



DISPLACEMENT INFORMATION DETECTING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

5 This invention relates to a displacement
information detecting apparatus, and particularly to
the field of displacement measurement for optically
measuring displacement information such as the amount
of displacement of an object and the displacement speed
10 of an object.

Related Background Art

 An encoder has heretofore been widely used to
measure the amount of displacement, the displacement
speed, etc. of an object. Most of methods of optically
15 measuring them use a movable grating and a reference
grating.

 (a-1) Generally, the reference grating is provided
integrally with a light source and a light receiving
portion, and is also called a fixed grating.

20 (a-2) On the other hand, as a special detecting
system, there is proposed a displacement measuring
apparatus having a detecting optical system by a
construction using a portion of a movable grating as a
reference grating as disclosed in Japanese Patent
25 Publication No. 36-11793, i.e., a so-called
self-projection type construction.

 Particularly, an encoder is of a simple

construction and yet can detect an amount of angular displacement, an amount of movement, etc. and is therefore widely used in machine tools and measuring apparatuses.

5 Fig. 1 of the accompanying drawings is a schematic view of the essential portions of an encoder proposed in Japanese Patent Publication No. 36-11793. In Fig. 1, a light beam from a light source 201 passes through an opening 202a formed in a base plate 202, whereafter
10 it enters a first area 204a of an optical scale 204 as a displaceable object provided with a radial grating (linear grating) as a substantially parallel light beam by means of a lens system 203.

 The light from the grating of the first area 204a
15 of the optical scale 204 is introduced to a second area 204b of the optical scale 204 through a lens system 205, a corner cube 206 and a lens system 207, and forms a grating image on the surface thereof. The light beam which had passed through the second area 204b is
20 condensed by a lens system 208 and is detected by a light receiving element 209.

 When at this time, the optical scale 204 moves in the direction of arrow 204c, the image formed on the optical scale 204 is displaced in the opposite
25 direction and therefore, a signal of a period twice as great as the grating resolving power (grating pitch) is obtained in the light receiving element 209.

The encoder shown in Fig. 1 obtains the displacement information of the optical scale 204 by the utilization of the periodic signal obtained by the light receiving element 209.

5 A system using this self-projection type detecting optical system has the following features:

(b-1) A detecting head which does not depend on the grating pitch can be realized.

(b-2) A periodic signal of double multiplication
10 of the grating resolving power is obtained.

Industrially, the feature (b-1) has a great merit in the market of encoder of which various resolving powers are required, and a detecting head of high flexibility having no resolution dependency can be
15 provided, and the lower cost by mass production is possible. Also, high resolving power detection is possible by the feature (b-2).

Because of a position detecting system having the detecting optical system by the self-projection type
20 construction having many excellent features as described above, there is required a method of obtaining a phase difference signal of 2CH or greater necessary as an encoder by a more compact construction.

25 SUMMARY OF THE INVENTION

It is a first object of the present invention to provide, in a displacement measuring apparatus having

the above-described self-projection type detecting
optical system according to the conventional art, an
information detecting apparatus using a phase
difference detecting system which can be made more
5 compact.

It is a second object of the present invention to
provide a displacement information detecting apparatus
suitable for a linear encoder or the like which can
reduce the space for the disposition of each member and
10 can achieve the simplification of the entire apparatus
and can alleviate the allowable error of the
disposition of each member and yet can detect the
displacement information of a displaceable object.

Other objects of the present invention will become
15 apparent from the following detailed description of
some embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of the essential
20 portions of an encoder according to the conventional
art.

Fig. 2 is a perspective view of the essential
portions of Embodiment 1 of the present invention.

Fig. 3 is a perspective view of the essential
25 portions of Embodiment 1 of the present invention.

Fig. 4 is an illustration of a portion of
Embodiment 1 of the present invention.

Figs. 5A, 5B and 5C are illustrations of a portion of Embodiment 1 of the present invention.

Fig. 6 is a perspective view of the essential portions of Embodiment 2 of the present invention.

5 Fig. 7 is a perspective view of the essential portions of Embodiment 2 of the present invention.

Fig. 8 is a cross-sectional view of the essential portions of Embodiment 2 of the present invention.

10 Fig. 9 is an illustration of an optical scale and a concave mirror in Embodiment 2 of the present invention.

Fig. 10 is an illustration of the optical scale in Embodiment 2 of the present invention.

15 Figs. 11A, 11B and 11C are illustrations of the grating portion of the optical scale and a signal from light receiving means in Embodiment 2 of the present invention.

20 Fig. 12 is an illustration of an image re-formed on the optical scale in Embodiment 2 of the present invention.

Fig. 13 is an illustration of a scale pitch and a superposed pitch with respect to the decentered amount of a concave surface in Embodiment 2 of the present invention.

25 Fig. 14 is an illustration of the scale pitch and the superposed pitch with respect to the decentered amount of the concave mirror in Embodiment 2 of the

present invention.

Figs. 15A and 15B are cross-sectional views of the essential portions of Embodiment 2 of the present invention.

5 Figs. 16A, 16B and 16C are illustrations showing the incident state of a light beam onto the optical scale in Embodiment 2 of the present invention.

Figs. 17A, 17B and 17C are illustrations showing another form of the incident state of a light beam onto
10 the optical scale in Embodiment 2 of the present invention.

Fig. 18 is a cross-sectional view of the essential portions of Embodiment 3 of the present invention.

Fig. 19 is a cross-sectional view of the essential
15 portions of Embodiment 4 of the present invention.

Fig. 20 is a cross-sectional view of the essential portions of Embodiment 5 of the present invention.

Fig. 21 is an enlarged perspective view of a portion of Fig. 20.

20 Figs. 22A and 22B are illustrations of another embodiment of the optical scale according to the present invention.

Figs. 23A and 23B are illustrations of another embodiment of the optical scale according to the
25 present invention.

Figs. 24A and 24B are illustrations of another embodiment of the optical scale according to the

present invention.

Figs. 25A and 25B are illustrations of another embodiment of the optical scale according to the present invention.

5 Figs. 26A and 26B are illustrations of another embodiment of the optical scale according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

10 Figs. 2 and 3 are perspective views of the essential portions of Embodiment 1 of the present invention, Fig. 4 is an illustration of a portion of Embodiment 1 of the present invention, and Figs. 5A to 5C are illustrations of a portion of Embodiment 1 of
15 the present invention.

In these figures, the reference numeral 1 designates a light source comprised, for example, of an LED or a semiconductor laser which emits a coherent light beam of a wavelength λ (632.8 nm). The reference
20 numeral 2 denotes a lens system comprising a spherical lens or an aspherical lens which condenses the light beam from the light source 1 and directs it to an optical scale 31 which will be described later.

The light source 1 and the lens system 2 each
25 constitute an element of light illuminating means LR. The reference numeral 31 designates an optical scale having the phase difference detecting function and the

amplitude type diffraction grating function.

The optical scale 31 is fixed relative to a moving object (not shown) and moves in a direction indicated by arrow 31e. The optical scale 31 is provided with a grating portion 31d having a black-and-white pattern, V-grooves or the like formed at a predetermined pitch in a direction orthogonal to the direction of movement on a base plate 31c.

In the present embodiment, there is shown a case where V-grooves are used. Figs. 5A and 5B are detailed views of the grating portion 31d of the optical scale 31, and two inclined surfaces 31b-1 and 31b-2 constituting a straight V-groove portion and a flat surface portion 31a are alternately arranged at a predetermined pitch P to thereby form the grating portion 31d. The width of the V-groove is $(1/2)P$, and each of the two inclined surfaces 31b-1 and 31b-2 forming the V-groove has a width of $(1/4)P$, and is inclined at a critical angle or greater, in the present embodiment, $\theta=45^\circ$, with respect to the flat portion 31a.

In the present embodiment, of the diffracted lights from the optical scale 31, three light beams, i.e., 0th-order diffracted light and $\pm$ first-order diffracted lights, are utilized. Here, the grooves of this grating portion 31d are made linear relative to the direction of movement of the optical scale 31.

In the present embodiment, the material of the optical scale 31 is plastic such as polycarbonate or acryl, and the optical scale is made by a method such as injection molding, compression molding, sheet molding or replica. The reference numeral 4 denotes a concave mirror comprising a spherical mirror, an elliptical mirror, a parabolic mirror, an aspherical mirror or the like. The concave mirror 4 is coincident with the Fouries transformation surface of the grating portion 31d.

In the present embodiment, each element is set so that a light beam 101 condensed by the lens system 2 and having entered a first area 31a of the optical scale 31 as shown in Fig. 3 may be diffracted by the optical scale 31 and at this time, the n th-order diffracted light (0th-order and $\pm$ first-order diffracted lights $L(0)$, $L(+1)$ and $L(-1)$) may be condensed on or near the surface 4b of the concave mirror 4 (on or near the pupil position of the concave mirror 4).

As shown in Fig. 4, the principal ray 101a of the incident light beam 101 and the principal ray 102a of a re-incident light beam 102 reflected by the concave mirror 4 and onto the optical scale 31 are symmetrical with respect to the optical axis 4a of the concave mirror 4. Also, the concave mirror 4 reflects convergent light beams (three diffracted light beams) transmitted from the optical scale 31, and forms an

interference image by the superposition of the three light beams on a second area 31b on the surface of the optical scale 31 (that is, superposes the three diffracted lights one upon another and forms an interference fringe). When at this time, the optical scale 31 is moved in the direction of arrow 31e, the re-formed image moves in a direction opposite to the direction of arrow 31e. That is, the grating portion and the interference pattern image are displaced relative to each other at a value double with respect to the amount of movement of the optical scale 31.

In the present embodiment, movement information of resolving power double that of the grating portion constructed on the optical scale 31 is obtained thereby.

The reference numeral 5 designates light receiving means having three photodetectors (light receiving elements) 5a, 5b and 5c for receiving through the lens system 2 three light beams provided by a light beam based on the phase relation between the interference pattern formed near the second area 31b of the grating portion 31d of the optical scale 31 and the V-grooves of the grating portion being geometrically refracted by and emerging from the second area 31b. The signal from this light receiving means 5 is processed by signal processing means 103 having a pulse count circuit and a discrimination circuit for the direction of movement,

and movement information is obtained therefrom.

The light source 1, the lens system 2 and the light receiving means 5 are fixed and held in a housing. This housing and the concave mirror 4 are mutually in a fixedly disposed relation.

Description will now be made of a method of detecting the movement information of the optical scale (moving object) 31 in the present embodiment. The light beam from the LED 1 which is an element of the light illuminating means may be condensed on or near the reflecting surface 4b of the concave mirror 4 by the lens system 2. This convergent light is made to enter the first area 31a on the grating portion 31d of the optical scale 31. Of the convergent light which has entered the first area 31a, a ray of light which has arrived at the first area, namely flat surface portion 31a of the grating portion 31d shown in Figs. 5A and 5B passes this flat surface portion 31a and travels to the concave mirror 4, and is imaged on the surface thereof. Also, a ray of light which has arrived at the inclined surface 31b-1 constituting the V-groove is totally reflected as shown and is directed to the other inclined surface 31b-2 constituting the V-groove and is also totally reflected on the inclined surface 31b-2 because the angle of inclination of the inclined surface 31b-1 is set to the critical angle or greater.

Thus, the ray of light which has finally arrived at the inclined surface 31b-1 of the grating portion 31d does not enter the concave mirror, but is returned toward-in the direction of incidence. Likewise, the
5 ray of light which has arrived at the other inclined surface 31b-2 constituting the V-groove repeats total reflection and is returned. Accordingly, the light beam arriving at the area of the two inclined surfaces 31b-1 and 31b-2 forming the V-groove in the first area
10 31a does not enter the concave mirror but is reflected thereby, and only the ray of light which has arrived at the flat surface portion 31a travels through the optical scale 31 to the concave mirror 4.

That is, in the first area 31a, the V-groove type
15 grating portion 31d has optical action similar to that of a transmission type amplitude diffraction grating. The light beam is diffracted by this grating portion 31d of the first area 31a, and 0th-order, $\pm$ first-order, $\pm$ second-order, ... diffracted lights are created by the
20 action of the grating portion, and those diffracted lights are condensed on the surface of the concave mirror 4. The condensed diffracted lights are reflected symmetrically with respect to an optical axis 4a, as shown in Fig. 4, and are re-imaged on the second
25 area 31b of the optical scale 31, and re-form an image of one-to-one magnification on the surface of the optical scale 31.

Here, the first area 31a and the second area 31b are areas different relative to the grating portion 31d of the linear grating (which may partly overlap each other) orthogonal to the direction of movement of the surface of the optical scale 31. At this time, the grating pitches of the first area 31a and the second area 31b are same because the optical scale 31 has the straight grating portion 31d.

In the present embodiment, the grating portion 31d of the first area 31a is projected onto the second area 31b on the grating portion 31d at one-to-one magnification so that an image (an inverted image) similar to the pitch of the grating portion 31d of the optical scale 31 may be formed. For this purpose, in the present embodiment, the concave mirror 4 is set to have a desired radius of curvature R , so that the principal ray 101a of the incident light beam 101 and the principal ray 102a of the re-incident light beam 102 may be symmetrical with respect to the optical axis 4a.

Thereby, a detection signal of good S/N ratio is obtained in such a manner that the pitches of the grating coincide with each other when the image of the grating portion of the first area 31a is re-formed on the surface of the second area 31b by the concave mirror 4.

The light beam which has entered the flat surface

portion 31a in the second area 31b is rectilinearly transmitted as shown in Fig. 5B, and arrives at the central photodetector 5c of the light receiving means 5. Also, the rays of light which have arrived at the
5 two inclined surfaces 31b-1 and 31b-2 forming the V-groove surfaces enter the respective surfaces at an angle of incidence of 45° and therefore, are greatly refracted in different directions and arrive at the photodetectors 5a and 5b at the opposite sides of the
10 light receiving means 5.

Thus, in the second area 31b, the light beam is divided into three directions and travels by the three kinds of surfaces differing in the direction of inclination from one another, i.e., the two inclined
15 surfaces 31b-1 and 31b-2 inclined in different directions with respect to the incident light beam and the flat surface portion 31a between the V-grooves, and arrives at the photodetectors 5a, 5b and 5c provided at positions corresponding to the respective surfaces.
20 That is, in the second area 31b, the grating portion 31d of the V-groove functions as a light wavefront dividing element.

That is, a light beam based on the phase relation between the grating portion of the second area 31b and
25 the interference pattern image formed on the surface thereof is deflected toward in three directions and enters the photodetectors 5a, 5b and 5c.

Here, when the optical scale 31 is moved, the quantities of light detected by the respective photodetectors 5a, 5b and 5c change. The balance among the quantities of light entering the respective
5 photodetectors changes in conformity with the relative displacement of the position of the grating portion 31d and the position of the image and as the result, assuming that the optical scale 31 has been moved in the direction of movement 31e, there is obtained a
10 change in quantity of light resulting from the movement of the optical scale 31 as shown in Fig. 5C. In Fig. 5C, the axis of abscissas represents the amount of displacement of the optical scale 31 and the axis of ordinates represents the quantity of received light.

15 Signals a, b and c correspond to the photodetectors 5a, 5b and 5c, respectively. When the optical scale 31 is moved in the opposite direction, the signal a becomes the output of the photodetector 5b and the signal b becomes the output of the
20 photodetector 5a and the signal c becomes the output of the photodetector 5c. On the basis of these signals, there is obtained movement information such as the movement speed and the direction of movement of the optical scale 31.

25 In the present embodiment, design may be made such that the light beam from the LED 1 is collimated by the lens system 2 and is made to enter the first area 31a

of the optical scale 31 and n th-order diffracted lights and 0th-order light from the optical scale 31 are reflected by a flat mirror and are made to enter the second area 31b of the optical scale 31 and images (interference fringes) by the three diffracted lights are formed on the surface thereof and the three lights from the second area 31b are received by the light receiving elements 5a, 5b and 5c. That is, the grating image formed on the second area is not limited to one by an ordinary imaging element such as the concave mirror shown in Figs. 2 and 3, but may be an image by an interference fringe pattern formed on the area of intersection among three light beams, for example, by an element as shown in Fig. 21 which will be described later.

Figs. 6 and 7 are perspective views of the essential portions of Embodiment 2 of the present invention, Fig. 8 is a cross-sectional view of the essential portions of Embodiment 2 of the present invention, Fig. 9 is an illustration of an optical scale and a concave mirror in Embodiment 2 of the present invention, Fig. 10 is an illustration of the optical scale in Embodiment 2 of the present invention, Figs. 11A, 11B and 11C are illustrations of the grating portion of the optical scale in Embodiment 2 of the present invention and a signal from light receiving means, Fig. 12 is an illustration of an image re-formed

on the optical scale Embodiment 2 of the present invention, Fig. 13 is an illustration of a scale pitch and a superposed pitch to the decentered amount of a concave mirror in Embodiment 2 of the present invention, Fig. 14 is an illustration of the scale pitch and the superposed pitch to the decentered amount of the concave mirror in Embodiment 2 of the present invention, Figs. 15A and B are cross-sectional views of the essential portions of Embodiment 2 of the present invention, Figs. 16A to 16C are illustrations of another embodiment showing the incident state of a light beam onto the optical scale in Embodiment 2 of the present invention, and Figs. 17A to 17C are illustrations of another embodiment showing an incident state of the light beam onto the optical scale in Embodiment 2 of the present invention.

In these figures, the reference numeral 1 designates a light source comprised, for example, of an LED or a semiconductor laser which emits a coherent light beam of a wavelength λ (632.8 nm). The reference numeral 2 denotes a lens system which, in the present embodiment, comprises a form in which a spherical lens or an aspherical lens is partly juxtaposed and which condenses the light beam from the light source 1 on one side and directs it to an optical scale 3 which will be described later.

The light source 1 and the lens system 2 each

constitute an element of light illuminating means LR.
The reference numeral 3 designates an optical scale
having the phase difference detecting function and the
amplitude type diffraction grating function, and
5 provided with a grating portion 3d comprising a
plurality of radial gratings (V-groove gratings having
2500 or 5000 slits) of a predetermined period on the
surface of a disc-like base plate 3c as shown in Figs.
10 and 11A to 11C. The base plate 3c of the optical
scale 3 is formed of an optically transmitting optical
material such as polycarbonate or plastic, and is
mounted on a portion of a rotatable member (not shown)
and is rotating toward in the direction of arrow 6
about a rotary axis 3e with the rotatable member.

15 Figs. 11A and 11B are detailed views of the
grating portion 3d of the optical scale 3, and two
inclined surfaces 30b-1 and 30b-2 constituting a
V-groove portion and a flat surface portion 30a are
alternately arranged at a predetermined pitch P to
20 thereby form the grating portion 3d. The width of the
V-groove is $(1/2)P$, and each of the two inclined
surfaces 30b-1 and 30b-2 forming the V-groove has a
width of $(1/4)P$, and each of the inclined surfaces
30b-1 and 30b-2 is inclined at a critical angle or
25 greater, in the present embodiment, $\theta=45^\circ$, with respect
to a straight line linking the bottom of the V-groove
and a perpendicular to the flat portion 30a together.

In the present embodiment, of the diffracted lights from the optical scale 3, three light beams, i.e., 0th-order diffracted light and $\pm$ first-order diffracted lights, are utilized. Here, the V-grooves
5 of the grating portion 3d are formed radially relative to the optical scale 3 and therefore, the pitch differs between the inner peripheral side and the outer peripheral side of the optical scale 3. Here, the pitch is defined as the value of the sum of the width
10 of the circumferential flat portion 30a and the width of the two inclined surfaces 30b-1 and 30b-2.

In the present embodiment, the material of the optical scale 3 is polycarbonate or plastic and the optical scale is made by a manufacturing method such as
15 injection molding or compression molding. The reference numeral 4 designates a concave mirror comprising a spherical mirror, an elliptical mirror, a parabolic mirror, an aspherical mirror or the like. The concave mirror 4 coincides with the Fourier
20 transformation surface of the grating portion 3d.

In the present embodiment, each element is set so that a light beam 101 condensed by the lens system 2 and having entered a first area 3a of the optical scale 3 as shown in Figs. 8 and 9 may be diffracted by the
25 grating portion of the optical scale 3 and at this time, nth-order diffracted light (0th-order and $\pm$ first-order diffracted lights $L(0)$, $L(+1)$ and $L(-1)$)

may be condensed on or near the surface 4b of the concave mirror 4 (at or near the pupil position of the concave mirror 4).

5 The optical axis 4a of the concave mirror 4 and the central ray (principal ray) 101a of the incident light beam 101 are decentered with respect to each other by a decentered amount Δ as shown in Fig. 9. The concave mirror 4 reflects convergent light beams (three diffracted light beams $L(0)$, $L(+1)$ and $L(-1)$)

10 diffracted and condensed by the optical scale 3, and forms an interference pattern image (image) based on the three diffracted lights as shown in Fig. 12 on the second area 3b on the surface of the optical scale 3. When at this time, the optical scale 3 is moved toward

15 in the direction of rotation 6, the formed image moves in a direction opposite to the direction of rotation 6. That is, the grating portion and the interference pattern image are displaced relative to each other at a value double the amount of movement of the optical

20 scale 3.

In the present embodiment, rotation information of resolving power of double multiplication of the grating portion constructed on the optical scale 3 is obtained thereby.

25 The reference numeral 5 designates light receiving means having three photodetectors (light receiving elements) 5a, 5b and 5c for receiving three light beams

provided by a light beam based on the phase relation between the interference pattern as shown in Figs. 11A to 11C formed near the second area 3b of the grating portion 3d of the optical scale 3 and the V-groove of the grating portion being geometrically refracted by the second area 3b and emerging therefrom, and passed through the other side of the lens system 2 than the side during incidence. A signal from this light receiving means 5 is processed by a signal processing circuit 103 having a pulse count circuit and a discriminating circuit for the direction of rotation, and rotation information is obtained therefrom. The light source 1, the lens system 2 and the light receiving means 5 are fixed and held in a housing PK. The housing PK and the concave mirror 4 are in a fixedly disposed relation.

Description will now be made of a method of detecting the rotation information of the optical scale (rotatable member) 3 in the present embodiment. Design is made such that a light beam from LED 1 which is an element of light illuminating means is condensed on or near the reflecting surface 4b of the concave mirror 4 by the lens system 2. This convergent light is made to enter the first area 3a on the grating portion 3d of the optical scale 3, as shown in Figs. 8 and 9. Of the convergent light which has entered the first area 3a, a ray of light which has arrived at the flat surface

portion 30a of the grating portion 3d shown in Figs. 11A to 11C passes the flat surface portion 30a and travels to the concave mirror 4, and is imaged on the surface thereof. Also, a ray of light which has
5 arrived at the inclined surface 30b-1 constituting the V-groove is totally reflected as shown in Figs. 11A to 11C and is directed to the other inclined surface 30b-2 constituting the V-groove and is also totally reflected on the inclined surface 30b-2 because the angle of
10 inclination of the inclined surface 30b-1 is set to a critical angle or greater.

The ray of light which has thus finally arrived at the inclined surface 30b-1 of the grating portion 3d does not enter into the concave mirror, but is returned
15 in the direction of incidence. Likewise, the ray of light which has arrived at the other inclined surface 30b-2 constituting the V-groove repeats total reflection and is returned. Accordingly, the light beam arriving at the range of the two inclined surfaces
20 30b-1 and 30b-2 forming the V-groove in the first area 3a does not enter into the optical scale 3 but is reflected, and only the ray of light which has arrived at the flat surface portion 30a travels through the optical scale 3.

25 That is, in the first area 3a, the grating portion 3d of the V-groove type has optical action similar to that of an amplitude diffraction grating of the

transmission type. The light beam is diffracted by
this grating portion 3d of the first area 3a, and
0th-order, $\pm$ first-order, $\pm$ second-order, ... diffracted
lights are created by the action of the grating portion
5 and the diffracted lights are condensed on the surface
of the concave mirror 4. The condensed diffracted
lights are reflected by the concave mirror 4 decentered
relative to the principal ray 101a, and are imaged on
the second area 3b of the optical scale 3 and form
10 images (the images of radial grooves) on the surface of
the optical scale 3.

Here, the first area 3a and the second area 3b are
areas which are radially different relative to the
grating portion 3d of the radial grating on the surface
15 of the optical scale 3 (or which may partly overlap
each other). At this time, the grating pitches of the
first area 3a and the second area 3b differ from each
other because the optical scale 3 has the radial
grating portion 3d. Further, in the irradiated area of
20 the second area 3b, the pitches of the inner peripheral
side and the outer peripheral side of the optical scale
3 differ from each other.

Then, in the present embodiment, the grating
portion of the first area 3a is enlargedly projected
25 onto the second area 3b on the grating portion 3d so as
to form an image (inverted image) similar to the pitch
of the radial grating portion 3d of the optical scale

3. For that purpose, in the present embodiment, the concave mirror 4 is set to have a desired radius of curvature R and is disposed eccentrically with respect to the principal ray 101a of the incident light beam
5 and the amount of deviation Δ relative to the incidence optical axis is selected to an optimum value.

Thereby, when the image of the grating portion of the first area 3a is formed on the surface of the second area 3b by the concave mirror 4, a detection
10 signal of good S/N ratio is obtained in such a manner that this image and the pitch of at least a portion of the radial grating coincide with each other.

The light beam which has entered the flat surface portion 30a in the second area 3b is rectilinearly
15 transmitted therethrough as shown in Fig. 11B, and arrives at the central photodetector 5c of the light receiving means 5 through the lens system 2. Also, the rays of light which have arrived at the two inclined surfaces 30b-1 and 30b-2 forming the groove surface are
20 incident thereon at an angle of incidence of 45° and therefore are greatly refracted in different directions and arrive at the photodetectors 5a and 5b at the opposite sides of the light receiving means 5 through the lens system 2.

25 Thus, in the second area 3b, the light beam is divided into three directions and travels by the three kinds of surfaces differing in the direction of

inclination from one another, i.e., the two inclined surfaces 30b-1 and 30b-2 inclined in different directions with respect to the incident light beam and the flat surface portion 30a between the V-grooves, and
5 arrives at the photodetectors 5a, 5b and 5c provided at positions corresponding to the respective surfaces. That is, in the second area 3b, the grating portion 3d of the V-groove functions as a light wavefront dividing element.

10 That is, the light beam based on the phase relation between the grating portion of the second area 3b and an interference pattern image formed on the surface thereof is deflected in three directions and enters the photodetectors 5a, 5b and 5c.

15 When the optical scale 3 is rotated, the quantities of light detected by the respective photodetectors 5a, 5b and 5c change. The balance among the quantities of light entering the photodetectors changes in conformity with the relative displacement of
20 the position of the grating portion 3d and the position of the image and as the result, assuming that the optical scale 3 has been rotated counter-clockwisely, there is obtained a change in the quantity of light resulting from the rotation of the optical scale 3 as
25 shown in Fig. 11C. In Fig. 11C, the axis of abscissas represents the amount of rotation of the optical scale 3 and the axis of ordinates represents the quantity of

received light.

Signals a, b and c correspond to the photodetectors 5a, 5b and 5c, respectively. When conversely, the optical scale 3 has been rotated
5 clockwise, the signal a becomes the output of the photodetector 5b and the signal b becomes the output of the photo-detector 5a and the signal c becomes the output of the photodetector 5c. On the basis of these signals, there is obtained rotation information such as
10 the angle of rotation and the amount of rotation or the rotational speed and the rotational acceleration of the optical scale 3.

Fig. 11C shows the state of a theoretical change in quantity of light when the contrast of the image
15 formed on the second area 3b is very high and nearly ideal.

Figs. 13 and 14 show the scale pitch of the grating portion with respect to the distance from the incident principal ray in the second area 3b in the
20 case of 2500 pulses (2500 P/R) and 5000 pulses (5000 P/R) per round as the grating portion on the optical scale 3 in the present embodiment and when the principal ray 101a of the light beam 101 incident on the first area 3a of the optical scale 3 is decentered
25 by Δ (when the decentered amount is Δ) with respect to the optical axis 4a of the concave mirror 4 when it is reflected by the concave mirror 4 and enters the second

area 3b.

Also, Figs. 13 and 14 show the superposed pitch with respect to the distance from the incident principal ray of the image of the grating portion when
5 by the concave mirror 4, the grating portion of the first area 3a is formed on the second area 3b when the decentered amount is Δ .

As shown in Figs. 13 and 14, when the decentered amount Δ is $\Delta: 0.62$ (nm), the distance of the second
10 area 3b from the incident principal ray is in the vicinity of 1.8 mm and the scale pitch and the superposed pitch are substantially coincident with each other.

In the present embodiment, an area of which the distance from the incident principal ray 101a is in the
15 vicinity of 1.8 mm is utilized.

In the present embodiment, design is made such that by the lens system 2, the light source 1 and the reflecting surface 4a of the concave mirror 4 become
20 substantially conjugate with each other and that $\pm$ nth-order diffracted lights from the optical scale 3 are condensed on or near the reflecting surface 4a of the concave mirror 4. Design is also made such that a portion of the optical scale 3 coincides with the
25 center of curvature of the concave mirror 4.

Thereby, the error of the displacement information obtained by the light receiving means 5 is made small

even if the gap between the optical scale 3 and the concave mirror 4 is more or less displaced from its set value. That is, the allowable value of the gap characteristic is alleviated.

5 Figs. 15A and 15B are illustrations of the incident light and reflected light when there is an error in the gap between the optical scale 3 and the concave mirror 4.

 When as shown in Fig. 15A, the optical scale 3 is
10 at the position of the radius of curvature of the concave mirror 4, i.e., the position of the best gap, the diffracted light diffracted by the V-groove is reflected by the concave mirror 4 and is condensed on the surface of the optical scale 3 and therefore, the
15 contrast of the interference fringes exhibits a maximum value.

 However, when as shown in Fig. 15B, the optical scale 3 is displaced from the position of the best gap, the diffracted light is not condensed on the optical
20 scale 3 after it is reflected on the surface of the optical scale 3 by the concave mirror 4 and therefore, the contrast of the interference pattern is reduced.

 Such a reduction in the contrast of the interference pattern is operatively associated with a
25 reduction in the output signal detected by the light receiving means and therefore, how much the contrast is reduced by the optical scale deviating from the best

gap becomes an important value.

Then, in the present embodiment, design is made such that the center of curvature of the concave mirror 4 is positioned near a point on the optical scale 3 and that the light source 1 and the concave mirror 4 become substantially conjugate with each other by the lens system 2, whereby the reduction in the contrast when the optical scale 3 is displaced from the best gap is made small and a signal of good S/N ratio is obtained.

In the present embodiment, as described above, the incidence position of the principal ray when it enters the optical scale and is reflected by the concave mirror and re-enters the optical scale is set so as to differ in the radial direction, whereby the degree of freedom of the disposition of the light source, the optical scale, the light receiving means, etc. is increased and the downsizing of the entire apparatus is achieved, and yet the rotation information of the rotatable object (optical scale) is detected highly accurately.

Also, design is made such that the light source and the concave mirror become substantially conjugate with each other by the lens system and further, a portion of the optical scale is set so as to be substantially the position of the radius of curvature of the concave mirror to thereby achieve the alleviation of the allowable value from the design

value of the gap between the optical scale and the concave mirror.

Figs. 16A to 16C and 17A to 17C are illustrations showing the optical path, in another embodiment, of a light beam 102 diffracted and imaged on the surface of the concave mirror 4 and reflected by the concave mirror 4 and passing through the second area 3b of the optical scale 3 after in the present embodiment, a light beam 101 emitted from the light source and passed through the lens system has entered the first area 3a of the optical scale 3.

Figs. 16A, 16B and 16C show a case where the light beam 101 passed through the lens system enters from the first area 3a nearer to the rotary axis 3e on the grating portion of the optical scale 3 and is reflected by the concave mirror 4 and re-enters the second area 3b farther from the rotary axis 3e.

That is, these figures show a case where by the concave mirror 4, the grating portion of the first area 3a is enlargedly imaged on the second area 3b. Fig. 16A shows a case where the light beam 101 enters the first area 3a perpendicularly thereto and is reflected by the concave mirror 4, and thereafter obliquely enters the second area 3b, and Figs. 16B and 16C show a case where the light beam 101 obliquely enters the first area 3a and the second area 3b, respectively.

Figs. 17A, 17B and 17C show a case where the light

beam 101 passed through the lens system enters from the first area 3a farther from the rotary axis 3e on the grating portion of the optical scale 3 and is reflected by the concave mirror 4 and re-enters the second area 3b nearer to the rotary axis 3e.

That is, these figures show a case where by the concave mirror 4, the grating portion of the first area 3a is reducedly imaged on the second area 3b. Fig. 17A shows a case where the light beam 101 obliquely enters the first area 3a and is reflected by the concave mirror 4, and thereafter enters the second area 3b perpendicularly thereto, and Figs. 17B and 17C show a case where the light beam 101 obliquely enters the first area 3a and the second area 3b, respectively. Again in the construction of Figs. 16A to 16C and 17A to 17C, an effect similar to that of the aforescribed Embodiment 2 is obtained.

Fig. 18 is a schematic view of the essential portions of Embodiment 3 of the present invention. This embodiment differs from Embodiment 2 shown in Figs. 6 to 10, 11A to 11C, 12 to 14, 15A, 15B, 16A to 16C and 17A to 17C only in

that a light beam from light illuminating means 1 is made to enter the first area 3a of the optical scale 3 as a parallel light beam by the lens system 2; and that 0th-order light and n th-order diffracted lights from the first area 3a of the optical scale 3

are condensed at the focus position of the concave mirror 4 by the concave mirror 4, and thereafter are made to enter the second area 3b of the optical scale 3 as divergent lights to thereby form interference
5 fringes on the surface thereof;

and in the other points, the construction of this embodiment is the same as that of Embodiment 2.

That is, in the present embodiment, as shown in Fig. 18, the light beam from the light illuminating
10 means 1 is collimated by the lens system and is made to enter the first area 3a on the rotatable optical scale 3 in which a grating portion having radial V-grooves disposed at a predetermined period is provided on the circumference of a disc, and diffracted light
15 diffracted by the grating portion of the first area 3a is reflected by the concave mirror 4 and is condensed at the focus position 4c thereof, whereafter it is made to enter the second area 3b of the optical scale as divergent light, and the light beam passed through the
20 grating portion of the second area 3b is received by the light receiving means 5 to thereby detect the displacement information of the optical scale 3.

At this time, the first area 3a and the second area 3b are positioned in different areas with respect
25 to the radial direction of the rotary axis 3e of the optical scale 3, and the concave mirror 4 forms an image of the first area 3a of the optical scale 3 on

the second area 3b by a decentering system.

Fig. 19 is a schematic view of the essential portions of Embodiment 4 of the present invention. This embodiment differs from Embodiment 2 shown in
5 Figs. 6 to 10, 11A to 11C, 12 to 14, 15A, 15B, 16A to 16C, 17A to 17C only in

that design is made such that when the light beam from the light illuminating means 1 is condensed by the lens system 2 and is made to enter the first area 3a of
10 the optical scale 3, it is condensed at the focus position 4c of the concave mirror 4; and

that the diffracted light from the first area 3a of the optical scale 3 is condensed at the focus position 4c, whereafter it becomes divergent light and
15 is reflected by the concave mirror 4, and thereafter becomes a parallel light beam and enters the second area 3b of the optical scale 3, and forms interference fringes on the surface thereof;

and in the other points, the construction of this
20 embodiment is the same as that of Embodiment 2.

That is, in the present embodiment, as shown in Fig. 19, the light beam from the light illuminating means 1 is condensed by the lens system 2 and is made to enter the first area 3a on the rotatable optical
25 scale 3 in which a grating portion having radial V-grooves disposed at a predetermined period is provided on the circumference of a disc, and the

diffracted light diffracted by the grating portion of the first area 3a is condensed at the focus position 4c of the concave mirror 4, whereafter it is reflected as a divergent light beam by the concave mirror 4 and is collimated, and thereafter is made to enter the second area 3b of the optical scale 3, and the light beam passed through the grating portion of the second area 3b is received by the light receiving means 5 to thereby detect the displacement information of the optical scale 3.

At this time, the first area 3a and the second area 3b are positioned in different areas with respect to the radial direction of the rotary axis 3e of the optical scale 3, and the concave mirror 4 images the first area 3a of the optical scale 3 on the second area 3b by the decentering system.

Fig. 20 is a schematic view of the essential portions of Embodiment 5 of the present invention, and Fig. 21 is an enlarged perspective view of a portion of Fig. 20. This embodiment differs from Embodiment 2 shown in Figs. 6 to 10, 11A to 11C, 12 to 14, 15A, 15B, 16A to 16C, 17A to 17C only in

that the light beam from the light illuminating means 1 is collimated by the lens system 2 and is made to enter the first area 3a of the optical scale 3; and

that the parallel lights of 0th-order light and nth-order diffracted lights diffracted by the grating

portion of the first area 3a are reflected by plane mirrors 41, 42 and 43, respectively, and are made to enter the second area 3b of the optical scale 3 to thereby form interference fringes on the surface thereof;

and in the other points, the construction of this embodiment is the same as that of Embodiment 2.

That is, in the present embodiment, as shown in Figs. 20 and 21, the light beam from the light illuminating means 1 is made into a parallel light beam 101 by the lens system 2 and is made to enter the first area 3a on the movable optical scale 3 in which a grating portion having straight V-grooves disposed at a predetermined period is provided on a base plate, and the parallel lights of 0th-order light $L(0)$ and n th-order ($n=1$) diffracted lights $L(+)$ and $L(-1)$ diffracted by the grating portion of the first area 3a are reflected by the plane mirrors 41, 42 and 43, respectively, and are made to enter the second area 3b of the optical scale 3, and the light beam passed through the grating portion of the second area 3b is received by the light receiving means 5 to thereby detect the displacement information of the optical scale 3.

The first area 3a and the second area 3b are positioned in different areas with respect to the radial direction of the rotary axis 3e of the optical

scale 3.

In each embodiment, the diffracted light passed through the first area of the optical scale 3 may be three or more light beams.

5 In the present invention, a V-groove grating having a V-shaped cross-section is used as the grating portion for detecting the phase difference of the optical scale, but any grating of other shape and functionally similar to the V-groove grating is
10 likewise applicable.

For example, optical scales having grating portions may be used as shown in Figs. 22A, 22B, 23A, 23B, 24A, 24B, 25A, 25B, 26A and 26B.

15 Figs. 22A and 22B are cross-sectional views of the essential portions of another embodiment of the grating portion 3d of the optical scale 3 according to the present invention. This embodiment differs from the embodiment shown in Figs. 11A to 11C in that the grating portion 3d is constituted by curved surfaces
20 having a curvature, instead of the flat inclined surfaces.

That is, a grating portion 3d comprising a plurality of radial gratings arranged at a predetermined period is provided on the surface of a
25 disc-like base plate 3c. This grating portion 3d is comprised of a flat surface portion 30a and two curved surfaces 30b-1 and 30b-2 having a curvature alternately

arranged at a predetermined pitch.

The area of Fig. 22A corresponds to the first area 3a, and Fig. 22A shows a state in which only a light beam having entered the flat surface portion 30a of the grating portion 3d passes through the optical scale 3 and a light beam having entered the curved surface 30b-1 (30b-2) is totally reflected by the curved surface 30b-1 (30b-2) and the flat surface portion 30a and is being returned in the direction of incidence.

Fig. 22B shows the optical path of a light beam having entered the second area 3b of the optical scale. Thus, the grating portion 3d, like that shown in Figs. 11A and 11B, has optical action similar to that of a transmission type amplitude diffraction grating.

Figs. 23A and 23B are cross-sectional views of the essential portions of another embodiment of the grating portion 3d of the optical scale 3 according to the present invention. This embodiment differs from the embodiment shown in Figs. 11A to 11C in that the grating portion 3d is constituted by curved surfaces 30b-1 and 30b-2 having a curvature, instead of the flat inclined surfaces, and a flat surface portion 30b-3 is formed between the curved surfaces, and in the other points, the construction of this embodiment is the same as that of the embodiment shown in Figs. 11A to 11C.

That is, a grating portion 3d comprising a plurality of radial gratings arranged at a

predetermined period is provided on the surface of a disc-like base plate 3c. This grating portion 3d is comprised of a flat surface portion 30a, two curved surfaces 30b-1 and 30b-2 having a curvature and a flat surface portion 30b-3 alternately arranged at a
5 predetermined pitch P.

The area of Fig. 23A corresponds to the first area 3a, and Fig. 23A shows a state in which only light beams having entered the flat surface portion 30a and
10 flat surface portion 30b-3 of the grating portion 3d pass through the optical scale 3 and a light beam having entered the curved surface 30b-1 (30b-2) is totally reflected by the curved surface 30b-1 (30b-2) and the flat surface portion 30a and is being returned
15 in the direction of incidence.

Fig. 23B shows the optical path of a light beam having entered the second area 3b of the optical scale. Thus, the grating portion 3d, like that shown in Figs. 11A and 11B, has optical action similar to that of a
20 transmission type amplitude diffraction grating.

Figs. 24A and 24B are cross-sectional views of the essential portions of another embodiment of the grating portion 3d of the optical scale 3 according to the present invention. This embodiment differs from the
25 embodiment of Fig. 6 in that the grating portion is constituted by triangular protruding portions (30b-1, 30b-2) instead of the V-grooves, and in the order

points, the construction of this embodiment is the same as that of the embodiment of Fig. 6.

That is, a grating portion 3d comprising a plurality of radial gratings arranged at a
5 predetermined period is provided on the surface of a disc-like base plate 3c. This grating portion 3d is comprised of a flat surface portion 30a and two flat surface portions 30b-1 and 30b-2 each comprising a flat surface alternately arranged at a predetermined pitch
10 P.

The area of Fig. 24A corresponds to the first area 3a, and Fig. 24A shows a state in which only a light beam having entered the flat surface portion 30a of the grating portion 3d passes through the optical scale 3
15 and a light beam having entered the flat surface portion 30b-1 (30b-2) is totally reflected by the other flat surface portion 30b-2 (30b-1) and is being returned in the direction of incidence.

Fig. 24B shows the optical path of a light beam
20 having entered the second area 3b of the optical scale. Thus, the grating portion 3d, like that shown in Figs. 11A and 11B, has optical action similar to that of a transmission type amplitude diffraction grating.

Figs. 25A and 25B are cross-sectional views of the
25 essential portions of another embodiment of the grating portion 3d of the optical scale 3 according to the present invention. This embodiment differs from the

embodiment of Figs. 11A to 11C in that a protruding portion comprising two curved surfaces 30b-1 and 30b-2 each having a curvature is formed instead of the V-groove, and in the other points, the construction of this embodiment is the same as that of the Figs. 11A to 11C embodiments.

That is, a grating portion 3d comprising a plurality of radial gratings arranged at a predetermined period is provided on the surface of a disc-like base plate 3c. This grating portion 3d is comprised of a flat surface portion 30a and two protruding curved surfaces 30b-1 and 30b-2 having a curvature alternately arranged at a predetermined pitch P.

The area of Fig. 25A corresponds to the first area 3a, and shows a state in which only a light beam having entered the flat surface portion 30a of the grating portion 3d passes through the optical scale 3 and a light beam having entered the curved surface 30b-1 (30b-2) is totally reflected by the curved surface 30b-1 (30b-2) and is being returned in the direction of incidence.

Fig. 25B shows the optical path of a light beam having entered the second area 3b of the optical scale. Thus, the grating portion 3d, like that shown in Figs. 11A and 11B, has optical action similar to that of a transmission type amplitude diffraction grating.

Figs. 26A and 26B are cross-sectional views of the essential portions of another embodiment of the grating portion 3d of the optical scale 3 according to the present invention. This embodiment differs from the
5 embodiment shown in Figs. 11A to 11C in that the grating portion 3d is constituted by curved surfaces 30b-1 and 30b-2 having a curvature, instead of the inclined surfaces each comprising a flat surface, and a flat surface portion 30b-3 is formed between the curved
10 surfaces, and in the other points, the construction of this embodiment is the same as that of the Figs. 11A to 11C embodiments.

That is, a grating portion 3d comprising a plurality of radial gratings arranged at a
15 predetermined period is provided on the surface of a disc-like base plate 3c. This grating portion 3d is comprised of a flat surface portion 30a and two curved surfaces 30b-1 and 30b-2 having a curvature alternately arranged at a predetermined pitch P.

20 Fig. 26A corresponds to the first area 3a, and shows a state in which only light beams having entered the flat surface portion 30a and flat surface portion 30b-3 of the grating portion 3d pass through the optical scale 3 and a light beam having entered the
25 curved surface 30b-1 (30b-2) is totally reflected by the curved surface 30b-1 (30b-2) and the curved surface 30b-2 (30b-1) and is being returned in the direction of

incidence.

Fig. 26B shows the optical path of a light beam having entered the second area 3b of the optical scale. Thus, the grating portion 3d, like that shown in Figs. 5 11A and 11B, has optical action similar to that of a transmission type amplitude diffraction grating.

According to each of the above-described embodiment, phase difference detection by the self-projection type detection system which has 10 heretofore been apt to become complicated in construction can be easily realized and further, it has become possible to provide a self-projection type detecting apparatus which is compact but yet makes a position of high resolving power detectable.

15 Particularly, the first and second areas are disposed in a direction perpendicular to the direction of grating arrangement which is a direction in which light beams spread to each other by wavefront division, whereby it becomes possible to dispose the light beam 20 illuminating means to the scale and the light receiving means without providing so much space therebetween, and a more compact construction can be realized.

Also, particularly, by a construction in which the diffracted light from the grating portion in the first 25 area is condensed and reflected near the concave mirror, and in the second area which is in a direction perpendicular to the movement of the first area, an

image is formed at such a magnification that it becomes substantially the same size as the second area, and the light from the second area is received, there can be achieved a displacement information detecting apparatus
5 suitable for an encoder in which the space for the disposition of each member is reduced and the simplification of the entire apparatus is contrived and also the allowable error of the disposition of each member is alleviated and yet which detects the
10 displacement information of a displaceable object highly accurately.



WHAT IS CLAIMED IS:

1. A displacement information detecting apparatus comprising:

5 a light beam illuminating system for making a light beam enter a first area of the grating portion of a relatively displaceable scale member provided with a grating portion having a wavefront dividing function in the direction of grating arrangement;

10 a reflecting member for reflecting the light beam having emerged from said first area into which the light beam has been made to enter by said light beam illuminating system to enter a second area which is in a direction substantially perpendicular to the grating arrangement relative to said first area; and

15 a plurality of light receiving portions for receiving a plurality of light beams created by the wavefront dividing function in said second area into which the light beam has been made to enter by said reflecting member, a signal corresponding to the displacement relative to said scale member being
20 provided by the light reception by each of said light receiving portions.

2. An apparatus according to Claim 1, wherein
25 said grating portion has periodic structure of flat regions and V-shaped groove regions, a light beam being emitted in a different direction from the surface of



each of the regions to thereby perform wavefront division.

3. An apparatus according to Claim 1, wherein
5 said grating portion functions as an amplitude grating in the first area.

4. An apparatus according to Claim 1, wherein the
displacement relative to said scale member is relative
10 linear movement displacement information.

5. An apparatus according to Claim 1, wherein the
displacement relative to said scale member is relative
rotational displacement information.

15

6. An apparatus according to Claim 1, wherein
said light beam illuminating system applies a
condensable light beam to said first area, said
reflecting member is a concave mirror, 0th-order light
20 and $\pm$ nth-order diffracted lights from the grating
portion in said first area are condensed on or near the
surface of said concave mirror, and said concave mirror
images said first area on said second area.

25 7. An apparatus according to Claim 6, wherein
0th-order light and $\pm$ nth-order diffracted lights
created in the grating portion of said first area by



diffraction are reflected by said concave mirror and superposed one upon another to thereby form an interference pattern.

5 8. An apparatus according to Claim 6, wherein said grating portion has a plurality of straight V-shaped groove regions.

10 9. An apparatus according to Claim 6, wherein said light beam illuminating system has a light source and a lens system for condensing the light from said light source and making said light source and the reflecting surface of said concave mirror substantially conjugate with each other.

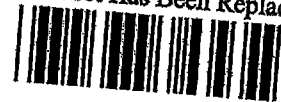
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10. An apparatus according to Claim 6, wherein a portion of said scale member is positioned at the center of curvature of said concave mirror.

20 11. A displacement information detecting apparatus comprising:

 a relatively displaceable scale member provided with a grating portion;

 a light beam illuminating system for making a
25 light beam from a light source enter a first area of the grating portion of said scale member as condensable light by a lens system;



a concave mirror for reflecting the light beam
having emerged from said first area into which the
light beam has been made to enter by said light beam
illuminating system to enter a second area, 0th-order
5 light and nth-order lights from the grating portion of
said first area being condensed on or near the surface
of said concave mirror, said concave mirror imaging
said first area on said second area; and

a light receiving portion for receiving the light
10 beam from said second area into which the light beam
has been made to enter by said concave mirror, a signal
corresponding to the displacement relative to said
scale member being provided by the light reception by
said light receiving portion.

15

12. A displacement information detecting
apparatus comprising:

a light beam illuminating system for making a
light beam enter a first area of a grating portion
20 having different grating widths in the diametral
direction thereof provided on a relatively rotatable
scale member;

a reflecting member for reflecting the light beam
having emerged from said first area into which the
25 light beam has been made to enter by said light beam
illuminating system to enter a second area of the
grating portion of said scale member having a grating



width differing from that of said first area; and

a light receiving portion for receiving the light beam from said second area into which the light beam has been made to enter by said reflecting member, a
5 signal corresponding to the displacement relative to said scale member being provided by the light reception by said light receiving portion.

13. An apparatus according to Claim 12, wherein
10 said reflecting member projects the image of the grating of said first area at a magnification substantially coinciding with the grating of said second area and so that the image may be inverted in the direction of movement of the grating portion.

15
14. A displacement information detecting apparatus comprising:

a light beam illuminating system for making a light beam enter a first area of a radial grating
20 portion provided on a relatively rotatable scale member;

a reflecting member for reflecting a diffracted light beam created by the diffraction of said first area into which the light beam has been made to enter
25 by said light beam illuminating system to enter a second area of the grating portion of said scale member which is at a position differing from said first area



with respect to the radial direction of relative rotation;

5 a light receiving portion for receiving the light beam from said second area into which the light beam has been made to enter by said reflecting member, a signal corresponding to the displacement relative to said scale member being provided by the light reception by said light receiving portion.

10 15. An apparatus according to Claim 14, wherein said grating portion has a grating having an amplitude type function.

15 16. An apparatus according to Claim 14, wherein 0th-order light and nth-order diffracted lights diffracted by the grating portion in said first area are reflected by said reflecting member and are superposed one upon another in said second area to thereby form an interference pattern.

20 17. An apparatus according to Claim 14, wherein said light beam illuminating system illuminates the light beam as a condensed light beam onto said scale member.

25 18. An apparatus according to Claim 17, wherein said reflecting member has a concave mirror for



reflecting 0th-order light and $\pm$ nth-order diffracted lights diffracted by the grating portion in said first area.

5 19. An apparatus according to Claim 14, wherein said light beam illuminating system illuminates the light beam as a parallel light beam onto said scale member.

10 20. An apparatus according to Claim 19, wherein said reflecting member has a plurality of plane mirrors for reflecting 0th-order light and $\pm$ nth-order diffracted lights diffracted by the grating portion in said first area.

15

21. The apparatus of Claim 14, wherein said grating portion has a plurality of V-shaped groove portions.

20 22. A displacement information detecting apparatus comprising:

a relatively rotatable scale member having a grating portion having a wavefront dividing function provided circumferentially on a disc;

25 a light beam illuminating system for making a light beam from a light source into condensable light by a lens system and making the light beam enter a



first area of the grating portion of said scale member;

5 a concave mirror for reflecting the light beam
having emerged from said first area into which the
light beam has been made to enter by said light beam
illuminating system to enter a second area which is at
a position different in the radial direction of
relative rotation relative to said first area of the
grating portion of said scale member, 0th-order light
and nth-order diffracted lights from the grating
10 portion in said first area being condensed on or near
the surface of said concave mirror, said concave mirror
imaging said first area on said second area; and

a light receiving portion for receiving the light
beam from said second area into which the light beam
15 has been made to enter by said concave mirror, a signal
corresponding to the displacement relative to said
scale member being provided by the light reception by
said light receiving portion.

20 23. An apparatus according to Claim 22, wherein
said grating portion has a plurality of V-shaped groove
portions.

24. An apparatus according to Claim 23, wherein
25 said concave mirror enlargedly or reducedly images said
first area on said second area.



25. An apparatus according to Claim 24, wherein said 0th-order light and said nth-order diffracted lights are reflected by said concave mirror and are superposed one upon another in said second area to
5 thereby form an interference pattern.

26. An apparatus according to Claim 25, wherein said light receiving portion has a plurality of light receiving portions, and light beams separated from the
10 light beam in said second area in which said interference pattern has been formed into a plurality of directions by said V-shaped groove portions are detected by corresponding ones of said plurality of light receiving elements.

15

27. An apparatus according to Claim 22, wherein said light source and the reflecting surface of said concave mirror are made substantially conjugate with each other by said lens system.

20

28. An apparatus according to Claim 22, wherein a portion of said scale member is positioned at the center of curvature of said concave mirror.