NASA CASE NO. ARC-10,932-1

PRINT FIG. 1 & 2

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(NASA-Case-ARC-10932-1) OPTICAL ALIGNMENT DEVICE Patent Application (NASA) 14 p HC $3.50 CSCL 20F
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OPTICAL ALIGNMENT DEVICE

Invention Abstract

The present invention relates to the field of optical alignment devices for aligning a mirror with an object, two objects or two mirrors.

The optical alignment devices as shown in Fig. 1 includes a beamsplitter 12 to be interposed along an optical axis between a pair of objects 14 and 13 for observing the degree of co-alignment thereof. Light from one of the objects such as the source 13 is reflected from the beamsplitter 12 into a retro-reflector 17 which reflects the light back through the beam-splitter 12 into an imaging system 18, such as a theodolite or telescope. Light from the other object, such as mirror 14, is reflected from the beamsplitter 12 into the same imaging system 18. The amount of displacement of the two images as observed by the imaging system is inversely related to the degree of co-alignment of the two objects.

The displacement of the two images is more readily observed by placing a red filter 16 in the light path between the retro-reflector 17 and the beam splitter 12 and placing a green filter 19 in the path of the light passing from the second object 14 into the beamsplitter 12. The red and green filters should have overlapping spectral bandedges as shown in Fig. 3. When the two images overlap, an intense yellow region is observed in the region of overlap as shown in Fig. 2. The mirror 14 or source 13 is then aligned so the red image is completely superimposed on the green image so that the entire image appears yellow. Utilizing the alignment system of the present invention, two objects can be coaligned to a very high degree of precision, such as plus or minus 2 seconds of arc.

The novel feature of the present invention is the provision of the optical alignment system incorporating the beamsplitter 12, retroreflector 17 and imaging system 18, such system to be positioned on the optical axis between a pair of objects to be co-aligned. The amount of displacement of the two images as viewed through the imaging system is inversely related to the degree of coalignment of the two objects. The optical alignment device is useful for aligning a mirror with an object, two objects or two mirrors.

Inventor: Norman L. Thomas

Employer: Lockheed Missiles & Space Company

Evaluator: Dean M. Chisel

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SHEET 1 OF 2

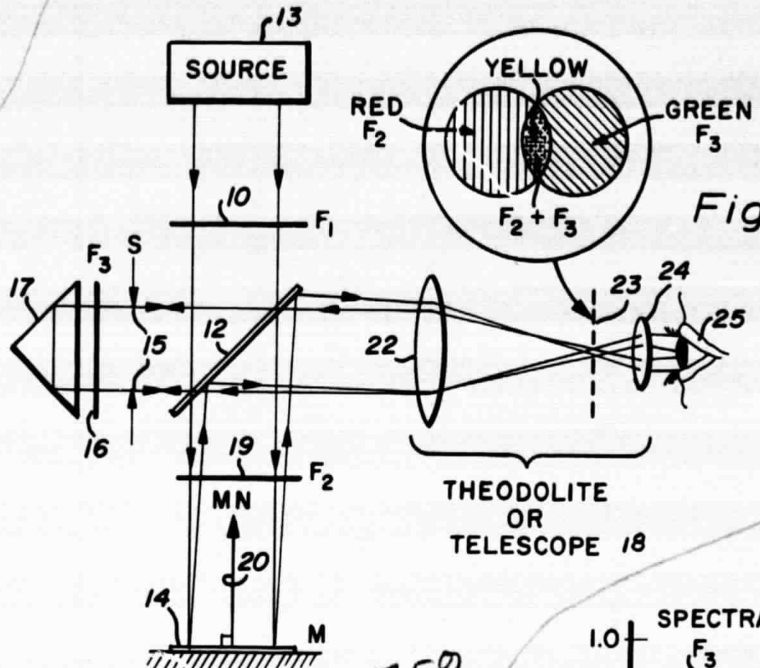

Fig_2

Fig_1

75%

681 001

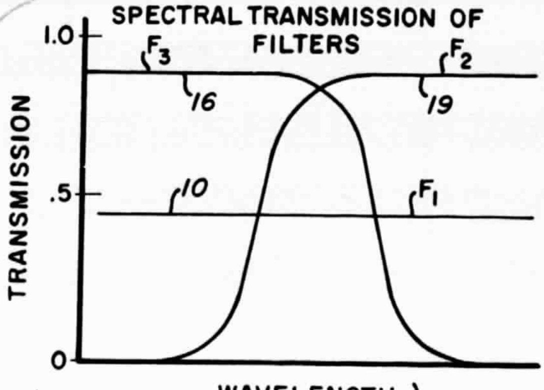

Fig.3

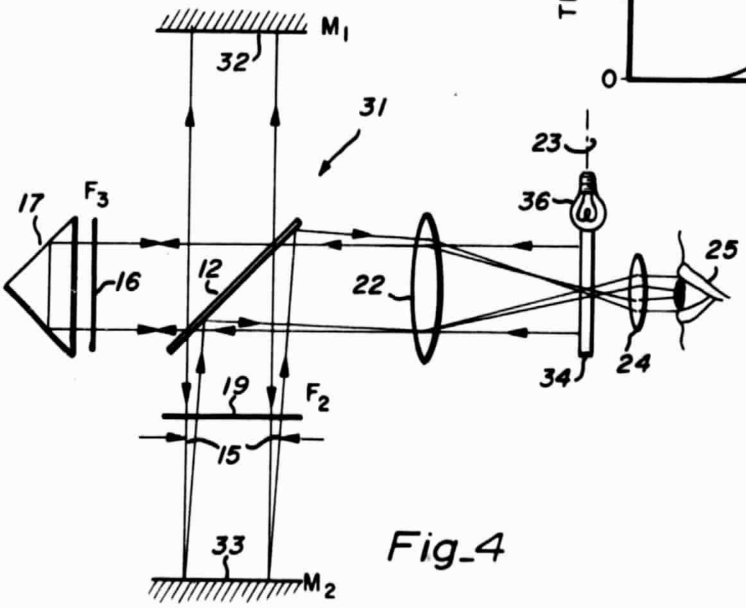

Fig_4

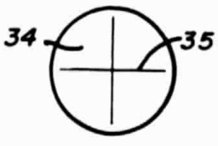

Fig_5

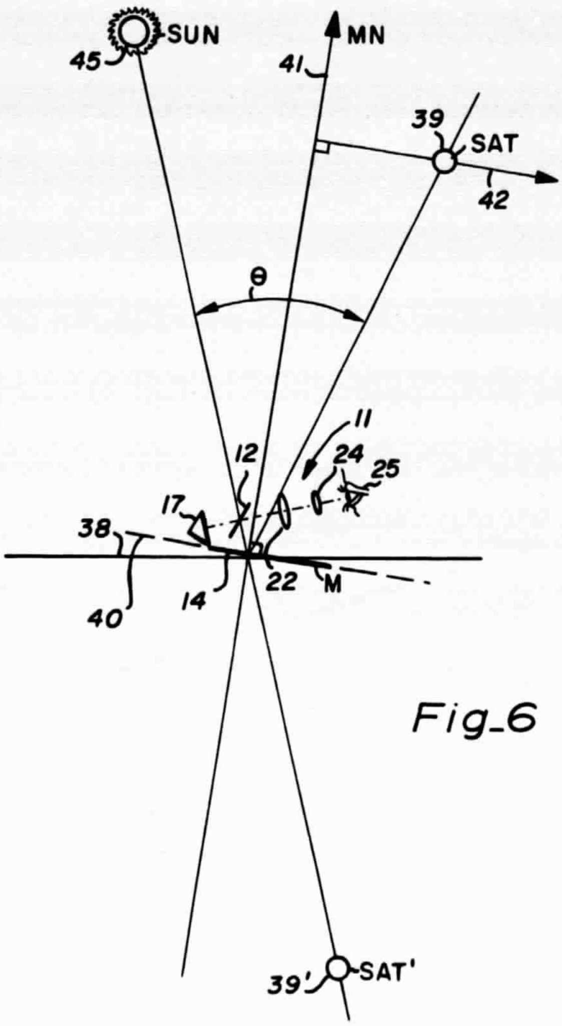

Fig_6

Application For Patent

of

NORMAN L. THOMAS

for

OPTICAL ALIGNMENT DEVICE

ABSTRACT OF THE DISCLOSURE

The optical alignment device includes a beamsplitter to be interposed between a pair of objects for observing the degree of coalignment thereof. Light from one of the objects is reflected from the beamsplitter into a retroreflector which reflects the light back through the beamsplitter into an imaging system. Light from the other object is reflected from the beamsplitter into the same imaging system. The amount of displacement of the two images is inversely related to the degree of coalignment of the two objects. The optical alignment device is useful for aligning a mirror with an object, two objects or two mirrors.

* *

The invention described herein was made in the performance of work under a NASA contract and is subject to provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

The present invention relates in general to optical alignment devices and more particularly to a method and apparatus for observing the degree of coalignment of a pair of objects.

DESCRIPTION OF THE PRIOR ART

Heretofore, a mirror was aligned to the geometric center of a light source, such as the sun, solar simulator, laser, light bulb or the like, by determining the centroid of the light source with a theodolite. The theodolite was then rotated 180° and autocollimated from the mirror which was to be aligned with the light source. This method was very time-consuming and tedious.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved alignment device for observing the degree of coalignment of a pair of objects.

In one feature of the present invention, the optical alignment device includes a beamsplitter for reflecting the light from one object into a retroreflector and thence back through the beamsplitter into an imaging system for imaging the first object, such beamsplitter also receiving light from a second object and splitting off a portion thereof and directing it into the imaging system for imaging the second object. The displacement of the two images is inversely related to the degree of coalignment between the two objects and the displacement of the images is relatively independent of small angular misalignments of the optical alignment device with the objects and imaging system.

In another feature of the present invention, light from the respective objects is filtered such that the first and second images have different spectra with overlapping spectral band edges so that super position of the two images, which is indicative of precise alignment, is more easily visualized due to formation of an image, at the region of super position, of the overlapping band edge color and of increased intensity.

In another feature of the present invention, variable stops are provided in the optical path of at least one of the objects so that the intensity of one of the images may be adjusted relative to the other.

In another feature of the present invention, an illuminated reticle is provided at the focal plane of the optical imaging system. This illuminated reticle is back projected through the beamsplitter for aligning mirrors on opposite sides of the beamsplitter.

Other features and advantages of the present invention become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic line diagram depicting an optical alignment system incorporating features of the present invention,

Fig. 2 is an enlarged schematic line diagram of displaced images of the first and second light sources formed at the focal plane of the optical imaging portion of the system of Fig. 1,

Fig. 3 is a plot of spectral transmission vs. wavelength depicting the optical transmission characteristics for the filters F_1, F_2, and F_3 employed in the optical alignment system of Fig. 1,

Fig. 4 is a schematic line diagram of an optical alignment system, similar to that of Fig. 1, employed for observing the degree of coalignment of first and second mutually opposed mirrors,

Fig. 5 is a schematic plan view of the illuminated reticle employed in the imaging system of the structure of Fig. 4, and

Fig. 6 is a schematic line diagram of optical alignment system incorporating features of the present invention for aligning a mirror to reflect light from the sun onto a satellite circling the earth.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Fig. 1, there is shown an optical alignment system 11 incorporating features of the present invention. More particularly, the optical alignment system 11 includes a plane beamsplitting mirror 12 interposed between and inclined at 45° to an optical axis between a source of light 13 and a mirror 14 which it is desired to align with the source 13, i.e., coalign the geometric center of the source 13 with the normal to the mirror 14.

The light source 13 preferably has twofold symmetry. Light rays emanating from the source 13 are attenuated by a neutral density filter 10 (F_1) for attenuating the intensity of the light passing therethrough. The light passing through the filter 10 falls upon the beamsplitting mirror 12 wherein a portion is split off of the beam path and thence directed orthogonally through a variable stop 15 and green filter 16 (F_3) to a retroreflector 17. The retroreflector reflects the light incident thereon back along essentially the same path through the beamsplitting mirror 12 to an imaging system 18, such as a theodolite or telescope. Suitable retroreflectors 17 include three mirrors at right angles to each other (cube corner), trihedral prism, or a lens with a small mirror in the focal plane of the lens (cats eye reflector).

A portion of the light emanating from the source 13 passes through the beamsplitting mirror 12 and thence through a complimentary (red) color filter 19 (F_2) to a mirror 14. The mirror 14 serves as a virtual object and light is reflected from the mirror 14 back to the beamsplitting mirror 12 and thence reflected therefrom into the imaging system 18.

The imaging system 18 includes an objective lens 22 which focuses both the red and green images at a focal plane 23. An eyepiece 24 is focused on the focal plane 23 for imaging the red and green images on the retina of the eye 25. The images as seen by the eye 25 (see Fig. 2) will include the red image of the source 13, as reflected from the retroreflector 17, and the green image of the source 13 as reflected from the mirror 14.

In this manner, the mirror 14 serves as a virtual object for the red image of the source. The degree of coalignment of the light rays emanating from the source 13 and those as reflected from the mirror 14 is inversely porportional of the displacement of the red and green images, as shown in Fig. 2. Angular displacement of the two images is due substantially only to the angular displacement of the mirror normal 20 and the optical axis of the rays emanating from the source 13 and falling upon the beamsplitter 12.

Referring now to Fig. 3, there is shown the spectral transmission characteristics of the neutral density filter 10, green filter 16 and the red filter 19. The band edges of both the green and red filters are chosen to have a region of spectral overlap in the yellow band edge of wavelengths so that when the two images are superimposed, an intense yellow region is seen by the eye 25. The mirror 14 is then readily aligned with the source 13 by adjusting the angle of the mirror normal 20 to the optical axis of the source 13 until the red and green images are superimposed into one image. This one image will have a yellow hue and slight displacements of the two images will show up as red and green fringes on opposite sides of the superimposed image. When the adjustments are made so that the two images are superimposed and the red and green fringes are eliminated, the mirror 14 is axially aligned to the source 13 to within a very high degree of precision such as plus or minus 2 seconds of arc.

As an alternative to the use of the theodolite or telescope 18 as an imaging system for imaging the light derived from the mirror 14 and the source 13, the theodolite or telescope may be replaced by a pinhole lens (not shown) through which the light from the source 13 and mirror 14 are imaged on a screen for viewing by the operator.

Referring now to Fig. 4, there is shown optical alignment system 31 useful for aligning first and second mirrors 32 and 33, respectively. The optical alignment system 31 is essentially the same as that previously described with regard to Fig. 1 with the exception that a reticle 34, having illuminated crosshairs 35 inscribed therein, is positioned in the focal plane 23 (see Fig. 5). In a typical example, the reticle 34 comprises a polished disk of quartz having the crosshairs 35 inscribed therein and illuminated from the edge by means of a light 36 so that essentially only the crosshairs 35 are brightly illuminated. The crosshair image 35 is projected via the objective lens onto the beamsplitter mirror 12. A portion of the light from the illuminated crosshairs 35 is projected from the beam-splitter mirror 12 onto the second mirror 33 and another portion of the light from the crosshairs image 35 passes through the beamsplitter mirror 12 to the retroreflector 17 and thence back to the beamsplitter mirror 12 and thence onto the first mirror 32.

Light reflected from the first mirror 32 is directed back onto the beamsplitter mirror 12 wherein a portion thereof is reflected back to the retroreflector 17 and thence through the beamsplitter mirror 12 to the objective lens 22 and to the eyepiece 24. Similarly, light reflected from mirror 33 is reflected from the beamsplitter mirror 12 to the objective lens 22 and thence to the eyepiece 25. Misalignment of the first and second mirrors 32 and 33 produces a displacement of the crosshair images projected to the eyepiece 24. A variable stop 15 is provided for adjusting the relative intensities of the two images as projected back to the eyepiece 24 such that small displacements of the images are more readily ascertained. The two mirrors 32 and 33 are then aligned by adjusting the angle of one of the mirrors until the red and green images of the reticle crosshairs pattern 35 are superimposed, as viewed by the eyepiece 24.

Referring now to Fig. 6, there is shown a method for aligning a mirror with the optical alignment device 11 of Fig. 1 so as to reflect sunlight onto a satellite 39. More particularly, the mirror 14 is supported from the surface of the earth 38 via suitable movable support structure and preferably one operated by suitable motors and the like for movement at a rate to track the satellite 39

In an optical system, a mirror, such as mirror 14, can be removed from the system for purposes of analysis if the mirror is replaced by an object, such as virtual satellite 39' located in the earth 38 at a position determined by rotation of the object by 180° about an axis of revolution 40 perpendicular to the mirror normal 41 (MN) and lying in the plane of the mirror 14 and being parallel to a line normal to the mirror normal 41 and passing through the object or satellite 39, such line being indicated by vector 42 in Fig. 6. When such a revolution of the satellite object 39 is made, it appears as a virtual satellite object 39' inside the earth. The mirror 14 is then adjusted to coalign the light emanating from the sun 45 with the light emanating from the virtual satellite 39'.

Thus, the optical alignment device 11 of Fig. 1, which conists of the beamsplitting mirror 12, retroreflector 17, objective lens 22, and eyepiece 24 is positioned above the mirror 14 and the sun source object 45, as visualized through the eyepiece 24, is superimposed on the satellite source object image. When this is accomplised, it will be found that the mirror normal 41 bisects the angle of divergence θ between the sun and the satellite 39, as viewed from the mirror 14. A shutter, not shown, may be provided between the optical alignment device 11 and the mirror 14 so that the sun's light may be shown onto the satellite only when the satellite 39 is in a predetermined position such as directly overhead, i.e., at the same longitude as that of the mirror 14.

Thus, it is seen that the optical alignment device 11 of Figs. 1, 4 and 6 may be utilized to coalign two objects, two sources or light collimators, a mirror to a source, or to coalign two mirrors facing one another.

The particular advantage of the coalignment system 11 of the present invention is that it is relatively insensitive to small angular misalignments of the optical alignment device 11 relative to the source or mirrors to be aligned. Furthermore, slight misalignments in the optics of the optical alignment device 11, such as those between the retroreflector 17 and the beamsplitting mirror 12 and the theodolite or telescope 18 do not unduly adversely affect the relatively high degree of optical alignment achievable with the optical alignment system of the present invention.

In addition, optical alignments of very high precision are rapidly performed using the optical alignment system of the present invention.