(12) UK Patent Application (19) GB (11) 2 095 399 A

(21) Application No **8208682**
(22) Date of filing **24 Mar 1982**
(30) Priority data
(31) **56/043753**
(32) **24 Mar 1981**
(33) **Japan (JP)**
(43) Application published **29 Sep 1982**
(51) **INT CL^3 G01B 11/00**
(52) Domestic classification **G1A** A3 EK G15 G1 G2 G7 P16 P17 P4 R7 S3 T14 T15 T26 T3 T4 T8
(56) Documents cited **US 4176276** **GB 1474049**
(58) Field of search **G1A**

(71) Applicants
Mitutoyo MFG Co. Ltd., 33-7 Shiba 5 chome, Minato-ku, Tokyo, Japan.
(72) Inventors
Satoshi Oomori
(74) Agents
Page, White and Farrer, 27, Chancery Lane, London WC2A 1NT.

(54) Photoelectrical displacement-measuring device

(57) A photoelectrical type displacement measuring device (Figure 3) comprises a light source (10), first and second scales (22, 24) each having graduations (22*a*, 24*a*) for receiving rays from the light source (10) and capable of forming images through interaction therebetween; a third scale (26) with graduations (26*a*) for receiving images from the first and second scales and capable of interacting with the images; and a receptor element (20) for receiving rays from the third scale (26); whereby relative displacement is detected through variation in the received light due to relative movement between the first, third and second scales, the scales each having graduations on surfaces not facing any other scales so that spacing variation between the scales can be increased without rendering the device unduly large. In another embodiment (Figure 4) the first scale (30) serves as the third scale, and the light rays are reflected at the second scale (32).

FIG. 3

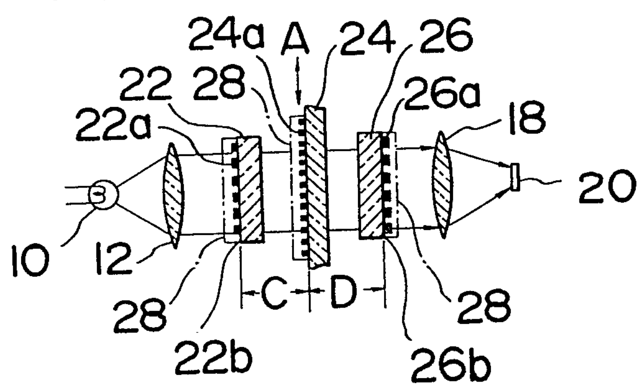

FIG. 4

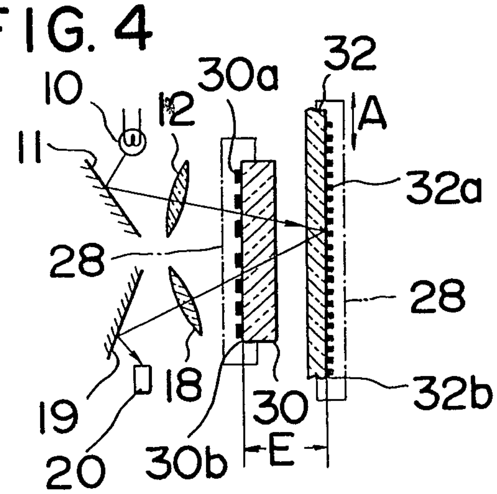

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FIG. 1

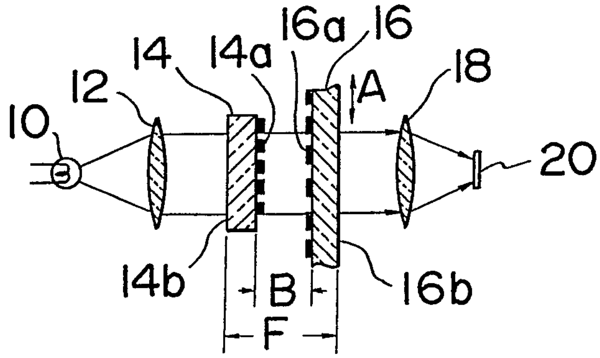


FIG. 2

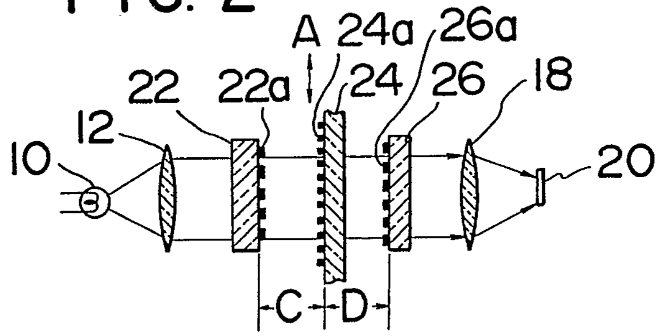


FIG. 3

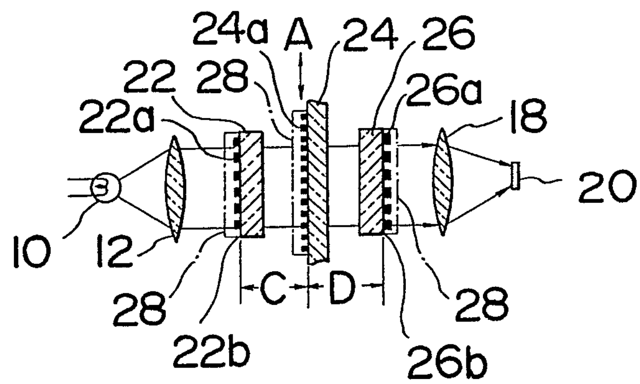
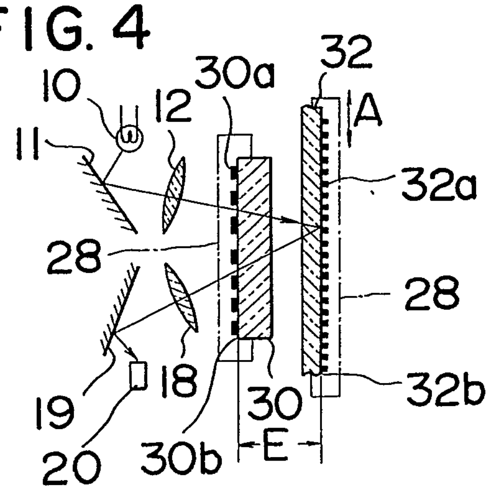


FIG. 4



SPECIFICATION

Photoelectrical type displacement measuring device

This invention relates to photoelectrical type displacement measuring devices, and more particularly to improvements in a photoelectrical type displacement measuring device suitable for use in a rectilinear displacement measuring instrument and comprising: a light source; a first and a second scales each formed thereon with graduation fringes for receiving rays emitted from the light source and capable of forming images through the interaction therebetween; a third scale formed thereon with graduation fringes for receiving the images formed and projected by the first and the second scales and capable of interacting with the images; and a receptor element for receiving rays emitted from the third scale; whereby a relative displacement value is detected through a variation in the value of received light due to a relative movement between the first, the third and the second scales.

In general, in a rectilinear displacement measuring instrument for measuring a length, etc. of a body, when a relative movement value between relatively movable members such for example as a movement value of a measuring element relative to the body, a movement value of a slider relative to a column and the like, there have been known such ones wherein a main scale is provided on one side and a detector including an index scale is affixed onto the other side and a relative displacement value between the main scale and the detector is photoelectrically read. In the accompanying drawings Figures 1 and 2 show prior art arrangements.

In the rectilinear displacement measuring instrument of the type described, in general, a photoelectrical type displacement measuring device as shown in Figure 1 is used. Refferring to the drawing, designated at 10 is a light source such as a lamp, 12 a collimator lens for turning rays given out by the light source 10 into parallel rays, 14 and 16 an index scale and a main scale, which are movable relative to each other by the reciprocation of the main scale 16 relative to the index scale 14 in a direction indicated by an arrow A in the drawing in accordance with a displacement of an object to be measured for example and respectively formed thereon with graduation fringes 14a and 16a which are light transmitting portions and light shielding portions arranged alternately and having widths equal to each other; 18 a condensing lens for condensing rays emitted from the main scale 16; and 20 a receptor element for receiving rays condensed by the condensing lens 18. The light source 10, the collimator lens 12, the index scale 14, the condensing lens 18 and the receptor element 20 are received in a substantially hermetically sealed casing for example, and affixed to the object to be measured. While, the main scale 16 is affixed to a base. The aforesaid graduation fringes 14a and 16a are formed such that a metal is deposited on a flat plate made of glass constituting a base member and the light transmitting portions are removed through the etching, whereby the graduation fringes are formed on the surfaces of the scales for example.

The rectilinear displacement measuring instrument provided with the photoelectrical type displacement measuring device described above features that, when the main scale 16 is displaced relative to the index scale 14 or the like in accordance with a relative displacement between the object to be measured and the base, a value of the light received by the receptor element 20 is periodically varied, whereby the value of relative movement between the object to be measured and the base is detectable from a variation in the value of the light received, so that the displacement of the object to be measured can be digitally measured.

Now, in the photoelectrical type displacement measuring device described above, in order to improve the resolving-power thereof, it is necessary to lessen the widths of the light transmitting portions and the light shielding portions of the graduation fringes 14a and 16a, in order to improve the accuracy in reading, it is necessary to lessen the opposing interval between the graduation fringes 14a and 16a (Refer to B in Figure 1), and the widths of the light transmitting portions and the light shielding portions of the graduation fringes and the opposing interval B between the graduation fringes are substantially proportional to each other. In consequence, when the widths of the light transmitting portions and the light shielding portions are selected to desired values so as to obtain a desired resolving-power, the opposing interval B between the graduation fringes corresponding to the desired width is automatically determined. Additionally, the tolerance limits of variation of the opposing interval B between the graduation fringes to the reference interval is substantially proportional to the opposing interval B. When the widths of the light transmitting portions and the light shielding portions of the graduation fringes are set to be 20 μm for example, it is necessary to maintain the opposing interval B between the graduation fringes within the scope of 30±10 μm, and, when the widths of the light transmitting portions and the light shielding portions of the graduation fringes are set to be 10μm, it is necessary to maintain the opposing interval B between the graduation fringes within the scope of 20±5 μm. In other words, it has been an important technical problem for the photoelectrical type measuring device how accurately the opposing interval B between the graduation fringes can be maintained.

Consequently, heretofore, the graduation fringes 14a and 16a have been formed on the opposing scale surfaces of the index scale 14 and the main scale 16, respectively, and the opposing interval between the index scale 14 and the main scale 16 has been secured by use of a sliding block, coating or the like. Notwithstanding, with the above-described conventional method, it has been comparatively easy to set the reference interval (30μm for example), however, it has been extremely difficult to maintain the variation of the opposing interval B between the scales within the minute tolerance limits of variation (± 10 μm for example) because of the adverse influences of the thermal deformation, mechanical destortion and the like caused to the scales.

As a photoelectrical type displacement measuring device capable of obviating the above-described disadvantage presented by the conventional two-scale photoelectrical type displacement measuring device using two scales including the index scale and the main scale as mentioned above and of increasing the tolerance limits of variation of the opposing interval between the scales, a three-scale photoelectrical type displacement measuring device shown in Figure 2 has been proposed in which light is emitted from the light source 10, a first scale 22 and a second scale 24 are formed with graduation fringes 22a and 24a, which are capable of forming images by the interaction therebetween, respectively, a third scale 26 is formed with graduation fringes 26a for receiving the images formed and projected by the first and the second scales 22 and 24 and interacting with the images, and the above-described three scales are used, whereby a relative displacement value is determined from a change in the value of the light received by the receptor element 20 in accordance with the relative movements between the first and the third scales 22, 26 and the second scale 24. With the photoelectrical type displacement measuring device using three scales as described above, when, for example, the widths of the light transmitting portions and the light shielding portions of the graduation fringes 22a and 26a in the first scale 22 and the third scale 26 are set to be 20μm, the widths of the light transmitting portions and the light shielding portions of the graduation fringes 24a in the second scale 24 are set to be 10μm and the interval C between the graduation fringes 22a of the first scale 22 and the graduation fringes 24a of the second scale 24 is set to be equal to the interval D between the graduation fringes 24a of the second scale 24 and the graduation fringes 26a of the third scale 26, the reference intervals of the respective intervals C and D can be increased to about 5 ~ 7 mm and their tolerance limits of variation can be increased to about 1 mm. However, in this photoelectrical type displacement measuring device using three scales, not only the tolerance limits of variation of the intervals between the graduation fringes but also the reference intervals thereof increase, and hence, if the graduation fringes 22a and 26a of the first scale 22 and the third scale 26 are formed on the inner surfaces thereof opposed to the second scale 24 as in the conventional two-scale photoelectrical type displacement measuring device using two scales, then the scale portions become large-sized in cooperation with the normal thicknesses of about 1 mm of the first and the third scales 22 and 26, there has been presented the problem that the displacement measuring device could not be assembled into a compact size rectilinear displacement measuring instrument in particular.

The present invention has been developed to obviate the above-described disadvantages of the prior art and a first object of the present invention is to provide a photoelectrical type displacement measuring device capable of increasing the tolerance limits of variation of the intervals between scales, and moreover, easy in being assembled into a compact size displacement measuring instrument.

A second object of the present invention is to provide a three-scale transmitting photoelectrical type displacement measuring device having the above-described advantages.

A third object of the present invention is to provide a reflecting photoelectrical type displacement measuring device having the above-described advantages.

A fourth object of the present invention is to provide a photoelectrical type displacement measuring device capable of facilitating cleaning of surfaces formed with graduation fringes of scales and of preventing disadvantages of light shielding by dust and the like adhered to the surfaces of the scales, troubles in sliding and the like.

To achieve the first object, according to the present invention, in a photoelectrical type displacement measuring device comprising a light source, a first and a second scales each formed thereon with graduation fringes for receiving rays emitted by the light source and capable of forming images through the interaction therebetween, a third scale formed thereon with graduation fringes for receiving the images formed and projected by the first and the second scales and capable of interacting with the images and a receptor element for receiving rays emitted from the third scale, whereby a relative displacement value is detected through a variation in the value of received light due to a relative movement between the first, the third and the second scales, the first, second and third scales are made of a material capable of transmitting light and graduation fringes of scales having surfaces not facing any other scales are formed on the surfaces not facing any other scales.

To achieve the second object, according to the present invention, the light source is desposed on the side of the first scale out of the first through third scales, the receptor element is disposed on the side of the third scale out of the first through third scales, the graduation fringes of the first scale are formed on the surface of the first scale on the side of the light source, and the graduation fringes of the third scale are formed on the surface of the third scale on the side of the receptor element.

To achieve the third object, according to the present invention, the first scale additionally functions as the third scale, the light source and the receptor element are disposed on the side of the first scale out of the first and the second scales, the graduation fringes of the first scale are formed on the surface of the first scale on the side of the light source and the receptor element, and the graduation fringes of the second scale are formed on the surface of the second scale not facing the first scale.

Additionally, the light source, the first and the third scales and the receptor element are all fixed and the second scale is made movable.

Further, the relationship of the width of the graduation fringes of the first, the second and the third scales is set to be 2 : 1 : 2.

Furthermore, the first, the second and the third scales are made of glass.

To achieve the fourth object, according to the present invention, the graduation fringes on the scales are coated with light transmission protective members.

According to the present invention, the relationship between the reference intervals of the graduation fringes and the tolerance limits of variation can be improved without rendering the device large in size and only the tolerance limits of variation can be increased to a considerable extent. In consequence, the manufacture, adjustment and the like of the device can be facilitated.

The exact nature of this invention, as well as other objects and advantages thereof, will be readily apparent from consideration of the following specification relating to the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof and wherein:

Figure 1 is a sectional view illustrating the principles of the conventional two-scale transmitting photoelectrical type displacement measuring device;

Figure 2 is a sectional view illustrating the principles of the conventional three-scale transmitting photoelectrical type displacement measuring device;

Figure 3 is a sectional view showing the arrangement of a first embodiment of the photoelectrical type displacement measuring device according to the present invention; and

Figure 4 is a sectional view showing the arrangement of a second embodiment thereof.

Detailed description will hereunder be given of the embodiments of the present invention with reference to the drawings.

According to the first embodiment of the present invention, as shown in Figure 3, in a three-scale transmitting photoelectrical type displacement measuring device comprising a light source 10, a collimator lens 12, a first scale 22 formed with graduation fringes 22a in which widths of the light transmitting portions and the light shielding portions are 20 μm, respectively, a second scale 24 formed with graduation fringes 24a in which widths of the light transmitting portions and the light shielding portions are 10 μm, respectively, a third scale 26 formed with graduation fringes 26a in which the light transmitting portions and the light shielding portions are 20 μm, respectively, a condensing lens 18 and a receptor element 20, the graduation fringes 22a and 26a of the first and the third scales 22 and 26, which have surfaces 22b and 26b not facing any other scales, are formed on the aforesaid surfaces 22b and 26b not facing any other scales, i.e., the surface of the first scale on the side of the light source 10 and the surface of the third scale 26 on the side of the receptor element 20. Other respects are similar to the conventional example, so that detailed description will be omitted.

In this embodiment, the thicknesses of the first and the third scales 22 and 26 (in general, about 1 mm, respectively) are absorbed by the intervals C and D of the graduation fringes 22a and 26a, thereby preventing from uselessly rendering the device large in size. In contrast thereto, in the conventional three-scale transmitting photoelectrical type displacement measuring device, the thickenesses of the first and third scales 22 and 26 are disposed at the outside of the graduation fringes 22a of the first scale 22 and also at the outside of the graduation fringes 26a of the third scale 26, respectively, thus requiring excessive spaces equal to the thicknesses of the glasses of the first and the third scales 22 and 26. Furthermore, the tolerance limits of variation of the intervals C and D between the scales are increased to about 1 mm in this embodiment as being the inherent advantage of the three-scale type device, thus facilitating the maintenance of the tolerance limits of variation.

In addition, the surfaces of the first through third scales 22, 24 and 26, which are formed with the graduation fringes 22a, 24a and 26a, may be coated with light transmission protective members 28 additionally functioning as reflection preventive films, respectively. In this case, cleaning of the surfaces of the scales, which are formed with the graduation fringes, is facilitated, thereby enabling to prevent disadvantages of light shielding by dust and the like adhered to the surfaces of the scales, troubles in sliding and the like.

Figure 4 shows the second embodiment of the present invention. In this embodiment, the present invention is applied to a reflecting photoelectrical type displacement measuring device comprising a light source 10, a reflector 11, a collimator lens 12, a first scale 30 additionally functioning as the third scale and formed with graduation fringes 30a, in which the widths of the light transmitting portions and the light shielding portions are set to be 20 μm, respectively, a reflecting type second scale 32 formed with graduation fringes 32a, in which the width of the light transmitting portions and the light shielding portions are set to be 10 μm, respectively, a condensing lens 18, a reflector 19 and a receptor element 20. Not only the first scale 30 additionally functioning as the third scale but also the reflecting type second scale 32 are made of a light-transmitting material such as glass, the graduation fringes 30a of the first scale 30 are formed on the surface 30b of the first scale 30 on the side of the light source and the receptor element, and the graduation fringes 32a of the second scale 32 are formed on the surface 32b of the second scale 32 not facing the first scale 30. In this embodiment also, the surfaces of the first and the second scales 30 and 32, on which the graduation fringes 30a and 32a are formed, are coated with light transmission protective members 28 additionally functioning as the reflection preventive films.

In this embodiment, the first scale 30 additionally functions as the third scale so as to omit the use of the third scale, and the thickness of the first scale 30 (normally about 1 mm) and the thickness of the second scale 32 (normally about 2 to 5 mm) are absorbed by an interval E between the graduation fringes 30a of the first scale 30 and the graduation fringes 32a of the second scale 32, so that the first scale 30 and the second scale 32 can be absorbed by a thickness substantially equal to an interval F (Refer to Figure 1) between the surface 14b of the index scale 14 on the side of the light source 10 and the surface 16b of the main scale 16 on the side of the receptor element 20 in the case of the conventional two-scale transmitting photoelectrical type displacement measuring device. In consequence, only the tolerance limits of variation of the interval E between the graduation fringes 30b and 32b can be considerably increased to about 1 mm, without rendering the device large in size as compared with the conventional two-scale transmitting photoelectrical type displacement measuring device.

Furthermore, in this embodiment, no graduation fringes are formed on the surfaces of the scales facing each other, so that cleaning of the surfaces of the scales facing each other can be facilitated, thereby enabling to readily prevent the disadvantage caused by dust and the like intruding between the scales.

Further, in this embodiment, like in the first embodiment, the graduation fringes 30a and 32a of the first and the second scales 30 and 32 are protected by the light transmission protective members 28, so that cleaning of the surfaces of the scales, on which the graduation fringes are formed, can be facilitated, thus enabling to readily prevent the disadvantage caused by dust and the like attached to the surfaces of the scales.

Additionally, in each of the above-described embodiments, the widths of the light transmitting portions and the light shielding portions of the first and the third scales are set to be 20 μm and the widths of the light transmitting portions and the light shielding portions of the second scale are set to be 10 μm, however, the absolute values of the widths of the graduation fringes of the light transmitting portions and the light shielding portions of the respective scales and the relationship therebetween (2 : 1 : 2) should not necessarily be limited to the above-described embodiments, but, as far as the device remains to be one in which the images are formed by the graduation fringes formed on the first and the second scales and the graduation fringes formed on the third scale can be interact with the images thus formed, any absolute values and the relationship other than those described above may be adopted.

In each of the above-described embodiments, the first through third scales are made of glass, however, the material for the first through third scales should not necessarily be limited to this, but, any other light transmitting material such as acrylic resin may be adopted.

It should be apparent to those skilled in the art that the above-described embodiments are merely representative, which represent the applications of the principles of the present invention. Numerous and varied other arrangements can be readily devised by those skilled in the art without departing from the spirit and the scope of the invention.

CLAIMS

1. A photoelectrical type displacement measuring device comprising: a light source; a first and a second scales each formed thereon with graduation fringes for receiving rays emitted from said light source and capable of forming images through the interaction therebetween; a third scale formed thereon with graduation fringes for receiving said images formed and projected by the first and the second scales and capable of interacting with said images; and a receptor element for receiving rays emitted from the third scale; whereby a relative displacement value is detected through a variation in the value of received light due to a relative movement between the first, the third and the second scales, characterized in that said first through third scales are all made of a material capable of transmitting light and graduation fringes of the scales having surfaces not facing any other scales are formed on the surfaces not facing any other scales.

2. A photoelectrical type displacement measuring device as set forth in claim 1, wherein said light source is disposed on the side of the first scale out of the first through third scales, said receptor element is desposed on the side of the third scale out of the first through third scales, said graduation fringes of the first scale are formed on the surface of the first scale on the side of the light source, and said graduation fringes of the third scale are formed on the surface of the third scale on the side of the receptor element.

3. A photoelectrical type displacement measuring device as set forth in claim 1, wherein said first scale additionally functions as the third scale, said light source and said receptor element are disposed on the side of the first scale out of the first and the second scales, said graduation fringes of the first scale are formed on the surface of the first scale on the side of said light source and said receptor element, and said graduation fringes of the second scale are formed on the surface of the second scale not facing the first scale.

4. A photoelectrical type displacement measuring device as set forth in claim 1, 2 or 3, wherein said light source, said first and said third scales and said receptor element are all fixed and said second scale is made movable.

5. A photoelectrical type displacement measuring device as set forth in claim 1, 2 or 3, wherein the relationship of the width of the graduation frings of the first, the second and the third scales is set to be 2:1:2.

6. A photoelectrical type displacement measuring device as set forth in claim 1, 2 or 3, wherein the first, the second and the third scales are made of glass.

7. A photoelectrical type displcement measuring device as set forth in claim 1, 2 or 3, wherein said graduation frings on the scales are coated with light transmission protective members.

8. A three-scale transmitting photoelectrical type displacement measuring device comprising: a light source; a transmitting type first scale made of a light transmitting material and formed at the surface thereof on the side of said light source with graduation fringes receiving rays from said light source; a transmitting type second scale made of a light transmitting material formed with graduation fring-

es receiving rays having transmitted through the first scale and capable of forming images through the inter-action with the graduation fringes of the first scale; a transmitting type third scale made of a light transmitting material formed on the surface thereof on the side of a receptor element with graduation fringes for receiving the images formed and projected by the first and the second scales and interacting with said images; and a receptor element for receiving rays emited from the third scale and disposed on a side opposite to said light source; whereby a relative displacement value is detected through a variation in the value of received light due to a relative movement between the first, the third and the second scales.

9. A reflecting photoelectrical type displacement measuring device comprising: a light source; a transmitting type first scale made of a light transmitting material formed at the surface thereof on the side of said light source with graduation fringes for receiving rays emitted from said light source and images refected at a second scale again; a reflecting type second scale made of a light transmitting material formed at the surface thereof not facing the first scale with graduation fringes for receiving rays having transmitted through the first scale and capable of forming images through the interaction with the graduation images on the first scale; and a receptor element for receiving the rays having transmitted through the first scale again and disposed on the same side as said light source; whereby a relative displacement value is detected through a variation in the value of received light due to a relative movement between the first, the third and the second scales.

10. A photoelectrical type displacement measuring device as set forth in claim 9, wherein said light source, said first scale and said receptor element are all fixed and said second scale is made movable.

11. A photoelectrical type displacement measuring device as set forth in claim 9, wherein the relationship between the widths of the graduation fringes of the first and the second scales is set to be 2 : 1.

12. A photoelectrical type displacement measuring device as set forth in claim 9, wherein said first and said second scales are made of glass.

13. A photoelectrical type displacement measuring device substantially as hereinbefore described with reference to Figure 3 or Figure 4 of the accompanying drawings.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1982.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.