

SPECIFICATION

Dynamic focus adjustment for transmissive or reflective optical disc memory systems

This invention is concerned with dynamic focus adjustment for transmissive or reflective optical disc memory systems.

The purpose of the principal objective lens in optical disc readers is to project a light spot of specified size (sometimes the minimum attainable) on an optically responsive information recording plane. This requires that the distance from objective to filmplane be accurately set for best focus and maintained there, even in the presence of physical disturbances. In the case of an optical read-only memory (OROM), these disturbances include axial runout and disc warpage, disc thickness variations, and environmentally-induced variations of critical optical disturbances. In order to compensate the optical system for these disturbances, an automatic focus adjustment system must generate a focus error signal and physically adjust the optical system to restore optimum focus.

In the prior art, including video disc devices, access to a particular data location is typically provided by a lead-screw or rack-and-pinion driven sled, which carries the entire optical system. The autofocus mechanism consists mainly of an electro-magnetic or a pneumatic positioner and the principal objective lens. The positioner adjusts the axial distance between lens and information recording plane in response to a control input which is developed from the focus error signal. Such an arrangement is not usable on fast optical memory discs because it cannot satisfy the requirements for both rapid random data access and focus tracking at high rotational disc speeds.

In U.S. Patent No. 4,051,529, entitled, "Focus Control System with Movable Mirror", the autofocus mechanism consists of a movable mirror located in the optical path between a light source and the principal objective lens. Movement of the mirror in response to a focus error signal compensates for variations in the critical optical path-lengths. In the prior art device, however, the total optical distance between movable mirror and optical recording medium is fixed, except for minor variations caused by the mirror motion. This is necessitated by the use of converging lenses in the system which establish an intermediate focal point between movable mirror and optical recording medium. Thus, in this prior art device, it is required that the entire optical system be carried on the sled. Such an arrangement would not be suitable for a random-access system, such as an OROM, since the mass of the optics would prevent the rapid lateral accessing motions of the sled required to achieve random access.

The present invention provides a focus control system for maintaining focus of a spot of light on an optical recording medium, comprising a source of a beam of light; movable means positioned adjacent the surface of said optical recording

medium for performing translational motion across a portion of said optical recording medium; a focussing lens mounted on said movable means, for directing said light beam to the surface of said optical recording medium to form a focussed spot of light thereon; and optical focus error correcting means operating in response to an error signal representing any change of focus of said spot of light on said surface to cause refocussing of said spot on said surface, said focus error correcting means being positioned remote from said movable means.

In a system as set forth in the last preceding paragraph, it is preferred that said focus error correcting means comprises a correcting lens; and drive means operating in response to said error signal to cause linear translation of said correcting lens, to re-focus said spot on said surface.

In a system set forth in the last preceding paragraph, it is preferred that said correcting lens comprises a collimating lens.

In a system as set forth in either one of the last two immediately preceding paragraphs, it is preferred that said movable means comprises a base; a fixed link mounted on said base; a sled; a free link connected to said sled; and a pair of flexible connecting members interconnecting said free link and said fixed link.

In a system as set forth in any one of the last three immediately preceding paragraphs, it is preferred that the ratio of the focal length of said correcting lens to said focussing lens is in the range 0.3 to 1.0.

In accordance with the illustrated preferred embodiment, the present invention provides an optical disc reader with an autofocus mechanism suitable for use on fast-turning, random-and-rapid-access optical disc readers such as an OROM. The focussing function is performed by movements of elements completely removed from the mechanical sled providing random-access to the OROM. It is thereby ensured that the device may be rapidly moved laterally across the OROM, while continuously maintaining proper focus.

In the preferred embodiment, the moving head is driven by a parallelogram suspension consisting of two flexible members and two rigid connecting links, one free but one rigidly mounted on the instrument base, the principal objective lens(es) being mounted on the free link. This suspension provides friction-free travel of the objective over the data field and reduces the mass of the moving components to a minimum. The flexure-supported optical head yields minimal access times to the recorded data, being most efficient where the required travel is small, i.e., a few millimeters.

There now follows a detailed description which is to be read with reference to the accompanying drawings of a focus control system according to the present invention; it is to be clearly understood that this system has been selected for description to illustrate the invention by way of example and not by way of limitation.

In the accompanying drawings:—

Figure 1 is a side view of the optical system in a

focus control system according to the present invention;

Figure 2 is a side view of the suspension of Figure 1; and

Figure 3 is a top view of the parallelogram suspension of an objective lens in a focus control system constructed according to the present invention.

Referring to Figures 1, 2, and 3, light from a source 15, such as a laser source, is focussed by a condenser 20 and projected towards an objective lens 10 by a collimated beam 26 is intercepted by a mirror 14 mounted on an objective carrier 16, in the form of a sled, at an angle of 45 degrees with respect to the axis of the objective 10. The collimation of the beam ensures that the optical path-length between the collimator 12 and the objective lens 10, the travelling objective, is uncritical, and therefore does not cause a shifting of the focal position at the surface of an optical recording medium 24, such as an OROM. This enables the collimator 12 and the light source 15 to be completely removed from the carrier 16. In practice, the beam cannot be perfectly collimated so to provide non-criticality of optical pathlength; the collimator 12 provides a weakly convergent beam which diffractively widens along its path length. This broadening of the convergent beam results in a region of the beam of narrowest diameter, which shall be denoted as a "waist", shown as 17 in Figure 2. In general, the beam 26 would be convergent down to the diameter of the waist 17, and then divergent thereafter. However, as shown in Figures 1 to 3, the apparatus is arranged to position the waist 17 at or near the midpoint of the path traversed by the carrier 16 across the OROM 24, and is of a width to slightly underfill the principal objective 10.

During operation, numerous factors may cause defocussing of the beam emergent from the lens 10 with respect to the OROM 24. Thus, such factors as axial runout, disc warpage, disc thickness variations, and temperature variations may all change slightly the back focal distance. Upon such occurrence, a focus error signal is generated, e.g., by one of several possible techniques: (1) detection of astigmatism in the reflected light beam; (2) monitoring the phase of the diffraction pattern as a function of bit-cell motion; (3) measuring the amplitude of the second derivative of the data signal; or (4) measuring the balance of illumination on a split detector.

The focus error signal controls a focus motor 13 which causes axial translation of the collimator 12. The required compensation movement (Δs) of the collimator 12 is related to the focus error (Δf) at the filmplane 24, by the square of the conjugate distance ratio, C_R , i.e., the square of the magnification between the collimating lens 12 and the objective lens 10. C_R is itself equal to the ratio of the effective focal lengths of the collimator 12 and the objective 10, and may be set to unity by using identical lenses on both ends.

Consequently, a small focus error at the objective

is corrected by axial movement of equal magnitude and opposite sign at the collimator.

Certain trade-offs are possible with this scheme. By placing a long conjugate at the objective 10, and a short one at the collimator 12, the required corrective movement is proportionally smaller. The dynamic response of the autofocus system is thus improved by the shorter stroke required of the focus motor. However, for this configuration to be practical, the performance requirements of the optical system must allow the use of a "slower" objective, i.e., if the spot size at the disc need not be the smallest attainable. For the specific requirements of an OROM, a ratio of $\Delta s/\Delta f = 0.3$ appears to be a practical minimum. This value corresponds to the use of relative apertures f/2.4 and f/1.3 for the objective and collimator, respectively.

In a particular preferred embodiment, the objective carrier 16 is driven by a parallelogram suspension including a link 23 fixedly mounted on a base, and a free link 25 carrying the carrier 16. The two links are connected by flexible connecting members 21, such as a pair of ligaments fabricated from beryllium copper or a spring alloy of high fatigue strength. The objective carrier 16 travels within the flexure range above a data field 18 on the OROM 24 in response to a flexure drive 27, which can be any known manner of deflecting a flexible member such as a "voice call", moving magnet, or other type of linear motor.

CLAIMS

1. A focus control system for maintaining focus of a spot of light on an optical recording medium, comprising:

a source of a beam of light;

movable means positioned adjacent the surface of said optical recording medium for performing translational motion across a portion of said optical recording medium;

a focussing lens mounted on said movable means, for directing said light beam to the surface of said optical recording medium to form a focussed spot of light thereon; and

optical focus error correcting means operating in response to an error signal representing any change of focus of said spot of light on said surface to cause refocussing of said spot on said surface, said focus error correcting means being positioned remote from said movable means.

2. A focus control system according to claim 1 wherein said focus error correcting means comprises:

a correcting lens;

drive means operating in response to said error signal to cause linear translation of said correcting lens, to re-focus said spot on said surface.

3. A focus control system according to claim 2 wherein said correcting lens comprises a collimating lens.

4. A focus control system according to either one of claims 2 and 3 wherein said movable means comprises:

a base;



focus control system according to the present invention;

Figure 2 is a side view of the suspension of Figure 1; and

5 Figure 3 is a top view of the parallelogram suspension of an objective lens in a focus control system constructed according to the present invention.

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50 motion; (3) measuring the amplitude of the second derivative of the data signal; or (4) measuring the balance of illumination on a split detector.

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100 comprising:

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movable means positioned adjacent the surface of said optical recording medium for performing translational motion across a portion of said
105 optical recording medium;

a focussing lens mounted on said movable means, for directing said light beam to the surface of said optical recording medium to form a focussed spot of light thereon; and

110 optical focus error correcting means operating in response to an error signal representing any change of focus of said spot of light on said surface to cause refocussing of said spot on said surface, said focus error correcting means being
115 positioned remote from said movable means.

2. A focus control system according to claim 1 wherein said focus error correcting means comprises:

a correcting lens;
120 drive means operating in response to said error signal to cause linear translation of said correcting lens, to re-focus said spot on said surface.

3. A focus control system according to claim 2 wherein said correcting lens comprises a
125 collimating lens.

4. A focus control system according to either one of claims 2 and 3 wherein said movable means comprises:
a base;



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- a fixed link mounted on said base;
a sled;
a free link connected to said sled; and
a pair of flexible connecting members
- 5 interconnecting said free link and said fixed link.
5. A focus control system according to any one
of claims 2 to 4 wherein the ratio of the focal
length of said correcting lens to said focussing
lens is in the range 0.3 to 1.0.
- 10 6. A focus control system substantially as
hereinbefore described with reference to the
accompanying drawings.