

PERFECT OPTICAL ALIGNMENT MADE SIMPLE

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INNOVATIVE OPTICAL SYSTEMS

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Perfect Optical Alignment Made Simple:
Utilizing the Lateral Transfer Hollow Retroreflector
For Boresighting, Beam Alignment and Beam Delivery

Introduction

Applications such as boresighting, beam alignment and beam delivery require the critical alignment of one optical axis or line of sight with another. In these applications, the beams must be parallel to each other with a high degree of accuracy, in some cases better than one second of arc. Often, this accuracy must be maintained in harsh environments, such as extreme temperatures and high vibration and shock.

Alignment in these situations is traditionally accomplished with expensive mirror mount setups that are inherently unstable and can change their accuracy at the time of alignment. This creates constant differences in readings and makes the process extremely difficult. In addition, mirror mounts are usually made by using mechanical interface parts that are not considered stiff structures. Thus, they require constant calibration after vibration, shock or even regular use.

The Lateral Transfer Hollow Retroreflector

A retroreflector is a prism which has the property of returning beams of parallel light directly to the light source, regardless of the physical orientation of the prism. This property makes the retroreflector a perfect device to be used as a reference and a beam delivery device between any two optical axes.

Retroreflectors are commonly made from a solid blank of optical glass, such as BK7 or quartz, which is shaped, ground and polished to the required specifications. Parallelism between the incoming and outgoing beams is dependent on the flatness of the polished reflecting surfaces and the accuracy of the three 90 degree dihedral angles formed by the intersections of the polished surfaces.

In a departure from common solid retroreflectors, PLX pioneered the development of the hollow retroreflector. This unique instrument is constructed of three first-surface mirrors assembled by a proprietary process into a mutually-orthogonal inside corner. The principal advantage of the hollow retroreflector over the solid is that the optical path is in air, rather than through solid material. Thus, the mirrors can be coated for maximization over a wide spectral range, from UV to far IR. This configuration also eliminates material absorption and achromatic aberration. Hollow retroreflectors can also be made much larger and more accurate than conventional solid units.

When a small beam of parallel light enters one side of a retroreflector, it will exit on the other side. However, in applications where the distance between the two optical axes is required to be substantial, a large retroreflector would be impractical from the point of view of cost, weight and size. In such cases, the LTHR will be the device of choice, due to the fact that it is a perfect lateral segment of a retroreflector and operates in the same way. Fig. 1 shows a configuration of a standard hollow retroreflector and also the segment of the retroreflector which constitutes the LTHR.

The LTHR was developed and patented by PLX. (Patents nos. 5024514 and 5361171, other patents pending.) It has the property of retroreflecting a parallel beam and displacing it any given distance. The LTHR is comprised of a flat mirror on one end and a roof mirror on the other end. In between, there is a connecting member that is tubing made from the same materials as the end mirrors. The tubing is made by fusing segments of flat materials together in a proprietary process to form a square profile. The mirrors are mounted on the tubing. The LTHR is considered “hollow” because the optical path is in air, rather than through solid glass components.

The major advantage of using the LTHR for beam alignment is that, once it is installed in a system, it never has to be adjusted. As the LTHR is basically a retroreflector, it is an invariant to parallel light in all coordinates. This excellent quality gives the user the freedom to mount the unit in his or her apparatus without major concern for proper orientation of the device. This property also makes the unit insensitive to vibration, shock or other sudden movements of the system by maintaining the beams constantly parallel alignment.

The LTHR has another significant advantage. It is a monolithic instrument, made from materials all having the same coefficient of expansion. This makes the instrument extremely thermally stable and allows it to operate over a wide temperature range.

In a particularly useful version of the LTHR, a 50-50 beamsplitter is substituted for the flat mirror. This permits the user to view a target which is a considerable distance from the area of measurement while simultaneously viewing a return crosshair from a parallel optical axis.

Accuracy of LTHR

Accuracy of LTHR can be specified in terms of beam deviation and wavefront distortion. Beam deviation from parallelism between the incoming and outgoing beams is given in seconds of arc. In applications where the clear aperture is fully illuminated, special consideration should be given to the wavefront requirement. Since the LTHR contains three first-surface mirrors, each mirror contributes to the wavefront error. The fully-illuminated roof mirror is especially sensitive to double-imaging due to high magnification. Thus, for example, in systems with 20X magnification, it is recommended that the roof dihedral accuracy be less than 5 arc seconds.

The LTHR can provide interferometer-quality performance, with sub-arc second beam deviation and better than $\lambda/10$ wavefront error ($\lambda = 632.8\text{nm}$). Accuracy is verified by comparing the exiting wavefront double pass through the LTHR from a reference mirror to the front surface of the same reference mirror. In a perfect LTHR, the two apertures will be in a null condition, and any tilt of one of the mirrors will introduce fringes that are resultant from beam deviation. Every LTHR is tested with this method and a complete software analysis can be provided with the unit. Fig. 2 shows the test setup.

Periscope Configuration (LTHP)

The LTHR is also available in a patented periscope configuration (LTHP). (Patent no. 5301067.) The LTHP is also an invariant, monolithic structure which utilizes front surface mirrors.

The LTHP is used to shift a beam laterally to any distance while maintaining the beam direction. The LTHP is also especially useful in cases where one of the mirrors is made as a 50-50 beamsplitter, allowing the same beam to be split in the same direction. See Fig. 3.

Multiple Configurations

In applications where the major beam must be aligned with two or more other optical axes, a multiple LTHR configuration is required. In this configuration, the exiting beam position can be constantly adjusted to any given distance from the entrance beam, while maintaining sub-arc second accuracy. This is accomplished by connecting two or more LTHR's, or a combination of LTHR's and LTHP's, at the entrance and exit apertures of the units. A special flange with a rotary bearing is then utilized to allow 360-degree movement of one of the units. The bearing mechanism need not be accurate at all, since each LTHR or LTHP is an invariant by itself and thus its orientation is not of any importance. See Figs. 4 and 5.

Suggested Applications and Solutions Using the LTHR and LTHP

Boresighting

Boresighting refers to the procedure of viewing a bore through a sight and aligning the centerline of the bore to be perfectly parallel to a distant line of sight or another bore. In boresighting situations involving high accuracies and severe environmental conditions, constant checking of the alignment is usually necessary.

The LTHR suggests a fresh new approach to boresighting. It eliminates the need for expensive optical mounts and presents a much more accurate and stable system. See Fig. 6. In a multiple configuration, as in Figs. 4 and 5, the LTHRs can substitute for a large Newtonian telescope in setups used to observe three or more optical axes at the same time.

Detector Mount Alignment

In certain spectroscopic applications, the line of sight of the telescopic light source (usually a Newtonian telescope) must be perfectly parallel to a receiver detector. In this case, the LTHR is placed such that the parallel light from the telescope will focus on the detector. By reflecting a perfectly parallel output beam, the LTHR will ensure that the detector can be properly positioned by X-Y movements such that the beam centroid will be centrally located. See Fig. 7.

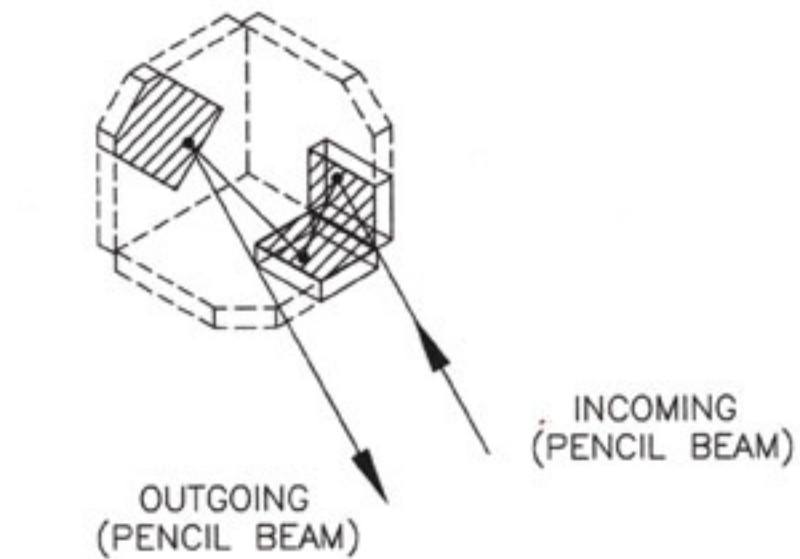
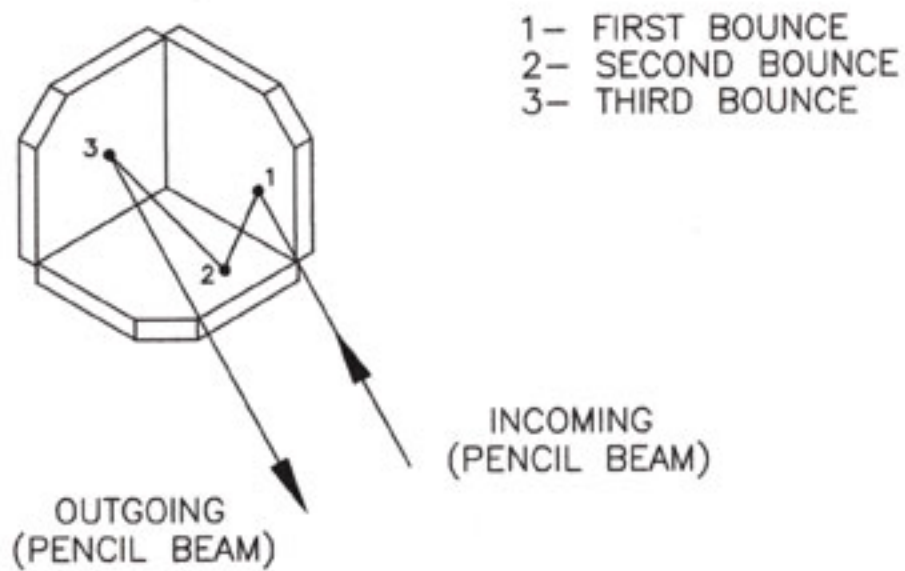
Beam Delivery Systems

An excellent beam delivery system is created by connecting LTHRs with rotational or swivel mounts. This configuration allows the LTHRs to move and point to different locations. The first-surface mirror elements of the LTHRs allow for high energy coatings to accommodate high-powered lasers in applications such as laser welding. Other similar applications include laser surgery, where a beam delivery system is required to point the beams at different locations during surgical procedures, and robotics, where a robotic arm is required to deliver an image or laser from one location to another. See Figs, 4 and 5.

Conclusion

The LTHR and LTHP are unique instruments which are readily available in off-the-shelf configurations to solve many optical alignment problems. In addition, PLX has considerable experience in working directly with customers to meet their specialized requirements. Utilizing our innovative technology, we've designed and built numerous state-of-the-art alignment instruments and systems, including: boresights for the AXAF X-Ray Telescope and various FLIR systems; space-borne hollow units for military and environmental satellite programs; critical elements of the fire-control system of the M1 Tank; and stress-free systems for Interferometric and spectroscopic instrumentation.

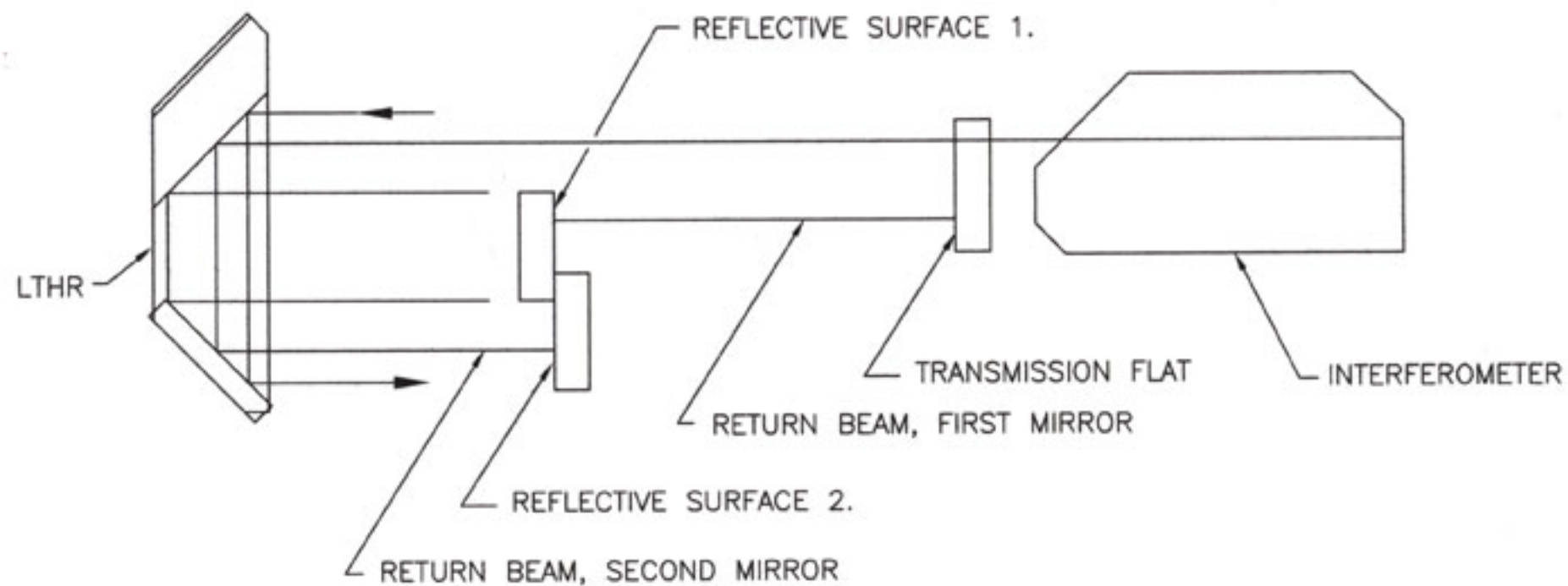
Call PLX today to discuss your application.



CONVENTIONAL HOLLOW
RETROREFLECTOR

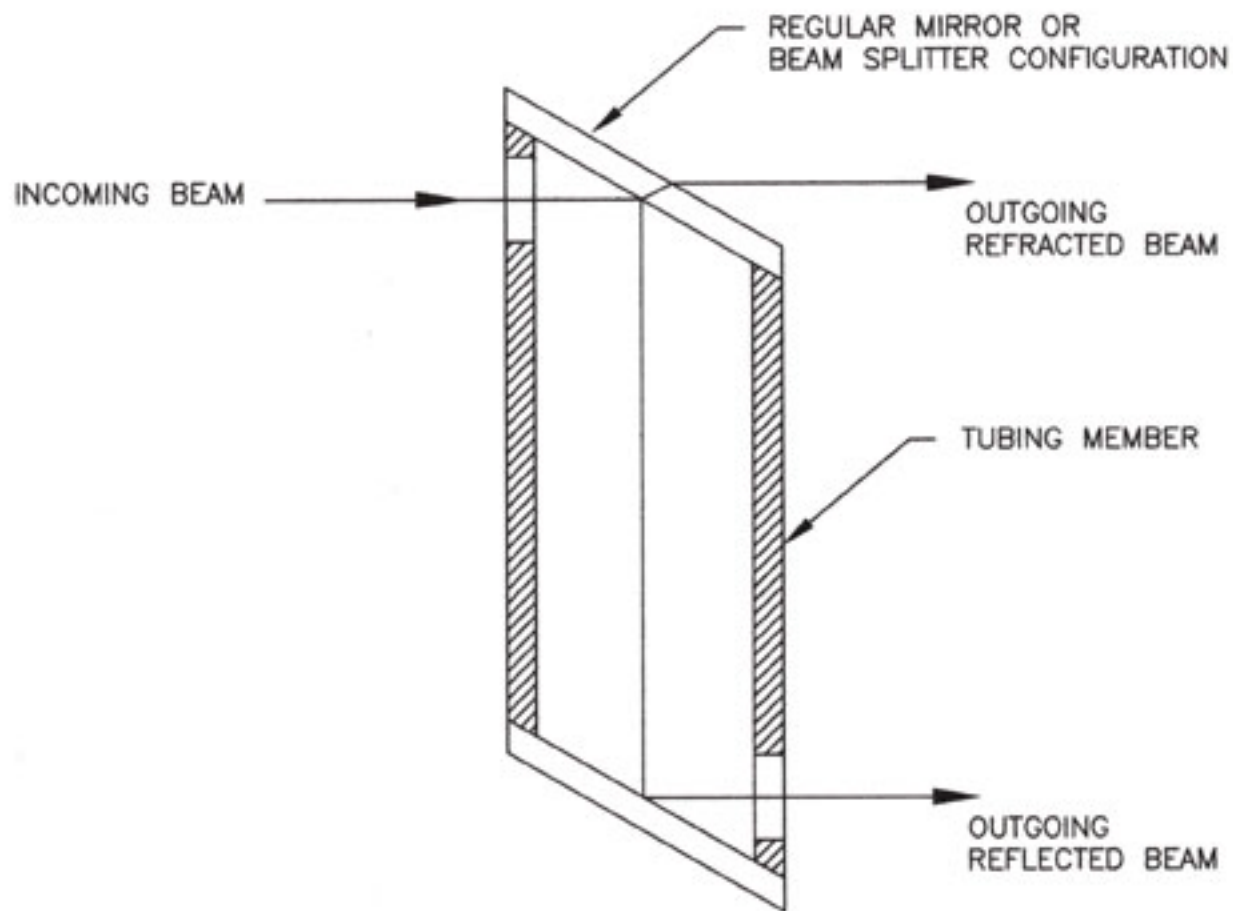
LATERAL TRANSFER HOLLOW
RETROREFLECTOR

FIGURE 1



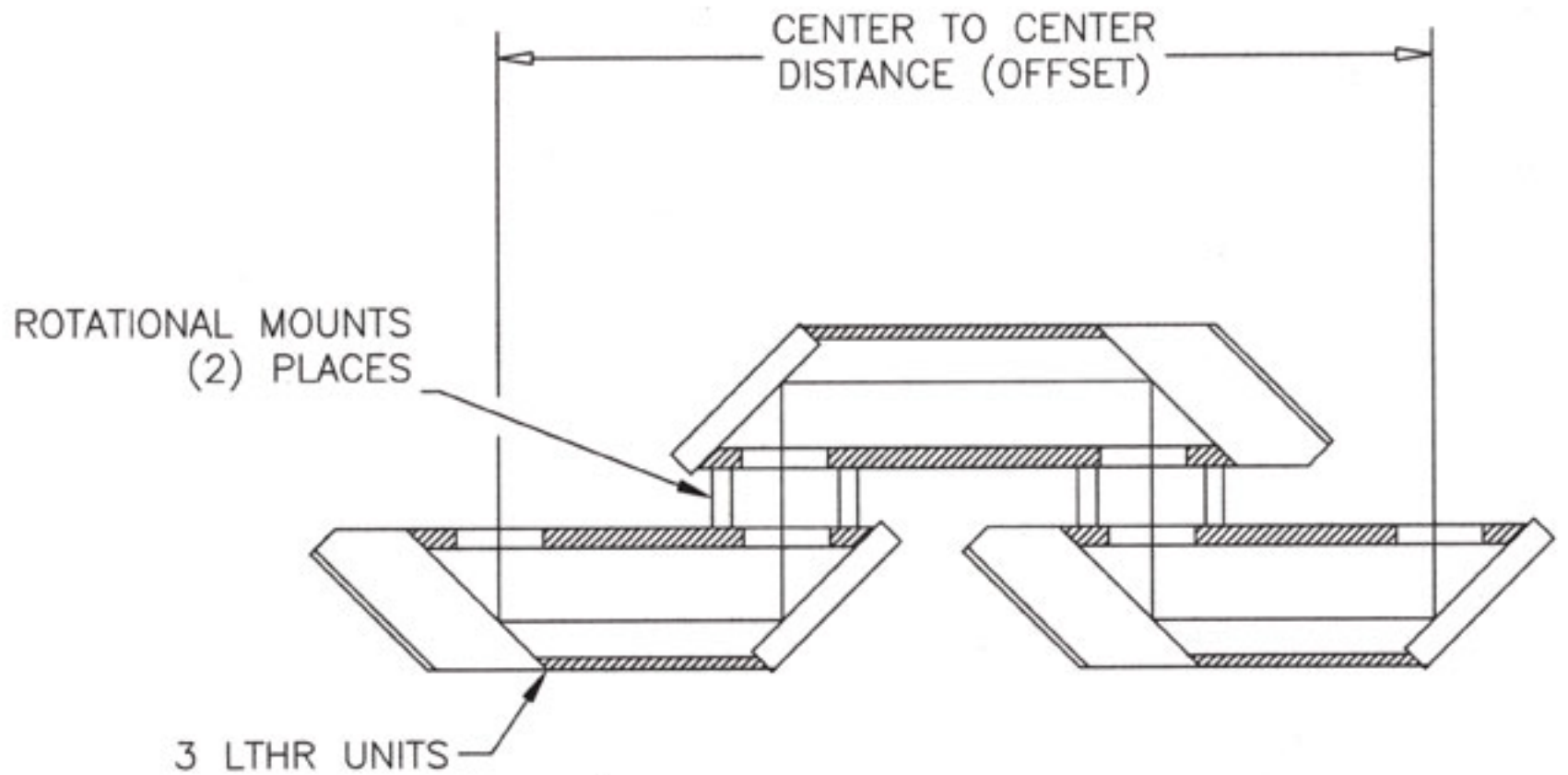
TEST SETUP FOR MEASUREMENT OF BEAM DEVIATION

FIGURE 2



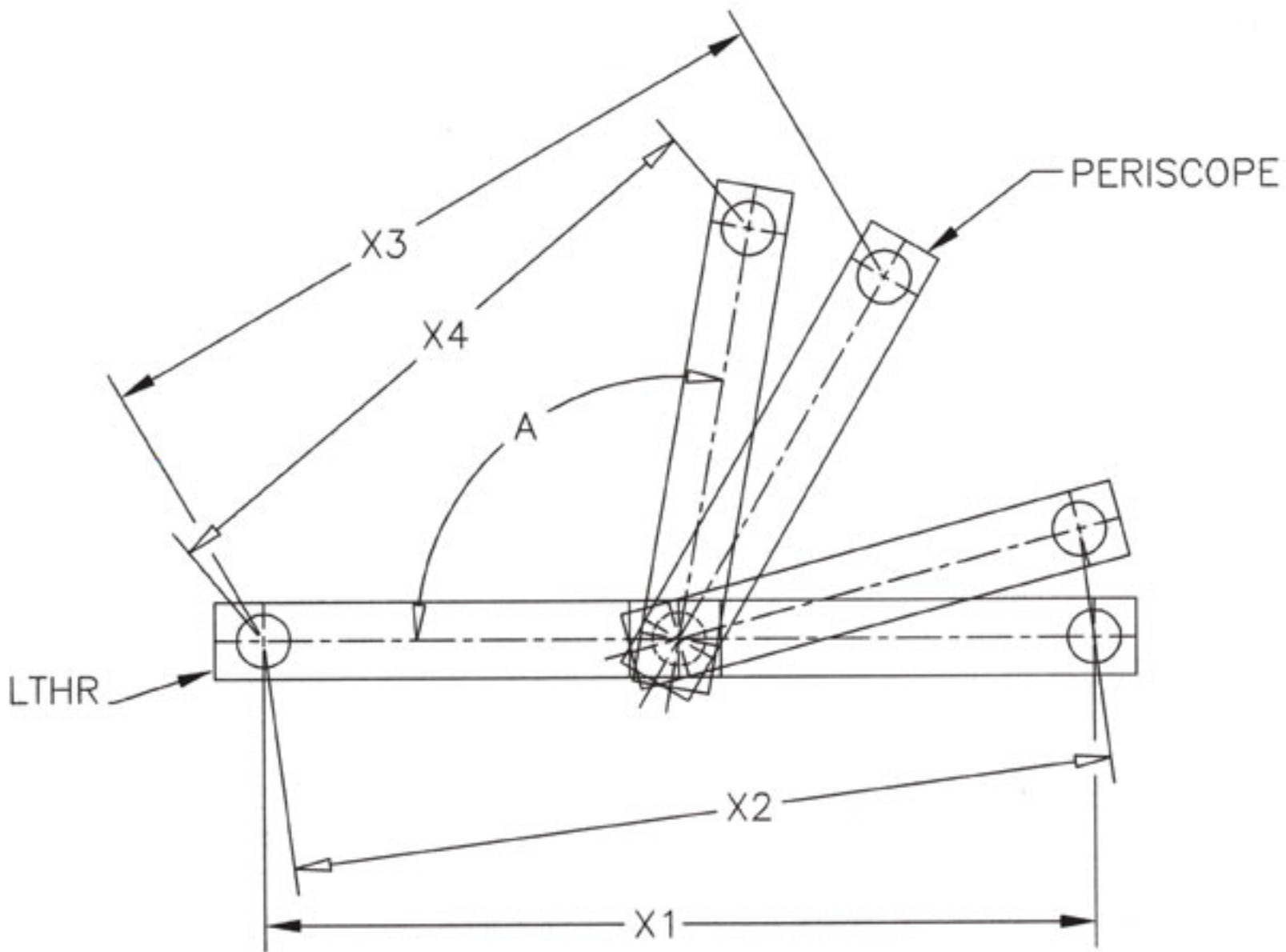
PERISCOPE CONFIGURATION (LTHP)

FIGURE 3



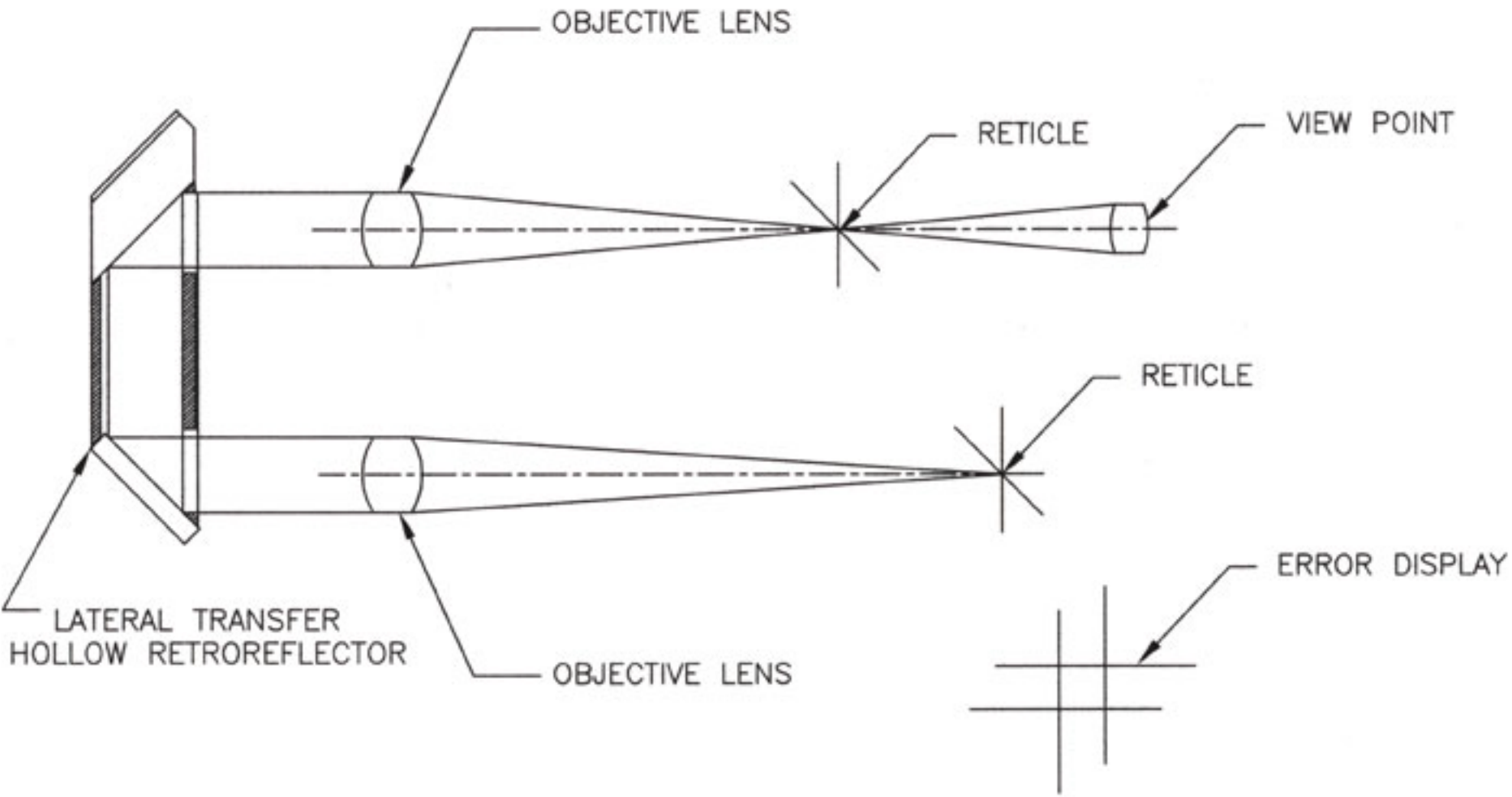
A THREE LTHR COMBINATION FOR LONG DISTANCE ALIGNMENT. THE ROTATIONAL MOUNT ENABLES ALIGNMENT FOR AN ADDITIONAL AXIS.

FIGURE 4



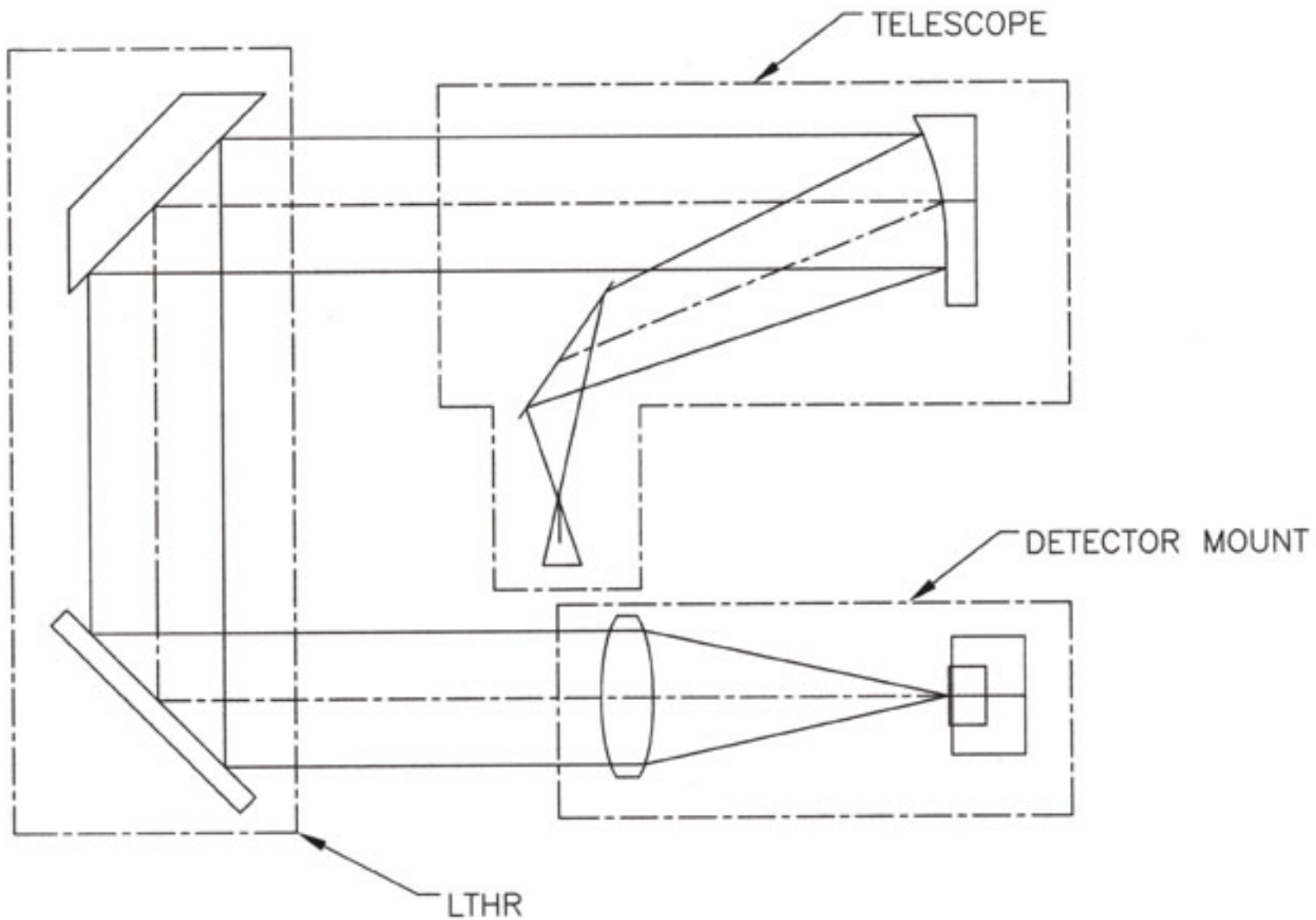
MULTIPLE CONFIGURATION
 DISTANCE "X" AS A FUNCTION OF ANGLE "A".

FIGURE 5



BORESIGHTING APPLICATION

FIGURE 6



SETUP FOR DETECTOR MOUNT ALIGNMENT

FIGURE 7