

Optical scanning unit comprising a detection system for detecting the position of a movable element within the unit



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The invention relates to an optical unit for scanning an information plane having an optically readable and track-wise arranged structure, which unit comprises a radiation source for supplying a radiation beam, an objective system for focusing the radiation beam to a scanning spot in the information plane, an adjustable element arranged
5 between the radiation source and the objective system for moving the scanning spot transversely to the track direction, a radiation-sensitive detection system for converting the radiation beam from the information plane into electric signals, and a position detection system for determining the position of the adjustable element.

10 An optical unit of this type can be used in an optical disc player, such as the well-known CD or CD-ROM players and optical players based on the principle of these players, to guide a radiation beam to an information plane of an optical record carrier and from the record carrier to a radiation-sensitive detection system. If the record carrier is provided with user information, such as an audio program or a video program, the radiation
15 beam from the radiation source is an unmodulated beam and this beam is modulated by the information structure in the information plane. The modulated beam from the record carrier is converted by the radiation-sensitive detection system into an electric signal representing the information which is being read out. If the record carrier is a blank record carrier, the beam from the source is modulated with information to be written and the radiation-sensitive
20 detection system is used only for deriving servosignals.

One of the great advantages of a disc system is that the recorded information is random accessible. The scanning spot can be positioned on each arbitrary track by moving the optical unit and the disc with respect to each other in the radial direction, i.e. a direction transverse to the track direction. Because of the small weight of the optical unit, such a
25 movement can be performed at a relatively fast rate. For new applications of the optical disc, it becomes necessary to further reduce the access time. It has already been proposed to realize faster access by inserting a movable element, for example, a mirror which deflects the beam over the aperture of the objective system so that the spot formed by the objective system is displaced transversely to the track direction. Use is then made of the fact that the objective

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system has an image field which is relatively large compared to the diameter of the spot, so that the spot still has a good quality in the case of a moderate movement of the spot within this field. In order to maintain the high spot quality, i.e. to keep the axis of the radiation beam close to the center of the objective system, during a fast radial movement of the spot, the objective system is also displaced, but at a smaller rate than the mirror. The displacement of the objective system should be related to the deflection of the beam by the mirror, so that the optical unit should comprise a position detection system for determining the angular position of the mirror.

An optical read/write unit comprising such a position detection system is known per se, for example, from U.S. Patent 4,423,496. This patent relates to an improvement of the tracking servosystem for maintaining the center of the scanning spot on the center line of the track being scanned. A tracking error signal, needed for a spot position correction, is obtained by projecting the radiation beam from the information plane on two detector elements, which occupy different radial positions with respect to the information track structure, and by subtracting the output signals of these detector elements. The tracking error signal is supplied to the drives of a pivotable mirror. This mirror deflects the radiation beam so as to fine-position the center of the spot on the center line of the track being scanned. However, movement of the mirror causes a change of the radiation intensity distribution on the position detector elements, which change is independent of the position of the spot with respect to the track being scanned. The tracking error signal is thus dependent on the angular position of the mirror. To eliminate this dependency, a position detection system is used to determine the angular position of the mirror, and the output signal of this system is combined with the tracking error signal to correct the tracking error signal and make this signal independent of the mirror position. The mirror position detection system described in U.S. Patent 4,423,496 uses either a separate position-sensing beam reflected at the rear side of the mirror and two detection elements arranged at this rear side, or a portion of the radiation beam transmitted by the pivotable mirror, or a portion of the radiation beam reflected by a surface in front of the mirror. In all of the embodiments of this mirror position detection system, the position detection elements are arranged in a plane which is different from the plane of the radiation-sensitive detection system.

It is an object of the present invention to provide a fast-access optical unit, wherein the range of movement of the movable element is minimum and the signal from the

position detection system is used to control the movement of at least the objective system by means of a dedicated and attractive position detection system.

5 This optical unit is characterized in that the position detection system comprises a weakly reflecting element arranged in the path of the radiation beam between the adjustable element and the objective system for reflecting a portion of the radiation beam as a position-sensing beam towards a radiation-sensitive position detector comprising at least two detector elements.

Not only the function, but also the construction of this position detection system is different from that described in U.S. Patent 4,423,496.

10 The optical unit is preferably characterized in that the normal to the reflecting plane of the weakly reflecting element extends at a small angle to the optical axis of the objective system.

By this measure, the position-sensing beam is spatially separated from the radiation beam.

15 The detection system is preferably further characterized in that the position detector is arranged in the same plane as the radiation-sensitive detection system.

The position detector and the detection system may then be integrated in one component so that the number of components of the optical unit as well as alignment problems can be reduced.

20 A first embodiment of the optical unit is characterized in that the reflecting element is a weakly reflecting flat plate, in which the normal to the plate surfaces extends at a small angle to the optical axis of the objective system.

A second embodiment of the optical unit is characterized in that the reflecting element is a weakly reflecting wedge having a small wedge angle.

25 A third embodiment of the optical unit, which comprises a $\lambda/4$ plate arranged between the movable element and the objective system, is characterized in that the weakly reflecting element is constituted by an uncoated surface of the $\lambda/4$ plate, which surface faces the objective system.

30 The $\lambda/4$ plate may be used in an optical unit wherein the radiation beam delivered the radiation source is linearly polarized, either to prevent radiation from being coupled back to the radiation source or, in combination with a polarizing beam splitter, to separate the beam reflected by the information plane from the radiation beam to the record carrier.

By using the $\lambda/4$ plate as the weakly reflecting element, the number of components of the optical unit is reduced to a minimum. Optimum use is thus made of the facts that an uncoated surface has a reflection of the order of 4% and that the position-sensing beam needs to have only a low intensity. It also suffices for the previous embodiments when one of the surfaces of the weakly reflecting element is uncoated, so that this element does not need to have a beam-separating layer.

The above embodiments may be further characterized in that the movable element is a plane mirror.

The invention also relates to an apparatus for reading information from and/or writing information in an information layer of an optical record carrier, which apparatus comprises supporting means for the record carrier, an optical unit for supplying a scanning beam focused to a scanning spot on the information layer, and means for moving the record carrier and the optical unit relative to each other. This apparatus is characterized in that the optical unit is a unit as described above.

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The invention will now be elucidated, by way of non-eliminative example, with reference to the accompanying drawings. In the drawings:

Fig. 1 is a cross-section of an apparatus for reading an optical record carrier;

Fig. 2 shows the principle of the mirror position detection method of the present invention;

Fig. 3 shows a first embodiment of the optical unit wherein the invention is implemented;

Fig. 4 shows a second embodiment of such an optical unit, and

Fig. 5 is a top view of a radiation-sensitive detection system which can be used in such an optical unit.

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Fig. 1 shows part of a round disc-shaped record carrier 1 in a radial cross-section. This record carrier comprises a transparent layer 2, one side of which is provided with an information layer 3. The information layer may be protected against environmental influences by a protective layer 4. Side 5 of the transparent layer, facing the optical unit 10, is referred to as the entrance plane. The transparent layer 2 may constitute a mechanical support for the information layer. It is also possible that the transparent layer only serves as a protective layer for the information layer. The mechanical support for the information layer may then be provided by a further layer at the other side of the information layer, for

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example, by the protective layer 4 or, in the case of a record carrier with two information layers, by a second information layer and a transparent layer arranged against the information layer 3. The information may be recorded in the information layer in the form of optically detectable areas arranged in substantially parallel, concentric or spiral tracks 5. In Fig. 1, these tracks extend in a direction perpendicular to the plane of the drawing. These areas may have any optically detectable form. For example, these areas may be pits in the information layer, or areas having a reflection coefficient or a magnetization direction different from their surroundings, or a combination of these forms.

The optical unit 10 comprises a radiation source 11, for example a laser diode, which emits a divergent beam 12, the scanning beam. A collimator lens 14 converts this beam into a parallel beam 15. This beam is incident on a reflecting mirror 17, which reflects the beam 15 to an objective system 20. The objective system converts the parallel beam 15 into a convergent beam 21 and focuses this beam to a radiation spot 23, the scanning spot, on the information layer 3. In Fig. 1, the objective system is represented by a single lens element, which may have one or two aspherical surface(s). The objective system may also comprise several lens elements, or a hologram.

During reading or writing information, the record carrier is rotated by a shaft 35, driven by a motor 36, so that one information track 5 is scanned. By moving the scanning spot 23 and the record carrier relative to each other in the radial direction r , all the concentric tracks or the complete spiral track can be scanned. The latter movement can be realized by mounting the optical unit or part thereof comprising at least the objective system on a sledge, which is movable in the radial direction. When record information is being read, radiation of the convergent beam 21 reflected by the information layer 3 is modulated with the information recorded in the successive information areas. This reflected information forms a reflected beam 24 which returns along the path of the convergent beam 21. The objective system converts this beam into a collimated beam 25, which is reflected by the mirror 17. A beam separator 27, for example a semitransparent mirror or prism, is arranged in the radiation path of the ongoing beam 15 and the returning beam 25. This element transmits part of the radiation of the beam 15 towards the record carrier and reflects part of the reflected beams towards a radiation-sensitive detection system 34. The beam 28 reflected by the element 27 passes a positive lens 30, which converts this beam into a convergent beam 31 and focuses the beam 31 in a detection spot 32 in the plane of the detection system 32. This detection system converts the radiation of the beam 31 into electric signals. One of these signals is an information signal S_i , which represents the information read from the information layer 3.

Another signal is a focus error signal S_f which represents a possible axial deviation of the focus 23 with respect to the information layer 3. This focus error signal, which can be generated in several ways and is known per se, is used as input signal for a focus control circuit 38. This circuit drives an axial actuator, not shown in Fig. 1, such that the axial position of the focus coincides with the plane of the information layer 3. A further signal supplied by the detection system 34 is a tracking error signal S_r , which represents a possible deviation of the center of the scanning spot 23 from the center line of the track being scanned. This tracking error signal, which can also be generated in several ways and is known per se, is used as input signal for a track control circuit 40. This circuit drives a radial actuator 42, which is an actuator for moving either the whole optical unit 10, or only the objective system in the radial direction, or an actuator for pivoting the mirror 17 in the direction of the arrow 18.

When information is being written in the information layer, the beam 12 from the source 11 is modulated with the information to be written. This modulation may be performed by a separate modulator, for example an acousto-optic modulator, which is arranged in the path of this beam and controlled by the information to be written. The modulation can also be realized by directly supplying the radiation source with the information to be written. Also when information is being written, the radiation-sensitive detection system 34 can supply a focus error signal and a tracking error signal. The information signal read from the information layer may then, for example, comprise information about data pre-recorded on the record carrier, such as addresses, which are used during writing of the information proper.

To allow reading information from, or writing information on, an arbitrary position in the information layer, the apparatus should provide fast access to such a position. This need for fast access, or short access time, becomes even more manifest if the information content of the record carrier increases. If the distance between the start position and the required track is relatively large, the scanning spot can be moved to the area of this track by displacing the optical unit. A movable element within the optical unit can be used for positioning the scanning spot on the required track. This element may be constituted by the pivotable mirror 17. This mirror has a low mass and can be moved quickly. If there is a small distance between the start position and the required track, the scanning spot can be moved through this distance by only pivoting the mirror. By pivoting this mirror, the direction of the beam 15 changes. The change of direction is translated by the objective system into a linear displacement of the scanning spot in the radial direction. Use is then

made of the fact that the image field of the objective system has a certain extent. To maintain the required, diffraction-limited, quality of the scanning spot when deflecting the beam 15, the position where the deflected beam enters the objective system should not deviate too much from the objective system axis. In order to fulfil this requirement, the radial position of the objective system can also be controlled by means of a further control circuit, which has a lower control band than that of the mirror 17, such that also the objective system has a spot-moving function. The pivotable mirror 17 is then used to realize small movements at a relatively high velocity, whereas larger movements of the spot at a smaller velocity are realized by displacing the objective system. The mirror 17 then only needs to be pivoted through a small range around its mid-position.

The displacement of the objective system 20 should be dependent on the deflection by the mirror 17. When the deflection angle of the mirror has reached a certain value, the objective system should be displaced in such a way that it moves the spot 23 through a distance which is equal to or larger than the distance through which this spot has been moved by the mirror, and the mirror is simultaneously reset to its mid-position or further backwards. In order to realize this, the angular position of the mirror should be determined.

Fig.2 shows the principle of the mirror position detection system of the present invention. In this Figure, only those elements which are relevant for the detection system are shown. For the sake of clarity, only the chief ray of the beam 15 incident on the pivotable mirror 17 and reflected by this mirror is shown. A weakly reflecting element 50 is arranged in the path of the beam reflected by the mirror. This element reflects only a minor part, for example less than 10%, of the radiation of the beam 15 as a sensing beam 51 towards a radiation-sensitive position detector 55. This detector has at least two separate detector elements 56 and 57 which are separated by a slit 58. A lens system 52 is arranged between the weakly reflecting element 50 and the detector 55 to focus the sensing beam 51 in a detector spot 59 in the plane of the detector 55. For better understanding, this plane is rotated through 90^0 with respect to the other elements of the system. The output signals of the detector elements 56 and 57 are supplied to the input ports of a differential amplifier 62. The output signal S_m of the differential amplifier is a measure of the angular position of the mirror 17. This signal is supplied to the driving circuit for the objective system.

The detection system is designed in such a way that, if the mirror 17 is in the mid-position and the beam 15 has the nominal direction, the center of the detector spot 59 is situated midway between the detector elements 56 and 57. These elements then receive the

same amount of radiation so that their output signals are equal and the output signal S_m is zero. When the mirror is pivoted, the detector spot moves in the plane of the position detector 55 along the double arrow 60. If the mirror 17 is turned to the left, the beam reflected by this mirror is deflected to the left, as indicated by the chief ray 15'. The sensing beam is then
5 deflected downwards, as indicated by the chief ray 51' and the detector spot moves downwards, for example to the position 59'. Detector element 56 then receives less radiation than detector element 57 and the signal S_m has a negative value. If the mirror 17 is turned to the right, the beam deflected by this mirror is deflected to the right, as indicated by the chief ray 51". The sensing beam is then deflected upwards, as indicated by the chief ray 51" and
10 the detector spot moves upwards, for example to the position 59". Detector element 56 then receives more radiation than detector element 57 and the signal S_m has a positive value. In this way, both the value and the sign of the angle through which the mirror 17 is pivoted can be determined. The situation depicted in Fig.2 may represent a practical embodiment wherein the lines of the chief rays 15' and 15" correspond to the maximum amount of deflection, in
15 the positive and negative direction, imparted to the scanning beam by the mirror 17, and the spots 59' and 59" correspond to the spots associated with the maximum deflections.

Fig. 3 shows a part of a first embodiment of an optical unit with the mirror angular position detection system of the invention. The weakly reflecting element is constituted by an element 70 which substantially transmits the radiation of the scanning beam
20 15 and reflects only a small part of this radiation, as the sensing beam 51. For the sake of clarity, only the chief ray of the sensing beam is shown. The sensing beam is directed to the plane of the radiation-sensitive detection system 32 in the same way and by the same elements, 17 and 27, as the scanning beam 25,28,31, and focused to a sensing spot 59 in this plane by the lens 30.

25 The plane of the flat weakly reflecting element 70 is arranged at a small angle α , of the order of 10° or smaller, with respect to a plane perpendicular to the axis of the objective system 20. Due to this, skew, arrangement of the element 70, the reflected sensing beam 51 is spatially separated from the scanning beam, so that the sensing spot 59 is separated from the spot 32. It will thus be possible to arrange the detector elements 56 and 57
30 of the position detection system in the same plane as the detector elements of the information detector 32 and to integrate all the detector elements in one device. Such an integration reduces the costs of the optical unit, because fewer elements are required and alignment becomes easier. A top view of such a detection device is shown at the right bottom part of Fig. 3. This device comprises the signal, focus error and tracking error detector 32 in the

form of a quadrant detector and the two detector elements 56,57 of the mirror position detector 55.

Instead of the flat plate 70 at a small angle α , an optical wedge having a small wedge angle can be arranged in the scanning beam, in which the skew surface of this wedge acts as the

5 weak reflector.

Fig. 4 shows a part of a second embodiment of the optical unit with the mirror angular position detection system of the invention. In this embodiment, the reflected scanning beam is separated from the ongoing scanning beam by the combination of a polarizing beam-splitting prism 75 and a $\lambda/4$ waveplate 77, where λ is the radiation wavelength of the scanning beam. This beam is linearly polarized in a direction corresponding to the transmission direction of the polarizing beam splitter so that the beam is fully transmitted to the mirror 17 and the record carrier 1. On its way to and from the record carrier, the scanning beam passes through the $\lambda/4$ plate 77 twice so that its direction of polarization is rotated through 90° in total when the (reflected) beam arrives again at the prism 75. The reflected scanning beam 25 is then reflected by the beam splitter 75 towards the radiation-sensitive detection system 34. Its compared with the semi-transparent mirror 27 of Figs.1 and 3, the combination of the beam splitter 75 and the $\lambda/4$ plate provides the advantage that the reflected scanning beam can be separated from the ongoing scanning beam without loss of radiation. The $\lambda/4$ plate is conventionally provided with an anti-reflection coating on both surfaces to prevent reflection at these surfaces.

According to the invention, one of these surfaces is not coated. The normal reflection of such an uncoated surface, of the order of 4%, is sufficient to use the radiation reflected by this surface as position-sensing radiation. The uncoated surface 78 of the plate 77 should be the upper surface of the plate 77 so that the radiation of the sensing beam 51 also passes through the $\lambda/4$ twice and the beam 51 is reflected by prism 75 towards the position detector 55. Like the element 70 in Fig. 3, the $\lambda/4$ plate 77 is arranged skew in the scanning beam, so that the sensing beam 51 is spatially separated from the scanning beam, and the detector elements of the sensing beam can be integrated with the other detector elements.

30 As the $\lambda/4$ plate also acts as a weakly reflecting element, a separate element for performing this function is no longer needed, so that the costs of the scanning unit can be reduced.

It is also known to arrange solely a $\lambda/4$ plate between the radiation source and the objective system in an optical scanning unit, without combining it with a polarization beam-splitting prism. Again the function of the $\lambda/4$ plate is to rotate the plane of polarization of the scanning beam on its way through the unit, but the aim is now to ascertain that
5 radiation of this beam arriving at the radiation source, i.e. parasitic radiation, has a direction of polarization which is different from that of the radiation emitted by the source. The parasitic radiation is thereby prevented from influencing the radiation emitted by the source. The invention can also be implemented in such an optical scanning unit by arranging the $\lambda/4$ plate between the moving mirror 17 and the objective system and leaving the plate surface
10 that is directed towards the objective system uncoated.

Also the weakly reflecting surface of the flat plate 70, or of its alternative; the wedge, in the embodiment of Fig. 3 may be an uncoated surface.

The signal detector shown in the right bottom part of Fig. 3 has four detector elements 80,81,82 and 83 which are separated from each other by strips extending in the
15 radial direction r and tangential direction t , respectively. Such a detector is used in combination with the so-called astigmatic focus error detection method. According to this method, the reflected scanning beam is made astigmatic, for example by arranging a cylindrical lens in front of the detector. An astigmatic beam has two, mutually perpendicular, astigmatic focal lines instead of one focal spot. The planes in which these focal lines are
20 situated have different axial positions. In a specific plane between these two planes, the astigmatic beam has a round cross-section. The detector 34 is arranged in this specific plane. If the focus of the scanning beam 21 is in the plane of the information layer 3, the spot 32 on the detector 34 is round and symmetric with respect to the detector elements 80,81,82 and 83, so that each of these elements receives the same amount of information. If the focus of the
25 scanning beam shifts in the axial direction with respect to the plane of the information layer, the astigmatic focal lines shift with respect to the plane of the detector 34. This means that the spot 32 on the detector 34 becomes an elliptical spot in which the long axis of the ellipse is at an angle of $+45^\circ$ or -45° with respect to the radial and tangential directions, depending on the sign of the focus shift. By summing the output signals of the detector elements 81 and
30 83 and those of the detector elements 80 and 82 and subtracting the sum signals from each other, the focus error signal S_f is obtained.

The tracking error signal S_r is obtained by summing the signals of the detector elements 80 and 83 and those of the detector elements 81 and 82 and subtracting the sum

signals from each other. This method of generating a tracking error signal is known as the push-pull tracking error method.

The information signal S_i is obtained by summing the output signals of the four detector elements 80,81,82 and 83.

5 Several focus error detection methods, alternative to the astigmatic method are known. The invention can be combined with each of these methods.

10 An alternative method of detecting tracking errors is the well-known three-spot tracking method. In addition to the scanning spot 23, the center of which should coincide with the center line of the track being scanned, two additional spots, oppositely shifted in the radial direction with respect to the central spot 23, are used in this method. The two follower spots scan the two borders of the track. The three spots can be obtained by arranging a diffraction grating between the radiation source 11 and the beam splitter 27, or 75, which splits the beam from the radiation source into one scanning beam and two tracking beams. After reflection at the information layer, the three beams are directed to the radiation-
15 sensitive detection system and focused thereon as three separate spots.

 Fig. 5 is a top view of a radiation-sensitive detection system which may be used in combination with the three-spot tracking method. This system comprises the quadrant detector 34 for information read out and focus error detection, the detector 55 for mirror position detection and two additional detectors 90 and 94 for tracking error detection. The
20 spots 32,59 98 and 99, respectively, are projected on these detectors. The spots 98 and 99 are formed by said tracking beams. The tracking error signal is obtained by subtracting the output signals of the detectors 90 and 94 from each other.

 As is also indicated in Fig. 5, each detector 90 and 94 may be divided into two detector elements 91,92 and 95,96, respectively. In addition to the three-spot tracking error
25 signal, push-pull signals may then also be obtained. This is known as the three-spot push-pull detection method.

CLAIMS:

1. An optical unit for scanning an information plane having an optically readable and track-wise arranged structure, which unit comprises a radiation source for supplying a radiation beam, an objective system for focusing the radiation beam to a scanning spot in the information plane, an adjustable element for moving the scanning spot transversely to the track direction, a radiation-sensitive detection system for converting the radiation beam from the information plane into electric signals, and a position detection system for determining the position of the adjustable element, characterized in that the position detection system comprises a weakly reflecting element arranged in the path of the radiation beam between the adjustable element and the objective system for reflecting a portion of the radiation beam as a position-sensing beam towards a radiation-sensitive position detector comprising at least two detector elements.
2. An optical unit as claimed in claim 1, characterized in that the normal to the reflecting plane of the weakly reflecting element extends at a small angle to the optical axis of the objective system.
3. An optical unit as claimed in claim 2, characterized in that the position detector is arranged in the same plane as the radiation-sensitive detection system.
4. An optical unit as claimed in claim 1,2 or 3, characterized in that the reflecting element is a weakly reflecting flat plate, in which the normal to the plate surfaces extends at a small angle to the optical axis of the objective system.
5. An optical unit as claimed in claim 1,2 or 3, characterized in that the reflecting element is a weakly reflecting wedge having a small wedge angle.
6. An optical unit as claimed in claim 1,2 or 3, further comprising a $\lambda/4$ plate, arranged between the movable element and the objective system, characterized in that the

weakly reflecting element is constituted by an uncoated surface of the $\lambda/4$ plate, which surface faces the objective system..

7. An optical unit as claimed in any one of claims 1-6, characterized in that the
5 movable element is a plane mirror.
8. An apparatus for reading information from and/or writing information in an
information layer of an optical record carrier, which apparatus comprises supporting means
for the record carrier, an optical unit for supplying a scanning beam focused to a scanning
10 spot on the information layer, and means for moving the record carrier and the optical unit
relative to each other, characterized in that the optical unit is a unit as claimed in any one of
claims 1-7.