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Design and fabrication of low-cost adjustable lens mounts

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ABSTRACT

The optomechanical design, assembly and alignment of optical system consisting of several lens assemblies can be quite expensive and complex because considerable time is needed for assembling and aligning the system. This paper presents the design and fabrication of adjustable mounts for relay lens assemblies in an optical test station. There are eleven relay lens assemblies in the system, and each lens cell contains six lenses. A modular design approach was used to facilitate the assembly of alignment of the system. Low-cost adjustable mounts, consisting of standard commercial components, were designed for each lens cell to provide tilt, centration, axial spacing and (focus) adjustments. The test station has six point sources (two rows of three LED's), whose divergent beams must be collimated. A simple frame type of adjustable mount was designed for each set of three collimating lenses to provide the necessary centration, tilt and focus adjustments. The optomechanical design and fabrication of these two types of adjustable lens mounts is described in this paper.

Keywords: adjustable lens mounts, relay lens assemblies, tilt adjustment, focus adjustment, centration adjustment

1. INTRODUCTION

The laser test station is capable of projecting six moving point sources into the field of view (FOV) of an optical system under test. The optical intensity and the angular position within the FOV can be controlled individually in real time during testing. The six beams are individually steered by two-axis commercial scanners, then combined into a single aperture, and finally expanded to fill the entrance pupil of the system under test.

The test station consists of the following three major subsystems:

1. The prescan optics to collimate the individual laser beams.

2. The two-axis beam deflection system to steer the beams.

3. The post scan optics to relay, combine and expand the beams to fill an aperture of 140 mm diameter.

The entire optical system consists of 75 lenses, 10 folding mirrors, six beam combiners and six two-axis scanners. This large number of optical elements makes their assembly and alignment a very challenging task since quite a few tilt, centration and axial spacing adjustments are needed to position the optics correctly on a single common optical axis. The system was divided into six modules to facilitate its assembly and alignment. These six modules consist of one laser source assembly, four relay lens modules, and one telescope assembly. The six modules were assembled and aligned individually at first, then assembled on 5' x 8' optical table, and finally aligned relative to each other.

Each relay lens module consists of three lens assemblies, two beam scanners, one folding mirror and one beam combiner. Each relay lens assembly consists of a custom lens cell containing six lenses, and a custom-designed mount to provide the adjustments needed for alignment. The folding mirror and beam combiner are mounted in standard commercial mounts. All these components are assembled on a single baseplate to facilitate their alignment. The telescope assembly consists of three lenses, which are bonded in individual mounts and then assembled on a flat baseplate made out of aluminum jig plate.

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2. DESIGN AND FABRICATION OF RELAY LENS MOUNTS

The test station consists of eleven relay assemblies, consisting of six lenses each, i.e. a total of 66 lenses that must be aligned correctly on a single optical axis. The six lens seats in each cell were precisely machined to achieve the correct centration, tilts and axial spacing. A typical lens cell and its adjustable mount are depicted (a cross-sectional view) in Fig. 1. The two sets of three lenses each are installed in the cell from two opposite directions. Therefore, it is important that all six lens seats be machined in one machining setup to achieve the desired centration, tilt and axial spacing accuracy[1]. Each lens cell was rough machined from 6061-T651 aluminum alloy, stress-relieved and then finish machined to ensure long term stability. The lenses are bonded directly to the cell by an optical grade RTV adhesive.

The adjustable lens mount, also illustrated in Fig. 1, is designed to provide an axial spacing, two tilt, and one height (centration) adjustments to position the lens cell correctly on the desired optical axis. The axial spacing and two tilt adjustments are provided by three fine-threaded screws, which are arranged on an orthogonal pattern. These screws are installed in the flange of the cell, and their ball tips are in contact with the mount L-bracket. A typical kinematic interface, consisting of a ball in a cone and slot, and on a flat surface has been used. Two extension springs of adequate stiffness, centered between two adjacent contact points, are used to preload the cell to ensure a positive contact under shock loads. An axial spacing adjustment can be made by moving the three screws equally, while a tilt adjustment can be accomplished by moving one screw, resulting in a tilt about an axis defined the other two screws[2].

A similar arrangement of three spring-loaded adjustment screws is employed for the height adjustment. In this case, two locking screws are also provided to retain the adjusted position. These screws are kept loose during the course of making adjustments, and then tightened to lock the adjusted position. It must be noted that care should be taken when tightening these screws, as excessive locking force can induce distortions in the mount and change the alignment.

The fabrication and assembly of this simple adjustable mount is quite straight forward. The L-bracket was machined out of a single piece of aluminum. The two triangular gussets on either side are provided to enhance the bending stiffness of the bracket. The bracket was rough machined, and then stress-releived prior to finish machining. All six adjustment screws, the extension springs and locking screws are standard off-the-shelf commercial items, which are inexpensive and readily available.

3. DESIGN OF ADJUSTABLE COLLIMATING LENS MOUNT

As mentioned earlier, the point sources consists of six laser diodes arranged in two rows of three each. Because of the space constraints, there was not enough room to provide individually adjustable mounts for each collimating lens located in front of the laser diodes. Therefore, a single frame type of mount was designed to hold the three lenses, and provide the centration, tilt and axial adjustments for collimating the beams. Although each lens can be adjusted individually in centration, the tilt and axial adjustments for all three lenses are coupled.

The picture-frame type of adjustable mounts for a set of three collimating lenses is shown in Fig. 2, with additional design details depicted in sectional views illustrated in Fig. 3. Each lens is bonded in a square holder, and held in place in the frame by a clamping plate, shown in section C-C, Fig 3. The horizontal and vertical (centration) adjustments can be made by two fine-threaded screws acting against two adjacent edges of the lens holder. Each screw is centered about two tiny compression springs installed into the opposite edge. Curved spring washers are provided under the three screws that hold the clamping plate to allow for sliding of the lens holder during centration adjustment. These screws are tightened after the desired centration has been achieved to retain the adjusted position. A similar adjustment scheme is provided for each of the three lenses for centration.

Three spring-loaded screws, shown in section A-A Fig. 3, are arranged on an orthogonal pattern to provide focus and tilt adjustments for the entire lens frame. The disadvantage of this design scheme is that the focus position of each lens can not be optimized individually. An iterative procedure was employed to find the best focal position for each lens one by one by moving the entire frame. The frame was then fixed at the closest position relative to the dewar faceplate to obtain the best focus position for one of the three lenses. A set of brass shims was then used under the lens holders to achieve the correct axial position for the other two lenses to obtain collimated output beams.

The two-axis tilt adjustment is made by moving either the top right or the bottom right screw shown in Fig. 2. As mentioned earlier, moving one of these screws results in a tilt about an axis defined by the other two screws. After the alignment has been completed, the adjusted positions can be locked in place by tightening the three set screws. As excessive force resulting from these set screws can distort the frame and misalign the lenses, another more benign locking method has also been provided in this design. It consists of two locking pins, which are threaded into the dewar faceplate, and pass through oversized holes in the mount frame shown in section B-B, Fig. 3. Once all the adjustments have been made, and alignment completed, a suitable epoxy is injected around these locking pins. The three axial /tilt adjustment screws and the locking set screws can even be removed from the mount after the epoxy has cured.

This adjustable lens mount also uses commercially available screws and springs, and simple parts that are fabricated from 6061-T6 aluminum. The fabricated parts do not require precision machining tolerances, and can be produced inexpensively. This low-cost adjustable lens mount design is quite suitable for applications requiring moderate alignment tolerances.

4. CONCLUSIONS

The design of two low-cost adjustable lens mounts have been presented. These lens mounts consist of commercially available screws and springs, and simple machined aluminum parts, and are capable of providing the necessary focus, tilt and centration adjustments for alignment. These adjustable mounts were successfully employed for aligning eleven relay lens assemblies and six collimating lenses in an optical test station . Very high-resolution adjustments (<5 microns) can be made by incorporating fine pitch screws in these designs. If standard 32 or 40 pitch screws are used, these designs are still suitable for applications requiring moderate-resolution (~10 microns) adjustments.

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5. REFERENCES

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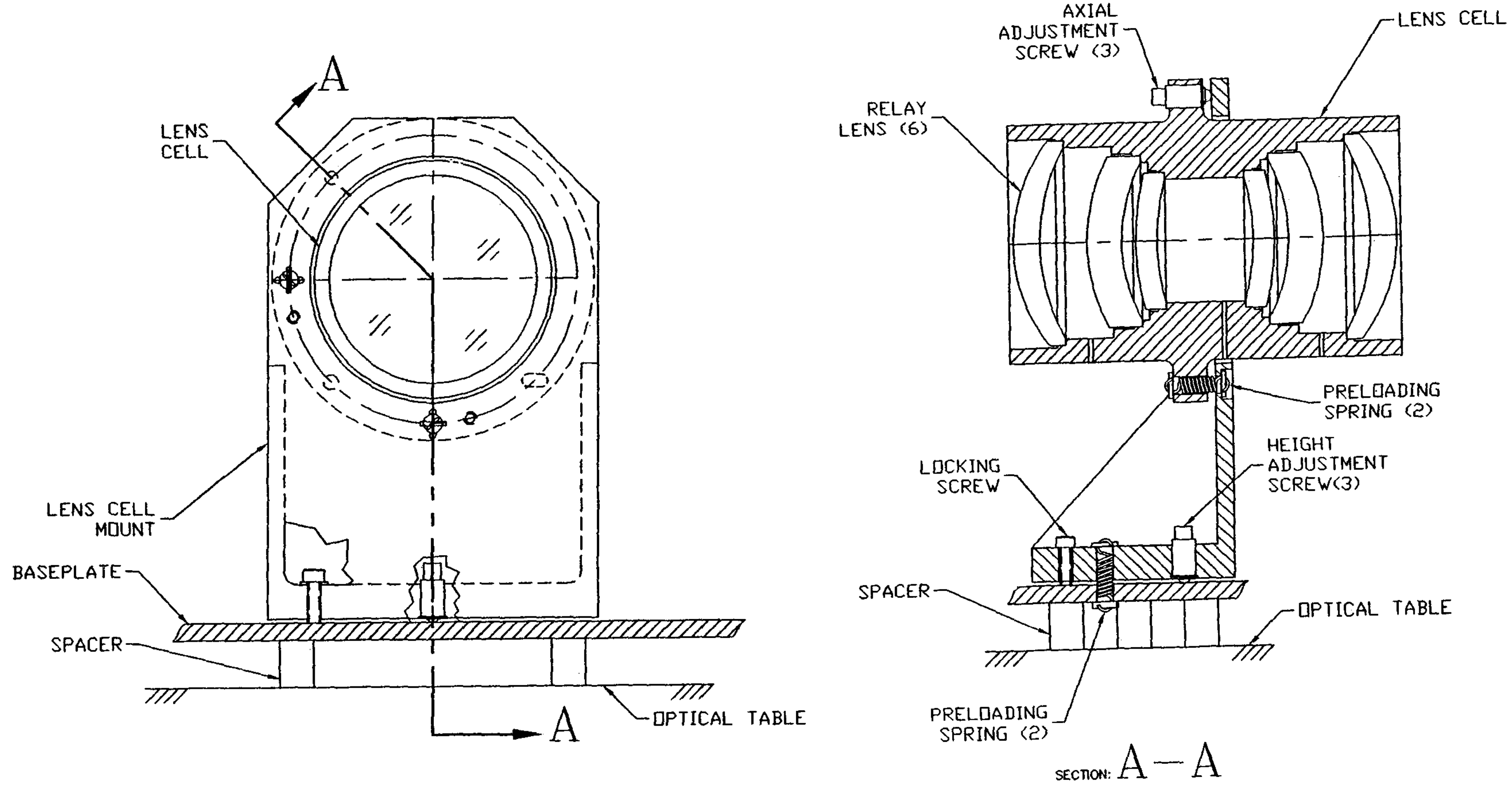

Figure 1: The adjustable mount for a typical relay lens assembly

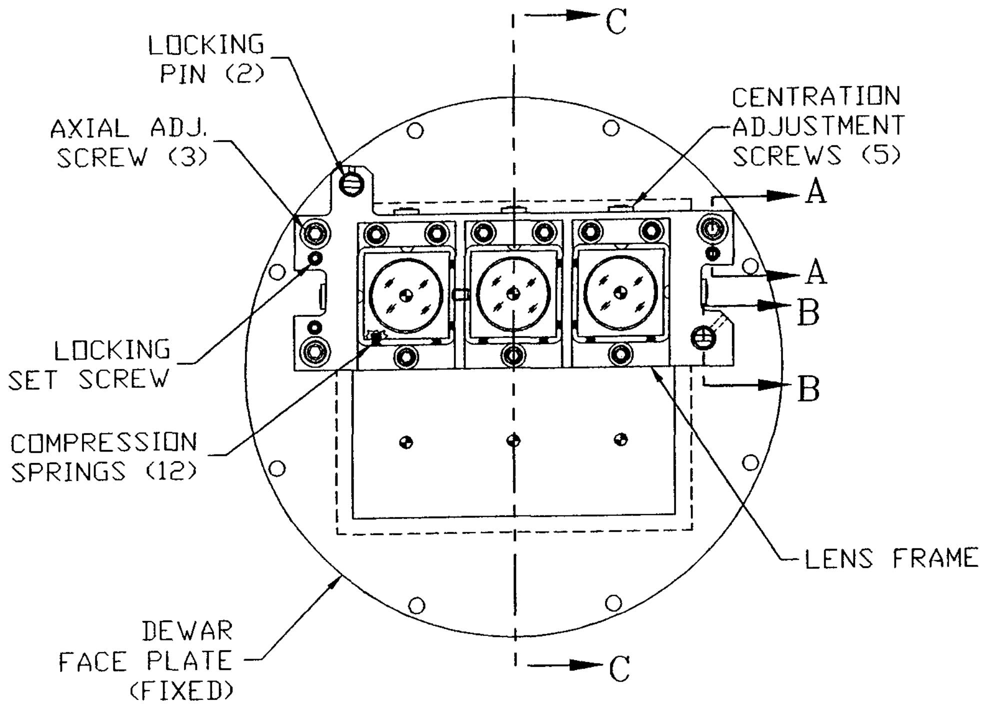

Figure 2: An adjustable mount for the three collimating lenses

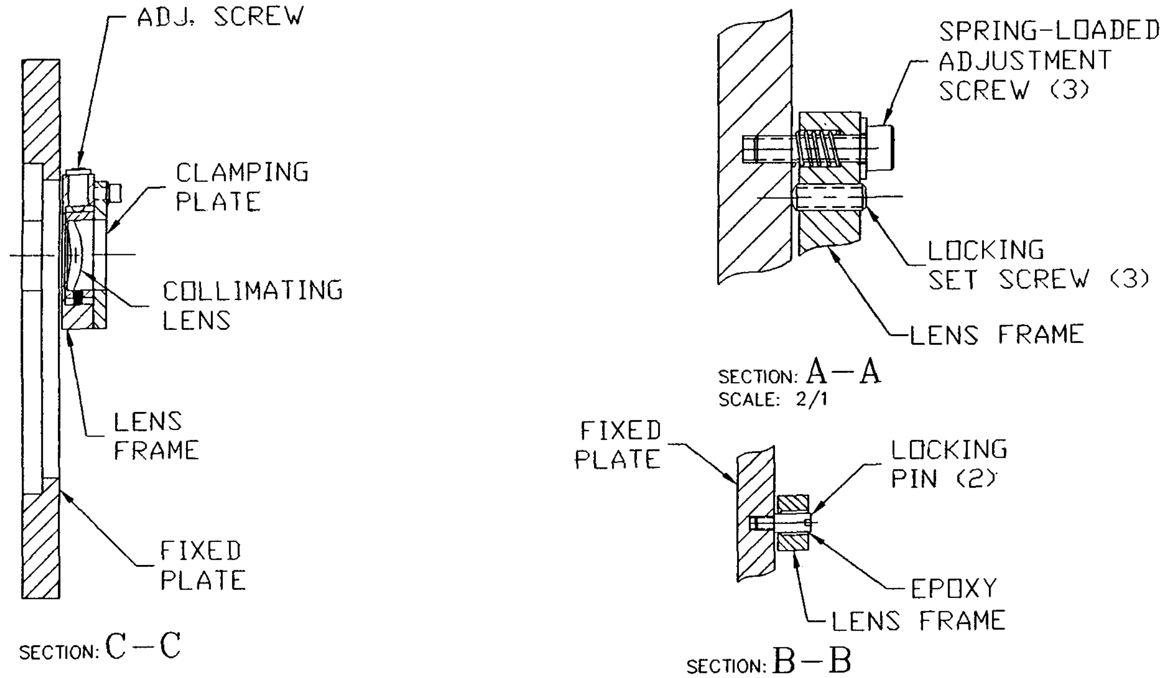

Figure 3: Sectional views showing design details of adjustment and locking methods