Elastomeric mounting of collimating lenses in space solar telescope

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ABSTRACT

The main optical system of Space Solar Telescope is composed of primary mirror, collimating lenses and imaging lenses. To satisfy imaging demands of wide range of wavelength (393nm- 656nm), the collimating lenses are composed of five components of which decentering errors are extremely stringent. To satisfy above situation, elastomeric mounting of lens is introduced for each component. The basic centering principle is discussed, the subcell assembly is introduced for the elastomeric mounting. Two aligning methods of are introduced for the alignment of subcells. Athermalization formulation of subcells is given. Besides, finite element model of such mounting is established for analyzing temperature change and elastomer shrinkage effects to lens surfaces.

Keywords: Elastomeric mounting, subcell assembly, centering method, athermalization, alignment measurement.

1. INTRODUCTION

To satisfy imaging demands of wide range of wavelength (393nm- 656nm), the collimating lenses in Space Solar Telescope are designed to have five components of which decentering errors are extremely stringent. Table 1 lists the aligning errors of each component.

Table 1: Aligning errors of each component

Component	Decentering error (mm)	Tilting error
Lens 5	0.006	3”
Lens 4	0.001	20”
Lens 3	0.003	5”
Lens 2	0.004	5”
Lens 1	0.004	3”

It shows that the minimum decentering error is 1μ, so those traditional methods, such as “drop in” assembly and “lathe” assembly, are inapplicable to this occasion.

The general way to mount lenses is in a barrel. The lenses are centered, edged and then mounted in the barrel with spacers, using the edges of the lenses and the barrel to define a single optical axis. To achieve precision alignment of the lenses, all the lens diameters must match the inside diameter of the barrel. The same is true of the spacers. They must all have the correct diameters to fit the barrel and must also have no wedge. The lens barrel and the spacers must be round and the inside diameter of the barrel straight.

The above requirement of precision is extremely difficult to achieve, especially to center and edge the lenses precisely. In optical shop, only spherical surfaces and center thickness of a lens can be guaranteed accurately. So any precision alignment of lenses must be based on the two spherical surfaces and thickness of lens.

2. CENTERING METHOD

2.1 Centering principle

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It is well known that two spherical centers of a lens uniquely establish the optical axis. Figure 1 shows a triplet lens that is perfectly centered, while neither the barrel nor the spacers are centered. That means lenses can be assembled in such mounts if one abandons the concept of using the barrel's inside diameter as the reference axis for alignment of the lenses. It is possible with a collimator, particular with a laser collimator, to use the lenses themselves to indicate the straightness of the optical axis. This is based on the concept that light from a point source on the optical axis of a lens reflects images from every lens of the surfaces, and every image is centered on a straight line.

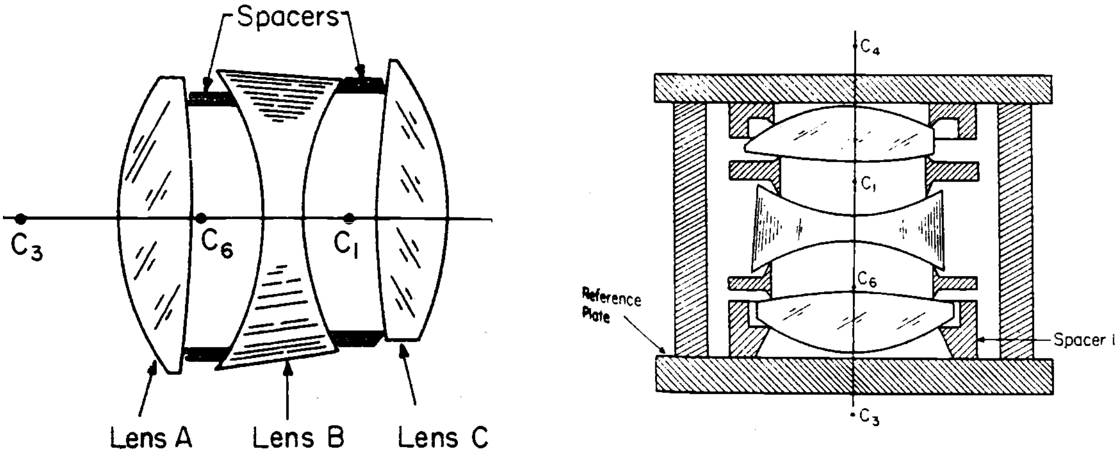

Figure 1 A triplet lens that is perfectly centered

2.2 Subcell assembly

If the air space between lens is so thin that the spacer is too thin to maintain its accurate shape, an alternate procedure called "subcell assembly" is adopted. Figure 2 shows two typical subcells in Space Solar Telescope. Each subcell is exactly plane-parallel and the thickness dimensions accurately meet the needs that when the two adjacent subcells are assembled together, the air space between two relative lenses is automatically assured.

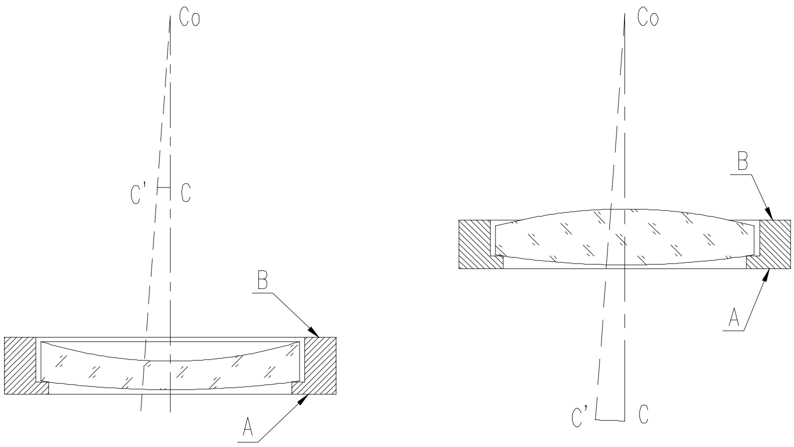

Figure 2 Schematic of two typical subcells

Registration of one optical surface against a machined surface of the subcell reduces the freedom of lens, and makes it easier to align the lens. As shown in Figure 2, when move a lens around, only one spherical center changes its position. So the optical axis of a lens can easily be adjusted perpendicular to surface A or B. Then the gap between the lens outside diameter and the subcell inside diameter is filled with an elastomeric room temperature vulcanizing (RTV)

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compound. After RTV curing, all subcells are assembled together one by one (Figure 3), only lateral adjustments are needed to accomplish aligning lenses.

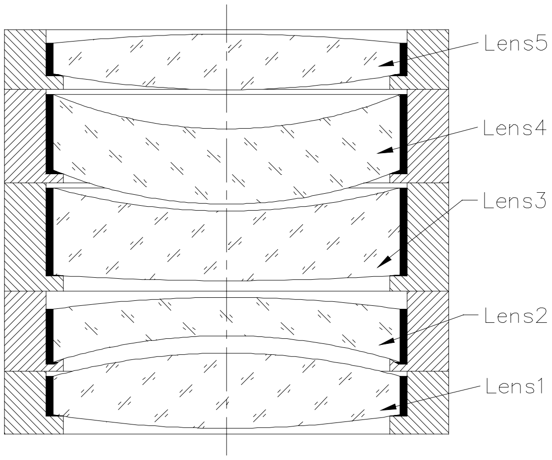

Figure 3 Subcell assembly of collimating lenses

3. MEASURING METHODS

There are several measuring methods when align one subcell. Figure 4 shows the optical system of a laser collimator for use in the assembly of lenses. The reference plate, the first and the second surfaces of the lens return wavefronts with differing curvatures. These three wavefronts form three sets of interference fringes similar to Newton's rings. When three surfaces have a common axis connecting their centers, the three interference patterns are concentric. Theoretically this method is also fit for multiple lens alignment, but since the next lens alignment will depend on previously aligned lens surfaces, so some accumulating errors will descend the accuracy of alignment.

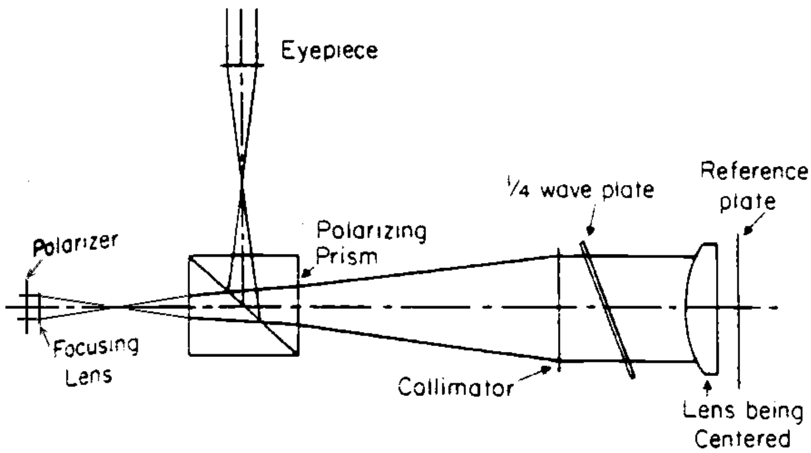

Figure 4 Laser collimator for aligning lenses

If a precisoin rotary table is given, another method of lens alignment can be achieved. The lens subcell is mounted on the rotary table, and the inside shoulder is first adjusted until it is concentric with the axis of rotation of the rotary table. To center the lens, both optical and mechanical measuring techniques are employed. Figure 5 shows two way of checking center of curvature alignment, one is autocollimation method, and another is interferometer method. After the five subcells have been aligned, the subcell assembly can be achieved using the same method.

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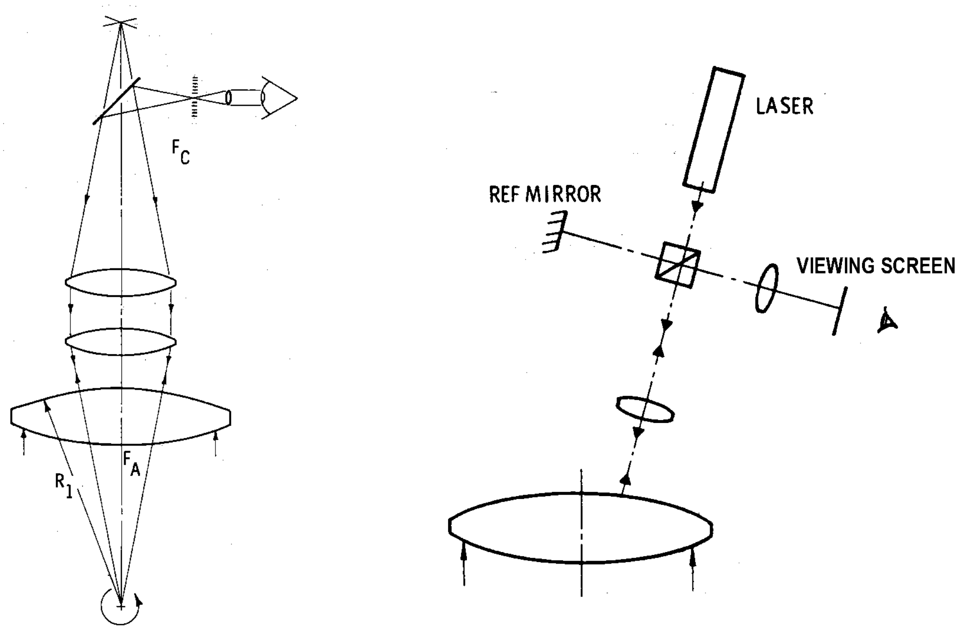

Figure 5 Two way of checking center of curvature alingment.

4. ATHERMALIZATION

Figure 6 shows a typical design for a lens suspended by an annular ring of resilient elastomeric material (typically epoxy, urethane, or room temperature vulcanizing rubber) within a cell. One side of the elastomer ring is unconstrained so as to allow the material to deform under compression or tension due to temperature changes and maintain a constant volume. Registration of one optical surface against a machined surface of the cell helps align the lens. Centration can be established prior to curing and maintained throughout the cure cycle with shims or external fixturing.

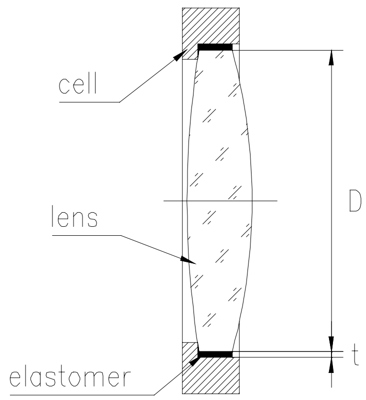

Figure 6 Schematic of elastomeric mounting of a lens

If the resilient layer has a particular radial thickness, the assembly will be athermal to first-order approximation in the radial direction. Stress buildup within the optomechanical components due to differential expansion or contraction is then resisted. This thickness is

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$$t = \frac{D \cdot (\alpha_M - \alpha_G)}{2(\alpha_E - \alpha_M)}, \quad (1)$$

where α_E, α_G and α_M is respectively the thermal expansion coefficient of the elastomer, lens and cell.

5. FEA MODELING

An axisymmetric element model of elastometric mounting (Figure 7) is established to predict elastomer shrinkage effects on optical surface distortions, and radial temperature distribution. To investigate the stress state in and around the elastomer layer, detailed model is given to get proper edge effects. Since the proper elastomer material is still being selected and the special parameters such as Poisson's ratio and Young's modulus have to be tested carefully, the above analyzing results haven't got yet.

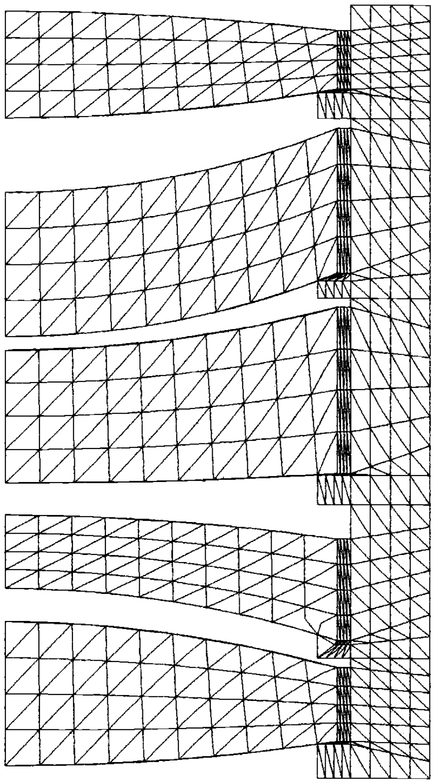

Figure 7 Axisymmetric element model of elastomeric mounting

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