Description

The invention relates to a scanning device for optically scanning an information plane, which device comprises a radiation source supplying a scanning beam and a mirror objective for focusing the scanning beam to a scanning spot in the information plane. The invention also relates to a mirror objective suitable for use in this scanning device and to a write and/or read apparatus provided with such a device.

Scanning an information plane is to be understood to mean both scanning for reading a prerecorded information plane and scanning for writing information in this plane by means of a radiation beam which is intensity-modulated in accordance with the information to be recorded. If a magneto-optical record carrier is recorded, the radiation beam may also have a constant intensity and the magnetic field may be modulated in accordance with this information to be recorded. The information plane may be a plane of an optical record carrier, but also a surface or a plane in an object to be examined, the scanning device then forming part of, for example a microscope.

A scanning device as described in the opening paragraph, intended for reading an optical record carrier, is known from British Patent Specification no. 1,541,596. This specification describes an optical scanning device which includes an objective comprising two mirrors whose reflective sides face each other. The one mirror is concave and its reflective side faces the record carrier. The other mirror, which is much smaller, is convex and its reflective side faces the radiation source. The radiation from the radiation source reaches the convex mirror via a passage in the larger concave mirror. The radiation is subsequently reflected towards the concave mirror and focused by this mirror to a radiation spot in the information plane of the record carrier.

The known objective forms part of a two-stage focusing system in which the entire mirror system is suspended in a magnetic coil with which the position of the objective with respect to the record carrier is controlled. The small mirror is mounted on a piece of piezo-electric material and can be moved up and down with the aid thereof so that a small extent of defocus is periodically produced in the information plane, which defocus is detected by a detection device and from which subsequently a focus-error signal is derived which is used for readjusting the position of the objective by means of the magnetic coil.

By using two separate mirrors in a close working relationship with each other, the known scanning device has a rather complicated structure and is sensitive to mechanical perturbations.

It is an object of the present invention to provide a compact and robust scanning device whose mirror objective is well corrected for spherical aberrations and which can readily be manufactured because the requirements of accuracy need not be too stringent.

The mirror objective of the scanning device according to the invention thereto comprises a transparent body having a first surface facing the radiation source and a second surface remote from the radiation source, said first surface having a first radiation window which is located symmetrically around the optical axis of the mirror objective and having a first reflector surrounding said window, said second surface having a second reflector which is located symmetrically around the optical axis and a second radiation window surrounding the second reflector, the radiation path through the mirror objective extending via passage through the first window, reflection on the second reflector, reflection on the first reflector and passage through the second window, at least the second radiation window having an aspherical surface.

An aspherical surface in a lens system is understood to mean a lens element surface whose fundamental shape is spherical but whose real shape deviates therefrom to a small extent in order to correct for spherical aberration which would be produced when using the lens element with spherical surfaces. The spherical fundamental shape may also have an infinitely large radius of curvature so that the said aspherical surface has a flat fundamental shape.

The scanning device comprising the said mirror objective is not only compact because the radiation path in this objective is folded, but the mirror objective is also well corrected for spherical aberration. According to the invention this is achieved by giving a radiation window an aspherical shape. Its advantage is that the accuracy of the shape of the aspherical surface may be considerably smaller, for example, a factor of 5 to 6 than the accuracy of the shape required for a reflective aspherical surface. This provides the possibility of manufacturing the mirror objective and hence the scanning device at reasonably low cost. By providing the second radiation window instead of the first radiation window with an aspherical surface a larger diffraction-limited image field can be obtained.

A scanning device as described in the opening paragraph is also described in the European Patent Application EP 0 294 902, which is prior art in the sense of art. 54(3) and (4) EPC.
The described optical scanning device comprises a mirror objective which is composed of a first and a second reflector arranged on the opposed surfaces of a transparent body and of a first and a second radiation window on these surfaces. In this mirror objective the spherical aberration is mainly corrected by the aspherical surface of the first reflector. The second radiation window of this objective is not shaped aspherically.

A very favourable embodiment of the scanning device, is characterized in that the second reflector has an aspherical surface.

This embodiment has a considerably larger, for example five times larger, image field than the embodiment in which only the second radiation window is aspherical. Moreover, since the surface conditions of the transmission portion and the reflector portion of the second surface are similar, this second surface can be manufactured more easily and with greater accuracy. To this end a mould having the desired profile may be made on a numerically controlled machine, and the profile can subsequently be transferred onto the mirror objective by means of a known technique described, inter alia, in US Patent No. 4,668,056.

The scanning device according to the invention can be used for scanning a radiation-transparent information plane. The inventive concept is, however, used to best advantage in a scanning device for scanning a radiation-reflecting information plane in which radiation from the information plane traverses the mirror objective so as to be focused on a radiation-sensitive detection system which is arranged on the same side of the mirror objective as the radiation source. This scanning device is further characterized in that the mirror objective comprises a beam-separating element for spatially separating the beam emitted by the radiation source and the beam reflected from the information plane and focused by the mirror objective.

The beam-separating element may be a semi-transparent mirror or cube arranged on the first radiation window.

However, the scanning device comprising a beam-separating element is preferably further characterized in that the beam-separating element is a diffraction element. This diffraction element can be relatively simply arranged on one of the surfaces of the mirror objective and moreover it can fulfil a second function to be described hereinafter.

A preferred embodiment of the scanning device comprising a mirror objective provided with a diffraction element is characterized in that the diffraction element is reflective and is arranged on the second reflector.

A second embodiment of such a scanning device is characterized in that the diffraction element is radiation-transparent and is arranged on the first radiation window. The diffraction element may alternatively be accommodated in the body of the mirror objective. This body may comprise two parts, the diffraction element being arranged on one of the two facing surfaces of the two parts.

The diffraction element may be formed in such a manner that it renders the beam incident on the detection system suitable for focus-error detection, in conjunction with an adapted detection system. A focusing error is understood to mean a deviation between the focusing plane of the mirror objective and the information plane.

A first embodiment of the scanning device comprising a diffraction element which is adapted for focus-error detection is characterized in that the diffraction element is an element introducing astigmatism and in that the radiation-sensitive detection system comprises four detectors which are arranged in four different quadrants around the chief ray of the beam diffracted by the diffraction element.

The element introducing astigmatism may be a linear grating which, due to its location in a non-parallel beam, introduces a certain extent of astigmatism in this beam. The shape of the radiation spot formed by this beam on the detection system is determined by the degree of focusing on the information plane.

In the case of a defocus this radiation spot is deformed to an elliptical spot whose major axis, dependent on the defocusing sign is located in one of the two mutually perpendicular directions, also referred to as the astigmatic directions. The separating strips between the four detectors extend at angles of approximately 45° to the astigmatic directions.

If a larger extent of astigmatism is desired, the diffraction element may be a diffraction grating having straight grating strips and a linear grating period. Preferably, the astigmatic diffraction element is a holographic grating having curved grating strips and a non-linear grating period. Imaging errors such as coma can be corrected by adapting the curvatures.

It is to be noted that the use of a grating having a linear grating period in combination with a four-quadrant detector for generating a focus-error signal is known per se from United States Patent no. 4,358,200. However, the device described in this patent does not comprise a mirror objective.

A second focus-error detection possibility which is preferred to the above-mentioned, so-called astigmatic method as far as temperature sensitivity and ease of control is concerned, is realised in an embodiment which is characterized in that the first diffraction element is a diffraction grating comprising two sub-gratings and splitting the diffracted scanning beam into two sub-beams and in that the composite detection system comprises two detector pairs, the first and second sub-beams co-operating with a first and a second detector pair, respectively.

In this device the scanning spot is re-imaged in two radiation spots on the detector pairs. Each radiation spot shifts transversely of the separating strip of the associated detector pair in dependence upon a focusing error of the scanning beam relative to the information plane. This shift can be detected by comparing the output signals of the detectors. This focus-error detection method is known as the double Foucault method.

A preferred embodiment of the last-mentioned device is characterized in that the sub-gratings have a varying grating period and in that the grating strips of the sub-gratings are curved.

Due to the varying grating period and the curved

grating strips the composite grating has a lens action and by displacing this grating in the direction of the bounding line of the sub-gratings the energy distribution of the radiation spots can be rendered symmetrical with respect to the associated detector pairs, inter alia because the imaging distance of the assembly of objective system and the grating is adapted to the distance, in the direction of the optical axis, between the diode laser and the detectors. This is particularly important if the detectors, in the form of photodiodes, and the diode laser are combined in one component and are fixed relative to each other. A composite grating having varying grating periods and curved grating strips, which grating is also referred to as hologram, provides the possibility of correcting imaging errors such as coma and astigmatism which may occur when using a grating with straight grating strips.

In principle, there are two embodiments of a scanning device in which the Foucault focus-error detection method is used. The first embodiment is characterized in that the grating strips of the one sub-grating have the same main direction as those of the other sub-grating, in that the average grating periods of the sub-gratings are different and in that the detector pairs are juxtaposed in a direction parallel to the bounding line between the sub-gratings. In this embodiment the sub-beams of the scanning beam are diffracted in the same direction but at different angles.

The second embodiment is characterized in that the sub-gratings have the same average grating period, while the main directions of the grating strips of the one sub-grating extend at a first angle and those of the other sub-grating extend at a second angle to the bounding line of the two sub-gratings and in that the detector pairs are juxtaposed in a direction transversely of the direction of the said bounding line. Now the sub-beams of the scanning beam are preferably diffracted at the same angles but in different directions. This embodiment is preferred to the previous embodiment due to its better assembly tolerances, adjusting facilities and stability.

The use of a mirror objective with a transparent body in a scanning device may have further advantages with regard to the positioning of the radiation source and the radiation-sensitive detection system.

For example, an embodiment of the scanning device according to the invention is characterized in that the radiation source is connected to the first radiation window. The radiation source is, for example a semiconductor laser a radiation-emitting surface of which is provided on the radiation window, or the radiation source is connected to the radiation window via an optical fibre or a series of fibres.

Furthermore an embodiment of the scanning device according to the invention, provided with a radiation-sensitive detection system may be characterized in that the radiation-sensitive detection system is arranged on the first radiation window in the radiation path of radiation which has been reflected from the information plane and which has traversed the mirror objective.

The radiation source, the optical fibres or the radiation-sensitive detection system are secured to the first radiation window by means of, for example a transparent adhesive. This results in a single compact and robust, integrated component accommodating the entire optical section of the scanning device.

The various embodiments of the scanning device according to the invention may comprise different types of radiation sources such as, for example, a single semiconductor laser, a semiconductor laser array or another radiation source which can be connected to the mirror objective directly or by means of optical fibres.

Embodiments of the invention will now be described in greater detail with reference to the accompanying drawings in which

Figs. 1, 2, 2a, 3 and 4 show various embodiments of the scanning device,

Figs. 5 and 6 show two embodiments of a diffraction element to be used in this device, with which element two sub-beams are obtained,

Fig. 7 shows another embodiment of a diffraction element to be used in the scanning device,

Fig. 8 shows the radiation-sensitive detection system associated with this diffraction element, and

Fig. 9 shows a scanning device for a magneto-optical record carrier.

Fig. 1 is a sectional view of a portion of an optical record carrier 10 having a reflecting information plane 11. A scanning device comprising a mirror objective 30 and a radiation source 40 is provided close to the record carrier. The radiation source 40 emits a scanning beam 20 which is focused to a scanning spot 21 in the information plane 11 by the mirror objective 30. The entire information plane can be covered by the scanning spot because the scanning device and the record carrier are movable with respect to each other, for example because the record carrier can rotate around an axis (not shown) perpendicular to the plane of the record carrier and because the scanning device can move in the radial direction with respect to the same axis.

The scanning beam 20 traverses the mirror objective and the beam enters the transparent body of the objective via the first radiation window 31. Subsequently the scanning beam is reflected on the convex reflector 32, so that the scanning beam widens and is incident on substantially the entire surface of the concave reflector 33. This reflector reflects the scanning beam as a convergent beam which is focused to a scanning spot 21 in the information plane 11 via the radiation window 34 and a portion of the transparent record carrier 10.

In the case of a reflective information surface with which, for example, optically readable digital audio discs known under the name of "Compact Disc" are provided, the beam reflected in the spot 21 is received by the mirror objective again and traverses the reverse path therein to the radiation window 31. The reflected beam may enter the radiation source and when using a semiconductor laser as a radiation source, it can be detected thereby. This so-called feedback read-out is described, for example in British Patent Specification no. 1,584,664. Preferably, however, a beam-splitting element, for example, a splitting cube 50 through which a portion of the reflected radiation is separated from the scanning beam 20 and is projected on a radiation-sensitive detection system 60 is arranged in the common radiation path of the emitted and the reflected radiation beams. Since the radiation reflected from the information plane 11 is modulated with the information stored in said information plane and scanned by the radiation spot, the information current is converted by the system 60 into an electric signal suitable for further processing.

The beam focused by the mirror objective 30 exhibits spherical aberration. As is known, inter alia from United States Patent no. 4,668,056, it is possible to correct for this aberration by using aspherical surfaces. It is obvious that the reflecting surface 33 is given an aspherical shape so as to obtain a relatively large diffraction-limited image field. However, according to the invention, the surface of one or of both radiation windows 31 and 34 is aspherical. Though the image field is then reduced, it has been found that it is still sufficiently large for the envisaged object: scanning a surface by means of a diffraction-limited spot. The great advantage of rendering a radiation window aspherical is that the requirements which must be imposed on the accuracy of the shape of the asphere are considerably less stringent than such requirements for a reflecting surface. For an aspherical surface used in transmission the shape tolerances are a factor of $\frac{n_1 - n_2}{2n_1}$ larger than those for an aspherical surface used in reflection. In this case n_1 is the refractive index of the lens material and n_2 is the refractive index of the surrounding medium.

For giving one or both radiation windows 31 and 34 of the mirror objective an aspherical shape the technique described in United States Patent No. 4,668,056 for giving the surface of a conventional lens an aspherical shape can be used. A mirror objective is then obtained in which the aspherical surface of a radiation window is constituted by the aspherical outer surface of a transparent synthetic material layer which is provided on the spherical surface of this window. The synthetic material may be a polymerisable synthetic material, for example a material being cured under the influence of ultraviolet radiation which is applied on the window in a liquid state and is given the desired shape by means of a mould.

In the embodiment of Fig. 1 the radiation window 31 has an aspherical surface 35. Fig. 2 shows a preferred embodiment in which the radiation window 34 is aspherical. As compared with the embodiment of Fig. 1, this embodiment has the advantage of a larger diffraction-limited image field. Like the embodiment of Fig. 1, the embodiment of Fig. 2 is suitable for reading a radiation-reflective information plane 11. The radiation reflected from this plane and received by the mirror objective 30 and condensed in a radiation beam 20' is separated from the beam 20 emitted by the radiation source 40 by means of a diffraction element 39 which is arranged on the radiation window 31.

The second surface 30 of the mirror objective according to Fig. 2 has a spherical portion and an aspherical portion. Such a surface is not easy to manufacture because the known replica technique for obtaining the aspherical surface portion must be performed on a surface which has a small cavity (the reflector portion 32).

In accordance with a further aspect of the present invention, the profile of the total portion of the surface 30 which is used for the lens action, i.e. the aspherical transmission portion as well as the reflector portion, is therefore preferably provided in one process step in a mould by means of, for example, a numerically controlled machine. This provides the very advantageous possibility of giving the reflector portion 32 an aspherical shape as well, so that the mirror objective can even be corrected better and over a larger image field.

Fig. 2a shows a small portion of a mirror objective with an aspherical reflector 32'. The Figure only shows small portions of the window 34 with an aspherical surface 35, situated on both sides of this reflector.

Notably the surface 32' must be manufactured with very great accuracy. The asphericity of this surface, i.e. the maximal deviations from the spherical fundamental shape, is of the order of, for example, ± 200 nm. To alleviate the requirements of accuracy to be imposed on the surface 32', a trial objective may be made in which the surface 32' approximates the desired shape as much as possible and in which the other surfaces have the desired shape. Subsequently, the mirror objective is measured. The residual aberrations found, which predominantly result from inaccuracies in the surface 32', may then be compensated by adapting the aspherical surface 35 of the radiation window. The ultimate objective can then be manufactured by using the new parameters of the surface 35 thus obtained. This objective is very well corrected for an image field which is, for example, five times as large as the objective in which only the radiation window 34 has an aspherical surface 35.

The diffraction element is, for example a diffraction grating having straight grating strips. This grating splits a beam incident thereon into a non-diffracted zero-order sub-beam and into two diffracted first-order sub-beams and a plurality of diffracted higher-order sub-beams. The grating parameters, such as the ratio between the width of the grating strips and those of the intermediate grating strips and, in the case of a phase grating, the shape and the depth of the grating grooves can be chosen to be such that the intensity product of the zero-order sub-beam formed at the first passage through the grating 39 and a first-order sub-beam formed at the second passage through the grating is maximum. It can be ensured that the first-order sub-beams formed at the first passage through the grating 39 are diffracted through such an angle that the radiation of these beams does not reach the detection system 60 after reflection by the information plane 11.

In the embodiment of Fig. 2 the radiation source 40 and the radiation-sensitive detection system 60 are arranged at some distance from the radiation window 31. This provides the advantage that when using a holographic grating as a diffraction element a fine control is still possible by moving the mirror objective with this grating relative to the detection system.

In the embodiment of Fig. 3 the radiation source 40 and the detection system 60 are arranged on the radiation window 31. The elements 40 and 60 may alternatively be connected to the window 31 via optical fibres. The grating 39 is now a reflecting grating and is arranged on the second reflector 32.

Fig. 4 shows an embodiment of the scanning device in which the diffraction grating 39 is arranged within the body of the mirror objective 30. This body is divided into two parts 36 and 37 in principle consisting of the same material and the grating is provided on one of the facing surfaces of the parts 36 and 37.

The grating 39 may be formed in such a way that the beam originating from this grating and facing the detection system 60 is suitable for supplying, in conjunction with an adapted detection system, a focus error signal. A first embodiment of such a grating with the associated detection system is shown diagrammatically in Fig. 5. The beam 20' is shown by way of its cross-section at the area of the grating 39. This grating 39 comprises two sub-gratings 41 and 42 which are separated from each other by the line 43. The grating strips of the sub-gratings are denoted by the reference numerals 44 and 45, respectively. These grating strips are separated by intermediate strips 46 and 47. In this embodiment the sub-gratings have the same grating period, but the main directions of the preferably curved grating strips 44 of the sub-grating 41 extend at a first angle to the bounding line 43, while the main directions of the curved grating strips 45 of the second sub-grating 42 extend at a second, preferably equally large but opposite angle to the bounding line. The sub-beams are substantially diffracted in a direction transversely of the main directions. Since the main directions are different, the sub-beams $20_a'$ and $20_b'$ are diffracted at different angles in the YZ plane. This means that in the plane of the detectors, the XY plane, the radiation spots $20_a'$ and $20_b'$ are displaced relative to each other in the Y direction. In this Figure and in the other Figures the references X, Y and Z are the axes of a system of coordinates whose origin 0 coincides with the centre of the radiation-emitting surface of the diode laser 40.

Radiation-sensitive detectors in the form of photodiodes 48, 49 and 50, 51, which are separated by narrow strips 52 and 53, are associated with each of the sub-beams $20_a'$ and $20_b'$, respectively. These detectors are positioned in such a way that in the case of a correct focusing of the beam 20 on the information plane 11 the intensity distribution of the radiation spots 22_a and 22_b formed by the sub-beams $20_a'$ and $20_b'$ is symmetrical relative to the detectors 48, 49 and 50, 51, respectively. When a focusing error occurs, the radiation spots $22_a'$ and $22_b'$ will become asymmetrically larger and the centre of the radiation distribution of each radiation spot is displaced transversely of the separating strips 52 and 53, respectively, of the associated detector pair.

If the output signals of the detectors 48, 49, 50 and 51 are represented by S_{48}, S_{49}, S_{50} and S_{51}, respectively, the focus-error signal S_f will be given by:

$$S_f = (S_{48} + S_{51}) - (S_{49} + S_{50})$$

A signal which is proportional to the information being read, or the information signal S_i is given by

$$S_i = S_{48} + S_{49} + S_{50} + S_{51}$$

Not only the composite grating of Fig. 5 but also the grating 39 shown in Fig. 6 can be used for generating a focus-error signal. In this Figure the scanning beam 20 and the reflected beam 20' are shown by means of their cross-section in the plane of the grating, with the sub-beams $20_a'$ and $20_b'$. The main directions of the preferably curved grating strips of the two sub-gratings 42 and 43 now extend at the same angle to the bounding line 43, while the average grating periods of the two sub-gratings are different. Consequently, the angle at which the sub-beam $20_a'$ is diffracted is different from the angle at which the sub-beam $20_b'$ is diffracted. This means that in the plane of the detectors 48, 49, 50 and 51 the radiation spots 22a and 22b are displaced relative to each other in the direction of the bounding line 43.

The sub-gratings 41 and 42 may have straight grating strips and a constant grating period. However, preferably a type of grating, also referred to as holograms, is used which has a varying grating period, the variation in the period being, for example of the order of several percents of the average grating period. Moreover, the grating strips of the two sub-gratings are curved, as is shown in Figs. 5 and 6. Thus, these sub-gratings have a variable lens action. Due to the

varying grating period the positions of the radiation spots 22_a and 22_b can be varied by displacing the grating 9 in its own plane. Aberrations in a direction perpendicular to the direction of the bounding line 43 can be minimised by suitable curvatures of the grating strips. The possibility of moving the positions of the radiation spots is particularly important if an integrated laser-photodiode unit is used, i.e. a component in which the diode laser and the photodetectors are arranged on one support and are therefore fixed relative to each other and thus have a fixed mutual distance in the Z direction. This distance is subject to manufacturing tolerances and cannot be corrected during assembly of the device by displacing the photodiodes relative to the laser diode in the Z direction.

An important advantage of the diffraction grating having curved grating strips, or hologram, as compared with a grating having straight grating strips is that the optical aberrations such as coma and astigmatism, which may occur when using the last-mentioned grating, can be avoided in the first-mentioned grating by taking these aberrations into account when manufacturing this holographic grating and by adapting the curvatures of the grating strips accordingly.

Fig. 7 shows an embodiment of a grating 70 converting the reflected scanning beam 20' into an astigmatic beam $20_1'$. This grating has straight grating strips 71 and a linearly varying grating period. The grating is dimensioned in such a way that the radiation of the beam 20' is largely diffracted in one order, for example the first order. The first-order beam $20_1'$ is no longer focused in one point but in two mutually perpendicular focal lines 75 and 76, the line 75 being located in a position where the beam $20_1'$ would be focused if the grating were not astigmatic. When a focusing error occurs, the focal lines 75 and 76 are simultaneously displaced in the same direction and over the same distance. A so-called four-quadrant detector 80 is arranged in a plane approximately halfway between the positions occupied by the astigmatic focal lines, if the scanning beam is sharply focused on the information plane. This detector, shown in Fig. 8, comprises four detectors 81, 82, 83 and 84 which are arranged in four different quadrants around the chief ray of the diffracted beam $20_1'$. If the scanning beam is sharply focused on the information plane 11, the radiation spot $22'_1$ formed by the beam $20_1'$ in the plane of the detectors is round, as is illustrated by the solid line circle in Fig. 8. If a focusing error occurs, the radiation spot $22_1'$ is deformed to an elliptical spot, as is illustrated by the broken line ellipses in Fig. 8. The major axis of the ellipse extends at an angle of 45° to the separating strips 85 and 86, the sign of the angle being determined by the sign of the focusing error. If the signals of the detectors 81, 82, 83 and 84 are represented by S_{81}, S_{82}, S_{83} and S_{84}, the focus-error signal S_f will be given by:

$$S_f = (S_{81} + S_{83}) - (S_{82} + S_{84}).$$

Also the grating 70 may be in the form of a holographic grating having curved grating strips, thus providing the said adjusting and correction possibilities.

Fig. 9 shows an embodiment of the scanning device specially suitable for writing and reading so-called magneto-optical record carriers. Such record carriers and write and read apparatuses therefor are described in inter alia the Article "Erasable magneto-optical recording" in "Philips Technical Review" Vol. 42, no. 2, 1985, pages 37-47. As described in this Article, a so-called differential method is used when reading a magneto-optical record carrier. The radiation which is reflected by the information plane and whose direction of polarisation is time-modulated in accordance with the information which has been read, is split after passage through the objective into two mutually perpendicularly polarised sub-beams which are incident on separate detectors. In the known device beam splitting is realised by means of a polarisation-sensitive beam splitter.

In the scanning device of Fig. 9 such a beam splitter is no longer required because the grating 39 supplies two spatially separated beams $20_1'$ and $20_2'$, preferably the +1 order beam and the -1 order beam. It can be ensured that these beams have the same intensity. Polarisers 90 and 91 are arranged between the detectors 60_1 and 60_2 so that the beam $20_1'$ incident on the detector 60_1 has a first direction of polarisation and the beam $20_2'$ incident on the detector 60_2 has a second direction of polarisation which is perpendicular to the first direction of polarisation.

In Fig. 9 the grating 39 is provided on the first radiation window 31. However, this grating is preferably provided on the reflector 32 because then the scanning device can be constructed in the most compact manner. This also applies to the other embodiments.

The invention has been described for use in a read apparatus, but it may alternatively be used in a write apparatus or in a combined write-read apparatus in which during recording the focusing and the tracking of the write beam are monitored. The focus-error and tracking-error detection systems described do not utilise special properties of the information surface 2. It is merely necessary and adequate that this surface is reflecting. Therefore the invention may be used in various scanning devices.

Claims

1. A scanning device for optically scanning an information plane (11), which device comprises a radiation source (40) supplying a scanning beam (20) and a mirror objective (30) for focusing the scanning beam to a scanning spot (21) in the information plane, characterized in that, the mirror objective is a transparent body having a first sur-

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varying grating period the positions of the radiation spots 22_a and 22_b can be varied by displacing the grating 9 in its own plane. Aberrations in a direction perpendicular to the direction of the bounding line 43 can be minimised by suitable curvatures of the grating strips. The possibility of moving the positions of the radiation spots is particularly important if an integrated laser-photodiode unit is used, i.e. a component in which the diode laser and the photodetectors are arranged on one support and are therefore fixed relative to each other and thus have a fixed mutual distance in the Z direction. This distance is subject to manufacturing tolerances and cannot be corrected during assembly of the device by displacing the photodiodes relative to the laser diode in the Z direction.

An important advantage of the diffraction grating having curved grating strips, or hologram, as compared with a grating having straight grating strips is that the optical aberrations such as coma and astigmatism, which may occur when using the last-mentioned grating, can be avoided in the first-mentioned grating by taking these aberrations into account when manufacturing this holographic grating and by adapting the curvatures of the grating strips accordingly.

Fig. 7 shows an embodiment of a grating 70 converting the reflected scanning beam 20' into an astigmatic beam $20_1'$. This grating has straight grating strips 71 and a linearly varying grating period. The grating is dimensioned in such a way that the radiation of the beam 20' is largely diffracted in one order, for example the first order. The first-order beam $20_1'$ is no longer focused in one point but in two mutually perpendicular focal lines 75 and 76, the line 75 being located in a position where the beam $20_1'$ would be focused if the grating were not astigmatic. When a focusing error occurs, the focal lines 75 and 76 are simultaneously displaced in the same direction and over the same distance. A so-called four-quadrant detector 80 is arranged in a plane approximately halfway between the positions occupied by the astigmatic focal lines, if the scanning beam is sharply focused on the information plane. This detector, shown in Fig. 8, comprises four detectors 81, 82, 83 and 84 which are arranged in four different quadrants around the chief ray of the diffracted beam $20_1'$. If the scanning beam is sharply focused on the information plane 11, the radiation spot $22'_1$ formed by the beam $20_1'$ in the plane of the detectors is round, as is illustrated by the solid line circle in Fig. 8. If a focusing error occurs, the radiation spot $22_1'$ is deformed to an elliptical spot, as is illustrated by the broken line ellipses in Fig. 8. The major axis of the ellipse extends at an angle of 45° to the separating strips 85 and 86, the sign of the angle being determined by the sign of the focusing error. If the signals of the detectors 81, 82, 83 and 84 are represented by S_{81}, S_{82}, S_{83} and S_{84}, the focus-error signal S_f will be given by:

$$S_f = (S_{81} + S_{83}) - (S_{82} + S_{84}).$$

Also the grating 70 may be in the form of a holographic grating having curved grating strips, thus providing the said adjusting and correction possibilities.

Fig. 9 shows an embodiment of the scanning device specially suitable for writing and reading so-called magneto-optical record carriers. Such record carriers and write and read apparatuses therefor are described in inter alia the Article "Erasable magneto-optical recording" in "Philips Technical Review" Vol. 42, no. 2, 1985, pages 37-47. As described in this Article, a so-called differential method is used when reading a magneto-optical record carrier. The radiation which is reflected by the information plane and whose direction of polarisation is time-modulated in accordance with the information which has been read, is split after passage through the objective into two mutually perpendicularly polarised sub-beams which are incident on separate detectors. In the known device beam splitting is realised by means of a polarisation-sensitive beam splitter.

In the scanning device of Fig. 9 such a beam splitter is no longer required because the grating 39 supplies two spatially separated beams $20_1'$ and $20_2'$, preferably the +1 order beam and the -1 order beam. It can be ensured that these beams have the same intensity. Polarisers 90 and 91 are arranged between the detectors 60_1 and 60_2 so that the beam $20_1'$ incident on the detector 60_1 has a first direction of polarisation and the beam $20_2'$ incident on the detector 60_2 has a second direction of polarisation which is perpendicular to the first direction of polarisation.

In Fig. 9 the grating 39 is provided on the first radiation window 31. However, this grating is preferably provided on the reflector 32 because then the scanning device can be constructed in the most compact manner. This also applies to the other embodiments.

The invention has been described for use in a read apparatus, but it may alternatively be used in a write apparatus or in a combined write-read apparatus in which during recording the focusing and the tracking of the write beam are monitored. The focus-error and tracking-error detection systems described do not utilise special properties of the information surface 2. It is merely necessary and adequate that this surface is reflecting. Therefore the invention may be used in various scanning devices.

Claims

1. A scanning device for optically scanning an information plane (11), which device comprises a radiation source (40) supplying a scanning beam (20) and a mirror objective (30) for focusing the scanning beam to a scanning spot (21) in the information plane, characterized in that, the mirror objective is a transparent body having a first sur-

face facing the radiation source and a second surface remote from the radiation source, said first surface having a first radiation window (31) which is located symmetrically around the optical axis (AA') of the mirror objective and having a first reflector (33) surrounding said window, said second surface having a second reflector (32) which is located symmetrically around the optical axis and a second radiation window (34) surrounding the second reflector, the radiation path through the mirror objective extending via passage through the first window (31), reflection on the second reflector (32), reflection on the first reflector (33) and passage through the second window (34), at least the second radiation window (34) has an aspherical surface (35).

2. A scanning device as claimed in Claim 1, characterized in that the second reflector (32) has an aspherical surface.

3. A scanning device as claimed in Claim 1 or 2 for scanning a radiation-reflecting information plane (11) in which radiation from the information plane traverses the mirror objective so as to be focused on a radiation-sensitive detection system (60) which is arranged on the same side of the mirror objective (30) as the radiation source (40), characterized in that the mirror objective comprises a beam-separating element (39) for spatially separating the beam (20) emitted by the radiation source and the beam (20) reflected from the information plane and focused by the mirror objective.

4. A scanning device as claimed in Claim 3, characterized in that the beam-separating element is a diffraction element (39).

5. A scanning device as claimed in Claim 4, characterized in that the diffraction element (39) is reflective and is arranged on the second reflector (32).

6. A scanning device as claimed in Claim 4, characterized in that the diffraction element (39) is radiation-transparent and is arranged on the first radiation window (31).

7. A scanning device as claimed in Claim 5, characterized in that the transparent body of the mirror objective comprises two parts (36, 37) which are arranged against each other, in that the diffraction element (39) is radiation-transparent and is arranged on one of the two facing surfaces of the two parts (36, 37).

8. A scanning device as claimed in Claim 4, 5, 6 or 7, characterized in that the diffraction element is an element (70) introducing astigmatism and in that the radiation-sensitive detection system (80) comprises four detectors (81, 82, 83 and 84) which are arranged in four different quadrants around the chief ray of the beam ($20'_1$) diffracted by the diffraction element.

9. A scanning device as claimed in Claim 4, 5, 6 or 7, characterized in that the diffraction element (39) is a diffraction grating comprising two sub-gratings (41, 42) and splitting the diffracted beam into two subbeams ($20'_a$, $20'_b$) and in that the detection system comprises two detector pairs (48, 49, 50, 51), a first ($20'_a$) and a second sub-beam ($20'_b$) co-operating with a first (48, 49) and a second detector pair (50, 51), respectively.

10. A scanning device as claimed in Claim 9, characterized in that the sub-gratings (41, 42) have a varying grating period and in that the grating strips (44, 45) of the sub-gratings are curved.

11. A scanning device as claimed in Claim 9 or 10, characterized in that the grating strips (44) of the one sub-grating (41) have the same main direction as those (45) of the other sub-grating (42), in that the average grating periods of the sub-gratings are different and in that the detector pairs (48, 49, 50, 51) are juxtaposed in a direction parallel to the bounding line (43) between the sub-gratings (41, 42).

12. A scanning device as claimed in Claim 9 or 10, characterized in that the sub-gratings (41, 42) have the same average grating period, in that the main directions of the grating strips (44) of the one sub-grating (41) extend at a first angle and those (45) of the other sub-grating (42) extend at a second angle to the bounding line (43) of the two sub-gratings and in that the detector pairs (48, 49, 50, 51) are juxtaposed in a direction transversely of the direction of the said bounding line (43).

13. A scanning device as claimed in any one of the preceding Claims, characterized in that the radiation source (40) is connected to the first radiation window (31).

14. A scanning device as claimed in any one of the preceding Claims, provided with a radiation-sensitive detection system, characterized in that the radiation-sensitive detection system (60) is arranged on the first radiation window (31) in the radiation path of radiation which has been reflected from the information plane (11) and which has traversed the mirror objective (30).

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15. A mirror objective characterized in that it is constituted by a transparent body having a first surface at the object side and a second surface at the image side, said first surface being provided with a first radiation window (31) arranged symmetrically about the optical axis (AA') of the mirror objective, and with a first reflector (33) surrounding said window, said second surface being provided with a second reflector (32) arranged symmetrically about the optical axis, and with a second radiation window (34) surrounding the second reflector., at least the second radiation window (34) has an aspherical surface (35).

16. A mirror objective as claimed in Claim 15, characterized in that the second reflector (32) has an aspherical surface (35).

17. An optical write and/or read apparatus provided with a scanning device as claimed in any one of Claims 1 to 14 or a mirror objective as claimed in Claim 15 or 16.

Patentansprüche

1. Abtastvorrichtung zum optischen Abtasten einer Informationsebene (11), wobei die Vorrichtung eine Strahlungsquelle (40) zur Lieferung eines Abtaststrahlenbündels (20) sowie ein Spiegelobjektiv (30) zum Fokussieren des Abtaststrahlenbündels zu einem Abtastfleck (21) in der Informationsebene enthält, dadurch gekennzeichnet, daß das Spiegelobjektiv ein durchsichtiger Körper ist, der eine der Strahlungsquelle zugewandte erste Oberfläche und eine von der Strahlungsquelle abgewandte zweite Oberfläche hat, wobei die genannte erste Oberfläche ein symmetrisch um die optische Achse (AA') des Spiegelobjektivs liegendes erstes Strahlungsfenster (31) hat und einen das genannte Fenster umgebenden ersten Reflektor (33), die genannte zweite Oberfläche einen symmetrisch um die optische Achse liegenden zweiten Reflektor (32) hat und ein den zweiten Reflektor umgebendes zweites Strahlungsfenster (34), wobei der Strahlungsweg durch das Spiegelobjektiv über den Durchgang durch das erste Fenster (31), Reflexion am zweiten Reflektor (32), Reflexion am ersten Reflektor (33) und Durchgang durch das zweite Fenster (34) verläuft, und daß mindestens das zweite Strahlungsfenster (34) eine asphärische Oberfläche (35) hat.

2. Abtastvorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der zweite Reflektor (32) eine asphärische Oberfläche hat.

3. Abtastvorrichtung nach Anspruch 1 oder 2 zum Abtasten einer strahlungreflektierenden Informationsebene (11), bei der von der Informationsebene kommende Strahlung das Spiegelobjektiv durchquert, um auf ein strahlungsempfindliches Detektionssystem (60) fokussiert zu werden, das auf der gleichen Seite des Spiegelobjektivs (30) angeordnet ist wie die Strahlungsquelle (40), dadurch gekennzeichnet, daß das Spiegelobjektiv ein bündeltrennendes Element (39) zum räumlichen Trennen des von der Strahlungsquelle emittierten Strahlenbündels (20) und des an der Informationsebene reflektierten und vom Spiegelobjektiv fokussierten Strahlenbündels (20) umfaßt.

4. Abtastvorrichtung nach Anspruch 3, dadurch gekennzeichnet, daß das bündeltrennendes Element ein Beugungselement (39) ist.

5. Abtastvorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß das Beugungselement (39) reflektierend ist und auf dem zweiten Reflektor (32) angeordnet ist.

6. Abtastvorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß das Beugungselement (39) strahlungsdurchlässig ist und auf dem ersten Strahlungsfenster (31) angeordnet ist.

7. Abtastvorrichtung nach Anspruch 5, dadurch gekennzeichnet, daß der durchsichtige Körper des Spiegelobjektivs zwei einander gegenüber angeordnete Teile (36, 37) umfaßt und daß das Beugungselement (39) strahlungsdurchlässig ist und auf einer der beiden einander zugewandten Flächen der beiden Teile (36, 37) angeordnet ist.

8. Abtastvorrichtung nach Anspruch 4, 5, 6, oder 7, dadurch gekennzeichnet, daß das Beugungselement ein Astigmatismus einbringendes Element (70) ist und daß das strahlungsempfindliche Detektionssystem (80) vier Detektoren umfaßt (81, 82, 83, 84), die in vier verschiedenen Quadranten um den Hauptstrahl des von dem Beugungselement gebeugten Strahlenbündels ($20'_1$) angeordnet sind.

9. Abtastvorrichtung nach Anspruch 4, 5, 6, oder 7, dadurch gekennzeichnet, daß das Beugungselement (39) ein Beugungsgitter mit zwei Teilgittern (41, 42) ist, das das gebeugte Strahlenbündel in zwei Teilbündel ($20'_a$, $20'_b$) aufteilt, und daß das Detektionssystem zwei Detektorpaare (48, 49, 50, 51) umfaßt, wobei ein erstes ($20'_a$) bzw. ein zweites ($20'_b$) Teilbündel mit einem ersten (48, 49) bzw. zweiten (50, 51) Detektorpaar zusammenwirkt.

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10. Abtastvorrichtung nach Anspruch 9, dadurch gekennzeichnet, daß die Teilgitter (41, 42) eine sich ändernde Gitterperiode haben und daß die Gitterstreifen (44, 45) der Teilgitter gekrümmt sind.

11. Abtastvorrichtung nach Anspruch 9 oder 10, dadurch gekennzeichnet, daß die Gitterstreifen (44) des einen Teilgitters (41) die gleiche Hauptrichtung haben wie die (45) des anderen Teilgitters (42), daß die mittleren Gitterperioden der Teilgitter unterschiedlich sind und daß die Detektorpaare (48, 49, 50, 51) in einer parallel zur Grenzlinie (43) zwischen den Teilgittern (41, 42) liegenden Richtung nebeneinander liegen.

12. Abtastvorrichtung nach Anspruch 9 oder 10, dadurch gekennzeichnet, daß die Teilgitter (41, 42) die gleiche mittlere Gitterperiode haben, daß die Hauptrichtungen der Gitterstreifen (44) des einen Teilgitters (41) einen ersten Winkel und die (45) des anderen Teilgitters (42) einen zweiten Winkel mit der Grenzlinie (43) zwischen den beiden Teilgittern bilden und daß die Detektorpaare (48, 49, 50, 51) in einer quer zur Richtung dieser Grenzlinie (43) liegenden Richtung nebeneinander liegen.

13. Abtastvorrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Strahlungsquelle (40) mit dem ersten Strahlungsfenster (31) verbunden ist.

14. Abtastvorrichtung nach einem der vorhergehenden Ansprüche, die mit einem strahlungsempfindlichen Detektionssystem versehen ist, dadurch gekennzeichnet, daß das strahlungsempfindliche Detektionssystem (60) auf dem ersten Strahlungsfenster (31) in dem Strahlungsweg von Strahlung angeordnet ist, die an der Informationsebene (11) reflektiert worden ist und das Spiegelobjektiv (30) durchquert hat.

15. Spiegelobjektiv, dadurch gekennzeichnet, daß es von einem durchsichtigen Körper mit einer ersten Oberfläche an der Objektseite und einer zweiten Oberfläche an der Bildseite gebildet wird, wobei die genannte erste Oberfläche mit einem symmetrisch um die optische Achse (AA') des Spiegelobjektivs liegenden ersten Strahlungsfenster (31) versehen ist und einem das genannte Fenster umgebenden ersten Reflektor (33), die genannte zweite Oberfläche mit einem symmetrisch um die optische Achse liegenden zweiten Reflektor (32) versehen ist und einem den zweiten Reflektor umgebenden zweiten Strahlungsfenster (34), und daß mindestens das zweite Strahlungsfenster (34) eine asphärische Oberfläche (35) hat.

16. Spiegelobjektiv nach Anspruch 15, dadurch gekennzeichnet, daß der zweite Reflektor (32) eine asphärische Oberfläche (35) hat.

17. Optisches Schreib- und/oder Lesegerät mit einer Abtasteinrichtung nach einem der Ansprüche 1 bis 14 oder einem Spiegelobjektiv nach Anspruch 15 oder 16.

Revendications

1. Dispositif de balayage pour balayer optiquement une surface d'information (11), ledit dispositif comporte une source de rayonnement (40) fournissant un faisceau de balayage (20) et un objectif à miroir (30) pour focaliser le faisceau de balayage sur un spot de balayage (21) dans la surface d'information, caractérisé en ce que l'objectif à miroir est un corps transparent présentant une première surface située vis-à-vis de la source de rayonnement et une deuxième surface éloignée de la source de rayonnement, ladite première surface comportant une première fenêtre de rayonnement (31) située symétriquement autour de l'axe optique (AA') de l'objectif à miroir et comportant un premier réflecteur (33) entourant ladite fenêtre, ladite deuxième surface comportant un deuxième réflecteur (32) situé symétriquement autour de l'axe optique et une deuxième fenêtre de rayonnement (34) entourant le deuxième réflecteur, le trajet de rayonnement à travers l'objectif à miroir s'étendant par un passage à travers la première fenêtre (31), par réfléchissement sur le deuxième réflecteur (32), par réfléchissement sur le premier réflecteur (33) et par un passage à travers la deuxième fenêtre (34), et en ce qu'au moins la deuxième fenêtre de rayonnement (34) présente une surface asphérique (35).

2. Dispositif de balayage selon la revendication 1, caractérisé en ce que le deuxième réflecteur (32) présente une surface asphérique.

3. Dispositif de balayage selon la revendication 1 ou 2 pour balayer une surface d'information réfléchissant le rayonnement (11), dans lequel le rayonnement provenant de la surface d'information traverse l'objectif à miroir de façon à être focalisé sur un système de détection sensible au rayonnement (60) disposé du même côté de l'objectif à miroir (30) que la source de rayonnement (40), caractérisé en ce que l'objectif à miroir comporte un élément séparateur de faisceau (39) pour séparer spatialement le faisceau (20) émis par la source de rayonnement et le faisceau (20) réfléchi à partir de la surface d'information et fo-

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calisé par l'objectif à miroir.

4. Dispositif de balayage selon la revendication 3, caractérisé en ce que l'élément séparateur de faisceau est un élément de diffraction (39).

5. Dispositif de balayage selon la revendication 4, caractérisé en ce que l'élément de diffraction (39) est réfléchissant et qu'il est disposé sur le deuxième réflecteur (32).

6. Dispositif de balayage selon la revendication 4, caractérisé en ce que l'élément de diffraction (39) est transparent au rayonnement et qu'il est disposé sur la première fenêtre de rayonnement (31).

7. Dispositif de balayage selon la revendication 5, caractérisé en ce que le corps transparent de l'objectif à miroir comporte deux parties (36, 37) disposées l'une contre l'autre, en ce que l'élément de diffraction (39) est transparent au rayonnement et qu'il est disposé sur l'une des deux surfaces situées vis-à-vis des deux parties (36, 37).

8. Dispositif de balayage selon la revendication 4, 5, 6 ou 7, caractérisé en ce que l'élément de diffraction est un élément (70) introduisant de l'astigmatisme et en ce que le système de détection sensible au rayonnement (80) comporte quatre détecteurs (81, 82, 83 et 84) qui sont disposés en quatre quadrants différents autour du rayon principal du faisceau ($20'_1$) diffracté par l'élément de diffraction.

9. Dispositif de balayage selon la revendication 4, 5, 6 ou 7, caractérisé en ce que l'élément de diffraction (39) est un réseau de diffraction comportant deux sous-réseaux (41, 42) et divisant le faisceau de balayage diffracté en deux sous-faisceaux ($20'_a$, $20'_b$) et en ce que le système de détection comporte deux paires de détecteurs (48, 49, 50, 51), un premier ($20'_a$) et un deuxième sous-faisceau ($20'_b$) coopérant avec une première (48, 49) respectivement une deuxième paire de détecteurs (50, 51).

10. Dispositif de balayage selon la revendication 9, caractérisé en ce que les sous-réseaux (41, 42) présentent une période de réseau variable et en ce que les bandes de réseau (44, 45) des sous-réseaux sont courbées.

11. Dispositif de balayage selon la revendication 9 ou 10, caractérisé en ce que les bandes de réseau (44) de l'un (41) des deux sous-réseaux présentent la même direction principale que celles (45) de l'autre sous-réseau (42), en ce que les périodes de réseau moyennes des sous-réseaux sont différentes et en ce que les paires de détecteurs (48, 49, 50, 51) sont juxtaposées dans une direction s'étendant parallèlement à la ligne de séparation (43) entre les sous-réseaux (41, 42).

12. Dispositif de balayage selon la revendication 9 ou 10, caractérisé en ce que les sous-réseaux (41, 42) présentent la même période de réseau moyenne, en ce que les directions principales des bandes de réseau (44) de l'un (41) des deux sous-réseaux s'étendent sous un premier angle et celles (45) de l'autre sous-réseau (42) s'étendent sous un deuxième angle vers la ligne de séparation (43) des deux sous-réseaux, et en ce que les paires de détecteurs (48, 49, 50, 51) sont juxtaposées dans une direction s'étendant transversalement à la direction de ladite ligne de séparation (43).

13. Dispositif de balayage selon l'une quelconque des revendications précédentes, caractérisé en ce que la source de rayonnement (40) est reliée à la première fenêtre de rayonnement (31).

14. Dispositif de balayage selon l'une quelconque des revendications précédentes, muni d'un système de détection sensible au rayonnement, caractérisé en ce que le système de détection sensible au rayonnement (60) est disposé sur la première fenêtre de rayonnement (31) située dans le trajet de rayonnement du rayonnement qui a été réfléchi à partir de la surface d'information (11) et qui a traversé l'objectif à miroir (30).

15. Objectif à miroir, caractérisé en ce qu'il est constitué d'un corps transparent présentant une première surface située du côté d'objet et une deuxième surface située du côté d'image, ladite première surface comportant une première fenêtre de rayonnement (31) disposée symétriquement autour de l'axe optique (AA') de l'objectif à miroir, et un premier réflecteur (33) entourant ladite fenêtre, ladite deuxième surface comportant un deuxième réflecteur (32) disposé symétriquement autour de l'axe optique, et une deuxième fenêtre de rayonnement (34) entourant le deuxième réflecteur, au moins la deuxième fenêtre de rayonnement (34) présente une surface asphérique (35).

16. Objectif à miroir selon la revendication 15, caractérisé en ce que le deuxième réflecteur (32) présente une surface asphérique (35).

17. Appareil d'enregistrement et/ou de lecture optique muni d'un dispositif de balayage selon l'une

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quelconque des revendications 1 à 14 ou d'un objectif à miroir selon la revendication 15 ou 16.