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OPTICAL DISC APPARATUS

1 BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention relates to an optical disc apparatus which can record, reproduce, or erase
5 information signals onto/from both of an optical disc having a recording density similar to that of a conventional CD (compact disc) and an optical disc having a recording density higher than the above recording density.

10 DESCRIPTION OF THE PRIOR ART

In recent years, in addition to an optical disc apparatus only for reproduction such as a CD player or the like, an optical disc apparatus which can record and reproduce an information signal is actively being
15 developed.

Ordinarily, the recording and reproduction of an information signal onto/from an optical disc are executed by converging a beam which is radiated from a semiconductor laser or the like onto a recording layer
20 of the optical disc by a lens. The recording layer here denotes a pit layer in the case of a CD and is a layer in which a deformation, a change in optical constant, a formation of a magnetic domain, or the like is performed by a converged laser beam in the case of a recordable
25 optical disc. To raise a recording density of the

1 optical disc, it is necessary to reduce a spot diameter
D of the converged beam. There is the following
relation among the spot diameter D, a numerical aperture
NA of the lens, and a wavelength λ of the laser beam.

$$D \propto \frac{\lambda}{NA} \quad \dots (1)$$

5 The above equation (1) denotes that the beam
spot diameter D decreases by using a lens of a large NA.
That is, by increasing NA, the high density recording
can be executed.

When NA of the lens increases, however, an
10 aberration of the converged beam due to an inclination
error of the disc called a tilt increases. Particular-
ly, a coma aberration increases. There is the following
relation among a wave front aberration W_c of the coma, a
tilt angle α , and NA when using a thickness d and a
15 refractive index n of the disc substrate.

$$W_c \propto \frac{n^2-1}{2n^3} \cdot d \cdot \alpha \cdot (NA)^3 \quad \dots (2)$$

The above equation (2) denotes that in the
case of using a lens of NA which is larger than that of
the conventional lens, even if a tilt angle is
identical, the coma aberration increases. It will be
20 understood from the equation (2), however, that there is
an effect to suppress the coma aberration by setting the
thickness d of the disc substrate to be thin. In the
optical disc for the high density recording, therefore,

1 it is preferable that the thickness of the disk
substrate is thinner than that of the conventional
optical disc, so that an optical head using an objective
lens corresponding to the thin disc substrate is needed.

5 On the other hand, even in the optical disc
apparatus corresponding to the high density recording,
it is preferable that the conventional optical disc of a
thick substrate can be also reproduced so that a great
amount of conventional software resources can be
10 utilized.

However, the optical head which has been
designed for a thin substrate cannot be used for an
optical disc of a thick substrate. The reasons will now
be described hereinbelow. The objective lens for an
15 optical disc has been designed so as to set off a
spherical aberration which occurs when the converged
beam passes in the disc substrate. Since such an
aberration is corrected in accordance with the thickness
of the disc substrate, the aberration correction is not
20 accurately performed for the converged beam which passes
through the disc substrate having a thickness different
from the design value. The above point will now be
explained with reference to the drawing. Figs. 18A and
18B are schematic side elevational views for explaining
25 a situation of the occurrence of the aberration due to
the disc substrates having different thicknesses. Fig.
18A is a diagram in the case of using an objective lens
which has been designed for a thin disc substrate and

1 shows traces of lights in a state in which a beam has
been converged through the disc substrate having the
same thickness as the design value. In the diagram, a
broken line indicates the surface of a recording layer
5 and all of the lights emitted from the objective lens
are converged to one point O on the recording layer
surface. Fig. 18B is a diagram in the case of using an
objective lens which has been designed for the same thin
disc substrate as that of Fig. 18A and shows traces of
10 lights in a state in which the beam has been converged
through the disc substrate having a thickness which is
thicker than the design value. In Fig. 18B, the lights
emitted from the outermost peripheral portion of the
objective lens are converged to a point O' on the
15 recording layer surface. However, the light locating
near the optical axis is converged at the front side.
Such a phenomenon is called a spherical aberration.
When such an aberration occurs, the objective lens
cannot converge the light beam until what is called a
20 diffraction limit. Therefore, in the case of using the
objective lens whose aberration has been corrected for a
thin disc substrate, an information signal cannot be
recorded, reproduced, or erased onto/from an optical
disc having a thick disc substrate. Similarly, in the
25 case of using the objective lens whose aberration has
been corrected for a thick disc substrate, an
information signal cannot be recorded, reproduced, or

- 1 erased onto/from an optical disc having a thin disc
substrate.

SUMMARY OF THE INVENTION

- 5 In consideration of the above drawbacks, it is
an object of the invention to provide an optical disc
apparatus which can record, reproduce, or erase informa-
tion signals onto/from a plurality of optical discs in
which thicknesses of disc substrates are different.

- 10 To accomplish the above object, according to
the invention, there is provided an optical disc
apparatus for recording, reproducing, or erasing
information signals onto/from an optical disc by
converging light fluxes onto a recording layer through a
transparent disc substrate, comprising: N converging
15 means whose aberrations have been corrected for N ($N \geq$
2) disc substrates having different thicknesses,
respectively; disc discriminating means for discriminat-
ing the thickness of the disc substrate of the optical
disc which has been loaded and for generating a
20 discrimination signal according to the result of the
discrimination; and control means for selecting one of
the converging means in which the occurrence of the
aberration due to the disc substrate is smallest in
accordance with the discrimination signal.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a constructional diagram of an

1 optical disc apparatus according to the first embodiment
of the invention;

Fig. 2 is a plan view showing an arrangement
of a main section of the optical disc apparatus in the
5 first embodiment;

Figs. 3A and 3B are perspective views of
cartridges of optical discs in the first embodiment;

Figs. 4A and 4B are schematic diagrams showing
cross sections of the optical discs and states of
10 convergences by objective lenses in the first
embodiment;

Fig. 5 is a constructional diagram of an
optical disc apparatus according to the second embodi-
ment of the invention;

15 Fig. 6 is a detailed constructional diagram of
optical heads in the second embodiment;

Fig. 7 is a constructional diagram of an
optical disc apparatus according to the third embodiment
of the invention;

20 Fig. 8 is a detailed constructional diagram of
an optical head in the third embodiment;

Figs. 9A and 9B are a detailed constructional
diagram of an optical head of an optical disc apparatus
according to the fourth embodiment of the invention;

25 Fig. 10 is a cross sectional view showing
optical discs whose substrate thicknesses are different
and converging states by convergence grating couplers
which have been designed in correspondence to the

1 optical discs according to the fifth embodiment,
respectively;

Fig. 11 is a schematic perspective view
showing a construction of an optical head of an optical
5 disc apparatus in the fifth embodiment;

Fig. 12 is a schematic perspective view
showing a construction of an optical head of an optical
disc apparatus according to the sixth embodiment of the
invention;

10 Fig. 13 is a schematic perspective view
showing a construction of an optical head of an optical
disc apparatus according to the seventh embodiment of
the invention;

Fig. 14 is a block diagram showing a
15 construction of the optical disc apparatus in the
seventh embodiment;

Fig. 15 is a block diagram showing a
construction of an optical disc apparatus according to
the eighth embodiment of the invention;

20 Fig. 16 is a schematic enlarged perspective
view showing a convergence grating coupler of an optical
head, an SAW transducer, and a portion in which surface
acoustic waves have been formed in the eighth
embodiment;

25 Fig. 17 is a characteristic diagram for
explaining the principle of the tracking control in the
eighth embodiment; and

1 Figs. 18A and 18B are schematic side
elevational views showing occurring situations of
aberrations due to disc substrates having different
thicknesses.

5 DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the invention will be described
hereinbelow on the assumption that thicknesses of disc
substrates are set to two kinds of thicknesses.

Fig. 1 is a constructional diagram of an
10 optical disc apparatus in the first embodiment of the
invention. Fig. 2 is a plan view showing an arrangement
of a main section of the embodiment. Figs. 3A and 3B
are perspective views of cartridges of optical discs in
the embodiment.

15 In Figs. 1 to 3A and 3B, reference numeral 1
denotes a first or second optical disc. Thicknesses of
disc substrates of both of the first and second optical
discs are different. Reference numeral 2 denotes a
cartridge which encloses the optical disc 1 and
20 protects. The cartridge 1 is made of plastics or the
like. Reference numeral 3 denotes a first optical head
and 5 indicates a second optical head. Each of the
optical heads is constructed by a converging optical
system comprising: an objective lens; a semiconductor
25 laser; a photo detector; a beam splitter; and the like
(all of the above components are not shown). Each of
the optical head detects an information signal, a

1 focusing error signal, and a tracking error signal which
have been recorded on the optical disc 1 on the basis of
an intensity or an intensity distribution of the
reflected lights of a laser beam irradiated onto the
5 optical disc 1 and generates a photo detection signal to
the outside. An information signal is recorded onto or
erased from the optical disc 1 by modulating an
intensity of the laser beam. Both of the optical heads
have bases to hold the above optical devices and
10 actuators. A reproduction information signal, a
focusing error signal, and a tracking error signal which
are generated from the photo detector of the first
optical head 3 are expressed by S_1 , F_1 , and T_1 ,
respectively. Similar signals which are generated from
15 the photo detector of the second optical disc 5 are also
expressed by S_2 , F_2 , and T_2 , respectively. Reference
numeral 4 denotes a first linear motor which is arranged
below the optical disc 1 and moves the first optical
head 3 in the radial direction of the disc in parallel
20 with the disc surface. Reference numeral 6 denotes a
second linear motor which is arranged below the optical
disc 1 so as to face the first linear motor 4 and moves
the second optical head 5 in a manner similar to the
first optical head 3.

25 As shown in Fig. 2, the second linear motor 6
is extended until the further outside of the outermost
peripheral portion of the optical disc 1. Therefore,
when the second optical head 5 moves to the outermost

1 side, the optical head 5 is projected from the lower
surface of the optical disc. Reference numeral 7
denotes a discrimination hole formed on the surface of
the cartridge 2.

5 The cartridge in the embodiment will now be
described with reference to Figs. 3A and 3B. The
discrimination hole 7 is closed in the case where the
optical disc 1 enclosed in the cartridge is the first
optical disc shown in Fig. 3A and is open in the case
10 where it is the second optical disc shown in Fig. 3B.
Reference numeral 23 denotes a slide shutter. Since the
optical disc apparatus of the embodiment has two optical
heads, two slide shutters are provided. When the
cartridges are removed from the optical disc apparatus,
15 the slide shutters are closed to protect the internal
discs from dusts.

Reference numeral 8 denotes a light emitting
diode (hereinafter, abbreviated to an LED) which is
arranged so as to be located over the discrimination
20 hole 7 when the cartridge 2 has been loaded into the
optical disc apparatus of the embodiment. Reference
numeral 9 denotes a photo diode arranged at a position
so as to face the LED 8 through the cartridge 2. The
photo diode 9 generates a detection signal to a system
25 controller 22, which will be explained hereinlater.
Reference numeral 10 denotes a first selector for
selecting either one of the first group of photo
detection signals (S_1 , F_1 , and T_1) of the first optical

1 head 3 and the second group of photo detection signals
(S₂, F₂, and T₂) of the second optical head 5 and for
outputting the selected signals. Reference numeral 11
denotes a tracking control circuit which receives the
5 tracking error signal T₁ or T₂ from among the output
signals of the first selector 10 and generates a
tracking actuator driving signal to a second selector
12, which will be explained hereinlater. Further,
reference numeral 12 denotes the second selector to
10 select either an actuator of the first optical head 3 or
an actuator of the second optical head 5 as a destina-
tion to which the tracking actuator driving signal is
supplied. Reference numeral 13 denotes a focusing
control circuit which receives the focusing error signal
15 F₁ or F₂ from among the signals which are generated from
the first selector 10 and generates a focusing actuator
driving signal to a third selector 14, which will be
explained hereinlater. Further, reference numeral 14
denotes the third selector for selecting either the
20 actuator of the first optical head 3 or the actuator of
the second optical head 5 as a destination to which the
focusing actuator driving signal is supplied. Reference
numeral 15 denotes a linear motor control circuit which
supplies a driving signal to a fourth selector 16, which
25 will be explained hereinlater, by a control signal which
is supplied from the system controller 22, which will be
described hereinlater. Reference numeral 16 denotes the
fourth selector to select either the first linear motor

1 4 or the second linear motor 6 as an output destination
of the driving signal supplied from the linear motor
control circuit 15. Reference numeral 17 denotes a
spindle control circuit which receives the reproduction
5 information signal S_1 or S_2 and generates a control
current to a spindle motor 18, which will be explained
hereinlater. Reference numeral 18 denotes the spindle
motor to rotate the optical disc 1. Reference numeral
19 denotes a signal processing circuit for executing
10 signal processes such as demodulation and/or decoding or
the like to the input signal S_1 or S_2 , for converting
into an audio signal or the like, or for outputting the
information signal to be recorded onto the optical disc
1 to an LD driving circuit 20, which will be explained
15 hereinlater. Reference numeral 20 denotes the LD
driving circuit to supply a driving current for allowing
laser beams to be emitted from the semiconductor lasers
of both of the optical heads to a fifth selector 21,
which will be explained hereinlater. Reference numeral
20 21 denotes the fifth selector to switch the output
destination of the above driving current to either one
of the first and second optical heads 3 and 5 in
accordance with a control signal from the system
controller 22, which will be explained hereinlater. The
25 system controller 22 generates the driving current for
allowing the LED 8 to emit the light and receives the
detection signal from the photo diode 9 and generates
control signals to the first to fifth selectors 10, 12,

1 14, 16, and 21. The system controller 22 also generates
control signals to the linear motor control circuit 15
and the signal processing circuit 19. In Fig. 1,
switching terminals in the first to fifth selectors 10,
5 12, 14, 16 and 21 on the first head side are designated
by "A" and those on the second head side are designated
by "B" in the diagram.

The first optical disc is a CD or an optical
disc having a recording density similar to that of the
10 CD and a thickness of the disc substrate is set to d_1 as
shown in Fig. 4A. For instance, assuming that the
optical disc shown in Fig. 4A is a CD, $d_1 = 1.2\text{mm}$. The
second optical disc is an optical disc which can execute
a recording at a higher density than that of the first
15 optical disc and a thickness of the disc substrate
assumes d_2 as shown in Fig. 4B. To reduce the
aberration of the converged spot due to a tilt error,
the thickness d_2 of the second optical disc is designed
so as to be smaller than d_1 . For example, $d_2 = 0.3\text{ mm}$.

20 The first optical head 3 has, for instance, a
semiconductor laser of a wavelength of 780 nm and an
objective lens of an NA of 0.45, so that the laser beam
can be converged to a spot diameter ϕ of about $2.1\text{ }\mu\text{m}$.
In addition, an optical design of the objective lens has
25 been made so as to correct the aberration by the disc
substrate of the thickness d_1 . The second optical head
5 has, for instance, the same semiconductor laser as
that of the first optical head and an objective lens of

1 an NA of 0.8, so that the laser beam can be converged
until a spot diameter of 1.2 μm . Moreover, an optical
design of the objective lens has been made so as to
correct the aberration by the disc substrate of the
5 thickness d_2 .

The operation of the optical disc apparatus of
the embodiment constructed as mentioned above will now
be described hereinbelow.

First, the case where the cartridge 2
10 enclosing the second optical disc has been loaded into
the optical disc apparatus of the embodiment will be
described. When the cartridge 2 is loaded, the LED 8
emits the light and the photo diode 9 detects the
presence or absence of a transmission light which passes
15 through the discrimination hole 7. As already described
in conjunction with Figs. 3A and 3B, since the
discrimination hole 7 is open in the case of the second
optical disc, the photo diode 9 detects the transmission
light and generates a detection signal to the controller
20 22. The controller 22 determines that the disc in the
loaded cartridge 2 is the second optical disc, so that
the controller 22 supplies control signals to the first
to fifth selectors 10, 12, 14, 16, and 21 so as to
select the terminals B on the second optical head side.
25 Thus, the semiconductor laser of the second optical head
5 is selected as an output destination of the driving
current which is supplied from the LD driving circuit
20. The photo detector of the second optical head 5 is

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REPLACED

1 selected as an input destination of the tracking control
circuit 11, focusing control circuit 13, spindle control
circuit 17, and signal processing circuit 19. The
actuator of the second optical head 5 is selected as an
5 output destination of the actuator driving signals of
the tracking control circuit 11 and focusing control
circuit 13. The second linear motor 6 is selected as an
output destination of the driving current of the linear
motor control circuit 15.

10 Therefore, the second optical head 5 irradi-
ates the laser beam and converges onto an information
track on the optical disc 1 without an aberration.
Simultaneously, the second optical head 5 detects the
reflected lights from the disc and generates the
15 information signal S_2 , focusing error signal F_2 , and
tracking error signal T_2 . Those signals are supplied
through the first selector 10 to the respective
circuits. That is, the signal S_2 is supplied to the
spindle control circuit 17 and signal processing circuit
20 19. The signal F_2 is supplied to the focusing control
circuit 13. The signal T_2 is supplied to the tracking
control circuit 11. The tracking control circuit 11
produces the tracking actuator driving signal in accord-
ance with the signal T_2 and supplies to the actuator of
25 the second optical head 5 through the second selector
12, thereby eliminating the tracking error. In a manner
similar to the above, the focusing control circuit 13
also produces the focusing actuator driving signal in

1 accordance with the signal F_2 and supplies to the
actuator of the second optical head 5 through the third
selector 14, thereby eliminating the focusing error.
The linear motor control circuit 15 generates the
5 driving current to the linear motor 6 in response to the
control signal from the system controller 22, thereby
moving the second optical head 5 in the inner or outer
rim direction of the optical disc 1. The spindle
control circuit 17 extracts a clock component from the
10 information signal S_2 and controls the spindle motor 18,
thereby rotating the optical disc 1 at a constant linear
velocity (CLV) or a constant angular velocity (CAV) or
the like. The signal processing circuit 19 executes
signal processes such as demodulation, decoding, and the
15 like to the information signal S_2 in the reproducing
mode and generates to the outside as audio or video
signals or the like. On the other hand, the signal
processing circuit 19 executes signal processes such as
encoding, modulation, and the like to the audio or video
20 signals or the like which have been supplied from the
outside in the recording mode and generates to the LD
driving circuit 20 as a recording signal. Until the
cartridge 2 is loaded, the second optical head 5 records
or reproduces the information signal onto/from the
25 second optical disc 1.

On the other hand, in the case where the
cartridge 2 enclosing the first optical disc has been
loaded into the optical disc apparatus of the

embodiment, since the discrimination hole 7 is closed, the photo diode 9 doesn't detect the transmission light. Therefore, the system controller 22 determines that the disc in the cartridge 2 is the foregoing first optical disc. Thus, the controller 22 generates control signals to the first to fifth selectors 10, 12, 14, 16, and 21 so as to select the terminals A on the first optical head side. Therefore, the semiconductor laser of the first optical head 3 is selected as an output destination of the driving current which is supplied from the LD driving circuit 20. The photo detector of the first optical head 3 is selected as an input destination of the tracking control circuit 11, focusing control circuit 13, spindle control circuit 17, and signal processing circuit 19. The actuator of the first optical head 3 is selected as an output destination of the actuator driving signals of the tracking control circuit 11 and focusing control circuit 13. The first linear motor 4 is selected as an output destination of the driving current of the linear motor control circuit 17. Therefore, the first optical head 3 irradiates the laser beam and converges onto the information track on the optical disc 1 without an aberration. Simultaneously, the reflected lights from the disc are detected and generated as the information signal S_1 , focusing error signal F_1 , and tracking error signal T_1 . The above signals are supplied through the first selectors 10 to the respective circuits. That is, the signal S_1 is

1 supplied to the spindle control circuit 17 and signal
processing circuit 19. The signal F_1 is supplied to the
focusing control circuit 13. The signal T_1 is supplied
to the tracking error detecting circuit 11. The sub-
5 sequent operations are similar to those in the case of
the second optical disc mentioned above.

In the case where the objective lens of the
second optical head is a lens of a high NA and a short
operating distance, it is necessary to set an interval
10 between the second optical head 5 and the surface of the
optical disc 1 to be fairly narrower than that in the
case of the first optical head 5. Therefore, while the
first optical disc is loaded, the controller 22 controls
the second linear motor 6, thereby moving the second
15 optical head 5 to the outside of the disc surface as
shown in Fig. 2. Due to this, it is possible to prevent
that the objective lens of the second optical head 5
collides with the optical disc 1 due to a surface
oscillation.

20 As described above, according to the
embodiment, by providing the first optical head 3 and
second optical head 5 having convergence optical systems
corresponding to the thicknesses of the disc substrates
of the first and second optical discs, the signal can be
25 preferably recorded, reproduced, or erased by the
optical head suitable for the thickness of each disc
substrate. Moreover, by providing the discrimination
hole 7 formed on the cartridge 2 and the disc

discriminating means comprising the LED 8 to detect the opening/closure of the discrimination hole 7 and the photo diode 9, merely by loading the cartridge 2, each of the optical heads can be automatically accurately selected.

Fig. 5 shows a constructional diagram of an optical disc apparatus according to the second embodiment of the invention. In the diagram, the second embodiment differs from the foregoing first embodiment with respect to a point that a third optical head 30 is arranged in place of the first and second optical heads 3 and 5 and a point that the second, third, and fourth selectors 12, 14, and 16 are omitted. That is, the tracking actuator driving current which is generated from the tracking control circuit 11 and the focusing actuator driving current which is generated from the focusing control circuit 13 are directly supplied to the third optical head 30. The driving current which is generated from the linear motor control circuit 15 is directly supplied to the first linear motor 4.

Further, Fig. 6 shows a detailed constructional diagram of the third optical head 30 in the second embodiment of the invention. In the diagram, reference numeral 1 denotes the first or second optical disc; 32 a first semiconductor laser as a light source; 33 a first collimating lens for converting a laser beam from the first semiconductor laser 32 into a parallel beam; 34 first beam splitter to divide the beam into two

1 beams; 35 a first mirror to change the direction of the
beam; 36 a first objective lens to converge the beam
onto the optical disc 1; 37 a first detecting lens to
converge the reflected lights which have been divided by
5 the beam splitter 34; and 38 a first photo detector to
obtain an information reproduction signal, a focusing
error signal, and a tracking error signal from the
converged reflected lights. The above components 32 to
38 construct a first converging optical system 31.

10 Reference numeral 39 denotes a lens holder to
hold the first objective lens 36 and a second objective
lens 46, which will be explained hereinlater. Reference
numeral 40 denotes an actuator to support the lens
holder 39. The driving currents are supplied from the
15 tracking control circuit 11 and focusing control circuit
13 to the actuator 40.

 Reference numeral 42 denotes a second
semiconductor laser as a light source; 43 a second
collimating lens to convert a laser beam from the second
20 semiconductor laser 42 into a parallel beam; 44 a second
beam splitter to divide the beam into two beams; 45 a
second mirror to change the direction of the beam; 46
the second objective lens to converge the beam onto the
optical disc 1; 47 a second detecting lens to converge
25 the reflected lights which have been divided by the
second beam splitter 44; and 48 a second photo detector
to obtain the information reproduction signal, focusing
error signal, and tracking error signal from the

1 converged reflected lights. The above components 42 to
48 construct a second converging optical system 41. The
above first converging optical system 31, the second
converging optical system 41, and the actuator 40 are
5 mounted on a same base member (not shown) and construct
the third optical head 30. The base member is ordinari-
ly made of aluminum or the like and is attached to the
first linear motor 4.

In a manner similar to the case which has been
10 described in the first embodiment of the invention, for
instance, the first objective lens 36 is designed so
that $NA = 0.45$ and the aberration by the disc substrate
of a thickness d_1 is corrected. The second objective
lens 46 is designed so that, for instance, $NA = 0.8$ and
15 the aberration by the disc substrate of a thickness d_2
is corrected.

The operation of the optical disc apparatus of
the embodiment constructed as mentioned above will now
be described hereinbelow. First, the case of the second
20 optical disc will be explained. When the cartridge 2 is
loaded into the optical disc apparatus of the embodi-
ment, the LED 8 emits the light and the photo diode 9
detects the presence or absence of the transmission
light which passes through the discrimination hole 7.
25 If the transmission light has been detected, the system
controller 22 determines that the disc in the loaded
cartridge 2 is the second optical disc, so that the
controller 22 selects the second converging optical

1 system 41 of the third optical head 30. That is, the
system controller 22 generates control signals to the
first and fifth selectors 10 and 21 so as to make the
second semiconductor laser 42 and the second photo
5 detector 48 operative. The laser beam emitted from the
second semiconductor laser 42 is converted into the
parallel beam by the second collimating lens 43. The
parallel beam is converged onto the second optical disc
1 by the second objective lens 46 through the second
10 beam splitter 44 and the second mirror 45. The laser
beam reflected by the disc is again converted into the
parallel beam by the second objective lens 46 and is
separated from the optical axis by the second beam
splitter 44 through the second mirror 45 and is
15 converged onto the second photo detector 48 by the
second detecting lens 47.

The second photo detector 48 produces the
information signal, focusing error signal, and tracking
error signal from the converged reflected light from the
20 disc and supplies to the first selector 10. The
actuator 40 finely moves the lens holder 39 in the
tracking and focusing directions by the driving currents
from the tracking control circuit 11 and the focusing
control circuit 13, thereby accurately converging the
25 laser beam onto an information track on the optical
disc 1.

Since the operations of the first linear motor
4, first selector 10, tracking control circuit 11,

1 focusing control circuit 13, linear motor control
circuit 15, spindle control circuit 17, spindle motor
18, signal processing circuit 19, LD driving circuit 20,
fifth selector 21, and system controller 22 are
5 substantially the same as the optical disc apparatus of
the first embodiment mentioned above, their descriptions
are omitted here.

On the other hand, in the case of the first
optical disc, since the photo diode 9 doesn't detect the
10 transmission light, the system controller 22 decides
that the disc in the loaded cartridge 2 is the first
optical disc mentioned above, so that the controller 22
selects the first converging optical system 31 of the
third optical head 30. That is, the system controller
15 22 generates control signals to the first and fifth
selectors 10 and 21 so as to make the first semi-
conductor laser 32 and the first photo detector 38
operative. The operation of the first converging
optical system 31 is substantially the same as that of
20 the second converging optical system 41 mentioned above.
Until the cartridge 2 is unloaded, the recording,
reproduction, or erasure of the information signal
onto/from the first optical disc is executed by the
first converging optical system 31.

25 As described above, according to the second
embodiment, in addition to the effect by the first
embodiment, since the first converging optical system 31
and the second converging optical system 41 are mounted

1 on the same base and construct the third optical head
30, the linear motor can be commonly used as a single
part and the number of parts can be reduced.

Fig. 7 shows a constructional diagram of an
5 optical disc apparatus according to the third embodiment
of the invention. In the diagram, the third embodiment
differs from the second embodiment with respect to a
point that a fourth optical head 50 is arranged in place
of the third optical head 30 and a point that the first
10 selector 10 and the fifth selector 21 are omitted. That
is, the photo detection signal which is generated from
the fourth optical head 50 is directly supplied to the
tracking control circuit 11, focusing control circuit
13, spindle control circuit 17, and signal processing
15 circuit 19. The driving current which is generated from
the LD driving circuit 20 is directly supplied to the
fourth optical head 50.

Further, Fig. 8 shows a detailed construc-
tional diagram of the fourth optical head 50 in the
20 third embodiment of the invention. In the diagram,
reference numeral 1 denotes the first or second optical
disc; 32 the first semiconductor laser as a light
source; 33 the first collimating lens to convert the
laser beam from the first semiconductor laser 32 into
25 the parallel beam; 34 the first beam splitter to divide
the laser beam into two beams; and 35 the first mirror
to change the direction of the beam. The first objec-
tive lens 36 and the second objective lens 46 are the

1 same as those mentioned in the second embodiment of the
invention. The first objective lens 36 is arranged
between the first mirror 35 and the optical disc 1. The
second objective lens 46 is arranged between the first
5 beam splitter 34 and the optical disc 1. Moreover, as
mentioned in the foregoing embodiment, the aberration of
the first objective lens 36 has been corrected in
correspondence to the first optical disc having the disc
substrate of the thickness d_1 . The aberration of the
10 second objective lens 46 has been corrected in corre-
spondence to the second optical disc having the disc
substrate of the thickness d_2 . Reference numeral 51
denotes a first shutter arranged between the first
objective lens 36 and the first mirror 35 and on the
15 optical path which passes through the first objective
lens 36. Reference numeral 52 denotes a second shutter
which is arranged between the second objective lens 46
and the first beam splitter 34 and on the optical path
which passes through the second objective lens 46. The
20 first and second shutters 51 and 52 open or close the
optical paths by control signals from the system
controllers 22, respectively. Reference numeral 37
denotes the first detecting lens to converge the
reflected lights which have been divided by the beam
25 splitter 34. Reference numeral 38 denotes the first
photo detector to obtain the information reproduction
signal, focusing error signal, and tracking error signal
from the converged reflected light.

1 Among the foregoing component elements, the
first objective lens 36 constructs the first converging
optical system mentioned in the second embodiment of the
invention together with the first semiconductor laser
5 32, the first collimating lens 33, the first beam
splitter 34, and the first mirror 35. The second objec-
tive lens 46 constructs the second converging optical
system together with the first semiconductor laser 32,
the first collimating lens 33, the first beam splitter
10 34, and the first mirror 35 which are commonly used for
the first converging optical system. The first converg-
ing optical system is mounted onto a common base (not
shown) together with the first and second shutters 51
and 52, thereby constructing the fourth optical head 50.
15 Since the lens holder 39 and the actuator 40 have the
same construction as those in the third optical head 30
in the second embodiment, their descriptions are omitted
here. The fourth optical head 50 is attached to the
first linear motor 4.

20 The operation of the optical disc apparatus in
the embodiment with the above construction will now be
described hereinbelow. The kind of optical disc is
detected in a manner similar to the above. When the
system controller 22 determines that the disc in the
25 loaded cartridge 2 is the second optical disc, the
controller 22 generates control signals to the first and
second shutters 51 and 52 of the fourth optical head 50.
When the control signals are supplied, the first shutter

1 51 is closed and the second shutter 52 is open. In the
above state, the laser beam emitted from the first
semiconductor laser 32 is converted into the parallel
beam by the first collimating lens 33 and is divided
5 into the transmission light and the reflected light by
the first beam splitter 34. The transmission light is
shut out by the first shutter 51 via the first mirror
35. Consequently, only the reflected light passes
through the second shutter 52 and is converged onto the
10 optical disc 1 by the second objective lens 46. The
light reflected by the optical disc 1 is again converted
into the parallel light by the second objective lens 46
and passes through the second shutter 52 and is
reflected and separated by the first beam splitter 34
15 and is converged onto the first photo detector 38 by the
first detecting lens 37. The first photo detector 38
generates the focusing error signal and tracking error
signal from the converged reflected light of the disc
and reproduces the information signal on the disc. The
20 above operations are executed until the cartridge 2 is
unloaded.

Since the operations of the first linear motor
4, tracking control circuit 11, focusing control circuit
13, linear motor control circuit 15, spindle control
25 circuit 17, spindle motor 18, signal processing circuit
19, LD driving circuit 20, and system controller 22 are
the same as those in the optical disc apparatus of the

1 foregoing first embodiment, their descriptions are
omitted here.

On the other hand, if the system controller 22
determines that the disc in the loaded cartridge 2 is
5 the first optical disc, the first shutter 51 is opened
and the second shutter 52 is closed. In the above
state, in the transmission light and the reflected light
by the first beam splitter 34, the reflected light is
shut out by the second shutter 52 and only the trans-
10 mission light passes through the first shutter 51 and is
converged onto the optical disc 1 by the first objective
lens 36. The other operations are executed in a manner
similar to those in the case of the second optical disc.

As mentioned above, according to the third
15 embodiment, in addition to the effects by the second
embodiment, since the first and second shutters 51 and
52 are provided as light flux selecting means, the
semiconductor laser, collimating lens, beam splitter,
detecting lens, and photo detector in each of the
20 converging optical system can be commonly used and the
size and weight of the optical head can be reduced.
Therefore, assuming that a driving force of the linear
motor is the same, the improvement of the performance
such as reduction of the seeking time and the like can
25 be realized.

Figs. 9A and 9B show a detailed constructional
diagram of an optical head of an optical disc apparatus
in the fourth embodiment of the invention. In Fig. 9A,

1 since the optical disc 1, first semiconductor laser 32,
first collimating lens 33, first beam splitter 34,
second objective lens 46, first detecting lens 37, and
first photo detector 38 are constructed in a manner
5 similar to those in the foregoing fourth optical head
50, their descriptions are omitted here. Reference
numeral 56 denotes a lens holder to hold the second
objective lens 46; 57 an actuator to which the lens
holder 56 is attached; 54 a wave front correcting lens
10 attached to a slider 55, which will be explained
hereinlater, so that the optical axis is in parallel
with the optical axis of the second objective lens 46;
and 55 the slider which supports the wave front
correcting lens 54 and is arranged so as to transverse
15 in the plane which is perpendicular to the light flux
between the first beam splitter 34 and the second
objective lens 46, thereby enabling the wave front
correcting lens 54 to be moved in such a plane.
Moreover, such a movable range is set to a position
20 (shown by P_1 in the diagram) where the wave front
correcting lens 54 is perfectly deviated out of the
light flux or a position (shown by P_2 in the diagram)
where the optical axis of the slider 55 coincides with
the optical axis of the second objective lens 46. The
25 above-mentioned component elements are attached to a
base (not shown) and construct a fifth optical head 53.

Fig. 9B is a plan view when the wave front
correcting lens 54 and the slider 55 are seen from

1 the direction of the optical axis. In the diagram, the
lens 54 is movable in the directions shown by arrows.
The wave front correcting lens 54 has been designed in a
manner such that a synthetic optical system with the
5 second objective lens 46 is identical to the foregoing
first objective lens. That is, the lens 54 has been
designed so as to correct the aberration by the disc
substrate of the first optical disc. In the fifth
optical head 53, the second objective lens 46 constructs
10 the second converging optical system mentioned in the
second embodiment of the invention together with the
first semiconductor laser 32, first collimating lens 33,
and first beam splitter 34 and can be also regarded such
that they construct the first converging optical system
15 by adding the wave front correcting lens 54 to the
second converging optical system.

Since a whole construction of the optical disc
apparatus in the fourth embodiment is substantially the
same as that of the optical disc apparatus of the third
20 embodiment shown in Fig. 7 mentioned above, its descrip-
tion is omitted here.

The operation of the optical disc apparatus in
the fourth embodiment with the above construction will
now be described hereinbelow with respect to only the
25 fifth optical head 53. The kind of optical disc is
detected in a manner similar to the above. If the
system controller 22 determines that the disc in the
loaded cartridge 2 is the second optical disc, the

1 controller 22 generates a control signal to the slider
55. When the control signal is supplied, the slider 55
moves the wave front correcting lens 54 to the position
 P_1 . The laser beam emitted from the first semiconductor
5 laser 32 is converted into the parallel light by the
first collimating lens 33 and is reflected by the first
beam splitter 34 and is converged onto the optical disc
1 by the second objective lens 46. The light reflected
by the optical disc 1 is again converted into the
10 parallel light by the second objective lens 46. The
parallel light passes through the first beam splitter 34
and is converged onto the first photo detector 38 by the
first detecting lens 37. The first photo detector 38
generates a photo detection signal in a manner similar
15 to the above. The above operations are executed until
the optical disc 1 is unloaded.

On the other hand, if the system controller 22
decides that the disc in the loaded cartridge 2 is the
first optical disc, the slider 55 moves the wave front
20 correcting lens 54 to the position P_2 . Thus, the laser
beam emitted from the first semiconductor laser 32
passes through the wave front correcting lens 54 and the
second objective lens 46 and is converged onto an
information track on the optical disc 1 without an
25 aberration. Thus, the operations similar to those in
the case of the second optical disc are executed.

As mentioned above, according to the embodi-
ment, in addition to the effects by the second embodi-

1 ment, since the wave front correcting lens 54 serving as
an aberration correcting means is held by the slider 55
and is movably arranged, the objective lens can be
commonly used and a total mass which must be moved by
5 the actuator 57 can be reduced. Thus, a burden to the
driving force of the actuator can be reduced and a low
electric power consumption can be accomplished.

The optical head 50 in the fourth embodiment
has the second objective lens 46 corresponding to the
10 optical disc having the disc substrate of the thickness
 d_2 and, further, corrects the aberration to the optical
disc having the disc substrate of the thickness d_1 by
the wave front correcting lens 54. However, an opposite
construction can be also used. Namely, the above effect
15 is also derived by a construction such that the first
objective lens 36 corresponding to the optical disc of
the disc substrate of the thickness d_1 is used in place
of the second objective lens 46 and a wave front
correcting lens which has been designed so as to correct
20 the aberration due to the disc substrate of the thick-
ness d_2 is provided.

Although the above three embodiments have been
described with respect to the case where there are two
kinds of thicknesses of the disc substrates, the
25 invention, can be also applied to the case of three or
more kinds of thicknesses of the disc substrates. In
such a case, the number of optical elements such as
objective lenses and the like is increased in accordance

1 with the number of kinds of thicknesses of the disc
substrates. With respect to the discriminating means of
the optical disc, three or more kinds of optical discs
can be discriminated by, for instance, checking a
5 plurality of discrimination holes which are formed in
the cartridge. For example, by forming n discriminating
holes, 2^n kinds of optical discs can be discriminated.

Further, although the discrimination hole 7
formed on the cartridge 2, the LED 8, and the photo
10 diode 9 have been used as disc discriminating means,
paints of different reflectances can be also coated onto
the surface of the cartridge 2 in place of the dis-
crimination hole or a mechanical switch or the like can
be also used in place of the LED and the photo diode.

15 Further, a difference between thicknesses of
the disc substrates can be also directly discriminated
by a reflected laser beam from the discs without using
the cartridge. For example, in the case of the converg-
ing optical system corresponding to the thin disc
20 substrate, a tracking error signal cannot be ordinarily
obtained from an optical disc of a thick disc substrate
due to a spherical aberration of the converging beam.
Consequently, two optical discs having different thick-
nesses can be discriminated by checking the presence or
25 absence of the tracking error signal. In such a case,
there is an excellent effect such that the apparatus is
simplified because there is no need to use the detecting
means such as LED and photo diode and the like.

1 The optical head in each of the above-
described optical disc apparatuses has been constructed
by a conventional optical system using the objective
lens made of a quartz glass or the like. An optical
5 head in each of optical disc apparatuses of embodiments,
which will be explained hereinlater, differs from the
above optical head and is constructed by forming an
optical system onto a thin film waveguide.

Fig. 10 is a block diagram showing a construc-
10 tion of an optical disc apparatus according to the fifth
embodiment of the invention. Further, Fig. 11 is a
schematic perspective view showing a construction of an
optical head of the optical disc apparatus in the fifth
embodiment of the invention. Since a construction shown
15 in Fig. 10 is substantially the same as that of the
optical disc apparatus in the second embodiment of the
invention shown in Fig. 5 except that a sixth optical
head 60 is used, its description is omitted here. The
sixth optical head 60 shown in Fig. 11 will now be
20 described in detail hereinbelow.

In Fig. 11, reference numeral 1 denotes the
same optical disc as that described in the foregoing
embodiments. Reference numeral 200 denotes an informa-
tion track formed on the optical disc 1. Reference
25 numeral 61 denotes a substrate formed by LiNbO_3 or the
like. The substrate 61 is attached to a head base
through a focusing actuator and a tracking actuator and
constructs the sixth optical head 60 together with them.

1 Since the focusing actuator, tracking actuator, and head
base which have conventionally been well known can be
used as those components, their detailed description and
the drawings are omitted here. Reference numeral 62
5 denotes an optical waveguide formed on the substrate 51
by Ti diffusion or the like; 63 a first semiconductor
laser coupled to an edge surface of the optical
waveguide 62; and 64 a first waveguide lens arranged on
an optical path of the waveguide light which has been
10 emitted from the first semiconductor laser 63 and
entered the optical waveguide 61. For instance, a
Fresnel lens formed by an electron beam lithography can
be used as a lens 64. Reference numeral 65 denotes a
first converging grating coupler formed on the optical
15 path of the parallel waveguide light. The coupler 65
emits the waveguide light to a position out of the
optical waveguide 62 and converges onto the optical disc
1. The first converging grating coupler 65 is a grating
having a chirp (irregular period) by a curve formed on
20 the waveguide by electron beam direct drawing or the
like. Reference numeral 66 denotes a first beam
splitter which is arranged between the first waveguide
lens 64 and the first converging grating coupler 65 and
separates the waveguide light which has been returned
25 into the optical waveguide 62 through the first
converging grating coupler 65 after it had been
reflected by the optical disc 1. Reference numeral 67
denotes a first waveguide converging lens which is

1 arranged on the optical path of the return waveguide
light which has been separated by the first beam
splitter 66 and converges the return light. Reference
numeral 68 denotes a first photo detector which is
5 coupled to the side surface of the optical waveguide 62
and detects the return waveguide light which has been
converged by the first waveguide converging lens 67.

Similarly, reference numeral 69 denotes a
second semiconductor laser coupled to the edge surface
10 of the optical waveguide 62; 70 a second waveguide lens
arranged on the optical path of the waveguide light
which has been emitted from the second semiconductor
laser 69 and entered the optical waveguide 61; and 71 a
second converging grating coupler formed on the optical
15 path of the parallel waveguide light. The coupler 71
emits the waveguide light to a position out of the
optical waveguide 62 and converges onto the optical disc
1. Reference numeral 72 denotes a second beam splitter
which is arranged between the second waveguide lens 70
20 and the second converging grating coupler 71 and
separates the waveguide light which has been returned
into the optical waveguide 62 through the second
converging grating coupler 71 after it had been
reflected by the optical disc 1. Reference numeral 73
25 denotes a second waveguide converging lens which is
arranged on the optical path of the return waveguide
light which has been separated by the second beam
splitter 72 and converges the return waveguide light.

1 Reference numeral 74 denotes a second photo detector
which is coupled to the side surface of the optical
waveguide 62 and detects the return waveguide light
converged by the second waveguide converging lens 73.

5 A curve chirp grating of the first converging
grating coupler 65 has been designed in a manner such
that, for instance, $NA = 0.45$ and the emission light can
be converged until a diffraction limit and the aberration
due to the disc substrate of the thickness d_1 can
10 be corrected. The second converging grating coupler 71
has been designed in a manner such that, for example, NA
 $= 0.8$ and the aberration due to the disc substrate of
the thickness d_2 can be corrected.

 The first and second beam splitters 66 and 72
15 are attached at positions which are deviated so that the
reflected light of each beam splitter does not enter the
other beam splitter as a stray light.

 Such an optical waveguide and a waveguide type
device have been described in detail in, for example,
20 Nishihara, Haruna, and Saihara, "Optical Integrated
Circuit", Ohm Co., Ltd., 1985, or the like. In the
invention, both of the above well-known optical
waveguide and waveguide type device can be used in the
optical waveguide 62 or the like.

25 The operation of the optical head in the fifth
embodiment with the above construction will now be
described hereinbelow.

1 If the optical disc 1 is the first optical
disc, the driving current is supplied to the first
semiconductor laser 63. Then, the laser 63 emits a
laser beam from one edge surface of the optical wave-
5 guide 62. The laser beam propagates as a waveguide
light. The waveguide light is converted into the
parallel light by the first waveguide lens 64. The
parallel light transmits the first beam splitter 66 and
subsequently enters the first converging grating coupler
10 65. The coupler 65 extracts the parallel light out of
the optical waveguide 62 and converges onto the informa-
tion track 200 on the first optical disc 1. The
reflected light from the disc surface again enters the
optical waveguide 62 through the first converging
15 grating coupler 65 and propagates as a return waveguide
light in the opposite direction. Further, the return
waveguide light is reflected in the direction of the
first waveguide converging lens 67 in the first beam
splitter 66. The lens 67 converges the return waveguide
20 light onto the first photo detector 68. The first photo
detector 68 detects the information signal and the servo
signals such as focusing error signal, tracking error
signal, and the like which have been recorded on the
first optical disc 1 on the basis of an intensity and an
25 intensity distribution of the return waveguide light and
generates to the outside. By modulating the driving
current which is supplied to the first semiconductor
laser 63, the sixth optical head 60 emits the intensity

1 modulated laser beam, thereby recording or erasing the
information signal onto/from the first optical disc 1.

On the other hand, if the optical disc 1 is
the second optical disc, the operations similar to those
5 in the case of the foregoing first optical disc are
executed by the second semiconductor laser 69, second
waveguide lens 70, second converging grating coupler 71,
second beam splitter 72, second waveguide converging
lens 73, and second photo detector 74.

10 The substrate 61 is supported from the head
base by a focusing actuator and a tracking actuator.
The position of the substrate 61 itself is controlled by
the foregoing servo signals so that the laser beam is
accurately irradiated onto the information track 200 on
15 the disc.

According to the fifth embodiment as mentioned
above, by providing the first converging grating coupler
65 which is formed on the optical waveguide 62 and
corresponds to the thickness of the disc substrate of
20 the first optical disc and the second converging grating
coupler 71 which is formed on the optical waveguide 62
and corresponds to the thickness of the disc substrate
of the second optical disc, a desired one of the
couplers 65 and 71 can be independently used in
25 accordance with the kind of disc, so that the aberration
of the converged spot can be corrected in accordance
with the thickness of the disc substrate and the signal
can be preferably recorded, reproduced, or erased.

1 Moreover, since the optical waveguide device having the
converging grating couplers is used, the size and weight
of the optical head can be reduced.

Although the thickness of the disc substrate
5 has been set into two kinds of thicknesses in the fifth
embodiment, the invention can be also applied to three
or more kinds of thicknesses of disc substrates. In
such a case, the number of component elements on the
substrate 61 is increased in accordance with the number
10 of thicknesses.

In the sixth optical head 60, either one of
the semiconductor lasers has been allowed to emit the
light. However, it is also possible to allow both of
the semiconductor lasers to simultaneously emit the
15 lights. In such a case, by designing two converging
grating couplers for the optical disc having the same
substrate thickness, two tracks on the optical disc 1
can be simultaneously reproduced or recorded. Thus,
there is an excellent effect such that the reproducing
20 or recording transfer speed can be doubled.

Fig. 12 is a schematic perspective view
showing a construction of an optical head of an optical
disc apparatus according to the sixth embodiment of the
invention.

25 In the diagram, the sixth embodiment has
substantially the same construction as that of the sixth
optical head 60 shown in Fig. 11 except a third beam
splitter 81 and a waveguide mirror 82 and the same parts

1 and components as those shown in Fig. 11 are designated
by the same reference numerals. That is, an optical
head of the sixth embodiment, namely, a seventh optical
head 80 is constructed in the following manner. In
5 place of the second semiconductor laser 69 and the
second waveguide lens 70 in the sixth optical head 60
shown in Fig. 11, the third beam splitter 81 is arranged
on the optical path between the waveguide lens 64 and
the beam splitter 66. In the two waveguide lights
10 divided by the third beam splitter 81, the waveguide
mirror 82 is arranged in the direction of the waveguide
divided in the direction different from the direction of
the first beam splitter 66 and the position of the
mirror 82 is set to a position where the waveguide light
15 reflected by the waveguide mirror 82 passes through the
second beam splitter 72.

The operation of the seventh optical head 80
with the above construction will now be described
hereinbelow.

20 The driving current is supplied to the first
semiconductor laser 63. The laser 63 emits a laser beam
from one edge surface of the optical waveguide 62. The
laser beam propagates as a waveguide light. The wave-
guide light is converted into the parallel light by the
25 first waveguide lens 64 and is divided into the trans-
mission light and the reflected light by the third beam
splitter 81. The transmission light is transferred to
the first converging grating coupler 65 through the

1 first beam splitter 66. The reflected light is
reflected by the waveguide mirror 82 and enters the
second converging grating coupler 71 through the second
beam splitter 72. The subsequent operations are
5 executed in a manner similar to those of the sixth
optical head 60 in the fifth embodiment of the
invention.

According to the sixth embodiment as mentioned
above, in addition to the effects by the foregoing fifth
10 embodiment, by dividing the waveguide light emitted from
one semiconductor laser into two lights by the third
beam splitter 81 and guiding to the respective converg-
ing grating couplers, the number of semiconductor lasers
which are used can be reduced.

15 Although the sixth embodiment has been
described on the assumption that the number of thick-
nesses of the disc substrates is set to two kinds of
thicknesses, the invention can be also applied to three
or more kinds of thicknesses of the disc substrates.
20 Now, assuming that the number of kinds of thicknesses of
the disc substrates is equal to N , it is sufficient to
use N converging grating couplers and $(N - 1)$ beam
splitters for dividing the waveguide light emitted from
the semiconductor laser. To equalize all of light
25 quantities of the laser beams which are converged onto
the discs, it is preferable to design the beam splitters
so as to set division ratios of the light quantities of
the beam splitters as follows.

1 : N - 1

1 : N - 2

1 : N - 3

.

.

.

1 : 1

1 Fig. 13 is a schematic perspective view
showing a construction of an optical head of an optical
disc apparatus according to the seventh embodiment of
the invention. Fig. 14 is a block diagram showing a
5 construction of the optical disc apparatus.

A construction of the optical head in Fig. 13
will be first described in detail.

In the diagram, since the optical disc 1,
information track 200, substrate 61, optical waveguide
10 62, first semiconductor laser 63 and first waveguide
lens 64 are fundamentally identical to the component
elements in the seventh optical head 80 shown in Fig.
12, their detailed descriptions are omitted here.
Reference numeral 91 denotes an SAW (surface acoustic
15 wave) transducer arranged on the optical waveguide 62 so
that a surface acoustic wave generated by the SAW
transducer crosses the optical path of the waveguide
light emitted from the first waveguide lens 64. The SAW
transducer 91 is constructed by a cross finger electrode
20 comprising a piezoelectric transducer of ZnO or the
like. Reference numeral 92 indicates a surface acoustic

1 wave generated by the SAW transducer 91; 96 a third
converging grating coupler formed on the optical path of
the waveguide light which has been diffracted by such a
surface acoustic wave 92 and propagates in the first
5 direction; and 97 a fourth converging grating coupler
which is likewise formed on the optical path of the
waveguide light propagating in the second direction.
Each of the couplers 96 and 97 emits the waveguide light
to a region out of the optical waveguide 62 and
10 converges onto the optical disc 1. Reference numeral 93
denotes a fourth beam splitter which is arranged between
the first waveguide lens 64 and the progressing path of
the surface acoustic wave 92 and reflects the waveguide
light returned into the optical waveguide 62 through the
15 third or fourth converging grating couplers 96 and 97
after it had been reflected by the optical disc 1.
Reference numeral 94 denotes a third waveguide converg-
ing lens which is arranged on the optical path of the
return light reflected by the fourth beam splitter 93
20 and converges the return light and 95 indicates a third
photo detector which is coupled to the side surface of
the optical waveguide 62 and detects the return light
converged by the third waveguide converging lens 94.

The above SAW transducer has also been
25 described in detail in the foregoing "Optical Integrated
Circuit" or the like and both of the well-known optical
waveguide and waveguide type device described in the
above literature can be also obviously used.

1 The operation of the optical head in the
seventh embodiment with the above construction will now
be described hereinbelow.

 The first semiconductor laser 63 emits a laser
5 beam from one edge surface of the optical waveguide 62.
The laser beam propagates as a waveguide light. The
waveguide light is converted into the parallel light by
the first waveguide lens 64 and transmits through the
fourth beam splitter 93. After that, the light trans-
10 verses the surface acoustic wave 92 generated from the
SAW transducer 91. At this time, the propagating
direction of the parallel waveguide light is changed by
an acoustic optical interaction with the surface
acoustic wave 92. Since a deflection angle at this time
15 changes in accordance with a frequency of the surface
acoustic wave 92, the waveguide light can be propagated
in any one of the directions of the third and fourth
converging grating couplers 96 and 97 in accordance with
frequencies of high-frequency voltages which are applied
20 to the SAW transducer 91 from the outside (it is now
assumed that the frequencies of the high-frequency
voltages are set to f_1 and f_2 , respectively). In the
case of the first optical disc, therefore, the high-
frequency voltage of the frequency f_1 is applied to the
25 SAW transducer 91 from the outside, thereby allowing the
parallel waveguide light to enter the third converging
grating coupler 96. The third converging grating
coupler 96 extracts the parallel waveguide light to a

1 region out of the optical waveguide 62 and converges
onto the information track 200 on the first optical disc
1. The reflected light from the disc surface again
enters the optical waveguide 62 through the third
5 grating coupler 96 and propagates as a return waveguide
light in the opposite direction. The progressing
direction of the waveguide light is changed by the
surface acoustic wave 92 and, after that, the waveguide
light is reflected in the direction of the third
10 waveguide converging lens 94 by the fourth beam splitter
93. The third waveguide converging lens 94 converges
the return light to the third photo detector 95. The
third photo detector 95 detects the information signal
and the servo signals such as focusing error signal,
15 tracking error signal, and the like which have been
recorded on the first optical disc 1 on the basis of an
intensity and an intensity distribution of the return
light and generates to the outside. By modulating the
driving current which is supplied to the first semi-
20 conductor laser 63, an eighth optical head 90 emits the
intensity modulated laser beam, thereby recording or
erasing the information signal onto/from the first
optical disc 1.

On the other hand, in the case of the second
25 optical disc, the high-frequency voltage of the
frequency f_2 is applied to the SAW transducer 91 from
the outside, thereby allowing the parallel waveguide
light to enter the fourth converging grating coupler 97.

1 The subsequent operations are executed in a manner
similar to those in the case of the first optical disc.

The substrate 61 is supported from the head
base by a focusing actuator and a tracking actuator (not
5 shown). The position of the substrate 61 itself is
controlled by the servo signals so that the laser beam
is accurately irradiated onto the information track 200
on the disc.

An optical disc apparatus having the eighth
10 optical head 90 mentioned above will now be described
with reference to Fig. 14.

In the diagram, the optical disc 1, cartridge
2, first linear motor 4, discrimination hole 7, LED 8,
photo diode 9, tracking control circuit 11, focusing
15 control circuit 13, linear motor control circuit 15,
spindle control circuit 17, spindle motor 18, signal
processing circuit 19, LD driving circuit 20 and system
controller 22 are the same as those in the optical disc
apparatus in the third embodiment according to the
20 invention. Reference numeral 90 denotes the eighth
optical head which is constructed by the waveguide
substrate, focusing actuator, tracking actuator, head
base and the like. Reference numeral 85 denotes a
constant voltage generating circuit which receives a
25 control signal from the system controller 22 and
generates a predetermined voltage V_i . Reference numeral
86 denotes a V/f converting circuit which receives the
voltage V_i from the constant voltage generating circuit

1 85 and generates a high-frequency signal of a frequency
f which is proportional to V_i . The V/f converting
circuit 86 generates a high-frequency signal of the
frequency f_1 when the input voltage $V_i = V_1$ and
5 generates a high frequency signal of the frequency f_2
when $V_i = V_2$. Reference numeral 87 denotes an SAW
driving circuit to apply a high-frequency voltage of the
same frequency as the frequency f of the high-frequency
signal supplied from the V/f converting circuit 86 to
10 the SAW transducer 91 of the eighth optical head 90.

The operation of the optical disc apparatus in
the seventh embodiment with the above construction will
now be described hereinbelow.

First, if the cartridge 2 enclosing the second
15 optical disc has been loaded into the optical disc
apparatus of the seventh embodiment, the system
controller 22 determines that the disc in the loaded
cartridge 2 is the second optical disc by the detection
signal of the photo diode 9, so that the controller 22
20 generates a control signal to the constant voltage
generating circuit 85 so as to generate the voltage V_2 .
The V/f converting circuit 86 converts the input voltage
 V_2 into the frequency f_2 , so that the SAW driving
circuit 87 applies the high-frequency voltage of the
25 frequency f_2 to the SAW transducer 91 of the eighth
optical head 90. Therefore, in the eighth optical head
90, the laser beam is irradiated from the second
converging grating coupler 97 and is converged without

1 an aberration onto the information track 200 on the
second optical disc having the disc substrate of the
thickness d_2 . At the same time, the third photo
detector 95 of the eighth optical head 90 detects a
5 focusing error signal and a tracking error signal from
the reflected light from the optical disc and supplies
to the tracking control circuit 11 and the focusing
control circuit 13. Further, the information signal on
the disc is supplied to the signal processing circuit 19
10 and the spindle control circuit 17.

On the other hand, in the case of the first
optical disc, the system controller 22 generates a
control signal to the constant voltage generating
circuit 85 so as to generate the voltage V_1 . The V/f
15 converting circuit 86 converts the input voltage V_1 into
the frequency f_1 , so that the SAW driving circuit 87
applies the high-frequency voltage of the frequency f_1
to the SAW transducer 91 of the eighth optical head 90.
Therefore, in the eighth optical head 90, a laser beam
20 is emitted from the first converging grating coupler 96
and is converged without an aberration onto the
information track 200 on the first optical disc having
the disc substrate of the thickness d_1 . The other
operations are executed in a manner similar to those in
25 the case of the foregoing second optical disc.

According to the embodiment as mentioned
above, in addition to the effects of the above sixth
embodiment, the number of semiconductor lasers which are

1 necessary in the eighth optical head 90 is only one and
each of the converging grating couplers does not simul-
taneously emit the laser beam, so that an emission power
of the semiconductor laser can be efficiently taken out
5 of the converging grating coupler. That is, the optical
head having a transfer efficiency better than that of
the seventh optical head 80 in the foregoing sixth
embodiment can be provided.

Further, by arranging the fourth beam splitter
10 93 between the waveguide lens 64 and the SAW transducer
91, the return lights from the two converging grating
couplers can be detected by one photo detector.

Although the number of thicknesses of the disc
substrates has been set to two kinds of thicknesses in
15 the embodiment, the invention can be also obviously
applied to three or more kinds of thicknesses of the
disc substrates. In such a case, the number of converg-
ing grating couplers is increased in accordance with the
number of kinds of thicknesses and the optical paths are
20 switched by the SAW transducer 91 in accordance with the
increased number of such couplers.

An optical disc apparatus in the eighth
embodiment of the invention will now be described.

Fig. 15 is a block diagram showing a construc-
25 tion of the optical disc apparatus in the eighth
embodiment. In the diagram, reference numeral 1 denotes
the first or second optical disc; 2 the cartridge; 4 the
linear motor; 7 the discrimination hole; 8 the LED; 9

1 the photo diode; 13 the focusing control circuit; 15 the
linear motor control circuit; 17 the spindle control
circuit; 18 the spindle motor; 19 the signal processing
circuit; 20 the LD driving circuit; 22 the system
5 controller; 85 the constant voltage generating circuit;
86 the V/f converting circuit; and 87 the SAW driving
circuit. The above component elements are the same as
those in the optical disc apparatus in the seventh
embodiment of Fig. 14 and their detailed descriptions
10 are omitted here. Reference numeral 90 denotes an
optical head which is substantially the same as the
eighth optical head 90 mentioned above except that the
optical head in the eighth embodiment does not have a
tracking actuator. Therefore, the optical head in Fig.
15 15 is also referred to as an eighth optical head 90
hereinafter for convenience of explanation. Reference
numeral 100 denotes a tracking error detecting circuit
which receives a tracking error signal from the third
photo detector 95 of the eighth optical head 90 and
20 generates a tracking error voltage V_{TE} to an adder 101,
which will be explained hereinafter. Reference numeral
101 denotes the adder. The voltage V_{TE} which is
generated from the tracking error detecting circuit 100
and the voltage V_i which is generated from the constant
25 voltage generating circuit 85 are supplied to the adder
101, so that the adder generates a voltage V_0 ($V_0 = V_{TE}$
+ V_i) to the V/f converting circuit 86. The V/f
converting circuit 86, SAW driving circuit 87, tracking

1 error detecting circuit 100, and adder 101 construct a
tracking control circuit 102. That is, it is the
inventive point of the eighth embodiment that the track-
ing control is executed by using the SAW transducer 91
5 of the eighth optical head 90.

The principle of the tracking control of the
eighth embodiment will now be described hereinbelow with
reference to the drawings. Fig. 16 is an enlarged
schematic perspective view of the converging grating
10 coupler, SAW transducer, and portion where a surface
acoustic wave has been formed. The waveguide light
which enters the converging grating coupler is oscil-
lated between solid lines and broken lines in accordance
with a microchange of the frequency of the surface
15 acoustic wave. Such an oscillation angle is called a
deflection angle (shown by θ). Therefore, the emission
light from the converging grating coupler is also oscil-
lated and the converged spot moves. Since the deflect-
ing angle θ changes in almost proportional to the
20 frequency of the surface acoustic wave, by changing the
frequency in accordance with the tracking error amount,
the converged spot can be accurately positioned onto the
information track.

The operation of the optical disc apparatus of
25 the embodiment constructed as shown in Fig. 15 will now
be described hereinbelow. First, if the disc in the
loaded cartridge 2 is the second optical disc, the
system controller 22 controls the constant voltage

1 generating circuit 85 so as to set the output voltage V_i
into V_2 . The output voltage V_{TE} of the tracking error
detecting circuit 100 has been initialized to "0". The
adder 101 adds the voltages V_i and V_{TE} and generates the
5 voltage $V_0 (= V_2)$ to the V/f converting circuit 86. The
V/f converting circuit 86 changes a frequency f_s of an
output signal in accordance with the input voltage V_0 .
The optical disc apparatus has been designed in a manner
such that the signal of a frequency $f_s (= f_1)$ is
10 generated when $V_0 = V_1$ and the signal of a frequency f_s
($= f_2$) is generated when $V_0 = V_2$ and the frequency f_s
changes in proportion to the input voltage V_0 . There-
fore, the V/f converting circuit 86 supplies a high-
frequency signal of the frequency f_2 to the SAW driving
15 circuit 87. The SAW driving circuit 87 applies a high-
frequency voltage of the frequency f_2 to the SAW trans-
ducer 91 of the eighth optical head 90. In the eighth
optical head 90, consequently, the laser beam is emitted
from the fourth converging grating coupler 97 and is
20 converged without an aberration onto the information
track on the second optical disc. At the same time, in
the eighth optical head 90, the reflected light from the
disc is detected by the third photo detector 95. A
tracking error signal is supplied to the tracking error
25 detecting circuit 100. A focusing error signal is
supplied to the focusing control circuit 13. The
information signal is supplied to the spindle control
circuit 17 and the signal processing circuit 19. The

1 tracking error detecting circuit 100 produces the
tracking error voltage V_{TE} in accordance with a track
deviation amount of the converged spot on the informa-
tion track 200 and supplies to the adder 101. The adder
5 101 sends the output voltage $V_0 = V_2 + V_{TE}$ to the V/f
converting circuit 86 as mentioned above. In accordance
with the output voltage V_0 , the output signal frequency
 f_s of the V/f converting circuit 86 is deviated from the
frequency f_2 by a value corresponding to the tracking
10 error (assumes d_f). As mentioned above, when the
frequency of the driving voltage to the SAW transducer
91 changes, the emitting position of the light from the
fourth converging grating coupler 97 changes and the
position of the converged spot on the optical disc 1
15 changes for the track. Therefore, by setting a convert-
ing equation between V_0 and f_s of the V/f converting
circuit 86 so as to allow the converged spot on the
optical disc 1 to approach the track, the tracking error
is eliminated. The other operations are executed in a
20 manner similar to those of the optical disc apparatus in
the seventh embodiment.

On the other hand, in the case of the first
optical disc, the system controller 22 controls the
constant voltage generating circuit 85, thereby setting
25 the output voltage V_i into V_1 . Thus, the V/f converting
circuit 86 generates a high-frequency signal of the
frequency f_1 to the SAW driving circuit 87 and the SAW
driving circuit 87 applies a high-frequency voltage of

1 the frequency f_1 to the SAW transducer 91 of the eighth
optical head 90. Consequently, in the eighth optical
head 90, the laser beam is emitted from the third
converging grating coupler 96 and is converged without
5 an aberration onto the information track 200 on the
first optical disc. At the same time, the tracking
error detecting circuit 100 supplies the tracking error
voltage V_{TE} to the adder 101 from the input signal T_1 .
The input voltage of the V/f converting circuit 86 is
10 set to $V_0 = V_1 + V_{TE}$ and the tracking error can be
eliminated in a manner similar to the case of the second
optical disc.

Fig. 17 is a graph showing the principle of
the tracking control of the embodiment and shows the
15 relations among the V_0 and f_s and the deflection angle
of the waveguide light in the eighth optical head 90.
As shown in the graph, by varying the V_0 and f_s by only
an amount which is proportional to the tracking error
signal from V_1 , accordingly, f_1 as a center in the case
20 of the first optical disc or by only an amount which is
proportional to the tracking error signal from V_2 ,
accordingly, f_2 as a center in the case of the second
optical disc, the oscillation angle of the waveguide
light can be finely varied. Therefore, by varying the
25 emitting positions of the light beams from the two
converging grating couplers, the converged spot can be
allowed to trace on the track.

1 According to the eighth embodiment as
mentioned above, in addition to the effects of the
foregoing seventh embodiment, the change-over of the
waveguide lights which enter the converging grating
5 couplers and the tracking control can be executed by the
SAW transducer 91. Thus, the optical head can be
simplified and the number of manufacturing steps can be
reduced.

 Since the surface acoustic wave 92 is located
10 between the fourth beam splitter 93 and the two converg-
ing grating couplers, the return waveguide light from
the optical disc 1 is not influenced by the tracking
control on the optical path after the surface acoustic
wave 92. Therefore, the converging position on the
15 third photo detector is not moved by the tracking
control, so that a deterioration in photo detection
signal can be prevented.

 In the embodiment, although the SAW transducer
has been used as both of the optical path switching
20 means and the optical path deflecting means for tracking
control, the SAW transducer can be also provided for the
optical head only for the tracking control. For
instance, it is also possible to form the SAW transducer
for the sixth optical head 60 in the fifth embodiment or
25 the seventh optical head 80 in the sixth embodiment and
to execute the tracking control.



CLAIMS:

1. An optical disc apparatus for recording, reproducing, or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:

N converging means (31, 41) whose aberrations have respectively been corrected for said N ($N \geq 2$) disc substrates having different thicknesses;

disc discriminating means (8, 9) for discriminating the thickness of the disc substrate of a loaded optical disc (1) and for generating a discrimination signal corresponding to the result of the discrimination; and

control means (22) for selecting the converging means in which the occurrence of the aberration due to the disc substrate is smallest in accordance with the discrimination signal.

2. An apparatus according to claim 1, wherein said converging means are objective lenses (36, 46), and said apparatus comprises:

N optical heads (3, 5) each of which has light emitting means,

one of said objective lenses each for converging the light flux which is emitted from the light emitting means onto the optical disc (1), and

photo detecting means each for detecting the reflected light from the optical disc (1);



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N optical head moving means (4, 6) which are arranged below the optical disc (1) and move the N optical heads in the radial direction of the optical disc;

disc discriminating means (8, 9) for discriminating the thickness of the disc substrate of the loaded optical disc and for generating the discrimination signal in accordance with the result of the discrimination; and

control means (22) for selecting the optical head having the objective lens in which the occurrence of the aberration due to the disc substrate is smallest in accordance with the discrimination signal,

and wherein the selected optical head records, reproduces, or erases the information signal onto/from the optical disc.

3. An apparatus according to claim 2, further comprising backward moving means (4, 6) for moving the non-selected optical heads to the outside of the optical disc (1) for a period of time when the optical head which has been selected by the control means is recording, reproducing, or erasing the information signal.

4. An apparatus according to claim 1, wherein said converging means are objective lenses (36, 46), and wherein said apparatus comprises:

an optical head (30) having N converging optical systems (31, 41) each of which is constructed by





light emitting means (32, 42),
one of said objective lenses (36, 46) each for
converging the light flux emitted from the light
emitting means onto the optical disc (1), and
photo detecting means (38, 48) for detecting
the reflected light from the optical disc (1);

optical head moving means (4) which is
arranged below the optical disc (1) and moves the
optical head in the radial direction of the optical
disc;

disc discriminating means (8, 9) for discrimi-
nating the thickness of the disc substrate of the loaded
optical disc (1) and for generating the discrimination
signal corresponding to the result of the
discrimination; and

control means (22) for selecting the light
emitting means of the converging optical system in which
the occurrence of the aberration due to the disc sub-
strate is smallest in accordance with the discrimination
signal and for allowing said light emitting means to
emit the light,

and wherein the selected converging optical
system records, reproduces, or erases the information
signal onto/from the optical disc (1).

5. An apparatus according to claim 1, wherein
said converging means are objective lenses (36, 46), and
wherein said apparatus comprises:

an optical head (50) having



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light emitting means (32),

light flux dividing means (34) which are arranged in the light flux from the emitting means and divide the emitted light flux into N light fluxes and deflect in different directions,

said N objective lenses (36, 46) for respectively converging said N light fluxes onto the optical disc,

light flux selecting means (51, 52) for selecting one of the N light fluxes divided by the light flux dividing means in accordance with a control signal and for allowing said light flux to pass, and

photo detecting means (38, 48) for detecting the light fluxes reflected by the optical disc (1);

optical head moving means (4) which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;

disc discriminating means (8, 9) for discriminating the thickness of the disc substrate of the loaded optical disc (1) and for generating the discrimination signal in accordance with the result of the discrimination; and

control means (22) for generating the control signal to the light flux selecting means in accordance with the discrimination signal and for selecting the light flux which passes through the objective lens in which the occurrence of the aberration due to the disc substrate is smallest,



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- 61 -

and wherein the optical head records, reproduces, or erases the information signal onto/from the optical disc by the selected light flux.

6. An apparatus according to claim 1, wherein said converging means comprises objective lens (46) and aberration correcting means (54), and wherein said apparatus comprises:

an optical head (53) having
light emitting means (32),
said objective lens (46) each for converging
the light flux emitted from the light emitting means
onto the optical disc (1),

photo detecting means (38) for detecting the
reflected light from the optical disc,

said N aberration correcting means (54), and
holding means (55) for holding said N aberration
correcting means, for selecting one of the N
aberration correcting means in accordance with a control
signal and for moving onto an optical path between the
light emitting means and the optical disc (1);

optical head moving means (4) which is
arranged below the optical disc and moves the optical
head in the radial direction of the optical disc;

disc discriminating means (8, 9) for discriminating
the thickness of the disc substrate of the loaded
optical disc and for generating the discrimination
signal according to the result of the discrimination;
and



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control means (22) for generating the control signal to said holding means in accordance with the discrimination signal and for moving the aberration correcting means onto said optical path in which the occurrence of the aberration due to the disc substrate is smallest onto said optical path,

and wherein the optical head records, reproduces, or erases the information signal onto/from the optical disc by the light flux which has transmitted the selected aberration correcting means.

7. An apparatus according to claim 1, wherein said converging means is converging grating couplers (65, 71) formed on an optical waveguide (62), and wherein said apparatus comprises:

an optical head (60) having
said optical waveguide (62) formed on a substrate (61),

N light emitting means (63, 69) each for emitting a waveguide light into the optical waveguide,

said N converging grating couplers (65, 71) each for emitting the waveguide light supplied from said N light emitting means to the outside of the optical waveguide and for allowing the reflected light from the optical disc (1) to enter, and

N photo detecting means (68, 74) each for detecting the reflected light and for generating as an information signal;



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optical head moving means (4) which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;

selecting means (21) for selecting the light emitting means to be allowed to emit the light from among the N light emitting means in accordance with a control signal;

disc discriminating means (8, 9) for discriminating the thickness of the disc substrate of the loaded optical disc and for generating the discrimination signal according to the result of the discrimination; and

control means (22) for generating the control signal to the selecting means in accordance with the discrimination signal and for allowing the light emitting means for emitting the waveguide light into the converging grating coupler in which the occurrence of the aberration due to the disc substrate is smallest to emit the light,

and wherein the optical head records, reproduces, or erases the information signal onto/from the optical disc by the light flux from the selected light emitting means.

8. An apparatus according to claim 1, wherein said converging means is converging grating couplers (65, 71) formed on an optical waveguide (62), and wherein said apparatus comprises:

an optical head (80) having



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- 64 -

said optical waveguide (62) formed on a substrate (61),

light emitting means (63) for emitting a waveguide light into said optical waveguide,

light flux dividing means (81) for dividing the waveguide light emitted from the light emitting means into N division waveguide lights,

said N converging grating couplers (65, 71) each for emitting each of the N divided waveguide lights to the outside of the optical waveguide and for allowing the reflected light from the optical disc (1) to enter, and

N photo detecting means (68) for respectively detecting the reflected lights from the N converging grating couplers and for generating as information signals;

optical head moving means (4) which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;

output switching means (10) for selecting and outputting one of output signals of said N photo detecting means in accordance with a control signal;

disc discriminating means (8, 9) for discriminating the thickness of the disc substrate of the loaded optical disc and for generating the discrimination signal in accordance with the result of the discrimination; and



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control means (22) for generating the control signal to the output switching means in accordance with the discrimination signal and for selecting the photo detecting means into which the waveguide light from the converging grating coupler in which the occurrence of the aberration due to the disc substrate is smallest enters.

9. An apparatus according to claim 1, wherein said converging means is converging grating couplers (96, 97) formed on an optical waveguide (62), and wherein said apparatus comprises:

an optical head (90) having
said optical waveguide (62) formed on a substrate (61),

light emitting means (63) for emitting a waveguide light into said optical waveguide,

optical path switching means (91) which is arranged on an optical path of the waveguide light and switches the propagating direction of the waveguide light in N directions in accordance with a control signal,

said N converging grating couplers (96, 97) which are respectively arranged in said N propagating directions which are switched by said optical path switching means and emit the waveguide light to the outside of the optical waveguide and allow the reflected light from the optical disc (1) to enter, and



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- 66 -

photo detecting means (95) for generating the reflected light as an information signal;

optical head moving means (4) which is arranged below the optical disc (1) and moves the optical head in the radial direction of the optical disc;

disc discriminating means (8, 9) for discriminating the thickness of the disc substrate of the loaded optical disc and for generating the discrimination signal in accordance with the result of the discrimination; and

control means (22) for generating the control signal to the optical path switching means in accordance with the discrimination signal and for switching the propagating direction of the waveguide light from the light emitting means to the direction of the converging grating coupler in which the occurrence of the aberration due to the disc substrate is smallest,

and wherein the optical head records, reproduces, or erases the information signal onto/from the optical disc by the light flux emitted from the selected converging grating coupler.

10. An apparatus according to claim 9, wherein said optical path switching means combines deflecting means (91) for changing the propagating direction of the waveguide light by a deflection angle according to a input signal,

and wherein said apparatus comprises:



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- 67 -

tracking error detecting means (100) for detecting a tracking error amount of a converged spot which has been converged onto the optical disc (1) and for generating a tracking error signal; and

tracking control means (102) for changing the input signal to the deflecting means in accordance with said tracking error signal and for eliminating the tracking error of the converged spot.

11. An apparatus according to any one of claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11, wherein said disc discriminating means comprises:

a cartridge (2) for enclosing the optical disc (1);

a discrimination hole (7) which is formed on the cartridge (2) and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc (1); and

detecting means (8, 9) for detecting the opening/closing state of the discrimination hole (7) and for generating a discrimination signal.

12. An apparatus according to any one of claims 2, 3, 4, and 5, wherein numerical apertures of at least two or more of said N objective lenses differ.

13. An apparatus according to claim 6, wherein numerical apertures of at least two or more of N synthetic optical systems constructed by the objective lens and the aberration correcting means differ.



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14. An apparatus according to any one of claims 7, 8, 9, and 10, wherein numerical apertures of at least two or more of the N converging grating couplers differ.

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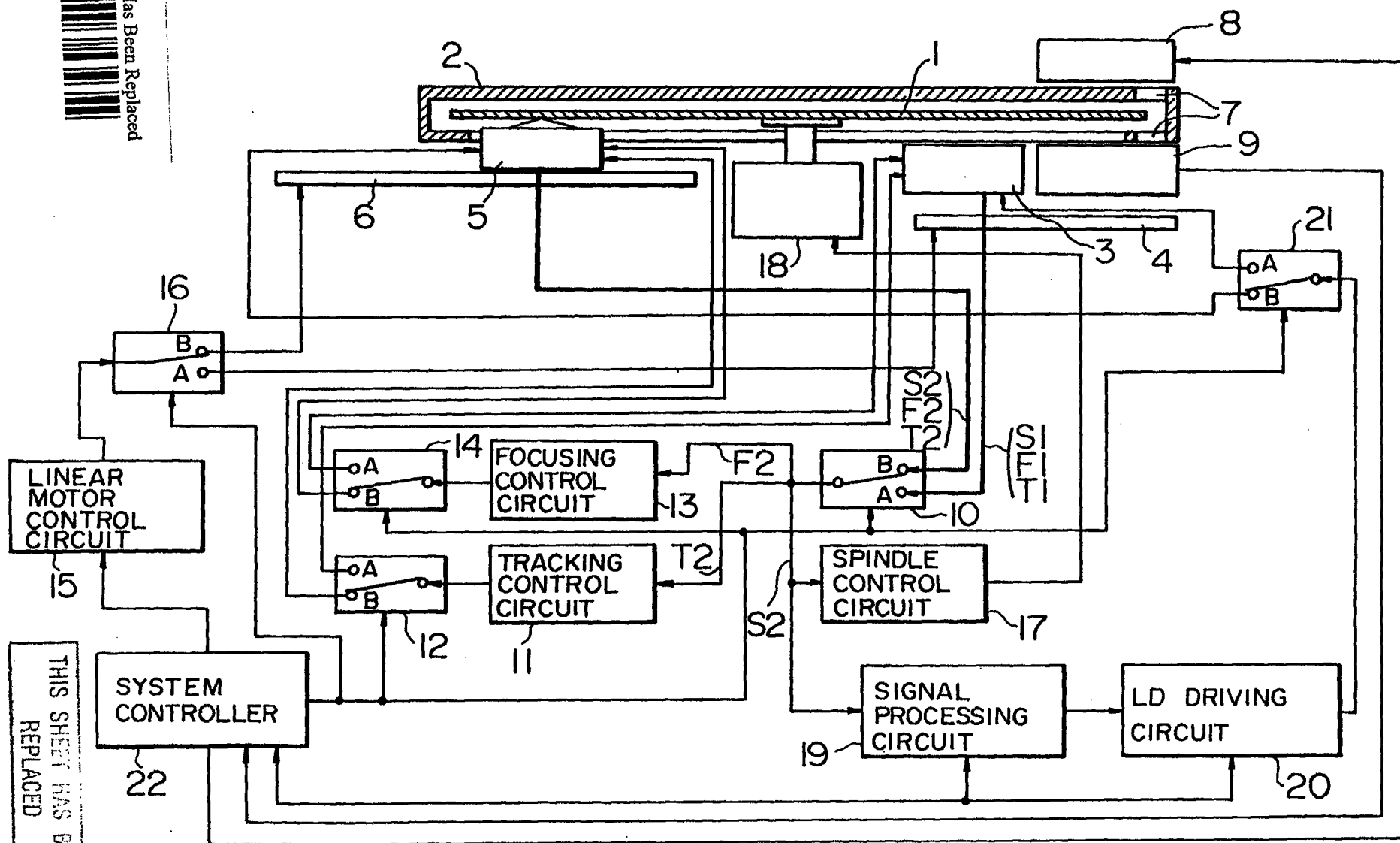


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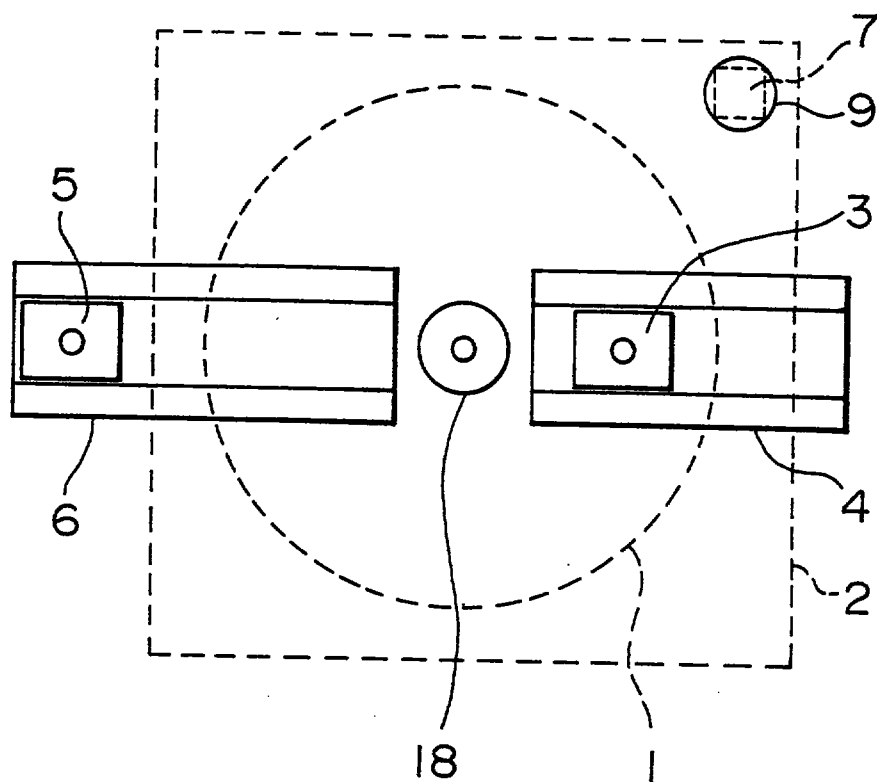
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FIG. 1



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FIG. 2



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FIG. 3A

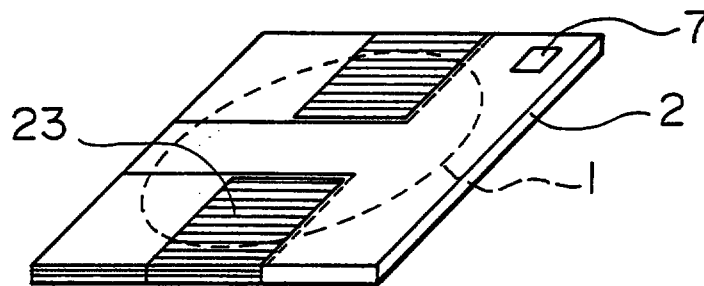
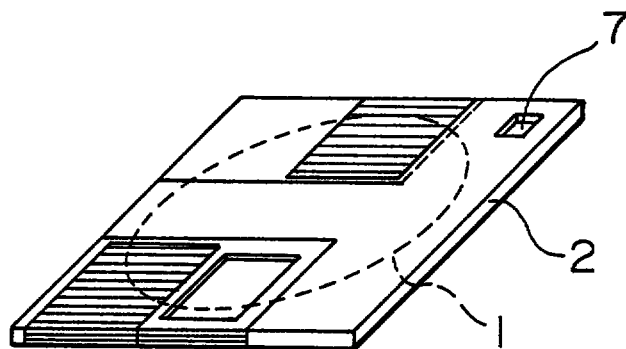


FIG. 3B



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FIG. 4A

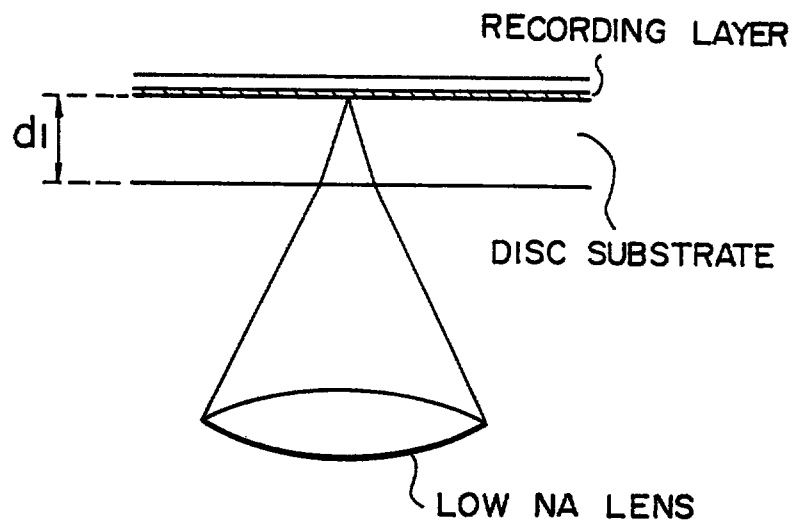
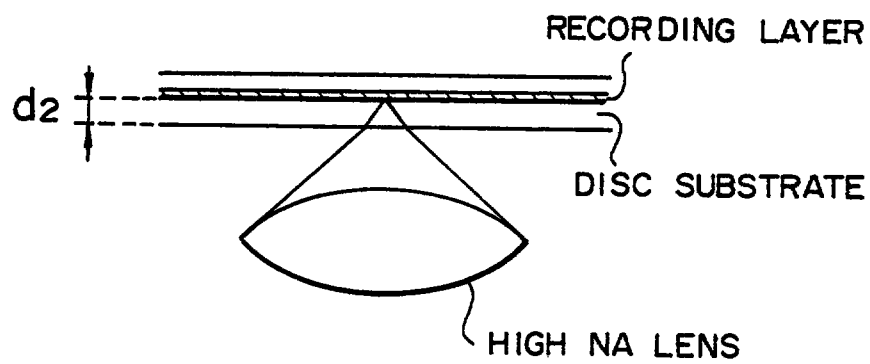


FIG. 4B



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FIG. 5

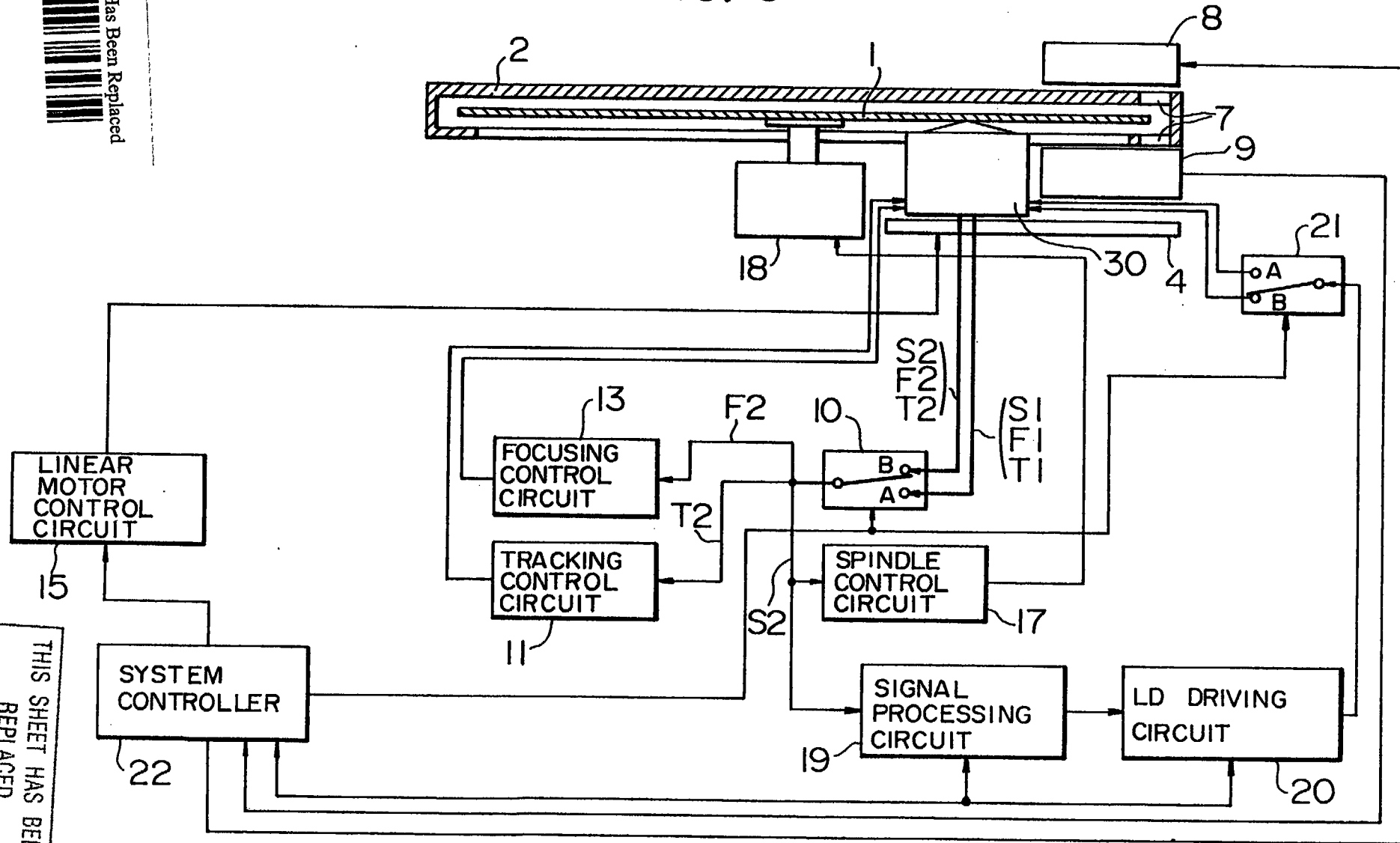
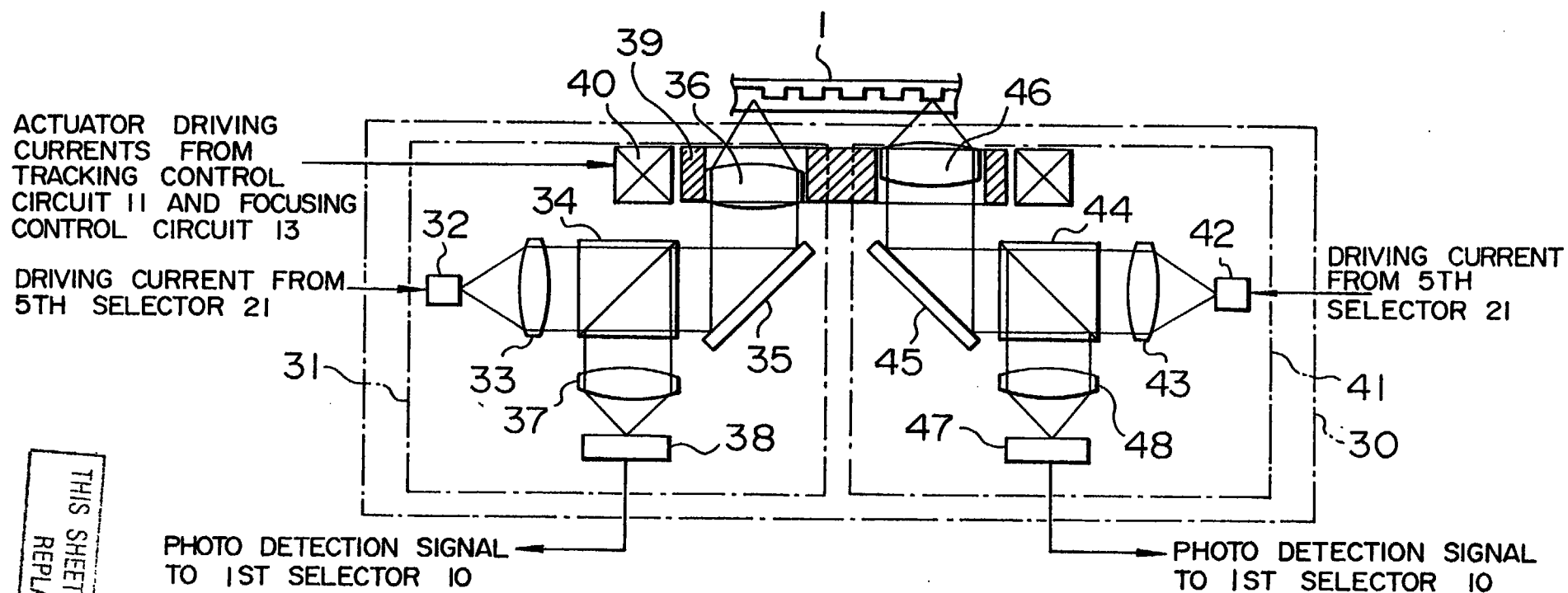
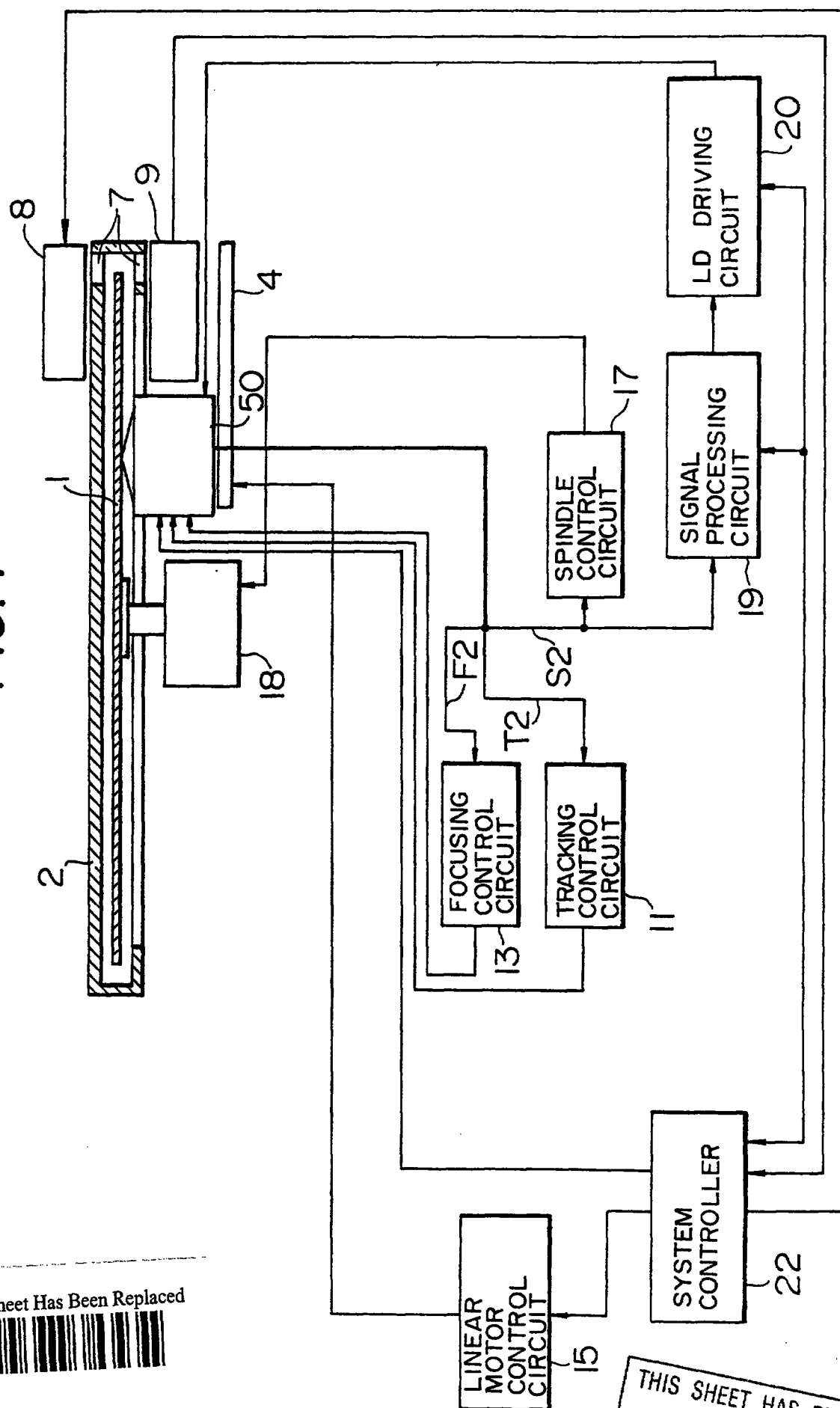


FIG. 6

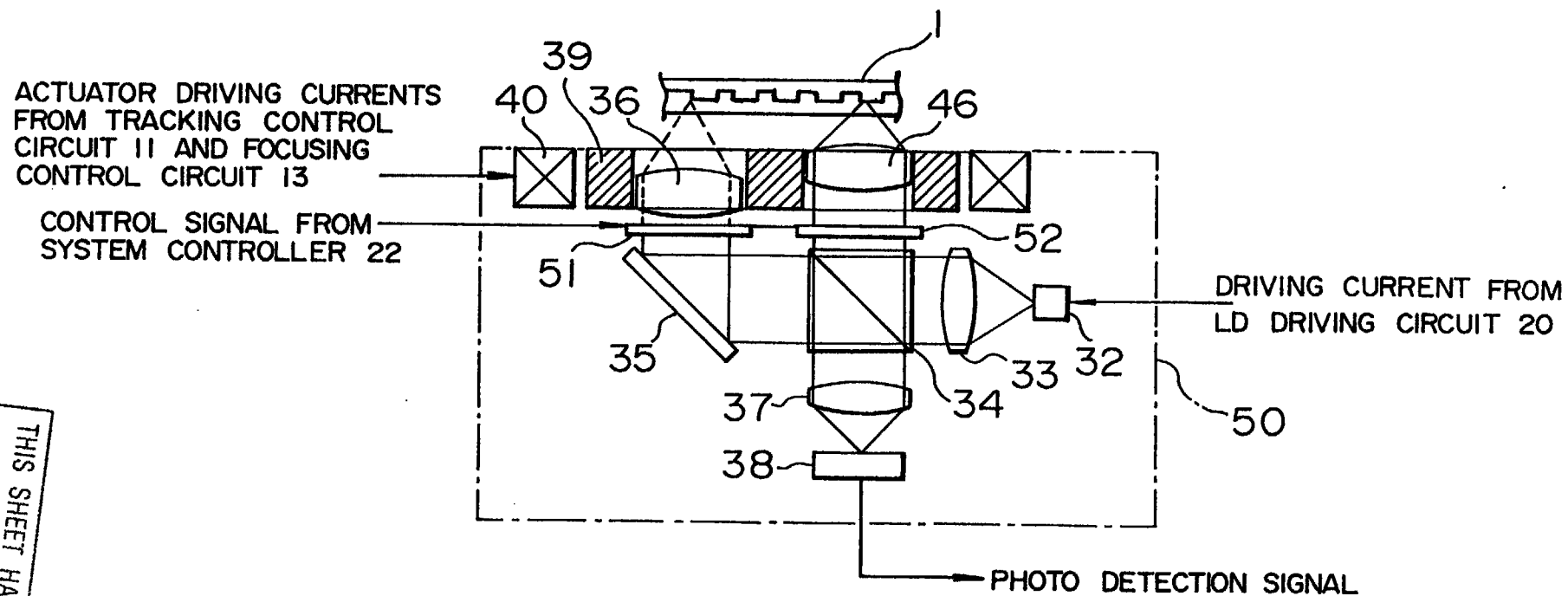


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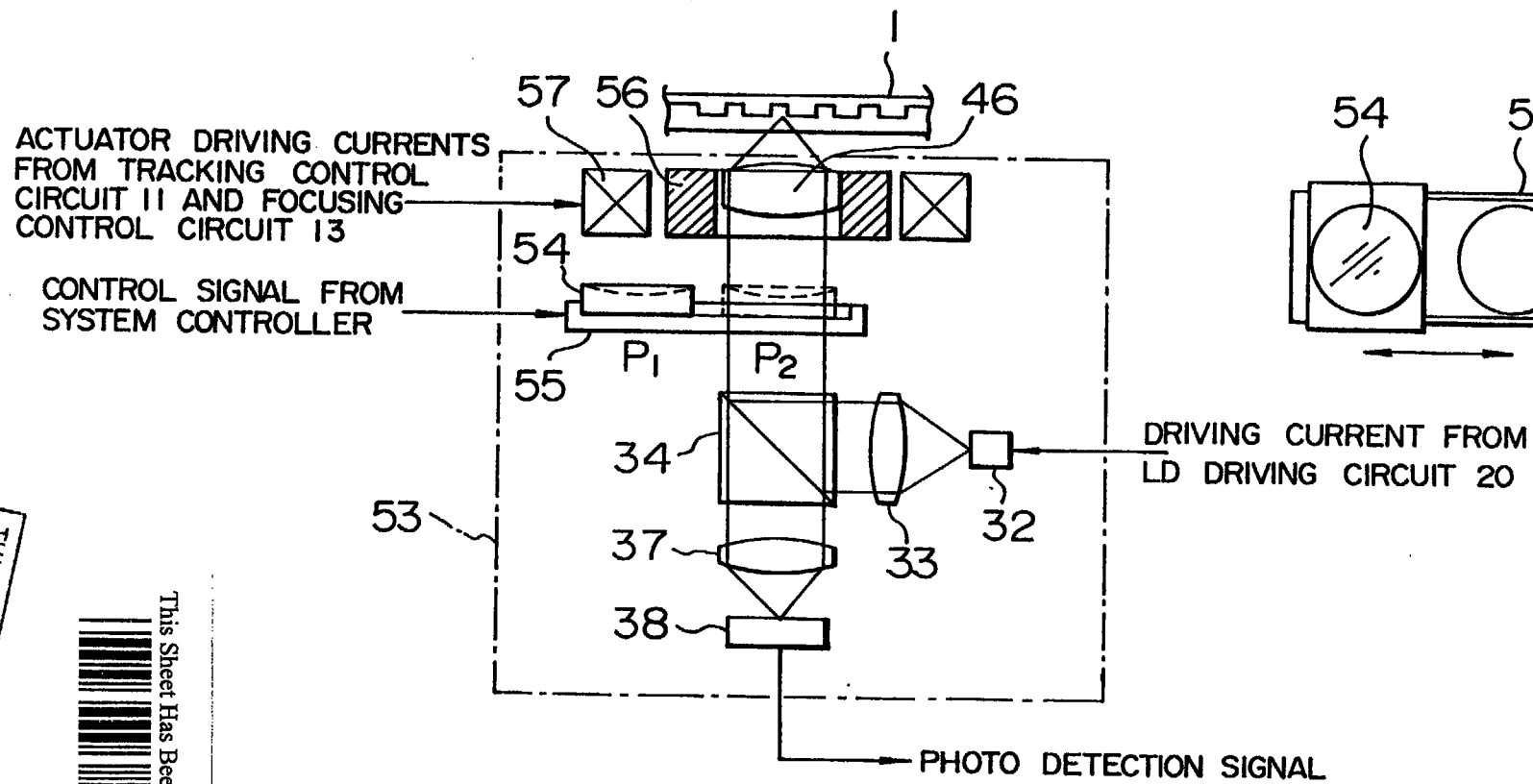
FIG. 8



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FIG. 9A

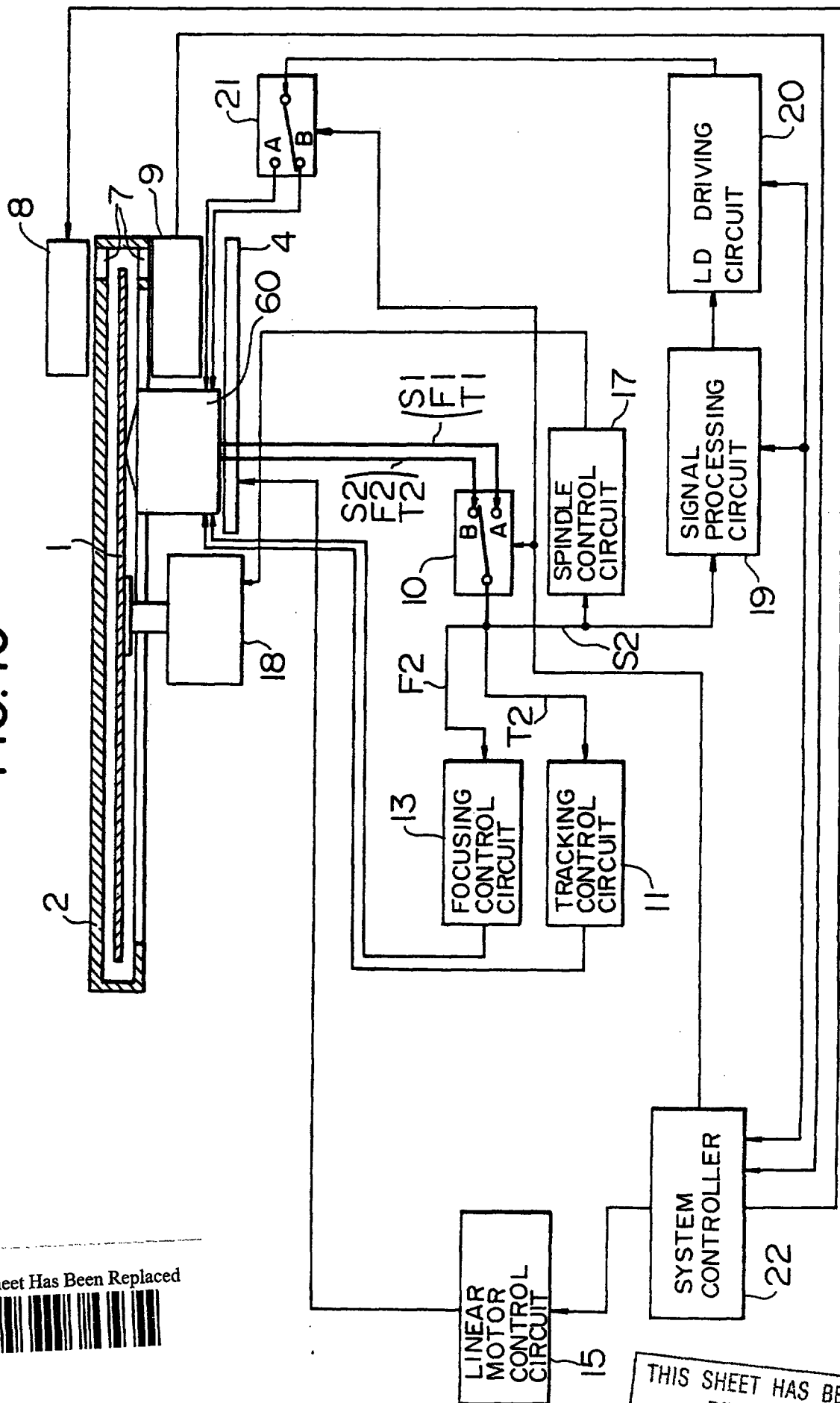
FIG. 9B



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FIG. 10

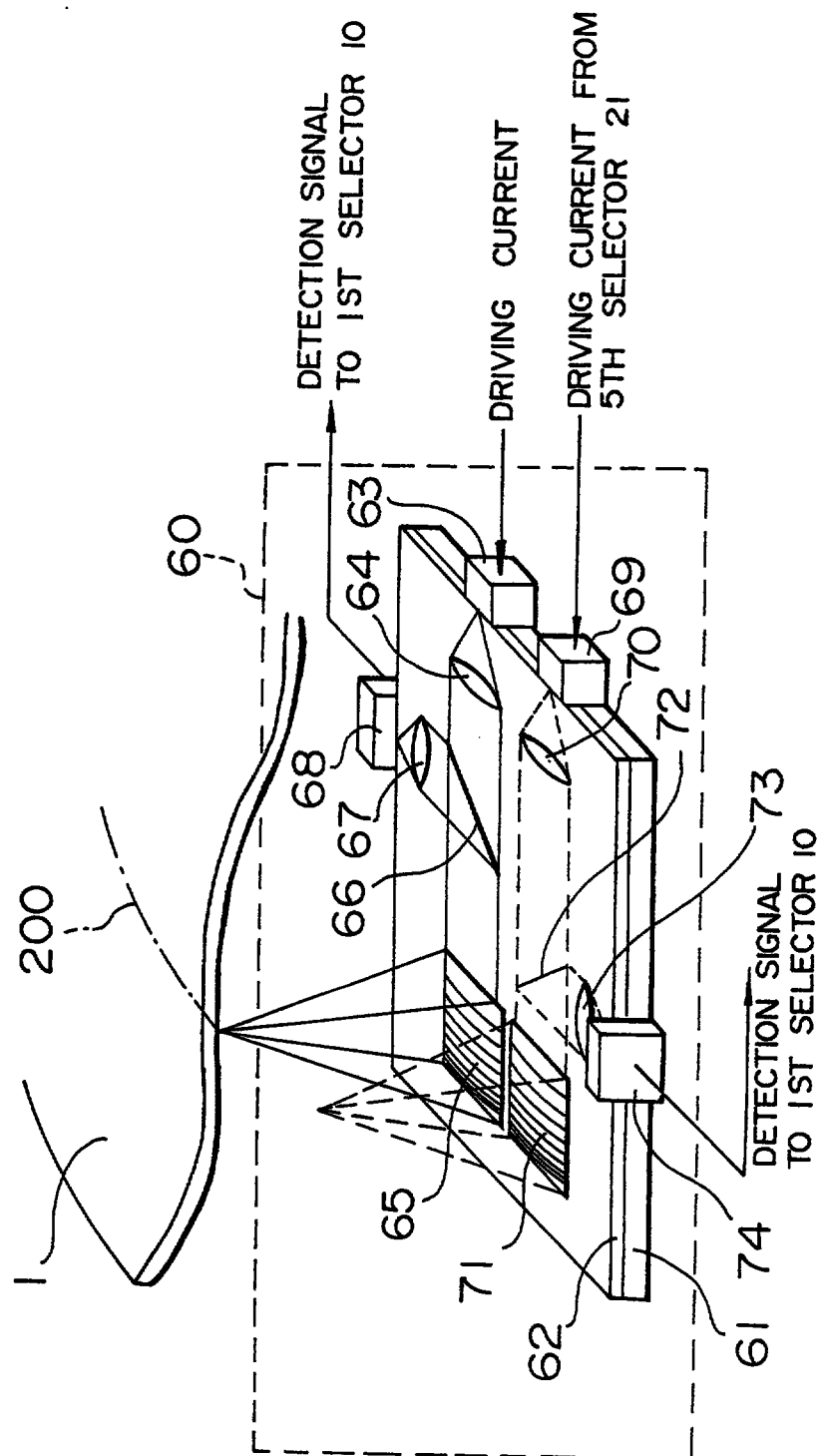


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FIG. 11

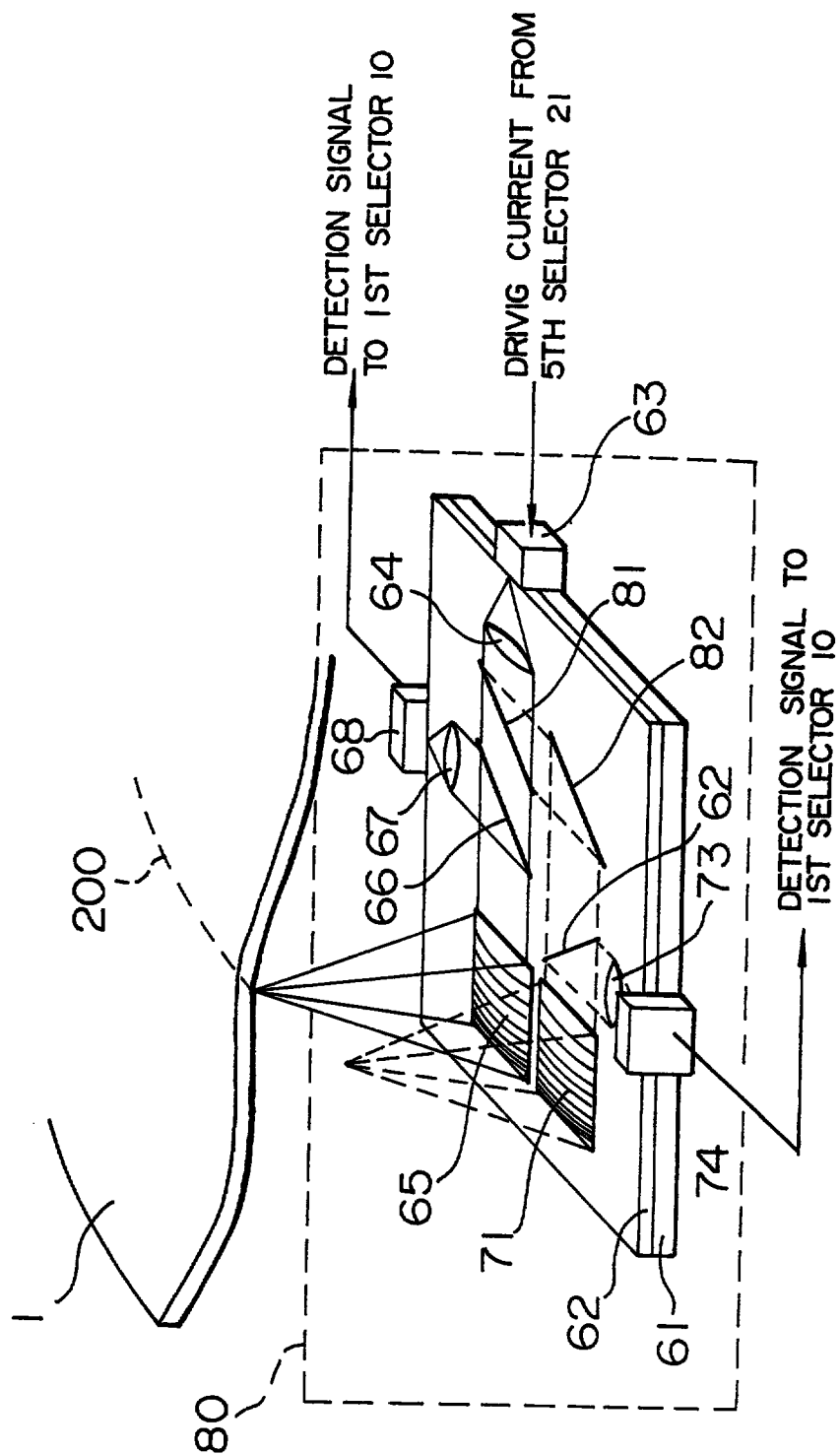


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FIG. 12

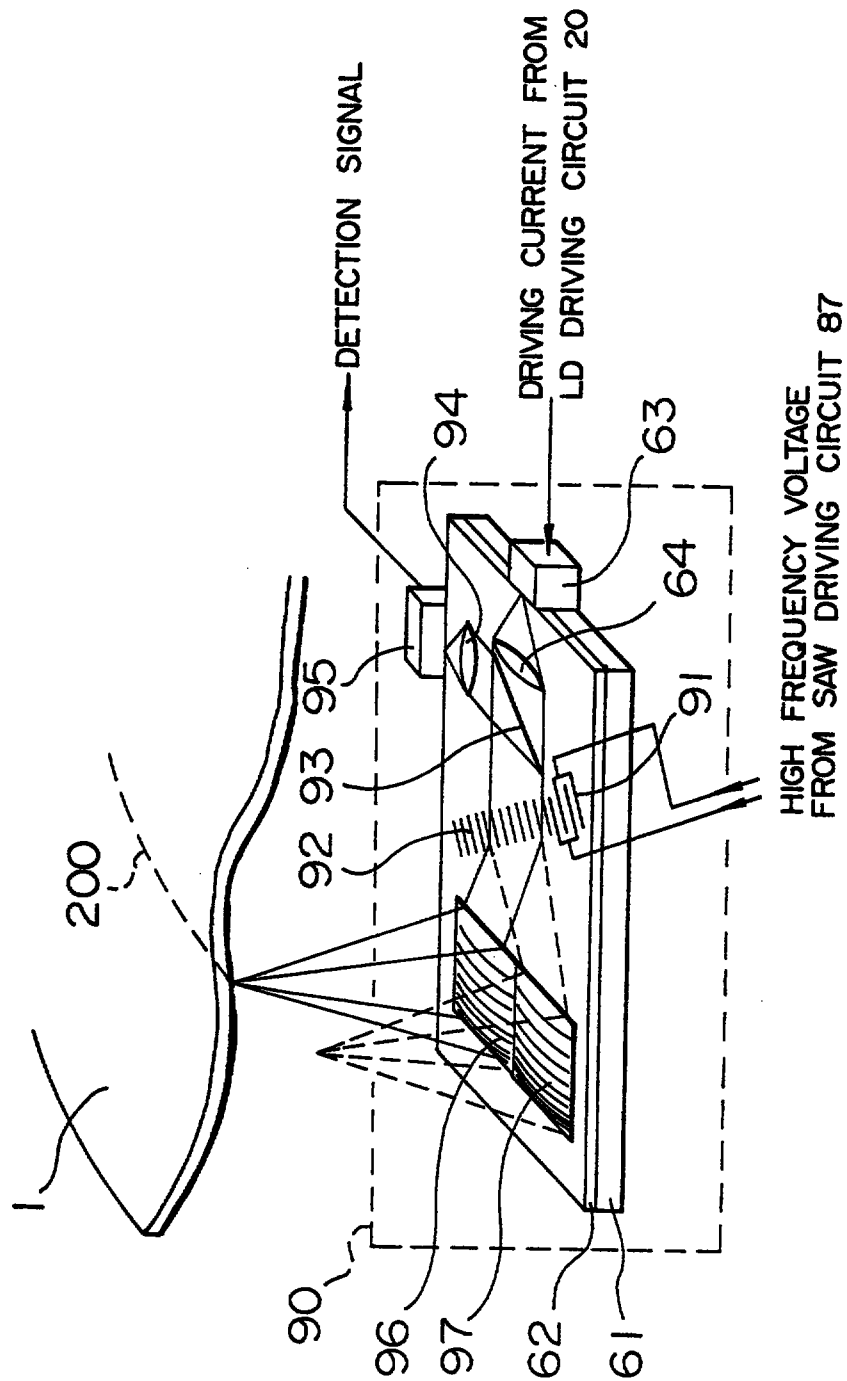


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FIG. 13



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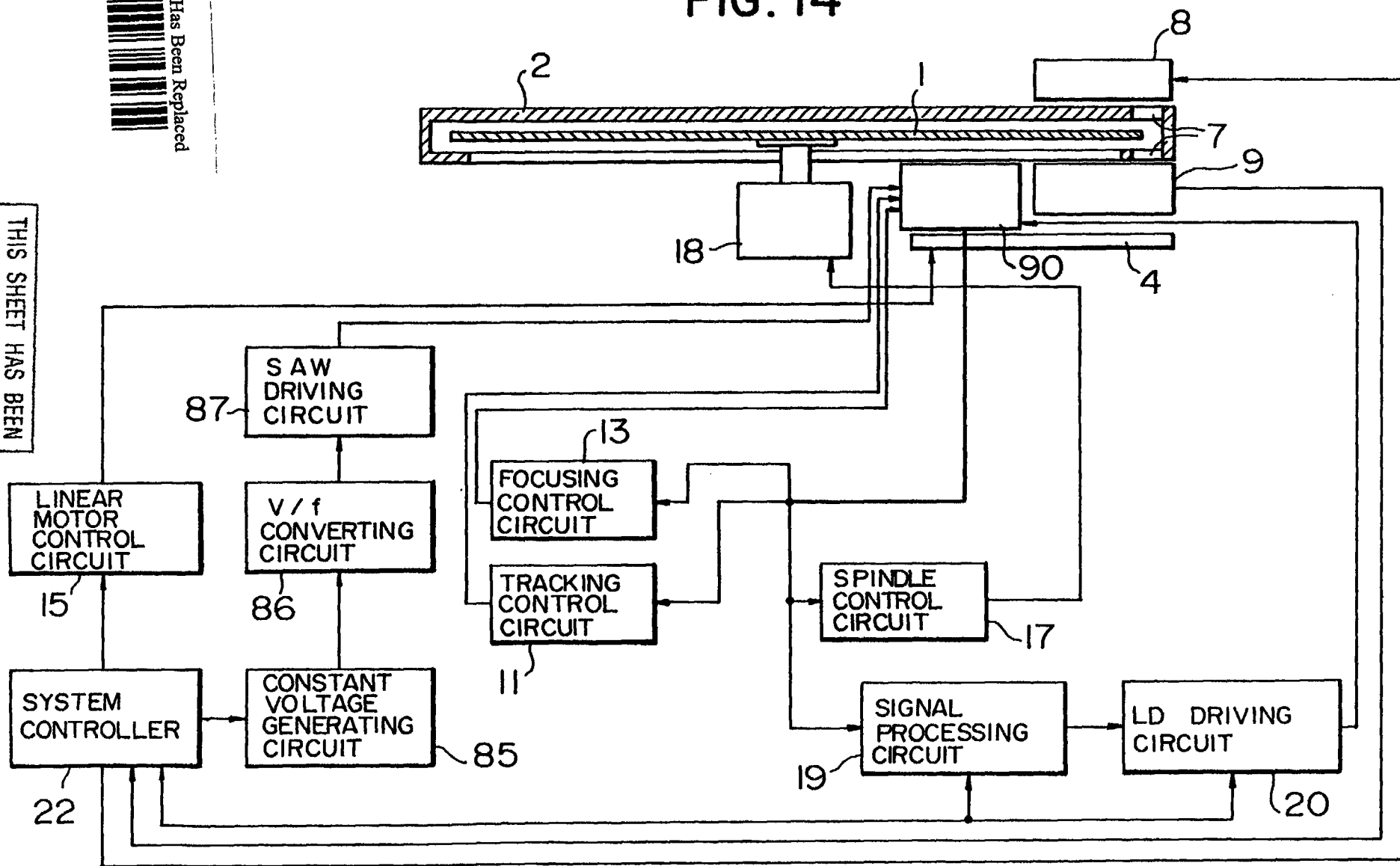


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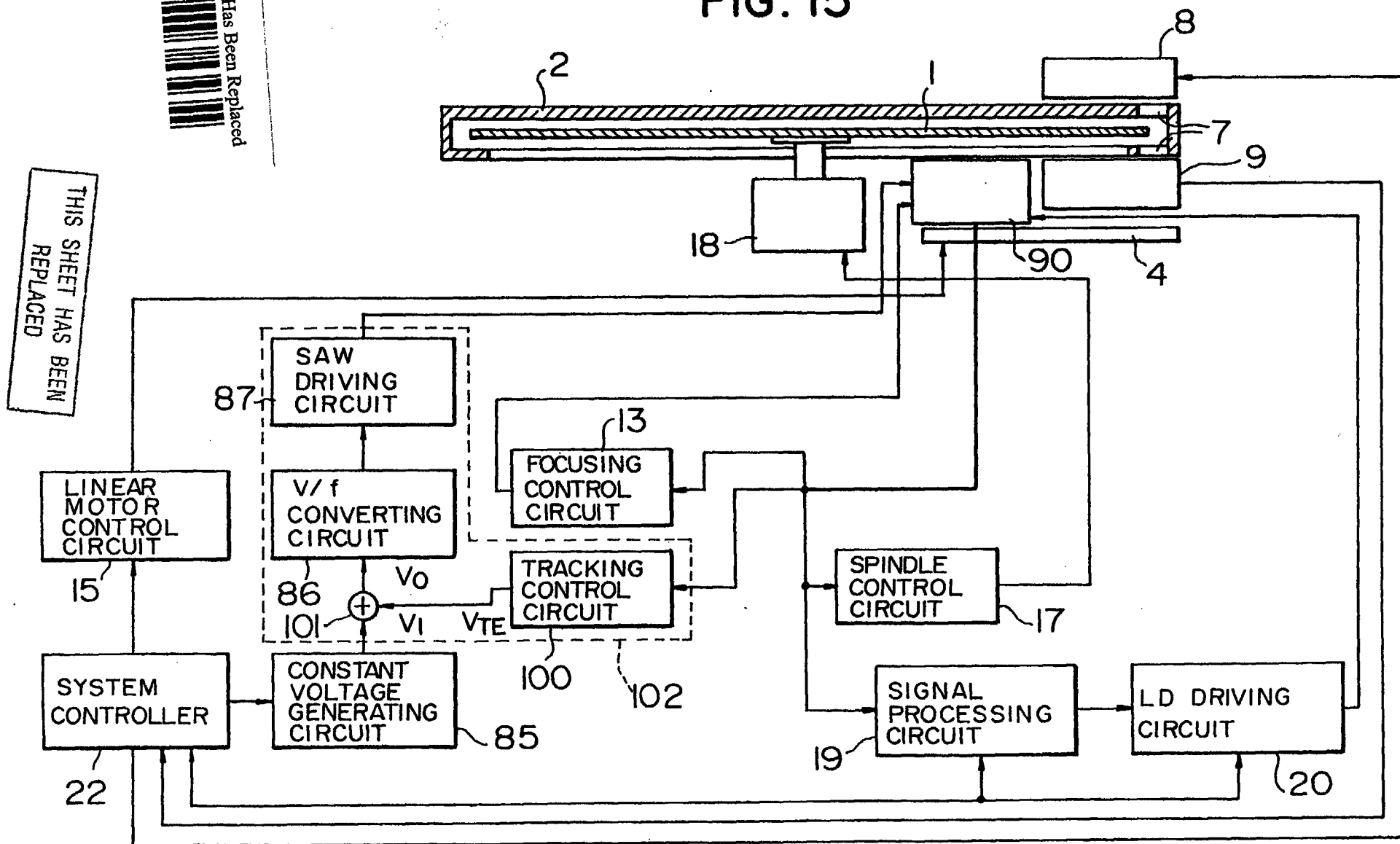
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FIG. 14



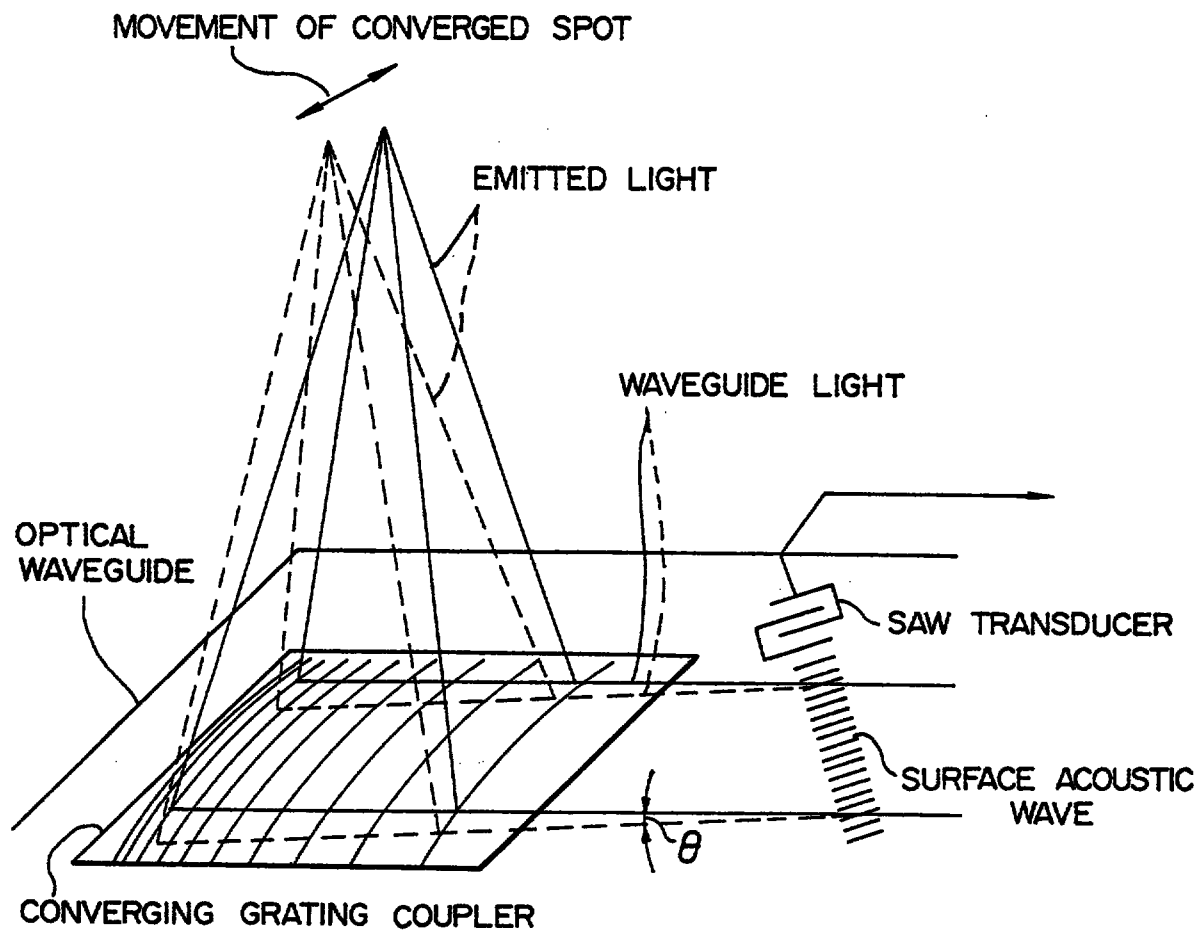
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FIG. 15



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FIG. 16

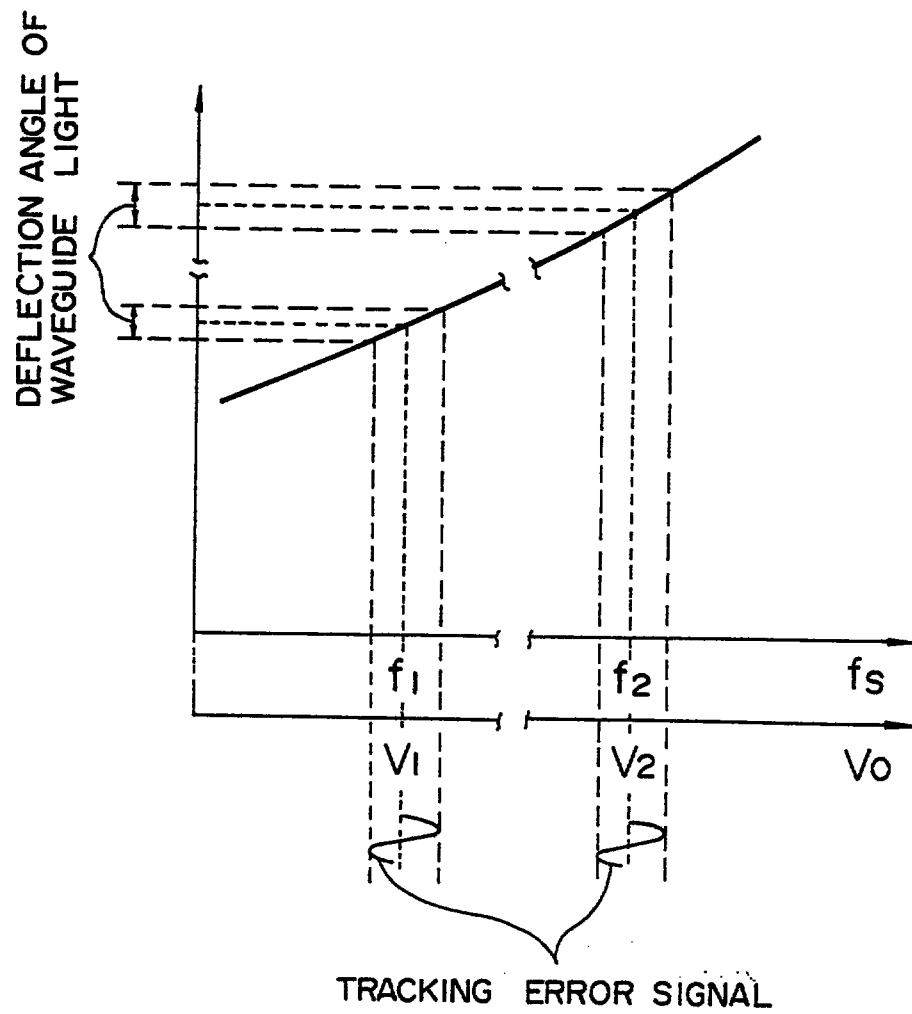


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FIG. 17



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FIG. 18A

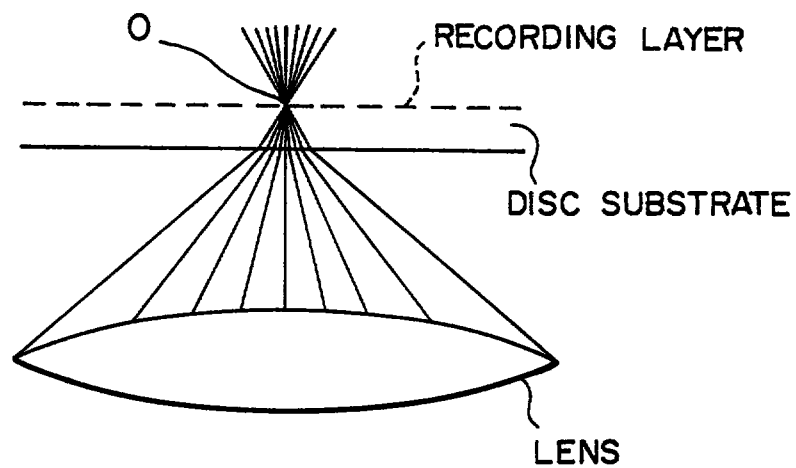
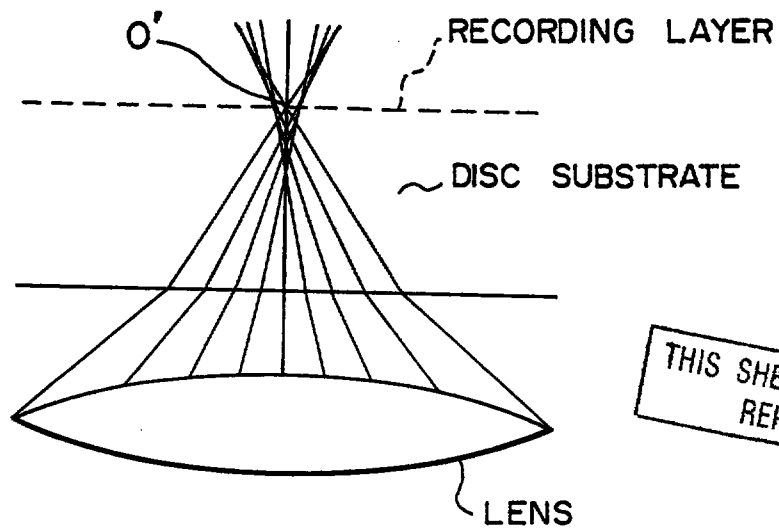


FIG. 18B



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ABSTRACT

OPTICAL DISC APPARATUS

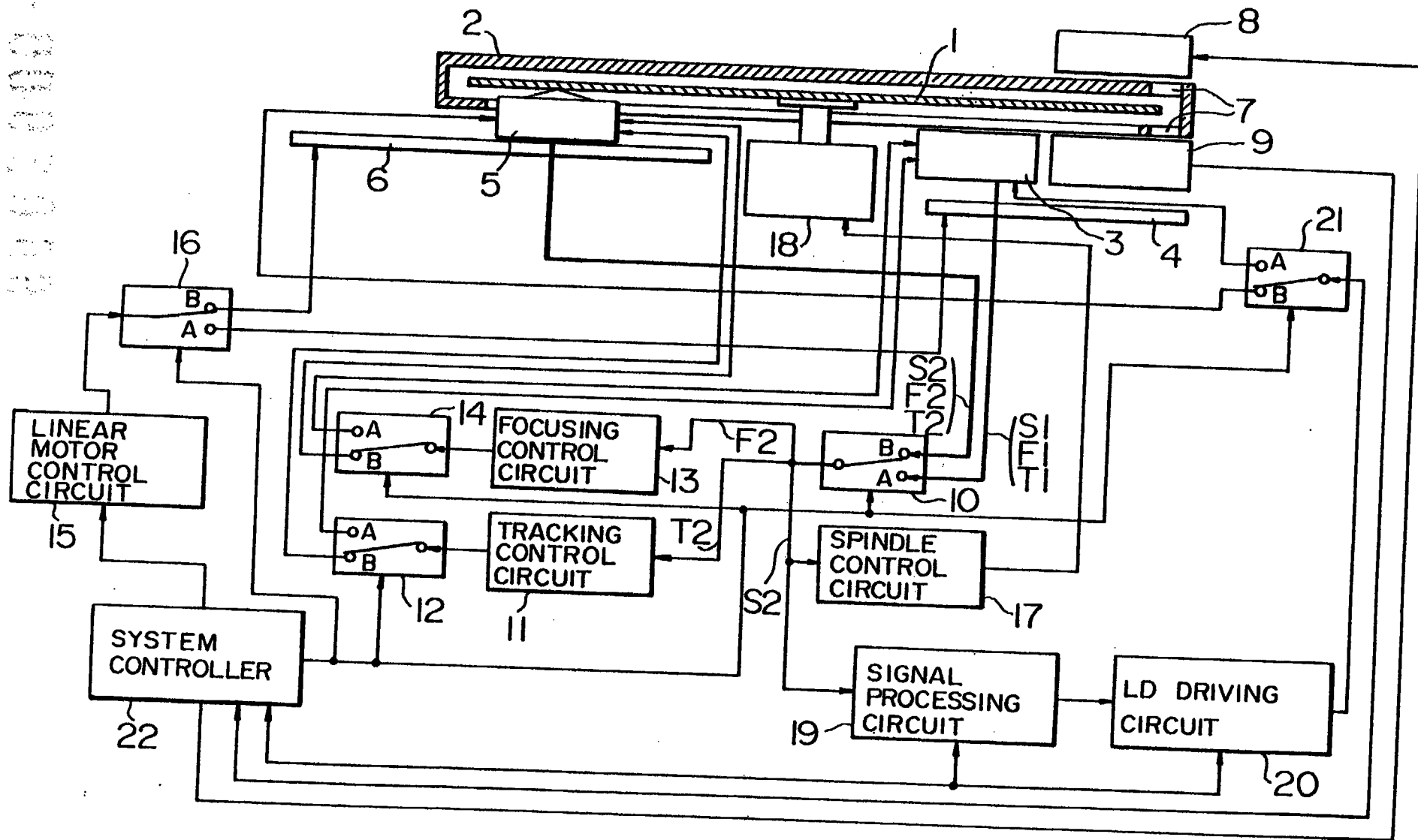
An optical disc apparatus for recording, reproducing, or erasing an information signal by converging a light flux onto a recording layer through a transparent substrate comprises: an optical head (30) having a plurality of objective lenses (36, 46) whose aberrations have respectively been corrected for a plurality of disc substrates of different thicknesses; and means (8, 9) for discriminating the thickness of the disc substrate. In accordance with the result of the discrimination of the thickness of the disc substrate of the loaded optical disc (1), the objective lens in which the occurrence of the aberration is smallest is used, so that the information signal can preferably be recorded, reproduced, or erased onto/from the optical discs (1) having different substrate thicknesses.

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FIG. 1

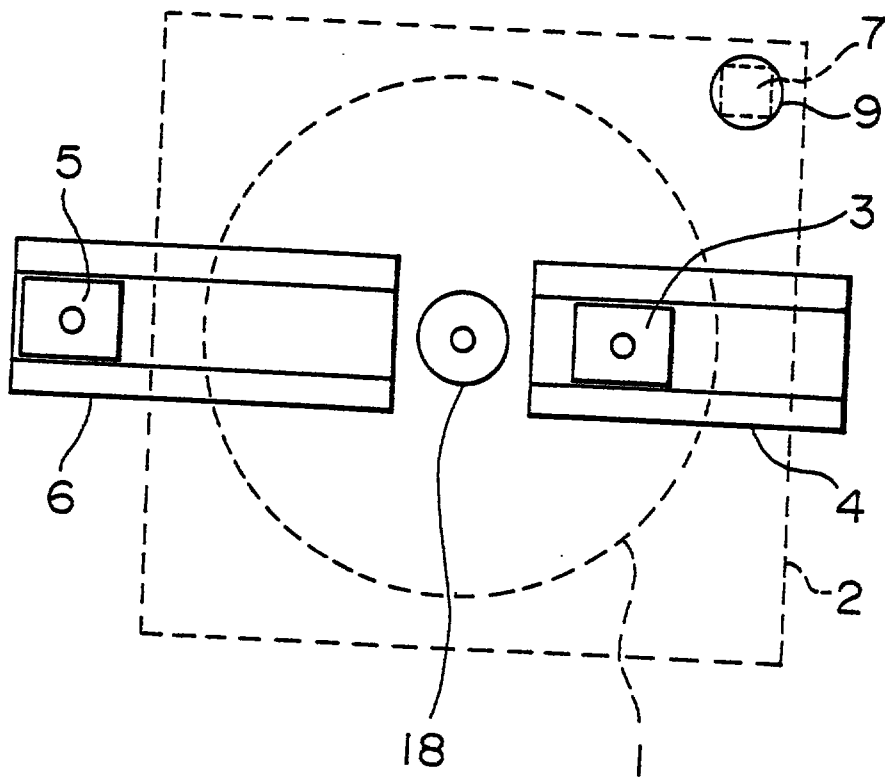


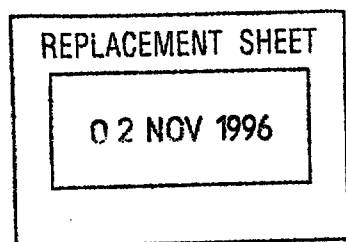
REPLACEMENT SHEET
02 NOV 1996

1/18 Substitute sheet - 1 November 1996

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FIG. 2





3/18 Substitute sheet - 1 November 1996

FIG. 3A

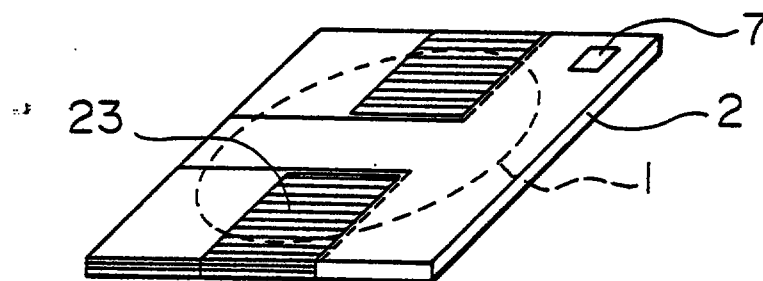
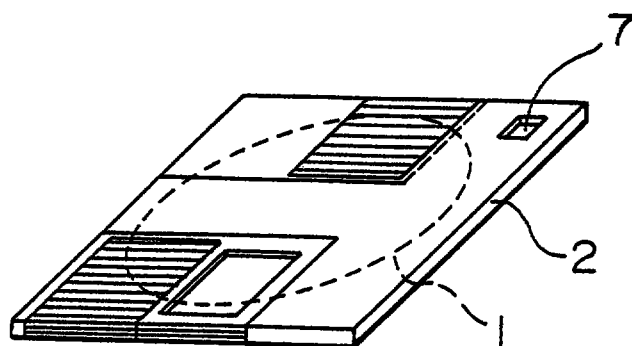
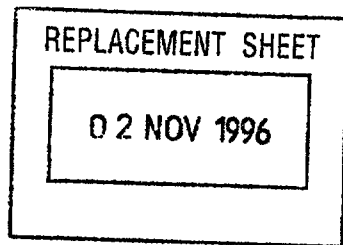


FIG. 3B





4/18 Substitute sheet - 1 November 1996

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FIG. 4A

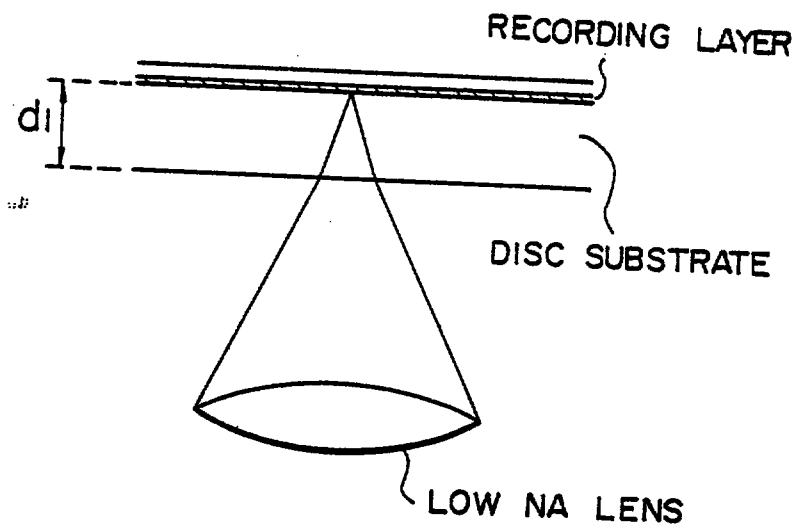
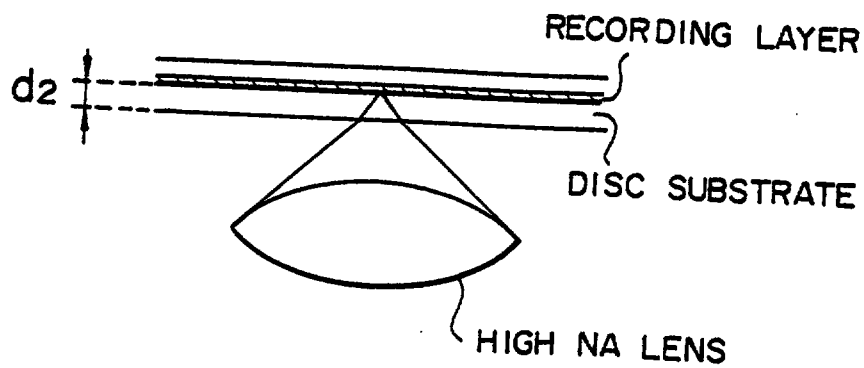


FIG. 4B



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FIG. 5

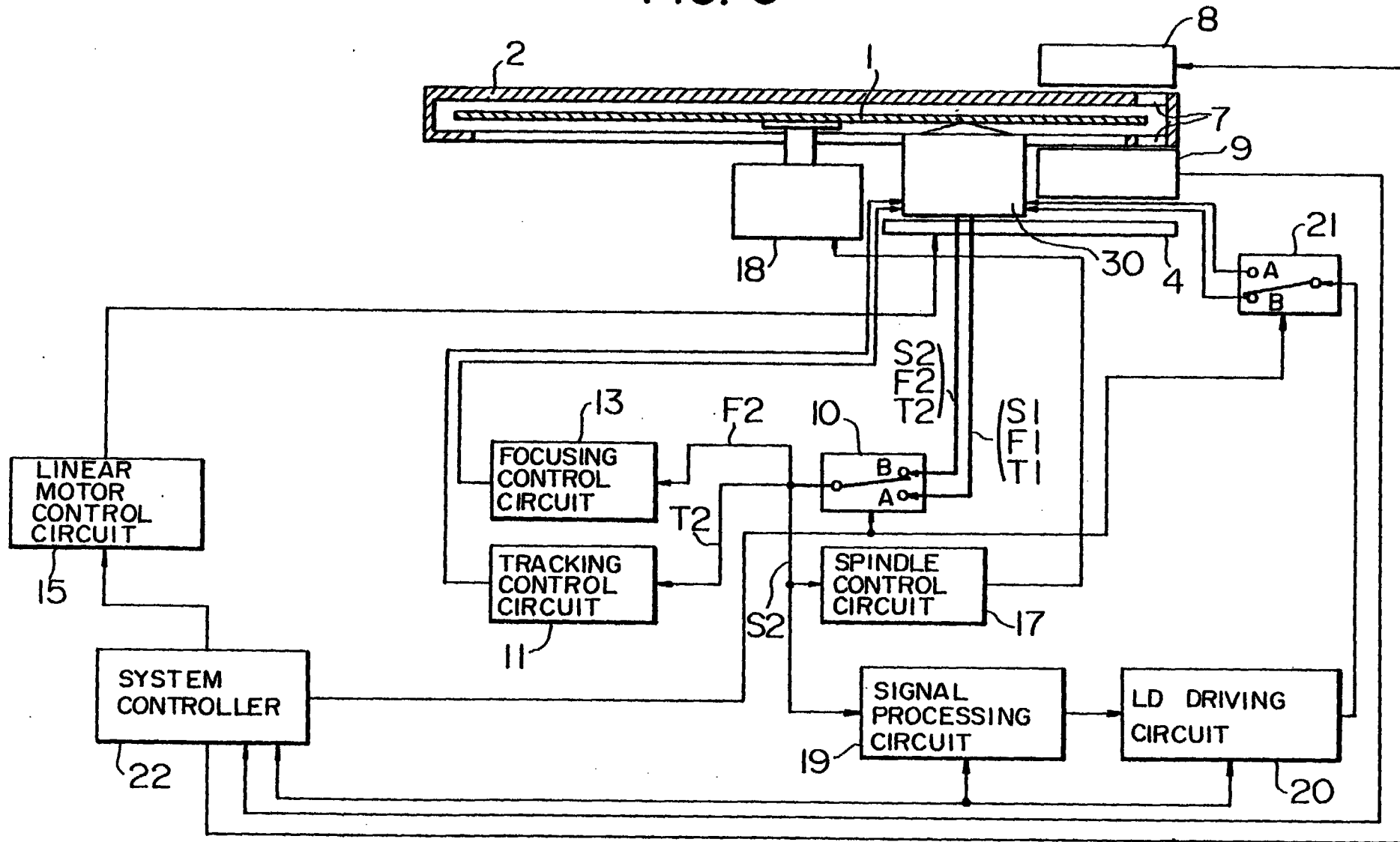
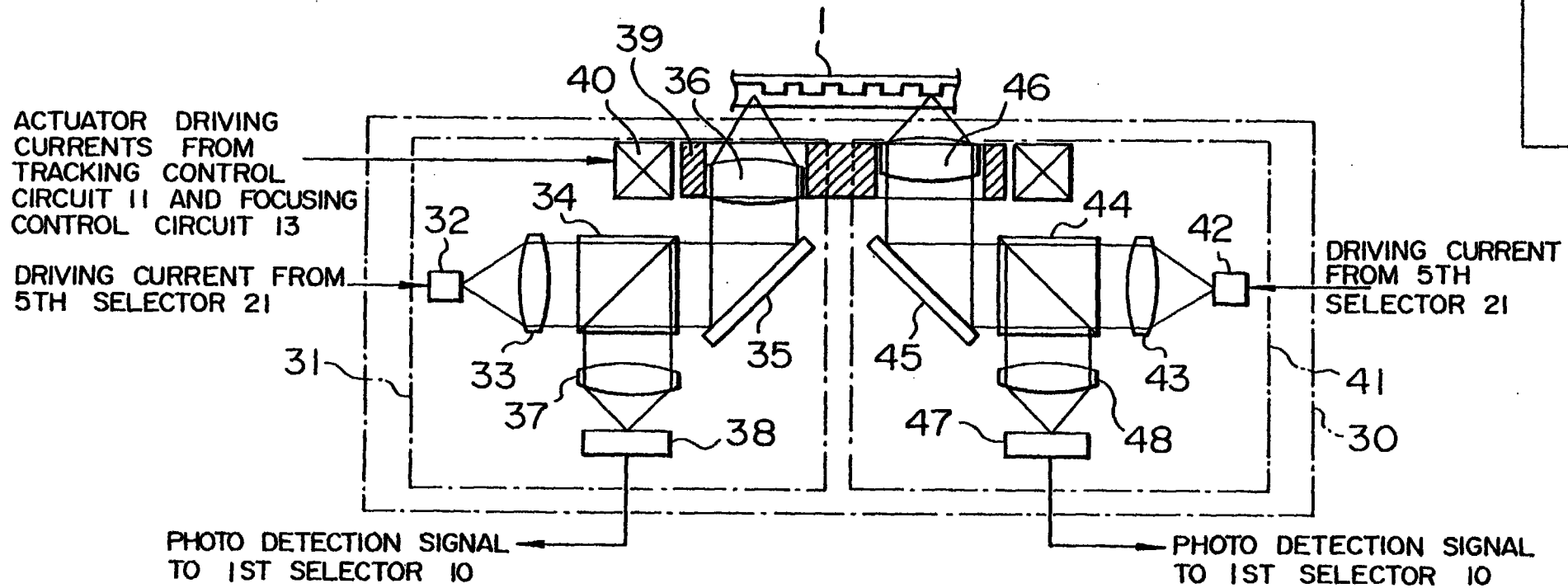


FIG. 6



REPLACEMENT SHEET
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6/18 Substitute sheet - 1 November 1996

FIG. 7

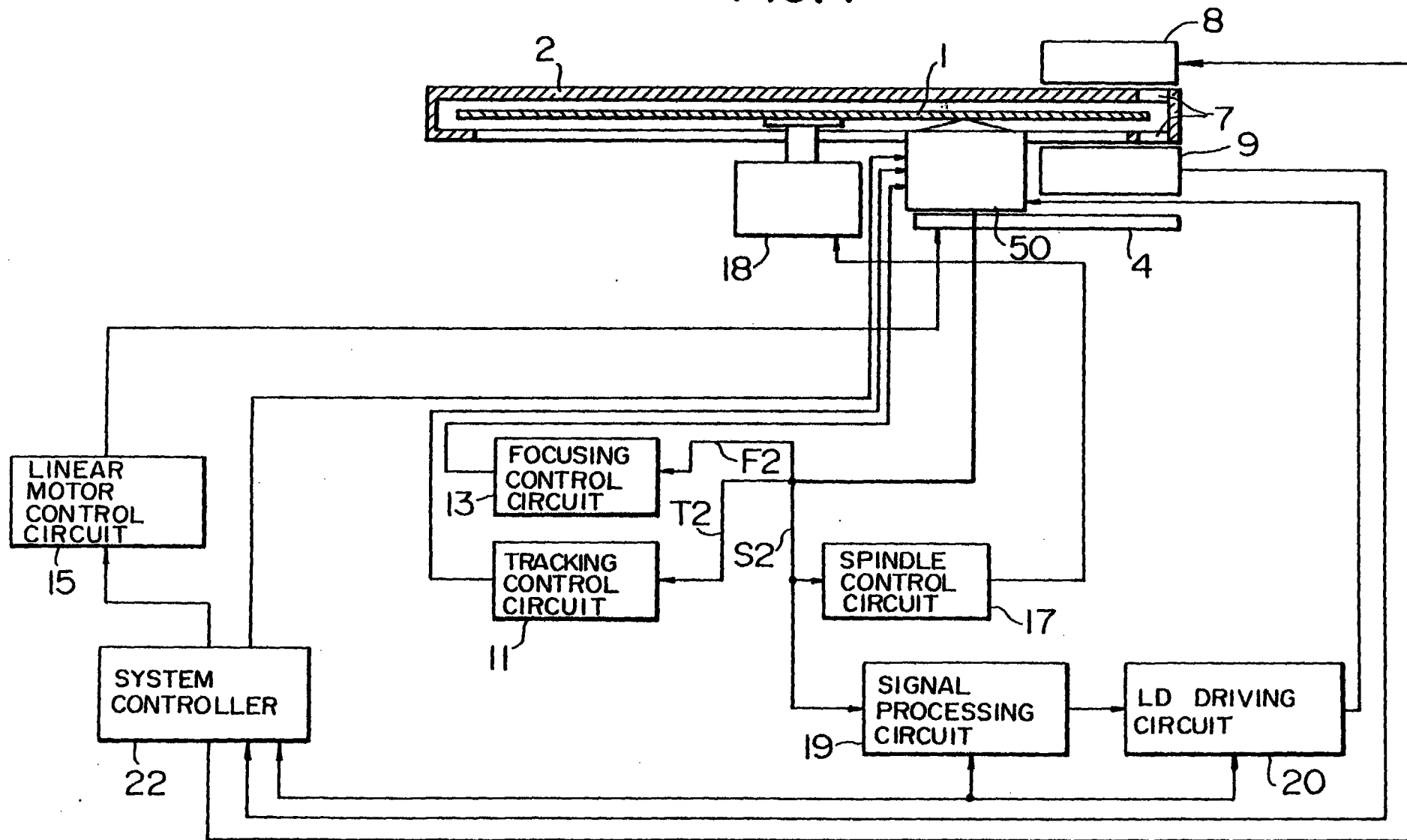
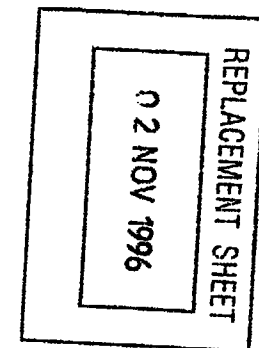
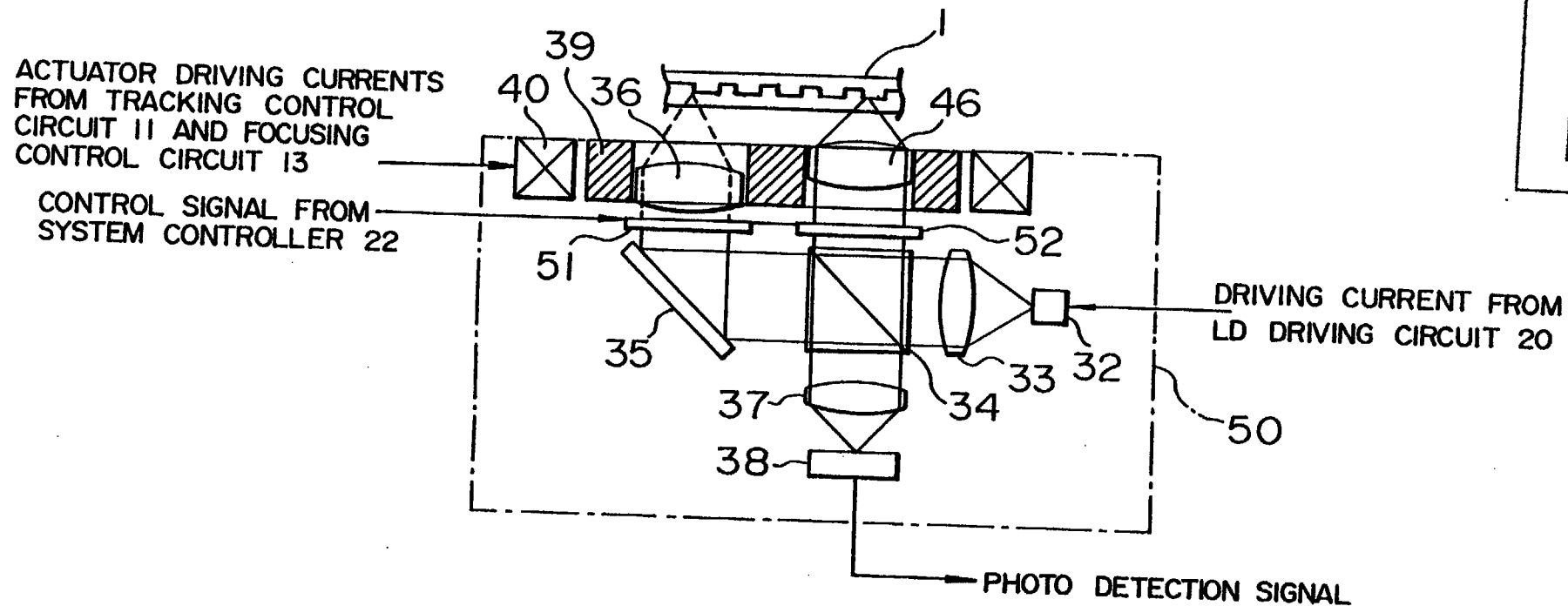


FIG. 8



8/18 Substitute sheet - 1 November 1996

FIG. 9A

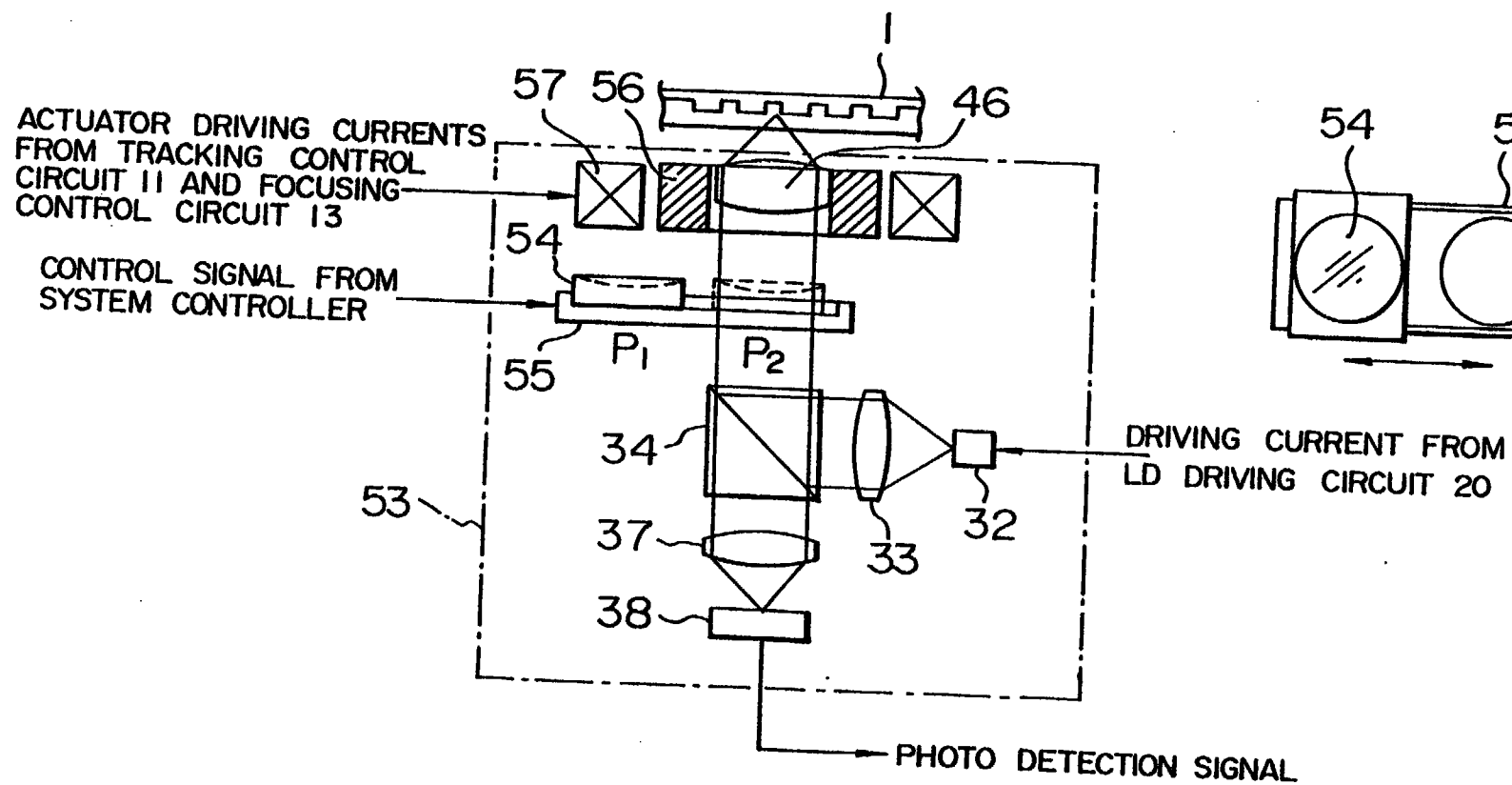
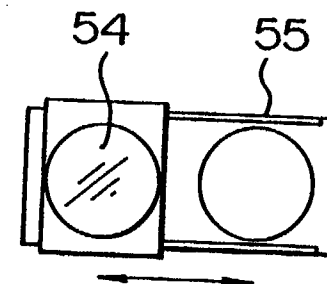


FIG. 9B

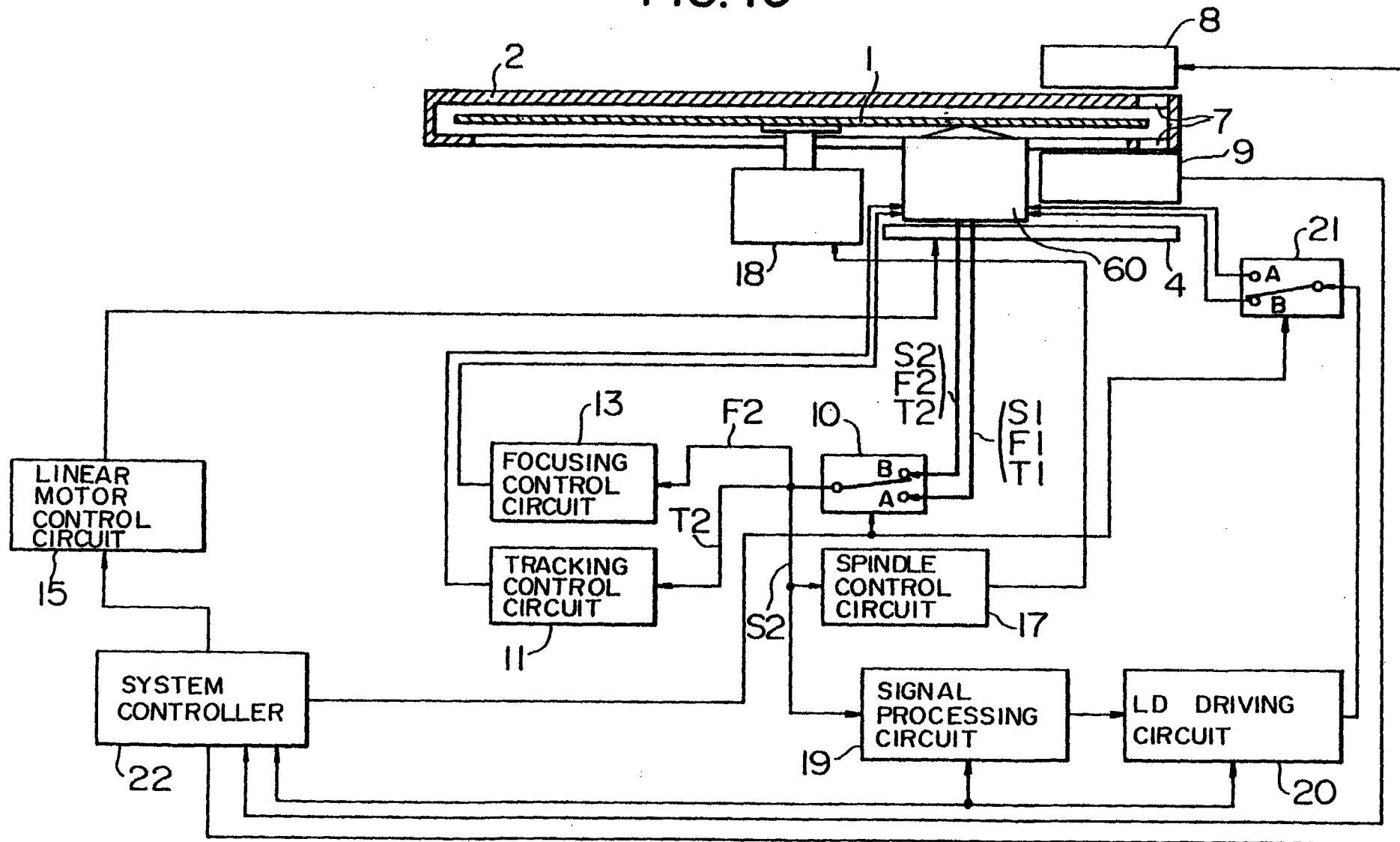


9/18 Substitute sheet - 1 November 1996

02 NOV 1996

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FIG. 10

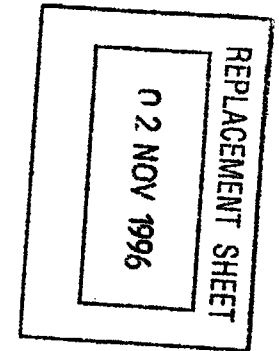
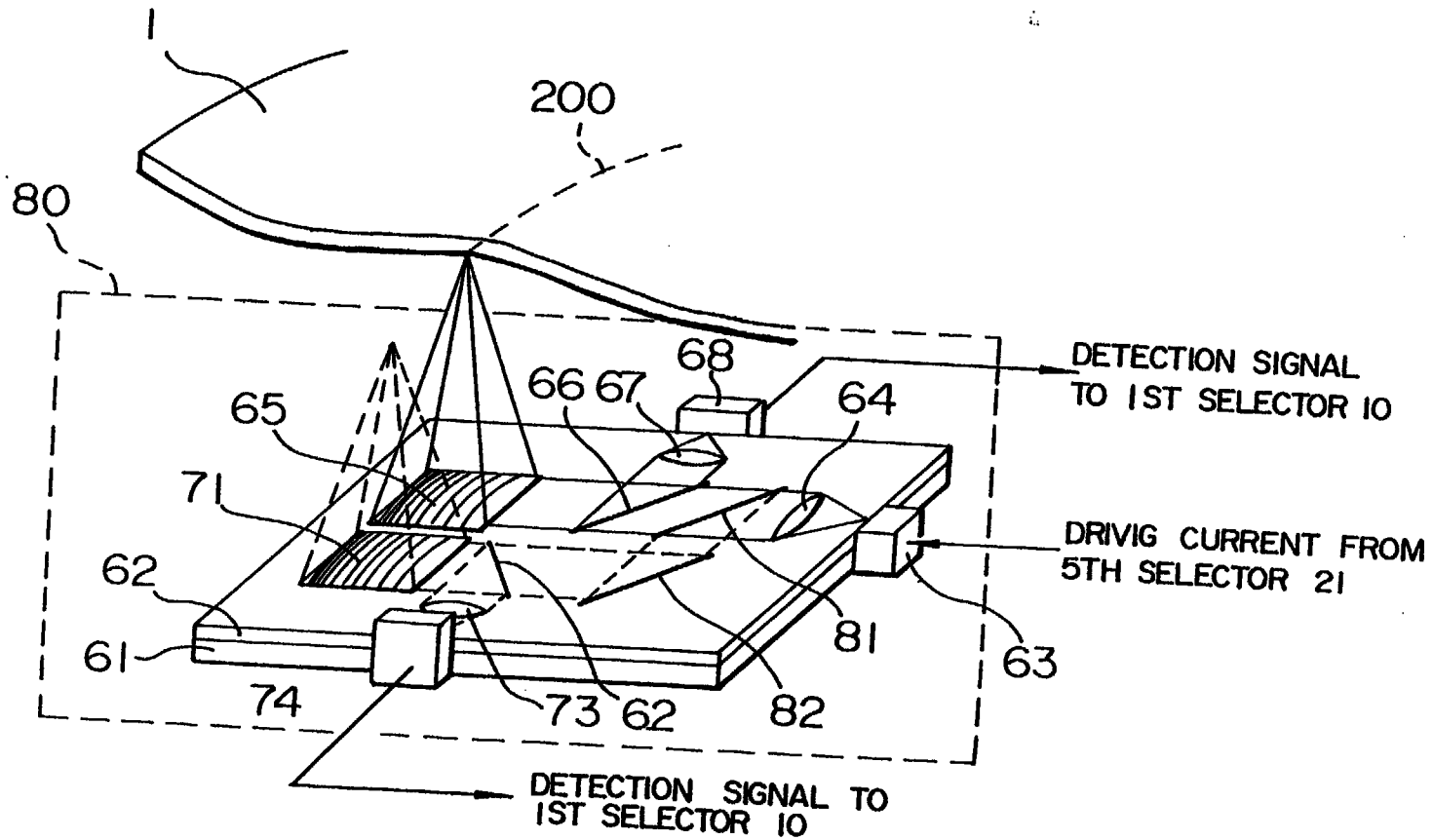


[illegible]

02 NOV 1996

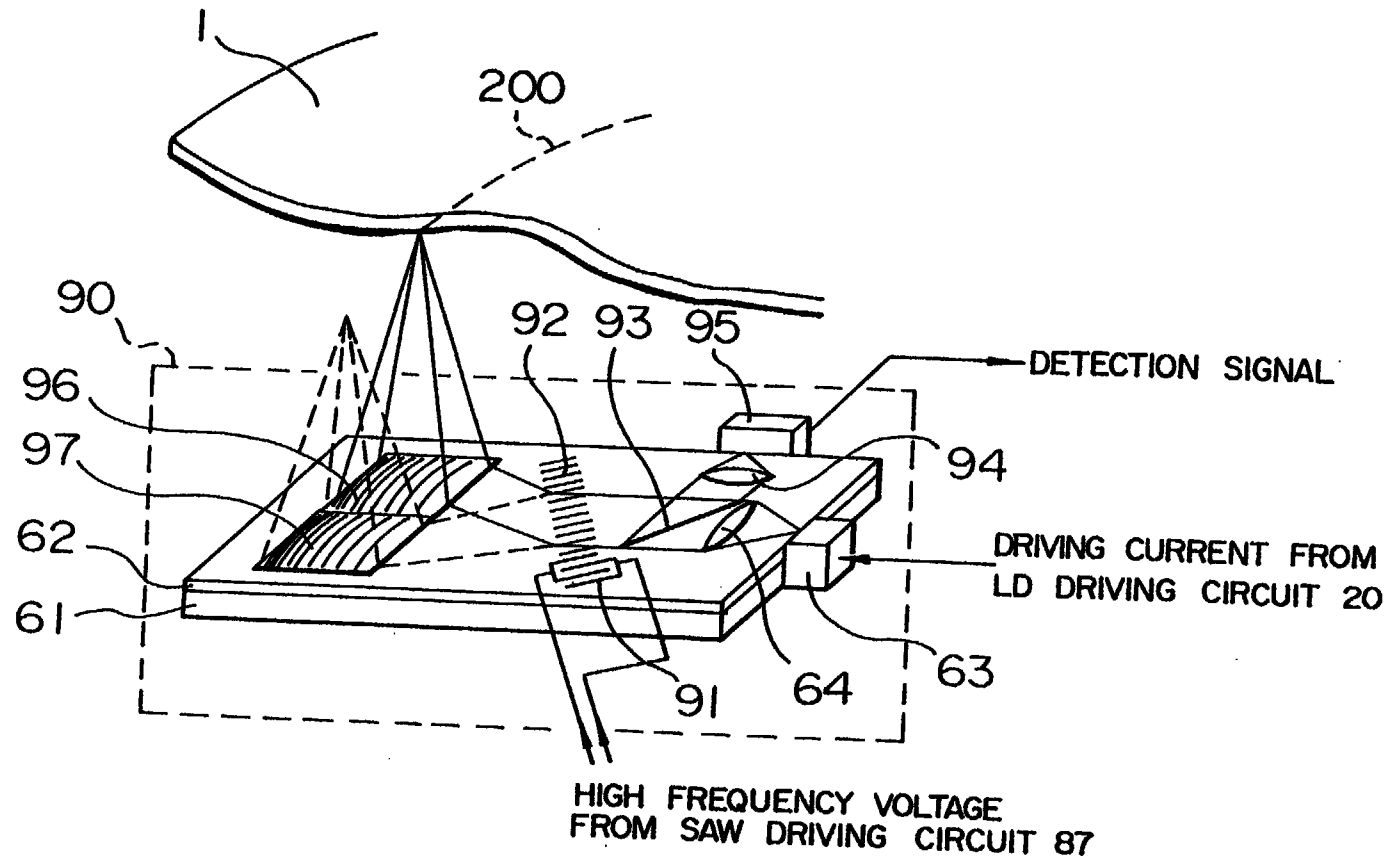
11/18 Substitute sheet - 1 November 1996

FIG. 12



12/18 Substitute sheet - 1 November 1996

FIG. 13

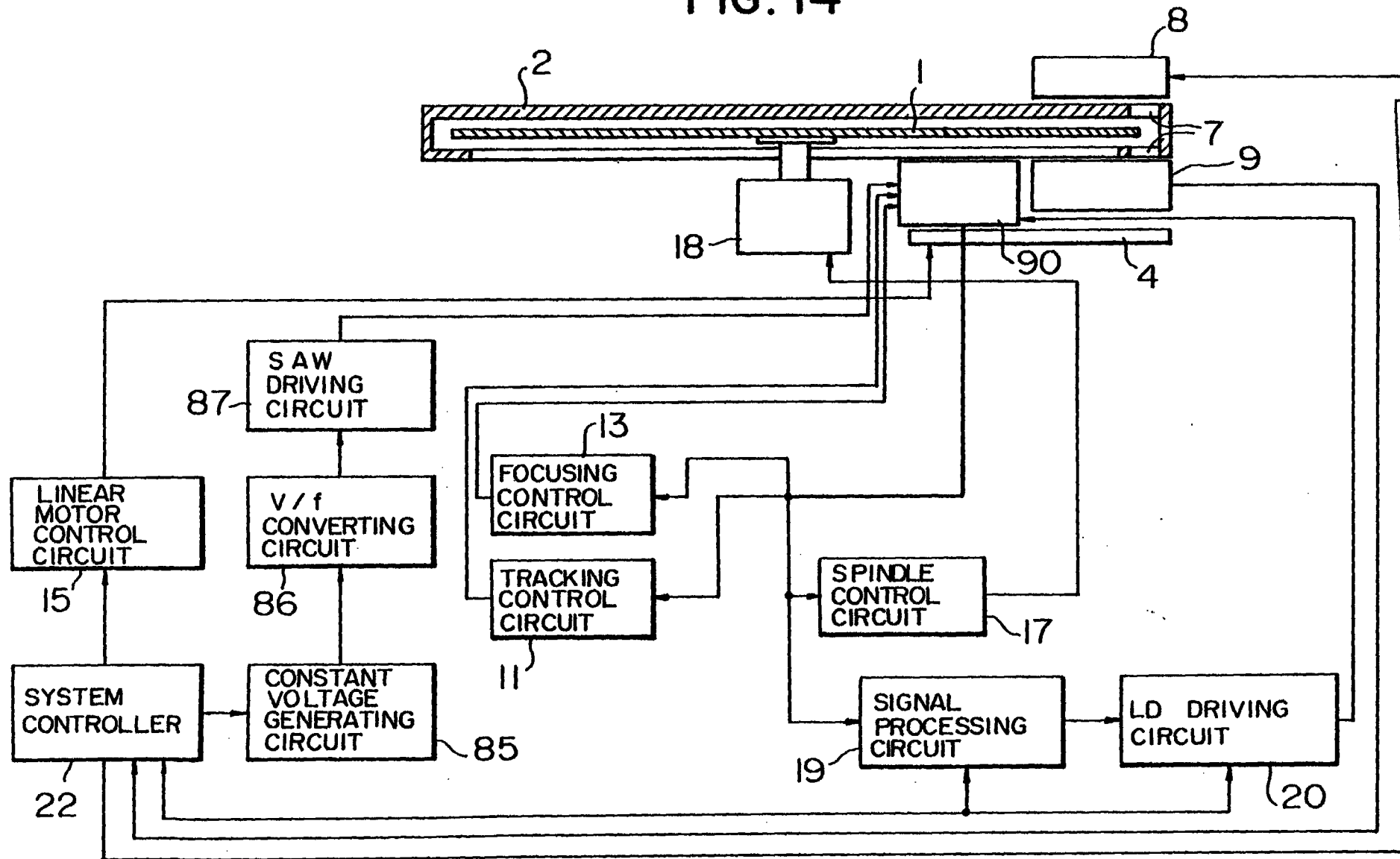


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02 NOV 1996

13/18 Substitute sheet - 1 November 1996

FIG. 14

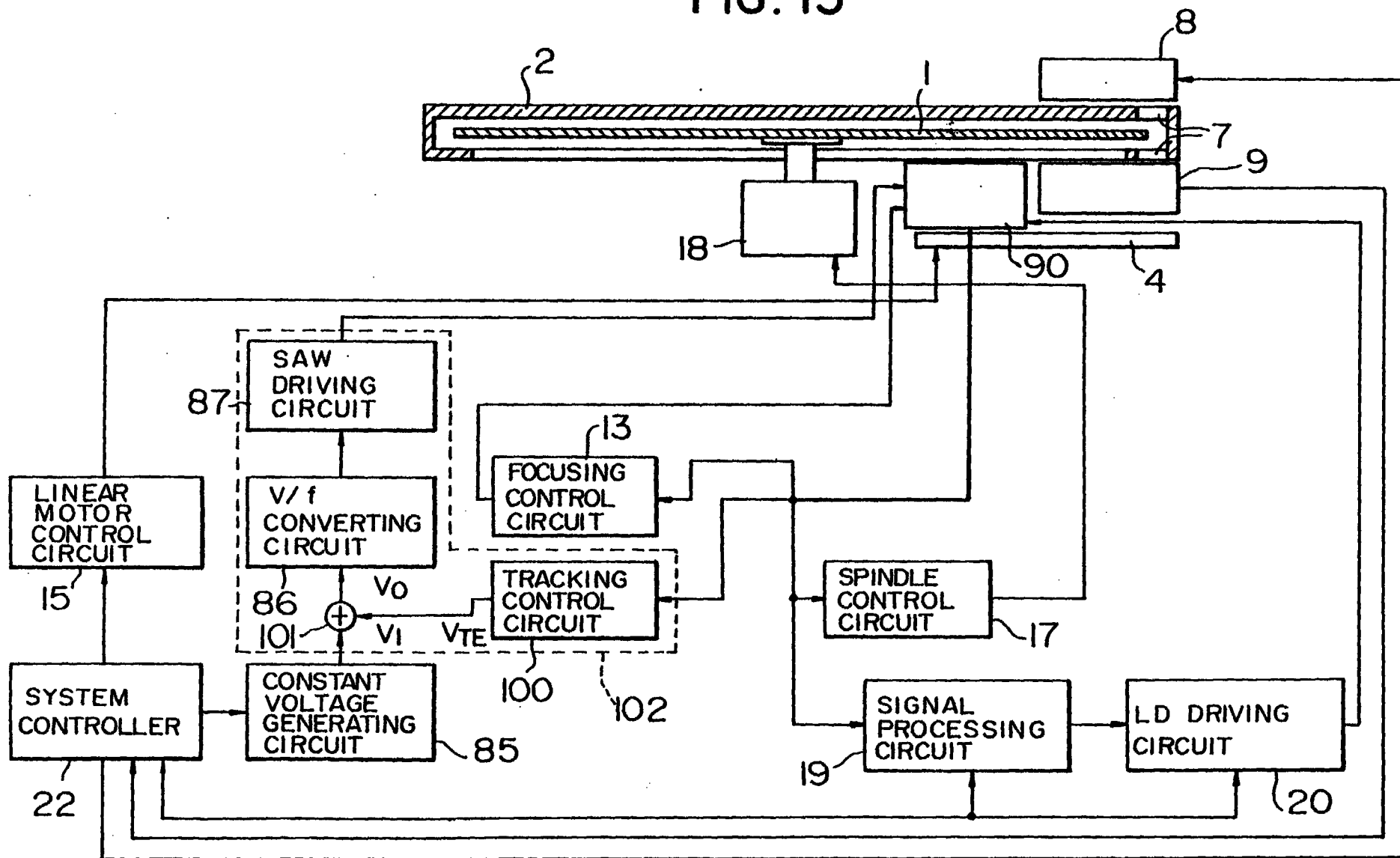


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02 NOV 1996

14/18 Substitute sheet - 1 November 1996

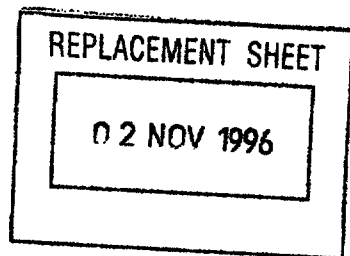
FIG. 15



02 NOV 1996

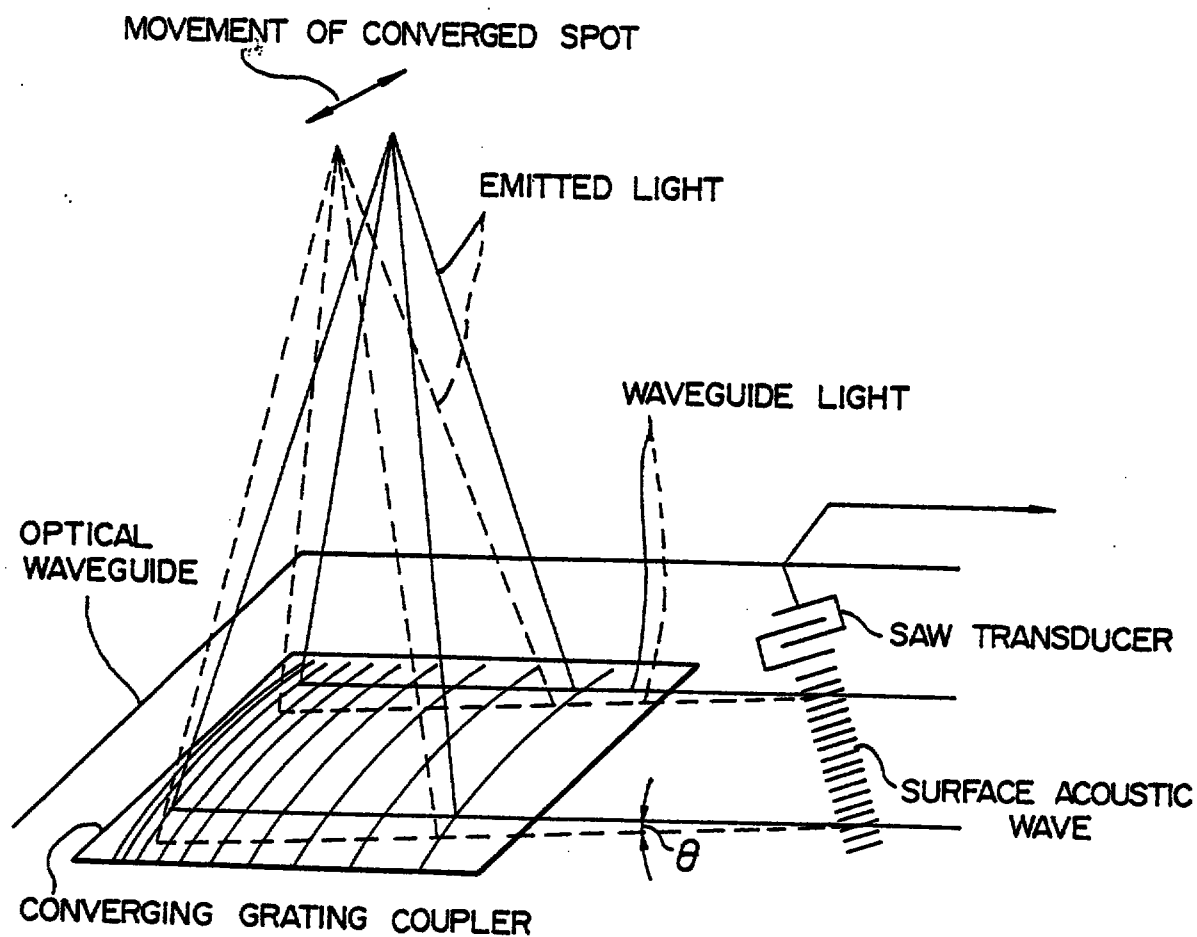
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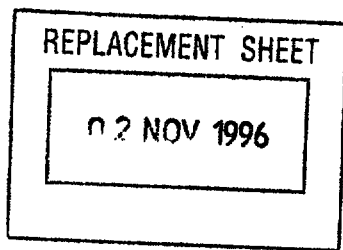
15/18 Substitute sheet - 1 November 1996



16/18 Substitute sheet - 1 November 1996

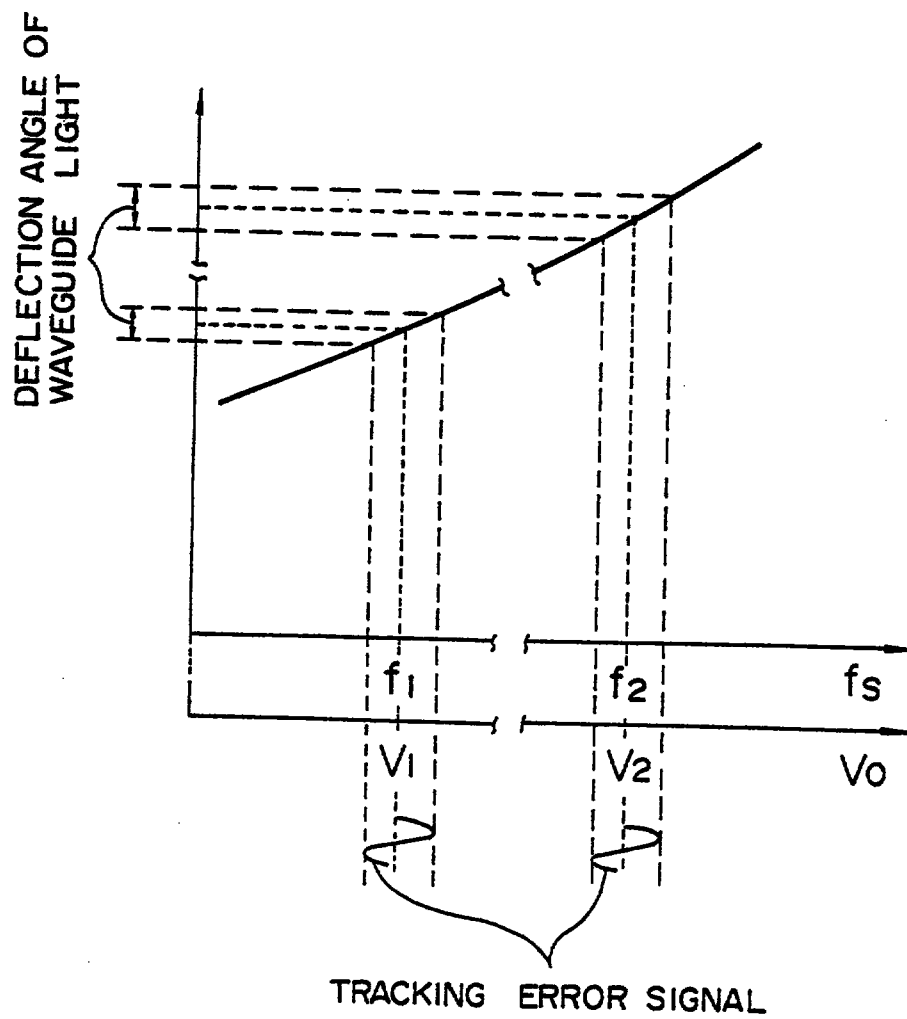
FIG. 16

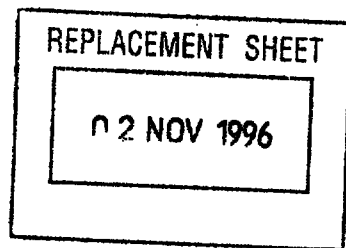




17/18 Substitute sheet - 1 November 1996

FIG. 17





18/18 Substitute sheet - 1 November 1996

FIG. 18A

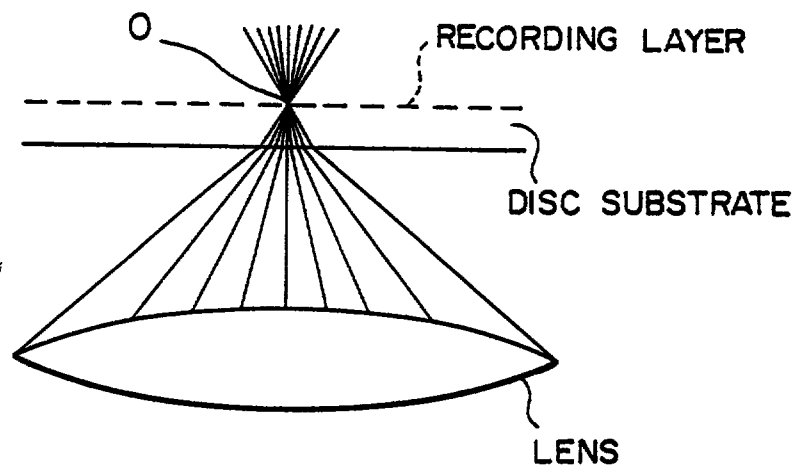
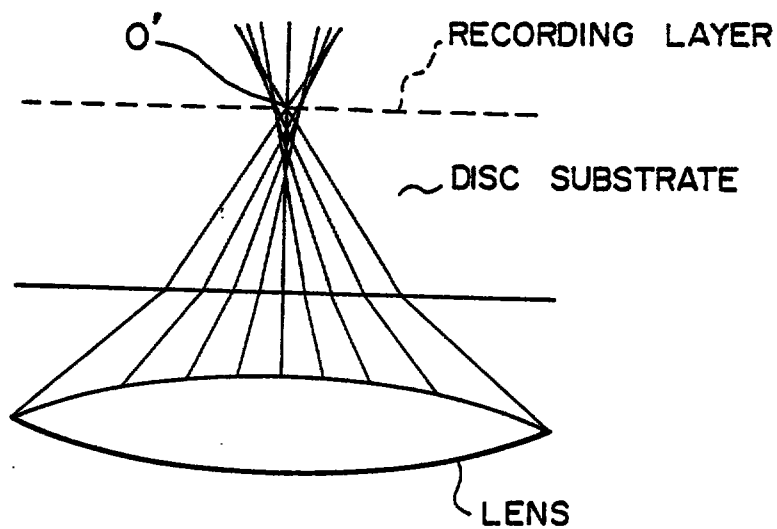


FIG. 18B



REPLACEMENT SHEET

02 NOV 1996

Substitute sheet - 1 November 1996

ABSTRACT

OPTICAL DISC APPARATUS

An optical disc apparatus for recording, reproducing, or erasing an information signal by converging a light flux onto a recording layer through a transparent substrate comprises: an optical head (30) having a plurality of objective lenses (36, 46) whose aberrations have respectively been corrected for a plurality of disc substrates of different thicknesses; and means (8, 9) for discriminating the thickness of the disc substrate. In accordance with the result of the discrimination of the thickness of the disc substrate of the loaded optical disc (1), the objective lens in which the occurrence of the aberration is smallest is used, so that the information signal can preferably be recorded, reproduced, or erased onto/from the optical discs (1) having different substrate thicknesses.

Figure 5.

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22 DEC 1997

4/18

Substitute sheet
20 December 1997

FIG. 4A

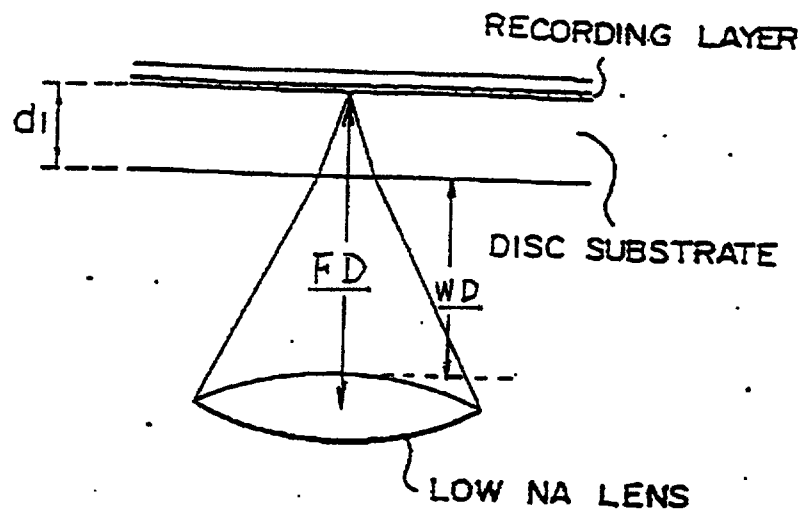
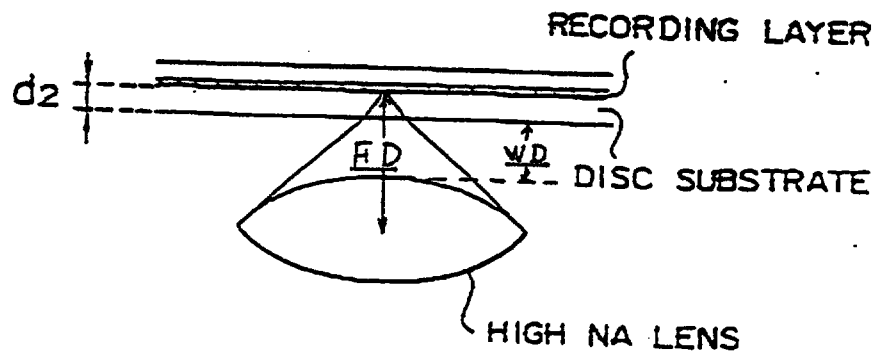
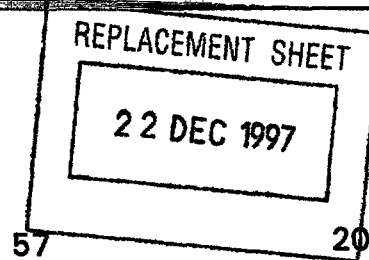


FIG. 4B





Substitute sheet
20 December 1997

We claim:

1. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:

(a) N optical heads, N being greater than or equal to 2, each comprising:

light emitting means,

objective lenses, whose aberrations have respectively been corrected for said N disc substrates having different thicknesses, each for converging the light flux which is emitted from the light emitting means onto the optical disc, and

a plurality of photo detecting means each for detecting the reflected light from the optical disc;

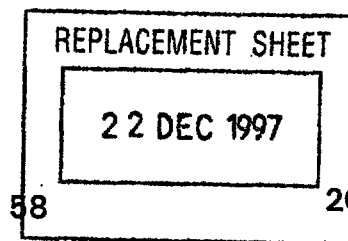
(b) N optical head moving means which are arranged below the optical disc and move the N optical heads in the radial direction of the optical disc;

(c) disc discriminating means for discriminating the thickness of the disc substrate of the loaded optical disc and for generating a discrimination signal in accordance with the result of the discrimination; and

(d) control means for selecting the optical head having the objective lens in which the occurrence of the aberration due to the disc substrate is smallest in accordance with the discrimination signal,

wherein the selected optical head records, reproduces or erases the information signal onto/from the optical disc.





Substitute sheet
20 December 1997

2. An apparatus according to claim 1, further comprising backward moving means for moving the nonselected optical heads to the outside of the optical disc for a period of time when the optical head which has been selected by the control means is recording, reproducing, or erasing the information signal.

3. An apparatus according to claim 1, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;

a discrimination hold which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.

4. An apparatus according to claim 2, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

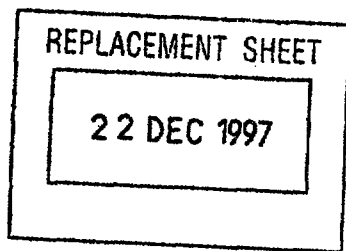
detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.



22 DEC 1997

5. An apparatus according to claim 1, wherein numerical apertures of at least two or more of said N objective lenses differ.
6. An apparatus according to claim 2, wherein numerical apertures of at least two or more of said N objective lenses differ.
7. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:
- (a) an optical head having N, N being greater than or equal to 2, converging optical systems each comprising:
 - light emitting means,
 - objective lenses, whose aberrations have respectively been corrected for said N disc substrates having different thicknesses, each for converging the light flux which is emitted from the light emitting means onto the optical disc, and
 - a plurality of photo detecting means each for detecting the reflected light from the optical disc;
 - (b) optical head moving means which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;
 - (c) disc discriminating means for discriminating the thickness of the disc substrate of the loaded optical disc and for generating a discrimination signal in accordance with the result of the discrimination; and
 - (d) control means for allowing the light emitting means, which belongs to





60

Substitute sheet
20 December 1997

the converging optical system in which the occurrence of the aberration due to the disc substrate is smallest in accordance with the discrimination signal, to emit light,

wherein the selected converging optical system records, reproduces or erases the information signal onto/from the optical disc.

8. An apparatus according to claim 7, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.

9. An apparatus according to claim 7, wherein numerical apertures of at least two or more of said N objective lenses differ.

10. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:

(a) an optical head including:

light emitting means,

light flux dividing means which are arranged in the light flux from the



22 DEC 1997

emitting means and divide the emitted light flux onto N, N being greater than or equal to 2, light fluxes and deflect in different directions,

N objective lenses, whose aberrations have respectively been corrected for said N disc substrates having different thicknesses, for respectively converging said N light fluxes onto the optical disc,

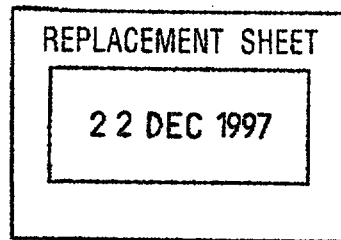
light flux selecting means for selecting one of the N light fluxes divided by the light flux dividing means and for allowing said light flux to pass, and

photo detecting means for detecting the light fluxes reflected by the optical disc;

- (b) optical head moving means which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;
- (c) disc discriminating means for discriminating the thickness of the disc substrate of the loaded optical disc and for generating a discrimination signal in accordance with the result of the discrimination; and
- (d) control means for generating a control signal to the light flux selecting means in accordance with the discrimination signal and for selecting the light flux which passes through the objective lens in which the occurrence of the aberration due to the disc substrate is smallest,

wherein the optical head records, reproduces or erases the information signal onto/from the optical disc by the selected light flux.





62

Substitute sheet
20 December 1997

11. An apparatus according to claim 10, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.
12. An apparatus according to claim 10, wherein numerical apertures of at least two or more of said N objective lenses differ.
13. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:

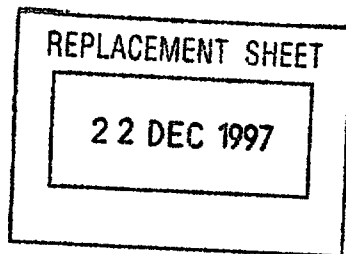
(a) an optical head including:

an optical waveguide formed on a substrate,

N light emitting means each for emitting a waveguide light into said optical waveguide, N being greater than or equal to 2,

N converging grating couplers, whose aberrations have respectively been corrected for said N disc substrates having different thicknesses, each for emitting the waveguide light supplied from said N light emitting means to the outside of the optical waveguide and for allowing the reflected light from the optical disc to enter, and





63

Substitute sheet
20 December 1997

N photo detecting means each for detecting reflected light and for generating an information signal;

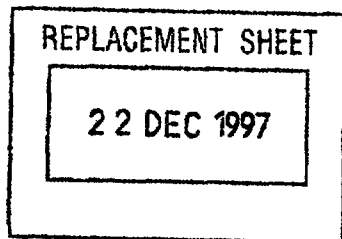
- (b) optical head moving means which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;
- (c) selecting means for selecting the light emitting means to be allowed to emit the light from among the N emitting means;
- (d) disc discriminating means for discriminating the thickness of the disc substrate of the loaded optical disc and for generating a discrimination signal according to the result of the discrimination; and
- (e) control means for generating a control signal in accordance with the discrimination signal, for providing said control signal to said selecting means and for allowing the light emitting means for emitting the waveguide light into the converging grating coupler in which the occurrence of the aberration due to the disc substrate is smallest,

wherein the optical head records, reproduces or erases the information signal onto/from the optical disc by the light flux from the selected light emitting means.

14. An apparatus according to claim 13, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;





64

Substitute sheet
20 December 1997

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.

15. An apparatus according to claim 13, wherein numerical apertures of at least two or more of the N converging grating couplers differ.
16. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:

(a) an optical head including:

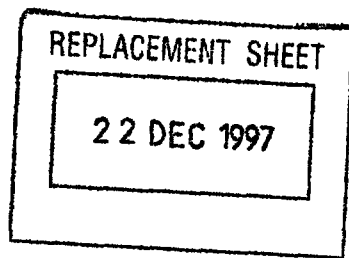
an optical waveguide formed on a substrate,

light emitting means for emitting a waveguide light into said optical waveguide,

light flux dividing means for dividing the waveguide light emitted from the light emitting means into N divided waveguide lights, N being greater than or equal to 2,

said N converging grating couplers, whose aberrations have respectively been corrected for said N disc substrates having different thicknesses, each for emitting each of said N divided waveguide lights to the outside of the optical waveguide and for allowing the reflected light from the optical disc to enter, and





65

Substitute sheet
20 December 1997

N photo detecting means for respectively detecting said reflected lights from the N converging grating couplers and for generating information signals;

- (b) optical head moving means which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;
- (c) output switching means for selecting and outputting one of the output signals of said N photo detecting means;
- (d) disc discriminating means for discriminating the thickness of the disc substrate of the loaded optical disc and for generating a discrimination signal in accordance with the result of the discrimination; and
- (e) control means for generating a control signal to the output switching means in accordance with the discrimination signal and for selecting the photo detecting means into which the waveguide light enters from the converging grating coupler in which the occurrence of the aberration due to the disc substrate is smallest.

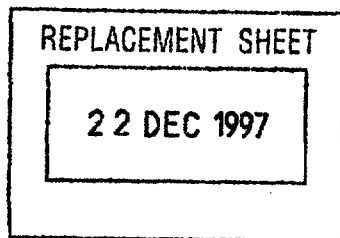
17. An apparatus according to claim 16, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.





66

Substitute sheet
20 December 1997

18. An apparatus according to claim 16, wherein numerical apertures of at least two or more of the N converging grating couplers differ.
19. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal by converging a light flux onto/from a recording layer through a transparent disc substrate, comprising:

(a) an optical head including:

an optical waveguide formed on a substrate,

light emitting means for emitting a waveguide light into said optical waveguide,

optical path switching means which is arranged on an optical path of said waveguide light and switches the propagating direction of the waveguide light in N directions in accordance with a control signal, N being greater than or equal to 2,

N converging grating couplers, whose aberrations have respectively been corrected for said N disc substrates having different thicknesses and which are respectively arranged in said N propagating directions which are switched by said optical path switching means and emit the waveguide light

to the outside of the optical waveguide and allow the reflected light from the optical disc to enter, and

photo detecting means for detecting the reflected light and generating an information signal;



REPLACEMENT SHEET

22 DEC 1997

67

Substitute sheet
20 December 1997

- (b) optical head moving means which is arranged below the optical disc and moves the optical head in the radial direction of the optical disc;
- (c) disc discriminating means for discriminating the thickness of the disc substrate of the loaded optical disc and for generating the discrimination signal in accordance with the result of the discrimination; and
- (d) control means for generating a control signal to the optical path switching means in accordance with the discrimination signal and for switching the propagating direction of the waveguide light from the light emitting means to the direction of the converging grating coupler in which the occurrence of the aberration due to the disc substrate is smallest,

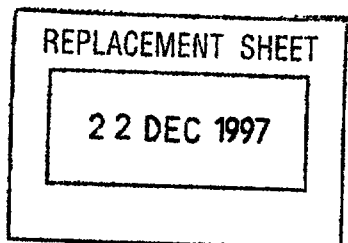
wherein the optical head records, reproduces or erases the information signal onto/from the optical disc by the light flux emitted from the selected converging grating coupler.

20. An apparatus according to claim 19, wherein said optical path switching means combines deflecting means for changing the propagating direction of the waveguide light by a deflection angle according to a input signal,

and wherein said apparatus comprises:

tracking error detecting means for detecting a tracking error amount of a converged spot which has been converged onto the optical disc and for generating a tracking error signal; and





68

Substitute sheet
20 December 1997

tracking control means for changing the input signal to the deflecting means in accordance with said tracking error signal and for eliminating the tracking error of the converged spot.

21. An apparatus according to claim 19, wherein said disc discriminating means comprises:

a cartridge for enclosing the optical disc;

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.

22. An apparatus according to claim 20, wherein said disc discrimination means comprises:

a cartridge for enclosing the optical disc;

a discrimination hole which is formed on the cartridge and whose opening/closing state differs in correspondence to the thickness of the disc substrate of the optical disc; and

detecting means for detecting the opening/closing state of the discrimination hole and for generating a discrimination signal.

23. An apparatus according to claim 19, wherein numerical apertures of at least two or more of the N converging grating couplers differ.



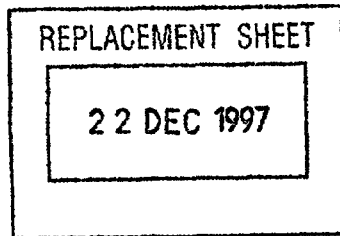
22 DEC 1997

24. An apparatus according to claim 20, wherein numerical apertures of at least two or more of the N converging grating couplers differ.
25. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from an optical disc having at least a transparent substrate and an information layer by converging a light flux onto said information layer through said transparent substrate, comprising an optical means having one of (a) N (where $N \geq 2$) different numerical apertures, (b) N different focal distances and (c) N different working distances, for converging the light flux on said information layer, wherein said optical disc corresponds to one of N types of optical discs provided with transparent substrates having different thicknesses and said optical converging means converges said light flux by employing one of (a) a larger one of said N numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, with respect to one of said optical discs having a thinner one of said substrates.
26. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any selected one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

at least one light emitting means for emitting said light flux;

N converging means having one of (a) different numerical apertures, (b) different focal distances and (c) different working distances and performing aberration correction over a transparent substrate of a respective one of said N optical discs, each of said N converging means operating to converge said light flux on the information layer of one of the N optical discs; and





70

Substitute sheet
20 December 1997

at least one photo detecting means for detecting reflected light from said optical discs,

wherein one of said converging means having (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical discs having a thinner one of said transparent substrates.

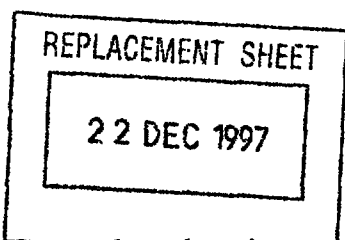
27. An optical recording/reproducing apparatus according to claim 26, wherein each of said N converging means is an objective lens.
28. An optical recording/reproducing apparatus according to claim 26, wherein each of said N converging means is a grating lens.
29. An optical recording/reproducing system for recording, reproducing or erasing an information signal onto/from any selected one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

at least one light emitting means for emitting said light flux;

a single converging means for converging said light flux on said information layer;

at least one optical wave front transforming means, at least one of said at least one optical wave front transforming means being disposed in an optical path connecting a light source, said converging means and one of said N optical discs; and





71

Substitute sheet
20 December 1997

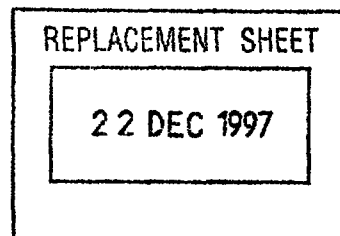
at least one ~~photo detecting means~~ for detecting reflected light from said one of said N optical discs,

wherein N composite converging optical systems having one of (a) different numerical apertures, (b) different focal distances and © different working distances and each including said converging means and one of said N optical wave front transforming means respectively perform aberration correction over a transparent substrate of a respective one of said N optical discs, and one of said composite converging optical systems having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical discs having a thinner one of said transparent substrates.

30. An optical recording/reproducing apparatus according to claim 29, wherein said converging means is an objective lens.
31. An optical recording/reproducing apparatus as in claim 29, wherein said converging means is a grating lens.
32. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any selected one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:
 - (a) N (where $N \geq 2$) optical heads each including: (i) a light emitting means for emitting a light flux, (ii) a converging means for converging the light flux emitted from said light emitting means onto an information layer of one of said N optical discs loaded in said apparatus and (iii) at



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Substitute sheet
20 December 1997

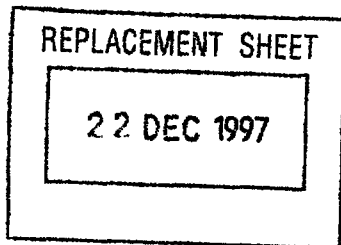
least one photo detecting means for detecting reflected light from said one of said N optical discs;

- (b) optical head moving means, adapted to be arranged on one side of an optical disc loaded in said apparatus, for moving said N optical heads in a radial direction of said optical disc loaded in said apparatus; and
- (c) control means for selecting one of said N optical heads,

wherein said converging means of each of said N optical heads have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over transparent substrates of respective ones of said N optical discs, one of said N optical heads provided with one of said converging means having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical discs having a thinner one of said transparent substrates, and said one of said N optical heads selected by said control means performs a recording, reproducing or erasing operation of said information signal on an optical disc loaded in said apparatus.

- 33. An apparatus according to claim 32, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and wherein said control means selects one of said N optical heads provided with one of said converging means that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.
- 34. An apparatus according to claim 33, wherein said discriminating means comprises:





73

Substitute sheet
20 December 1997

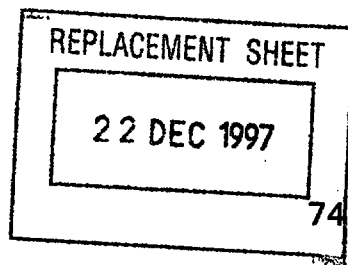
a cartridge for enclosing the optical disc loaded in said apparatus;

said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on a type of said optical disc loaded in said apparatus; and

detecting means for detecting the open/closed state characteristic of said discrimination hole.

35. An apparatus according to claim 32, further comprising backward-moving means, operative when the optical head is selected by said control means, for moving ones of the optical heads not selected by said control means to outside of the selected optical disc during a recording, reproducing or erasing operation of said information signal.
36. An apparatus according to claim 32, further comprising a light emission control circuit for controlling intensity of the light flux emitted by said light emitting means; a focus control circuit for controlling a focus position of the light flux converged on the optical disc; a tracking control circuit for controlling a tracking position of the light flux converged on the optical disc; and an optical head movement control circuit for controlling said optical head moving means; at least one of said light emission control circuit, said focus control circuit, said tracking control circuit and said optical head movement control circuit being switched with respect to one of the N optical heads selected by said control means.
37. An apparatus according to claim 32, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3mm and





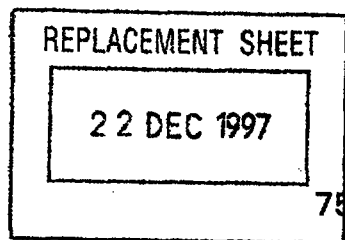
Substitute sheet
20 December 1997

about 1.2mm and said converging means have numeral apertures which include at least one of about 0.45 and about 0.8.

38. An optical recording/reproducing apparatus according to claim 32, wherein said converging means is an objective lens.
39. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:
 - (a) an optical head provided with N (where $N \geq 2$) optical systems each including (i) light emitting means for emitting said light flux, (ii) a converging means for converging the light flux emitted from said light emitting means onto an information layer of one of said N optical discs loaded in said apparatus and (iii) photo detecting means for detecting reflected light from said one of said N optical discs;
 - (b) optical head moving means, adapted to be arranged on one side of an optical disc loaded in said apparatus, for moving said optical head in a direction of the optical disc loaded in said apparatus to traverse a recording track thereof; and
 - (c) control means for causing light emission of said light emitting means in one of said N focus optical systems,

wherein said converging means of said N optical systems have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over





Substitute sheet
20 December 1997

transparent substrates of respective ones of said N optical discs, one of said N optical systems provided with one of said converging means having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical disc having a thinner one of said transparent substrates, and the one of said focus optical systems having said light emitting means caused to emit light by said control means performs a recording, reproducing or erasing operation of said information signal on an optical disc loaded in said apparatus.

40. An apparatus according to claim 39, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and wherein said control means causes light emission of the light emitting means of one of said

focus optical systems having the converging means that generates a least aberration due to the transparent substrate of the loaded optical disc.

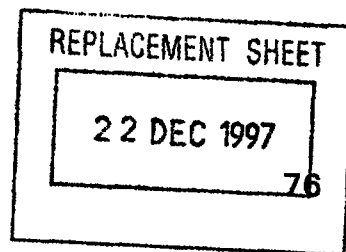
41. An apparatus according to claim 40, wherein said discriminating means comprises;

a cartridge for enclosing the optical disc loaded in said apparatus;

said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on a type of said optical disc loaded in said apparatus; and

detecting means for detecting the open/closed state characteristic of said discrimination hole.

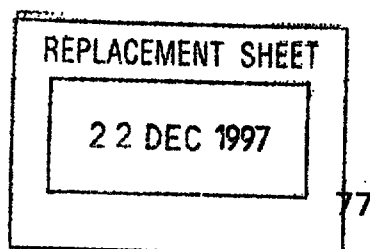




Substitute sheet
20 December 1997

42. An apparatus according to claim 39, further comprising a light emission control circuit for controlling intensity of the light flux emitted by said light emitting means; a focus control circuit for controlling a focus position of the light flux converged on the optical disc; and a tracking control circuit for controlling a tracking position of the light flux converged on the optical disc; at least one of said light emissions control circuit, said focus control circuit and said tracking control circuit being switched with respect to the selected one of the N optical heads having the focus optical system having said light emitting means caused to emit light by said control means.
43. An apparatus according to claim 39, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging means have numeral apertures which include at least one of about 0.45 and about 0.8.
44. An apparatus according to claim 39, wherein said converging means is an objective lens.
45. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:
- (a) an optical head including (i) a light emitting means for emitting a light flux, (ii) a light flux dividing means arranged in a radiation direction of said light emitting means for dividing the light flux emitted from said light emitting means into N (where $N \geq 2$) light fluxes, (iii) N





Substitute sheet
20 December 1997

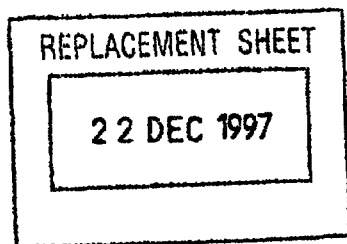
converging means for converging said N light fluxes onto said information layer of one of said optical discs loaded in said apparatus and (iv) at least one photo detecting means for detecting reflected light from said one of said optical discs loaded in said apparatus; and

- (b) optical head moving means, adapted to be arranged on one side of said optical disc loaded in said apparatus, for moving said optical head relative to the optical disc loaded in said apparatus to traverse a recording track thereof;

wherein said N converging means have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over transparent substrates of respective ones of said N optical discs, one of said converging means having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical discs having a thinner one of said transparent substrates, and said optical head performs a recording, reproducing or erasing operation of said information signal on said optical disc loaded in said apparatus.

46. An apparatus according to claim 45, further comprising light flux selecting means for selecting and passing one of the N light fluxes divided by said light flux dividing means according to a control signal and control means for outputting said control signal to said light flux selecting means to select the light flux to be passed through one of the N converging means.
47. An apparatus according to claim 46, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and wherein said control means selects one of the light fluxes according to said





discrimination signal to be passed through one of the converging means that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.

48. An apparatus according to claim 47, wherein said discriminating means comprises:

a cartridge for enclosing the optical disc loaded in said apparatus;

said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on a type of said optical disc loaded in said apparatus; and

detecting means for detecting the open/closed state characteristic of said discrimination hole.

49. An apparatus according to claim 45, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging means have numeral apertures which include at least one of about 0.45 and about 0.8.
50. An optical recording/reproducing apparatus according to claim 45, wherein said converging means is an objective lens.
51. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:



REPLACEMENT SHEET

22 DEC 1997

79

Substitute sheet
20 December 1997

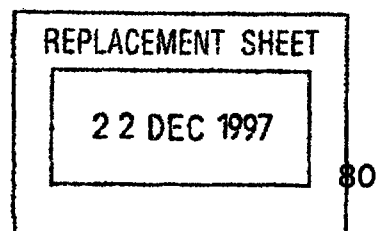
(a) an optical head including (i) light emitting means for emitting said light flux, (ii) a converging means for converging said light flux onto said information layer, (iii) N (where $N \geq 2$) optical wave front transforming means, and (iv) at least one photo detecting means for detecting reflected light from the optical disc; and

(b) optical head moving means, adapted to be arranged on one side of an optical disc loaded in said apparatus, for moving said optical head relative to the optical disc loaded in said apparatus to traverse a recording track thereof;

wherein a plurality of converging optical systems comprising at least one of (i) said converging means and (ii) said N optical wave front transforming means have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over respective transparent substrates of said N optical discs, one of said converging optical systems having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances is selected for one of said N optical discs having a thinner one of said transparent substrates, and said selected converging optical system performs a recording, reproducing or erasing operation of said information signal on said optical disc loaded in said apparatus.

52. An apparatus according to claim 51, wherein said optical head further includes holding means for holding said N optical wave front transforming means and for, responsive to a control signal, placing a selected one of said N optical wave front transforming means in an optical path between said light emitting means and said objective lens and control means for outputting said control signal to said holding means to place said selected one of said N optical wave front transforming means in the optical path between said light emitting means and said converging means.





Substitute sheet
20 December 1997

53. An apparatus according to claim 51, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and wherein said control means selects one of the light fluxes according to said discrimination signal to be passed through one of the converging optical systems that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.

54. An apparatus according to claim 53, wherein said discrimination means comprises:

a cartridge for enclosing the optical disc loaded in said apparatus;

said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on a type of said optical disc loaded in said apparatus; and

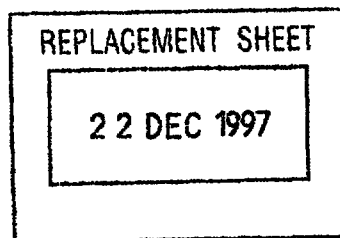
detecting means for detecting the open/closed state characteristic of said discrimination hole.

55. An apparatus according to claim 51, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging optical systems have disc side numeral apertures which include at least one of about 0.45 and about 0.8.

56. An optical recording/reproducing apparatus according to claim 51, wherein said converging means is an objective lens.

57. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said





81

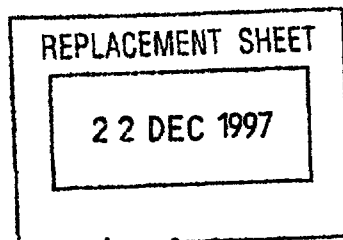
Substitute sheet
20 December 1997

optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

- (a) an optical head including (i) a waveguide formed on a substrate, (ii) N (where $N \geq 2$) light emitting means for directing waveguide light into said waveguide, (iii) N converging grating couplers for directing the waveguide light received from said N light emitting means to outside of said waveguide and for receiving reflected light from an optical disc loaded in said apparatus and (iv) N photo detecting means for detecting said reflected light through said converging grating couplers and for outputting the detected light as said information signal;
- (b) an optical head moving means, adapted to be arranged on one side of the optical disc loaded in said apparatus, for moving said optical head in a radial direction of the optical disc loaded in said apparatus; and
- (c) control means for providing a control signal to select one of said N light emitting means to emit light,

wherein said N converging grating couplers have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over transparent substrates of respective ones of said N optical disc, one of said converging grating couplers having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical discs having a thinner one of said transparent substrates, and the light flux emitted from said selected light emitting means causes said optical head to perform a recording, reproducing or erasing





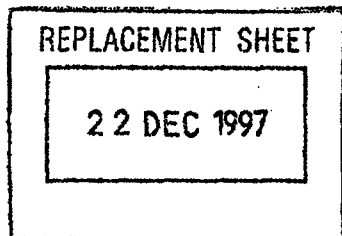
82

Substitute sheet
20 December 1997

operation of said information signal on said optical disc loaded in said apparatus.

58. An apparatus according to claim 57, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and wherein said control means causes light emission of the light emitting means of one of said converging grating couplers that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.
59. An apparatus according to claim 58, wherein said discriminating means comprises:
- a cartridge for enclosing the optical disc loaded in said apparatus;
- said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on a type of said optical disc loaded in said apparatus; and
- detecting means for detecting the open/closed state characteristic of said discrimination hole.
60. An apparatus according to claim 57, further comprising a light emission control circuit for controlling intensity of the light flux emitted by said light emitting means, said light emission control circuit being switched with respect to the selected one of the N converging grating couplers.
61. An apparatus according to claim 57, wherein the transparent substrates of said N optical discs having thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging grating couplers have numerical apertures which include at least one of about 0.45 and about 0.8.





83

Substitute sheet
20 December 1997

62. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

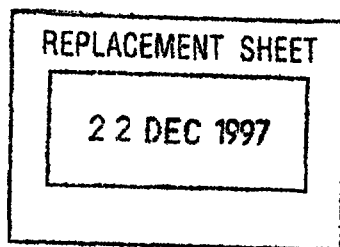
(a) an optical head including (i) a waveguide formed on a substrate, (ii) light emitting means for directing waveguide light into said waveguide, (iii) light flux branching means for branching the waveguide light received from said light emitting means into N (where $N \geq 2$) branch waveguide lights, (iv) N converging grating couplers for directing said N branch waveguide lights to outside of said waveguide and also for receiving reflected light from the optical disc loaded in said apparatus and (v) N photo detecting means for detecting said reflected light through said N converging grating couplers and for outputting the detected light as said information signal;

(b) an optical head moving means, adapted to be arranged on one side of the optical disc loaded in said apparatus, for moving said optical head in a radial direction of the optical disc loaded in said apparatus; and

(c) control means for providing a control signal to select and output one of the output signals of said N photo detecting means,

wherein said N converging grating couplers have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over transparent substrates of respective ones of said N optical discs, one of said converging grating couplers having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected





84

Substitute sheet
20 December 1997

for use with one of said N optical disc having a thinner one of said transparent substrates, and said optical head performs a recording, reproducing or erasing operation of said information signal on said optical disc loaded in said apparatus.

63. An apparatus according to claim 62, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and wherein said control means selects one of the output signals of said photo detecting means for detecting the reflected light returned through the converging grating coupler that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.

64. An apparatus according to claim 63, wherein said discriminating means comprises:

a cartridge for enclosing the optical disc loaded in said apparatus;

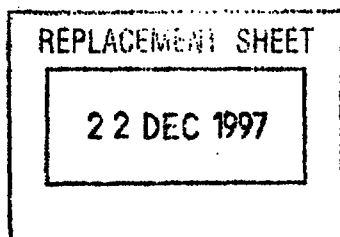
said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on the type of said optical disc loaded in said apparatus; and

detecting means for detecting the open/closed state characteristic of said discrimination hole.

65. An apparatus according to claim 62, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging grating couplers have numerical apertures which include at least one of about 0.45 and about 0.8.

66. An optical recording/reproducing apparatus for recording, reproducing or





85

Substitute sheet
20 December 1997

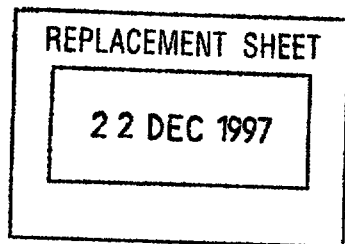
erasing an information signal onto/from any one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

(a) an optical head including (i) a waveguide formed on a substrate, (ii) light emitting means for directing waveguide light into said waveguide, (iii) optical path switching means arranged in an optical path of said waveguide light for switching a propagation direction of said waveguide light according to a control signal to N (where $N \geq 2$) propagation directions, (iv) N (where $N \geq 2$) converging grating couplers, arranged in the N propagation directions switched by said optical path switching means, for directing waveguide lights travelling in said N propagation directions to outside of said waveguide and for receiving reflected light from the optical disc loaded in said apparatus and (v) photo detecting means for detecting said reflected light through said converging grating couplers and for outputting the reflected light as said information signal; and

(b) an optical head moving means, adapted to be arranged on one side of the optical disc loaded in said apparatus, for moving said optical head in a radial direction of the optical disc loaded in said apparatus,

wherein said N converging grating couplers have one of (a) respective numerical apertures, (b) respective focal distances and (c) respective working distances and perform aberration correction over transparent substrates of respective ones of said N optical discs, one of said N converging grating couplers having one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances, is selected for use with one of said N optical discs having a thinner one of said transparent substrates, and said optical head performs a recording,





86

Substitute sheet
20 December 1997

reproducing or erasing operation of said information signal on said optical disc loaded in said apparatus.

67. An apparatus according to claim 66, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging grating couplers have numeral apertures which include at least one of about 0.45 and about 0.8.
68. An apparatus according to claimed 66, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and control means for outputting said control signal to said optical path switching means in response to said discrimination signal to switch the propagation direction of the waveguide light from the light emitting means to a direction of one of said converging grating couplers that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.
69. An apparatus according to claim 68, wherein said discriminating means comprises:
- a cartridge for enclosing the optical disc loaded in said apparatus;
- said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on the type of said optical disc loaded in said apparatus; and
- detecting means for detecting the open/closed state characteristic of said discrimination hole.

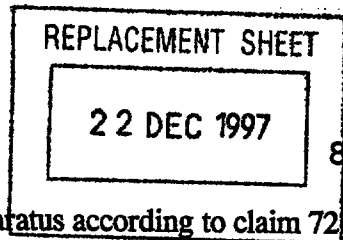


22 DEC 1997

70. An apparatus according to claim 66, wherein said optical path switching means includes deflecting means for changing the propagation direction of the waveguide light by a deflection angle corresponding to a predetermined input signal; tracking error detecting means for detecting a tracking error quantity of a spot converged on the optical disc and for outputting said tracking error quantity as a tracking error signal; and tracking control means for changing said input signal to said deflection means according to said tracking error signal to remove a tracking error of said converged spot.
71. An apparatus according to claim 66, wherein said optical path switching means is a surface acoustic wave transducer arranged to intersect with the optical path of the waveguide light emitted from said light emitting means.
72. An optical recording/reproducing system for recording, reproducing or erasing an information signal onto/from any one of plural optical discs each having at least a transparent substrate and an information layer by converging a light flux on said information layer through said transparent substrate, said system comprising:
- a plurality of optical heads;
- a plurality of optical head moving means, adapted to be arranged on one side of an optical disc loaded in said apparatus in a radial direction of said optical disc on a center thereof, for moving said optical head in a direction relative to the optical disc so as to traverse a recording track thereof; and
- a cartridge for enclosing any one of said optical discs and having N openings arranged in a radial direction of an optical disc enclosed therein on the center thereof.



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Substitute sheet
20 December 1997

73. An apparatus according to claim 72, wherein said optical discs have transparent substrates of different thicknesses.
74. An apparatus according to claim 72, wherein the N openings of said cartridge are mutually independently opened and closed.
75. An apparatus according to claim 72, wherein said cartridge has a discrimination hole for providing an indication of a type of the optical disc loaded in said apparatus.
76. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from an optical disc having at least a transparent substrate and an information layer by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

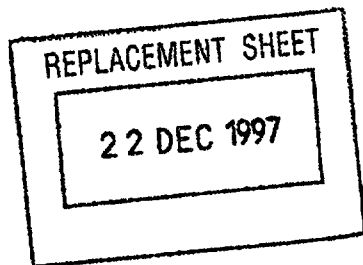
at least one light emitting means for emitting a light flux;

a converging means for converging said light flux on said information layer of one of N (where $N \geq 2$) optical discs loaded in said apparatus and performing aberration correction over respective transparent substrates of said N optical discs having different thicknesses; and

at least one photo detecting means for detecting reflected light from said optical disc loaded in said apparatus through said converging means and for outputting the detected reflected light as an electrical signal,

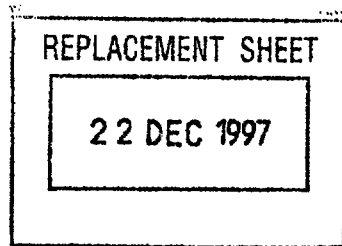
wherein the thickness of the transparent substrate of the optical disc is discriminated by said electrical signal.





77. An optical recording/reproducing apparatus according to claim 76, wherein said converging means is one of an objective lens and a grating lens.
78. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from an optical disc having at least a transparent substrate and an information layer by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:
- at least one light emitting means for emitting a light flux;
- a signal objective lens for converging said light flux on said information layer;
- N (where $N \geq 2$) optical wave front transforming elements one of which is arranged in an optical path between said light emitting means and said objective lens; and
- at least one photo detecting means for detecting reflected light from said optical disc through said objective lens and for outputting the detected reflected light as an electrical signal,
- wherein composite converging optical systems corresponding to combinations of (i) said objective lens and (ii) said N optical wave front transforming means perform aberration correction over respective transparent substrates of N optical discs having different thicknesses, and the thickness of the transparent substrate of the optical disc loaded in said apparatus is discriminated by said electrical signal.
79. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from an optical disc having at least a transparent substrate and an information layer by converging a light flux on





Substitute sheet
20 December 1997

said information layer through said transparent substrate, said apparatus comprising:

at least one light emitting means for emitting a light flux;

N grating lenses for performing aberration correction over respective transparent substrates of N (where $N \geq 2$) optical discs having different thicknesses to converge said light flux on said information layer of one of said optical discs loaded in said apparatus; and

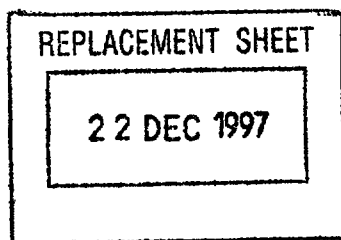
at least one photo detecting means for detecting reflected light from said optical disc loaded in said apparatus through said grating lenses and for outputting the detected reflected light as an electrical signal,

wherein the thickness of the transparent substrate of the optical disc loaded in said apparatus is discriminated by said electrical signal.

80. An optical recording/reproducing apparatus for recording, reproducing or erasing an information signal onto/from any one of N types (where $N \geq 2$) of optical discs having transparent substrates of different thicknesses, each of said N optical discs having at least a transparent substrate and an information layer, by converging a light flux on said information layer through said transparent substrate, said apparatus comprising:

(a) an optical head including (i) light emitting means for emitting said light flux, (ii) optical means for converging said light flux onto said information layer, and (iii) at least one photo detecting means for detecting reflected light from the optical disc; and





91

Substitute sheet
20 December 1997

(b) optical head moving means, adapted to be arranged on one side of an optical disc loaded in said apparatus, for moving said optical head relative to the optical disc loaded in said apparatus to traverse a recording track thereof;

wherein said optical means comprises one of (a) N different numerical apertures, (b) N different focal distances and (c) N different working distances and performs aberration correction over respective transparent substrates of said N optical discs, one of (a) a larger one of said numerical apertures, (b) a shorter one of said focal distances and (c) a shorter one of said working distances is selected for one of said N optical discs having a thinner one of said transparent substrates, and said optical means performs a recording, reproducing or erasing operation of said information signal on said optical disc loaded in said apparatus.

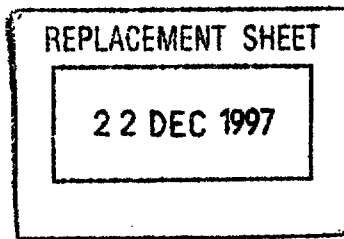
81. An apparatus according to claim 80, further comprising disc discriminating means for discriminating a type of said optical disc loaded in said apparatus and for outputting a discrimination signal according to a discrimination result, and a control means for selecting the converged light flux, according to said discrimination signal, that generates a least aberration due to the transparent substrate of the optical disc loaded in said apparatus.

82. An apparatus according to claim 81, wherein said discriminating means comprises:

a cartridge for enclosing the optical disc loaded in said apparatus;

said cartridge having a discrimination hole which has an open/closed state characteristic which differs depending on a type of said optical disc loaded in said apparatus; and





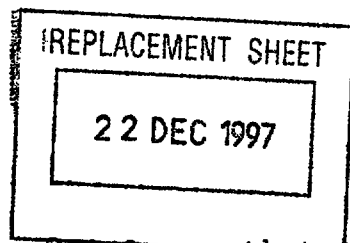
92

Substitute sheet
20 December 1997

detecting means for detecting the open/closed state characteristic of said discrimination hole.

83. An apparatus according to claim 80, wherein the transparent substrates of said N optical discs have thicknesses which include at least one of about 0.3 mm and about 1.2 mm and said converging optical systems have disc side numeral apertures which include at least one of about 0.45 and about 0.8.





Substitute sheet
20 December 1997

an NA of 0.8, so that the laser beam can be converged until a spot diameter of $1.2 \mu\text{m}$. Moreover, an optical design of the objective lens has been made so as to correct the aberration by the disc substrate of the thickness d_2 .

In Figs 4A and 4B respective focal distances FD and working distances WD are shown.

The operation of the optical disc apparatus of the embodiment constructed as mentioned above will now be described herein below.

First, the case where the cartridge 2 enclosing the second optical disc has been loaded into the optical disc apparatus of the embodiment will be described. When the cartridge 2 is loaded, the LED 8 emits the light and the photo diode 9 detects the presence or absence of a transmission light which passes through the discrimination hole 7. As already described in conjunction with Figs. 3A and 3B, since the discrimination hole 7 is open in the case of the second optical disc, the photo diode 9 detects the transmission light and generates a detection signal to the controller 22. The controller 22 determines that the disc in the loaded cartridge 2 is the second optical disc, so that the controller 22 supplies control signals to the first to fifth selectors 10, 12, 14, 16, and 21 so as to select the terminals B on the second optical head side. Thus, the semiconductor laser of the second optical head 5 is selected as an output destination of the driving current which is supplied from the LD driving circuit 20. The photo detector of the second optical head 5 is