EUROPEAN PATENT SPECIFICATION

Date of publication and mention of the grant of the patent: 14.11.2001 Bulletin 2001/46

Application number: 95104723.2

Date of filing: 30.03.1995

Fixed point detecting device
Festpunktdetektionsvorrichtung
Dispositif de détection d’un point fixe

Designated Contracting States: CH DE FR GB LI NL

Priority: 31.03.1994 JP 6390194

Date of publication of application: 04.10.1995 Bulletin 1995/40

Proprietor: Sony Precision Technology Inc.
Shinagawa-ku Tokyo (JP)

Inventor: Tamiya, Hideaki,
c/o Sony Magnescale Inc.
Shinagawa-ku, Tokyo 141 (JP)

Representative: Grünecker, Kinkeldey,
Stockmair & Schwanhäusser Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

References cited:
• PATENT ABSTRACTS OF JAPAN vol. 017, no. 161 (P-1512), 29 March 1993 & JP 04 324316 A (SONY MAGNESCALE INC), 13 November 1992,

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
BACKGROUND OF THE INVENTION

[0001] The present invention relates to a fixed point detecting device according to the preamble of claim 1, and more particularly, to a fixed point detecting device using detection of lights diffracted by holographic diffraction gratings, which is suitable for detection of a displacement of a substrate upon multiplex exposure of an integrated circuit, and detection of the origin of an encoder, etc. Such a fixed point detecting device is known from JP-A 4-324316.

[0002] As for an X-ray exposure drawing device for manufacturing integrated circuits and a length measuring device to be used for accurate machining, the reference point or the origin is established to measure an exact position or distance. The fixed point detecting device is used for establishing such reference point or origin.

[0003] One of known fixed point detecting devices is disclosed in JP-A 61-153501. This device is constructed to detect a fixed point through a mark, and includes a laser generator, a position sensor, etc. A laser beam out of the laser generator is diffracted by diffraction gratings of the mark, and first-order diffracted lights are detected by the position sensor. The position sensor serves to determine an angle of diffraction at which the intensity of diffracted lights is maximum. A value of the angle of diffraction at which the intensity of diffracted lights is maximum is varied when a laser beam spot passes across a boundary of two portions of the mark, i.e. before and behind the boundary of the two portions of the mark. The fixed point is detected by such variation in the angle of diffraction.

[0004] Another of the known fixed point detecting devices is a variant of the above device. This variant uses two transmission and volume-type holographic diffraction gratings or holograms and two photo detectors. As for the transmission and volume-type holographic diffraction gratings, diffracted lights are gone out on both sides with respect to the direction of incident lights. Therefore, the photo detectors are disposed adjacent to each other. Zero-order diffracted lights, positive first-order diffracted lights, negative first-order diffracted lights, and high-order diffracted lights are obtained by the diffraction gratings. Among them, the photo detectors detect positive first-order diffracted lights.

[0005] The other of the known fixed point detecting devices is disclosed in JP-A 4-324316. This device includes a stationary portion and a movable portion which is movable in the direction of measurement, a stationary portion having an optical system and a detecting system, and the movable portion having a substrate and two volume-type holographic diffraction gratings or holograms disposed therein. The two holograms are disposed on the substrate on an upper side thereof to be adjacent to each other. The two holograms are constructed symmetrically with respect to a center plane. That is, angles of inclination of distributed planes of the holograms are symmetrically and continuously varied on both sides of the center plane, and grating intervals or grating-pitch thereof are symmetrically and continuously varied on both sides of the center plane. The two holograms are disposed so that points at which the diffraction efficiencies become maximum are different from each other in the direction of measurement.

[0006] When the movable portion is moved relative to the stationary portion, i.e. with respect to light receivers and a light source which are stationary, light diffracted by the first hologram is detected by the first light receiver, whereas light diffracted by the second hologram is detected by the second light receiver. As for the two holograms, the points at which the diffraction efficiencies become maximum are different from each other, so that a peak position of a luminous intensity curve of diffracted light detected by the first light receiver is different from a peak position of a luminous intensity curve of diffracted light detected by the second light receiver. That is, there exists a point at which the two luminous intensities are equal to each other. Such point is a fixed point obtained by this fixed point detecting device.

[0007] However, the above known fixed point detecting devices have the following drawbacks.

[0008] As for the first prior art reference, the position sensor serves as a light receiving device. The position sensor is constructed to detect an angle of diffraction at which the intensity of diffracted lights is maximum, resulting in low resolving power. Moreover, a position sensor is expensive which allows accurate detection of the angle of diffraction.

[0009] As for the second prior art reference, the two holographic diffraction gratings have grating intervals or grating pitches different from each other, and the positive first-order diffracted lights and the negative first-order diffracted lights are gone out on both sides with respect to the direction of incident lights. Therefore, in order to detect the two positive first-order diffracted lights, the two photo detectors should be disposed adjacent. Moreover, the two positive first-order diffracted lights should be separated completely for detection through the photo detectors. This can be obtained by simply enlarging a difference between the grating interval of the first hologram and the grating interval of the second hologram. However, when enlarging a difference between the grating intervals of the two holograms, an error is increased with a variation in a wavelength of lights out of the light source.

[0010] As for the third prior art reference, since the two holograms are constructed symmetrically with respect to the center plane, the fixed point is not changed even with a variation in the wavelength of lights out of
the light source. However, the two light receivers should be disposed accurately with respect to the two holograms. If not, the resolving power is lowered.

[0011] It is, therefore, an object of the present invention to provide a fixed point detecting device which enables accurate determination of a fixed point.

SUMMARY OF THE INVENTION

[0012] According to one aspect of the present invention, there is provided a system for detecting a fixed point, the system having an axis of measurement, comprising: the features of claim 1.

[0013] Another aspect of the present invention lies in providing a system for detecting a fixed point, the system having an axis of measurement, comprising: the features of claim 14.

[0014] Some embodiments of the present invention use a hologram, comprising:

- a transparent substrate; and
- two portions formed on said transparent substrate, said two portions being arranged symmetrically and having grating vectors symmetrically inclined and the same grating interval.

[0015] An example which is useful for understanding the present invention describes a method of forming a hologram having two portions separated by an imaginary center plane perpendicular thereto, comprising the steps of:

- preparing a transparent substrate having a photosensitizer placed thereon and a masque having a wedge-shaped section with a pointed end;
- disposing said masque above said transparent substrate on the imaginary center plane so that said pointed end faces said transparent substrate; and
- irradiating plane waves from both sides of said imaginary center plane to said transparent substrate at two different angles of incidence.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1 is a diagrammatic view showing a first embodiment of a fixed point detecting device according to the present invention;

- Fig. 2 is a view similar to Fig. 1, showing volume-type holograms;
- Fig. 3 is a view similar to Fig. 1, showing a second embodiment of the present invention;
- Fig. 4 is a view similar to Fig. 3, showing a third embodiment of the present invention;
- Fig. 5 is a view similar to Fig. 4, showing a fourth embodiment of the present invention;
- Fig. 6 is a view similar to Fig. 5, showing a fifth embodiment of the present invention;
- Fig. 7 is a view similar to Fig. 6, showing a sixth embodiment of the present invention;
- Fig. 8 is a view similar to Fig. 7, showing a seventh embodiment of the present invention;
- Fig. 9 is a view similar to Fig. 8, showing an eighth embodiment of the present invention;
- Fig. 10 is a view similar to Fig. 9, showing a ninth embodiment of the present invention;
- Fig. 11 is a view similar to Fig. 10, showing a tenth embodiment of the present invention;
- Fig. 12 is a perspective view with an electric processing circuit, showing the eighth embodiment as shown in Fig. 9;
- Figs. 13A and 13B are graphs illustrating luminous intensity curves and a luminous intensity difference curve obtained by the fixed point detecting device according to the present invention;
- Fig. 14 is a view similar to Fig. 11, showing an example of a method of forming the volume-type holograms;
- Fig. 15 is a view similar to Fig. 14, showing another example of a method of forming the volume-type holograms;
- Fig. 16 is a view similar to Fig. 12, showing an eleventh embodiment of the present invention;
- Fig. 17 is a block diagram illustrating the electric processing circuit in the eleventh embodiment as shown in Fig. 16;
- Figs. 18A to 18C are views similar to Figs. 13A and 13B, illustrating output signals of two differential amplifiers and an adder of the fixed point detecting device according to the present invention;
- Fig. 19 is a view explaining a function of the eleventh embodiment as shown in Fig. 16; and
- Fig. 20 is a view similar to Fig. 19, explaining a case wherein the fixed point detecting device according to the present invention is used in a linear encoder.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Referring to the drawings wherein like reference numerals designate like parts throughout the views, a description will be made with regard to preferred embodiments of a fixed point detecting device according to the present invention.

[0018] Figs. 1 and 2 show a first embodiment of the present invention. Referring to Fig. 1, a fixed point detecting device includes a transparent substrate 31 and two holographic diffraction gratings 32, 33 formed on an upper side 31A thereof. Disposed above the substrate 31 is a light source 12, and disposed therebelow is a pair of light receivers 22, 23 for receiving diffracted lights.

[0019] The substrate 31 and the holographic diffraction gratings 32, 33 constitute a movable portion, whereas the light source 12 and the light receivers 22, 23 constitute a stationary portion. It is noted that a condenser
Referring to Fig. 2, the holographic diffraction gratings 32, 33 are formed by volume-type holograms. As for such holograms, a refractive index is changed from \( n_1 \) to \( n_2 \) at a predetermined pitch \( d \). Diffraction gratings are formed with such a change in the refractive index. Referring to Fig. 1, thick lines 42, 43 indicate distributed planes of the refractive index of the volume-type holograms. An interval of each plane 42, 43 is referred to as a grating interval or grating pitch \( d \).

Grating vectors \( V \) are perpendicular to the distributed planes 42, 43. Hereafter, the holographic diffraction gratings are referred to as holograms whenever need arises. Assume between the two holograms 32, 33 a center plane 35 which is perpendicular to upper sides of the holograms 32, 33. Suppose that the angle of inclination of the distributed planes 42, 43 with respect to the center plane 35 is \( \phi \). The angles of inclination of the grating vectors \( V \) with respect to the distributed planes 42, 43 are 90° - \( \phi \).

As shown in Figs. 1 and 2, the two holograms 32, 33 are constructed symmetrically with respect to the center plane 35. The two holograms 32, 33 have the grating vectors \( V \) symmetrically inclined at the same angle of inclination with respect to the center plane 35. Moreover, the two holograms 32, 33 have the same grating interval or grating pitch \( d \).

Diffraacted lights obtained by the two holograms 32, 33 have the following features:

1) When incident lights are fell on the holograms 32, 33 perpendicularly with respect to the upper sides thereof, i.e. in parallel to the center plane 35, the angles of diffraction of two positive first-order diffracted lights 1A, 1B, i.e. angles \( \theta \) of diffracted lights formed with the center plane 35, have opposite signs and the same absolute value. That is, the two positive first-order diffracted lights 1A, 1B are gone out symmetrically with respect to incident lights;

2) The angles of diffraction \( \pm \theta \) of the two positive first-order diffracted lights 1A, 1B are not changed along an axis of measurement or in the direction of measurement. That is, when moving the two holograms 32, 33 along the axis of measurement, the angles of diffraction \( \pm \theta \) of the two positive first-order diffracted lights 1A, 1B are constant; and

3) A luminous intensity difference between positive and negative same-order diffracted lights is large. By way of example, the luminous intensity of the positive first-order diffracted light 1A is fully larger than that of a negative first-order diffracted light 1a.

The use of such diffracted lights produces the following advantages:

1) Even if positions of the light receivers 22, 23 with respect to the two holograms 32, 33 are changed in the direction of a thickness of the substrate 31, beam spot positions on the light receivers 22, 23 have the same amount of deviation, so that two luminous intensity curves obtained by the light receivers 22, 23 have the same amount of variation, having no change in a point of intersection of the two luminous intensity curves;

2) Even if a wavelength of lights out of the light source 12 is changed, the beam spot positions on the light receivers 22, 23 have the same amount of deviation, so that the two luminous intensity curves obtained by the light receivers 22, 23 have the same amount of variation, having no change in the point of intersection of the two luminous intensity curves; and

3) The light receivers 22, 23 do not receive needless high-order diffracted lights.

When a diameter \( D \) of an illuminated point or zone, i.e. beam spot, on the upper side of each hologram 32, 33 by lights out of the light source 12 is between 10 and 100 \( \mu m \), the grating interval or pitch \( d \) of the holographic diffraction gratings 32, 33 is between 0.1 and 100 \( \mu m \).

In the embodiments of the present invention, in order to produce diffracted lights, lights out of the light source 12 having a wavelength \( \lambda \) of 780 nm are fell on the holograms 32, 33 having the grating interval of pitch \( d \) of 1 \( \mu m \) so as to meet the Bragg's equation \( \sin \theta = m \lambda / d \) where \( m = 0, \pm 1, \pm 2, \ldots \). Thus, high diffraction efficiency over 90 % is obtained.

Moreover, even if the diameter \( D \) of the beam spot is between 30 and 60 \( \mu m \), the accuracy in the order of 0.01 \( \mu m \) is possible in connection with detection of the fixed point. This detection accuracy can further be increased by further decreasing the diameter \( D \) of the beam spot.

Referring again to Fig. 1, in the first embodiment, the holographic diffraction gratings 32, 33 are transmission and volume-type holograms. Therefore, the positive first-order diffracted lights 1A, 1B are gone out on the side opposite to incident lights through the transparent substrate 31. The light receivers 22, 23 are disposed on the side opposite to the light source 12 with respect to the holograms 32, 33.

Preferably, lights out of the light source 12 are fell on the holograms 32, 33 perpendicularly with respect to the upper sides thereof, i.e. in parallel to the center plane 35. When the movable portion, i.e. the substrate 31, is moved relative to the stationary portion, i.e. the light source 12 and the light receivers 22, 23, a beam spot produced by lights out of the light source 12 sweeps on the upper sides of the holograms 32, 33, such beam spot traverses the center plane 35. Thus, referring to Figs. 13A and 13B, the luminous intensity difference curves as shown in Fig. 13A and the luminous intensity difference curve as shown in Fig. 13B are obtained. It is noted that Fig. 1 shows a state that lights are fell on just a portion of the center plane 35.
[0030] Fig. 3 shows a second embodiment of the present invention. The second embodiment is a variant of the first embodiment as shown in Fig. 1. In the second embodiment, the holographic diffraction gratings 32, 33 are reflection and volume-type holograms. Therefore, the positive first-order diffracted lights 1A, 1B are arranged to detect zero-order diffracted lights 0 are detected by the third light receiver 24. Moreover, a gate signal is obtained by the zero-order diffracted lights 0 detected by the third light receiver 24. The gate signal corresponds to a curve G1 indicated by a dotted line in Fig. 13B. The gate signal G1 can be used for confirming a presence of the fixed point. By way of example, when a curve C3 indicated by a fully-drawn line in Fig. 13B is obtained, it is necessary to judge whether the curve C3 is obtained by the first and second light receivers 22, 23 or due to the other factor such as noise. If the gate signal G1 is obtained simultaneously with the curve C3, it is confirmed that the curve C3 is a luminous intensity difference curve.

[0031] Fig. 4 shows a third embodiment of the present invention. The third embodiment is a variant of the first embodiment as shown in Fig. 1. In the third embodiment, the holographic diffraction gratings 32, 33 are transmission and volume-type holograms. Moreover, a reflecting film 37 is arranged on a lower side 31B of the transparent substrate 31. The light receivers 22, 23 are disposed on the same side as the light source 12 with respect to the substrate 31. Lights out of the light source 12 are diffracted by the holograms 32, 33, and the positive first-order diffracted lights 1A, 1B reach the reflecting film 37 through the transparent substrate 31 are reflected by the reflecting film 37, and received by the light receivers 22, 23 after passing through the substrate 31 again. In the third embodiment, although the transmission-type holograms 32, 33 are used, the light receivers 22, 23 can be disposed on the same side as the light source 12, enabling a reduction in size of the device.

[0032] In the third embodiment, in place of disposing the reflecting film 37 on the lower side 31B of the transparent substrate 31, a reflecting plate 39 is disposed below the substrate 31. In the same way as in the third embodiment as shown in Fig. 4, the light receivers 22, 23 are disposed on the same side as the light source 12 with respect to the substrate 31. Lights out of the light source 12 are diffracted by the holograms 32, 33, and the positive first-order diffracted lights 1A, 1B which reach the reflecting plate 39 through the transparent substrate 31 are reflected by the reflecting plate 39, and received by the light receivers 22, 23 after passing through the substrate 31 again.

[0033] In the third embodiment, in place of disposing the reflecting film 37 on the lower side 31B of the transparent substrate 31, a reflecting plate 39 is disposed below the substrate 31. In the same way as in the third embodiment as shown in Fig. 4, the light receivers 22, 23 are disposed on the same side as the light source 12 with respect to the substrate 31. Lights out of the light source 12 are diffracted by the holograms 32, 33, and the positive first-order diffracted lights 1A, 1B which reach the reflecting plate 39 through the transparent substrate 31 are reflected by the reflecting plate 39, and received by the light receivers 22, 23 after passing through the substrate 31 again.

[0034] Fig. 6 shows a fifth embodiment of the present invention. The fifth embodiment is a variant of the first embodiment as shown in Fig. 1. In the fifth embodiment, in addition to the two receivers 22, 23, a third receiver 24 is arranged to detect zero-order diffracted lights 0. The three light receivers 22, 23, 24 are disposed on the opposite side to the light source 12 with respect to the substrate 31. Lights out of the light source 12 are diffracted by the holograms 32, 33, and the positive first-order diffracted lights 1A, 1B are detected by the two light receivers 22, 23, whereas the zero-order diffracted lights 0 are detected by the third light receiver 24.

[0035] In the fifth embodiment, the luminous intensity difference curve is obtained out of the two luminous intensity curves of the positive first-order diffracted lights 1A, 1B detected by the first and second light receivers 22, 23. Moreover, a gate signal is obtained by the zero-order diffracted lights 0 detected by the third light receiver 24. The gate signal corresponds to a curve G1 indicated by a dotted line in Fig. 13B.
ing lights 1A’, 1B’ are parallel to incident lights. That is, if incident lights are perpendicular to the upper sides of the holograms 32, 33, i.e. in parallel to the center plane 35, the diffracted lights 1A’, 1B’ obtained by the second diffraction are perpendicular to the upper sides of the holograms 32, 33, i.e. in parallel to the center plane 35.

[0042] As for the second advantage, when lights out of the light source 12 are perpendicularly fell on the upper sides of the holograms 32, 33, outgoing lights are always parallel to each other as indicated by broken lines in Fig. 7 even if the wavelength of lights out of the lights source 12 is varied. Generally, as expressed by the Bragg’s equation, if the wavelength λ of light is changed, the angle of diffraction θ is changed. Therefore, if the wavelength of light is changed, the angle of diffraction θ due to the first diffraction by the holograms 32, 33 is changed, and the angle of diffraction due to the second diffraction by the holograms 32, 33 is also changed. A change in the angle of diffraction θ due to the first diffraction is corrected by a change in the angle of diffraction due to the second diffraction.

[0043] As for the third advantage, some difference between the diffraction efficiencies of the holograms 32, 33 can be compensated. As described above, the second diffraction is carried out by the other hologram than that of the first diffraction. Suppose, for example, that the diffraction efficiencies of the first and second holograms 32, 33 are η1, η2, respectively. When the first diffraction is carried out by the first hologram 32, and the second diffraction is carried out by the second hologram 33, the total efficiency is η1 x η2. On the other hand, when the first diffraction is carried out by the second hologram 33, and the second diffraction is carried out by the first hologram 32, the total efficiency is η2 x η1.

[0044] Therefore, even if some difference exists between the diffraction efficiencies of the holograms 32, 33, the total efficiency which corresponds to a product of the diffraction efficiencies is the same, i.e. η1 x η2 = η2 x η1, and luminous energies of diffracted lights detected by the two light receivers 22, 23 are always the same.

[0045] Fig. 8 shows a seventh embodiment of the present invention. The seventh embodiment is a variant of the sixth embodiment as shown in Fig. 7. In the seventh embodiment, in addition to the two light receivers 22, 23, third and fourth light receivers 24, 25 are arranged to detect the zero-order diffracted lights. The light receivers 22, 23, 24, 25 are disposed on the same side as the light source 12 with respect to the substrate 31. Lights out of the light source 12 are diffracted by the holograms 32, 33, and the positive first-order diffracted lights 1A’, 1B’ are detected by the first and second light receivers 22, 23, whereas the zero-order diffracted lights 0A, 0B are detected by the third and fourth light receivers 24, 25.

[0046] In the seventh embodiment, a first luminous intensity curve is obtained by adding the positive first-order diffracted light 1A’ detected by the first light receiver 22 and the zero-order diffracted light 0A detected by the third light receiver 24, whereas a second luminous intensity curve is obtained by adding the positive first-order diffracted light 1B’ detected by the second light receiver 23 and the zero-order diffracted light 0B detected by the fourth light receiver 25. One luminous intensity difference curve is obtained by the two luminous intensity curves.

[0047] Therefore, even if some difference exists between the diffraction efficiencies of the holograms 32, 33, a stable luminous intensity difference curve is always obtained due to a detection made by adding the zero-order diffracted light and the first-order diffracted light.
that the light receivers 22, 23 should be disposed distant from the light source 12. Contrarily, if the thickness $t_s$ of the substrate 31 is smaller, the positions of the outgoing lights 1A', 1B' are close to the light source 12, so that the light receivers 22, 23 should be disposed close to the light source 12.

[0053] On the other hand, according to the ninth embodiment, each of the two holograms 32, 33 comprises two portions. That is, the first hologram 32 includes an inner portion 32A adjacent to the center plane 35 and an outer portion 32B distant from the center plane 35, the two portions having grating vectors and grating pitches "d" different from each other. Likewise, the second hologram 33 includes an inner portion 33A adjacent to the center plane 35 and an outer portion 33B distant from the center plane 35, the two portion having grating vectors and grating pitches "d" different from each other.

[0054] In the ninth embodiment, the outgoing lights 1A', 1B' are inclined with respect to incident lights so that the light receivers 22, 23 can be disposed distant from or close to the light source 12. Fig. 10 shows a case that the outgoing lights 1A', 1B' are inclined to be close to incident lights so as to dispose the light receivers 22, 23 close to the light source 12.

[0055] It is noted that the outer portions 32B, 33B of the holograms 32, 33 may be constructed so that the outgoing lights 1A', 1B' are inclined outward with respect to incident lights. In that case, the light receivers 22, 23 can be disposed more distant from the light source 12.

[0056] Fig. 11 shows a tenth embodiment of the present invention. The tenth embodiment is a variant of the eighth embodiment as shown in Fig. 9. In the tenth embodiment, the grating vectors of the holograms 32, 33 are inclined in the direction opposite to the inclination of the grating vectors in the eighth embodiment as shown in Fig. 9. Moreover, although the reflecting film is not arranged on the lower side 31B of the substrate 31, diffracted lights are totally reflected by the lower side 31B of the substrate 31. The two light receivers 22, 23 are disposed on the side opposite to the light source 12.

[0057] In the tenth embodiment, the second diffraction is carried out by the same holograms as those of the first diffraction. When lights out of the light source 12 illuminate the vicinity of the center plane 35, the light 1A diffracted by the first hologram 32 is totally reflected by the lower side 31B of the substrate 31, then diffracted by the first hologram 32. The diffracted light 1A' obtained by the first hologram 32 is detected by the first light receiver 22.

[0058] Likewise, the light 1B diffracted by the second hologram 33 is totally reflected by the lower side 31B of the substrate 31, then diffracted by the second hologram 33. The diffracted light 1B' obtained by the second hologram 33 is detected by the second light receiver 23.

[0059] According to the tenth embodiment, when lights out of the light source 12 are fell on the holograms 32, 33 perpendicularly with respect to the upper sides thereof, i.e. in parallel to the center plane 35, diffracted lights received by the light receivers 22, 23 are parallel to incident lights to the holograms 32, 33.

[0060] That is, lights out of the light source 12 are fell on the holograms 32, 33 perpendicularly with respect to the upper sides thereof, i.e. in parallel to the center plane 35, and the diffracted lights 1A', 1B' obtained by the second diffraction are gone out from the holograms 32, 33 perpendicularly with respect to the lower sides thereof, i.e. in parallel to the center plane 35.

[0061] Fig. 12 is a general view of the eighth embodiment as shown in Fig. 9. Referring to Fig. 12, a cover glass 51 is disposed on the upper sides of the holograms 32, 33 through an adhesive agent layer 49. The electric processing circuit 29 may be constructed in a way similar to the known electric processing circuit. It is noted that in Fig. 12, reference numerals 14A to 14C designate a condenser lens.

[0062] Fig. 13A shows two luminous intensity curves C1, C2 obtained by the light receivers 22, 23, and Fig. 13B shows a luminous intensity difference curve C3 obtained by the differential amplifier 29-2.

[0063] Referring to Fig. 13A, the two luminous intensity curves C1, C2 are constant after luminous intensity signals increase. This reveals that the diffraction efficiency is improved by the fixed point detecting device of the present invention. According to the present invention, since the intensities of the positive first-order diffracted lights 1A, 1B detected by the light receivers 22, 23 are extremely great, detecting portions of the light receivers 22, 23 are saturated. Flat portions of the two luminous intensity curves C1, C2 indicate such saturation. Therefore, the luminous intensity difference curve C3 is constant before and behind the zero cross point as shown in Fig. 13B.

[0064] Referring next to Fig. 14, a description will be made with regard to an example of a method of forming the volume-type holograms 32, 33 on the upper side 31A of the substrate 31. A photosensitizer 53 is placed on the upper side 31A of the substrate 31, and a masque 55 is perpendicularly disposed thereabove. From both sides of the masque 55, plane waves 61, 62, 63, 64 are simultaneously fell on the upper side 31A of the substrate 31 at angles of incidence $\pm \theta_A, \pm \theta_B$, exposing the photosensitizer 53.

[0065] The plane waves 61, 62 having the angles of incidence $+ \theta_A, \mp \theta_B$ serve to form the first hologram 32 on the right side of the center plane 35, whereas the plane waves 63, 64 having the angles of incidence $- \theta_A, - \theta_B$ serve to form the second hologram 33 on the left side of the center plane 35. In such a way, by this method, the two symmetrical holograms 32, 33 are simultaneously formed on both sides of the center plane 35.

[0066] The masque 55 has a slender wedge-shaped section, and a sharp-pointed end portion. The masque 5 is disposed so that the end portion is in contact with the upper side 31A of the substrate 31. It is preferable to avoid as much as possible a production of a shadow of the masque 55 on the center plane 35.
The two holograms 32, 33 are disposed in the direction and on both sides of the object 75. Each hologram 77A, 77B are dislocated with each other in the vertical direction by the thickness of the adhesive agent 41. Therefore, if the thickness of the adhesive agent 41 is fully decreased, the same structure as that of the eighth embodiment in Fig. 9 is obtained. It is noted that the two transparent substrates 31, 51 serve as a cover glass, respectively.

Fig. 16 is a general view of an eleventh embodiment of the present invention. In the eleventh embodiment, the fixed point detecting device is constructed to include two fixed point detecting portions. The fixed point detecting device of the type may be used, for example, in an X-ray exposure drawing device. The X-ray exposure drawing device includes two rails 71, 71 and a stage 73 which is movable thereon in the direction of measurement or X-direction.

An object to be detected 75, for example, a photosensitizer, is placed on an upper side 73A of the stage 73, and the object 75 has a fixed point P to be detected. By way of example, in case of carrying out double exposure on the photosensitizer, the fixed point P should accurately be detected by the fixed point detecting device. Conventionally, such detection of the fixed point P is carried out by a single fixed point detecting device. Therefore, when the stage 73 is yawed as indicated by arrows "y" in Fig. 16 with respect to the direction of measurement or X-direction, the fixed point cannot be detected accurately.

On the other hand, according to the eleventh embodiment, since the fixed point P is detected by the two fixed point detecting portions, an error due to such yawing can be eliminated.

In the eleventh embodiment, holograms 77A, 77B are placed on the upper side 73A of the stage 73 and on both sides of the object 75. Each hologram 77A, 77B includes two holograms 32, 33 as described above. The two holograms 32, 33 are disposed in the direction of measurement or X-direction, and constructed to be symmetrical with respect to the center plane.

Two fixed point detecting portions are disposed corresponding to the holograms 77A, 77B, each portion having an optical system and a detecting system. The optical system includes the light source 12, and the detecting system includes a pair of light receivers 22, 23 and the electric processing circuit 80.

In the eleventh embodiment, as shown in Fig. 16, the fixed point detecting device includes an adder 81 for adding output signals of the differential amplifiers 80-2, and a comparator 83 which inputs output of the adder 81.

Figs. 18A to 18C show output signals of the two differential amplifiers 80-2 and the adder 81. A curve C3-1 of a fully-drawn line in Fig. 18A indicates an output signal of the first differential amplifier 80-2, and a curve C3-2 of a fully-drawn line in Fig. 18B indicates an output signal of the second differential amplifier 80-2, and a curve C4 of a fully-drawn line in Fig. 18C indicates an output signal of the adder 81.

Referring next to Fig. 19, a description will be made with regard to an error due to yawing and a function of compensating this. As shown in Fig. 19, the X-axis is taken via the fixed point P of the object to be detected 75 and in the direction of measurement. Suppose that the holograms 77A, 77B placed on the upper side 73A of the stage 73 of the X-ray exposure drawing device are symmetrically disposed with respect to the X-axis, and that a distance from the X-axis to each hologram 77A, 77B is "t". The fixed point detecting devices are disposed corresponding to the holograms 77A, 77B on both sides of the object 75.

When the stage 73 of the X-ray exposure drawing device is yawed, the holograms 77A, 77B are yawed on the upper side 73A of the stage 73 are also yawed as indicated by arrows "y" in Fig. 19. Thus, the holograms 77A, 77B produce rotary motion around the fixed point P. Specifically, the two holograms 77A, 77B are moved by the same distance in the opposite direction. The first hologram 77A is moved by ΔX in the negative direction of the X-axis, whereas the second hologram 77B is moved by ΔX in the positive direction of the X-axis.

Referring again to Figs. 18A to 18C, curves of a broken line indicate output signals of the two differential amplifiers 80-2 and the adder 81 when the stage 73 is yawed. The curve C3-1’ of a broken line in Fig. 18A indicates an output signal of the first differential amplifier 80-2, and the curve C3-2’ of a broken line in Fig. 18B indicates an output signal of the second differential amplifier 80-2, and the curve C4’ of a broken line in Fig. 18C indicates an output signal of the adder 81.

The output signal of the adder 81 is provided to the comparator 83, obtaining the zero cross point. As indicated by the curve C4’ of a broken line in Fig. 18C, the output signal of the adder 81 is varied with yawing, while the zero cross point is not changed. In the eleventh
embodiment, the output signals of the two differential amplifiers 80-2 are varied with yawing, which are added, however, by the adder 81, having a variation part canceled.

[0082] Fig. 20 shows an example wherein the fixed point detecting device of the present invention is used in a linear encoder. The linear encoder has a scale substrate 75-1 having an upper side on which a diffraction grating 75-2 for detecting a displacement is disposed along the axis of measurement or X-axis. A displacement in the axis of measurement (X-axis) is detected by the diffraction grating 75-2. The holograms 77A, 77B are symmetrically placed on both sides of the diffraction grating 75-2 for detecting a fixed point.

[0083] In this example, the fixed point detecting device includes two fixed point detecting portions corresponding to the two holograms 77A, 77B, each portion having an optical system and a detecting system. It is noted that such optical system and detecting system of the fixed point detecting portion may be the same as those in the eleventh embodiment of the present invention as shown in Fig. 16. In such a way, in this example also, an error due to yawing of the scale substrate 75-1 can be eliminated in the same way as in the eleventh embodiment.

Claims

1. A system for detecting a fixed point, the system having an axis of measurement, comprising:

   a light source (12) for providing light;

   means for diffracting light provided by said light source (12), said diffracting means having two portions (32, 33) adjacent to each other and separated by an imaginary center plane (35) perpendicular thereto, said two portions (32, 33) being symmetrically arranged on both sides of said imaginary center plane (35);

   means for detecting intensities of light diffracted by said two portions (32, 33) of said diffracting means, said detecting means having at least two light receivers (22, 23);

   the fixed point being obtained by determining a point at which said intensities of diffracted light detected by said two light receivers (22, 23) have the same magnitude when moving said diffracting means relative to said light source and said detecting means along the axis of measurement.

   characterized in that

   said diffracting means is disposed on a transparent substrate (31), and has grating vectors (V) which are symmetrically inclined with respect to said imaginary center plane and the same grating interval (d); and

   said diffracted light includes positive and negative same-order diffracted light, wherein a luminous intensity difference is large between said positive and negative same-order diffracted light;

2. A system as claimed in claim 1, wherein said diffracting means includes a holographic diffraction grating.

3. A system as claimed in claim 2, wherein said hologram is of a transmission-type.

4. A system as claimed in claim 2, wherein said hologram is of a reflection-type.

5. A system as claimed in claim 3, wherein said two light receivers (22, 23) are disposed on the side opposite to said light source (12) with respect to said hologram.

6. A system as claimed in claim 2, further comprising a reflecting surface arranged on the side opposite to said light source (12) with respect to said hologram, said reflecting surface reflecting lights diffracted by said two portions (32, 33) of said hologram.

7. A system as claimed in claim 6, wherein said two light receivers (22, 23) are disposed on the same side as said light source (12) with respect to said hologram.

8. A system as claimed in claim 6, wherein said reflecting surface includes a film (37) placed on said transparent substrate (31).

9. A system as claimed in claim 6, wherein said reflecting surface includes a plate (39) disposed below said transparent substrate (31).

10. A system as claimed in claim 6, wherein said reflecting surface includes a lower side of said transparent substrate (31).

11. A system as claimed in claim 10, wherein light diffracted by said two portions (32, 33) of said hologram is incident on said lower side of said transparent substrate (31) at an angle greater than a critical angle.

12. A system as claimed in claim 6, wherein light reflected by said reflecting surface is again diffracted by
said two portions (32, 33) of said hologram to obtain outgoing light that is parallel to light out of said light source (12).

13. A system as claimed in claim 6, wherein each of said two portions (32, 33) of said hologram includes an inner portion (32A, 33A) adjacent to said imaginary center plane (35) and an outer portion (32B, 33B) distant from said imaginary center plane (35), said inner portion and said outer portion having grating vectors inclined at angles of inclination different from each other with respect to said imaginary center plane, whereby light out of said light source is subjected to a first diffraction by said inner portion of each of said two portions of said hologram and, after being reflected by said reflecting surface, a second diffraction by said outer portion of each of said two portions of said hologram.

14. A system for detecting a fixed point, the system having an axis of measurement, comprising:

- two plates being disposed on a common stage (73), said two plates being disposed symmetrically with respect to said axis of measurement on both sides of said fixed point (P);
- each of said plates including a hologram (77A, 77B) being disposed on a transparent substrate for diffracting light, each of said holograms having two portions adjacent to each other and separated by an imaginary center plane perpendicular thereto, said two portions being symmetrically arranged on both sides of said imaginary center plane, and having grating vectors symmetrically inclined with respect to said imaginary center plane and the same grating interval;
- two detectors arranged corresponding to said two plates, each detector including a light source (12) and a pair of light receivers (22, 23) arranged to detect an intensity of light diffracted by said holograms;
- electric processing circuits (80) connected to each of said pairs of light receivers (22, 23), each of said electric processing circuits (80) including a differential amplifier (80-2); and
- electric circuit means including an adder (81), said adder (81) being connected to said differential amplifiers (80-2) and adding output signals (C3-1, C3-2; C3-1', C3-2') of said differential amplifiers (80-2) to form an added output signal (C4; C4');

the fixed point (P) being obtained by determining a point at which said added output signal (C4; C4') is zero when moving said two plates relative to said two detectors along said axis of measurement.

15. A system as claimed in claim 14, wherein said electric circuit means include two pairs of current-voltage converters, two differential amplifiers (29), an adder (81), and a comparator (83).

Patentansprüche

1. System zum Erfassen eines festen Punktes, wobei das System eine Messachse hat und umfasst:

   - eine Lichtquelle (12) zum Erzeugen von Licht;
   - eine Einrichtung zum Beugen von durch die Quelle (12) erzeugtem Licht, wobei die Beugungseinrichtung zwei Abschnitte (32, 33) aufweist, die aneinandergrenzen und durch eine imaginäre Mittelebene (35) senkrecht dazu getrennt sind, und die zwei Abschnitte (32, 33) symmetrisch auf beiden Seiten der imaginären Mittelebene (35) angeordnet sind;
   - eine Einrichtung zum Erfassen von Intensitäten durch die zwei Abschnitte (32, 33) der Beugungseinrichtung gebeugten Lichtes, wobei die Erfassungseinrichtung wenigstens zwei Lichtempfänger (22, 23) aufweist;
   - wobei der feste Punkt bestimmt wird, indem ein Punkt festgestellt wird, an dem die Intensitäten gebeugten Lichtes, die von den zwei Lichtempfängern (22, 23) erfasst werden, den gleichen Betrag aufweisen, wenn die Beugungseinrichtung in Bezug auf die Lichtquelle und die Erfassungseinrichtung entlang der Messachse bewegt wird,

   dadurch gekennzeichnet, dass:

   - die Beugungseinrichtung auf einem transparenten Substrat (31) angeordnet ist und Gittervektoren (V) aufweist, die in Bezug auf die imaginäre Mittelebene symmetrisch geneigt sind und das gleiche Gitterintervall (d) aufweisen; und
   - das gebeugte Licht Beugungslicht gleicher positiver und negativer Ordnung enthält, wobei eine Lichtstärkendifferenz zwischen dem Beugungslicht gleicher positiver und negativer Ordnung groß ist.

2. System nach Anspruch 1, wobei die Beugungsein-
richtung ein holografisches Beugungsgitter enthält.

3. System nach Anspruch 2, wobei das Hologramm vom Durchlassstyp ist.

4. System nach Anspruch 2, wobei das Hologramm vom Reflektionstyp ist.

5. System nach Anspruch 3, wobei die zwei Lichtempfänger (22, 23) auf der der Lichtquelle (12) in Bezug auf das Hologramm gegenüberliegenden Seite angeordnet sind.


7. System nach Anspruch 6, wobei die zwei Lichtempfänger (22, 23) in Bezug auf das Hologramm auf der gleichen Seite wie die Lichtquelle (12) angeordnet sind.

8. System nach Anspruch 6, wobei die reflektierende Fläche einen Film (37) enthält, der sich auf dem transparenten Substrat (31) befindet.

9. System nach Anspruch 6, wobei die reflektierende Fläche eine Platte (39) enthält, die unter dem transparenten Substrat (31) angeordnet ist.

10. System nach Anspruch 6, wobei die reflektierende Fläche eine untere Seite des transparenten Substrats (31) einschließt.

11. System nach Anspruch 10, wobei durch die beiden Abschnitte (32, 33) des Hologramms gebeugtes Licht auf die Unterseite des transparenten Substrats (31) in einem größeren als einem Grenzwinkel auftrifft.

12. System nach Anspruch 6, wobei durch die reflektierende Fläche reflektiertes Licht emeut durch die zwei Abschnitte (32, 33) des Hologramms gebeugt wird, um austretendes Licht zu erzeugen, das parallel zum Licht von der Lichtquelle (12) ist.


14. System zum Erfassen eines festen Punktes, wobei das System eine Messachse aufweist und umfasst:

- zwei Platten, die auf einem gemeinsamen Tisch (73) angeordnet sind, wobei die zwei Platten in Bezug auf die Messachse symmetrisch auf beiden Seiten des festen Punktes (P) angeordnet sind;
- wobei jede der Platten ein Hologramm (77A, 77B) enthält, das auf einem transparenten Substrat angeordnet ist, um Licht zu beugen, und wobei jedes der Hologramme zwei Abschnitte aufweist, die aneinandergrenzen und durch eine imaginäre Mittelebene senkrecht dazu getrennt sind, wobei die zwei Abschnitte symmetrisch auf beiden Seiten der imaginären Mittelebene angeordnet sind und Gittervektoren aufweisen, die in Bezug auf die imaginäre Mittelebene symmetrisch geneigt sind und das gleiche Gitterintervall aufweisen;
- zwei Detektoren, die entsprechend den beiden Platten angeordnet sind, wobei jeder Detektor eine Lichtquelle (12) und ein Paar Lichtempfänger (22, 23) enthält, die so angeordnet sind, dass sie eine Intensität von Licht erfassen, das durch die Hologramme gebeugt wird;
- elektrische Verarbeitungsschaltungen (80), die mit jedem des Paars von Lichtempfängern (22, 23) verbunden sind, wobei jede der elektrischen Verarbeitungsschaltungen (80) einen Differenzverstärker (80-2) enthält;
- eine elektrische Schaltungseinrichtung, die einen Addierer (81) enthält, wobei der Addierer (81) mit den Differenzverstärkern (80-2) verbunden ist, und Ausgangssignale (C3-1, C3-2; C3-1', C3-2') der Differenzverstärker (80-2) addiert, um ein addiertes Ausgangssignal (C4; C4') zu erzeugen;
- wobei der feste Punkt (P) bestimmt wird, indem ein Punkt festgestellt wird, an dem das addierte Ausgangssignal (C4; C4') Null beträgt, wenn die zwei Platten in Bezug auf die zwei Detektoren entlang der Messachse bewegt werden.
15. System nach Anspruch 14, wobei die elektrische Schaltungseinrichtung zwei Paare Strom-Spannungs-Wandler, zwei Differenzverstärker (29), einen Addierer (81) und einen Komparator (83) enthält.

Revendications

1. Système pour détecter un point fixe, le système possédant un axe de mesure comprenant :

une source de lumière (12) pour fournir de la lumière ;
un moyen pour diffracter la lumière fournie par ladite source de lumière (12), ledit moyen de diffraction comportant deux portions (32, 33) adjacentes .l'une à l'autre et séparées par un plan central imaginaire (35) perpendiculaire à celles-ci, les deux portions précitées (32, 33) étant agencées d'une manière symétrique des deux côtés dudit plan central imaginaire (35) ;
le point fixe étant obtenu en déterminant un point auquel lesdites intensités de la lumière diffractée par lesdites deux portions (32, 33) dudit moyen de diffraction, ledit moyen de détection comportant au moins deux récepteurs de lumière (22, 23) ;
la lumière diffractée comprend la lumière diffractée positive et négative de même ordre, où une différence d'intensité lumineuse est grande entre ladite lumière diffractée positive et négative de même ordre.

2. Système selon la revendication 1, où ledit moyen de diffraction comprend un réseau de diffraction holographique.

3. Système selon la revendication 2, où ledit hologramme est du type à transmission.

4. Système selon la revendication 2, où ledit hologramme est du type à réflexion.

5. Système selon la revendication 3, où les deux récepteurs de lumière précités (22, 23) sont disposés sur le côté opposé à ladite source de lumière (12) par rapport audit hologramme.

6. Système selon la revendication 2, comprenant en outre une surface de réflexion agencée sur le côté opposé à ladite source de lumière (12) par rapport audit hologramme, ladite surface de réflexion réfléchit les lumières diffractées par lesdites deux portions (32, 33) dudit hologramme.

7. Système selon la revendication 6, où les deux récepteurs de lumière précités (22, 23) sont disposés sur le même côté que ladite source de lumière (12) par rapport audit hologramme.

8. Système selon la revendication 6, où ladite surface de réflexion comprend un film (37) placé sur ledit substrat transparent (31).

9. Système selon la revendication 6, où ladite surface de réflexion comprend une plaque (39) disposée dans le substrat transparent (31).

10. Système selon la revendication 6, où ladite surface de réflexion comprend un côté inférieur dudit substrat transparent (31).

11. Système selon la revendication 10, où la lumière diffractée par lesdites deux portions (32, 33) dudit hologramme est incidente sur ledit côté inférieur dudit substrat transparent (31) selon un angle plus grand qu'un angle critique.

12. Système selon la revendication 6, où la lumière réfléchie par ladite surface de réflexion est de nouveau diffractée par lesdites deux portions (32, 33) dudit hologramme pour obtenir une lumière sortante qui est parallèle à la lumière sortant de ladite source de lumière (12).

13. Système selon la revendication 6, où chacune des deux portions précitées (32, 33) dudit hologramme comprend une portion intérieure (32A, 33A) adjacente audit plan central imaginaire (35) et une portion extérieure (32B, 33B) distante dudit plan central imaginaire (35), ladite portion interne et ladite portion externe ayant des vecteurs de réseau optique inclinés selon des angles d'inclinaison qui diffèrent l'un de l'autre par rapport audit plan central imaginaire par quoi la lumière sortant de ladite source de lumière est soumise à une première diffraction par ladite portion interne de chacune desdites deux portions dudit hologramme, et après avoir été
réfléchie par ladite surface de réflexion, une seconde diffraction par ladite portion externe de chacune desdites deux portions dudit hologramme.

14. Système pour détecter un point fixe, le système possédant un axe de mesure, comprenant :

deux plaques étant disposées sur un étage commun (73), lesdites deux plaques étant disposées symétriquement par rapport audit axe de mesure des deux côtés dudit point fixe (P) ;

chacune desdites plaques incluant un hologramme (77A, 77B) disposé sur un substrat transparent pour diffracter la lumière, chacun desdits hologrammes ayant deux portions adjacentes l'une à l'autre et séparées par un plan central imaginaire perpendiculaire à celles-ci, lesdites deux portions étant agencées d'une manière symétrique des deux côtés dudit plan central imaginaire et ayant des vecteurs de réseau optique inclinés symétriquement par rapport audit plan central imaginaire et le même intervalle de réseau ;

deux détecteurs agencés d'une manière correspondante auxdites deux plaques, chaque détecteur incluant une source de lumière (12) et une paire de récepteurs de lumière (22, 23) agencés pour détecter une intensité de lumière diffractée par lesdits hologrammes ;

des circuits de traitement électriques (80) connectés à chacun de ladite paire de récepteurs de lumière (22, 23), chacun desdits circuits de traitement électriques (80) incluant un amplificateur différentiel (80-2) ;

un moyen de circuit électrique comprenant un additionneur (81), ledit additionneur (81) étant connecté auxdits amplificateurs différentiels (80-2) et additionnant les signaux de sortie (C3-1 ; C3-2 ; C3-1' ; C3-2') desdits amplificateurs différentiels (80-2) pour former un signal de sortie additionné (C4 ; C4') ;

le point fixe (P) étant obtenu en déterminant un point auquel ledit signal de sortie additionné (C4 ; C4') est zéro lors d'un déplacement desdites deux plaques relativement auxdits deux détecteurs le long dudit axe de mesure.

15. Système selon la revendication 14, où ledit moyen de circuit électrique comprend deux paires de convertisseurs de tension de courant, deux amplificateurs différentiels (29), un additionneur (81) et un comparateur (83).