(12) UK Patent Application (19) GB (11) 2 199 137 (13) A

(43) Application published **29 Jun 1988**

(21) Application No **8722238**

(22) Date of filing **22 Sep 1987**

(30) Priority data
(31) **61/302187** (32) **18 Dec 1986** (33) **JP**

(71) Applicant
Yokogawa Electric Corporation

(Incorporated in Japan)

9-32 Nakacho 2-chome, Musashino-shi
Tokyo 180, Japan

(72) Inventors
Kenta Mikuriya
Akira Ohya
Minoru Nakagawara
Hideo Hirukawa
Shoji Uehara

(74) Agent and/or Address for Service
Hughes Clark & Co.
63 Lincoln's Inn Fields, London, WC2A 3JU

(51) INT CL^4
G01N 21/86

(52) Domestic classification (Edition J):
G1A A2 A3 C12 C13 C8 D1 EE G1 G2 G5 G6 G7 G8 G9 MB P15 P17 P1 P6 R7 S4 T14 T15 T25 T3 T8
U1S 2102 2119 2190 G1A

(56) Documents cited
None

(58) Field of search
G1A
G5J
Selected US specifications from IPC sub-class G01N

(54) Test system for optical disks

(57) The test system comprises a motor 2 for rotating an optical disk 1 at constant speed; an encoder 21 for generating a pulse output corresponding to an angle of rotation of the motor spindle; a measuring head 3 containing a detector 37 for optically detecting displacements of a focusing lens 31 driven by focus and tracking servo mechanisms for causing a laser beam to follow the guide groove of the disk; a feed mechanism for moving the measuring head radially of the disk; a controller 5 for controlling the motor, servo mechanisms, and feed mechanism; an A/D converter 6 for converting an output signal from the measuring head proportional to focusing lens displacement at a timing according to the pulse output of the encoder; and a computer 7 for commanding the controller and computing the output of the A/D converter to determine the shape of the optical disk, whereby displacement of the focusing lens is directly controlled by the optical detector. The optical displacement detector may comprise an apertured plate (371, Fig 3 not shown) attached to the focusing lens and interposed between a light source (373) and a quadrant photo-detector (374).

FIG. 2

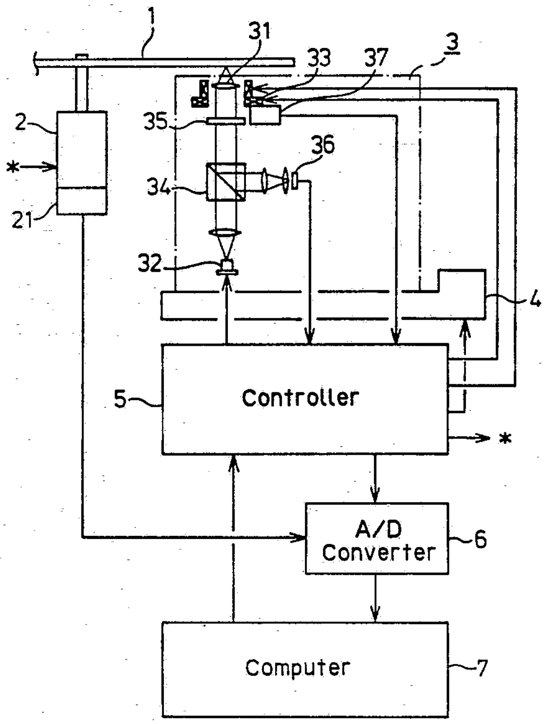


FIG. 1

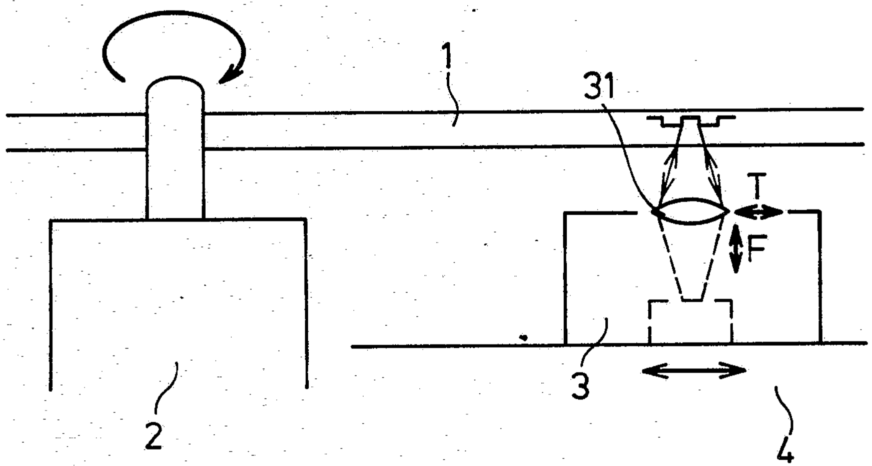


FIG. 2

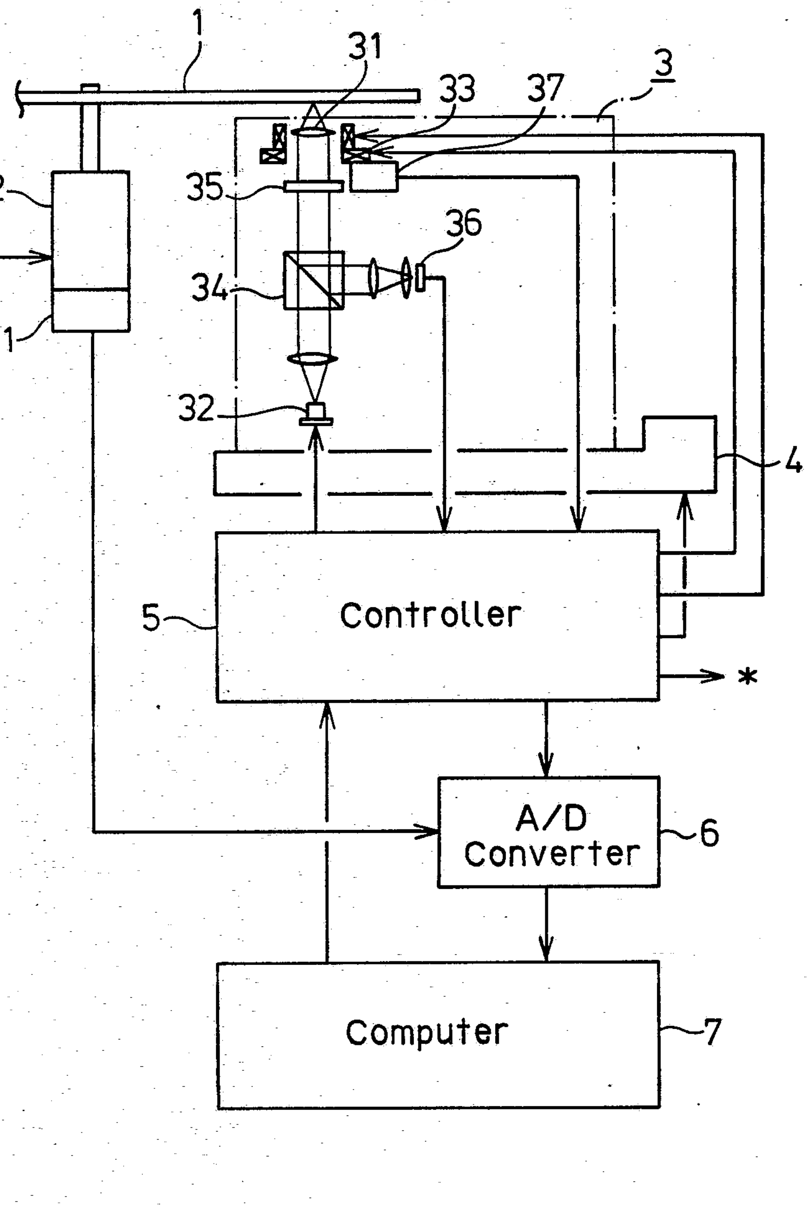

1
31
33
37
3
2
35
36
*
34
21
32
4
Controller
5
*
A/D Converter
6
Computer
7

FIG. 3

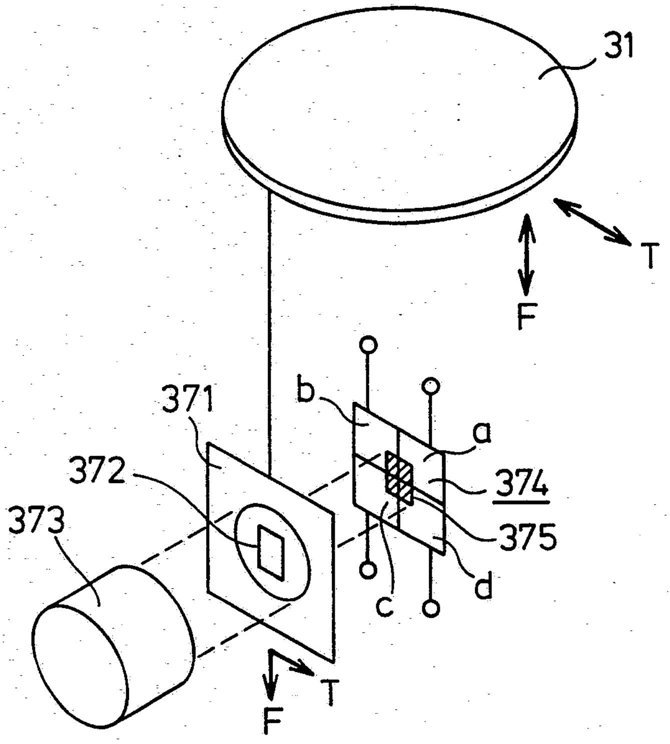


FIG. 4

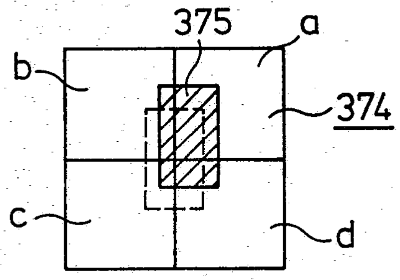


FIG. 5

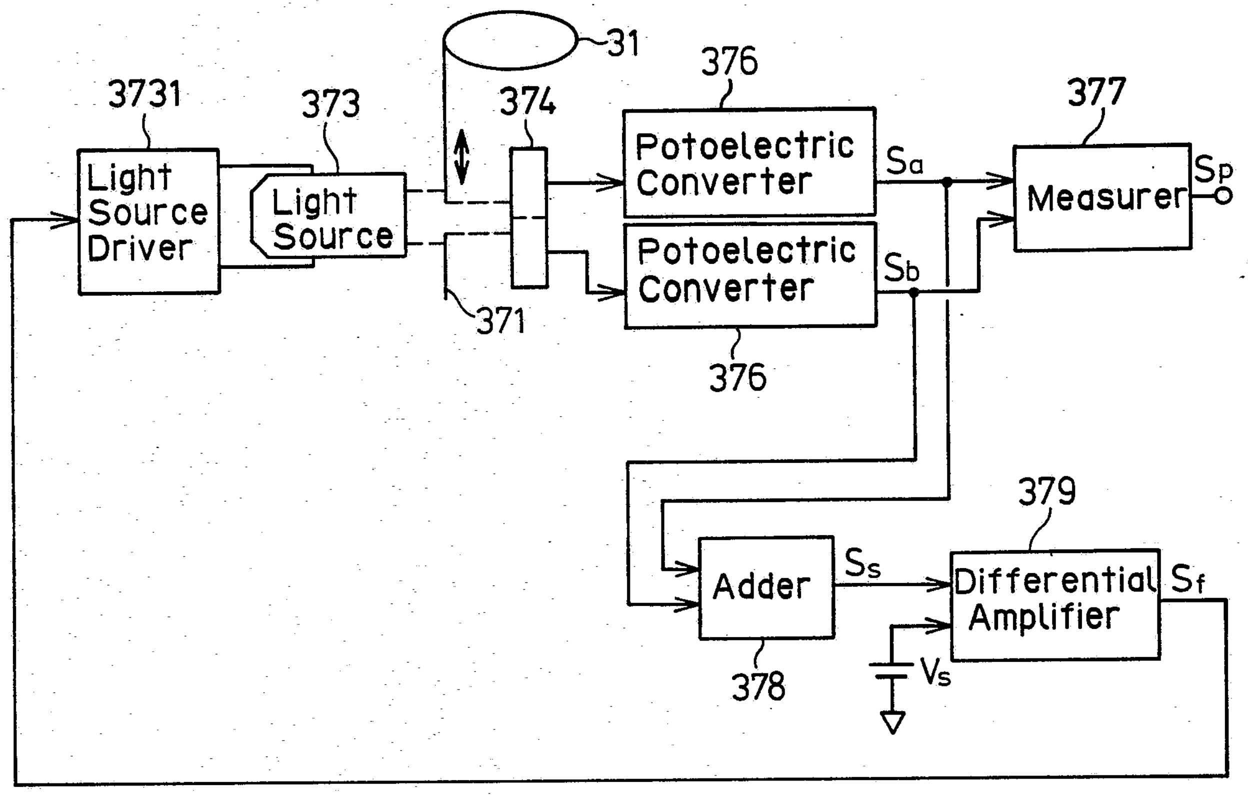


FIG. 6(a)

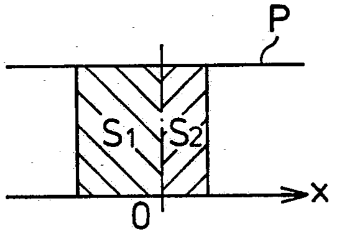


FIG. 6(b)

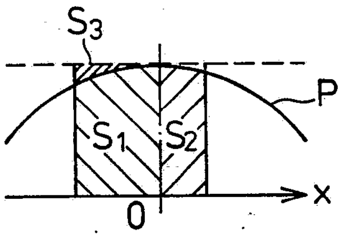


FIG. 6(c)

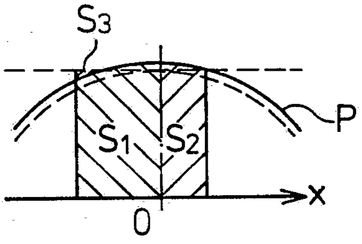


FIG. 7

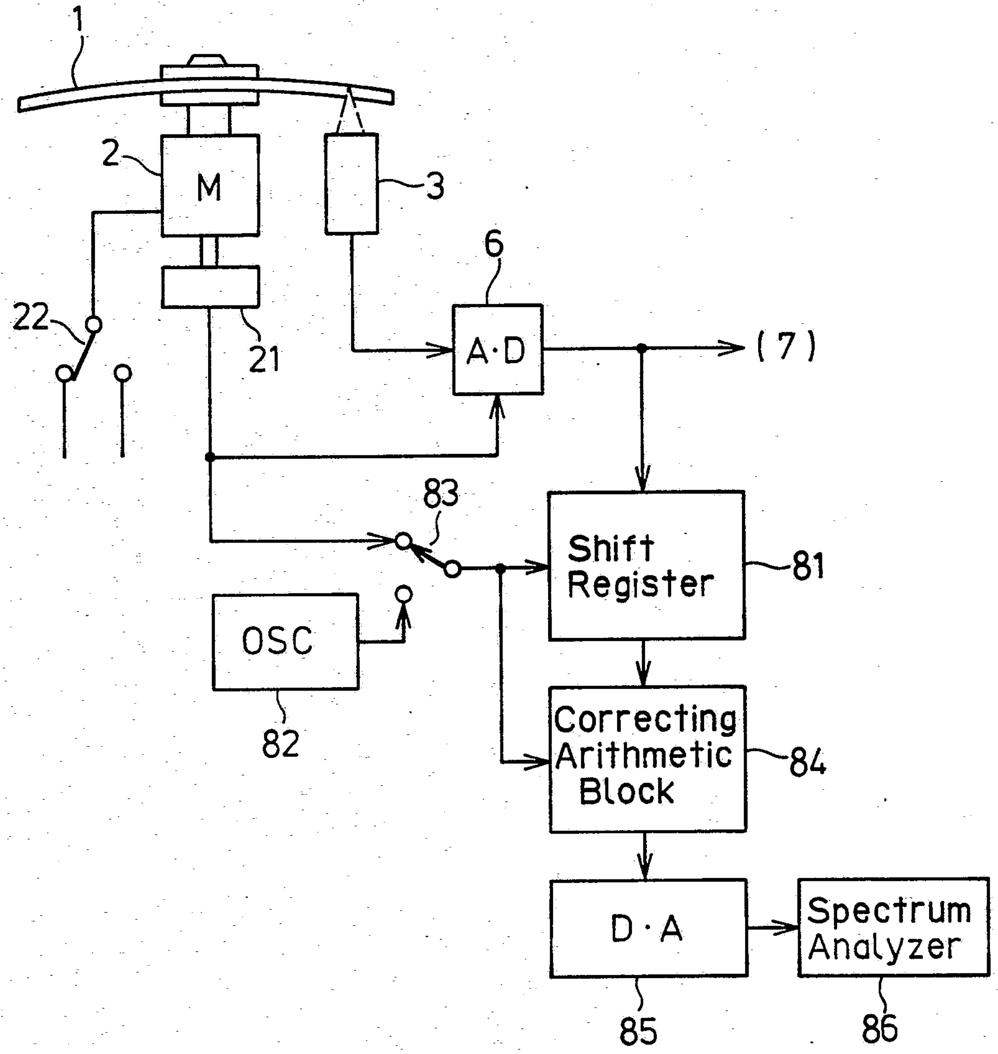

1
2
M
3
6
A·D
(7)
22
21
83
Shift Register
81
OSC
82
Correcting Arithmetic Block
84
D·A
Spectrum Analyzer
85
86

FIG. 8

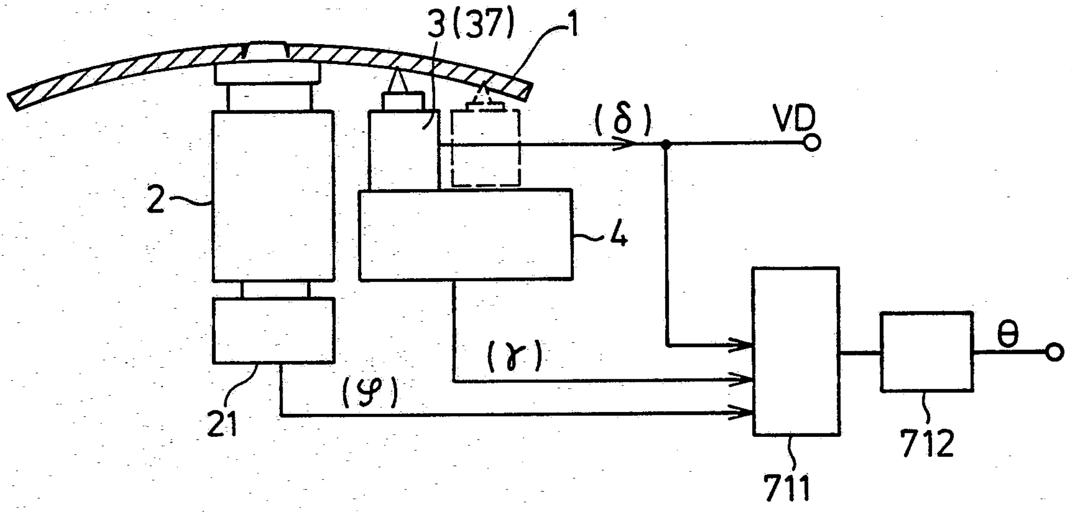


FIG. 9

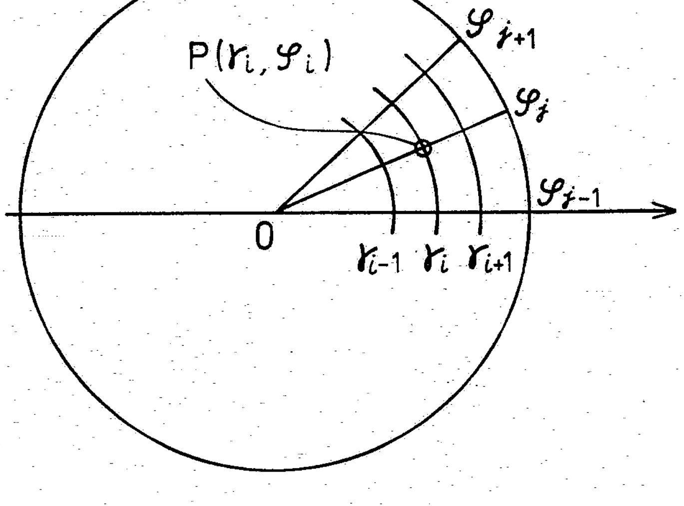


FIG. 10

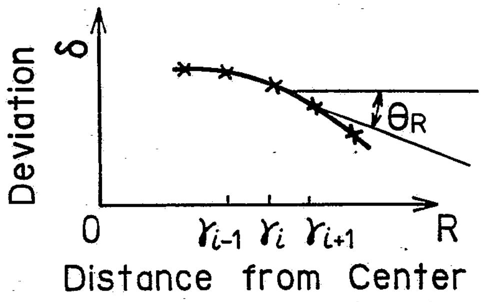


FIG. 11

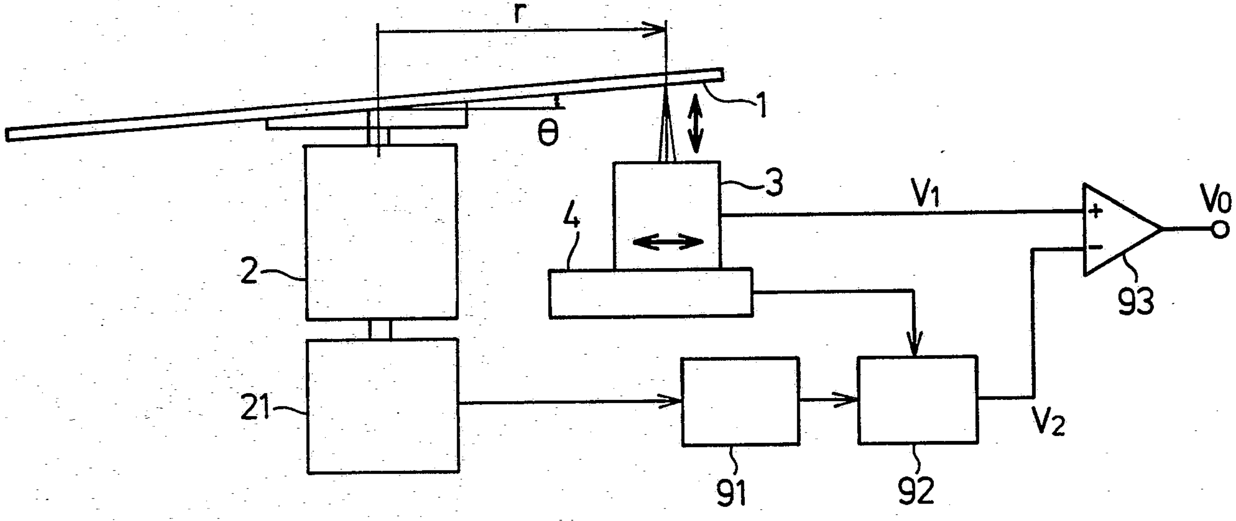


FIG. 13

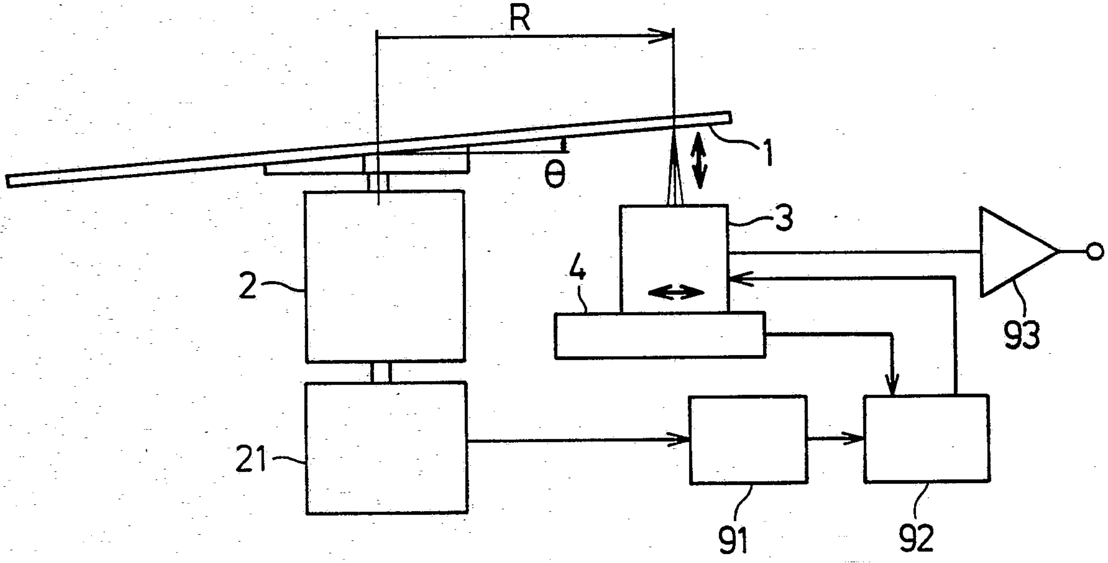


FIG. 12(a)

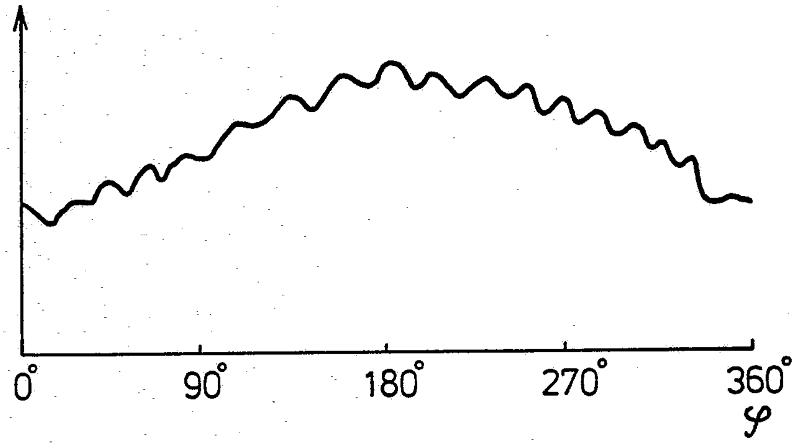


FIG. 12(b)

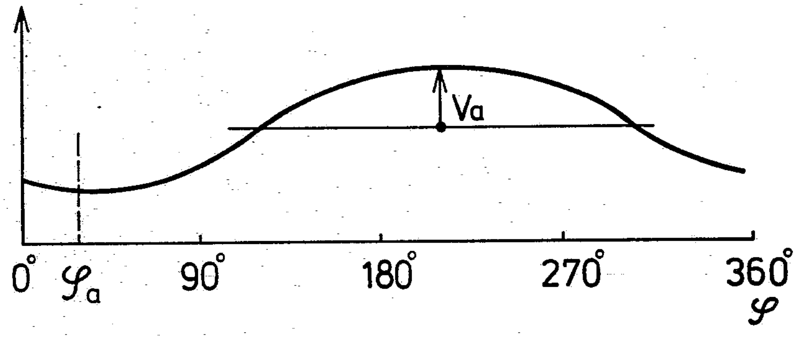


FIG. 12(c)

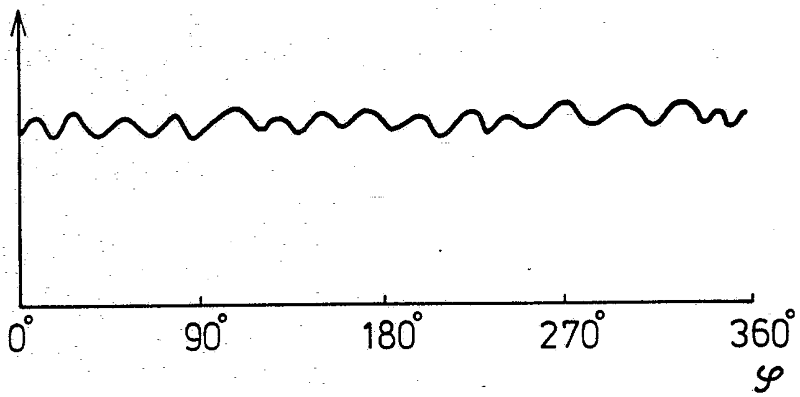


FIG. 14

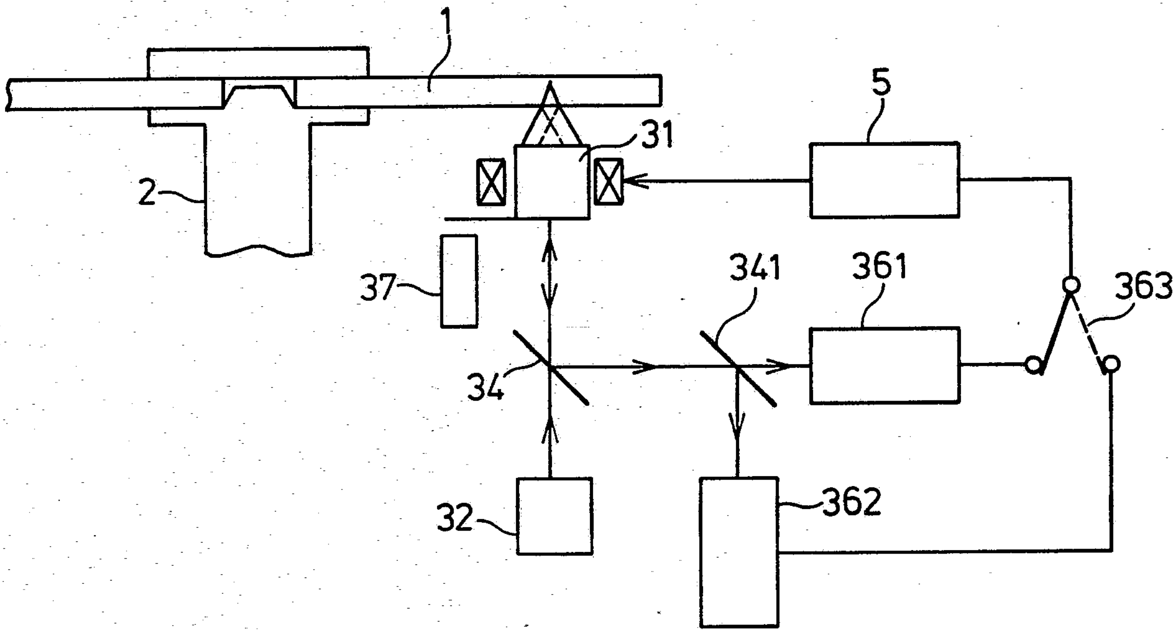


FIG. 15

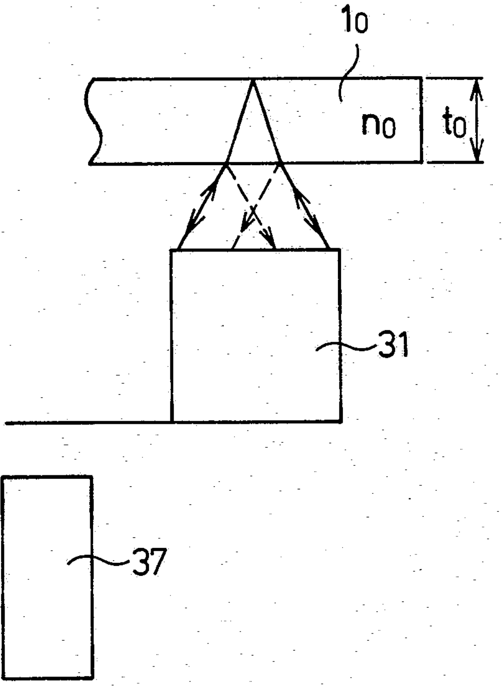


FIG. 16

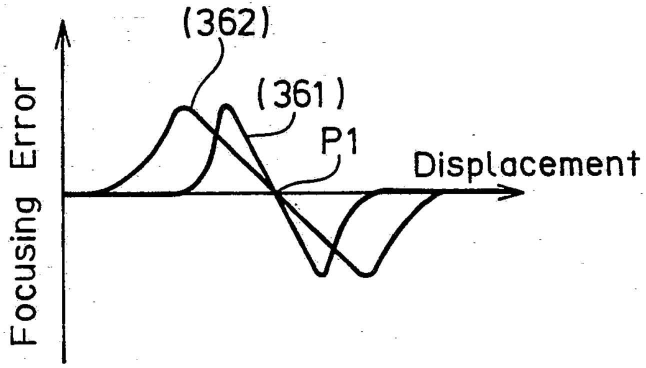


FIG. 17

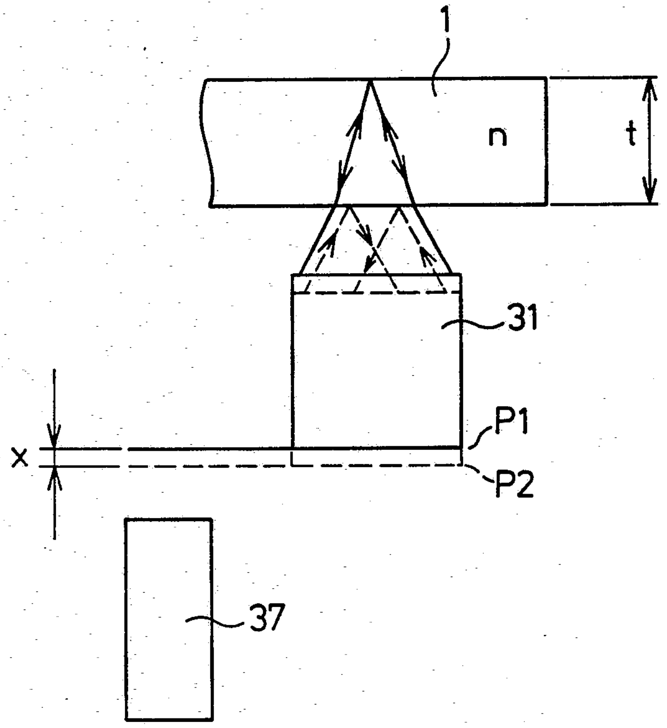


FIG. 18

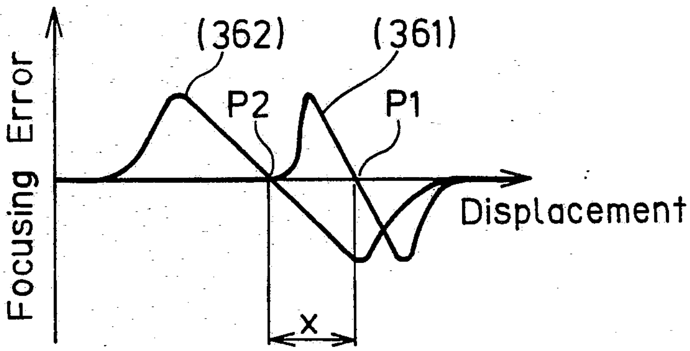


FIG. 19

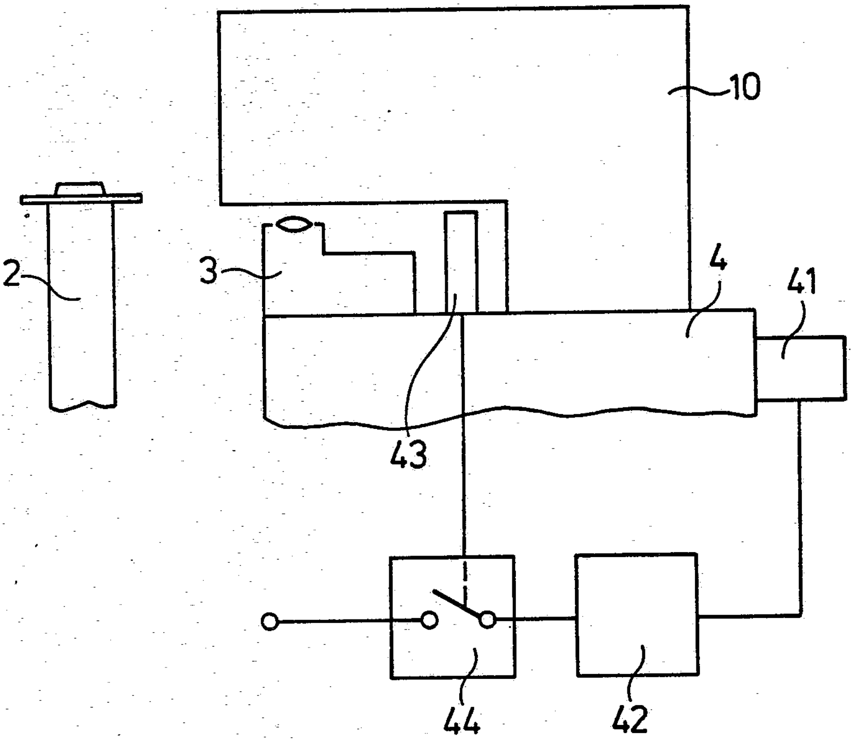
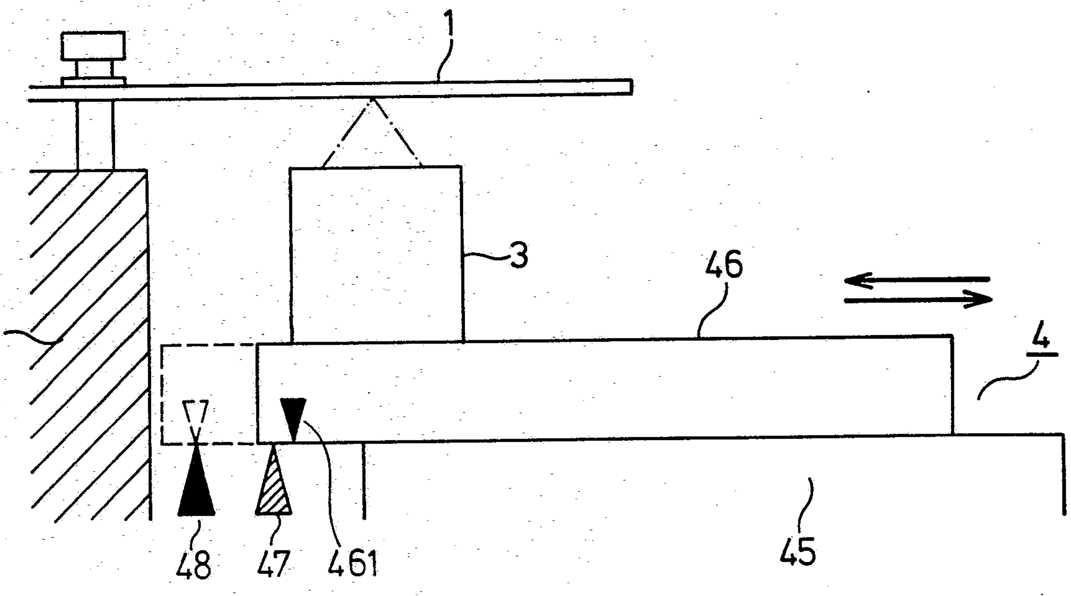


FIG. 20



TEST SYSTEM FOR OPTICAL DISKS

The present invention relates to an optical disk test system for measuring the mechanical characteristics of optical disks.

Generally speaking, the mechanical characteristics of an optical disk concern its shape such as axial runout or concentricity and are associated with how effective focusing and tracking servos are. As to the focus servo, the thickness of a substrate is important in relation to aberration, and the axial runout and its high frequency component (i.e., acceleration) is important from the aspect of controllability. As the tracking servo, on the other hand, not only the tilt and the concentricity but also radial acceleration (i.e., circularity) are important factors.

The present invention has an object to realize with a simplified construction an optical disk test system which can eliminate the drawbacks of the system of the prior art described with reference to Figure 1 below, detect the displacements of the focusing lens accurately in the focusing and tracking directions and measure the mechanical characteristics of an optical disk accurately.

According to the present invention, there is provided a test system for optical disks, comprising: a spindle motor for holding and rotating an optical disk at a constant speed; an encoder for generating a pulse output corresponding to the angle of rotation of said spindle motor; a measuring head, including focus servo and tracking servo mechanisms for causing the focal point of a laser beam irradiating said optical disk to follow the guide groove of said optical disk, and a displacement detector for optically detecting the displacement of a focusing lens driven by said servo mechanisms, said measuring head being operative to generate an output signal proportional to the displacement of said focusing lens; a feed mechanism for moving said measuring head in the radial direction of said optical disk; a controller for controlling the operations of said spindle motor, the focus servo and tracking servo mechanisms of said measuring head, and said feed mechanism; an analog/digital converter for analog-to-digital converting the output of said measuring head at a timing according to the pulse output of said encoder; and a computer for commanding said controlling and for computing the output of said analog/digital converter to determine the shape of said optical disk. Accordingly, the displacement of the focusing lens of said measuring head are directly detected by means of said displacement detector of the optical type.

In order that the invention may be clearly understood and readily carried into effect, test systems in accordance therewith will now be described, by way of exanmple, in relation to a prior art system and with reference to the accompanying drawings, in which:

Figure 1 is a diagram showing one example of an optical disk test system according to the prior art;

Figure 2 is a diagram showing one embodiment of an optical disk test system according to the present invention;

Figure 3 is a diagram showing one embodiment of a displacement detector to be used in the optical disk test system of Figure 2;

Figure 4 is a diagram showing the incident state of a beam spot on a multi-divided sensor of the system of Figure 3;

Figure 5 is a diagram showing the structure of another embodiment of the displacement detector shown in Figure 3;

Figures 6(a), 6(b), and 6(c) are diagrams showing the changes in the amount of incident light on a multi-divided sensor of the system of Figure 5;

Figure 7 is a diagram showing the structure of one embodiment of an axial runout and concentricity measuring system;

Figure 8 is a diagram showing a principle for measuring tilt;

Figures 9 and 10 are explanatory diagrams showing the geometric shape of an optical disk for explaining the operation of computing the tilt in the system of Figure 8;

Figure 11 is a diagram showing the structure of one embodiment of a correction method of correcting a vertical axis error of a spindle motor;

Figures 12(a), 12(b), 12(c) are graphs for explaining the operations of the correction method of Figure 11;

Figure 13 is a diagram showing the structure of another embodiment of the method of correcting the vertical axis error;

Figure 14 is a diagram showing the structure of one embodiment of a principle for measuring a substrate thickness;

Figures 15 to 18 are explanatory diagrams showing measuring operations of the system of Figure 14;

Figure 19 is a diagram showing one embodiment of a protecting mechanism for protecting a feed mechanism during a calibrating operation; and

Figure 20 is a diagram showing the structure of one embodiment of a limiter mechanism of a slide portion of the feed mechanism.

Figure 1 is a diagram showing one example of an optical disk test system according to the prior art.

In Figure 1 reference numeral 1 denotes an optical disk; numeral 2 a spindle motor optical disk 1 on which the optical disk is clamped and rotated at a constant speed; and numeral 3 a measuring head including focus servo and tracking servo mechanisms for causing the focal point of a laser beam irradiating the optical disk 1 to follow the guide groove of the disk 1, and a displacement detector for optically detecting the displacement of a focusing lens 31 driven by those servo mechanisms. The measuring head 3 generates an output signal proportional to the displacement of the focusing lens 31. Numeral 4 indicates a feed mechanism for moving the measuring head 3 in the radial direction of the optical disk 1. The optical disk test system basically has a function similar to that of a reproducing system, and the focusing lens 31 is subjected to the servo control in a focusing direction F and in a tracking direction T so that the position (in the reproducing state) of the guide groove of the optical disk 1 may be irradiated with the laser beam. If, therefore, the displacements in the two directions F and T of the focusing lens 31 at this time are detected it is possible to measure the magnitudes of the axial runout and concentricity of the optical disk 1. Noting the displacement in the focusing direction, for example, it is possible to measure the axial runout, the runout acceleration, the tilt and the substrate thickness. Noting the displacement in the tracking direction, moreover, it is possible to measure the concentricity and radial acceleration (i.e., roundness). For detecting those displacements of the focusing lens 31, on the other hand, the drive current of a lens actuator for displacing the focusing lens 31 is utilized, or a differential transformer or a capacity type displacement sensor is used. In case, however, the displacement of the focusing lens 31 is detected by making use of the drive current as above, the detection is affected by the frequency characteristics, hysterisis and frictional force of the lens actuator so that the displacement of the focusing lens 31 cannot be accurately detected. Since the differential transformer or the capacity type displacement sensor is a detector detecting a one-dimensional displacement, on the other hand, two independent detectors have to be used for detecting the displacements of the focusing lens 31 in the focusing direction F and in the tracking direction T. Since, moreover, interference occurs between the servo mechanism for the focusing and tracking directions F and T, the outputs of the individual detectors have to be corrected so as to eliminate those influences.

Figure 2 is a diagram showing the structure of one embodiment of the optical disk test system according to the present invention. In Figure 2, the components similar to those of Figure 1 are denoted by common reference numerals. Numeral 21 denotes an encoder for generating a pulse output according to the angle of rotation of the spindle motor 2. The measuring head 3 is composed of the focusing lens 31, a laser beam source 32, a lens actuator 33, a beam splitter 34, a $\lambda/4$ plate 35, a light receiving element 36 and a displacement detector 37. In this measuring head 3, the focal state on the optical disk 1 is detected by the light receiving element 36 to generate feedback signals for the focusing and tracking servo mechanisms, and the displacement of the focusing lens 31 is detected by the displacement detector 37 to generate an output signal proportional to the displacement of the focusing lens 31. The displacement detector 37 is one of the optical type for converting the displacement of the focusing lens 31 into changes in an amount of light. Numeral 5 denotes a controller for driving the lens actuator 33 in accordance with the output of the light receiving element 36 to operate the focus servo mechanism and the tracking servo mechanism and controls the operations of the spindle motor 2 and the feed mechanism 4. Numeral 6 denotes an analog/digital converter (which will be abbreviated to "A/D converter") for analog-to-digital converting the output signal of the measuring head 3 at a timing according to the pulse output of the encoder 21. Numeral 7 denotes a computer for commanding the controller 5 and for computing the output of the A/D converter 6 to determine the shape of the optical disk 1. In the optical disk test system thus constructed, the operation sequences of the individual portions are selected in response to the commands of the computer 7, and a variety of mechanical characteristics of the optical disk 1 such as the axial runout or concentricity are measured on the basis of those commands.

Figure 3 is a diagram showing the structure of one embodiment of the displacement detector to be used in the optical disk test system of the present invention. In Figure 3, the parts similar to those of Figure 2 are denoted by the common numerals. Numeral 371 denotes a shielding plate having a rectangular aperture 372 and fixed on the focusing lens 31. Numeral 373 denotes a light source for irradiating the shielding plate 371 with a parallel beam having a spot diameter larger than the moving range of the aperture 372. Numeral 374 denotes a multi-divided sensor made receptive of a beam spot 375 having passed through the aperture 372 of the shielding plate 371 for locating the position thereof. The sensor 374 is exemplified by a four-divided sensor. On the other hand, the shielding plate 371 is arranged in a plane containing the two displacing directions F and T of the focusing lens 31 and is displaced two-dimensionally with the displacement of the forcusing lens 31.

As a result, if the focusing lens 31 is displaced in the focusing direction F and the tracking direction T by the servo mechanisms, the shielding plate 371 is also displaced in the directions F and T so that the position of incidence of the beam spot 375 on the multi-divided sensor 374 is accordingly shifted.

Here, this multi (or four)-divided sensor 374 is formed with four light receiving faces or quadrants (a to d) for generating output signals Sa to Sd proportional to the amount of light of the beam incident upon the individual quadrants. As a result, if the beam spot 375 changes its incidence position in accordance with the displacement of the shielding plate 371, the magnitudes of (or the balance among) those four output signals Sa to Sd will change. Thus, by arithmetically processing these output signals Sa to Sd, the displacements of the shielding plate 371, i.e., the focusing lens 31 in the two directions F and T can be simultaneously determined.

Specifically, the displacement Vf of the focusing lens 31 in the focusing direction F is expressed by the following equation:

$$Vf = Sa + Sb - Sc - Sd.$$

Likewise, the displacement Vt in the tracking direction T is expressed by the following equation:

$$Vt = Sa - Sb - Sc + Sd.$$

Figure 4 shows an example of the incident state of the beam spot 375 on the multi-divided sensor 374. Since the beam spot 375 incident upon the multi-divided sensor 374 is retangular, as shown, the amounts (or areas) of light of the beam spot 375 incident upon the light receiving faces a to d of the individual quadrants are proportional to the displacement of the shielding plate 371 so that a high linearity can be attained. Incidentally, the reason why the beam spot 375 (or the apperture 372) is made rectangular is to provide sensitivity in the displacement directions F and T. If the sides perpendicular to the direction T are made the longer, the sensitivity to the displacement in the direction T can be enhanced. This means that the sensitivities in the directions F and T can be equalised if the shape of the beam spot 375 (or the aperture 372) is made square.

Thus, if the shielding plate 371 is fixed on the focusing lens 31 so that its motions may be detected by the multi-divided sensor 374, the two-directional displacements of the focusing lens 31 can be converted as they are into the two-dimensional motions of the shielding plate 371 so that the displacements of the focusing lens 31, i.e., the concentricity and axial runout of the optical disk 1 can be accurately measured by the single detector (e.g., the multi-divided sensor 374). Since, moreover the displacements in the focusing direction F and the tracking direction T are simultaneously measured, the influences due to the interferences between the two servo mechanisms can be eliminated.

Incidentally, in the foregoing description, the individual sides of the aperture 372 of the shielding plate 371 and the dividing axes of the light receiving faces a to d of the multi-divided sensor 374 are oriented in parallel with the directions of displacement F and T of the focusing lens 31 (or the shielding plate 371), as best desired. In case these relations are broken due to the mounting errors of the individual elements so that errors occur in the measurements, the errors are corrected in an arithmetic circuit.

Figure 5 is a diagram showing another embodiment of the displacement detector shown in Figure 3. The shown system realizes the displacement detector which detects the total sum of the output signals coming from the individual light receiving faces of the multi-divided sensor and controls the emission of the light source so that the total sum may always be constant, to compensate the reduction in the linearity due to the intensity distribution of the light without any span change due to aging. In Figure 5: reference numeral 3731 denotes a light source driver for driving the light source 373; numeral 376 photoelectric converters for converting the amounts of light of the individual light receiving faces of the multi-divided sensor 374 into the electric signals Sa and Sb; numeral 377 a measurer for processing the output signals Sa and Sb of the photoelectric converters 376 to generate an output Sp corresponding to the displacement of the shielding plate 371; numeral 378 an adder for determining the total sum of the output signals Sa and Sb; and numeral 379 a differential amplifier for comparing the output Ss of the adder 378 with a constant threshold level Vs to feed back a differential signal Sf to the light source driver 3731. Incidentally, for simplicity of discussion, the shielding plate 371 is made movable only in the direction of one axis, and the multi-divided sensor 374 is a two-divided one.

In the displacement detector thus constructed, as has been described above, the balance in the amount of incident light on the multi-divided sensor 374 will change if the shielding plate 371 displaces in accordance with the displacement of the focusing lens 31. This makes a difference between the output signals Sa and Sb of the two photoelectric converters 376. Since this difference between the output signal Sa and Sb is proportional to the displacement of the shielding plate 371, the output Sp obtained from the measurer 377 is proportional to the displacement of the shielding plate 371, i.e., the focusing lens 31. On the other hand, the adder 378 and the differential amplifier 379 constitute together a feedback circuit for detecting the total sum of the output signals Sa and Sb of the respective light receiving faces of the multi-divided sensor 374 to control the emission of light of the light source 373 such that the total sum may always take a constant value. As a result, in case the light emitted from the light source 373 has an intensity distribution so that the amount of light incident upon the multi-divided sensor 374 changes in accordance with the displacement of the shielding plate 371, the emission of the light source 373 is so controlled that the amount of incident light may be constant.

Here, the actions of the feedback circuit will be described in the following. Figures 6(a), 6(b), 6(c) are diagrams showing the changes in the amount of incident light in the multi-divided sensor 374. First of all, if the intensity distribution P of light is even in the direction of movement x of the shielding plate 371, as shown in Figure 6(a), the amounts of incident light upon the respective light receiving faces are proportional to areas S1 and S2, if these areas S1 and S2 are those of beam spots incident upon the respective light receiving faces of the multi-divided sensor 374, so that the output signal Sp obtained from the measurer 377 is proportional to the displacement of the shielding plate 371.

In case, however, the intensity distribution P is not even, as shown in Figure 6(b), the outputs (Sa, Sb) of the multi-divided sensor 374 are proportional to the area below the curve P so that their difference is not proportional to the displacement, even if the shielding plate 371 is displaced, to have a non-linear error according to an area S3.

If, therefore, the feedback is made so that the total sum Ss of the output signals Sa and Sb coming from the respective light receiving faces of the multi-divided sensor 374 takes a constant value, the intensity P changes, as shown in Figure 6(c), to reduce the area S3. As a result, the output Sp of the measurer 377 approaches a value proportional to the displacement of the shielding plate 371 so that it is highly linear irrespective of the intensity distribution of the light.

If the intensity distribution P can be approximated by the following equation, for example, its linearity can be improved at a ratio of about 43%:

$$P = -0.1x^2 + 1.$$

If this feedback is made, moreover, the amount of emission can be maintained constant so that no measurement span will change, even in case the emission efficiency drops due to the aging of the light source 373.

The individual measurement items will be described in the following in connection with their principle and operations.

The axial runout is measured in terms of the displacement of the focusing lens 31 in the focusing direction and is differentiated twice or subjected to a Fourier transformation and is expanded on the frequency axis to determine the axial acceleration. On the other hand, the tilt is calculated from the axial runouts at the four points around the measurement point.

The concentricity is the difference between the center of the guide groove of the optical disk 1 and the center of rotation of the spindle motor 2 and is measured in terms of the displacement of the focusing lens 31 in the tracking direction. The concentricity is differentiated twice or subjected to a Fourier transformation and expanded on the frequency axis to determine its radial acceleration. On the other hand, the circularity is determined in terms of difference between the inscribed and circumscribed circles of the measured concentricity values.

Figure 7 is a diagram showing the structure of one embodiment of the measuring system for measuring the axial runout and concentricity. In the shown system, the guide groove of the optical disk 1 is subjected to the focusing and tracking servos to measure the axial runout and concentricity. Then, the measurements are conducted with the optical disk 1 being rotated at a speed lower than the rated speed. At the same time, the output of the A/D converter 6 is temporarily stored in accordance with the pulse signal of a frequency proportional to the rotating speed so that the data are read out, if their analog signal processing is required, in accordance with the pulse signal of the frequency proportional to the rated rotating speed until they are subjected to the digital-to-analog conversion (which will be abbreviated to the D/A conversion).

Thus, if the optical disk 1 is rotated at the low speed, the ordinary servo mechanisms are enabled to follow, even in case the characteristics (e.g., the runout acceleration) of the optical disk 1 are too bad for the servo mechanisms to follow, so that the characteristics can be measured. Incidentally, in case the number of rotations is low, the output of the encoder 21 is proportional to the angle of rotation of the optical disk 1. Since the correspondence between the output (at the measurement point) of the encoder 21 and the measured output is unchanged, the arithmetic processing of the measured data by the computer 7 is not troubled.

In Figure 7, reference numeral 22 denotes a changeover switch for changing over the rotating speed of the spindle motor 2; numeral 81 a shift register; numeral 82 an oscillator for generating a pulse signal having a frequency proportional to the rated rotating speed; numeral 83 a second change-over switch; numeral 84 a correcting arithmetic block; numeral 85 a digital-to-analog converter (which will be abbreviated to the D/A converter); and numeral 86 an analog meter such as a spectrum analyzer.

First of all, in a measurement state, the output signal of the A/D converter 6 having been A/D converted at a timing according to the pulse output of the encoder 21 is inputted to the computer 7 and read in the shift register 81 in response to the clock of the pulse output of the encoder 21. Here, in case the measurement signal corresponding to the axial runout is to be analogly processed, the data stored in the shift register 81 are read out in response to the clock of the output pulse signal of the oscillator 82 and inputted to the correcting arithmetic block 84. This correcting arithmetic block 84 corrects the positional error of the measuring head 3 in the axial direction, the tilt error of the optical disk mounting head and deformation coming from the rotations of the optical disk 1. If, therefore, these corrected outputs are fed to the analog meter 86 after they have been subjected to the D/A conversion, it is possible to obtain the measurement signal having the same time axis as that when the optical disk 1 is rotated at the rated speed so that analog frequency analysis can be performed.

Figure 8 is a diagram showing the principle of measuring the tilt. In Figure 8, reference numeral 711 denotes a memory for storing a measurement signal VD corresponding to the axial runout δ, which is obtained by the measuring head 3 (i.e., the displacement detector 37), as well as the information of the measurement point, which concerns the angle of rotation ϕ determined from the output pulse of the encoder 21 and the distance of the measuring head 3 from the center of rotation 0 of the optical disk 1. Numeral 712 denotes tilt computing means for computing the runout, i.e., the tilt of the optical disk 1 by using the measured information δ, ϕ and r stored in the memory 711. Incidentally, these functions are inclusive in the computer 7.

Figures 9 and 10 are explanatory diagrams showing the geometric shape of the optical disk 1 for explaining the operations of the arithmetic means 712. On the optical disk 1, there is imagined as located in a lattice a point P (r_i, ϕ_j), of which the ordinates r_1, t_2, - - -, r_{i-1}, r_i and r_{i+1} are assigned in the radial direction whereas the ordinates ϕ_1, ϕ_2, - - -, ϕ_{j-1}, ϕ_j and ϕ_{j+1} are assigned in the direction of rotation.

In a manner to correspond to the lattice located point P(r_i, o_j), the axial runout δ (r_i, ϕ_j) is measured in accordance with the rotations of the optical disk 1 and the movement of the measuring head 3 and is sent to the memory 711. Next, the tilt θ at each point P (r_i, ϕ_j) is determined by the tilt computing means 712. The tilt θ is decomposed in the radial direction ϕ_R and in the direction of the angle of rotation ϕ_0 and determined by the following equations:

$$\theta_R(r_i, \phi_j) = \frac{\delta(r_{i+1}, \phi_j) - \delta(r_{i-1}, \phi_j)}{r_{i+1} - r_{i-1}} \qquad (1)$$

and

$$\theta_\phi(r_i, \phi_j) = \frac{\delta(r_i, \phi_{j+1}) - \delta(r_i, \phi_{j-1})}{r_i(\theta_{j+1} - \theta_{j-1})} \qquad (2)$$

Moreover, the absolute value $|\theta|$ is determined by the following equation

$$|\theta(r_i, \phi_j)| = \sqrt{\theta_R^2(r_i, \phi_j) + \theta_\phi^2(r_i, \phi_j)} \qquad (3)$$

Incidentally, the tilt can be determined not by using the runout δ (r_i, ϕ_j) directly but making an equation of a curved surface which can suit the best points around the point P (r_i, ϕ_j), so as to reduce influences of the errors in the measurement.

Now, in case the axial runout or the like is to be measured as above, it is necessary to correct the vertical axis error of the spindle motor 2 holding the optical disk 1.

Figure 11 is a diagram showing the structure of one embodiment of the correction method of correcting the vertical axis error of the spindle motor 2. In Figure 11: reference numeral 91 denotes a staticizer for expressing the pulse signal, which is outputted from the encoder 21, in a spacially determined state; numeral 92 an error eraser for outputting a signal corresponding to the vertical axis error of the optical disk 1 in accordance with the angle of rotation ϕ of the optical disk 1 stored by the staticizer 91, and numeral 93 a differential amplifier for determining a difference between the output V1 of the measuring head 3 and the output V2 of the error eraser 92.

Figures 12(a), 12(b), 12(c) are graphs for explaining the operations of the system of Figure 11. The axial runout error δ_ε (ϕ) due to the vertical axis error θ is given by the following equation (4):

$$\delta_\varepsilon(\phi) = \frac{r\ \theta}{\rho} \sin\ n(\phi + \phi_\varepsilon) \qquad (4)$$

Here: ϕ designates the angle of rotation (degs) of the optical disk 1; r designates the gap from the measuring head 3 to the center of rotation; ρ designates a numerical value having a value 57.296 |degs/rad| for converting the degree value into a radial value; and ϕ_ε designates the phase angle in the difference between the start position of the encoder 21 and the angle of the vertical axis.

Next, the axial runout $\delta_D(\phi)$ of the optical disk 1 is expressed with a Fourier coefficient by using the angle referring to the first mounting state:

$$\delta_D(\phi) = \sum_{n=1}^{\infty} \delta_n \sin n(\phi + \phi_n) \tag{5}$$

Then, the output V1 of the measuring head 3 is given by the following equation with the signal shown in Figure 12(a):

$$V1(\varphi) = \delta_D(\varphi) + \delta_c(\phi) \tag{6}$$

As a result, the output of the signal shown in Figure 12(b) to be given by the following equation is outputted from the error eraser 92:

$$V2(\varphi) = \delta_c(\phi) = \frac{R\theta}{\rho} \sin(\phi + \varphi_c) \tag{7}$$

If the difference between the signals of the equations (6) and (7) is made by the differential amplifier 93, it is possible to determine the axial runout $\delta_D(\phi)$ of the optical disk 1 to be determined, as shown in Figure 12(c). Incidentally, the vertical axis error θ indispensable for the error eraser 92 and the direction $\phi \xi$ on the turntable are measured by using the reference disk having a rotating face of excellent flatness.

Figure 13 is a diagram showing the structure of another embodiment for the method of correcting the vertical axis error. As shown, the output of the error eraser 92 is connected with the focal position adjustor (i.e., the lens actuator 33) built in the measuring head 3.

Since the signal corresponding to the vertical axis error $\delta_{\varepsilon}(\theta)$ is introduced into the focal position adjustor, the output of the measuring head 3 is freed from the influence of the vertical axis error.

In case the whole surface of the optical disk 1 is scanned, on the other hand, the vertical axis error $\delta_{\varepsilon}^{*}(\theta)$ may be determined at a specified distance R, and the signal corresponding to the vertical axis error $\delta_{\varepsilon}^{*}(\theta).(r/R)$ in proportion to the distance r of the measuring head 3 may be outputted from the error eraser 92.

The substrate thickness is measured from the difference in the displacement outputs when the surface and back (i.e., recording face) of the optical disk 1 are sequentially subjected to the focusing servo. Here, a focus error detecting system for the surface is added to the optical system of the focusing servo so that the measurements may be reliable within the moving range of ± 1 mm of the focusing lens 31.

Figure 14 is a diagram showing the structure of one embodiment of the measuring principle for the substrate thickness. In Figure 14: reference numeral 341 denotes a half-mirror; numeral 361 a first focal state detector composed of the aforementioned light receiving element 36 or the like; numeral 362 a second focal state detector;

and numeral 363 a change-over switch for feeding the outputs of the first and second focal state detectors 361 and 362 selectively to the controller 5 (i.e., the servo amplifier). The first focal state detector 361 is constructed to have a zero output when the recording face of the optical disk 1 is focused. On the other hand, the second focal state detector 362 is constructed to have a sensitivity only to the reflected beam coming from the transparent surface of the disk, if the optical disk 1_0 used has known reflectively n_0 and thickness t_0 and is focused on its recording face, and to have a zero output. As a result, the sensitivity characteristics of the first and second focal state detectors 361 and 362 at this time are plotted in Figure 16. In the focal position P1 in which the recording face is focused, more specifically, both the first and second focal state detectors 361 and 362 are zero so that the focus error is generated around that focal position P1.

Now, in the substrate thickness measuring system thus constructed, the measuring operations are as follows, if the optical disk 1 measured has a reflectivity n and a thickness t. First of all, the change-over switch 363 is connected with the first focal state detector 361, and the recording face of the optical disk 1 is focused, as shown in Figure 17, by making use of the output of the first focal state detector 361. In case, at this time, the reflectivity n and thickness t of the optical disk 1 are different from the reflectivity n_0 and thickness t_0 of the aforementioned optical disk 1_0, the output of the second focal state detector 362 is not zero even if the output (i.e., the focus error) of the first focal state detector 361 is zero. This behavior is shown in Figure 18. In Figures 17 and 18, the point P1 presents a point in which the recording film is focused.

Next, the change-over switch 363 is changed to the second focal state detector 362 so that the position of the focusing lens 31 is displaced to reduce the output of the second focal state detector 362 to zero. The position (i.e., the focal position) in which the second focal state detector 362 takes the zero output is designated at P2.

If the displacement of the focusing lens 31 at this time is designated at x, the thickness t of the optical disk 1 is determined from the following equation.

$$t = (t_0 / n_0 + x)\ n = t_0 n / n_0 + x \cdot n$$

Here, for $n = n_0$ and $t = t_0$, the displacement x at this time is far smaller than the thickness t of the optical disk 1 so that the thickness t of the optical disk 1 can be measured by the focusing lens 31 having a small stroke and the displacement detector 37. Since the necessary stroke is small, moreover, the actuator of the focusing lens 31 and the displacement detector 37 can be used in the vicinity of the neutral point in which the controllability is the best.

Thus, in the optical disk test system of the present invention, the displacement of the focusing lens 31 of the measuring head 3 is directly detected by the displacement detector 37 of optical type. As a result, the simple structure can realize the optical disk test system which can detect the displacements of the focusing lens 31 accurately in the focusing and tracking directions thereby to measure the mechanical characteristics of the optical disk accurately.

Next, a protecting system of the optical disk test system of the present invention will be described in the following.

Figure 19 is a diagram showing one embodiment of the protecting mechanism for preventing a calibrating member from being broken by errors of the feed mechanism or the like when the displacement detector 37 is to be calibrated. In Figure 19, reference numeral 10 denotes a calibrating member which is set on the feed mechanism 4 for calibrating the displacement detector 37. This calibrating member 10 has a disk member to be positioned on the measuring head 3, for example, for calibrating the displacement detector 37 by moving up and down the disk member in a suitable manner and by measuring the displacement of the disk member at this time with a scale. Numeral 41 denotes a drive motor of the feed mechanism 4; numeral 42 a drive circuit for driving the drive motor 41 in response to the command of the controller 5 or the like; numeral 43 a detector having a micro-switch or a proximity switch for detecting that the calibrating member 10 is set on the feed mechanism; and numeral 44 a switch inserted into a portion of the drive circuit 42 for interrupting the drive circuit 42 in response to the detected output of the detector 43. The switch 44 can make use of the contact output of the detector 43.

Moreover, the position of insertion of the switch 44 should not be limited to the input side of the drive circuit 42 but may be located at the power line of the drive motor 41.

In the protecting mechanism thus constructed, the switch 44 is always off so that the drive circuit 42 is interrupted, with the calibrating member 10 being set on the feed mechanism 4. Even in case the drive command of the feed mechanism is generated by causes such as the defects or errors of the system, the drive (power) signal is not applied to the drive motor 41 so that the errors of the feed mechanism 4 can be prevented. As a result, the calibrating member 10 can be prevented from impinging upon the spindle motor 2 or the like due to errors of the feed mechanism so that it can be protected without fail.

Figure 20 is a diagram showing one embodiment of a limiter mechanism for limiting the moving range of the slide of the feed mechanism 4 so that the measuring head 3 or the like carried on the feed mechanism 4 may be prevented from impinging upon the spindle motor 2 therearound and from being broken. In Figure 18, reference numeral 45 denotes a stationary portion, and numeral 46 denotes a slide portion. The measuring head 3 or the like is carried on the slide portion 46 so that the irradiating (or measuring) position of the laser beam is moved in the radial direction of the optical disk 1 as the slide portion 46 slides. Moreover, numerals 47 and 48 denote detectors made of micro-switches or proximity switches for detecting the passage of the end 461 of the slide portion 46.

In the limiter mechanism thus constructed, the moving velocity of the slide portion 46 is decelerated in accordance with the output of the detector 47 to halt the slide portion 46. This makes it possible to accelerate the moving velocity of the slide portion 46 until the limit position is reached and to halt the slide portion reliably with little overshoot. As a result, the measuring head 3 carried on the slide portion 46 can be reliably protected against any damage.

As has been described hereinbefore, the optical disk test system according to the present invention comprises: a spindle motor for holding and rotating an optical disk at a constant speed; an encoder for generating a pulse output corresponding to the angle of rotation of the spindle motor; a measuring head, including focus servo and tracking servo mechanisms for causing the focal point of a laser beam irradiating the optical disk to follow the guide groove of the optical disk, and a displacement detector for optically detecting the displacement of a focusing lens driven by the servo mechanisms, the measuring head being operative to generate an output signal proportional to the displacement of the focusing lens; a feed mechanism for moving the measuring head in the radial direction of the optical disk; a controller for controlling the operations of the spindle motor, the focus servo and tracking servo mechanisms of the measuring head and the feed mechanism; an analog/digital converter for analog-to-digital converting the output of the measuring head at a timing according to the pulse output of the encoder; and a computer for commanding the controller and for computing the output of the analog/digital converter to determine the shape of the optical disk. As a result, it is possible with the simple structure to realize the optical disk test system which can detect the displacements of the focusing lens accurately in the focusing and tracking directions thereby to measure the mechanical characteristics of the optical disk accurately.

CLAIMS:

1. A test system for optical disks, comprising:

a spindle motor for holding and rotating an optical disk at a constant speed;

an encoder for generating a pulse output corresponding to the angle of rotation of said spindle motor;

a measuring head, including focus servo and tracking servo mechanisms for causing the focal point of a laser beam irradiating said optical disk to follow the guide groove of said optical disk, and a displacement detector for optically detecting the displacement of a focusing lens driven by said servo mechanisms, said measuring head being operative to generate an output signal proportional to the displacement of said focusing lens;

a feed mechanism for moving said measuring head in the radial direction of said optical disk;

a controller for controlling the operations of said spindle motor, the focus servo and tracking servo mechanisms of said measuring heads, and said feed mechanism;

an analog/digital converter for analog-to-digital converting the output of said measuring head at a timing according to the pulse output of said encoder; and

a computer for commanding said controller and for computing the output of said analog/digital converter to determine the shape of said optical disk.

2. An optical disk test system according to Claim 1, wherein said measuring head includes; a shielding plate having a rectangular aperture and arranged in a plane containing focusing and tracking directions of said focusing lens while being fixed relative to said focusing lens; a light source for irradiating said shielding plate with a parallel beam having a spot diameter larger than the range of movement of said aperture; and a multi-divided sensor for detecting the light having passed through the aperture of said shielding plate, and wherein said displacement detector detects the displacement of said focusing lens by making use of the output signals of said multi-divided sensor.

3. An optical disk test system according to Claim 2, wherein said displacement detector has a feedback circuit for detecting the total sum of the output signals of said multi-divided sensors coming from respective light receiving faces to control the amount of emission of said light source such that said total sum may always take a constant value.

4. An optical disk test system according to Claim 1, wherein said controller includes means for rotating said spindle motor at a speed lower than a rated speed of rotation.

5. An optical disk test system according to Claim 1 wherein said computer includes a memory for storing the output signal of said measuring head corresponding to the

axial runout of said optical disk 1 together with data of the point of measurement so that a tilt may be computed from the axial runout of said optical disk.

6. An optical disk test system according to Claim 1, wherein said controller includes an error eraser for generating a signal corresponding to error in the vertical axis of said spindle motor, which has been measured in advance by making use of a reference disk, in accordance with the pulse output of said encoder so that the output signal of said measuring head may be corrected in accordance with the output of said error eraser.

7. An optical disk test system according to Claim 1, wherein said measuring head includes: a first focal state detector for detecting whether or not the recording film of said optical disk is focused; a second focal state detector made receptive of the reflected beam shared with said first focal state detector; and a change-over switch for feeding back the outputs of said first and second focal state detectors selectively to said controller when a plate thickness is measured, and wherein said second focal state detector is made sensitive only to the reflected beam coming from the surface of the transparent side of an optical disk having known reflectivity and thickness to generate a zero output when the recording face of said known optical disk is focused.

8. A test system for optical disks substantially as hereinbefore described with reference to Figures 2 to 20 of the accompanying drawings.

Published 1988 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office,
Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Multiplex techniques ltd, St Mary Cray, Kent. Con. 1/87.