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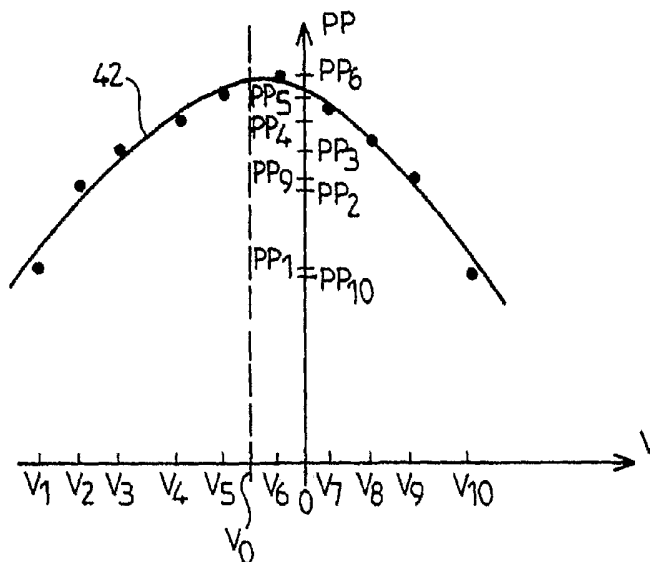
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- (71) Applicant (for all designated States except US): **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **JUTTE, Petrus** [NL/FR]; c/o Société Civile SPID, 156 Boulevard Haussmann, F-75008 Paris (FR). **BAKX, Johannus** [NL/NL];

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(54) Title: METHOD OF DETERMINING SETTING OF SPHERICAL ABERRATION CORRECTOR



(57) Abstract: The invention discloses a method of determining the setting of a spherical aberration correction to be applied to an optical beam in an apparatus for reading data from and/or writing data onto an optical data carrier, especially a Blu ray disk. An incident beam is generated and focused onto the optical data carrier so as to produce a reflected beam. A spherical aberration correction is applied to the incident beam. A difference signal, which results from a difference between the intensities of two substantially symmetrical portions of the reflected beam, for example the radial push pull signal (PP) or the radial wobble signal, is measured during a relative movement between the incident beam and the optical data carrier. A specific setting (VO) of the spherical aberration correction, which maximizes the amplitude of the difference signal, is determined.

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METHOD OF DETERMINING SETTING OF SPHERICAL ABERRATION CORRECTOR

FIELD OF THE INVENTION

5 The present invention relates to an apparatus for reading data from and/or writing data onto an optical data carrier, to a method of determining the setting of a spherical aberration correction to be applied to an optical beam in such an apparatus, and to an optical data carrier.

10 The invention applies to any optical data carrier format and especially to Blu-ray disks (BD).

BACKGROUND OF THE INVENTION

15 The manufacturing process causes optical data carriers to have a substrate thickness that locally or globally deviates from the standard thickness. The spherical aberration caused by a thickness error is particularly large in Blu-ray optical pickups because of the high numerical aperture (i.e. 0.85) of the objective lens. This is even more critical in dual layer BD media, where the spacer layer thickness causes an additional error. Moreover, even if the manufacturing tolerance were small enough, the fixed correction provided by objective lens would not suit both layers of dual layer BD media. Hence, accurate spherical aberration
20 correction is required in order to read and write a Blu-ray disk, especially a multiple layer disk, with sufficiently low jitter. The spherical aberration can be corrected by making the beam towards the objective lens slightly converging or diverging, depending on whether the thickness error is negative or positive. Other correction methods, such as compensation by means of a liquid crystal cell, have also been proposed.

25 Detection of the spherical aberration is a prerequisite for correction. Patent application US A-2003/0053393 discloses an embodiment 11, with which the spherical aberration is detected from a defocus characteristic of a push pull signal. More precisely, amplitudes of push pull signals are obtained while a focal point is moved from a correct focusing position along forward/backward directions, and the difference between these
30 amplitudes is then calculated. The positional shift of a peak of the defocus characteristic of the push pull signal serves to provide a signal which is assumed to be directly proportional to the spherical aberration. A disadvantage of this detection method is that the subsequent compensation of the spherical aberration requires a knowledge of the quantitative relation

between the driving voltage of the liquid crystal phase compensating element and the spherical aberration correction.

SUMMARY OF THE INVENTION

5 One of the objects of the invention is to provide a method and apparatus capable of accurately correcting the spherical aberration occurring in an apparatus for reading data from and/or writing data onto an optical data carrier. Another object of the invention is to provide a simple and cost-effective method and apparatus for accurate determination and correction of the spherical aberration occurring in an apparatus for reading data from and/or writing data
10 onto an optical data carrier.

With this invention, these objects are achieved by an apparatus as stated in claim 1 and a method as stated in claim 9.

A basic idea of the invention is that the better the spherical aberration correction, the smaller the spot size on the groove of the optical data carrier; and the more the returning light
15 is modulated due to the local structure of the optical data carrier, such as data pits, groove, radial modulation of the groove, if any, and the like. In other words, an optimal correction should improve the locality of the interaction between the incident beam and the recording layer of the data carrier. The difference between two substantially symmetrical beam portions is used for canceling out common-mode components, especially the high-frequency
20 components of written data, the noise due to dust and scratches, and continuous background noise, as the case may be. Hence, the emphasis is put on the structures which are transverse to the direction of scanning. These structures have a regular pattern, which does not depend substantially upon the data. Suitable difference signals are, for example, the conventional radial push-pull signal when the radial tracking is off and the conventional radial wobble
25 signal when the radial tracking is on.

An advantage of this method and apparatus lies in the fact that, unlike the prior art method, the compensation of the spherical aberration does not require knowledge of the calibration curve of the spherical aberration correction actuator, i.e. of the quantitative relation between the driving voltage of the spherical aberration correction actuator and the
30 spherical aberration correction. The specific setting obtained is already calibrated for the spherical aberration correction actuator of the apparatus.

The feature defined in claim 3 has the advantage that the specific setting can be accurately derived with a limited number of measurements, so that the determination is faster.

The feature defined in claim 4 has the advantage that the preset range can be made wide enough to cover the entire tolerance of the media layer thickness in accordance with media type, so that the appropriate setting is always found.

5 The spherical aberration can be compensated in a stationary way, by using a constant setting for the whole recording layer. However, the feature defined in claim 5 has the advantage that the spherical aberration can be compensated more precisely, by determining and indexing a specific setting at different radial positions and then applying the specific setting as a function of the current radial position of the incident beam. The indexation of the specific setting provides a fast recovery of the appropriate setting at each radial jump of the
10 incident beam. Thus, variations in the thickness of a layer along the radius of the disk can be taken into account and corrected.

The invention applies to both single recording layer media and multiple recording layer media. In the latter case, at least one specific setting of the spherical aberration correction must be determined for each recording layer. The feature defined in claim 6 has the
15 advantage that the indexation of the specific setting provides a fast recovery of the appropriate setting whenever the incident beam jumps to a different layer. The indexation of the specific settings in accordance with the recording layer and the indexation in accordance with the radial position can also be used in combination.

The features defined in claims 7 and 8 have the advantage that the radial push-pull
20 signal and a signal representing the wobble of the track, if any, are already available in most existing systems for other purposes, such as radial tracking, addressing, etc. The feature defined in claim 8 has a further advantage, i.e. that a radial wobble signal can be made continuously available in the radial closed loop situation, i.e. while the focusing spot is following the track. Hence, the determination of the specific optimal setting can take place
25 during regular operation, i.e. while writing or reading data.

The feature defined in claim 10 has the advantage that the specific setting or settings determined in accordance with the invention, are made available for future use, so that the determination process has to be carried out only once per disk or disk area.

The invention also provides an optical data carrier as stated in claim 11. At start-up,
30 the data representing the spherical aberration correction setting can be read by an optical pickup and used for setting an associated spherical aberration correction actuator fast and accurately. For example, several spherical aberration correction settings may be encoded on the optical data carrier with indexation data for indexing the settings as a function of the corresponding radial position and layer to which they pertain.

These and other aspects of the invention will be apparent from and will be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 The invention will now be described in more detail, by way of example, with reference to the accompanying drawings, in which:
- Figure 1 is a schematic plan view of an optical disk for use in an apparatus in accordance with embodiments of the invention.
 - Figure 2 is a schematic partial cross-sectional view of the optical disk taken on line II-II
10 of Figure 1 in the case of a single layer disk.
 - Figure 3 is a view similar to Figure 2 in the case of a dual layer disk.
 - Figure 4 is a schematic enlarged perspective view showing portion IV of Figure 1.
 - Figure 5 is a schematic representation of an apparatus according to one embodiment of the present invention for reading data from and/or writing data onto an optical data
15 carrier.
 - Figure 6 is a block diagram of a preprocessing circuit of the apparatus of Figure 5.
 - Figure 7 is an example of a typical variation of the amplitude of a radial push-pull signal with respect to a thickness error of a substrate layer of the optical disk.
 - Figure 8 is a graph showing an illustrative result of a curve-fitting step in the method of
20 Figure 9.
 - Figure 9 is a block diagram of a method for setting a spherical aberration correction in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

25 Fig. 1 shows an inscribable data carrier 1. The data carrier 1 is an optical disk having tracks each forming a 360° turn of a spiral line 3. Each track comprises a groove 4 and a land 5. The data carrier has at least one recording layer for the purpose of recording data. Figure 2 shows a small part of the data carrier 1 in sectional view in the case of a single-layer disk. The recording layer 6 is deposited on a transparent substrate 7 and is covered by a protective
30 layer 8. Figure 3 is a similar sectional view in the case of a dual-layer disk. A transparent spacer layer 10 separates the two recording layers 6 and 9. In each recording layer, the data is recorded in the grooves 4. An incident optical beam 11 is radiated through the substrate or transmission layer 7 for the purpose of scanning the tracks 3 for reading or writing data. Disk standards provide several dimensional specifications, such as track pitch, transmission layer

thickness, and spacer layer thickness. In BD (Blu-ray Disk), for example, the transmission layer specification is 100 microns and the spacer layer specification is between 20 and 30 microns.

5 Fig. 4 shows an enlarged portion of the data carrier 1, which comprises an empty track 12 and a written track 13. In the recording layer 6, the data bits are represented as pits 14 having different lengths. A pit 14 makes a reflected beam interfere destructively with the incident beam so as to produce substantial drops in intensity on a detector. As represented, the tracks have a continuous sinusoidal deviation from their average centerline, which is called wobble. In some implementations, the wobble is used for tracking, i.e. maintaining the
10 focused beam on a track. The wobble frequency is different for different standards, for example 820kHz in DVD+RW and 141kHz in DVD-RW or DVD-RAM. In some standards, the wobble is modulated to carry addressing information. In DVD+RW, DVD+R and BD (Blu-ray Disk), for example, the wobble is phase-modulated. In DVD-RW, the wobble is
15 frequency-modulated. However, the presence of wobble is not required in certain embodiments of the invention.

Fig. 5 shows an example of an apparatus for reading data from and writing data onto the data carrier 1. The apparatus of Fig. 5 comprises an optical source 15, for example a
20 semiconductor laser. The optical source 15 generates an incident optical beam 11, which is directed onto the data carrier 1 by means of an optical system comprising, inter alia, a beam splitter 16, a collimator lens 17, and an objective lens 18. The collimator lens 17 produces a substantially parallel beam 11a, which is focused by the objective lens 18 so as to produce a focusing spot 21 on the data carrier 1. For the spot 21 to scan the tracks, the data carrier 1 is
25 rotated about a shaft 22 by a motor 23. An actuator 24, for example an electromagnetic actuator, is capable of moving the objective lens 18 parallel to the optical axis thereof, in order to vary a depth of the focusing spot 21. An actuator 19, for example an electromagnetic actuator, is capable of moving the collimator lens 17 parallel to the optical axis thereof in order to render the beam 11 a slightly convergent or divergent for the purpose of correcting
30 any spherical aberration. When the thickness of the transmission layer 7 is smaller than the standard value, the incident beam 11a is rendered more convergent by moving the collimator lens 17 towards the objective lens 18. A control unit 20 controls the actuators 19 and 25, as will be explained below. The carrier 1 reflects the incident beam 11. The reflected beam 25 is separated from the incident beam 11 by the beam splitter 16 and impinges on a quadruple

photodetector 26, which passes the intensity signals A, B, C and D to a preprocessing circuit 27. The entire optical system is fitted on a single support so as to constitute an integrally moveable optical head 38.

5 As is shown in more details in Fig. 6, the quadruple photodetector 26 has four sensors 26A-26D for sensing the intensities of four portions 25A-25D of the reflected beam 25. The arrow R represents the relation between the beam portions and the radial direction of the data carrier 1 and the arrow T represents the relation between the beam portions and the tangential direction of the data carrier 1. In other words, sensor 26A detects an intensity corresponding
10 to an inner upper quarter of the spot 21 as reflected by the data carrier 1 and sensor 26C detects an intensity corresponding to an outer lower quarter. The preprocessing circuit 27 processes the intensity signals A-D generated by the sensors 26A-26D so as to produce a data signal $HF=A+B+C+D$ and a radial push-pull signal $PP=A+B-(C+D)$. In addition, a DPD detector circuit 28 is capable of producing a radial error signal RES when the scanned
15 recording layer has data pits.

Reverting to Fig. 5, the radial push-pull signal PP and the radial error signal RES are passed on to a radial servo circuit 29 responsible for controlling the position of the optical head 38 in the radial direction of the data carrier 1, as is usual in the art. The data signal HF is
20 passed on to a data recovery mechanism, which need not be further described here. A wobble recovery circuit 30 filters the radial push-pull signal PP so as to extract a wobble signal WS, which is passed on to the control unit 20. For example, the wobble frequency may be about 800kHz. The wobble recovery circuit 30 may also remove the data-to-wobble crosstalk. For example, the control unit 20 demodulates the wobble signal WS to extract the addressing
25 information carried by the wobble signal WS. This addressing information is used, for example, in order to derive the current position of the spot 21 on the data carrier 1. During reading, erasing or writing, the control unit 20 can compare the current position of the spot 21 with the desired position and determine parameters for a jump of the optical system to the required position. The parameters of the jump are fed to the servo circuit 29.

30 The control unit 20, including one or several microprocessors, is responsible for several control tasks. Arrow 31 represents its capability of controlling the servo circuit 29. Arrow 32 represents its capability of controlling the focus actuator 24, so as to keep the focusing spot 21 focused on a selected recording layer of the data carrier 1. Arrow 33 represents its capability of controlling the optical source 11, for example when writing data onto the data

carrier 1. Arrow 34 represents its capability of controlling the spherical aberration correction actuator 19, in accordance with embodiments of the invention to be described in more detail below.

5 Fig. 7 is a graph showing a theoretical calculation result. The x-axis represents the thickness error of the transmission layer of a Blu-ray disk, i.e. the difference between the actual transmission layer thickness traveled by the beam and the standard-specified thickness. As is usual in the art, the objective lens 18 provides a preset correction for the spherical aberration that corresponds to the standard thickness. Any departure from the standard
10 thickness results in a residual spherical aberration. The y-axis represents the peak-to-peak intensity of the radial push-pull signal PP as the spot is scanning a recording layer of the disk. The signal is computed for an open-loop scanning, i.e. with radial servo disabled.

The calculation result shows that the radial push-pull amplitude curve 3 reaches its highest point for a zero thickness error and varies in a substantially parabolic manner about
15 that highest point. This is due to the fact that, in the absence of any thickness error, i.e. for a zero residual spherical aberration, the spot size is minimal, so that the modulation of the returning light due to the pits and the groove and other structural elements of the recording layer is maximal. A typical target for correcting the spherical aberration caused by thickness error on a Blu-ray disk is to bring the residual spherical aberration down to a level
20 corresponding to +/- 2 microns thickness error or lower. The plot of Fig. 7 shows that achieving this accuracy is quite possible if one measures the amplitude of the signal PP vs. the spherical aberration correction over a range corresponding to a substrate thickness error between, for example, -10 microns and + 10 microns.

25 A similar result is obtained in a radial closed-loop situation (i.e. radial servo enabled) when substituting the radial wobble signal for the radial push-pull signal. Embodiments of the method of determining an optimal setting of the spherical aberration correction in accordance with the invention are derived from the above theoretical results.

30 A first embodiment of the invention is described with reference to Figs. 8 and 9.

When a spherical aberration correction is needed for the first time, for example when a disk is inserted in the apparatus, the following steps are executed:

Measurement acquisition step 40 :

While the radial servo circuit 29 is disabled (i.e. the optical head 38 is at a fixed radial position) and the disk is rotating, the control unit 20 sequentially sets the driving voltage V of the actuator 19 to a plurality of voltage levels $V_1, V_2 \dots V_7$. The amplitude PP_i of the signal PP is determined for each voltage level V_i , which corresponds to a respective position of the collimator lens 17. The measurement data set (V_i, PP_i) is stored in the memory 36.

The signal PP oscillates as a function of the lateral position of the spot with respect to the groove, which varies because of the absence of radial tracking and because of the eccentricity of the disk. The groove need not be wobbling for the signal PP to oscillate.

Since each measurement is averaged over a complete revolution of the disk, it is not very sensitive to scratches, dust, or electronic noise.

The voltage levels are selected such that the collimator lens 17 scans a preset range 37, which is sufficiently large to cover all possible values of the spherical aberration. This range can be determined by taking into account the tolerances of the transmission layer thickness (and spacer layer thickness, if any) according to the media standard. The number of measurements is selected in accordance with the range to be scanned 37 and the accuracy that is needed. The number of measurements shown in Fig. 8 is purely illustrative.

Curve fitting step 41:

A fitting curve 42 is calculated by means of a conventional method so as to fit the measurement data set (V_i, PP_i) . Preferably, a parabolic interpolation curve is used, since the theoretical curve should be close to a second-order polynomial.

Optimal setting determination step 43:

The driving voltage level V_o , for which the fitting curve 42 reaches its highest point, is determined. The voltage V_o is the desired optimal setting of the collimator lens actuator 19, for which any residual spherical aberration due to thickness errors of the transmission layer, and of the spacer layer if any, should be suppressed. This optimal setting can then be applied to the actuator 19 for reading or writing data. It should be emphasized that the optimal setting V_o is obtained in a format which is already calibrated for the actuator 19 used in the measurement acquisition step.

Storing the optimal setting (step 44):

The optimal setting V_o or any equivalent data representing the same is stored in the memory 36 of the apparatus or written on the data carrier 1. If stored in the apparatus, the optimal setting data may be indexed with a data carrier identifier, so that the appropriate

optimal setting data can be recovered when the same data carrier is inserted in the apparatus at a later time, without having to repeat the determination procedure. Similarly, the optimal setting data may be indexed with an apparatus identifier if it was stored on the data carrier.

5 The optimal setting data may also be stored in a portable format, so that it can be recovered and used by a plurality of optical pickups. However, portability of the optimal setting data requires that every spherical aberration correction actuator can be accurately controlled with a portable signal. If a stepper motor is used, the step size is very accurate, so the portable optimal setting data can consist of a number of steps. In addition, an accurate zero position of every correction actuator is needed. One of the means by which the zero
10 position of the stepper motor can be detected is an optical sensor. Portability of the optimal setting data is by no means mandatory. The optimal setting determination procedure is fast and may be repeated whenever a disk is inserted in the apparatus.

For multiple-layer data carriers, the optimal setting determination procedure must be carried out at least once for each recording layer. Then the corresponding optimal setting data
15 is also indexed with a layer identifier, which may be, for example, a focusing position of the objective lens actuator 24.

On multiple-layer disks, the combined thickness of the transmission layer and the spacer layer(s) is likely to have a substantial variation in different positions along the radius of the disk. This may be the case for the transmission layer of a single-layer disk, too. Hence,
20 in a preferred embodiment of the invention, the optimal setting is determined at several radial positions of the optical head 38. The corresponding optimal setting data is indexed as a function of the radial position for which it has been determined. Then the control unit 20 will be capable of reading the appropriate optimal setting data on the data carrier 1 or in the memory 36 when the optical head 38 moves from one position to another; so as to update the
25 setting of the actuator 19 in accordance with the optimal setting data.

In a second embodiment of the invention, the radial wobble signal WS is used instead of the signal PP. The optimal setting determination procedure in accordance with the second embodiment is similar to that of the first embodiment, so only the differences will be
30 described here.

In order to acquire the radial wobble signal WS, the radial servo 29 is switched on. The radial position of the optical head 38 is now controlled in a closed-loop so as to maintain the focusing spot 21 on the tracks. The steps 40 to 44 of Fig. 9 are carried out in the same manner, but the control unit 20 now uses the signal WS instead of the signal PP.

This has the major advantage that the setting determination and the application of the spherical aberration correction can take place during regular operations, during reading or writing of data. The wobble signal WS is due to the fact that the groove position varies sinusoidally. As the radial push-pull signal PP measures the position of the spot with respect to the groove, the signal PP will be sinusoidal, too. The wobble signal WS can be regarded as a small variation of the signal PP across its zero-crossing.

The above methods of determining the optimal setting of the spherical aberration correction may be implemented with a computer program 39 loaded into the control unit 20. Although the control unit 20 has been represented as a single block, it does not necessarily consist of a single integrated component. The control unit 20 may be a combination of several items of hardware and software.

In the apparatus, it is possible to use types of spherical aberration correction actuator other than the above-mentioned actuator for setting the position of the collimator lens along the optical path of the incident beam. Other suitable spherical aberration correction actuators include, for example, actuators capable of varying an interval of a two-group objective lens, liquid-crystal phase compensating elements, additional lens assemblies, and the like. An actuator for setting the position of the collimator lens has the advantage of a minimal cost and bulk, since a collimator lens is generally needed anyway.

Where signal to noise ratio is not critical, a downgraded difference signal such as A-D or B-C may be used instead of the regular push-pull signal PP. The quadruple photodetector that is used in the above embodiments is not limitative. For example, a double photodetector having a dividing line in a parallel relation to the direction of the tracks to be scanned may be used instead.

In the above embodiments, a specific setting of the spherical aberration correction is determined by maximizing the amplitude of the radial push-pull signal or the amplitude of the radial wobble signal. During the reading or writing of data, this specific setting is applied to the spherical aberration correction actuator in order to provide an optimal correction of the spherical aberration caused by thickness errors in the data carrier.

The use of the verb "to comprise" or "to include" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. Furthermore, the use of the article "a" or "an" preceding an element or step does not exclude the presence of a plurality of such elements or steps. The invention may be implemented by means of hardware

as well as software. Not every "means" stated in a claim will necessarily correspond to a separate element of hardware in the apparatus. The same item of hardware may encompass several "means". In the claims, any reference signs placed between parentheses shall not be construed as limiting the scope of the claims.

CLAIMS

1 An apparatus for reading data from and/or writing data onto an optical data carrier (1),
said apparatus comprising:

- 5 an optical source (15) for generating an incident beam,
a spherical aberration correction actuator (19) for applying a spherical aberration correction
to said incident beam,
a spherical aberration correction controller (20) for selectively varying a setting of the
spherical aberration correction applied to the incident beam,
10 an objective lens (18) for focusing said incident beam onto said optical data carrier,
an optical detection assembly (26) for detecting respective intensities of two substantially
symmetrical portions of a reflected beam (25), said two portions being opposed one to the
other substantially transversely to a direction (T) of relative movement between said incident
beam and said optical data carrier,
15 a difference signal generator (27, 30) for generating a difference signal (PP, WS) resulting
from a difference between the intensities of said two reflected beam portions, and
determination means (20) for determining a specific setting (VO) of said spherical aberration
correction, which maximizes an amplitude of said difference signal.

2 An apparatus as claimed in claim 1, wherein said determination means includes a
20 measurement acquisition means for acquiring a plurality of measurements (PPi) of the
difference signal amplitude vs. a corresponding plurality of settings (Vi) of the spherical
aberration correction.

3 An apparatus as claimed in claim 2, wherein said determination means further
includes curve fitting means for generating a curve (42), which fits said plurality of
25 measurements, wherein said specific setting (VO) corresponds to a maximum of said curve.

4 An apparatus as claimed in claim 2, wherein said plurality of settings spans a preset
range (37) of the spherical aberration correction.

5 An apparatus as claimed in claim 1, further comprising indexation means (20) for
indexing said specific setting as a function of a radial position of said incident beam (21)
30 along a radius of the optical data carrier.

6 An apparatus as claimed in claim 1, further comprising indexation means (20) for
indexing said specific setting as a function of a corresponding recording layer of the optical
data carrier.

7 An apparatus as claimed in claim 1, wherein said optical data carrier is a disk (1) and said difference signal is a radial push pull signal (PP).

8 An apparatus as claimed in claim 1, further comprising tracking means (29) for
5 maintaining said incident beam on a track (3) of said optical data carrier, wherein said difference signal represents a wobble of said track, on which said incident beam is maintained.

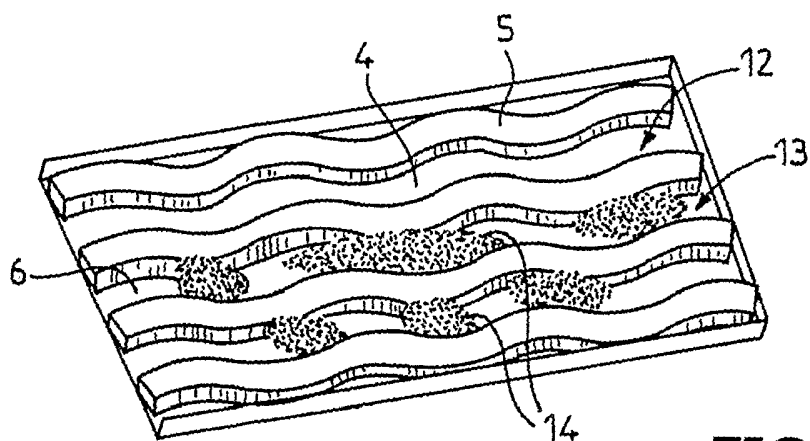
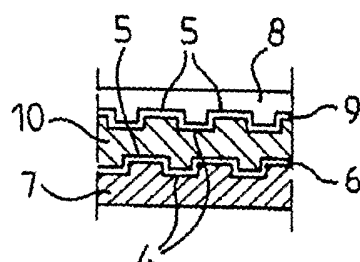
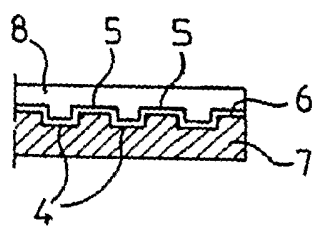
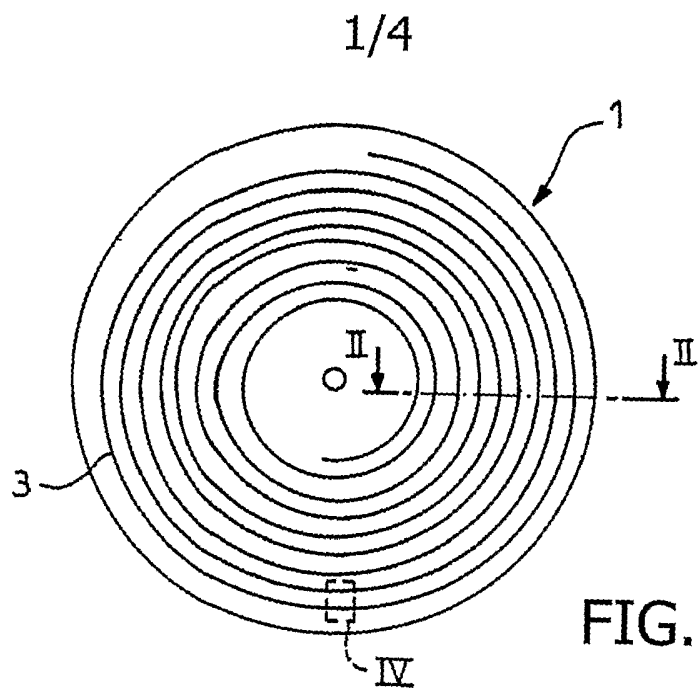
9 A method of determining the setting of a spherical aberration correction to be applied to an optical beam in an apparatus for reading data from and/or writing data onto an optical data carrier (1), said method comprising the steps of:

10 generating an incident beam (11),
applying a spherical aberration correction to said incident beam,
focusing said incident beam onto said optical data carrier so as to produce a reflected beam (25),
measuring a difference signal (PP, WS), which results from a difference between the
15 intensities of two substantially symmetrical portions of said reflected beam, said two portions being opposed one to the other substantially transversely to a direction (T) of relative movement between said incident beam and said optical data carrier,
determining (43) a specific setting of said spherical aberration correction, which maximizes an amplitude of said difference signal.

20 10 A method as claimed in claim 9, further comprising the step of storing (44) said specific setting of the spherical aberration correction in said apparatus or on said optical data carrier.

11 An optical data carrier (1), which carries readable data representing a specific spherical aberration correction setting obtainable by the method as claimed in claim 9.

25



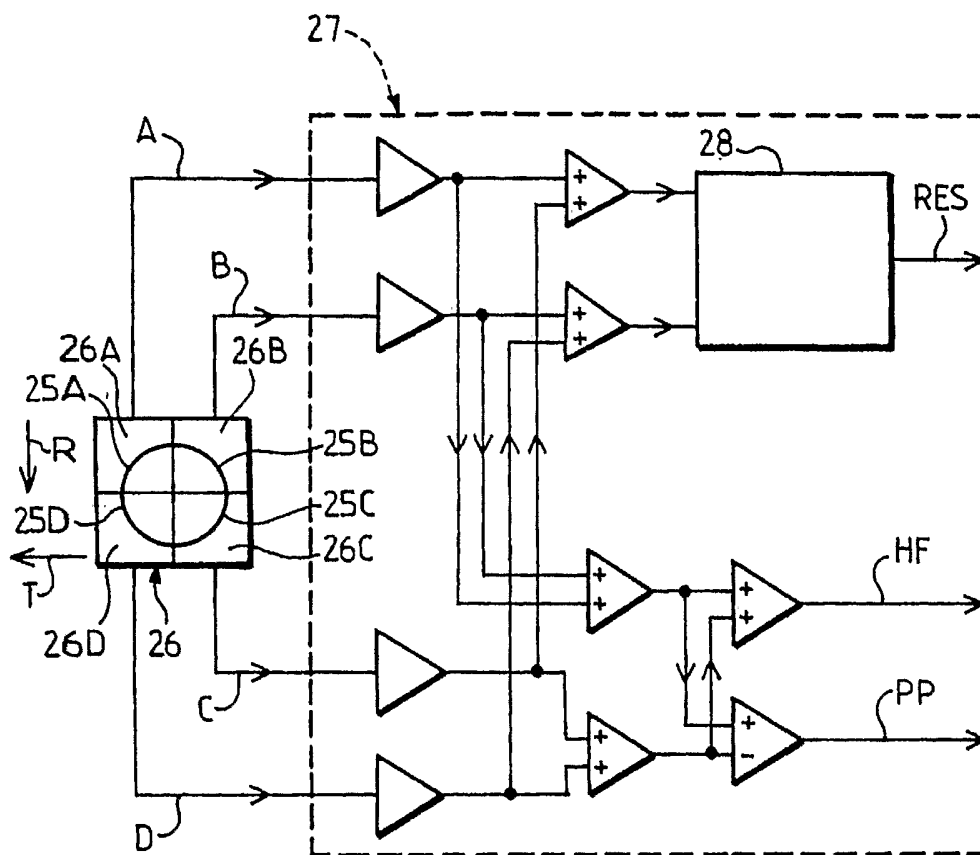


FIG.6

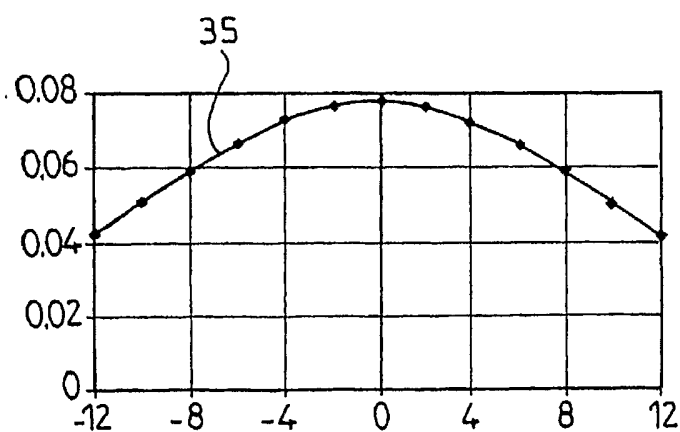


FIG.7

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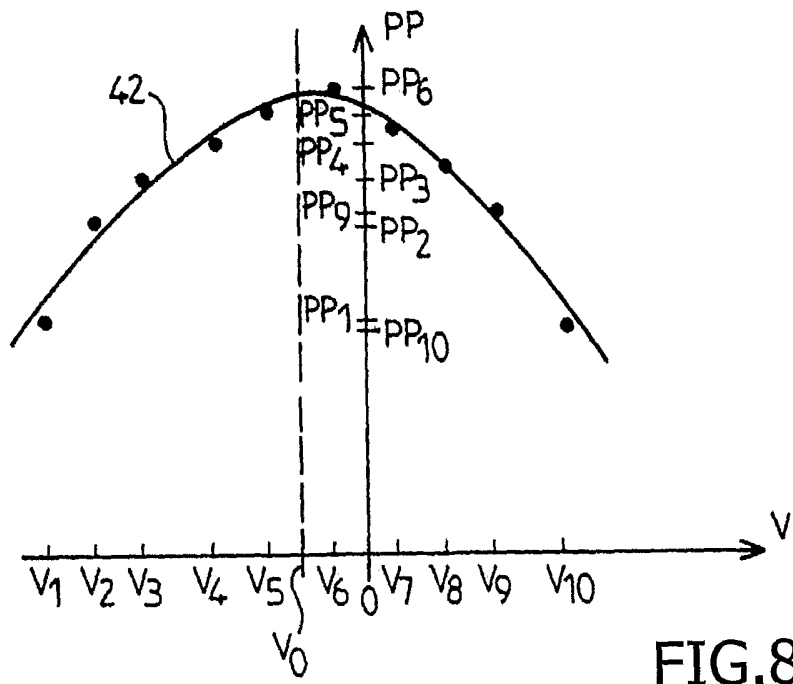


FIG.8

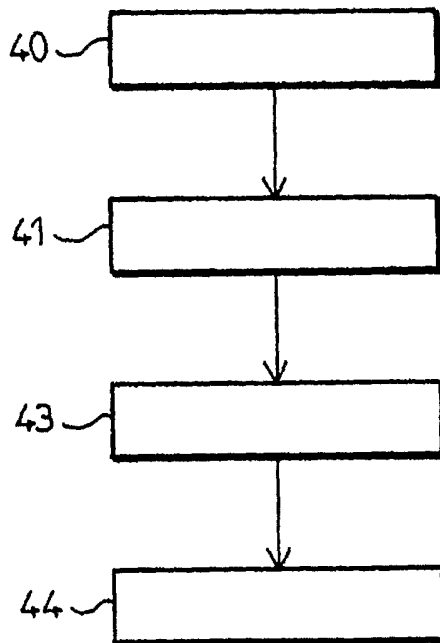


FIG.9