

Description

The present invention relates to an apparatus for detecting the focus error of a radiant energy beam with respect to a surface according to the introductory portion of claim 1.

Such an apparatus being provided with two independent apertures for two reflected beams is already known (see US—A—203 031 and IBM Technical Disclosure Bulletin, Vol. 15, No. 2, July 1972, pages 504—505).

It is the object of the present invention to improve the known apparatus by providing a more compact and simple focussing system.

In accordance with the invention this object can be obtained by using the features presented within the characterizing portion of claim 1.

Further improvements of the invention are presented within the framework of subclaims 2 to 4.

Other aspects and advantages of the invention will become apparent from the following more detailed description, taken in conjunction with the accompanying drawings.

Figure 1 is a schematic view showing a combination of optical and electrical components configured in accordance with the present invention;

Figure 2 is a fragmentary view of a portion of Fig. 1, showing in more detail the relationship between two split reflected beams and an aperture; and

Figure 3 is a graph showing the relationship between the electrical output of the detector shown in Fig. 1 and the relative focal distance between an objective lens and a surface.

As shown in the drawings for purposes of illustration, the present invention is concerned with a focus detector. More particularly the invention relates to a focus detector particularly well suited for use in recording and playback machines in which a radiant energy beam, such as a light beam from a laser or other source, is directed onto a recording surface, either to record information on or to reproduce information from the surface.

The beam reflected from the recording surface is split into two equal portions which are focused and apertured in such a manner that equal amounts of radiant power in the two portions of the beam will impinge upon respective detector elements only when the original beam is exactly focused on the recording surface. Whenever there is relative movement away from the in-focus condition, more light falls on one detector element than the other, and a differential output signal is produced indicative of both the magnitude and polarity of the focus error.

More specifically, as shown in Fig. 1, a collimated, linearly polarized laser light beam is incident on a condensing lens, indicated by reference numeral 10, and then passes through a polarizing beam splitter 12 and a quarter-wave plate 14. The beam is circularly polarized

by the quarter wave plate 14 and is then focused onto a recording surface 16 by means of an objective lens 18. After reflection from the recording surface 16, with its sense of circuit polarization reversed, the beam returns through the objective lens 18 to the quarter-wave plate 14, where it is linearly polarized in a plane orthogonal to the polarization plane of the original beam incident upon the beam splitter 12.

The beam emerging from the quarter-wave plate 14 is now reflected by the beam splitter 12 to a conventional beam splitter 20, which reflects half of the light beam and transmits the other half through to a mirror 22. The beam portion transmitted to the mirror 22 is reflected therefrom and converges to a first focal point 24. An aperture 26 is disposed in the path of this reflected beam at a location beyond the focal point 24, and, as will shortly be appreciated, the aperture limits the amount of light in the beam and passes a portion of it to one segment 28a of a split diode detector.

The portion of the beam reflected at beam splitter 20 converges to a second focal point 30, after passing through the same aperture 26. The spacings and dimensions of the components are such that the aperture 26 operates to limit the amount of light in this second beam portion which, after convergence at the focal point 30, impinges on the other segment 28b of the split photodiode.

The optical elements of the system described are so aligned and positioned that, when the original beam is exactly in focus on the recording surface 16, equal powers or intensities of light are passed through the aperture with respect to each of the two beam portions. Consequently, equal light powers are incident upon the two segments 28a and 28b of the split photodiode detector, and equal electrical signals are generated on output lines 32a and 32b therefrom. These lines are connected as inputs to a differential amplifier 34, the output of which, on line 36, indicates the magnitude and polarity of the focus error.

Lines 32a and 32b are also connected to capacitors 38a and 38b, respectively, the other terminals of which are connected to opposite ends of a resistor having two series-connected portions 40a and 40b. A sum signal is derived from the junction of the resistors, as shown at 42.

As shown in Fig. 2, the aperture 26 is operative to decrease the amount of light in each of the reflected beam portions. When the recording surface 16 and the objective lens 18 move relative to each other in such a manner that there is a movement away from the in-focus position, both focal points 24 and 30 move in the same direction. Accordingly, it will be seen that if, for example, the focal points move towards the photodiode segments 28a and 28b, the aperture 26 will be effective to decrease the amount of light in the beam portion converging

at point 30, and to increase the amount of light in the beam portion converging at point 24. Thus, photodiode segment 28b will produce a larger output than photodiode segment 28a, and a corresponding differential output on line 36 from the differential amplifier 34 will result. Conversely, if the focal points 24 and 30 move away from the photodiode segments 28a and 28b, the amount of light falling on segment 28a will increase and that falling on 28b will decrease, resulting in a differential output signal on line 34 of different polarity.

The complete output characteristic is shown in Fig. 3, from which it will be seen that the characteristic is substantially linear for some distance on each side of the in-focus position, which corresponds to a position of zero electrical output. It will also be apparent from the characteristic that, if the error in focus is relatively large, both focal points will be displaced to the same side of the aperture 26, after which any further movement will result in a decrease in the output from the photodiode segment whose output was, until then, increasing. Consequently, the response characteristic will eventually fall to zero again for large focus errors, as indicated by the outer portions of the transfer characteristic shown in Fig. 3. Naturally, it is desirable to operate the focus detector in the central linear region of its characteristic.

Since the response of the device is dependent upon a differential mode of operation, power fluctuations in the laser beam do not change the position of the focus null. The range of the device, which is defined as the change in distance of the objective lens system with respect to the recording surface between maximum and minimum output voltages from the device, is dependent principally upon the aperture size. Increasing the aperture diameter results in a narrower range, while decreasing the aperture diameter increases the range. In one experiment, it was found that a 0.25 millimeter diameter aperture yields a nine-micron range. In this configuration, the slope in the region of interest is substantially linear, and focus changes of the order of 0.1 micron are easily detected. The sensitivity of the device, as reflected by the slope of the characteristic, is dependent upon such factors as laser power and disc reflectivity. The range of the device, however, is independent of these variables.

It will be appreciated that extreme care must be taken to align the various optical elements properly to achieve the characteristics shown. The first step in alignment is to ensure that the diode sensing elements lie in the plane of the optical path such that the two incoming beams fall within the two light sensitive detection areas. Then the quarter-wave plate is rotated to achieve maximum power at the aperture and the first beam is centered on the aperture by adjusting the mirror 22 to produce maximum power on the diode portion 28a. Next the second beam is centered on the aperture by

adjusting the beam splitter 20. Then the gain of the amplifier 34 is adjusted so that minimum and maximum deflections are equidistant from the null point of the amplifier. The assembly of the entire apparatus is then adjusted until the device indicates zero output when the original beam is exactly in focus on the recording surface.

As shown by the beam indicated in broken lines in Fig. 1, the lens 18 may also be used to focus a write beam onto the surface 16, as is the case in some recording systems. The read beam, shown in solid lines, is then focused slightly "behind" the write beam with respect to the direction of motion of the surface 16, and reads back the recorded information signal.

It will be appreciated from the foregoing that the present invention represents a significant advance in the field of focus detectors, especially as these are employed in relation to recording devices using focused radiant energy beams for recording, playback, or both. In particular, the device of the invention provides a precise and substantially linear measure of focus error, in such a manner that it may be easily adapted for use with focus control systems.

Claims

1. Apparatus for detecting the focus error of a radiant energy beam with respect to a surface (16) to which it is directed through an objective lens (18) said apparatus comprising: beam splitting means (20, 22) disposed in the path of a beam reflected from the surface (16) back through the objective lens (18), said beam splitting means producing first and second reflected beams of approximately equal power; aperture means (26) disposed in the path of said first and second reflected beams such that, when the original beam is focused on the surface, the first reflected beam converges to a first focal point prior to encountering said aperture means and the second reflected beam converges to a second focal point after encountering said aperture means; detection means (28a, 28b) disposed in the paths of said first and second reflected beams after passing through said aperture means (26), for producing electrical signals proportional to the power of each of the first and second reflected beams; and subtraction means for producing a signal proportional to the difference between the powers of the first and second reflected beams, characterized in that, said aperture means (26) is a single aperture; said beam splitting means (20, 22) being so arranged that said two beams intersect at said aperture means (26); and said detection means having two transducer elements (28a, 28b) positioned to receive said beams, respectively.

2. Apparatus as set forth in claim 1, and further including: summing means (38a, 38b, 40a, 40b) for producing a signal proportional to

at point 30, and to increase the amount of light in the beam portion converging at point 24. Thus, photodiode segment 28b will produce a larger output than photodiode segment 28a, and a corresponding differential output on line 36 from the differential amplifier 34 will result. Conversely, if the focal points 24 and 30 move away from the photodiode segments 28a and 28b, the amount of light falling on segment 28a will increase and that falling on 28b will decrease, resulting in a differential output signal on line 34 of different polarity.

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Since the response of the device is dependent upon a differential mode of operation, power fluctuations in the laser beam do not change the position of the focus null. The range of the device, which is defined as the change in distance of the objective lens system with respect to the recording surface between maximum and minimum output voltages from the device, is dependent principally upon the aperture size. Increasing the aperture diameter results in a narrower range, while decreasing the aperture diameter increases the range. In one experiment, it was found that a 0.25 millimeter diameter aperture yields a nine-micron range. In this configuration, the slope in the region of interest is substantially linear, and focus changes of the order of 0.1 micron are easily detected. The sensitivity of the device, as reflected by the slope of the characteristic, is dependent upon such factors as laser power and disc reflectivity. The range of the device, however, is independent of these variables.

It will be appreciated that extreme care must be taken to align the various optical elements properly to achieve the characteristics shown. The first step in alignment is to ensure that the diode sensing elements lie in the plane of the optical path such that the two incoming beams fall within the two light sensitive detection areas. Then the quarter-wave plate is rotated to achieve maximum power at the aperture and the first beam is centered on the aperture by adjusting the mirror 22 to produce maximum power on the diode portion 28a. Next the second beam is centered on the aperture by

adjusting the beam splitter 20. Then the gain of the amplifier 34 is adjusted so that minimum and maximum deflections are equidistant from the null point of the amplifier. The assembly of the entire apparatus is then adjusted until the device indicates zero output when the original beam is exactly in focus on the recording surface.

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It will be appreciated from the foregoing that the present invention represents a significant advance in the field of focus detectors, especially as these are employed in relation to recording devices using focused radiant energy beams for recording, playback, or both. In particular, the device of the invention provides a precise and substantially linear measure of focus error, in such a manner that it may be easily adapted for use with focus control systems.

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2. Apparatus as set forth in claim 1, and further including: summing means (38a, 38b, 40a, 40b) for producing a signal proportional to



the sum of the powers of the first and second reflected beams, and therefore proportional to the intensity of radiant energy reflected from the surface (16).

3. Apparatus as set forth in claim 2, wherein said signal proportional to the sum of the powers of the first and second beams is used in the reproduction of information recorded on the surface (16).

4. Apparatus as set forth in claim 1, wherein said detection means includes a split photodiode (28a, 28b) and a differential amplifier (34).

Patentansprüche

1. Einrichtung zur Feststellung des Fokusfehlers eines Bündels aus Strahlungsenergie bezüglich einer Oberfläche (16), auf die das Bündel durch eine Objektlinse (18) gerichtet wird, mit folgenden Bestandteilen: Vorrichtungen (20, 22) zur Strahlteilung, die in dem Weg eines von der Oberfläche (16) durch die Objektlinse (18) zurückreflektierten Strahlenbündels angeordnet sind und erste und zweite reflektierte Strahlenbündel mit ungefähr gleicher Leistung erzeugen; Blendenvorrichtungen (26), die im Weg des ersten und des zweiten Strahlenbündels so angeordnet sind, daß bei auf der Oberfläche fokussiertem ursprünglichen Strahlenbündel das erste reflektierte Strahlenbündel zu einem ersten Brennpunkt konvergiert, bevor es auf die Blende trifft, und das zweite reflektierte Strahlenbündel zu einem zweiten Brennpunkt konvergiert, nachdem es die Blende getroffen hat; Detektorvorrichtungen (28a, 28b), die in den Wegen der ersten und der zweiten reflektierten Strahlenbündel nach dem Durchgang durch die Blende (26) angeordnet sind, um elektrische Signale proportional zur Leistung in jedem der ersten und zweiten reflektierten Strahlenbündel zu erzeugen; und Subtraktionsvorrichtungen, um ein Signal zu erzeugen, das proportional zur Differenz zwischen den Leistungen des ersten und des zweiten reflektierten Strahlenbündels ist, dadurch gekennzeichnet, daß die Blendenvorrichtungen (26) eine einzelne Blende darstellen, daß die Vorrichtungen (20, 22) zur Strahlteilung so angeordnet sind, daß sich die beiden Strahlenbündel bei der Blendenvorrichtung (26) kreuzen und daß die Detektorvorrichtungen zwei Wandlerelemente (28a, 28b) aufweisen, die so angeordnet sind, daß sie jeweils eines der Strahlenbündel empfangen.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß Summiervorrichtungen (38a, 38b, 40a, 40b) vorgesehen sind, um ein Signal zu erzeugen, das proportional zur Summe der Leistungen des ersten und des zweiten reflektierten Strahlenbündels ist und daher proportional zur Intensität der von der Oberfläche (16) reflektierten Strahlungsenergie.

3. Einrichtung nach Anspruch 2, dadurch gekennzeichnet, daß das zur Summe der Leistun-

gen des ersten und des zweiten Strahlenbündels proportionale Signal zur Wiedergabe der auf der Oberfläche (16) aufgezeichneten Information verwendet wird.

4. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Detektorvorrichtungen eine geteilte Photodiode (28a, 28b) und einen Differentialverstärker (34) enthalten.

Revendications

1. Dispositif pour détecter l'erreur de foyer d'un faisceau d'énergie rayonnante par rapport à une surface (16) vers laquelle il est dirigé à travers un objectif (18), ledit dispositif comprenant: un moyen diviseur des rayons (20, 22) disposé dans le trajet d'un faisceau réfléchi par la surface (16) à travers l'objectif (18), ledit moyen diviseur des rayons produisant des premier et second faisceaux réfléchis d'une puissance à peu près égale; un moyen formant ouverture (26) disposé dans le trajet desdits premier et second faisceaux réfléchis de façon que, quand le faisceau d'origine est focalisé sur la surface, le premier faisceau réfléchi converge vers un premier point focal avant de rencontrer ledit moyen formant ouverture et le second faisceau réfléchi converge vers un second point focal après avoir rencontré ladite ouverture; un moyen de détection (28a, 28b) disposé dans les trajets desdits premier et second faisceaux réfléchis après passage à travers ledit moyen formant ouverture (26), pour produire des signaux électriques proportionnels à la puissance de chacun desdits premier et second faisceaux réfléchis; et un moyen de soustraction pour produire un signal proportionnel à la différence entre les puissances des premier et second faisceaux réfléchis, caractérisé en ce que ledit moyen formant ouverture (26) est une ouverture simple; ledit moyen diviseur des rayons (20, 22) étant agencé de façon que lesdits deux faisceaux se coupent audit moyen formant ouverture (26); et ledit moyen de détection ayant deux éléments transducteurs (28a, 28b) placés pour recevoir respectivement lesdits faisceaux.

2. Dispositif selon la revendication 1 et comprenant de plus: un moyen d'addition (38a, 38b, 40a, 40b) pour produire un signal proportionnel à la somme des puissances des premier et second faisceaux réfléchis, et par conséquent proportionnel à l'intensité de l'énergie rayonnante réfléchie par la surface (16).

3. Dispositif selon la revendication 2, où ledit signal proportionnel à la somme des puissances des premier et second faisceaux est utilisé dans la reproduction de l'information enregistrée sur la surface (16).

4. Dispositif selon la revendication 1, où ledit moyen de détection comprend une photodiode divisée (28a, 28b) et un amplificateur différentiel (34).

