOBBLING WAVEFORM OF INNER CIRC. BORDER 14
WOBBLING WAVEFORM OF OUTER CIRC. BORDER 15
0 rad
π rad
π /2 rad
3 π /2 rad
NOTE:
→ : PHASE 0 OF COMPOSITE WAVEFORM
↑ : PHASE π /2 rad
← : PHASE π rad
↓ : PHASE 3 π /2 rad

FIG.20

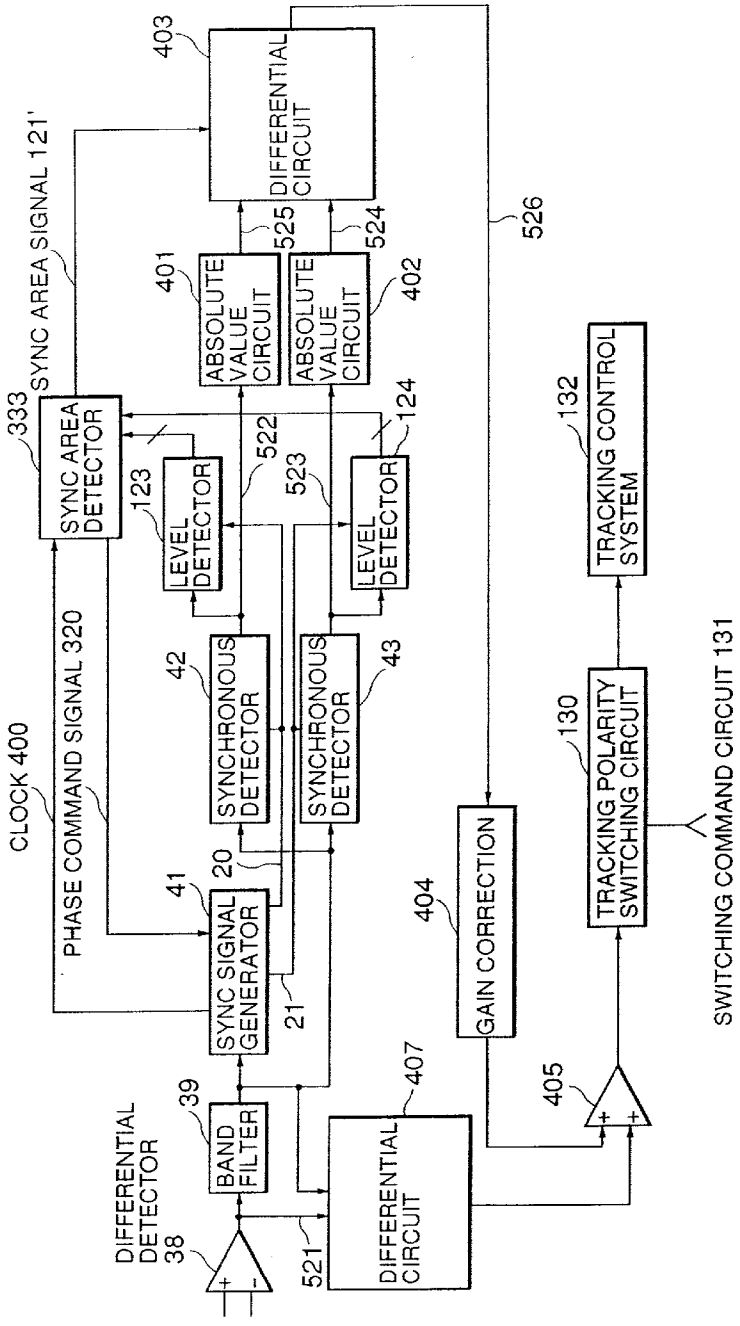

403
DIFFERENTIAL CIRCUIT
526
SYNC AREA SIGNAL 121'
401
ABSOLUTE VALUE CIRCUIT
525
524
ABSOLUTE VALUE CIRCUIT
402
333
SYNC AREA DETECTOR
123
LEVEL DETECTOR
522
523
LEVEL DETECTOR
124
132
TRACKING CONTROL SYSTEM
CLOCK 400
PHASE COMMAND SIGNAL 320
42
SYNCHRONOUS DETECTOR
SYNCHRONOUS DETECTOR
43
130
TRACKING POLARITY SWITCHING CIRCUIT
SWITCHING COMMAND CIRCUIT 131
41
20
SYNC SIGNAL GENERATOR
21
404
GAIN CORRECTION
DIFFERENTIAL DETECTOR 38
39
BAND FILTER
521
DIFFERENTIAL CIRCUIT
407
405

FIG.21

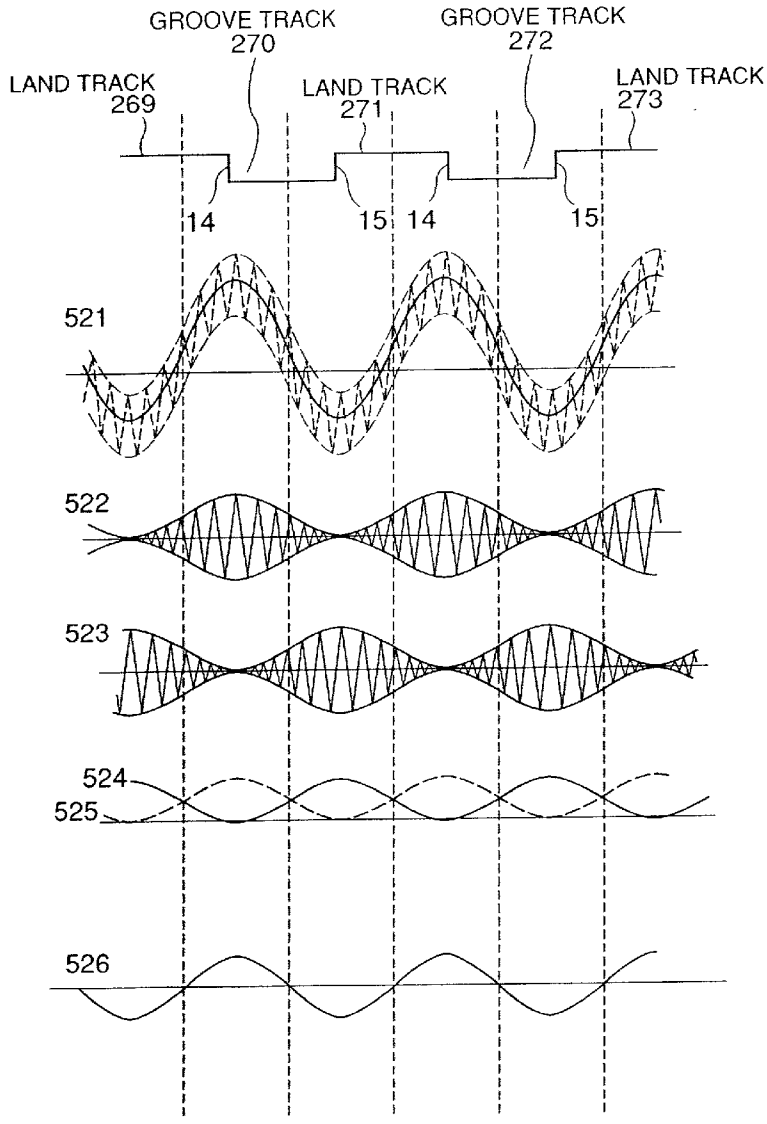

GROOVE TRACK
270
GROOVE TRACK
272
LAND TRACK
269
LAND TRACK
271
LAND TRACK
273
14
15
14
15
521
522
523
524
525
526

FIG.22

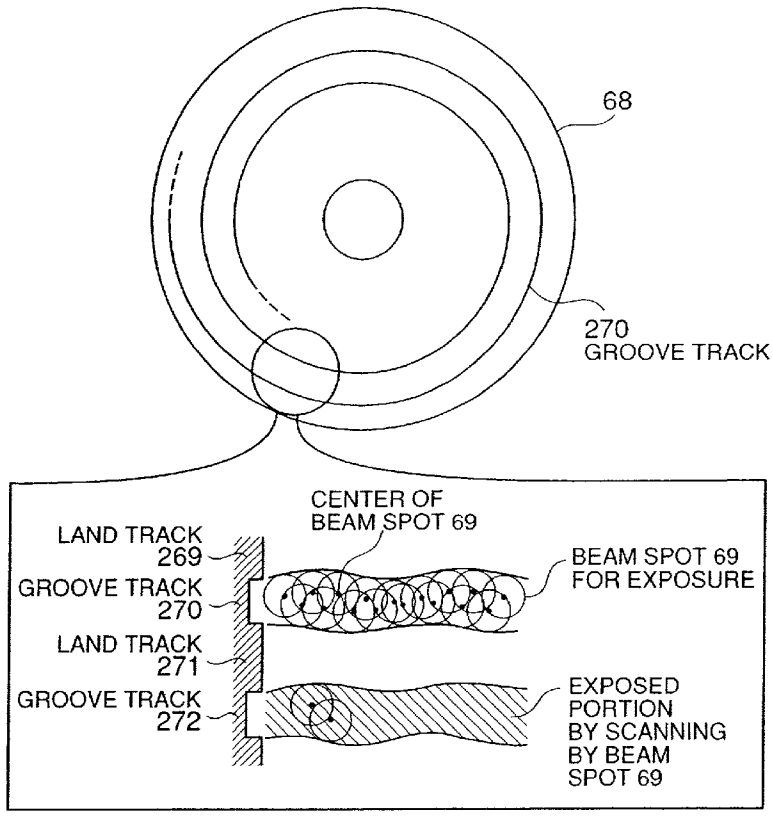

68
270
GROOVE TRACK
CENTER OF
BEAM SPOT 69
LAND TRACK
269
GROOVE TRACK
270
LAND TRACK
271
GROOVE TRACK
272
BEAM SPOT 69
FOR EXPOSURE
EXPOSED
PORTION
BY SCANNING
BY BEAM
SPOT 69

FIG.23

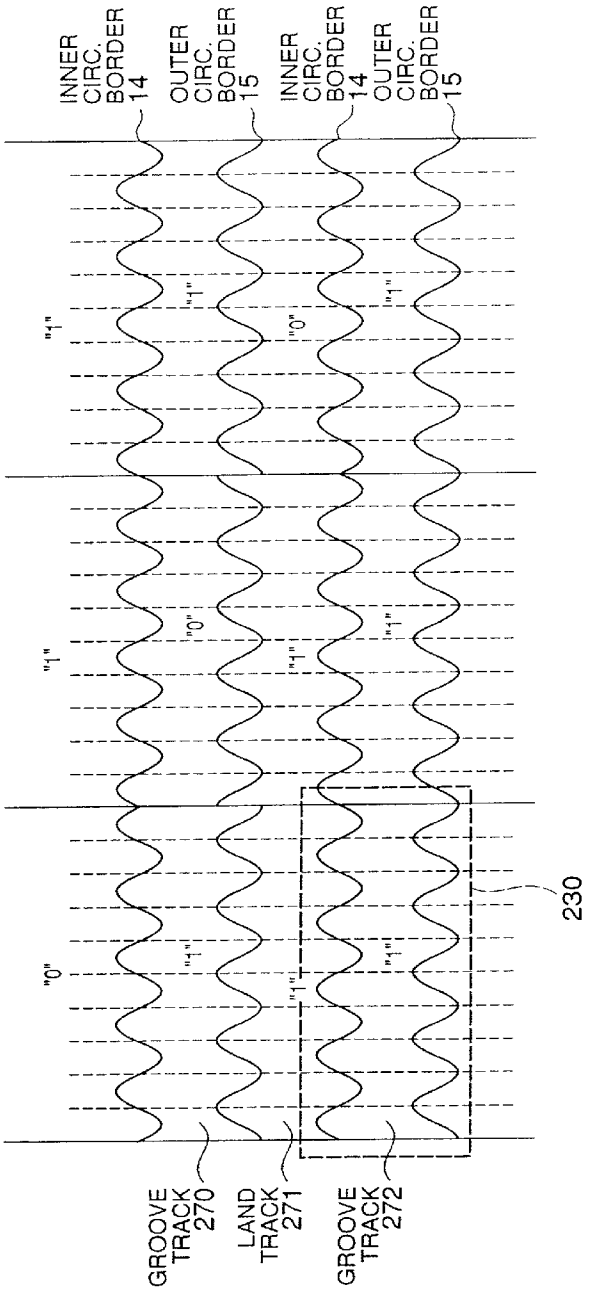

INNER CIRC. BORDER 14
OUTER CIRC. BORDER 15
INNER CIRC. BORDER 14
OUTER CIRC. BORDER 15
"1"
"0"
"1"
"0"
"1"
"1"
"1"
"1"
"1"
"1"
"1"
"1"
"1"
"1"
"1"
"1"
230
GROOVE TRACK 270
LAND TRACK 271
GROOVE TRACK 272

FIG.24A WOBBLING WAVEFORM OF OUTER CIRC. BORDER 15 OF GROOVE TRACK 270

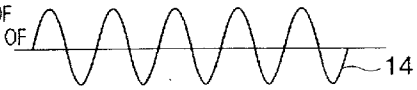


FIG.24B WOBBLING WAVEFORM OF INNER CIRC. BORDER 14 OF TRACK 272

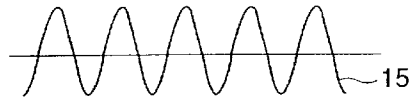


FIG.24C OUTPUT (DETECTION SIGNAL) 231 OF BAND FILTER 39

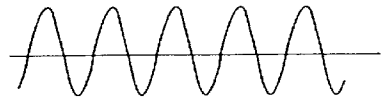


FIG.24D WAVEFORMS OF REFERENCE SIGNAL 420 AND DETECTION SIGNAL 231

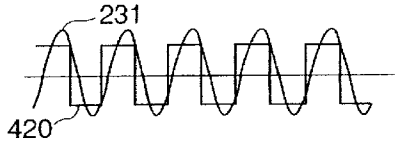


FIG.24E WAVEFORM OF MULTIPLICATION RESULT OF REFERENCE SIGNAL 420 AND DETECTION SIGNAL 231

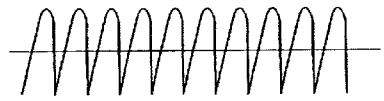


FIG.24F COMPONENTS BY DECOMPOSITION OF WAVEFORM (e)

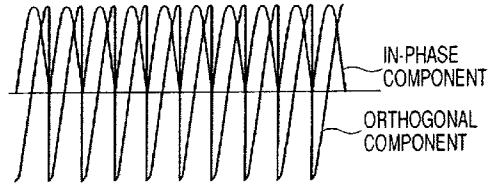


FIG.24G WAVEFORM OF MULTIPLICATION RESULT OF REFERENCE SIGNAL 421 AND DETECTION SIGNAL 231

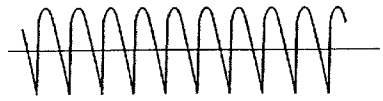


FIG.24H COMPONENTS BY DECOMPOSITION OF WAVEFORM (g)

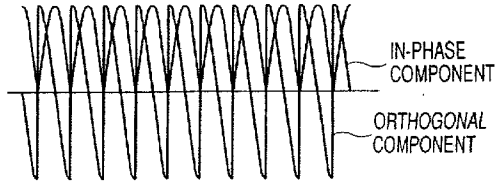


FIG.25

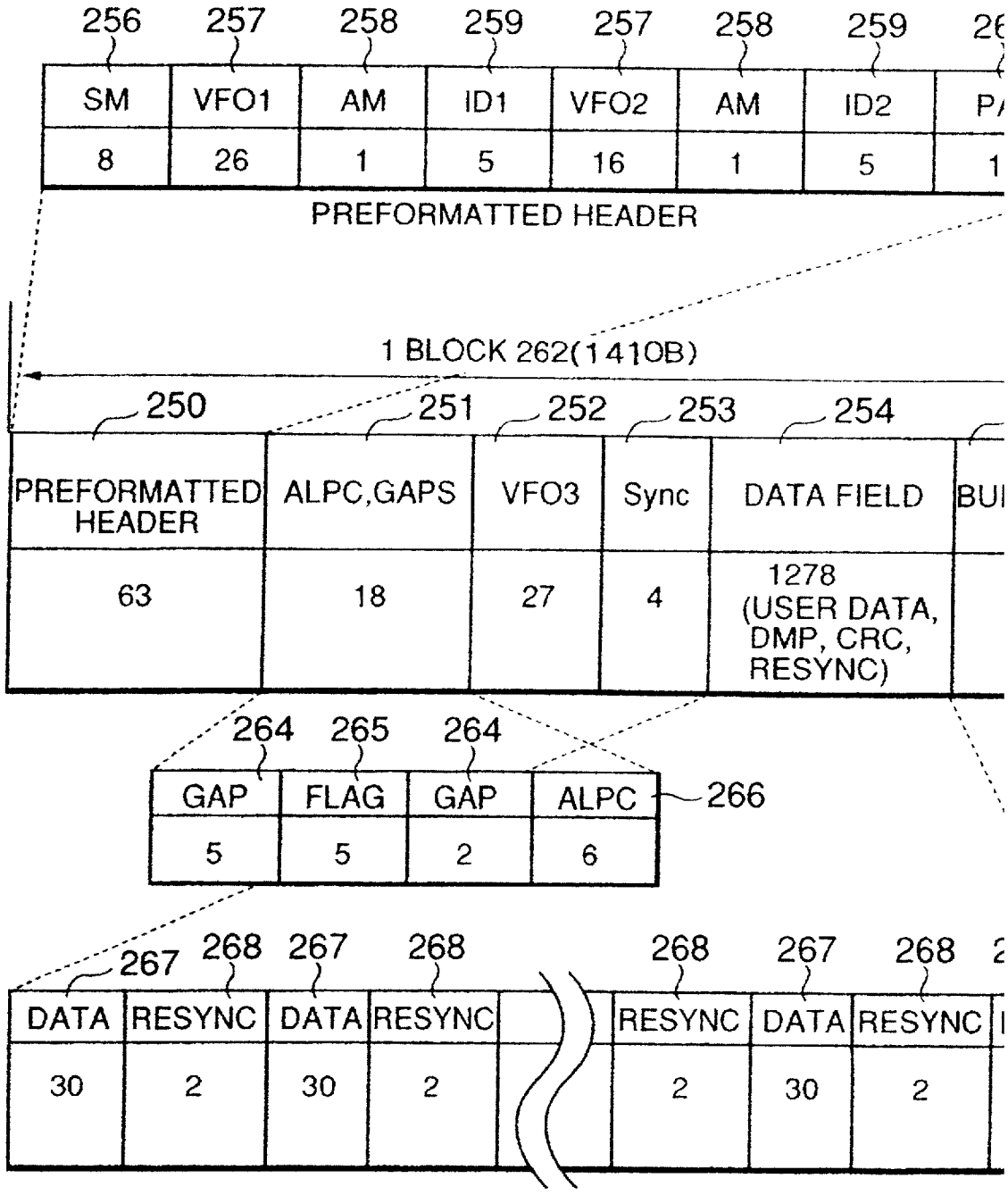

256
257
258
259
257
258
259
SM
VFO1
AM
ID1
VFO2
AM
ID2
8
26
1
5
16
1
5
PREFORMATTED HEADER
1 BLOCK 262(1410B)
250
251
252
253
254
PREFORMATTED HEADER
ALPC,GAPS
VFO3
Sync
DATA FIELD
63
18
27
4
1278 (USER DATA, DMP, CRC, RESYNC)
264
265
264
GAP
FLAG
GAP
ALPC
266
5
5
2
6
267
268
267
268
268
267
268
DATA
RESYNC
DATA
RESYNC
RESYNC
DATA
RESYNC
30
2
30
2
2
30
2

FIG.26

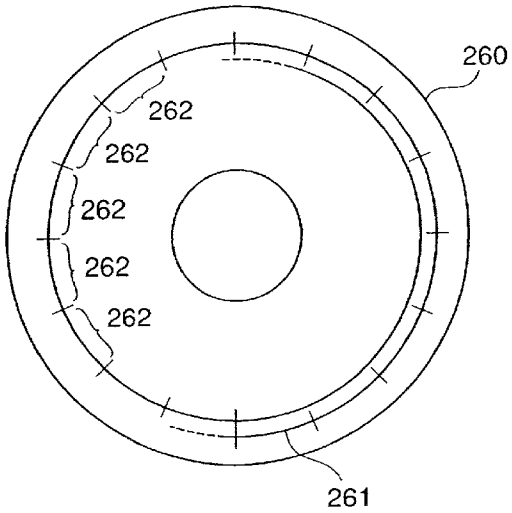


FIG.27

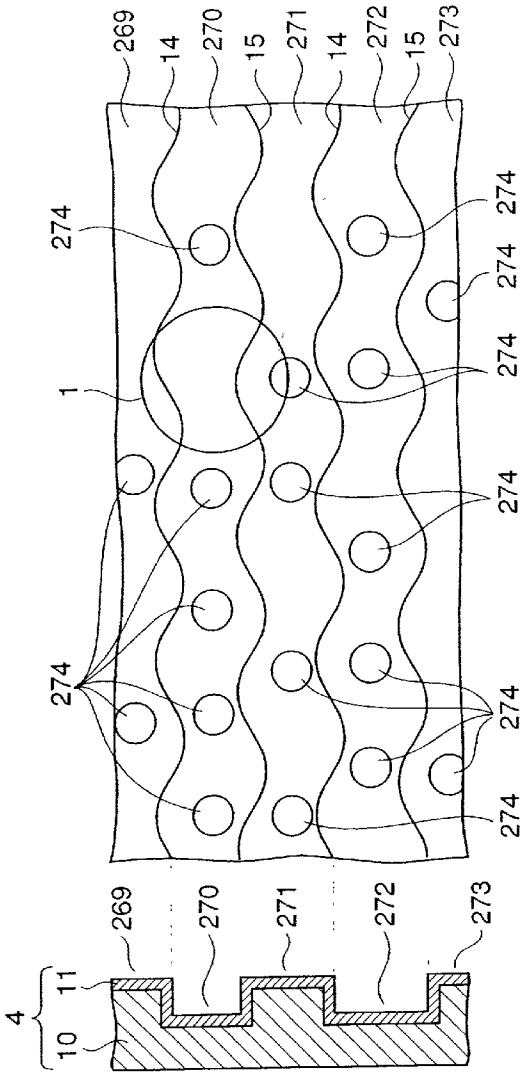


FIG.28

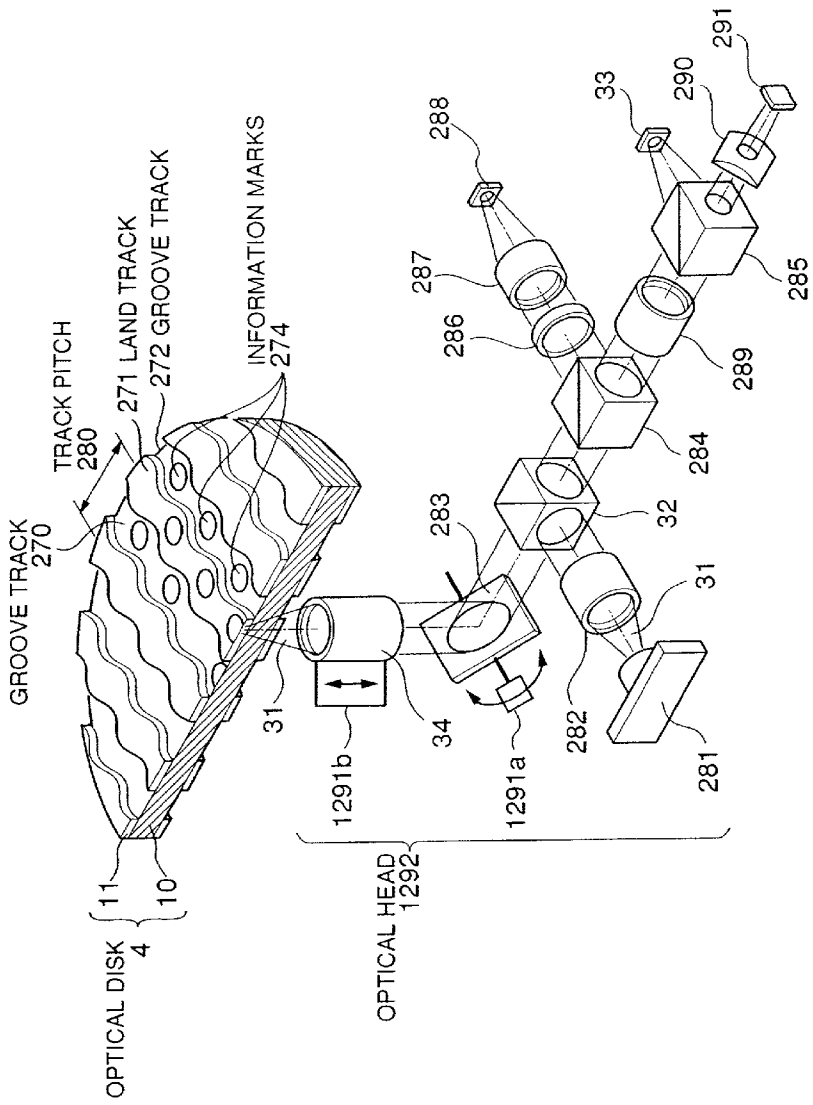
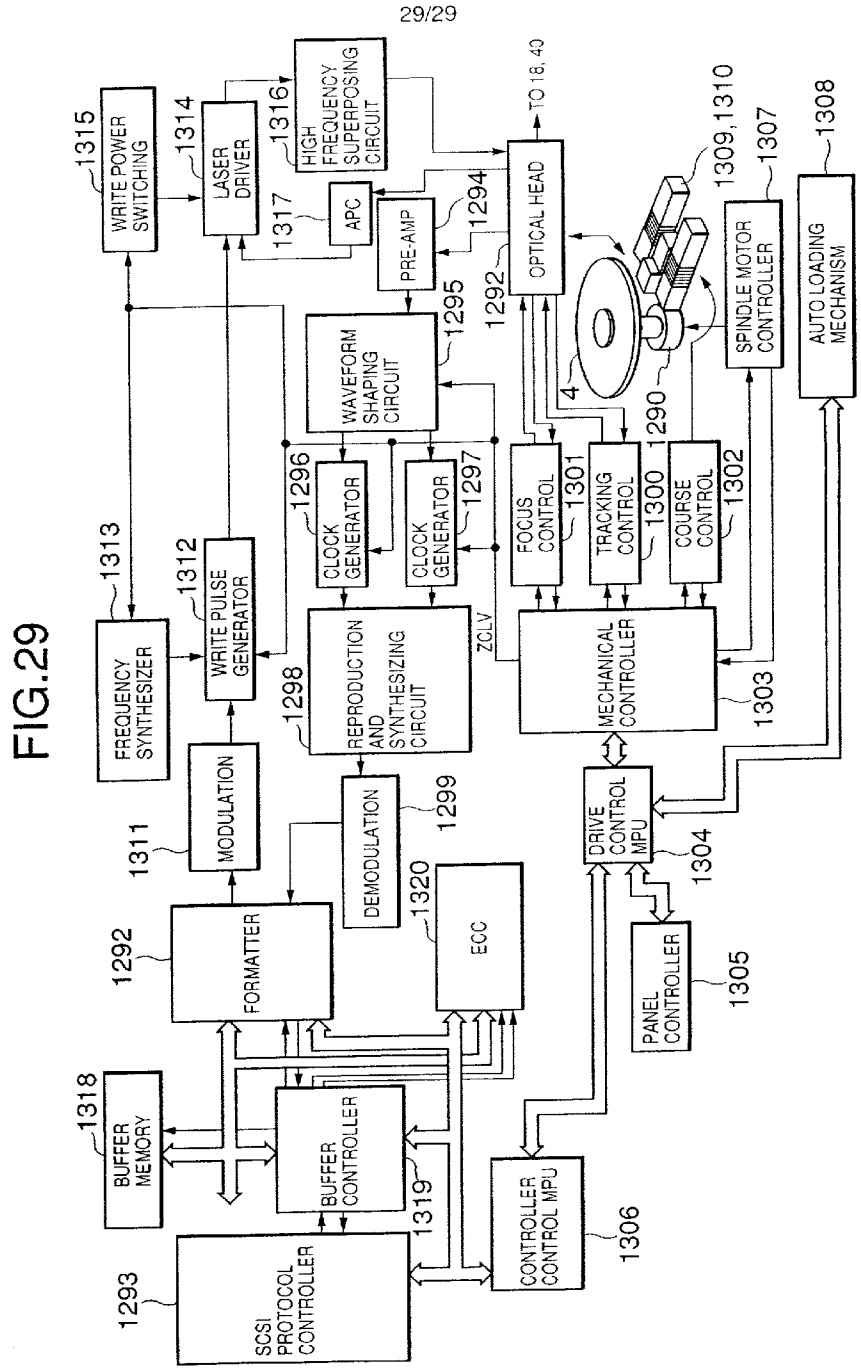

GROOVE TRACK
270
TRACK PITCH
280
271 LAND TRACK
272 GROOVE TRACK
INFORMATION MARKS
274
OPTICAL DISK
4
11
10
OPTICAL HEAD
1292
31
1291b
34
1291a
283
282
281
32
284
286
287
288
289
285
33
290
291

FIG.29


29/29
1315
WRITE POWER SWITCHING
1314
LASER DRIVER
1316
HIGH FREQUENCY SUPERPOSING CIRCUIT
TO 18, 40
1317
APC
1294
PRE-AMP
1292
OPTICAL HEAD
1309,1310
1307
SPINDLE MOTOR CONTROLLER
1308
AUTO LOADING MECHANISM
1295
WAVEFORM SHAPING CIRCUIT
4
290
1313
1312
WRITE PULSE GENERATOR
1296
CLOCK GENERATOR
1297
CLOCK GENERATOR
FOCUS CONTROL
1301
TRACKING CONTROL
1300
COURSE CONTROL
1302
FREQUENCY SYNTHESIZER
1298
REPRODUCTION AND SYNTHESIZING CIRCUIT
ZCLV
MECHANICAL CONTROLLER
1303
1311
MODULATION
1299
DEMODULATION
DRIVE CONTROL MPU
1304
1292
FORMATTER
1320
ECC
PANEL CONTROLLER
1305
1318
BUFFER MEMORY
BUFFER CONTROLLER
1319
1293
SCSI PROTOCOL CONTROLLER
CONTROLLER CONTROL MPU
1306

INFORMATION RECORDING MEDIUM WHICH INDICATES INFORMATION ACCORDING TO THE WOBBLING OF A TRACK AND INFORMATION RECORDING AND REPRODUCING APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to an information recording medium for optically recording or reproducing information, and an information recording and reproducing apparatus for recording or reproducing information on the information recording medium.

[0003] 2. Prior Art

[0004] Optical disks are known, such as compact disks and magnetooptical disks, which optically record information by changes in the reflectance factor or changes in the polarization direction of reflected light, for example. A track **261** is formed in a spiral form on the surface of an optical disk as shown in **FIG. 26**. Along this track on the optical disk, information marks caused by the changes in the reflectance factor or the changes in the polarization direction of the reflected light are formed to record information on a surface of an optical disk **260**.

[0005] A circuit of the track **261** is divided into an integral number of blocks **262**. Each block **262** is divided according to a predetermined disk format into a plurality of areas, on each of which user data and control information for use in recording or reproducing user data is recorded. The blocks are also called sectors.

[0006] As an example of disk formats, the format of a rewritable magnetooptical disk 130 mm in diameter and with a recording capacity of 1.3 GB, standardized by ISO (International Standardization Organization) will be described with reference to **FIG. 25**. In **FIG. 25**, the numbers given below the information areas denote the numbers of bytes of the related items of information.

[0007] The capacity for one block (sector) **262** is 1410 bytes. One block includes at its leading end a preformatted header segment **250** of 63 bytes. In the format of **FIG. 25**, information in the preformatted header **250** is recorded with information marks consisting of prepits formed at the time of manufacture of the optical disk. Information other than that in the preformafted header segment **250** is not preformatted, but is recorded with rewritable information marks.

[0008] The preformatted header segment **250** includes a sector mark segment (SM) **256** to record information to indicate the leading end of this block, a VFO segment **257**, an address mark segment (AM) **258**, an address information segment (ID) **259**, and a PA segment **267**. The address information segment (ID) **259** has recorded therein information to indicate the location of this block **262** on the optical disk **260**, and has a self-clocking function to generate a clock signal from its own information during reproduction. The VFO segment **257** has recorded therein information to designate a specific frequency for pull-in when generating a clock signal for the address information segment **259**. The AM segment **258** has recorded therein information to indicate that there is an address information segment (ID) **259** in the subsequent segment. In each preformatted header, a VFO segment **257**, an AM segment **258**, and an address information segment **259** are arranged twice in succession, and the PA segment **267** is provided to adjust the length of the information marks in the whole area of the preformatted header segment **250**.

[0009] Behind the preformatted header segment **250**, an ALPC-GAPS segment **251** is provided. The ALPC-GAPS segment **251** includes a FLAG segment **265** to show whether or not data has been recorded in a data field **254**, an ALPC segment **266** for recording information to control the power of the laser in recording, and GAP segments **264** as buffer portions placed between the segments.

[0010] Following this, a data field **254** for recording user data is provided. The data field **254** also has a self-clocking function. Before the data field **254**, a VFO segment **252** and a SYNC segment **253** are provided. In the VFO segment **252**, a specific frequency is recorded for pull-in for generating a clock signal in synchronism with data when reproducing data from the data field **254**. In the SYNC segment **253**, information about timing for demodulating information during reproduction is recorded.

[0011] In the data field **254**, RESYNC segments **268** and data segments **267** are alternately provided. The RESYNC segments **268** are provided to re-attain synchronism when loss of synchronism occurs between data and clock during the self-clocking operation. Data **267** consists of information 1040 bytes long, which includes user data of 1024 bytes, a CRC segment to check if user data is read correctly, and a DMP segment to show where error data is when error data occurs due to corruption of data, and ECC codes of 160 bytes added to correct the error data. When recording, two bytes of RESYNC **268** are added for every 30 bytes of data **267**.

[0012] In the rear of the data field **254**, a buffer segment **255** is provided. The clock for recording information has a fixed frequency, and therefore when a variation occurs in the rotating speed of the motor to drive the optical disk or when the center of the track **261** deviates from the center of rotation, the linear velocity of the laser beam for writing on the track **261** varies, but the buffer **255** absorbs this variation.

[0013] In the conventional format standardized by ISO, in one block **262** of 1410 bytes, the user data capacity at which the user can record data is 1024 bytes in the data field **254**. Therefore, the recording efficiency of user data is 1024/1410, namely, 72.6%. The remaining 27.4% is accounted for by the address information segment **259** and control signals of VFO segments **257**, **252**, when reproducing so that the recording efficiency of user data is not so high.

[0014] For this reason, to improve the recording efficiency of user data, JP-A-49-103515 discloses a technique by which the track is made to fluctuate with minute waves, and address information of the track is recorded by the variation of the frequency of the waves. Specifically, the track is formed during the manufacture of the optical disk such that the center of the track is made to fluctuate minutely (by wobbling) in the width direction of the track, the frequency of this wobbling is varied along the longitudinal direction of the track, by which the address information of the track is represented. Since the address information is recorded by the wobbling of the track, it is not necessary to record the address information with the information marks, and accord-

ingly the area for recording user data with the information marks can be increased. Thus, the recording efficiency of user data can be enhanced.

[0015] However, the above technique in JP-A-49-103515 is unable to use a track width smaller than the diameter of the beam spot of the laser beam in reproduction. The reason for this is that if the track width is narrower than the beam spot, the leakage of information from adjacent tracks increases, making it difficult to reproduce information correctly.

[0016] In literature titled International Symposium on Optical Memory 1995 (ISOM '95) TECHNICAL DIGEST Fr-D4 "A NEW DISC FOR LAND/GROOVE RECORDING ON AN MSR DISC, a land/groove track structure was proposed in which, as shown in **FIG. 1**, grooves **3** are formed mutually separated by a fixed space on the surface of the optical disk, and while those grooves **3** are used as tracks, lands **2** between the grooves **3** are also used as tracks. In this structure, since the tracks on the lands **2** are adjacent to the tracks in the grooves **3**, there is a level difference corresponding to the depth h between the adjacent tracks. Therefore, as shown in **FIG. 1**, the diameter of the reproducing beam spot **1** of the laser beam is larger than the track width in the reproduction process, and also when the reproducing beam spot **1** extends over the adjacent tracks on both sides of the track from which data is reproduced, with the phases of reflected beams from the adjacent tracks, a phase difference corresponds to the difference in the height h of the tracks, thus making it possible to prevent the leakage of information from the adjacent tracks. Therefore, the track width can be made smaller than the beam spot diameter, so that the track density can be increased. Also in this literature, as shown in **FIG. 1**, another technique was revealed in which the border between the land **2** and the groove **3** is made to wobble, and address information is recorded with the wobbling frequency. Also, a structure was proposed in which the track width is smaller than the reproducing beam spot, and there are always two borders between the land **2** and the groove **3** within the reproducing beam spot **1**, and therefore address information is represented by wobbling only one of the two borders.

[0017] However, in the structure in that literature as shown in **FIG. 1**, since the part wobbles is the border between the land and the groove, the wobbling motion of the border is shared by the track on the land side and the track on the groove side. Therefore, not only when the center of the reproducing beam spot **1** is located on the land side **2** but also when the beam spot is located on the groove side, the wobbling motion of the same border is detected, and accordingly address information specified by the wobbling frequency is produced. Hence, it is impossible to decide from the address information reproduced by wobbling whether the reproducing beam spot **1** is on the track of the land side **2** or on the track of the groove side **3**. If for some reason the tracking servo fails to keep track and the reproducing beam spot shifts to the adjacent track, this cannot be detected from address information, with the result that there is a possibility that information of the adjacent track is reproduced and recorded by mistake.

SUMMARY OF THE INVENTION

[0018] A first object of the present invention is to provide an information recording medium which stores address information in such a manner that information can be securely recorded or reproduced on the target track, while increasing the track density.

[0019] A second object of the present invention is to provide an information reproducing apparatus for reading information from such an information recording medium in this patent application.

[0020] To accomplish the first object mentioned above, the present invention provides an information recording medium as shown below, that is:

[0021] an information recording medium comprising:

[0022] a substrate;

[0023] a plurality of tracks formed on said substrate, said plurality of tracks including a plurality of groove tracks consisting of a plurality of grooves formed mutually spaced apart by a fixed space, and a plurality of land tracks formed in areas between adjacent groove tracks,

[0024] wherein said grooves are so formed as to represent information by wobbling waveforms of borders wobbling between said groove tracks and said land tracks, wherein the period of the wobbling waveforms of said borders is fixed, and wherein the phases of the wobbling waveforms of said borders are such that the waveforms of the opposing portions of the adjacent borders facing each other across each said track are out of phase with each other by a predetermined phase difference.

[0025] To accomplish the second object mentioned above, the present invention provides an information reproducing apparatus as shown below, that is:

[0026] an information reproducing apparatus comprising:

[0027] a rotating portion to rotate an information recording medium on which information has been recorded by wobbling said borders on both sides of a track with different phases;

[0028] a beam irradiating portion for irradiating a beam spot on said track of said information recording medium;

[0029] a photodetector for receiving a reflected beam of said beam spot from said information recording medium;

[0030] detection means for detecting a composite waveform including waveforms on said borders on both sides from the received beam intensity of said photodetector;

[0031] reference signal generating means for generating two reference signals respectively synchronized with the phases of the wobbling of said borders on both sides; and

[0032] information reproducing means for separately reproducing information of the wobbling waveform of said borders on both sides by mul-

tiplying said composite waveform by said two reference signals respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] **FIG. 1** is an explanatory diagram showing the track structure of the land/groove method of the conventional optical disk;

[0034] **FIG. 2** is an explanatory diagram showing the wobbling waveforms of the borders of tracks **270**, etc. of the optical disk according to a first embodiment of the present invention;

[0035] **FIG. 3** is an explanatory diagram showing the wobbling waveforms of the borders of tracks **270**, etc. of the optical disk according to the first embodiment of the present invention;

[0036] **FIG. 4** is an explanatory diagram showing the principle of reproducing address information from the wobbling waveforms of the borders of the tracks **270**, etc. of the optical disk of the first embodiment of the present invention;

[0037] **FIG. 5A** is an explanatory diagram showing a part of the structure of the recording and reproducing apparatus for recording or reproducing information on the optical disk according to the first embodiment of the present invention;

[0038] **FIG. 5B** is a block diagram showing a detailed structure of a circuit **41** in **FIG. 5A**;

[0039] **FIG. 6** is an explanatory diagram showing the movement of the beam spot on an original disk of an optical disk according to a second embodiment of the present invention when exposing the original disk to light;

[0040] **FIG. 7A** is an explanatory diagram showing an example of the shape of the sync area **12** on the optical disk according to the first embodiment of the present invention;

[0041] **FIG. 7B** is an explanatory diagram showing an example of the shape of the sync area **12** on the optical disk according to the first embodiment of the present invention;

[0042] **FIG. 7C** is an explanatory diagram showing an example of the shape of the sync area **12** on the optical disk according to the first embodiment of the present invention;

[0043] **FIG. 8** is a block diagram of a light exposure system for producing an original disk for the optical disk according to the second embodiment of the present invention;

[0044] **FIG. 9A** is a block diagram showing a detailed structure of the address recording control circuit **73** of the exposure system of **FIG. 8**;

[0045] **FIG. 9B** is a block diagram showing a detailed structure of the deflection signal generator **91** of **FIG. 9A**;

[0046] **FIG. 10** is an explanatory diagram showing waveforms of signals used in the circuits related to **FIGS. 3 and 9**;

[0047] **FIG. 11A** is a block diagram showing a circuit structure for reproducing address information on the optical disk according to a third embodiment of the present invention;

[0048] **FIG. 11B** is a block diagram showing a detailed structure of the synchronous signal generator **41** in **FIG. 11A**;

[0049] **FIG. 12** is a block diagram showing a more detailed circuit structure of a part of the circuit of **FIG. 11A**;

[0050] **FIG. 13** is an explanatory diagram showing waveforms of signals used in the circuit of **FIG. 15A**;

[0051] **FIG. 14A** is an explanatory diagram showing a modulation rule used in the method of recording or reproducing address information on the optical disk according to a fourth embodiment of the present invention;

[0052] **FIG. 14B** is an explanatory diagram for explaining bit combinations on the track borders, used in the recording or reproducing method of **FIG. 14A**;

[0053] **FIG. 15A** is a block diagram showing a circuit structure for reproducing address information on the optical disk in the recording or reproducing method of **FIG. 14**;

[0054] **FIG. 15B** is a block diagram showing a detailed structure of the synchronous signal generator **41** of **FIG. 15A**;

[0055] **FIG. 16** is a block diagram showing a more detailed structure of a part of the circuit of **FIG. 15A**;

[0056] **FIG. 17A** is an explanatory diagram showing a modulation rule used in the method of recording or reproducing address information on the optical disk according to a fifth embodiment of the present invention;

[0057] **FIG. 17B** is an explanatory diagram showing examples of data each bit on the track borders, modulated by the recording or reproducing method of **FIG. 17A**;

[0058] **FIG. 18A** is an explanatory diagram showing an example in which timing data **1800** is included in address information in the fifth embodiment shown in **FIGS. 17A, 17B**;

[0059] **FIG. 18B** is an explanatory diagram showing an example in which timing data **1800** is included in address information in the fifth embodiment shown in **FIGS. 17A, 17B**;

[0060] **FIG. 19** is an explanatory diagram showing an example of address information recorded by the recording or reproducing method of **FIGS. 14A, 14B**;

[0061] **FIG. 20** is a block diagram showing a circuit structure for detecting a track shift signal from a detection signal of address information on the optical disk according to a sixth embodiment of the present invention;

[0062] **FIG. 21** is an explanatory diagram showing waveforms of signals detected by the circuit in **FIG. 20**;

[0063] **FIG. 22** is an explanatory diagram for explaining a relationship between the beam spot and the track shape on the original disk exposed by the exposure system in **FIG. 9A**, and showing on an enlarged scale the grooves formed on the information recording medium (disk) in the present invention;

[0064] **FIG. 23** is an explanatory diagram showing the area scanned by the beam spot when reading one bit on the track **272** of the optical disk in **FIG. 3**;

[0065] **FIGS. 24A** to **24**H are explanatory diagrams showing waveforms of signals when demodulating address information using the circuit of **FIG. 5A**;

[0066] **FIG. 25** is an explanatory diagram showing an example of ISO format of the conventional magnetooptical disk;

[0067] **FIG. 26** is an explanatory diagram showing a relationship between the tracks and the blocks of the conventional optical disk;

[0068] **FIG. 27** is an explanatory diagram showing the information mark and wobbling waveforms of the borders of tracks on the optical disk according to the first embodiment of the present invention;

[0069] **FIG. 28** is an explanatory diagram showing the structure of the optical system of the optical head **1292** of the optical disk recording and reproducing apparatus according to the first embdiment of the present invention; and

[0070] **FIG. 29** is a block diagram showing the structure of the whole optical disk recording and reproducing apparatus according to the first embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

[0071] A first embodiment of the present invention will be described.

[0072] To begin with, an optical disk according to the first embodiment of the present invention will be described.

[0073] As shown in **FIGS. 2 and 27**, an optical disk **4** according to the first embodiment is formed as an optical disk of the land/groove track structure which uses grooves **270**, **272**, etc. and lands **269**, **271**, **273**, etc. as the tracks formed mutually spaced a fixed distance apart in a spiral form with respect to the center of the disk. As shown in **FIG. 2**, one circuit of the track **270**, for example, is divided into an integral number of blocks **11**, and each block **11** is divided into a synchronous (sync) area **12**, a data area **16**, and a CRC area **17**. The blocks **11** may be provided by a generally well-known method. For example, the CAV (Constant Angular Velocity) method may be used in which the number of blocks **11** per circuit of the track is the same from the innermost track to the outermost track of the optical disk **4**, or the M-CAV (Modified CAV) method may be used in which the optical disk **4** is divided into some zones in the radial direction, and the same number of blocks **11** are in each circuit of the tracks in the same zone, and the number of blocks **11** per circuit of the track is greater for outer zones and smaller for inner zones.

[0074] Data in the data area **16**, as shown in **FIG. 27**, is recorded with information marks formed along the track **270**, etc. Address information **13** on the tracks **270**, etc. is recorded by wobbling the borders of the tracks **270**, etc. of the data area **16**. Therefore, data using information marks **274** and the address information **13** using wobbling of the border of the track are recorded simultaneously in the same area.

[0075] Meanwhile, the information marks **274** of the optical disk according to the first embodiment are formed by heating the recording film **11** of the optical disk **4** by condensing the laser beam on the surface of the optical disk as described later, and the information mark differs in light reflectance factor from that of the surrounding area. However, the optical disk **4** according to the present invention is not limited to the type in which the information marks **274** are formed as thermally formed traces having a different reflectance factor from that of the surrounding area. Optical disks may be used which apply other kinds of information marks, such as a mark whose direction of polarization differs from that of the surrounding area, or a mark formed by other methods.

[0076] The sync area **12** is used to generate a reference signal and a clock signal used when reading data in the address information **13** and the data area **16**. The composition of the sync area will be described later. The CRC area **17** has recorded therein information used to check whether user data is read correctly. This information is the same as in the CRC segment used in the conventional format in **FIG. 25**. Information in the CRC area **17** is recorded with the information marks **274**. Note that in the first embodiment, also in the CRC area **17**, like in the sync area **12**, address information **13** is recorded by wobbling the borders **14**, **15** of the tracks **270**, etc.

[0077] In the first embodiment, address information **13** is recorded with different wobbling waveforms, as shown in **FIG. 27**, which are generated by wobbling the borders **14**, **15** of the tracks **270**, etc. of the data area **16** and the CRC area **17** in different wobbling waveforms as shown in **FIG. 27**. Address information **13** indicates where the borders **14**, **15** are located on the optical disk **4**. Therefore, even if there is only one groove track **270**, the wobbling waveform differs between the border **14** at the inner circumference side and the border **15** at the outer circumference side of the groove track **270**.

[0078] Specifically, as shown in **FIG. 3**, the borders **14**, **15** of the tracks **270**, etc. are partitioned, and each subdivision is denoted as one bit, and data "0" or data "1" are represented by the wobbling waveforms. Meanwhile, the number of bits in each block is fixed regardless of whether the block is located at the track on the inner circumference side or at the track on the outer circumference side. The number of periods of the wobbling waveforms should be decided so that a predetermined number of waves are included in each bit area (five periods in **FIG. 3**). The phase of the wobbling waveforms should be decided so that in a given bit, the wobbling waveform of data "0" is identical in oscillation period with the wobbling waveform of data "1", but those waveforms are 180 degrees out of phase with each other (a phase difference of 180 degrees). However, the phase of the wobbling waveform on the border **14** on the inner circumference side of the groove track **270** or **272** should invariably be set to lag or lead by on that of the wobbling waveform on the border **15** on the opposite, outer circumference side of the track, by 90 degrees, in other words, those waveforms should have an orthogonal relationship. As the phases are set as described above, even seen from the land track **271**, the wobbling waveform on the border **15** on the inner circumference side lags or leads on that of the wobbling waveform on the border **14** on the opposite, outer circumference side by 90 degrees in phase, in other words, those waveforms have an orthogonal relationship. Because the adjacent bits represent different pieces of data because the items of the wobbling waveforms are set for each bit, when the adjacent

bits represent different data, that is, when the adjacent bits represent "1""0" or "0""1", the wobbling waveform is discontinuous on the border over the two bits.

[0079] **FIG. 3** shows the wobbling waveforms of the borders **14**, **15** of the tracks **270**, etc. In **FIG. 3**, the tracks **270**, **271**, and **272** are drawn in straight lines for the sake of convenience, and they are concentric on an actual optical disk **4**. As shown in **FIG. 3**, on the groove track **270**, data "011" is represented on the border **14** on the inner circumference side, and data "101" is represented on the border **15** on the outer circumference side by wobbling waveforms. Data "110" is represented by wobbling of the border on the inner circumference side of the groove track **272**, while data "111" is represented on the outer circumference side.

[0080] As has been described, by recording different items of address information **13** on the track, which indicate the respective locations of the borders **14**, **15** on the optical disk **4**, it is therefore possible to read address information **13** of the borders **14**, **15** on both sides of the track when reproducing the information marks **274**. For example, by moving the reproducing beam spot **1** along the groove track **270** to read information on the groove track **270**, it is possible to read address information "011" from the border **14** on the inner circumference side and "101" from the border **15** on the outer circumference side simultaneously with data by the information marks **274**. By a combination of "011" and "101", it can be confirmed that the track irradiated by the reproducing beam spot **1** is the groove track **270**. If the tracking servo should fail to keep track and it becomes obscure which track the reproducing beam spot **1** is irradiating, but so long as address information **13** which is detected is a combination of "101" and "110", it can be known that the reproducing beam spot **1** is shifted to the land track side **271**. Thus, it is easy to decide which the beam spot **1** is irradiating, the groove track, such as **270** or the land track, such as **271**.

[0081] Meanwhile, the wobbling waveforms are formed by forming grooves, **270**, **272**, and so on, such that the borders of the grooves assume wobbling waveforms. This will be described later. Though **FIG. 3** shows that there are waveforms of five periods in one bit, the number of periods is not limited to five, but may be any number.

[0082] For an actual structure of the sync area **12**, any of the structures of **FIGS. 7A, 7B** and 7C may be used. **FIG. 7A** shows a structure having optically identifiable marks **51**, **52**, **53** and **54**. In this case, in the sync area **12**, grooves, such as tracks **270**, **272**, are not formed in the sync area **12**, and the sync area **12** is flush with the surface of land tracks, such as **271**. The marks, such as **51**, are pits formed on the surface, and are formed simultaneously in the process of forming grooves for groove tracks **270**, **272** during the manufacture of the optical disk **4**. Those marks **51**, **52**, **53** and **54** are arranged close to the borders **14**, **15** of the tracks, **270** etc., and are shared by the adjacent tracks. For example, the sync area **12** of the groove track **270** has the marks **52**, **53**, while the sync area **12** of the groove track **272** has the marks **53**, **54**. The space in the track-lengthwise direction of two marks, such as **51**, **52** etc. in the sync area **12** is formed so as to be synchronous with the wobbling waveforms of the address signal. Therefore, by dividing the frequency of a signal obtained from the space between the marks, such as **51**, of the sync area **12**, a reference signal synchronous with the wobbling waveform can be generated. In addition, two marks, such as **51**, **52** are arranged not in the center of the track **270** etc. but in the vicinity of the border **14**, **15** so that those marks wobble to the left and right with respect to the center of the track **270** etc. Therefore, by using a well-known sampling-servo method in order to find a level difference between the marks **51** and **52**, a shift of the reproducing beam spot **1** from the track center can be known. Thus, according to a signal from the sync area **12**, it is possible to correct the shift of address information **13** from the track.

[0083] The sync areas **12** of structures in **FIGS. 7B and C** have groove tracks **270**, **272** formed therein to represent sync signals by the wobbling waveforms at the borders **14**, **15** of the tracks, such as **270**. In the sync area **12** in **FIG. 7**B, the border **14** on the inner circumference side and the border **15** on the outer circumference side of the groove track **270** etc. have wobbling waveforms of the same period and phase. The wobbling waveforms in the sync area **12** are made to have a larger amplitude than that of address information **13** so that the wobbling waveforms in the sync area **12** can be detected easily. In this structure, regardless of where the reproducing beam spot **1** is irradiating, the groove tracks **270**, **272**, or the land track **271**, or the intermediate regions, the sync area **12** can be detected by detecting a region having the wobbling waveforms of the sync area. In the structure in **FIG. 7**B, the sync area **12** has a length for five periods equal to the length of other areas. In the structure in **FIG. 7**C, in order to increase the proportion of the data area **13** in the block **11** by decreasing the length of the sync area **12**, the wobbling waveforms of the sync area **12** are set as one period, but instead of this, have a larger amplitude than in **FIG. 7B**.

[0084] Referring to **FIG. 4**, description will be made of the principle of the method of detecting address information **13** represented by the wobbling waveform from the optical disk according to the first embodiment of the present invention. To make it easy to understand the principle of the method of detecting address information according to the present invention, description will be made with reference to the waveforms in **FIG. 4** which schematically represents signal waveforms. As shown in **FIG. 5**A, the reproducing beam spot is moved along a track, specifically, the land track **271**, for example, and a reflected luminous flux is detected by a two-piece detector **33**, whose light receiving face is split in half. As a result, a detection signal of the two-piece detector **33**, in other words, an output difference signal obtained from the left and right light receiving faces of the detector **33** is a composite waveform resulting from algebraically adding together a signal **415** or **416** representing the wobbling waveform of the border **15** on the inner circumference side of the land track **271** and a signal **417** or **418** representing the wobbling waveform of the border **14** on the outer circumference side of the track **271**. The signals **415** and **416** respectively correspond to the waveforms representing "0" and "1" on the border **15** on the inner circumference side. Therefore, the signals **415** and **416** are 180 degrees out of phase with each other. Similarly, signals **417** and **418** correspond to the waveforms representing "0" and "1" of the border **14** on the outer circumference side, so that the signals **417** and **418** are 180 degrees out of phase with each other. Because the wobbling waveform of the border **15** on the inner circumference side is 90 degrees out of phase with the wobbling waveform of the border **14** on the outer circumference side, in other words, because the

two waveforms are formed so as to be orthogonal to each other, the signals **417**, **418** are orthogonal to the signals **415**, **416**.

[**0085**] According to the present invention, synchronous detection is performed by generating a reference signal **420** for use in detecting signals **415**, **416** of wobbling waveforms on the border on the inner circumference side of the track, and a reference signal **421** for use in detecting signals **417**, **418** of wobbling waveforms on the border on the outer circumference side of the track. The reference signals **420**, **421** are orthogonal to each other. By using a fact that the signals **417**, **418** on the outer circumference side are orthogonal to the signals **415**, **416** of wobbling waveforms on the border on inner circumference side, the signals **415**, **416** of wobbling waveforms on the border on the inner circumference side and the signals **417**, **418** of wobbling waveforms on the border on the outer circumference side are separated and detected from a detection signal in the form of a composite waveform. The reference signals **420**, **421** are generated by a method, which will be described later, using signals from the sync area **12** on the optical disk **4**.

[**0086**] To begin with, a detection signal and two reference signals **420**, **421** are multiplied respectively and integrated with respect to time. The detection signal is multiplied by the reference signal **420** for the inner circumference side, and integrated with respect to time. For the sake of clarity, the signals **415**, **416** from the inner circumference side and the signals **417**, **418** from the outer circumference side are respectively multiplied by the reference signal **420**, and integrated with respect to time. When the reference signal **420** is multiplied by the signals **417**, **418** on the outer circumference side, since they are orthogonal to each other, the multiplication results are as indicated by the signals **424**, **425**, and they are reduced to zero by time integration. More specifically, the signals of the wobbling waveform on the outer circumference side of the track are reduced to zero by this process and disappear. On the other hand, when this reference signal is multiplied by signals **415**, **416** on the inner circumference side, since they are synchronized, the multiplication results are as indicated by signals **422**, **423**. When those signals are integrated, bit "0" becomes a signal of negative level and bit "1" becomes a signal of positive level, so that the phases of the wobbling waveforms on the border **14** can be converted to amplitude levels. As described, the detection signal is subjected to synchronous detection using the reference signal **420**, and only the address information **13** in the wobbling waveform on the border on inner circumference side can be obtained as amplitude levels.

[**0087**] Similarly, the detection signal and the reference signal **421** for the outer circumference side are multiplied together, and integrated with respect to time. When the reference signal **421** is multiplied by the signals **417**, **418** on the borders on the outer circumference side, since these signals are orthogonal to each other, the multiplication results are as indicated by the signals **426**, **427**, and when they are integrated with respect to time, they are reduced to zero. In other words, the signals of the wobbling waveform on the inner circumference side of the track become zero and become negligible. On the other hand, when the reference signal **421** is multiplied by the wobbling waveforms **415**, **416**, since these signals are synchronized, the multiplication results become signals **428**, **429**, and when integrated, bit "0" becomes a signal of negative level, and bit "1" becomes a signal of positive level, the phases of the wobbling waveforms on the border can be converted into amplitude levels. As has been described, when the detection signal is subjected to synchronous detection by the reference signal **421**, only the address information **13** in the wobbling waveform on the outer circumference side can be detected as amplitude levels.

[**0088**] By those processes, address information **13** recorded on the borders on the inner circumference side and outer circumference side of the track can be separated and obtained. By comparing the respective items of address information, it can be accurately known whether the reproducing beam spot is located on the groove track **270** or **272**, or on the land track **271**, or on which track, **270**, **272**, or **271**, the beam spot is located.

[**0089**] The configuration of the whole recording and reproducing apparatus for reading address information according to the above-mentioned principle will now be described with reference to **FIGS. 5A, 5B, 28**, and **29**.

[**0090**] The recording and reproducing apparatus according to the first embodiment includes an optical disk **4**, an optical head **1292**, an electric circuit system, and a drive system as shown in **FIG. 29**. The optical head **1292** incorporates an optical system for recording and reproducing data from the optical disk **4** (**FIG. 28**). The drive system includes a spindle motor **1290** for rotating the optical head **1292**, a tracking actuator **1291***a* for driving the laser beam **31** in the width direction of the track, and a focus actuator **1291***b* for driving the laser beam **31** in the optical axis direction. The electric circuit system includes a signal processing system for supplying a signal to be recorded on the optical disk **4** to the optical head **1292**, and processing a signal read out from the optical disk **4**, and a control system for controlling the drive system.

[**0091**] The optical disk **4** according to the first embodiment is 120 mm in diameter, and has two, front and rear substrates glued together. A recording film **11** is placed between the two substrates. The substrate **10** on the side on which a light beam from the optical head **1292** is irradiated is made of plastic 0.6 mm in thickness. Information is recorded and reproduced by condensing and passing the laser beam **31** through the substrate **10**. On the surface of the recording film **11** on the substrate **10**, there are provided groove tracks such as **270**, **274**, and land tracks such as **271** formed between the groove tracks such as **270**, **272** as mentioned above. A track pitch **280** is defined as the space between the groove tracks, such as **270**, and is 1.2 um in this first embodiment. The recording film **11** is a film chiefly composed of Ge and is about 300 Angstrom in thickness, and formed on the substrate **10** by vapor deposition. The information mark **274** is an area having a different reflectance factor from that of the surrounding area and formed by irradiating a laser beam **31** from the optical head **1292** onto the recording film **11** through the substrate **10**, to thereby cause a thermal change on the recording film **11**.

[**0092**] The optical head **1292**, as shown in **FIG. 28**, includes a semiconductor laser **281** for emitting a laser beam **31**, and a collimator lens **282**, a galvano mirror **283**, and objective lens arranged in succession along the optical path of the laser beam **31** emitted from the semiconductor laser **281**. Arranged between the collimator lens **282** and the

galvano mirror **283** is a beam splitter **32** for separating the beam (of the laser beam **31**) reflected by the optical disk **4** from the laser beam **31**. The reflected beam separated by the beam splitter **32** is divided by another beam splitter **284** into two luminous fluxes. An analyzer **286**, a collective lens **287**, and a photodetector **288** are arranged on the optical path of one luminous flux, and those elements constitute an information mark detecting optical system for detecting the information marks **274**. The other luminous flux, after being condensed by the collective lens **289**, is further separated by another beam splitter **285** into two luminous fluxes, and on the optical path of one luminous flux, there are arranged a cylindrical lens **290** and a four-piece divided detector **291**, which constitute a focus error signal detecting optical system for detecting a focus error signal representing an extent of shift of the optical disk **4** from the focus of the objective lens **34**. On the optical path of the other luminous flux separated by the beam splitter **285**, the two-piece photodetector **33** is arranged. The detection signal of the two-piece photodetector **33** is used for detection of address information **13** represented by the wobbling of the borders, such as **14**, of the tracks, such as **270**, and also for detection of a track shift signal.

[**0093**] The output power of the semiconductor laser **281** is about 35 to 40 mW when recording the information marks **274** on the optical disk **4**, or about 3 to 5 mW when reproducing the information marks **274** and the address information **13** from the optical disk **4**.

[**0094**] Description will now be made of the operation of each element when reproducing information from the optical disk **4**. The laser beam **31** emitted from the semiconductor laser **271** is collimated by the collimator lens **282**, and then deflected by the beam splitter **32**, and further deflected by the galvano mirror **283**, and condensed by the objective lens **34** to form a reproducing beam spot **1** on the optical disk **4** as shown in **FIGS. 5A and 28**. **FIG. 5A** shows the shape of the recording film **11** when the optical disk is seen from the side of the substrate **10**, and therefore in **FIG. 5**A, the shapes of the grooves and lands of the tracks, such as **270**, are inverted.

[**0095**] The reflected beam of the laser beam **31** from the optical disk **4** again passes through the objective lens **34**, is reflected by the galvano mirror **283**, passes through the beam splitter **32**, and is separated by the beam splitter **284** into two fluxes. One luminous flux is condensed as it passes through the analyzer **286** and the collective lens **287**, and detected by the photodetector **288**. Output of the photodetector **288** is processed by an electric circuit to be described later, so that signals from the information marks **274** are detected. The other luminous flux separated by the beam splitter **284**, after being condensed by the collective lens **289**, is separated by a beam splitter **285**, and one luminous flux is condensed by the cylindrical lens **290**, and detected by the four-piece photodetector **33**. Output of the photodetector **33** is processed by a well-known astigmatism process to obtain a focus error signal.

[**0096**] The other luminous flux separated by the beam splitter **285** is detected by the left and right light receiving faces of the two-piece photodetector **33**. The parting plane of the photodetector **33** is parallel with the longitudinal direction of the groove track **270**. The signals of the left and right receiving faces of the two-piece photodetector are input into a differential detector **38** and an adder **40**. Output of the differential detector **38**, like a signal **521** in **FIG. 21**, is in a shape formed by superimposition of signals from wobbling of the borders **14**, **15** of the tracks **270**, etc. on the track shift signal. Therefore, a band filter **39** is used to pass only the oscillation frequency of the signals from wobbling of the borders **14**, **15** of the tracks **270**, etc. for input into synchronous detectors **42**, **43**. On the other hand, output of the adder **40** is input to a synchronous signal generator **41** to generate reference signals **420**, **421** in **FIG. 4**.

[**0097**] More specifically, the synchronous signal generator **41** generates reference signals **421**, **422** using the circuit in **FIG. 5B** according to a signal from the sync area **12** of the optical disk **4**. For example, if the sync area **12** has prepit marks of a mark string of **51**, **52** in **FIG. 7A, a** prepit mark detecting circuit **46**, shown in **FIG. 5**B, of the synchronous signal generator **41** detects a signal corresponding to the mark string of **51**, **52** from output of the adder **40**. This sync areas **12**, as described before, are provided at fixed intervals on the tracks, such as **270**, so that by using this signal to start the phased locked loop (PLL) **47**, clock pulses with a frequency of a specified multiple of the repeating frequency of this signal are generated. The sync area **12** is synchronous with the wobbling frequency of the borders **14**, **15** of the tracks **270**, etc. Therefore, by starting frequency division by a frequency divider **48** in step with clock pulses generated by a PLL **47**, the frequency divider **48** generates reference signals **420**, **421** which are equal both in wobbling frequency and phase of the wobbling to the borders **14**, **15** of the tracks **270**, etc.

[**0098**] For example, in the optical disk **4** on which the borders **14**, **15** of the groove tracks **272**, etc. wobble in the wobbling waveforms shown in **FIG. 23**, the output signal (hereafter referred to as a detection signal **231**) of the band filter **39** when the reproducing beam spot **1** is scanning the area **230** enclosed by a dotted line along the groove track **272** is shown in **FIG. 24C**. The detection signal **231** output from the band filter **39** has a waveform (**FIG. 24C**) which is an algebraically added waveform of the wobbling waveform (**FIG. 24A**) of the inner circumference border **14** of the groove track **272** and the wobbling waveform (**FIG. 24B**) of the outer circumference border **15** of the groove track **272**. When this detection signal **231** is multiplied by a reference signal **420** from the synchronous signal generator **41** by means of the synchronous detector **42** (**FIG. 24D**), a waveform shown in **FIG. 24E** can be obtained. The waveform in **FIG. 24E** can be divided into an in-phase component (corresponding to the inner circumference side wobbling waveform of the groove **2**) of the reference signal **420** and a component orthogonal to the reference signal **420** (this component corresponds to the wobbling waveform of the border **15** on the outer circumference side of the groove track **272**) (**FIG. 24F**). Therefore, when the waveform of **FIG. 24E** is integrated by the synchronous detector **42**, the orthogonal component is reduced to zero, with the result that only the in-phase component appears, and in the case of **FIG. 24**F, the output level is on the positive side, and it is found that the signal is bit "1". Therefore, by comparing the level of output of the synchronous detector **42** with a predetermined level using a comparator **44** and deciding whether the output level is positive or negative, it is possible to detect whether wobbling data of the inner circumference side border **14** of the groove track **272** is "0" or "1", and thus demodulate the address information **13**.

[0099] Similarly, if synchronous detection is performed on the detection signal **231** with the synchronous detector **43** by using a reference signal **421** which is 90 degrees out of phase with a reference signal **420**, a resulting waveform is as shown in **FIG. 24**G, and if this waveform is analyzed, a waveform as shown in **FIG. 24H** is obtained. If this waveform is integrated by the synchronous detector **43**, the orthogonal component is reduced to zero, and only the in-phase component appears. In the case of the waveform of **FIG. 24**H, the output level is positive, and a signal of bit "1" is detected. Therefore, by deciding whether the output level is positive or negative by comparing the output level of the synchronous detector **43** with a preset level by the comparator **45**, it is possible to detect whether the wobbling data of the outer circumference side border **15** of the groove track **272** is "0" or "1", and thus demodulate the address information **13**. The demodulated address information is sent to the formatter **1292 (FIG. 29)** of the electric circuit system of the recording and reproducing apparatus, and is also sent through an SCSI interface **1293** to a CPU (not shown) connected with the recording and reproducing apparatus.

[0100] Output of the photodetector **288** is amplified by a preamplifier **1294** in **FIG. 29**, and after passing through a waveform shaping circuit **1295**, is input to reproduction clock generators **1296**, **1297** to generate a reproduction clock signal. Data discrimination is performed by a reproduction and synthesizing circuit **1298** using the reproduction clock and output of the waveform generator circuit **1295**, and data consisting of the information marks **274** is demodulated by a demodulator circuit **1299**. The demodulated data of information marks **274** is sent to the formatter **1292 (FIG. 29)** of the electric circuit system of the recording and reproducing apparatus, and is also sent through the SCSI interface **1293** to a CPU (not shown) connected with the recording and reproducing apparatus.

[0101] When information is recorded on the optical disk **4**, the formatter **1292** receives data to record through the SCSI interface from the host unit, data is converted by the modulator circuit **1311** into a modulated signal, and input into a write pulse generator circuit **1312**. The write pulse generator circuit **1312** generates recording pulses corresponding to the position to record data on the track of the optical disk **4** in accordance with a recording clock generated by a frequency synthesizer **1313**, and sends the pulses to a laser driver **1314**. A write power switching circuit **1315** sets laser power for recording at the laser driver **1314**. The laser driver **1314** generates a pulse waveform to drive the semiconductor laser **281** from the set laser power and recording pulses. A high frequency superimposing circuit **1316** outputs a waveform, formed by superimposing a high frequency on the pulse waveform, to the semiconductor laser **281** to drive the laser **281**. Output of the semiconductor laser **281** is monitored by an auto power controller **1317**, and fed back to the laser driver **1314**. Thus, a laser beam **31** of high energy is irradiated to a desired track, so that the recording film **11** is heated and information marks **274** are formed.

[0102] Description will now be made of control of the drive system while data is being reproduced or recorded on the optical disk **4**.

[0103] Output of the differential detector **38** is input to a circuit (not shown) to detect a track shift signal of the spot of the laser beam **31** by a well-known method, such as the push-pull method, and thereby detect a track shift signal. Output of the four-piece detector **291** is input to a circuit (not shown) to detect a focus error signal of the spof of the laser beam **31** by a method, such as the astigmatism method, and thereby detect a focus error signal.

[0104] A track shift signal is input to a tracking control circuit **1300**, and a control signal to drive a tracking actuator **1291***a* is generated. According to this signal, the tracking actuator **1291** a moves the galvano mirror **283** to position the sopt of the laser beam **31** along a desired track, such as **270**. The focus error signal is input to the focus control circuit **1301** to generate a control signal to drive the focus actuator **1291***b*. In response to this control signal, the focus actuator **1291***b* drives the objective lens **34** in the optical axis direction, and thereby performs focus servo to maintain focus of the objective lens **34** on the surface of the optical disk **4**.

[0105] Access of the spot of the laser beam **31** onto the optical disk **4** is performed by a fine actuator **1309** for a minute range, but when the beam spot is moved over a long range, the course actuator **1310** is used to move the whole optical head. During tracking, the fine actuator **1309** and the course actuator **1310** move in an interlocked motion with each other. Therefore, even if the center of the optical disk **4** deviates from the center of the spindle motor **1290** which rotates the optical disk **4**, the spot of the laser beam **31** can be made to stably follow the tracks **270**, etc.

[0106] When giving the spot of the laser beam **31** long-range access to a desired track, the optical head **1292** is moved by the course actuator **1310** over a long distance to the vicinity of the track. Then, the beam spot is moved by an interlocked motion of the fine actuator **1309** and the course actuator **1310** so that the beam spot is positioned at the target track. The series of motions are performed by the actuators **1309**, **1310** under control of a mechanical controller **1303** by exchange of information among the mechanical controller **1303**, the tracking control circuit **1300**, and the course control circuit **1302**. The spindle motor **1290** is driven by the spindle motor control circuit **1307** so that the optical disk **4** rotates stably at a specified number of revolutions.

[0107] The whole drive system is controlled by a drive control MPU **1304**, and signals are exchanged among an auto loading mechanism **1308**, the mechanical controller **1303**, and a controller control MPU **1306** etc. The optical disk **4** is attached and detached to and from the spindle by the auto loading mechanism **1308** under control of the drive control MPU **1304**. Further, the beam spot is positioned for recording and reproduction by controlling the mechanical controller **1303**, signals are processed for recording and reproduction by controlling the controller control MPU **1306**, and maintenance information is obtained by controlling the panel control unit.

[0108] Meanwhile, arranged between the formatter **1292** and the SCSI interface **1293** are a buffer memory **1318** and a buffer controller **1319**. The buffer memory **1318** temporarily stores reproduced data bound for the host unit, and record data to be recorded that is received from the host unit, and the buffer controller **1319** controls the buffer memory **1318**. The controller control MPU **1306**, etc. are connected with an ECC circuit **1320** for correction of error data.

[0109] In the first embodiment, a reproduction clock signal are generated from a signal of the sync area **12**, while on

the other hand, for the recording clock signal, a clock signal of fixed frequency output from the frequency synthesizer **1313** is used, but needless to say, a clock signal generated from a signal of the sync area **12** can be used for recording. A variation occurs in the relative linear velocity of the beam spot on the track during recording due to a variation in the number of revolutions of the optical disk **4** or the eccentricity of the center of the optical disk **4** with respect to the rotating center of the spindle motor. When this variation occurs, a recording clock signal generated from a signal of the sync area **12** also varies with this variation, so that by using the recording clock signal, information marks **274** can be recorded at a fixed frequency on the track.

[**0110**] Description will be made of the optical disk producing method according to a second embodiment of the present invention for the optical disk **4** according to the first embodiment.

[**0111**] To begin with, the shape of the shape of the tracks, such as **270**, on the optical disk **4**, and the shape of the mark string of **51**, **52** etc. of the sync area **12** are precisely formed on the surface of a glass substrate in a disk form as shown in **FIG. 22**, and from this glass substrate, an original disk **68** is formed. The original disk **68** has a photoresist film **68***a* deposited on a flat glass substrate **68***b* (**FIG. 6**), and patterns of tracks **270**, etc. are transferred to the photoresist film **68***a* by exposure to light, and the original disk **68** are formed by developing the photoresist film. The shape of the surface of this original disk **68** is transferred to a metal such as nickel to form a metal stamper. When a plastic substrate **10** is molded by a method such as injection molding using this stamper, a plastic substrate **10** having tracks **270**, etc. and mark strings, such as **51**, **52** of the sync area **12** formed on the surface can be produced (**FIG. 10**). Subsequently, by forming a recording film **11** on the plastic substrate **10** by vapor deposition, for example, and attaching another substrate to the substrate **10**, an optical disk **4** is completed.

[**0112**] At this time, since the optical disk **4** according to the first embodiment has a structure which represents address information **13** by wobbling the borders **14**, **15** of the tracks **270**, etc., it is necessary to precisely form the shapes of the tracks **270**, etc. having wobbling waveforms (of the borders **14**, **15**) of desired phase on the surface of the original disk **68**. Therefore, in this embodiment, by scanning the beam spot **69** while wobbling in the radial direction of the disk on the disk-shape glass substrate **68***b* covered on its surface with the photoresist film **68***a*, the hatched area in **FIG. 22** is exposed to light. The area exposed to light is removed by a developing process and thereby groove tracks **270**, **272**, etc. are formed. The portion between the adjacent groove tracks **270**, **271** remains after the exposure, and becomes a land track **271**. Thus, an original disk **68** is formed as shown in **FIG. 22**.

[**0113**] The method of light exposure of the original disk **68** and the light exposure system used will be described with reference to **FIGS. 6 and 8**. **FIG. 8** shows a light exposure system to be used for exposure of the original disk **68** to light. **FIG. 6** shows scanning of the beam spot **69** used when the groove tracks **270**, etc. are formed on the original disk **68**. Here, an explanation will be given for the case where the sync area **12** recorded on mark strings **51**, **52** etc. in **FIG. 7A**.

[**0114**] In **FIG. 8**, the beam **64** from the light source **61**, after having its intensity adjusted by the intensity modulator **62**, passes through a beam deflector **63**, is reflected by a mirror **66** to the original disk **68**, and is condensed by the objective lens **67** to the original disk **68**. Thus, a minute beam spot **69** is irradiated to the glass substrate **68***b* covered on its surface with a photoresist film **68***a*. The beam deflector **63**, driven by a deflector drive circuit **76**, minutely oscillates the optical axis of the beam **64**. Therefore, the beam spot **69** on the original disk **68** minutely oscillates in the radial direction of the original disk **68**. The amplitude of the oscillation is the width of the groove tracks **270**, etc. If this width of the oscillation is made to vary with the wobbling waveforms of the borders **14**, **15** of the groove tracks **270**, etc., light exposure can be performed in the shape of the groove track **270** whose borders **14**, **15** wobble. In this manner, while the beam spot **69** is made to oscillate, the rotating motor **71** joint to a spindle **70** is driven by a motor drive circuit **72** to rotate the original disk **68**. At the same time, a carriage **65** on which a bending mirror **66** and an objective lens **67** are mounted is moved gradually in the radial direction of the original disk **68** by a carriage drive circuit **74**. The amount of movement of the carriage **65** is set as the amount of track pitch **280** (**FIG. 28**) by which the center of the beam spot **69** is shifted each time the original disk **68** makes a turn. By those motions, the tracks **270**, etc. are formed in a spiral form at intervals of the track pitch **280**, and the borders **14**, **15** of the groove tracks **270**, etc. can be made to wobble with specified phases. The carriage drive circuit **74** and the motor drive circuit **72** are controlled with feedback by the address recording control circuit **73**. The address recording control circuit **73** sends a deflection signal **104** to the deflector drive circuit **76**. The address recording control circuit **73** sends an intensity modulation signal to a modulator drive circuit **75**.

[**0115**] The structure of the address recording control circuit **73** will be described in detail with reference to **FIGS. 9A, 9B**.

[**0116**] As shown in **FIG. 9A**, the address recording control circuit **73** includes an address signal generator **92**, and a reference clock circuit **95** for outputting a reference clock signal. Moreover, the address recording control circuit **73** includes an intensity signal generator **90** for outputting an intensity signal **105** to the modulator drive circuit **75**, and a deflection signal generator **91** for generating a deflection signal **104**, a head position control circuit **93** for outputting a signal to specify a drive amount to the carriage drive circuit **74**, and a rotation control circuit **94** or outputting a signal to specify a drive amount to the motor drive circuit **72**.

[**0117**] The address signal generator **92** receives rotation information **79** showing the current number of revolutions from the rotating motor **71** together with movement information **78** showing the current position from the carriage **65**, and generates a head command signal showing a drive amount of the carriage **65** to make groove tracks **270**, etc. in a spiral form. The head position control circuit **93** compares a head command signal with the movement information **78**, and outputs a signal to control the carriage **65** to the carriage drive circuit **74**. The address signal generator **92** obtains a number of revolutions corresponding to the position of the track **270**, for example, by using rotation information **79**, and outputs this number as a rotation command signal to the rotation control circuit **94**. The rotation control circuit **94** compares rotation information **79** with the rotation com-

mand signal, and controls the rotating motor so as to rotate at a specified number of revolutions corresponding to the position of the head.

[0118] The address signal generator **92** generates an address signal showing the address of the groove track **270**, for example, on the basis of rotation information **78** and movement information **79**, and outputs the address signal to the deflection signal generator **91**. Furthermore, the address signal generator **92** generates a clock signal **103** (**FIG. 10**) by dividing the frequency of the reference clock from the reference clock circuit **95**, and outputs the clock signal to the deflection signal generator **91**. From those signals, the deflection signal generator **91** generates a deflection signal **104** (**FIG. 10**) using a circuit to be described later. In addition, the address signal generator **92** generates an intensity command signal. On the basis of the intensity command signal, the intensity signal generator **90** generates an intensity modulation signal **105** (**FIG. 10**) to modulate the intensity of the beam **64** to form marks **51**, **52**, etc. in the sync area **12**. To have the marks **51**, **52** of the sync area **12** formed such that they wobble to right and left from the center of the track, the address signal generator **92** generates and outputs a synchronous area command signal to the deflection signal generator **91**.

[0119] The structure of the deflection signal generator **91** and the method of generating a deflection signal **104** will be described with reference to **FIG. 9B**. An address signal is input to an address modulator **96**, generates an address of the inner circumference side border **14** of the groove track **270**, e.g., a signal of "110", and an address of the outer circumference side border **15**, e.g., a signal of "110". The two addresses are converted by the phase modulator circuit **97** into wobbling waveforms representing "1" and "0" according to a difference of the phase as shown in **FIG. 3**, thus forming an amplitude signal **100** corresponding to the address of the inner circumference side border **14** and an amplitude signal **101** (**FIG. 10**) corresponding to the address of the outer circumference side border **15**. Those signals are input to the deflection signal generator **98**. A clock signal **103** is input to a scan signal generator **99**, which generates a scan signal **102** for scanning the beam spot **69** in the radial direction of the original disk **68**, and outputs the scan signal to the deflection signal generator **98**. The deflection signal generator **98** generates a deflection signal (**FIG. 10**) by modulating the amplitude of the scan signal **102** by using the amplitude signal **100** and the amplitude signal **101** so that the beam spot **69** scans between the inner circumference side border **14** and the outer circumference side border **15**. The synchronous area command signal is input to the deflection signal generator **98**. The deflection signal generator **98** generates a deflection signal **104** to cause the beam spot **69** to deflect in synchronism with the scan signal **102** in the sync area **12** so as to shift about **114** of the track pitch **280** to the left and right of the groove track, such as **270**.

[0120] By using a deflection signal **104** designed to work as mentioned above, by performing the light exposure process on the original disk **68** with the light exposure system in **FIG. 8**, the shape of the groove track **270**, for example, showing address information in wobbling waveforms of the borders **14**, **15** and the shape of the mark strings **51**, **52** in the sync area **12** in **FIG. 7A** are exposed to light. Therefore, by perfroming the developing process on the original disk **68**, the original disk **68** for the optical disk **4** according to the second embodiment can be produced.

[0121] In the above description, the exposure method was discussed referring to the case of the sync area **12** in **FIG. 7A**, but the other forms of sync area **12** shown in **FIGS. 7B and 7C** can also be formed by exposure. However, in the cases of **FIGS. 7B and 7C**, since the sync area **12** is formed by grooves, the deflection signal **104** is made so that the sync area **12** is exposed to light in a shape of a groove.

[0122] Description will next be made of the method and the circuit for reproducing address information according to a third embodiment of the present invention. This detection method reproduces address information **13** from the optical disk **4** without using the sync area **12**.

[0123] In the optical disks having the sync area **12** as shown in **FIGS. 7A, 7B** and 7C, information marks **274** cannot be recorded in the sync area **12**, and the sync area **12** occupies that portion of the track. If reference signals **420**, **421** and a reproducing clock signal can be detected from the wobbling waveforms of the borders of the tracks **270**, etc., there is no need to provide the sync area **12**, and the data recording efficiency can be improved.

[0124] According to the third embodiment, in place of the sync area **12**, a synchronous (SYNC) segment is provided which has the same phase as the wobbling waveforms of the inner circumference side border **14** and the outer circumference side border **15** of the track. The SYNC segment is like the sync area **12** of **FIG. 7B**, but as shown in **FIG. 7B**, the wobbling amplitude of the sync area **12** is made larger than the wobbling amplitude of the address information **13**, and therefore information marks **274** cannot be recorded in the sync area **12**, but the SYNC segment is set to have the same wobbling amplitude as in address information **13**. Therefore, information marks **274** can be recorded in the SYNC segment in the same way as in other areas.

[0125] Referring to **FIG. 11**, description will start with the method of generating reference signals **420**, **421** from an optical disk **4** according to the third embodiment without using the sync area **12**. As described above, in address information **13**, the wobbling waveforms of the borders **14**, **15** of the tracks **270**, etc. have the same frequency, but differ in phase. The phase differences take no more than four states: 0 degree, 90 degrees, 180 degrees, and 270 degrees, so that timing at zero crossing of the detection signal **231** (**FIGS. 5 and 24**) when the wobbling of a groove is detected corresponds to 4t (t is a natural number) times the frequency of the wobbling. Accordingly, the circuit structures of **FIGS. 5A and 5B** are changed into those in **FIGS. 11A and 11B**, and the timing at zero crossing of the detection signal **231** is detected by a zero cross detector **125**, and in synchronism with the timing, a PLL (phase locked loop) **126** is started. By this arrangement, a signal having a frequency four times the wobbling frequency can be produced. What is more, if the relative linear velocity between the reproducing and recording beam spot **1** and the track **270** varies due to a minute variation in the rotating speed of the spindle motor **1290** (**FIG. 29**) or the eccentricity of the optical disk **4** with respect to the rotating center of the spindle motor **1290**, the signal produced as mentioned above also varies with those variations. Therefore, this signal is synchronous with the recorded wobbling waveform, and by dividing the frequency of this signal by a frequency divider **127**, a synchronous

signal of a wobbling waveform with the same frequency as the recorded wobbling waveform can be obtained.

[0126] The synchronous signal of the frequency-divided wobbling waveforms has a frequency synchronous with the wobbling waveforms, but it is not known whether the phase is synchronous with the wobbling waveforms. To generate reference signals **420**, **421**, it is necessary to provide a synchronous signal synchronous in phase with the wobbling waveforms, so that this phase needs to be decided. To this end, the frequency divider **127** is used to generate signals having four phases, 0 degree, 90 degrees, 180 degrees and 270 degrees on the basis of output of the PLL **126**. Any one of those signals is in phase with the wobbling waveforms. The above-mentioned SYNC segment is used to select the synchronized phase out of the four phases.

[0127] Out of detection signals **231**, a detection signal **231** from ordinary address information **13** and a detection signal **231** from the SYNC segment are separated by using a sync detection circuit **133**. Specifically, with a detection signal **231** of ordinary address information **13**, regardless of what phase the detection signal **231** has, both synchronous detectors **42**, **43** provide a positive or negative level of output. However, on the SYNC segment, only one of the synchronous detectors **42**, **43** provides a positive or negative level of output, and the other detector provides zero output. Therefore, since level decision circuits **123**, **124** identify the area where either one of outputs of the synchronous detectors **42**, **43** becomes zero, the SYNC segment can be detected. **FIG. 12** shows detail of the level decision circuits **123**, **124**. A signal from synchronous detector **42** is compared with a positive level v**1** and a negative level v**2** by comparators **226**, **227**, **228**, and **229** in the level decision circuits **123**, **124**. If output of the synchronous detector **42** is larger than v**1**, a level "1" signal synchronous with the reference signal **420** appears at an output signal **206** of a flip-flop **200**. If output of the synchronous detector **42** is between v**1** and v**2**, in other words, if output of the synchronous detector **42** is close to zero, a level "1" signal synchronous with the reference signal **420** appears at a signal **205** after passing through flip-flops **202**, **203**, and an AND circuit **201**. Similarly, if output of the synchronous detector **42** is smaller than v**2**, a level "1" signal appears at a signal **207** from a flip-flop **204**.

[0128] The detailed operation of the level decision circuit **123** has been described. Similarly, in the level decision circuit **124**, if output of a synchronous detector **43** is larger than v**1**, a level "1" signal synchronous with the reference signal **421** appears at a signal **218**. If output of the synchronous detector **43** is between v**1** and v**2**, a signal "1" signal synchronous with the reference signal **421** appears at a signal **219**, and, if output of the synchronous detector **43** is smaller than v**2**, a level "1" signal appears at a signal **220**.

[0129] Signals **206**, **207** or signals **218**, **220** showing if output is larger than v**1** or smaller than v**2** are ORed by the logical OR circuits **208**, **216**. The results of these logical operations and signals **205**, **219** showing zero of the decision circuits **123**, **124** are ANDed by the logical AND circuits **209**, **217**. When the results of those logical operations are ORed by the logical OR circuit **210**, a sync signal **121**, which shows that the detection signal **231** is a signal from the SYNC segment, can be obtained.

[0130] When the SYNC segment is detected as mentioned above, signals for reference signals **420**, **421** can be selected from the signals with four phases mentioned earlier, using the detection signal **231** from the SYNC segment.

[0131] Description will be made of the principle for selecting signals for the reference signals **420421** from signals with four phases. Since the reference signal **421** is 90 degrees out of phase with the reference signal **420**, if the phase of the reference signal **420** is decided, it follows that the phase of the reference signal **421** can be decided. One of the signals of four kinds of phases 0 degree, 90 degrees, 180 degrees and 270 degrees generated by the frequency divider **127**, to take an example, a signal with the phase of 0 degrees is input from the synchronous signal generator **41** into the synchronous detector **42** as a reference signal **420**. A signal 90 degrees out of phase with the reference signal **420**, that is, a signal of a phase of 90 degrees is input to the synchronous detector **43** as a reference signal **421**. Since the SYNC segment is formed such that the wobbling waveform of the inner circumference side border **14** and the wobbling waveform of the outer circumference side border **15** are in phase with each other, either one of the outputs of the synchronous detectors **42**, **43** in **FIG. 5A** in relation to the SYNC segment is zero, and the other output becomes a positive or a negative level. At this time, there are two factors for deciding if either one of outputs is zero, positive or negative: one is the phase of the wobbling waveform in the SYNC segment and the other is the position at which the reproducing beam spot **1** is located, i.e. the groove tracks, **270**, etc. or the land tracks **271**, etc.

[0132] Accordingly, since the wobbling waveform of the SYNC segment is already known, by selecting a groove track **270** or the like or a land track **271** or the like, by positioning the beam spot at the selected track using the tracking control system **132** and the tracking polarity switching circuit **130** included in the tracking control circuit **1300**, and by knowing which of the outputs of the synchronous detectors **42**, **43** is 0, it can be decided whether the phase relationship between the reference signal **420** which was input and the reference signal **420** to be input is 0 degrees or 180 degrees, or 90 degrees or 270 degrees.

[0133] For example, when the phase relationship is known to be 0 or 180 degrees by the above decision, by further detecting if a non-zero output from the outputs of the synchronous detectors **42**, **43** is positive or negative, a further decision can be made as to whether the phase relationship is 0 degrees or 180 degrees. Similarly, if the phase relation is known to be 90 degrees or 270 degrees by the above decision, a further decision can be made as to whether the phase relationship is 90 degrees or 270 degrees.

[0134] The above-mentioned decisions can be made by a circuit block as shown in **FIG. 12**. In **FIG. 12**, the switching command circuit **131** is a part of the mechanical controller **1303**, and switches over the selection of the groove track, such as **270**, or the land track, such as **271**. The logical AND operations are carried out by AND circuits **212**, **213**, **214** and **215** between, on one hand, a signal **225** of a polarity which indicates whether the track, such as **270**, selected by the switching command circuit **131** is a groove or a land, and, on the other hand, signals **206**, **207**, **218**, and **220** showing the synchronous detector output level being larger than v**1** or smaller than v**2**, as detected by the level decision circuits **123** and **124**. Note that one of the signals with four kinds of phases of 0 degrees, 90 degrees, 180 degrees, and 270

degrees, produced by the above-mentioned frequency divider **127**, that is, a signal of a phase of 0 degrees, for example, is input as a reference signal **420** from the synchronous signal generator **41** to the synchronous detector **42**. As the reference signal **421**, a signal which is 90 degrees out of phase with the reference signal **420** is input to the synchronous detector **43**.

[**0135**] In the circuit of **FIG. 12**, when the reference signal **420** currently being input is 0 degree out of phase (in other words, in synchronism) with a correct signal which should have been input as the reference signal **420**, the signal **221** is at the level of "1", or when the phase difference is 90 degrees, the signal **222** is at the level "1", or when the phase difference is 180 degrees, the signal **233** is at "1", or when the phase difference is 270 degrees, the signal **224** is at "1". Thus, in the phase command signal **120** consisting of signals **221** to **224**, by detecting which signal is at the level "1", a decision can be made as to how the phase of the reference signal **420** currently being input is shifted from the phase of a reference signal **420** which is correct and should have been input.

[**0136**] By inputting the phase command signal **120** into the selector **128** and having the selector **128** select any of the four signals with different phases, which are generated by the phase divider **127**, a correct reference signal **420** can be selected. For example, when the signal **222** which is 90 degrees out of phase with a correct phase is at the level "1" in the phase command signal **120**, the selector **128** selects a signal formed by adding a phase of 270 degrees to the reference signal **420** currently being input, and the synchronous detector **42** outputs this signal as the reference signal **420**. On the other hand, as the reference signal **421**, a signal obtained by adding 90 degrees to the reference signal **420** is output.

[**0137**] Thus, reference signals **420**, **421** can be formed from the wobbling waveform detection signal **231** of the borders **14**, **15**. The reference signals **420**, **421** vary in accordance with variation in the linear velocity of the reproducing beam spot on the tracks **270**, etc. due to the variation in the number of revolutions of the current optical disk **4** or the eccentricity of the optical disk **4**, and so on. Therefore, by using the reference signals **420**, **421**, the information marks **274** and the address information **13** can be accurately demodulated.

[**0138**] Description will now be made of the method of generating a recording and a reproducing clock signal used when recording and reproducing data from the wobbling waveforms of the borders **14**, **15** on the tracks **270**, etc. Applied to this method is the fact that the oscillation frequency of PLL **126** in **FIG. 11** is 4t times the wobbling frequency as described above. More specifically, the oscillation frequency of PLL **126** is multiplied by a specified number. For example, if the wobbling frequency of the borders **14**, **15** is set at 7.5 kHz or so and the frequency of a recording or reproducing clock signal is set at 7.5 MHz, then the oscillation frequency of the PLL **126** is 4t times the wobbling waveforms, namely, 150 kHz. By multiplying this 150 kHz by a specified number (e.g., 50), a recording signal or a reproducing clock signal can be produced. When this recording or reproducing clock signal is used, even if the linear velocity of the recording and reproducing beam spot **1** on the tracks **270**, etc. varies due to a minute variation in the number of revolutions of the optical disk **4**, and the eccentricity of the optical disk **4**, information marks **274** can be recorded and reproduced.

[**0139**] Subsequently, description will be made of the method of reproducing address information **13** and the circuit structure for reproduction according to a fourth embodiment of the present invention.

[**0140**] In the third embodiment of the present invention, it is necessary to decide the phases of the reference signals **420**, **421** for use in detecting address information **13**, but in the fourth embodiment, address information is detected without deciding the phases.

[**0141**] In the fourth embodiment of the present invention, a composite waveform of the waveforms of the inner circumference side border **14**, and the outer circumference side border **15** of each track **270**, for example is detected for each bit. When recording address information **13**, in other words, when tracks are formed on the original disk **68** by the light exposure process, it is arranged that the phase of the composite waveform of the subsequent bit is shifted by an amount decided by a predetermined rule from the phase of the preceding bit, and address information **13** is recorded utilizing the phase difference between the composite waveforms. The actual wobbling waveforms of the borders **14**, **15** are formed as waveforms obtained by decomposing the composite waveform. When reproducing address information **13**, the phase of the composite waveform of each bit is detected, and a phase difference from the preceding bit is obtained by using the differential detector **38**, and the band filter **39**. By collating the obtained phase difference with the above-mentioned rule, address information is reproduced.

[**0142**] Description of this will now be given in more detail. Data "1" and "2", represented by the borders **14**, **15** of the tracks **270**, etc. are combined to form pairs of data of the inner circumference side border and data of the outer circumference side border. The result is that data of a given bit is any one of the following four cases: a case of "0" on the inner circumference side border and "0" on the outer circumference side border; a case of "0" on the inner circumference side border and "1" on the outer circumference side border; a case of "1" on the inner circumference side border and "0" on the outer circumference side border; a case of "1" on the inner circumference side border and "1" on the outer circumference side border. The phases of the composite waveforms differ among all of the above fours pairs. In the fourth embodiment, by using this, in relation to the phase of the composite waveform of the preceding bit, the degree of shift in the phase of the composite waveform of the next bit is set for various pairs of the composite waveforms arranged in a row. The phase differences and the corresponding pairs of the composite waveforms are formulated as a rule.

[**0143**] **FIG. 14A** is an example of the rule. To be more specific, when data "0" is recorded at the inner circumference side border and data "0" at the outer circumference side border at a given bit, the phase of the composite waveform for this bit is set to be the same as the phase of the composite waveform of the preceding bit. Alternatively, when data "0" is recorded at the inner circumference side border and data "1" at the outer circumference side border, the phase of the composite waveform of this bit is set to lead $\pi/2$rad on the phase of the composite waveform of the preceding bit. When

data "1" is recorded at the inner circumference side border and data "0" at the outer circumference side, the phase of the composite waveform of this bit is set to lead π rad on the phase of composite waveform of the preceding bit. When "1" is recorded at the inner circumference side border and "1" at the outer circumference side border, the phase of the composite waveform of this bit is set to lead 3 π/2rad on the phase of the composite waveform of the preceding bit.

[**0144**] When an original disk **68** is prepared, the phase of the composite waveform representing data of address information is obtained according to this rule, and by decomposing this composite waveform, the wobbling waveforms of the borders **14**, **15** are determined. As has been described with reference to **FIGS. 24A, 24B** and **24**C, the detection signal **231 (FIG. 24C)** output from the band filter **39** is a composite waveform of the wobbling waveform of the inner circumference side and the wobbling waveform of the outer circumference side of the track. Therefore, by detecting the amount of shift of the phase of the detection signal **231** from the preceding bit, data of the inner circumference side border and data of the outer circumference side border can be reproduced together as a combination of data only from the phase difference.

[**0145**] However, since data of the border is shared by the groove track, such as **270**, and the land track, such as **271**, if data is to be recorded according to the above rule in a combination of the inner circumference side border **14** and the outer circumference side border **15** of the groove track side **270**, it is impossible to record data of the same bit on the land track side **271** because of the above rule. Therefore, as indicated by the broken line in **FIG. 14**B, the inner and outer borders are combined in a pair **1402** of the groove track side **270** etc. and the land track side **271** etc. at every other bit. Like the SYNC segment in the preceding embodiment, synchronous segments **1401**, by which the phases of the inner circumference side border and the outer circumference side border are matched, are provided at fixed intervals. When reproducing the composite waveform of the pair **1402**, this synchronous segment **1401** is detected, and by counting down the clocks on the basis of this synchronous segment, signals indicating the bit areas are formed, and by using the bit indication signals, the pair **1402** on the groove track, such as **270**, and the pair **1402** on the land track, such as **271**, are separated and detected.

[**0146**] Description will be continued with reference to an illustrative example. For example, as shown in **FIG. 19**, data "0" or "1" of address information **13** is going to be recorded at the borders of the tracks. Supposing that data at the inner circumference side border **14** of the groove track **270** is denoted by A, and data at the outer circumference side border **15** is denoted by B, then the first bit is (0, 0) for (A, B). Suppose that (1, 0) is going to be recorded at the next bit. In this case, it is necessary to record a composite waveform which is by π out of phase with the composite waveform of the preceding bit. Accordingly, if the phase of the composite waveform of the preceding bit **(0, 0)** is 0, the phase of the composite waveform of bit **(1, 0)** is π, so that the phases of the wobbling waveforms of each border are as shown in **FIG. 19**. If (0, 1) is recorded next to (1, 0), it is required to record a composite waveform which is π/2 out of phase with the composite waveform of the preceding bit. Hence, the phases of the composite waveform of bit **(0, 1)** and the wobbling waveforms of the borders are as shown in **FIG. 19**. After this, by deciding the phases of the composite waveforms, the phases of the wobbling waveforms of the borders can be decided.

[**0147**] Meanwhile, in reproduction, like in the preceding embodiment, a clock signal is generated which has a frequency four times the wobbling frequencies of the borders **14**, **15** of the track, and by dividing the frequency of the clock signal, reference signals **420**, **421** for synchronous detection are produced. The phase may take four states, but any phase may be used. The reason for this is as follows. The reason for this is that, since data can be reproduced only from the phase difference of the composite waveform, the only thing required first of all is to find the phase of the composite waveform of the first bit, and thereafter data can be reproduced using a difference from the preceding bit. In this case, if the phases of the reference signals **420**, **421** are not selected correctly, data at the first bit cannot be read correctly, but from the next bit onward correct data can be reproduced. Because address information **13** can be recorded repeatedly at the borders of one track **270**, for example, there is no problem even if data at the first bit cannot be read correctly. By performing synchronous detection by varying the phases of the reference signals **420**, **421** according to data of reproduced address information **13**, it is possible to generate reference signals **420**, **421** of correct phases on the basis of the phase of the previous data.

[**0148**] **FIGS. 15 and 16** are circuit block diagrams for demodulating address data according to the address information reproducing method mentioned above. The synchronous segment detection circuit **333**, just as in sync signal detection by the detection circuit **133** in the third embodiment, detects the synchronous segment **1401**, and outputs a synchronous segment signal **121'** in **FIG. 13**. The synchronous sync detection circuit **333** generates a groove/land modulator signal **326** from a signal which has detected the synchronous segment **1401**. The groove/land modulator signal **326** is a modulation signal to indicate whether the pair **1402** for a bit is on the groove track, such as **270**, or on the land track, such as **271**. Those two signals are input to the address demodulator circuit **422**, and are used as timing signals in demodulating data. The address demodulator **422***a* receives outputs from the synchronous detectors **42**, **43** in the form of binary signals to which those outputs have been converted by the comparators **44**, **45**. The address demodulator **422***a*, according to timing controlled by the synchronous segment signal **121'** and the groove/land modulator signal **326**, separates address information of a data pair at a groove track, such as **270**, and a data pair at a land track, such as **271**, to thereby reproduce (demodulate) data according to the above-mentioned rule.

[**0149**] Description will now move on to the detailed circuit structure and the operation of the synchronous detection circuit **333**. As has been described, the synchronous detection circuit, using the same circuit structure and operation as in the sync detection circuit **133**, generates a synchronous segment signal **121'** shown in **FIG. 16**. The synchronous detection circuit **333** divides the frequency of the clock signal in the counter **340** of the data timing generator **325** by using the synchronous segment signal **121'** and the clock signal **400** to thereby generate a signal **350** (**FIG. 13**) corresponding to bit periods, and subdivides the signal **350** by half, and generates a groove/land modulator signal **326** in synchronism with the synchronous segment

signal **121'**. The synchronous detection circuit **333** generates signals to detect the phases of the composite waveforms of each bit by performing logical operations at the circuits **208**, **209**, **210**, **216**, **217**, **312**, **313**, **314**, and **315** using binary signals **205**, **206**, **207**, **218**, **219**, and **220** converted from outputs of the synchronous detectors **42**, **43**. The synchronous segment detection circuit **333** associates the outputs of the AND circuits **312**, **313**, **314**, and **315** with four kinds of data of the pairs **1402**, and inputs the results to memories **327**, **328**, **329** and **330**. The memories **327**, **328**, **329** and **330** store the phases of the pairs **1402** on the groove tracks, such as **270**, and the phases of the pairs **1402** on the land tracks, such as **271**, and reads out the preceding phase when data of the next pair on the same track is demodulated.

[**0150**] The detailed structure of the memories **327** to **330** will be described with reference to the memory **327** as an example. The memory **327** takes the output of the AND circuit **312** into the flip-flop circuits **341** and **343** respectively at the leading edge of the groove/land modulator signal **326** and at the leading edge of the inverted signal of the groove/land modulator signal **326**, and sends out the output as it is selected by the selector **342** according to the polarity of the groove/land demodulator signal **326**. The output of the memories **327**, **328**, **329**, and **330** is used as a phase command signal **320** to select signals of correct phases by controlling the selector **428** to produce reference signals **420**, **421** of correct phases.

[**0151**] Description will be made of the method of reproducing address information **13** and the circuit structure for reproduction according to a fifth embodiment of the present invention.

[**0152**] In the preceding embodiment, data on both borders **14**, **15** of each track, such as **270** is recorded and reproduced as data in a pair **1402** for every bit. In the fifth embodiment of the present invention, data on the borders **14**, **15** of a track, such as **270**, is independently modulated and recorded. To be more specific, data for a bit on the inner circumference side border **14** of a track **270**, for example, is recorded by a phase difference with respect to the wobbling waveform of data at the preceding bit. The phase differences with respective pieces of data should be decided as a rule in advance as shown in **FIG. 17A**. The rule in **FIG. 17A** is as follows: When data at the next bit is "0" on a certain border **14**, or **15** regardless of whether data at the preceding bit is "0" or "1", a wobbling waveform of the same phase as in the wobbling waveform at the preceding bit should be set, and when data at the next bit is "1", a wobbling waveform of a phase leading by π on the phase of the wobbling waveform at the preceding bit should be set. When data is represented with a phase difference of a wobbling waveform for each border **14**, if it is clear which of outputs of the synchronous detectors **42**, **43** is data on the inner circumference side border of a track, such as **270** and which of outputs is data on the outer circumference side border, then separate items of data which correspond to the synchronous detectors **42**, **43** can be detected even though the phases of the reference signals **420**, **421** are 180 degrees out of phase with each other.

[**0153**] Note that the SYNC segments having the same wobbling waveform on the inner and outer circumference side borders are provided at fixed periods also in this fifth embodiment.

[**0154**] In order to decide which of the synchronous detectors **42**, **43** outputs data on the inner circumference side of the track and which of those detectors **42**, **43** outputs data on the outer circumference side of the track, it is only necessary to use the methods of sync detection and phase decision of the reference signals described with reference to **FIGS. 11 and 12**. In other words, since the phase of the wobbling waveform in the SYNC segment has already been decided, and depending on whether the location of the beam spot **1** is on a groove track or on a land track, the polarity of outputs of the synchronous detectors **42**, **43** is detected when the phases of the reference signals **420**, **421** are zero. Therefore, by detecting the polarity of the level of output of the synchronous detectors **42**, **43**, the phases of the reference signals **420**, **421** can be decided correctly.

[**0155**] In the fifth embodiment in **FIG. 17**, instead of the above-mentioned SYNC segment or synchronous segment **1401**, data for synchronization may be recorded at fixed periods on both borders **14**, **15**. For example, as shown in **FIG. 18A**, two synchronous bits **1811** are secured in fixed periods, in which data "01" is recorded, for example, to show that those two bits are for synchronization purpose. By this arrangement, the sync bits **1811** can be detected regardless of the state of phase by the same detection principle as in the embodiment in **FIG. 17**. The frequency of the timing signal for detecting the sync bits **1811** may be divided to generate a reproducing clock signal or a recording clock signal. When output of the synchronous bits **1811** is zero, the area where output of the synchronous detector **42** or **43** is zero is detected by the level decision detectors, so that the uncertainty of the phases of the reference signals **420**, **421** is reduced by half. In other words, it is known which side the track the synchronous detectors **42**, **43** correspond to, the inner circumference side or the outer circumference side. Also in the fifth embodiment in **FIG. 17**, as shown in **FIG. 18B**, like in the case of the synchronous segment **1401**, by inserting bit **1812** of a predetermined phase at fixed intervals in data, a reproducing clock signal or a recording clock signal can be generated from a signal of this bit **1812**. In addition, timing by which to correctly set the phases of the reference signals **420**, **421** is increased, so that recovery from loss of synchronism can be achieved quickly, thereby enhancing reliability.

[**0156**] Finally, description will be made of a sixth embodiment of the present invention.

[**0157**] In this embodiment, the method of detecting a track shift signal without offset will be discussed.

[**0158**] When the reproducing beam spot goes across a track, output of the differential detector **38**, shown in **FIG. 20**, which has a similar circuit structure as in **FIG. 5A** is represented by the signal **521** in **FIG. 21**, having a wobbling frequency component (the dotted line) superimposed on the track shift signal (the solid line). At this time, as the center of the beam on the two-piece detector **33** of **FIG. 5A** deviates from the split center of the two-piece detector **33**, offset occurs in the signal **512** of **FIG. 21**, and the position of the zero point of the track shift signal shifts from the center of the track, such as **270**. Only the wobbling frequency component is extracted from the signal **521** by the band filter **39**, then signals **522** and **523** are obtained as outputs of the synchronous detectors **42**, **43**. Specifically, the wobbling frequency component corresponding to the phase

of the waveform at the inner circumference side border **14** of the groove track **270**, for example, has a large absolute amplitude on the inner circumference side of the groove track, such as **270**, and the absolute values of the outputs are greatest on the inner circumference side border **14** and smallest on the outer circumference side **15** of the groove track, such as **270**. The wobbling frequency component corresponding to the phase of the outer circumference side border of the groove track, such as **270**, has a large absolute amplitude on the outer circumference side of the groove track, such as **270**, and the absolute values of the outputs are greatest on the outer circumference side border **15** and smallest on the inner circumference side border **14** of the track, such as **270**.

[**0159**] Therefore, when those absolute values are captured by the absolute value detectors **401**, **402** of **FIG. 20**, the signals **524**, **525** are detected as the beam spot moves. When a difference between those signals is acquired by the differential circuit **403**, a track shift signal **526** without offset can be detected. By using this signal for tracking control, tracking control can be performed with high accuracy.

[**0160**] Also, by using this signal, a track shift signal with offset can be corrected. The wobbling frequency component extracted from the signal **521** by is removed by the differential circuit **407** to generate a track shift signal which includes only an offset component. Thereafter, gain of the signal **526** is corrected by the gain correction circuit **404**, and signals are added by the adder **405** with their polarities matched, to thereby correct the offset component. As the offset correction method, a well-known method may be adopted. The track shift signal after the correction process has its track shift polarity switched according to the polarity shift instruction of the land and groove tracks using the tracking polarity switching circuit **130**, and sent to the tracking control circuit **132**.

[**0161**] As has been described, in the optical disk **4** according to each of the above-mentioned embodiments, the inner and outer circumference side borders **14**, **15** of each track, such as **270** are wobbled with different phases to record different items of address information **13** on the inner and outer circumference side borders **14**, **15**. Therefore, even if the diameter of the beam spot **1** during reproduction is larger than the track width and the beam spot **1** extends over the tracks on both sides of the track from which data is to be read, the track can be identified by address information which has been read out. Accordingly, even if the track width is about one-half of the diameter of the beam spot **1**, the track can be identified accurately to read information. Also in recording, the track can be identified correctly to record information marks **274**.

[**0162**] With the optical disk **4** in those embodiments of the present invention, even in the area where address information **13** has been recorded by wobbling of the borders **14**, **15** of the track, such as **270**, and the borders **14**, **15** of the track **270**, for example, have wobbling waveforms, user data or the like can be recorded by using information marks **274**. For this reason, it it not necessary to provide areas dedicated to recording of address information **13** on the optical disk **4**. Therefore, since it it not necessary to use, for example, the VFO unit for use when reading address information **13**, the user data recording efficiency can be improved compared with the case of using address information recorded in the conventional preformatted header.

[**0163**] Furthermore, in the embodiment shown in **FIG. 11**, for example, a clock signal can be generated from the wobbling waveform on the track, such as **270**, so that the sync area **12** is not required, thus making it possible to improve the recording efficiency of user data.

[**0164**] Description will be made of the user data recording efficiency of the optical disk **4** in this embodiment by comparing with the prior art. In this embodiment, address information **13** is recorded on borders on both sides of a track, and therefore it is not necessary to secure on the track the areas for preformatting address information (ID) **259** as in the conventional ISO format in **FIG. 25**. Since the address information (ID) segment **259** is not required, those segments arranged to read the address information segment **259**, such as the VFO segment **257**, the address mark segment **258**, and the PA segment **263**, become unnecessary. The sector mark (SM) segment **256** also becomes unnecessary because the same function is performed by the sync area **12**, SYNC segment, or the sync segment **1401** in this embodiment. Further, in this embodiment, a reproducing clock signal can be generated from the sync area **12** or the wobbling waveforms of the track, and therefore the VFO segment **252** and the RESYNC segment **268** in **FIG. 25** become unnecessary. The clock generated from a signal from the sync area **12** may be used as a recording clock signal. Therefore, even when a variation occurs in the rotating speed of the optical disk rotating motor, information marks can be recorded at a fixed frequency, so that the buffer **255** becomes unnecessary.

[**0165**] Accordingly, in the optical disk **4** in this embodiment, out of the conventional format in **FIG. 25**, 63 bytes of the preformatted header **250**, 69 bytes of the VFO segments **257**, **252**, 23 bytes of the buffer segment **255**, and 78 bytes of the RESYNC segment **268** become unnecessary. As a result, the data recording efficiency of user data is 1014/1219 bytes, namely 84%. Note that in the conventional ISO format in **FIG. 25**, the data recording efficiency of user data is 1024/1410, namely 72.6%.

[**0166**] In the third embodiment in **FIG. 11**, since a recording clock signal is generated from the wobbling waveform, the sync area **12** is not required, and thus the data recording efficiency can be further improved.

[**0167**] Therefore, according to the present invention, the user data recording efficiency of the optical disk **4** can be increased to at least 80% so that the data recording efficiency can be raised to an extremely high efficiency.

[**0168**] As is clear from the foregoing description, according to the present invention, there is provided an information recording medium with an improved track density, which has address information recorded in advance so that information can be recorded or reproduced on a target track securely in recording or reproducing data. Also, an information reproducing method and an information reproducing apparatus capable of reproducing information from the information recording medium according to the present invention are provided. Moreover, a track forming method and a track forming apparatus can be provided for forming a track on the information recording medium according to the present invention.

What is claimed is:

1. An exposure system for an original disk for an information recording medium, comprising:

a rotating device for driving an original disk;

a beam irradiating portion for irradiating a beam spot for exposure on said original disk;

a scanning means which performs exposure to light in a shape of a track by scanning said beam spot in a radial direction of said original disk; and

control means for controlling the width of scanning by said scanning means;

wherein said control means controls said scanning means so that the borders on both sides of said track shift in phase from each other with a predetermined phase difference.

2. An exposure system according to claim 1, wherein said track is a groove track, and said control means controls said scanning means so that the borders on both sides of said groove track shift in phase from each other with the predetermined phase difference therebetween.

3. An exposure system according to claim 2, wherein a plurality of groove tracks are provided, and said control means controls said scanning means so that the borders on both sides of each of said groove tracks shift in phase from each other with a predetermined phase difference therebetween.

4. An exposure system according to claim 3, wherein said groove tracks alternate with land tracks and said control means controls said scanning means so that the borders on both sides of a respective groove track and a respective adjacent land track shift in phase from each other with a predetermined phase difference therebetween.

5. An exposure system according to claim 1, wherein said track having the borders on both sides thereof shifted in phase from each other with the predetermined phase difference enables reproduction of information therefrom.

6. An exposure system for an original disk for an information recording medium, comprising:

a rotating motor which drives an original disk;

an optical head which irradiates a beam for exposure on said original disk;

a scanner which performs exposure to light in a shape of a track by scanning said beam in a radial direction of said original disk; and

a controller which controls a width of the scanning by said scanner;

wherein said controller controls said scanner so that borders on both sides of said track shift in phase from each other with a phase difference.

7. An exposure system according to claim 6, wherein said phase difference is a predetermined phase difference.

8. An exposure system according to claim 6, wherein said borders on both sides of said track having a wobbling shape which is indicative of information.

9. An exposure system according to claim 8, wherein said information includes address information of said track.

10. An exposure system according to claim 6, wherein said track is a groove track, and said controller controls said carriage so that the borders on both sides of said groove track shift in phase from each other with a phase difference.

11. An exposure method for an original disk for an information recording medium, comprising the steps of:

driving an original disk;

irradiating a beam for exposure on the original disk;

performing exposure to light in a shape of a track by scanning the beam in a radial direction of the original disk; and

controlling a width of the scanning so that borders on both sides of the track are shifted in phase from each other with a phase difference.

12. An exposure method according to claim 11, wherein the phase difference is a predetermined phase difference.

13. An exposure method according to claim 11, wherein the borders on both sides of the track have a wobbling shape which is indicative of information.

14. An exposure method according to claim 13, wherein the information includes address information on the track.

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