

Dec. 12, 1961

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3,012,469

ALIGNING DEVICE

Filed June 1, 1959

2 Sheets-Sheet 1

FIG. 1

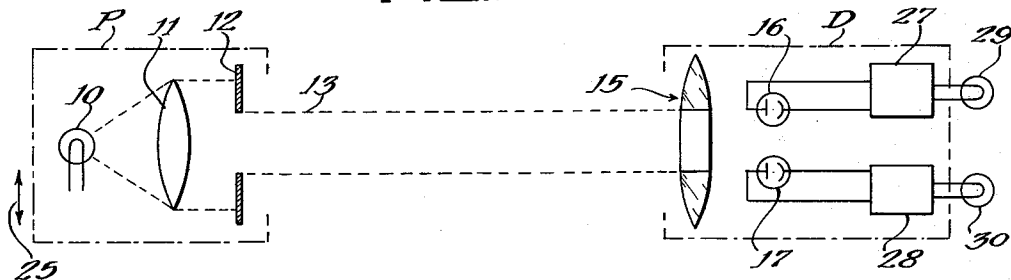


FIG. 2

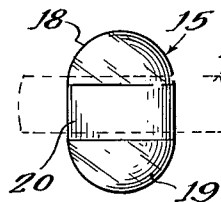


FIG. 3

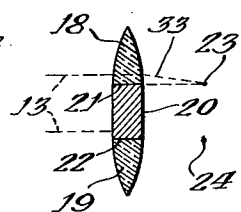


FIG. 4



FIG. 5

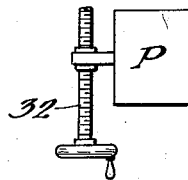


FIG. 6

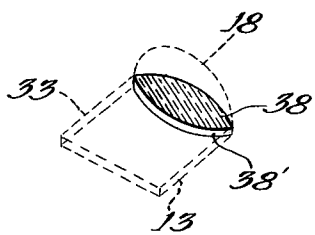


FIG. 7

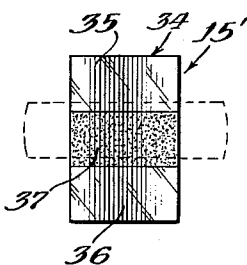


FIG. 8

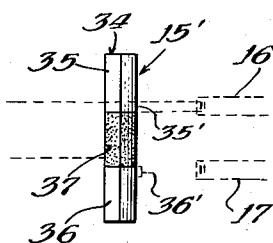


FIG. 9

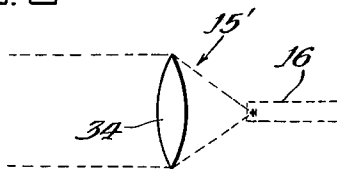
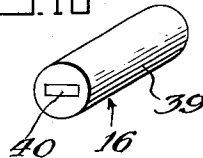


FIG. 10



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FIG. 12

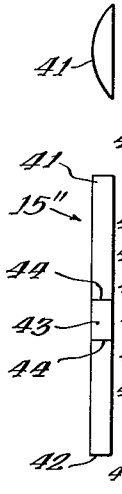


FIG. 11

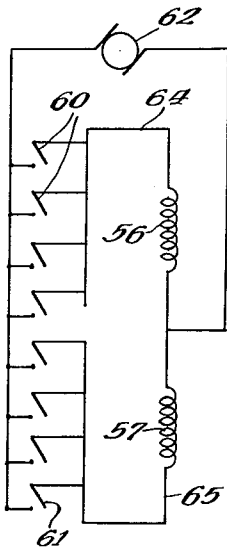


FIG. 14

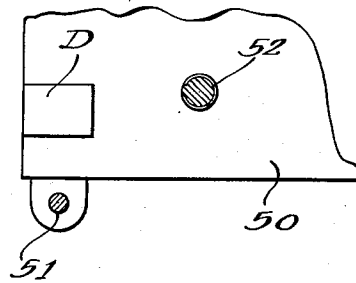


FIG. 13

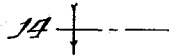


FIG. 15

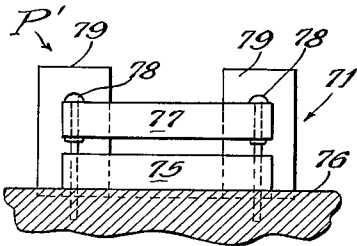
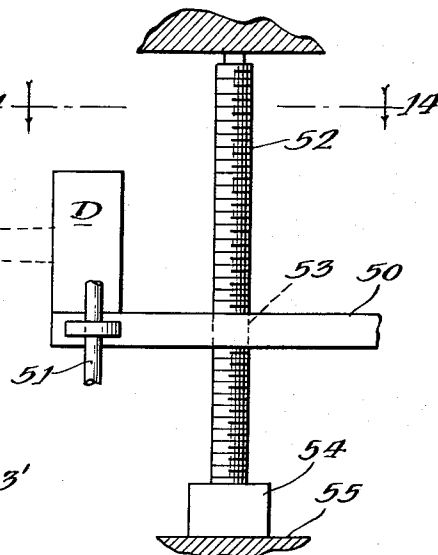
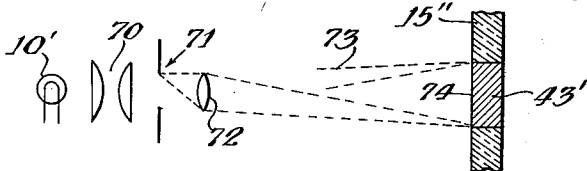


FIG. 16

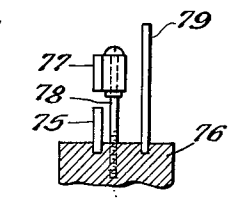


FIG. 17

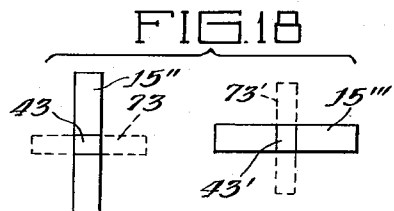


FIG. 18

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ALIGNING DEVICE

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17 Claims. (Cl. 88—14)

This invention relates to improvements in aligning devices.

It is an object of this invention to provide an aligning device which includes an optical system which is responsive with a high degree of sensitivity to a slight relative displacement of a light beam with respect to a detector in order to produce a signal which is selectively responsive to the direction of displacement. Thus the signal may be utilized to actuate means for restoring the relative positions of the projecting or receiving apparatus to the normal or non-signal position. In the alternative the signal can be used to actuate one or the other of two indicators.

The sensitivity which is characteristic of the present invention is achieved by the use of light gathering means whereby a very slight displacement of the beam will provide sufficient light energy to actuate the signal producing means.

According to one embodiment of the invention, the detector is provided with a split lens, the two lens portions being separated by a distance which is substantially identical to the thickness of the light beam. Thus the detector provides two separate focal points, one for each lens portion.

Another object of this invention is to provide a detector having two separate foci so that two separate photoelectric devices may be utilized, one for indicating a signal responsive to relative beam displacement in one direction and the other for providing a signal which is responsive to relative beam displacement in the other direction.

A further object is to provide an improved aligning device which is responsive to a substantial extent of displacement to either side of the aligned position. According to this aspect of the invention, the two lens portions are in the form of a cylindrical lens which may be extended for a substantial distance in either direction from the neutral point, and a plurality of spaced photocells may be utilized to the end so that a beam displacement of increased amplitude may be utilized to actuate the signal producing means.

Still another object is to provide for an aligning device of the type indicated, an inexpensive split lens assembly for the detector.

A still further object is to provide a self aligning control mechanism embodying a plurality of photocells which is arranged in such a manner as to avoid cumulative response due to ambient light.

Other objects, features, and advantages will become apparent as the description proceeds.

With reference now to the drawings in which like reference numerals designate like parts:

FIG. 1 is a diagram showing a preferred embodiment of this invention;

FIG. 2 is an elevation of the split lens assembly shown in FIG. 1;

FIG. 3 is a sectional view taken along lines 3—3 of FIG. 2;

FIGS. 4 and 5 are diagrams indicating applications of the invention;

FIG. 6 is a diagram illustrating the operation of the split lens assembly of FIGS. 2 and 3;

FIGS. 7, 8 and 9 are elevation, end, and top views, respectively, of a modified form of split lens assembly;

FIG. 10 is a view of a preferred type of photocell;

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FIG. 11 is a diagram showing still another modification of split lens assembly together with the electrical control means associated therewith;

FIG. 12 is a top view of the split lens assembly of FIG. 11;

FIG. 13 is a diagram showing another application of the invention embodying the split lens assembly modification shown in FIGS. 11 and 12;

FIG. 14 is a fragmentary plan view taken along line 14—14 of FIG. 13;

FIG. 15 is a diagram showing a modified form of projector;

FIG. 16 is an elevation of the adjustable slot shown in FIG. 15;

FIG. 17 is an end view of FIG. 16, and

FIG. 18 is a diagram showing still another application of the invention.

With reference now to FIGS. 1—3, the aligning device comprises a projector P and a detector D. The projector P comprises a suitable light source 10, a collimating lens 11, and a slot 12 through which the beam is projected to provide a horizontal band 13 of light.

The detector D comprises a convex split lens assembly 15, and two photo-responsive devices 16 and 17 located behind the same. The photo-responsive devices may be connected to suitable amplifiers 27 and 28 respectively to energize indicators 29 and 30, such as indicating lights.

The split lens assembly 15 as shown in FIGS. 2 and 3 comprises two lens segments, such as one would obtain by cutting an ordinary spherical lens into two halves, providing an upper lens half 18 and a lower lens half 19. The line of the cut being perpendicular to an axial plane, provides for each lens half a straight edge 21, 22, along which the rays of an overlapping band 13 are refracted toward the axial plane. These lens halves 18 and 19 are separated by an opaque spacer 20, and the parts are suitably secured to each other, as by cement. The arrangement thus provides a focus 23 for the upper lens half 18 and a separate focus 24 for the lower lens half 19.

The thickness of the band 13 is equal to or slightly less than the thickness or vertical dimension of the opaque spacer 20. Thus, when the projector and the detector are aligned with each other, the band 13 will fall entirely on the opaque spacer 20 with the result that no light will be transmitted through the lens assembly 15.

However, when a relative displacement occurs, as indicated by the arrow 25, the band will slightly overlap one or the other of the straight edges 21, 22. As shown in FIGS. 2 and 3, when the band 13 overlaps the edge 21, the overlapping portion 33 of the band will pass through the upper lens half 18 and come to a focus at the upper focus 23.

The photo-responsive device 16 is located at focus 23 and the photo-responsive device 17 is located at focus 24. Therefore, assuming that the projector has been displaced upwardly, or that the detector has been displaced downwardly, the indicating light 29 will be energized according to the conditions shown in FIGS. 2 and 3. When the relative displacement is in the opposite direction, then the indicator 30 will be energized. Thus a signal is produced which is selectively responsive to a relative displacement of the parts in one direction or the other, and this signal can be used to actuate either one of two indicators, as shown, or other means as will be hereinafter described.

According to this invention, the combination of a light beam in the form of a band and a spherical lens having a straight edge provides an arrangement which is sensitive to very slight relative displacements. Sensitivity may be regulated by so selecting the components that an overlapping portion 33 of minimum thickness

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will provide sufficient light to trip the photo-sensitive devices 16 or 17. For instance with a lens of $\frac{1}{2}$ inch radius, it has been found possible to detect a relative displacement of less than $\frac{3}{64}$ of an inch in one direction or the other.

One application of the invention is shown in FIG. 4 in which the projector P is subject to vertical movement, as indicated by the cam 31. The indicating lights 29 and 30 will indicate the times at which the projector passes through the aligned position and the direction of movement.

Another application is shown in FIG. 5 in which the projector P may be mounted on some element which it is desired to align; the lead screw 32 can be operated in one direction or the other in accordance with indications of the lights 29 and 30 in order to properly align the projector P with the detector.

In the modification of FIGS. 7-9, the split lens assembly 15' is a cylindrical lens rather than spherical, and comprises an integral member 34 providing upper and lower portions 35 and 36 rather than two separate members. Since the cylindrical lens 34 does not refract the rays in the vertical direction, it is only those relatively narrow portions 35' and 36' which are directly aligned with the sensitive areas of photo-responsive devices 16 and 17 that are effective in focusing the parallel light rays on the devices 16 and 17. All other portions of the lens 34 are non-functional. In other words, the parallel rays of the band 13 that pass above or below the portion 35' will not be refracted downwardly or upwardly toward the photo-responsive device 16 to actuate it. However, the intermediate portion of the lens 34 which lies between the portions 35' and 36' is preferably rendered opaque to block out any non-parallel rays, as by an opaque coating 37 or a strip of adhesive tape.

It has been found that sensitivity is not materially diminished by the use of a cylindrical lens rather than a spherical lens. To illustrate, the diagram of FIG. 6 shows a geometrical lens element 38 which is immediately adjacent the straight edge 21 and which corresponds in thickness to that portion of the upper lens half 18 which is traversed by an overlapping band portion 33 of minimum thickness. This element 38 functions substantially as a cylindrical lens. As a matter of fact, as its thickness approaches zero, the spherical surface 38' approaches a cylindrical surface in configuration. Therefore, if the components are so selected that the combination is responsive to an overlapping band portion 33 of minimum thickness, such as $\frac{1}{32}$ of an inch, the combination will be equally responsive whether the split lens assembly is cylindrical or spherical.

As shown in FIG. 10, the photo-responsive device 16, 17 may be in the form of a photo-conductive end cell. This comprises a cylindrical glass envelope 39 which encloses at one end a ceramic wafer having a coating of photo-conductive material on one side. Electrodes (not shown) overlap the end portions of the coated wafer, leaving between them a sensitive area which is a rectangle $\frac{3}{16}$ of an inch long by approximately $\frac{3}{64}$ of an inch wide, the electrodes running along the length direction. Thus, as shown in FIG. 10, the device 16 includes, in addition to the glass envelope 39, a rectangular photo-sensitive area 40, of the dimensions above indicated. The sensitive surface 40 is preferably disposed with its longitudinal axis horizontal, i.e. parallel to the width of the band, with result that the functional portion 35' of lens 34 is $\frac{3}{64}$ of an inch thick and the surface 40 will never receive a greater quantity of light, no matter how great the extent of overlap, than that provided by an overlapping band portion having a thickness of $\frac{3}{64}$ of an inch. An example of a suitable photocell of this type is one sold under the trademark Clairex, type CL-404.

In operation, the modification in FIGS. 7-9 is the

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same as that shown in FIG. 1-3, except that the width of the light band 13 is determined primarily by the distance between the photocells 16 and 17, rather than by the distance between the edges 21 and 22.

A still further modified form of split lens assembly 15' is shown in FIG. 11. According to this modification the upper and lower cylindrical lens portions 41 and 42 are of greater vertical dimensions than those shown in FIGS. 7 to 9, and may be made of Lucite. For example, it has been found that a relatively inexpensive plano-convex lens, as shown in FIG. 12, may be fabricated by cutting a segment from polished Lucite rod stock, and then polishing the plane surface. Due to the longitudinal light transmitting characteristics of Lucite, it is desirable to provide a light barrier between the upper and lower portions 41 and 42, such as the two barriers 44 if the spacer 43 be also made of Lucite as shown in FIG. 11, or to provide a spacer of opaque material as shown in FIG. 15. In the case of a Lucite spacer, the surface additionally may be coated or taped if desired.

The purpose of the FIG. 11 arrangement is to provide a response over a greater amplitude of displacement. For this reason, in addition to the photocells 45 and 46 which are located immediately behind, and slightly above and slightly below, respectively, the light barriers 44, other photocells 47, 47' and 47'' are provided above the photocell 45. Also other photocells 48, 48' and 48'' are disposed below the photocell 46. Assuming a band thickness of 1 inch, which is determined by the spacing of the photocells 45 and 46 with respect to each other, the spacing of the photocells 45, 47, 47' and 47'' with respect to each other will be slightly less than 1 inch, say $\frac{7}{8}$ of an inch. Similarly, the photocells 46, 48, 48' and 48'' will be spaced from each other by a distance of approximately $\frac{7}{8}$ of the light band thickness. Thus, there may be instances in which the light band may overlap or impinge upon two photocells, but within the operative limits there will never be a situation in which it does not impinge upon any photocell, except when the projector P and the detector D are in exact alignment.

An application of this embodiment is shown in FIGS. 13 and 14, in which the projector P is mounted on a fixed base and the detector D is mounted on an object 50 which is to be aligned with respect to the projector. The object 50 may be mounted for vertical movement in a plurality of guides 51, and its vertical position is determined by suitable drive means 52-54. The drive means may be of any suitable type, electric or hydraulic. In the embodiment shown, it comprises a lead screw 52 and a reversible motor 54. The lead screw 52 passes through a threaded opening 53 in the object 50 and is suitably supported at its upper and lower ends in a framework 55. The lead screw is driven by the reversible motor 54 for rotation in either the elevating or the lowering direction. The motor 54 is provided with an elevating winding 56 and a lowering winding 57, as shown in FIG. 11. Thus, the detector D may be utilized to control the operation of the drive means 52-54 so that the object 50 is automatically maintained in alignment with respect to the projector P.

The electric circuit for accomplishing this result is diagrammatically shown in FIG. 11, in which a separate amplifier and relay component is provided for each one of the photocells 45 to 48. As shown, there are two banks of amplifier-relays, one bank comprising the relays 58 which are individually connected with the photocells 45, 47, 47' and 47''. These relays 58 control the relay switches 60 which are connected in parallel with each other and in series with the elevating winding 56 to provide an operating circuit 64.

The amplifier-relays 59 of the other bank are separately connected to the photocells 46, 48, 48' and 48'', and serve to actuate separate relay switches 61 which are connected in parallel with each other and in series with

the lowering winding 57 to provide an operating circuit 65. The operating circuits 64 and 65 are connected to a standard power source 62.

In operation assume that the object 50 has been displaced below its normal aligned position to an extent such that the light band impinges only on the photocell 47". This will actuate the uppermost relay and relay switches 58 and 60, and thus energize the elevating winding 56. As the lead screw rotates to elevate the object 50, the photocell 47' will be moved upwardly until the light band impinges thereupon. At first, the light band will impinge upon both cells 47" and 47', and then on photocell 47' only, etc. Thus, the next to the top relay switch 60 will be closed prior to the time that the uppermost relay switch 60 is opened, etc. to the end that the circuit to the elevating winding 56 will always remain closed until such as the band of light impinges entirely upon the opaque spacer 43, at which time the elevating winding 56 is de-energized, and comes to a rest in its aligned position.

By providing a separate amplifier-relay for each photocell, cumulation of response due to ambient light is avoided. In other words, the operating circuit 64, 65 will not be energized until such time that the signal from at least one of the photocells is strong enough to trip its associated amplifier-relay which of course has been adjusted so that it is not responsive to merely ambient light.

A modified type of projector is shown in FIG. 15 which is suitable for operation when the projector and receiver are located at a considerable distance from each other. According to this modification, the band 73 is a projected band rather than a collimated band as shown in FIG. 1. As shown in FIG. 15, a condenser lens 70 is located between the slot 71 and the light source 10', and a projection lens 72 is located in front of the slot 71. Thus an image 74 of the slot 71 is projected on the split lens assembly 15". This arrangement has the advantage of providing improved definition of the slot, and consequently more accurate operation. Since the band is in the form of an image, any desired magnification can be introduced.

Furthermore, the slot 71 may be in the form of adjustable slot as shown in FIGS. 16 and 17. The adjustable slot comprises a fixed blade 75 which is suitably mounted on a base 76, and a movable blade 77 which is adjustably supported by screws 78. Thus, by regulating the screws 78, the thickness of the band can be controlled to a fine degree. The adjustable slot mechanism also includes side barriers 79 so that the band 73 may be of a definite width.

As diagrammatically indicated in FIG. 18, alignment along two axes may be obtained by duplicating the projector and detector devices shown and by mounting the reversible drive means 52-54 on a second drive means which operates along the second axis. In other words, two projectors are utilized, one for producing the horizontal light band 73 which impinges upon the vertically oriented split lens assembly 15", and the other projector producing a vertical band 73' for impinging upon a horizontally oriented split lens assembly 15".

Although only preferred embodiments of this invention have been shown and described herein, it will be understood that various modifications and changes may be made in the construction shown without departing from the spirit of my invention as pointed out in the appended claims.

I claim:

1. An aligning device comprising projecting means for projecting a band of light of predetermined thickness, and a detector spaced from said projecting means and disposed in the path of said light band, said detector comprising a split lens assembly comprising two spaced lens portions, each lens portion having a separate focus, and first and second photo-responsive signal producing means

located at said two foci respectively, the spacing between said lens portions being such that the distance between them is substantially equal to but not less than the thickness of said light band so that both of said photo-responsive signal producing means cannot be simultaneously energized by said light band, whereby when said projecting means and said detector are aligned, said light band will not fall upon either of said lens portions, and when not aligned, said light band will fall upon one or the other of said lens elements and actuate one or the other of said signal producing means depending upon which one of said lens portions is traversed by said light band.

2. An aligning device as claimed in claim 1 which includes an indicator associated with each of said signal producing means to indicate the direction of relative displacement of said projecting means and detector from their aligned position.

3. An aligning device as claimed in claim 1 which includes reversible drive means for causing relative displacement of said detector and said projecting means, said reversible drive means including two actuating means for operating said reversible drive means in opposite directions, one of said actuating means being associated with said first photo-responsive signal producing means to cause operation of said drive means in one direction and toward the aligned position of said projecting means and said detector, and the other of said actuating means being associated with said second photo-responsive signal producing means to cause operation of said drive in the opposite direction and toward said aligned position, whereby said projecting means and detector are automatically maintained in alignment with each other.

4. An aligning device comprising projecting means for projecting a band of light of predetermined thickness, and a detecting device spaced from said projecting means and disposed in the path of said light band, said detecting device comprising a split lens assembly having two spaced spherical lens segments and a spacer disposed between the same, each lens segment providing a separate focus, and first and second photo-responsive signal producing means located at said two foci respectively, the spacing between the straight edges of said lens segments being such that the distance between them is substantially equal to but not less than the thickness of said light band, whereby when said projecting means and said detector are aligned, said light band will not fall upon either of said lens segments, and when not aligned, said light band will fall upon one or the other of said lens segments and actuate one or the other of said signal producing means depending upon which one of said lens segments is traversed by said light band.

5. An aligning device as claimed in claim 4 in which said spacer is opaque.

6. An aligning device as claimed in claim 4 in which each lens segment is a 180° segment.

7. An aligning device comprising projecting means for projecting a band of light of predetermined thickness, and a detector spaced from said projecting means and disposed in the path of said light band, said detector comprising a split lens assembly including an elongate cylindrical lens, first and second photo-responsive signal producing means located along the focus of said cylindrical lens, the spacing between said two signal producing means being such that the distance between them is substantially equal to but not less than the thickness of said light band, whereby when said projector means and said detector are aligned, said light band will not be focussed upon either of said photo-responsive signal producing means, and when not aligned, said light band will be focussed upon one or the other of said signal producing means and actuate the same to produce a signal which is selectively responsive to the direction of displacement from the aligned position.

8. An aligning device as claimed in claim 7 in which said cylindrical lens is a double convex lens.

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9. An aligning device as claimed in claim 7 in which said cylindrical lens is a plano-convex lens.

10. An aligning device as claimed in claim 7 in which said cylindrical lens is fabricated from Lucite.

11. An aligning device as claimed in claim 7 in which an intermediate portion of said cylindrical lens is provided with an opaque coating.

12. An aligning device as claimed in claim 7 in which an intermediate portion of said cylindrical lens is covered with a strip of adhesive tape to render the same opaque.

13. An aligning device as claimed in claim 7 in which said cylindrical lens is made in two parts.

14. An aligning device as claimed in claim 7 including reversible drive means associated with one of the devices to be aligned for restoring said projecting means and detector to aligned position, first and second operating circuits for actuating said drive means in opposite directions, said first operating circuit being controlled by said first signal producing means, and said second operating circuit being controlled by said second signal producing means.

15. An aligning device comprising projecting means for projecting a band of light of predetermined thickness, and a detector spaced from said projecting means and disposed in the path of said light band, said detector comprising a split lens assembly having two spaced cylindrical lens elements mounted in substantial alignment with each other to provide an interrupted line focus, a spacer disposed between said cylindrical lens elements, and first and second photo-responsive signal producing means located along said line focus on either side of said spacer, the spacing between said signal producing means being such that the distance between them is substantially equal to but not less than the thickness of said light band, whereby when said projecting means and said detector are aligned, said light band will not be focussed upon either of said photo-responsive signal producing means, and when not aligned, said light band will be focussed upon one or the other of said signal producing means and actuate the same to produce a signal which is selectively responsive to the direction of displacement from the aligned position.

16. An aligning device comprising projecting means for projecting a band of light of predetermined thickness, and a detector spaced from said projecting means and disposed in the path of said light band, said detector comprising a split lens assembly including an elongate cylindrical lens, first and second photo-responsive signal pro-

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ducing means located along the focus of said cylindrical lens, each of said photo-responsive signal producing means including a series of photocells located along said line focus, the photocells of each series being spaced from each other by distances less than the width of said light band, relay means for each series of photocells, each relay means providing a separate relay switch connected to each of said photocells for actuation by the energization thereof by said light band, an operating circuit for each relay means, the relay switches of each relay means being electrically connected into its associated operating circuit in parallel relationship so as to avoid cumulative response of the photocells of a given series, and reversible drive means energized by said operating circuits for restoring the alignment of said projecting means and detector, said operating circuits causing operation of said reversible drive means in one or the other of two opposite directions depending upon which one of said two photo-responsive signal producing means is energized by said light band, and the distance between said two series of photocells being such that both of said operating circuits cannot be simultaneously rendered operative by said light band.

17. An optical system comprising means for projecting a beam of light having parallel boundaries providing a band of predetermined thickness, and receiver spaced from said projecting means and disposed in the path of said light beam, said receiver comprising two spaced ray converging portions, each portion having a separate focus, the spacing between said portions being such that said light beam cannot impinge upon both of said ray converging portions simultaneously, whereby the rays of said beam will be converged upon one or the other of said foci depending upon the alignment of said projecting means and said receiver, but not both.

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