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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)*: **HENDRIKS, Bernardus, H., W.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **KUIPER, Stein** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agents: UITTENBOGAARD, Frank et al.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

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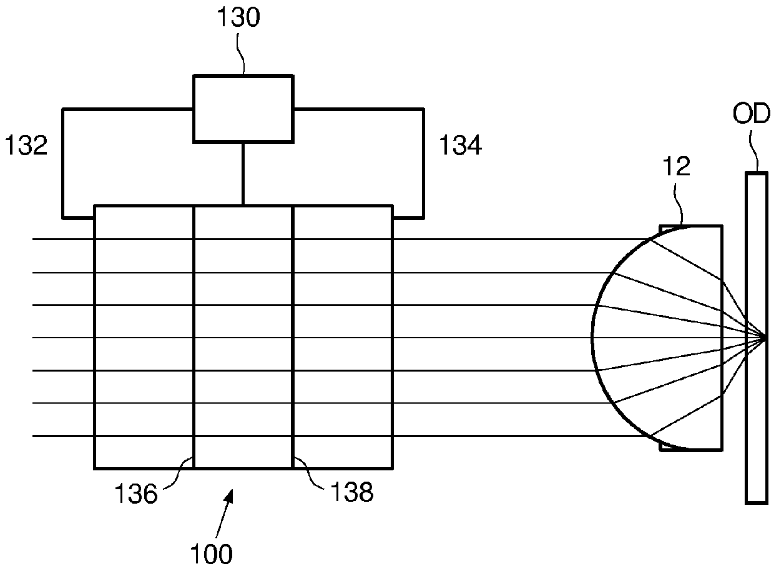
(54) Title: DUAL LAYER READOUT WITH IMPROVED TOLERANCES



(57) Abstract: An optical scanning device for scanning an optical record carrier (OD) with an objective lens (12) for converging a radiation beam to a spot (18) on an information layer (3,4) of the record carrier (OD), and an optical correcting system (10) for changing the vergence of the radiation beam and the amount of spherical aberration in the radiation beam towards the objective lens, wherein the vergence and the amount of spherical aberration in the radiation beam can be adapted independently.

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Dual layer readout with improved tolerances

TECHNICAL FIELD

The invention relates to an optical scanning device, and an optical element for use therein, for scanning an information layer of an optical record carrier, the device being adapted for scanning information layers at different depths within the record carrier.

BACKGROUND OF THE INVENTION

The invention relates to an optical scanning device, and an optical element for use therein, for scanning an information layer of an optical record carrier, the device being adapted for scanning information layers at different depths within the record carrier. In particular, but not exclusively, the invention relates to an optical compensator arranged to compensate for spherical aberrations generated by different optical path lengths through which the beam travels in an optical record carrier to and from different information layers in the record carrier.

There is a need for the production of optical record carriers of high capacity. The capacity can be increased by providing more than one information layer in the record carrier. A typical construction of such a record carrier having two information layers is to have a transparent cover layer over the first information layer and another transparent cover layer between the first and second information layers, so that the two information layers are positioned at different depths within record carrier. There is also a need for optical scanning devices that are capable of reading and recording such high capacity record carriers. There is also a need for optical scanning devices which are capable of reading different types of record carriers which have their information layers located at different depths within the record carrier, for example, compact discs (CD), digital versatile discs (DVD) and blu-ray discs (BD). Thus, there is a need for optical scanning devices that can scan information layers at different depths within a record carrier.

In order to scan an information layer within a record carrier, an optical scanning device focuses a radiation beam on the information layer which is to be scanned. Refocusing the radiation beam from a first information layer at one depth within the record carrier to a second information layer at another depth will result in a change in the optical path length through which the beam travels in the transparent cover layers of the record carrier to and from different information layers in the record carrier. Different amounts of spherical aberration are generated by the record carrier due to the change in optical path length of the radiation beam. This change in spherical aberration deteriorates the resolution of the optical spot formed. Various methods are known for compensating for this change in spherical aberration.

The objective lens may be constructed of two or more lens elements that can be moved axially with respect to each other to provide spherical aberration compensation. This method has the disadvantage that the required mechanical movement of the lens elements results in a scanning device with additional moving parts that is more complex and expensive to manufacture.

Another method is to change the conjugate (object distance) of the objective lens by changing the radiation beam that impinges on the objective lens from a collimated beam (having substantially parallel light beams) into a convergent or divergent beam. This can be accomplished, for example, by mechanically adjusting the position of a collimator lens with respect to the radiation source to produce a convergent or divergent beam instead of a collimated beam. This change in the vergence of the beam entering the objective lens changes the conjugate of the objective lens and also causes the objective lens to generate an additional amount of spherical aberration. At a certain vergence, the amount of additional spherical aberration may be just enough to compensate for the spherical aberration generated by the difference in thickness of the transparent layers through which the radiation beam passes to scan the information layers.

However, this method requires additional moving parts to move the collimator lens. Furthermore, the compensating spherical aberration is all produced by the objective lens, resulting in the tolerance for field of view being significantly reduced. To overcome the latter drawback, the additional compensating spherical aberration may be generated in a compensating element separate from the objective lens so that the beam entering the objective lens is already aberrated. This can be accomplished, for example, by passing the radiation beam through a twisted nematic liquid crystal cell to selectively rotate the polarization of the beam and then, when the beam is in a convergent state, through a birefringent plate to produce spherical aberration therein. A drawback of this construction is that the tolerance for de-centering of the objective lens (needed for tracking purposes) with respect to the aberration-generating device is reduced.

One prior method for producing both a conjugate change and a compensating amount of spherical aberration in an element separate from the objective lens uses an electrowetting switchable fluid cell as a compensator. WO2004/084188 discloses an optical scanning device with such a compensator which both introduces spherical aberration and changes the vergence of the radiation beam. The compensator generates different amounts of vergence and spherical aberration in a radiation beam when in a first state and when in a second state, the different amounts of vergence and spherical aberration being such as to at least partially compensate for the change in spherical aberration when the device switches from scanning a first information layer to scanning a second information layer.

In this system, by proper choice of the refractive index of the two fluids used in the fluid cell, the vergence change may be such that no refocusing is needed of the objective lens, while the amount of spherical aberration produced by the compensator is such that the amount of spherical aberration generated by the compensator and by the objective lens due to the vergence change of the beam sufficiently compensates for the additional amount of spherical aberration generated by the change in optical path length when different information layers are scanned.

However, in order to manufacture an optical scanning device incorporating such a compensator that will introduce the correct amount of spherical aberration, the manufacture of the components and assembly of the components into a system must be within certain tolerances. Any deviation from these manufacturing tolerances will result in an amount of spherical aberration generated by the device that is different for each assembled device. As a result, the optimal amount of spherical aberration to be generated by the compensator for a certain conjugate change in the objective lens will differ for each assembled device.

It is an object of the invention to provide an improved spherical aberration compensation system and an optical scanning device including an improved spherical aberration compensation system, capable of scanning information layers at differing depths within an optical record carrier.

SUMMARY OF THE INVENTION

In accordance with the invention, an optical scanning device is provided for scanning an optical record carrier when positioned in a scanning location in the device, the optical record carrier having a transparent cover layer with a thickness and at least one information layer, and the device being adapted for scanning the at least one information layer. The device includes a radiation source for generating a radiation beam, and an objective lens located in an optical path between the radiation source and the scanning location, for converging a radiation beam to a spot on an information layer. The device also includes an optical correcting system for changing the vergence of the radiation beam and the amount of spherical aberration in the radiation beam towards the objective lens, so that the vergence and the amount of spherical aberration in the radiation beam can be adapted independently.

The optical correcting system preferably comprises a set of fluids having a first meniscus having a first radius and a second meniscus having a second radius, the first radius and second radius being separately adaptable. The set of fluids may be located in a single container comprising the first meniscus and second meniscus, or the set of fluids may be located in two containers, one comprising the first meniscus and the other comprising the second meniscus.

The optical correcting system may comprise at least one movable collimator lens for changing the vergence of the radiation beam entering the objective lens and an optical element adapted for changing the amount of spherical aberration in the radiation beam entering the objective lens. The optical element may comprise a liquid crystal material, or a set of fluids having a meniscus.

The optical scanning device may be adapted for scanning an optical record carrier having at least first and second information layers, a first transparent layer thickness above the first information layer introducing a first amount of spherical aberration and a second transparent layer thickness above the second information layer introducing a second amount of spherical aberration, wherein the optical correcting system can be adapted to compensate for the first amount of spherical aberration and second amount of spherical aberration when scanning the first and second information layers respectively. The optical correcting system preferably changes the vergence of the radiation beam to converge the radiation beam to a spot on one of the information layers and changes the amount of spherical aberration in the radiation beam to minimize spherical aberration in the radiation beam.

The optical scanning device may be adapted for scanning a first type of optical record carrier having a transparent cover layer with a first thickness introducing a first amount of spherical aberration and for scanning a second type of optical record carrier having a transparent cover layer with a second thickness introducing a second amount of spherical aberration, wherein the optical correcting system can be adapted to compensate for the first amount of spherical aberration and second amount of spherical aberration when scanning the at least one information layer.

The optical scanning device may be operated by adjusting the correcting system to change the vergence of the radiation beam to converge the radiation beam to a spot on an information layer of the optical record carrier, and adjusting the correcting system to change the amount of spherical aberration in the radiation beam to minimize spherical aberration in the radiation beam. The method of operating the optical scanning device may further include scanning the optical record carrier with the radiation beam to derive a read signal, measuring jitter of the read signal, and adjusting the optical correcting system based on the jitter measurement.

The invention additionally relates to an optical correcting system adapted for use in an optical scanning device, where the optical scanning device includes a radiation source for generating a radiation beam and an objective lens for converging the radiation beam to a spot on an information layer of an optical record carrier, and the optical correcting system is adapted for changing the vergence of the radiation beam and independently changing the amount of spherical aberration in the radiation beam. The optical correcting system preferably comprises a set of fluids having a first meniscus having a first radius and a second meniscus having a second radius, the first radius and second radius being separately adaptable. The set of fluids may be located in a single container comprising the first meniscus and second meniscus, or may be located in two containers, the first container comprising the first meniscus and the second container comprising the second meniscus.

Thus, the invention provides an optical correcting system that permits the vergence of the radiation beam and the amount of spherical aberration in the radiation beam to be adjusted independently. This results in an improved spherical aberration compensation system that permits the conjugate of the objective lens and the amount of spherical aberration in the beam to be adjusted separately. As a result, manufacturing errors and tolerances in the components and assembly of the system may be taken into account and the optimal amount of spherical aberration compensation generated for each system. Furthermore, unnecessary moving parts are avoided. In addition, at least part of the compensating spherical aberration is produced by a compensating element separate from the objective lens, so that the tolerance for field of view is not significantly reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Further aspects, features and advantages of various embodiments of the invention will become apparent from the following description, given by way of example only, of preferred embodiments of the invention, referring to the accompanying drawings, wherein :

Fig. 1 is a schematic diagram of an optical scanning device arranged in accordance with embodiments of the invention;

Fig. 2 is a schematic diagram of an electrowetting fluid cell for use in an embodiment of the invention;

Figs. 3 and 4 are schematic diagrams of an arrangement including an electrowetting fluid cell of Fig. 2 for use in an embodiment of the invention; and

Fig. 5 is a schematic diagram of an arrangement including two electrowetting fluid cells for use in an embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 is a schematic diagram of major components of an optical scanning device for scanning an optical record carrier. The record carrier may be, for example, an optical disc such as a CD, DVD or BD type disc. A dual layer disc is shown in the example, although the invention may be readily used with single layer or other multi-layer discs.

The optical disc OD comprises a substrate 1 and a transparent cover layer 2, behind which two information layers 3,4 are arranged, at different depths within the disc, separated by a further transparent layer 5. The transparent cover layer 2, has the function of protecting the uppermost information layer 3, while mechanical support is provided by the substrate 1.

Information may be stored in the information layers 3,4 of the optical disc in the form of optically detectable marks arranged in substantially parallel, concentric or spiral tracks, not indicated in Fig. 1. The marks may be in any optically readable form, e.g. in the form of pits, or areas with a reflection coefficient or a direction of magnetization different from their surroundings, or a combination of these forms.

The scanning device includes an optical pickup unit (OPU) mounted on a radially-movable arm. The OPU may include all components illustrated in Fig. 1, other than the disc OD. A radiation source 6, for example a semiconductor laser, emits a diverging radiation beam 7. A beam splitter 8, in this example a polarizing beam splitter, reflects the radiation beam within a lens system. The lens system includes a collimator lens 9, an objective lens 12 and a condenser lens 11. The objective lens 12 is mounted on a movable mounting 13 held within mechanical actuators (not shown) for performing radial tracking servo and focus servo adjustment of the position of the objective lens 12. The scanning device also includes an optical switching arrangement including a compensator 10, in this embodiment a switchable fluid cell, to be discussed in further detail below.

The collimator lens 9 refracts the diverging radiation beam 7 to form a collimated beam 15. By collimated, we intend to mean a substantially parallel beam, for which the compound objective lens has a transverse magnification substantially equal to zero. The objective lens 12 transforms the collimated radiation beam 15 into a converging beam 16 having a high numerical aperture (NA) which comes to a spot 18 on the information layer, 3 or 4, being scanned. Note that, although the objective lens is shown as a single lens 12, it may be a compound lens including two or more lens elements.

Radiation of the converging beam 16 reflected by the information layer 3 or 4 forms a diverging reflected beam 20, which returns along the optical path of the forward converging beam. The objective lens 12 transforms the reflected beam 20 to a substantially collimated reflected beam 21, and the beam splitter 8 separates the forward and reflected beams by transmitting at least part of the reflected beam 21 towards the condenser lens 11.

The condenser lens 11 transforms the incident beam into a convergent reflected beam 22 focused on detection systems, generally indicated by a single element 23, although a plurality of detector elements may be used. The detection systems capture the radiation and convert it into electrical signals. One of these signals is an information signal 24, the value of which represents the information read from the information layer being scanned. Another signal is a focus error signal 25, the value of which represents the axial difference in height between the spot 18 and the respective information layer 3,4 being scanned. Another signal is a tracking error signal 26, the value of which represents a radial deviation of the spot from the track being scanned. Each of the signals 25,26 are input to the focus servo and tracking servo mechanical actuators controlling the position of mounting 13 during scanning.

A layer switching signal 30 is input into the compensator 10. The layer switching signal 30 represents the selected information layer 3 or 4 in the optical disc currently being scanned. In one embodiment, an electrowetting fluid cell 100 is used as the compensator.

Fig. 2 is a schematic diagram of an electrowetting fluid cell 100 for use in an embodiment of the invention. The fluid cell 100 comprises a cylindrical first electrode 102 forming a capillary tube, sealed by means of a transparent front element 104 and transparent back element 106 to form a fluid chamber containing two fluids.

The central portion of the cylinder is filled with a first, transparent and non-conductive fluid A. At each side of the fluid A, a second, transparent and conductive fluid B is present, which fluid has a different refractive index than the first fluid A. The non-miscible fluids A and B at the left side of Fig. 2 are separated by a first meniscus 114, which forms a first variable-focus lens element. The fluids A and B at the right side of Fig. 2 are separated by a second meniscus 115, which forms the second variable-focus lens element. Suitable fluids may be liquid or vapor. In addition, three different fluids A, B and C may be used.

In one embodiment the two fluids consist of two non-miscible liquids in the form of an electrically insulating first liquid A, such as a silicone oil or an alkane, referred to herein further as "the oil", and an electrically conducting second liquid B, such as an aqueous salt solution. In another embodiment, an oil such as polydimethyl (8-12%)-phenylmethylsiloxane copolymer may be used as the first liquid A. The two liquids are preferably arranged so as to have equal densities so that the lens functions independently of orientation, i.e. without dependence on gravitational effects between the two liquids. This may be achieved by an appropriate choice of the first liquid constituent; for example alkanes or silicone oils may be modified by addition of molecular constituents to increase their density to match that of the salt solution.

Depending on the choice of the oil used, the refractive index of the oil may preferably vary between 1.25 and 1.60. Likewise, dependent on the amount of salt added, the salt solution may preferably vary in refractive index between 1.33 and 1.48. The fluids in this embodiment are selected such that fluid A has a higher refractive index than fluid B, although in other designs the fluid A may have a lower refractive index than fluid B. For example, the fluid A may be a (per) fluorinated oil, which has a lower refractive index than water. In this case the amorphous fluoropolymer layer is preferably not used, because it may dissolve in fluorinated oils.

The first electrode 102 is a cylinder of inner radius typically between 1 mm and 20 mm. The electrode 102 is preferably formed from a metallic material and is coated with an insulating layer 108, for example of parylene. The insulating layer 108 preferably has a thickness of between 50 nm and 50 μm, with typical values lying between 1 μm and 10 μm. Alternatively, the electrode 102 may be a conducting coating applied on the inner wall of a tube. An alternative fluid contact layer is e.g. a paraffin coating.

The insulating layer 108 is preferably coated with a fluid contact layer 10 that reduces the hysteresis in the contact angle of the menisci with the cylindrical wall of the fluid chamber. The fluid contact layer is preferably formed from an amorphous fluorocarbon such as Teflon Tm AF1600 produced by DuPont^{TM}. The fluid contact layer 110 has a thickness of between 5 nm and 50 µm. The AF1600 coating may be produced by repeated dip coating of the electrode 102. A homogeneous layer of material of substantially uniform thickness is formed thereby since the cylindrical sides of the electrode are substantially parallel to the cylindrical electrode. Dip coating is preferably performed by dipping the electrode whilst moving the electrode into and out of the dipping solution along its axial direction. The parylene coating may be applied by chemical vapor deposition. The wettability of the fluid contact layer 110 by the second fluid is preferably substantially equal on both sides of the intersection of the menisci 114, 115 with the contact layer 110 when no voltage is applied between the first electrode and the second and third electrodes. Additional details of the construction of electrowetting fluid cells are described in patent publication nos. WO 03/069380, WO 2004/038480 and WO 2004/084188, the contents of which are incorporated herein by reference.

Second and third annular electrodes 112 and 113 are arranged at each end of the fluid chamber, in this case adjacent the front and back elements 104 and 106 respectively. At least a portion of the second and third electrodes are arranged in the fluid chamber such that the electrodes act on the second fluid B.

The fluids A and B are non-miscible so that they tend to separate into separate fluid bodies with menisci 114 and 115 in between them. When no voltage is applied between the first electrode 102 and the second and third electrodes 112 and 113, the fluid contact layer 110 has a higher wettability with respect to the first fluid A than the second fluid B. Due to electrowetting, the wettability by the second fluid B varies upon application of a voltage between the first electrode 102 and the second electrode 112 and/or third electrode 113, which tends to change the contact angle of the meniscus at the three-phase line.

The three-phase line is the line of contact between the fluid contact layer 110 and the two fluids A and B. The shape of the meniscus 114 is thus variable in dependence on the applied voltage V1, and the shape of the meniscus 115 is variable in dependence on the applied voltage V2. The meniscus is called concave if the meniscus is hollow as seen from the fluid having the higher refractive index. If this fluid is regarded as a lens, this lens would normally be called concave if the meniscus is concave according to the definition in the previous sentence. The curvatures of the menisci 114, 115 and thus the focal distances of the two lens elements formed by the menisci can be changed independently from each other by means the controllable voltages V1 and V2, respectively.

Depending on the design of the fluid cell 100, a low voltage V1 applied between electrodes 102 and 112 may cause meniscus 114 to adopt a first concave meniscus shape. In this configuration, the initial contact angle between the meniscus 114 and the fluid contact layer 110 measured in the fluid B is relatively large. Since the fluid A has a higher refractive index than the fluid B, the lens formed by the meniscus 114 has a negative power in this configuration. This causes the collimated beam 120 passing through the lens formed by the meniscus 114 to become diverged, and it also generates an additional amount of spherical aberration in the beam 120.

A progressively higher voltage applied between electrodes 102 and 112 may reduce the concavity of the meniscus 114, produce a flat planar meniscus, and produce a convex meniscus in turn. As a result, the meniscus lens formed by meniscus 114 changes from a negative power to a positive power, and the collimated beam 120 after passing through the meniscus lens changes from diverged to collimated to converged. This change in configuration of the meniscus lens will also cause the amount of additional spherical aberration generated in the meniscus lens to change. Thus, both the vergence of the beam and the amount of spherical aberration in the beam are controlled by the voltage controlling the shape of the meniscus.

Note, the configuration of the meniscus will vary in dependence on the selection of the fluids A and B, in dependence on their surface tensions. By selecting oil with a higher surface tension, and/or by adding a component, such as ethylene glycol, to the salt solution, which reduces its surface tension, the initial contact angle can be decreased. In this way a relatively wide range of lens powers can be produced without requiring the use of excessive voltages.

The meniscus 115 can be similarly controlled independently via voltage V2 applied between electrodes 102 and 113, to cause meniscus 115 to adopt a concave, flat or convex meniscus shape. The collimated beam 120 passes through both menisci 114 and 115 and thus the resulting beam 122 may be diverged, collimated, or converged according to the shapes of the menisci 114, 115 and the voltages V1 and V2. In addition, the resulting beam 122 will have different amounts of spherical aberration dependent on the shapes of the menisci 114 and 115.

The fluid cell 100 can be used to independently control the vergence of the beam and the spherical aberration in the beam. By selectively controlling the shape of the menisci of the fluid cell, the vergence of the radiation beam passing through the fluid cell can be adjusted, and the spherical aberration of the radiation beam can then be adjusted without changing the vergence of the beam. For example, Table 1 shows five different configurations of an electrowetting fluid cell giving rise to a converging beam focused at 20mm behind the fluid cell. Each configuration results in a different amount of spherical aberration generated in the beam by the fluid cell. The electrowetting device in this example includes a first fluid having a refractive index of n=1.4 forming two menisci with a second fluid having a refractive index of n=1.35. The radiation beam has a wavelength of 405 nm.

The left column of Table 1 shows the radius r1 of the meniscus closest to the radiation source, and the middle column shows the radius r2 of the meniscus closest to the objective lens (a positive value for radius indicates that the center of the radius of the meniscus is to the right of the meniscus). The right column shows the amount of spherical aberration OPDrms generated in the beam by the fluid cell for each of the five configurations of the electrowetting device. By changing the shape of the two menisci, the spherical aberration of the beam passing through the fluid cell can be altered while the vergence of the beam remains unchanged.

Radius r1 (mm)	Radius r2 (mm)	OPDrms (mλ)
1.093	Infinite	60.8
-10.611	-1	95.2
2.164	-2	18.2
1.605	-3	21.2
1.429	-4	27.0

TABLE 1

Fig. 3 shows a schematic diagram of an arrangement including a fluid cell 100, objective lens 12 and optical disc OD having two information layers (not shown). A collimated radiation beam from the radiation source of the optical scanning device passes through the electrowetting fluid cell 100 and is modified to produce modified radiation beam which is focused by objective lens 12 on to an information layer of optical disc OD.

The arrangement includes a voltage control circuit 130 for applying selected voltage signals 132 and 134 to control the shape of menisci 136 and 138 respectively. In a configuration for scanning dual-layer discs, the signals 132, 134 are selected in dependence on the information layer desired to be scanned. Signals 132, 134 are selected to control the shape of menisci 136, 138 to adjust the vergence of the beam to alter the conjugate of the objective lens 12 to focus the beam on the information layer desired to be scanned. Signals 132, 134 are also selected to generate a compensating amount of spherical aberration in the radiation beam that reduces the total spherical aberration in the radiation beam, i.e. the spherical aberration due to the fluid cell 100, objective lens 12, and cover layers of the optical disc.

For example, in one state, during the scanning of the upper information layer at a lesser depth, a relatively high selected voltage is applied to produce a substantially planar meniscus curvature as shown in Fig. 3. In another state, during the scanning of the lower information layer at a greater depth within the optical disc, a relatively low selected voltage is applied to produce a spherical meniscus curvature as shown in Fig. 4 (note, the vergence change of the radiation beam is not shown in the drawings).

Table 2 shows the radii r1, r2 of the menisci of the fluid cell having parameters as described above, for scanning an optical disc having a transparent cover layer above the first information layer of thickness d1 = 0.1 mm and transparent cover layers above the second information layer of thickness d2 = 0.11 mm. Table 2 shows the corresponding total amount of spherical aberration generated by the total system when the conjugate of the objective lens is adjusted to scan the first information layer (0.1 mm cover) and the second information layer (0.11mm cover).

	Radius r1 (mm)	Radius r2 (mm)	OPDrms (mλ)
0.1 mm cover	Infinite	Infinite	4.9
0.11 mm cover	-5.104	5.677	28.3

TABLE 2

Note that the spherical aberration values shown in Table 2 will vary significantly due to variations in the design parameters of the components of the optical scanning device and the optical disc, such as errors in the thickness of the objective lens or in the cover layers of the disc.

For example, for the fluid cell having parameters as described above when scanning an information layer having a cover layer thickness of 0.1 mm, will generate a spherical aberration OPDrms value of 4.9 mλ. If the objective lens has a thickness error resulting in a thickness 10 μm smaller than its design value of 0.710 mm, the spherical aberration value increases to 94.0 mλ, which is too much for accurate disc readout. By adjusting the radii of the menisci of the fluid cell, the spherical aberration value can be reduced to 33.8 mλ, within acceptable limits.

Table 3 shows the radii r1 and r2 of the menisci and resulting spherical aberration values for scanning information layers having a 0.1 mm and 0.11 mm cover thicknesses, when the objective lens is at its design value and when it is smaller than its design value by 10 μm due to manufacturing error. It can be seen that different curvatures of the menisci are required to read the information layers with acceptable values of spherical aberration when the objective lens has a thickness error in it.

	Radius r1 (mm)	Radius r2 (mm)	OPDrms (mλ)
No thickness error in objective			
0.1 mm cover	Infinite	Infinite	4.9
0.11 mm cover	-5.104	5.677	28.3
10 μm thickness error in objective			
0.1 mm cover	5.695	-6.262	33.8
0.11 mm cover	Infinite	Infinite	1.0

TABLE 3

Note that the radii of the menisci can be determined by measuring the electrical capacitance of the electrowetting fluid cell, because as the radius of a meniscus changes, the contact surface area between a fluid and the fluid cell wall changes thus changing the capacitance of the fluid cell. Once the radius of a meniscus is determined for a given voltage signal applied to the fluid cell, a lookup table may be constructed to determine the radius when a particular voltage signal is applied and vice versa, although other methods may also be used.

One method for determining the values for the voltage signals applied to the fluid cell is described below. Initially, a value for the radius of the first meniscus is selected. This may, for example, be an infinite radius to produce a flat meniscus. The first voltage signal is applied to produce a flat first meniscus, and the second voltage signal is adjusted to adjust the shape of the second meniscus while scanning the disc and measuring the jitter of the read signal. The second meniscus is adjusted until a minimum value of jitter is obtained. This procedure is then repeated for the first meniscus, i.e. the first voltage signal is adjusted to adjust the shape of the first meniscus while scanning the disc and measuring the jitter of the read signal, until a minimum value of jitter is again obtained. This procedure can be repeated until a predetermined value of jitter is obtained, or for a certain number of repetitions.

This procedure may be repeated for any other information layers present in the optical disc, preferably starting the procedure using the settings obtained for one of the information layers. Alternatively, a look-up table or calculation may be used to determine the settings for any other information layers based on the settings obtained for the one information layer.

An alternative method for determining the voltage signals to be applied to the fluid cell is to use a sensor in the optical scanning device which can measure the amount of spherical aberration present in the beam, rather than measuring jitter. This sensor may be used in the procedure described above.

This procedure to adjust the fluid cell may be performed when the optical scanning device is first powered up. This will enable the scanning device to adjust to correct to tolerance errors the objective lens and other parts of the scanning device itself. The procedure may also be performed each time a disc is inserted in the optical scanning device. This will enable the scanning device to adjust to correct to tolerance errors the optical disc as well, such as variances in the thickness of the cover layers. The procedure may also be performed each time a read and/or record operation is initiated.

It should be noted that even discs which have not previously been recorded by the user include a small portion of the disc which contains prerecorded information, such as information regarding the type of the disc and certain parameters of the disc. This prerecorded information may be used for the procedure to determine settings for the fluid cell. Alternatively, the optical scanning device may record a signal onto the disc and use this signal as the basis for determining the settings for the fluid cell.

The above embodiments are to be understood as illustrative examples of the invention. Further embodiments of the invention are envisaged. In one alternative embodiment shown in Fig. 5, two separate electrowetting fluid cells 202, 204 each with a single meniscus (206 and 208 respectively) can be used in combination in place of one electrowetting fluid cell with two menisci. Other means for independently adjusting the vergence of a radiation beam and the spherical aberration in the beam may also be used, such as a moveable collimator to adjust the vergence of the beam in combination with a twisted nematic (TN) liquid crystal cell and a birefringent plate to produce different amounts of spherical aberration. The radiation beam passes through the twisted nematic liquid crystal cell that selectively rotates the polarization of the beam by 90 degrees. The beam, in a convergent state, then passes through the birefringent plate to produce spherical aberration in the beam. The birefringent plate produces different amounts of spherical aberration depending on the state of the TN cell. An example of such an arrangement is described in WO-0124174, the contents of which are incorporated herein by reference.

The invention can be used for spherical aberration compensation for multi-layer record carriers and/or to obtain compatibility between different types of record carriers, such as CD, DVD, and BD. The invention can be used in optical recording systems to widen the manufacturing tolerances permitted in scanning devices and record carriers while achieving multi-layer and multiple disc-type compatibility. The invention can also be used to widen the manufacturing tolerances permitted in other types of optical systems, such as camera modules and microscopes. Furthermore, the invention can be used for spherical aberration compensation in relation to reading a signal from a disc or for writing information to the disc.

The invention can also be applied, for example, when an optical scanning device switches between information layers to conduct alternate read and write operations, as may be performed in an optical scanning device in the form of a video recorder capable of conducting time-lapse recording and playback simultaneously.

It is to be understood that any feature described in relation to one embodiment may also be used in other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

CLAIMS:

1. An optical scanning device for scanning an optical record carrier (OD) when positioned in a scanning location in the device, the optical record carrier having a transparent cover layer (2) with a thickness and at least one information layer (3,4), the device being adapted for scanning the at least one information layer, the device comprising:

- a radiation source (6) for generating a radiation beam;
- an objective lens (12), located in an optical path between the radiation source and the scanning location, for converging a radiation beam to a spot (18) on an information layer; and
- an optical correcting system (10) for changing the vergence of the radiation beam and the amount of spherical aberration in the radiation beam towards the objective lens,

characterized in that with the optical correcting system the vergence and the amount of spherical aberration in the radiation beam can be adapted independently.

2. An optical scanning device according to claim 1, wherein the optical correcting system (10) comprises a set of fluids (A,B) having a first meniscus (114) having a first radius and a second meniscus (115) having a second radius, the first radius and second radius being separately adaptable.

3. An optical scanning device according to claim 2, wherein the set of fluids (A,B) are located in a single container comprising the first meniscus (114) and second meniscus (115).

4. An optical scanning device according to claim 2, wherein the set of fluids are located in a first container (202) and a second container (204), the first container comprising the first meniscus (206) and the second container comprising the second meniscus (208).

5. An optical scanning device according to claim 1, wherein the optical correcting system comprises at least one movable collimator lens for changing the vergence

of the radiation beam entering the objective lens (12) and an optical element adapted for changing the amount of spherical aberration in the radiation beam entering the objective lens.

6. An optical scanning device according to claim 5, wherein the optical element comprises a liquid crystal material.

7. An optical scanning device according to claim 5, wherein the optical element comprises a set of fluids having a meniscus.

8. An optical scanning device according to any preceding claim, for scanning an optical record carrier (OD) having at least first and second information layers (3,4), a first transparent layer thickness above the first information layer (3) introducing a first amount of spherical aberration and a second transparent layer thickness above the second information layer (4) introducing a second amount of spherical aberration, wherein the optical correcting system (10) can be adapted to compensate for the first amount of spherical aberration and second amount of spherical aberration when scanning the first and second information layers respectively.

9. An optical scanning device according to claim 8, wherein the optical correcting system (10) changes the vergence of the radiation beam to converge the radiation beam to a spot (18) on one of the information layers (3,4) and changes the amount of spherical aberration in the radiation beam to minimize spherical aberration in the radiation beam.

10. An optical scanning device according to any claims 1-7, for scanning a first type of optical record carrier having a transparent cover layer with a first thickness introducing a first amount of spherical aberration and for scanning a second type of optical record carrier having a transparent cover layer with a second thickness introducing a second amount of spherical aberration, wherein the optical correcting system (10) can be adapted to compensate for the first amount of spherical aberration and second amount of spherical aberration when scanning the at least one information layer.

11. A method of operating the optical scanning device of any preceding claim, comprising:

- adjusting the correcting system (10) to change the vergence of the radiation beam to converge the radiation beam to a spot (18) on an information layer (3,4) of the optical record carrier (OD); and
- adjusting the correcting system (10) to change the amount of spherical aberration in the radiation beam to minimize spherical aberration in the radiation beam.

12. A method of operating the optical scanning device according to claim 11, comprising:

- scanning the optical record carrier (OD) with the radiation beam to derive a read signal;
- measuring jitter of the read signal; and
- adjusting the optical correcting system (10) based on the jitter measurement.

13. An optical correcting system (10) adapted for use in an optical scanning device, the optical scanning device comprising a radiation source (6) for generating a radiation beam and an objective lens (12) for converging the radiation beam to a spot (18) on an information layer (3,4) of an optical record carrier (OD), characterized in that the optical correcting system is adapted for changing the vergence of the radiation beam and independently changing the amount of spherical aberration in the radiation beam.

14. An optical correcting system according to claim 13, wherein the optical correcting system (10) comprises a set of fluids (A,B) having a first meniscus (114) having a first radius and a second meniscus (115) having a second radius, the first radius and second radius being separately adaptable.

15. An optical correcting system according to claim 14, wherein the set of fluids (A,B) are located in a single container comprising the first meniscus (114) and second meniscus (115).

16. An optical correcting system according to claim 14, wherein the set of fluids (A,B) are located in a first container and a second container, the first container comprising the first meniscus (114) and the second container comprising the second meniscus (115).

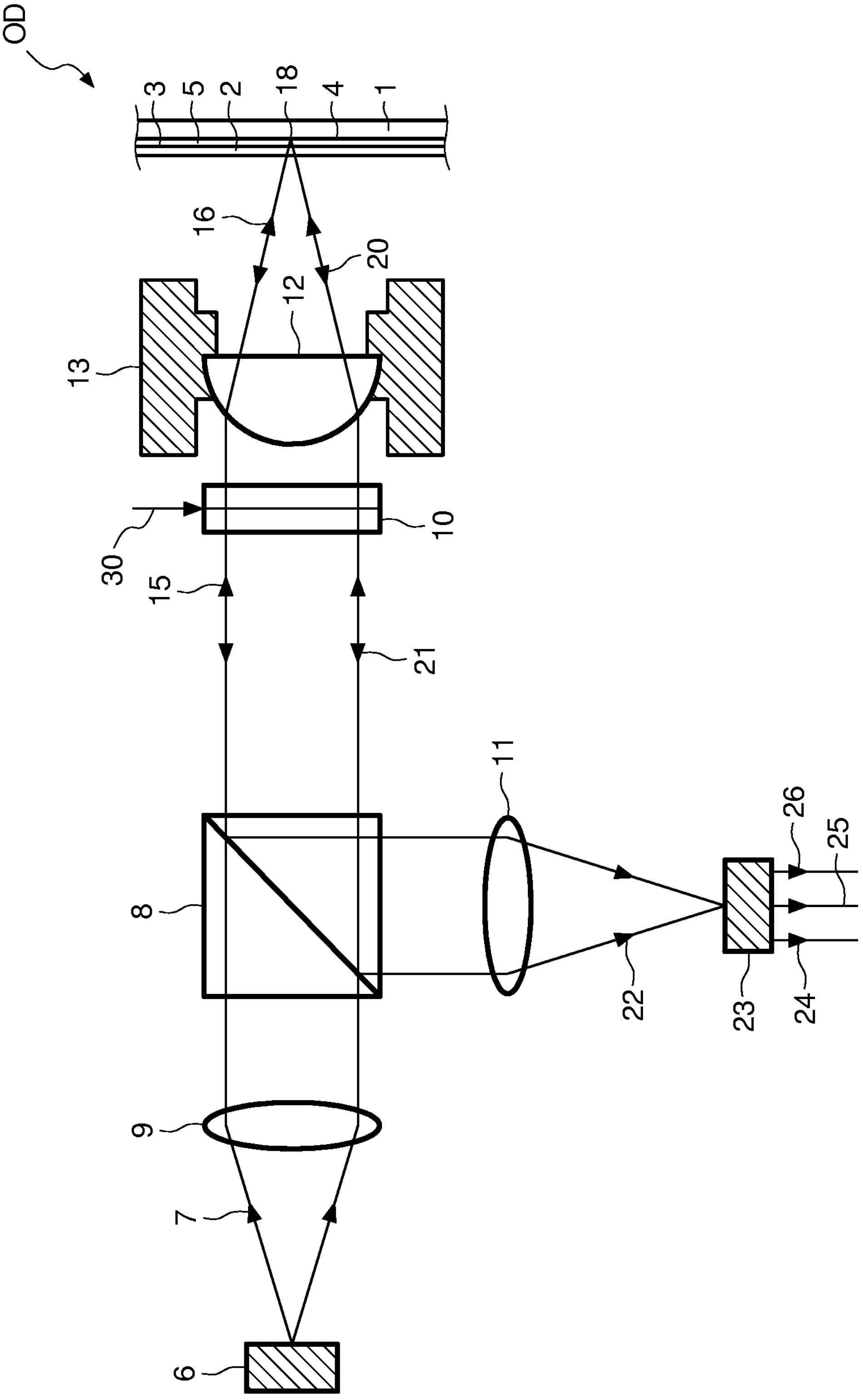

FIG. 1

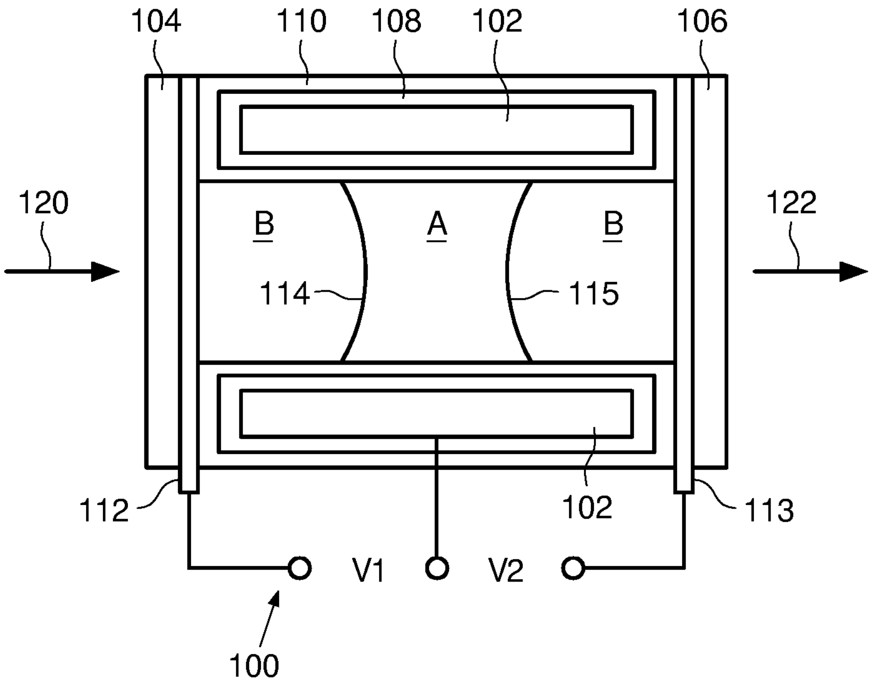
104
110
108
102
106
120
122
B
A
B
114
115
112
102
113
V1
V2
100

FIG. 2

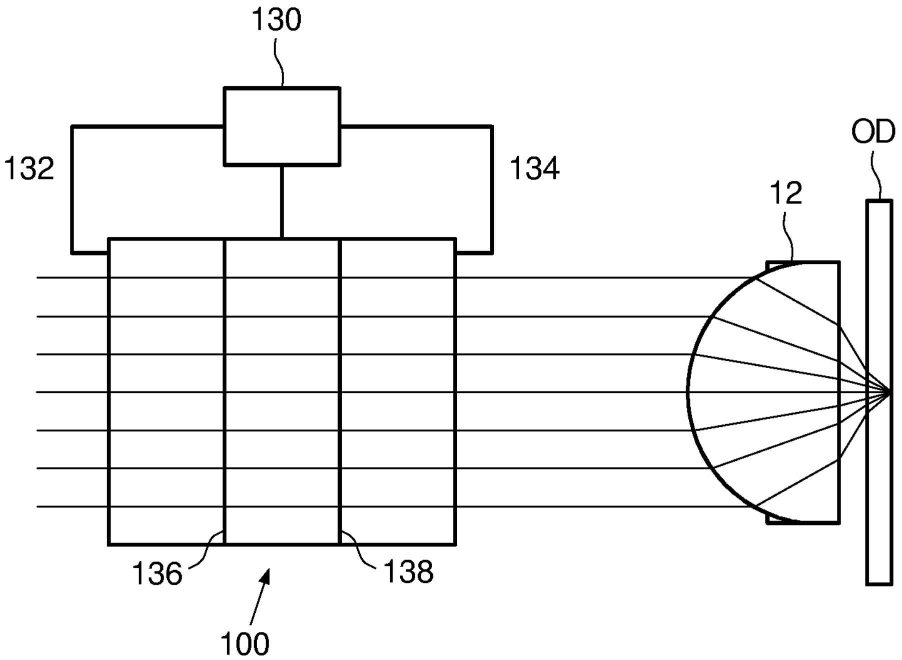
130
132
134
OD
12
136
138
100

FIG. 3

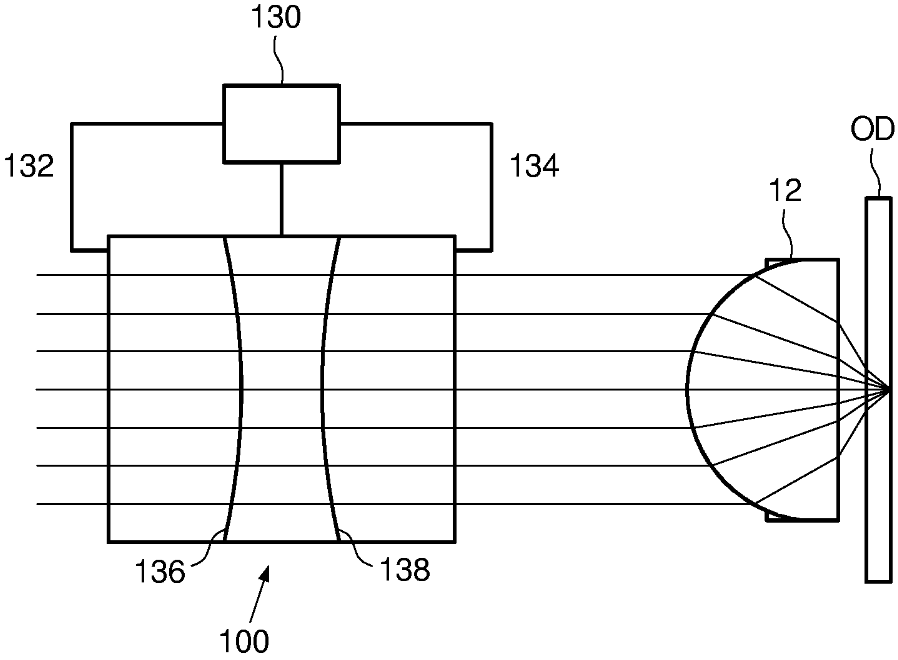

FIG. 4

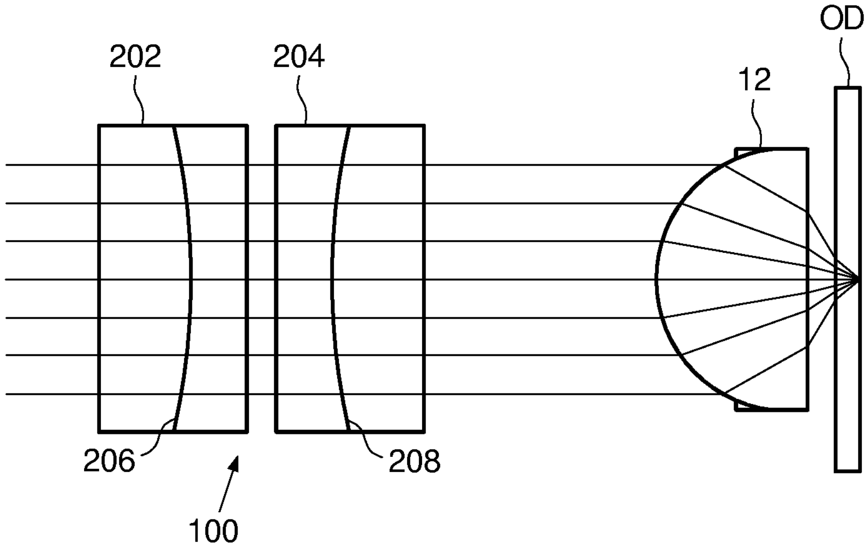

FIG. 5