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Opto-electronic focusing-error detection device

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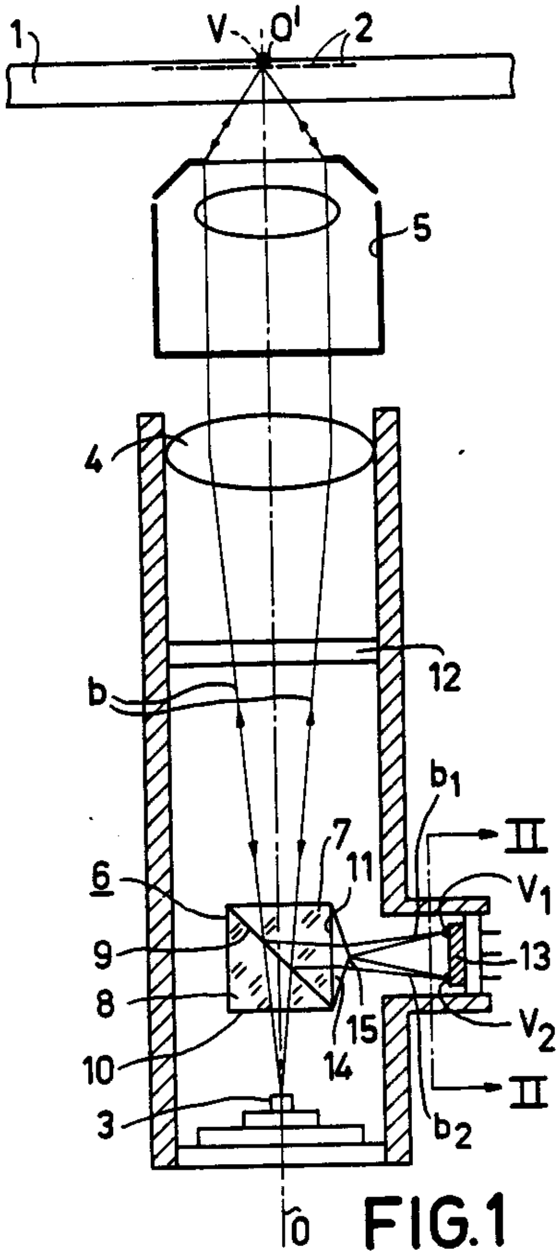

FIG.1

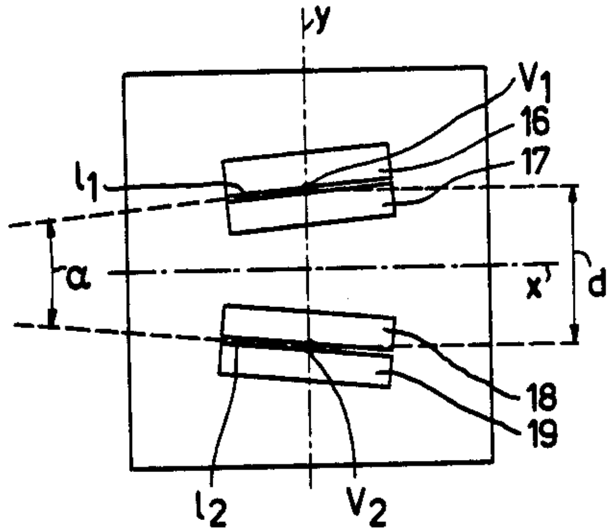

FIG.3

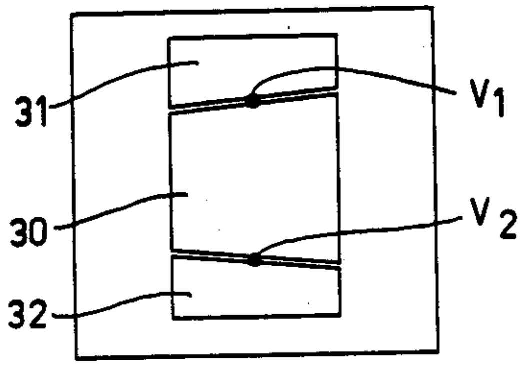

FIG.4

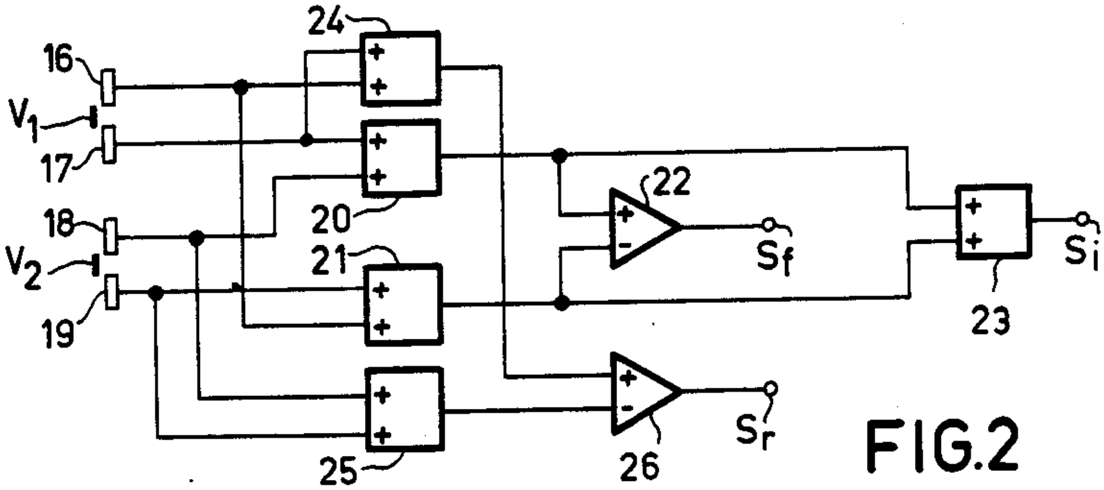

FIG.2

"OPTO-ELECTRONIC FOCUSING-ERROR DETECTION DEVICE"

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The invention relates to an opto-electronic focusing-error detection device for detecting a deviation between a first radiation-reflecting surface and a plane of focusing of an objective system in optical imaging apparatus, in particular apparatus for reading a record carrier having an optical radiation-reflecting information structure or apparatus for optically recording information in a record carrier, which focusing error-detection device comprises a beam-splitter arranged in the path of a radiation beam reflected by the first surface to form two subbeams, and a radiation sensitive detection system arranged to receive said subbeams and comprising a plurality of detectors which are separated from each other by narrow strips, first and second separating strips being associated one each with said subbeams, the outputs of the detectors being connected to the inputs of an electronic circuit in which a focusing-error signal is derived from the detector signals.

Such a device is described in the article: "PCM-Schallplatte für die 80er Jahre" in "Radio Mentor" 45 (1979), pages 138-140. This device comprises a radiation source in the form of a semiconductor-diode laser. The read beam emitted by this laser is focused on an information structure of a disk-shaped record carrier by an objective system. The read beam which has been reflected by the information structure traverses the objective system a second time and subsequently passes through a beam-splitter prism arranged between the radiation source and the objective system. This prism diverts the modulated read beam from the radiation path of the beam emitted by the source, so that the modulated beam can be received by a radiation-sensitive detection system which supplies an electric signal in conformity with the modulation of the last-mentioned beam.

Optical systems which are used for imaging very small information details and which operate with a large numerical aperture have a small depth of focus. In such imaging systems, which are used in, for example, microscopes or apparatus for reading optical record carriers with very small details or apparatus for recording information in a record carrier, it is essential that a deviation between the actual and the desired plane of focusing can be detected in order to correct the focusing in response thereto. For this purpose, as is described in the aforementioned article, a roof prism may be arranged on the exit face of the beam-splitter prism. The roof prism splits the beam into two subbeams which are received by separate detectors of the radiation-sensitive detection system. This system comprises, for example, four radiation-sensitive detectors which are arranged along a line transverse to the refractive edge of the roof prism. Subtracting the sum of the signals from the two inner detectors from the sum of the signals from the two outer detectors yields a signal which is proportional to a focusing error.

In this focusing-error detection system the distance between the centres of the radiation spots formed in the plane of the detectors should be equal to the distance between the separating strips of the detectors and the radiation spots should be positioned correctly relative to the detectors, so that the radiation spots are disposed symmetrically relative to the associated separating strip when the beam is focused correctly. If the distance between the centres of the radiation spots is not correct and/or if the radiation spots are not positioned correctly an erroneous focusing-error signal is obtained and correct focusing is then impossible.

It is an object of the present invention to arrange the detectors in such a way that after assembly of the focusing-error detection system the distance between the centres of the radiation spots can be made equal to the distance between the separating strips and so that the position of the radiation spots can be corrected.

To this end the invention provides an opto-electronic focusing-error detection device for detecting a deviation between a first radiation-reflecting surface and a plane of focusing of an objective system in optical imaging apparatus, which focusing-error detection device comprises a beam splitter arranged in the path of a radiation beam reflected by the first surface to form two subbeams, a radiation-sensitive detection system arranged to receive said subbeams and comprising a plurality of detectors which are separated from each other by strips, first and second separating strips being associated one each with said subbeams and being inclined at an acute angle to one another, and an electronic circuit connected to receive the detector signals and in which a focusing-error signal is derived from the detector signals.

The desired object can be achieved by moving the two subbeams in one or two directions within the plane of the detectors when the beam is correctly in focus.

In a preferred embodiment of the focusing-error detection system the angle between the separating strips is substantially 22°.

With this choice of the angle the adjustment range is sufficiently large and the slope of the focusing-error characteristic remains large even when the detector has limited dimensions.

In apparatus for reading and/or recording information in a track on a radiation-reflecting information surface of a record carrier, which apparatus comprises a focusing-error detection device in accordance with the invention, the detection device may comprise four separate detectors, beam-splitting taking place in a plane which is effectively transverse to the track direction, and the electronic circuit may comprise means for deriving a signal which provides an indication of the transverse position, relative to the information track, of the radiation spot formed in the plane of the information surface.

The invention will now be described in more detail, by way of example, with reference to the drawing, in which:

Figure 1 shows an embodiment of an apparatus provided with the present focusing-error detection device,

Figure 2 shows the separate detectors and the electronic processing circuit,

Figure 3 shows a preferred embodiment of the detection device, and

Figure 4 shows a further embodiment of the detection device.

Figure 1 shows a small part of a disk-shaped record carrier 1 in radial cross-section. The radiation-reflecting information structure is disposed on the upper side of the record carrier and comprises a multitude of information areas, not shown, arranged along information tracks 2. The information structure is scanned by a read beam b produced by a radiation source 3, for example a semiconductor-diode laser. A lens 4 forms the diverging beam into a parallel beam of such a cross-section that the pupil of an objective system 5 is filled adequately. This objective system then forms a radiation spot V of minimal dimensions on the information structure.

The read beam is reflected by the information structure and, as the record carrier moves relative to the read beam, the reflected beam is time-modulated in conformity with the information stored in the record carrier. In order to separate the modulated beam from the beam emitted by the radiation source a beam-splitter prism 6 is arranged between the radiation source and the objective system. This prism may comprise two prismatic elements 7 and 8, between which a beam-splitting layer 9 is disposed. The entrance face and the exit face of the prism 6 are designated 10 and 11 respectively. The layer 9 may be a semitransparent layer. In order to minimise the loss of radiation in the read unit a polarization-sensitive beam-splitting layer may be used. A $\lambda/4$ plate 12, λ being the wavelength of the read beam b, should then be arranged between the objective system and the prism 6.

Said prism is traversed twice by the read beam and rotates the plane of polarization of this beam through 90° in total. The beam emitted by the radiation source is then transmitted almost completely by the prism, whereas the modulated beam is reflected almost completely towards a radiation-sensitive detection system 13. This system supplies a signal which is modulated in accordance with the information stored in the record carrier.

In order to generate a focusing-error signal which provides an indication of the magnitude and the direction of a deviation between the plane of focusing of the objective system and the plane of the information structure a roof prism 14 is arranged on the exit face 11 of the beam-splitter prism 6 and the radiation-sensitive detection system 13 comprises, for example, four radiation-sensitive detectors. In Figure 2, which illustrates the focusing-error detection principle, these detectors are designated 16, 17, 18 and 19. This Figure is a view of the detectors taken along the line II-II' in Figure 1. The refractive edge 15 of the prism 14 may be parallel to the optical axis, 00' in Figure 1, of the read unit. However, preferably, as is shown in Figure 1, the roof prism is arranged in such a way that the refractive edge 5 is transverse to the optical axis 00'. This enables a tracking-error signal to be derived from the detector signals.

The roof prism splits the beam <u>b</u> into two subbeams b_1 and b_2 which cooperate with the detectors 16, 17 and the detectors 18, 19 respectively.

Figures 1 and 2 show the situation in which the read beam is focused exactly in the plane of the information structure. The read unit may be constructed so that the focus of the reflected beam is disposed exactly in the plane of the detectors. In the case of correct focusing the subbeams b_1 and b_2 are symmetrically incident on their associated detectors 16, 17 and 18, 19 respectively. In the case of a focusing error the energy distribution within the subbeams b_1 and b_2 respectively relative to their associated detectors changes, which may be regarded as a displacement of the radiation spots V_1 and V_2 formed by the subbeams relative to the detectors. If the focus of the beam emitted by the radiation source is disposed above the plane of the information structure, the beams b_1 and b_2 are moved inwards and the detectors 16 and 19 receive less radiation energy than the detectors 17 and 18. If the focus of the read beam emitted by the radiation source is disposed below the plane of the information structure the reverse happens and the detectors 17 and 18 receive a less radiation energy than the detectors 16 and 19. As shown in Figure 2, by applying the signals from the detectors 17 and 18 to a first adder 20 and those from the detectors 16 and 19 to a second adder 21 and applying the signals from these adders to a differential amplifier 22, a focusing-error signal S_f is obtained. The information signal S_i can be obtained by means of a third adder 23, whose inputs are connected to the adders 20 and 21. Consequently, the signals S_f and S_i are given by: $S_f = (S_{17} + S_{18})-(S_{16} + S_{19})$ and $S_i=S_{16}+S_{17}+S_{18}+S_{19}$ respectively.

Either the base, as is shown in Figure 1, or the refractive edge 15 of the roof prism 14 may be disposed on the exit face 11 of the beam-splitter prism. For the selected large value of the apex angle of the roof prism, for example approximately 170°, the prism 14 will have substantially the same effect in either case. The apex angle is selected to be as large as possible in order to ensure that the detection elements can be arranged as close as possible to each other and can be constructed as one integrated detector.

The focusing-error signal is determined by the position of the centre of the radiation spots V_1 and V_2 relative to the separating strip of the detectors 16 and 17 and to the separating strip of the detectors 18 and 19 respectively. Care must be taken that when the beam b_1 is correctly focused the distance between the centres of the radiation spots is equal to the distance between the separating strips. Because of tolerances in the optical elements of the focusing-error detection device deviations in the distance between the radiation spots may occur. If the distance between the radiation spots is too large said radiation spots will be shifted outwards relative to the detectors even in the case of correct focusing, so that a positive focusing error signal will be supplied. If the distance between the radiation spots is too small a negative focusing-error signal will be supplied.

In order to permit the distance between the centres of the detector pairs 16, 17 and 18, 19 to be adapted to the distance between the centres of the radiation spots during assembly of the device the detector system is constructed as shown in Figure 3. The detector pairs are no longer arranged parallel to each other, but in such a way that the separating strip l_1 of the detectors 16 and 17 makes an acute angle α with the separating strip l_2 of the detectors 18 and 19. In Figure 3 the two radiation spots V_1 and V_2 are shown as having a mutual distance d which corresponds to the distance between the separating strips measured along the line y through the centre of the detector system. If the distance between the radiation spots V_1 and V_2 is greater than d, the subbeams b_1 and b_2 should be shifted in such a way that the radiation spots V_1 and V_2 are moved to the right until the centres of the radiation spots are disposed exactly on the separating strips. If the distance between the centres of the radiation spots is too small they should be shifted to the left.

For adjustment of the read unit during assembly for correct focus the positions of the radiation spots V_1 and V_2 relative to the detectors are determined by measuring the detector signals. By means of this measurement the positions of the radiation spots may be corrected, for example, by displacing and/or by tilting the prism 6, in such a way that the centres of the radiation spots are disposed on the separating strips l_1 and l_2.

The sensitivity of the focusing error detection device is optimal if the strips l_1 and l_2 extend in the x-direction, i.e. extend transversely of the direction y in which the radiation spots V_1 and V_2 move in the case of focusing errors. If angle α is of the order of 22° then, although the dimensions of the detectors are limited, the distance between the separating strips can be adapted satisfactorily to the distance between the radiation spots V_1 and V_2, whilst the sensitivity to focusing errors remains great enough.

By arranging the refractive edge 15 of the prism 14 transverse to the optical axis 00', as is shown in Figure 1, the radiation spots V_1 and V_2 are shifted relative to each other in a direction which is effectively transverse to the track direction. In this case it is possible to derive a signal which provides an indication of the position of the read spot V relative to the centre of a track to be read from the signals supplied by the four detectors 16, 17, 18 and 19. As is shown in Figure 2, this signal S_r, is obtained by applying the signals from the detectors 16 and 17 to a summing device 24 and those from the detectors 18 and 19 to a summing device 25 and by applying the signals from the summing devices to a differential amplifier 26. Consequently, the signal S_r is given by:

$$S_r = (S_{16} + S_{17}) - (S_{18} + S_{19}).$$

If the detection system 13 is not used for generating a tracking signal S_r this system may comprise only three detectors, as is shown in Figure 4. The strip 1_1 separating the detectors 31 and 30 and the strip 1_2 separating the detectors 32 and 30 again make an acute angle with each other. The focusing error signal S_f is given by:

$$S_f = (S_{31} + S_{32}) - S_{30}.$$

The invention has been described for use in conjunction with an optical read unit, but may alternatively be employed in a write unit or in a combined read-write unit. The write unit is of a construction similar to the read unit described. For the recording of information, for example by melting pits into a metallic layer, more energy is required than for reading and, moreover, the write beam must be time-modulated in accordance with the information to be recorded. As radiation source in the write unit a gas laser, such as HeNe laser, may be used, together with a modulator, such as an electro-optical or acousto-optical modulator, arranged in the path of the write beam. Alternatively, a diode laser may be used, the write beam being modulated by varying the current through the diode laser, so that no separate modulator is required.

The focusing-error detection device described does not employ special properties of the optical information structure or of the surface on which it is to be focused. The only requirement is that this surface is radiation-reflecting. The focusing-error detection device may therefore be used in various apparatus which require very accurate focusing, for example in microscopes.

CLAIMS:

1. An opto-electronic focusing-error detection device for detecting a deviation between a first radiation-reflecting surface and a plane of focusing of an objective system in optical imaging apparatus, which focusing-error detection device comprises a beam splitter arranged in the path of a radiation beam reflected by the first surface to form two subbeams, a radiation-sensitive detection system arranged to receive said subbeams and comprising a plurality of detectors which are separated from each other by strips, first and second separating strips being associated one each with said subbeams and being inclined at an acute angle to one another, and an electronic circuit connected to receive the detector signals and in which a focusing-error signal is derived from the detector signals.

2. An opto-electronic focusing-error detection device as claimed in Claim 1, wherein the angle between the separating strips is substantially 22°.

3. Apparatus for reading and/or recording information in a track on a radiation-reflecting surface of a record carrier, which apparatus comprises a focusing-error detection device as claimed in Claim 1 or 2, wherein the detection device comprises four separate detectors, beam-splitting takes place in a plane which is effectively transverse to the track direction, and the electronic circuit comprises means for deriving a signal which provides an indication of the transverse position, relative to the information track, of the radiation spot formed in the plane of the information surface.

4. An opto-electronic focusing-error detection device substantially as described with reference to Figures 1, 2 and 3 of the accompanying drawing.

5. An opto-electronic focusing-error detection device substantially as described with reference to Figures 1 and 4 of the accompanying drawing.

6. Apparatus for reading and/or recording information in a track on a radiation-reflecting surface of a record carrier, said apparatus comprising a focusing error detection device and a tracking error detection device as claimed in Claim 4.

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