Synopsis of Paper
"Lens Mounting Techniques"
P. R. Yoder, Jr.

Proc. Of SPIE Vol. 0389, Optical System Engineering 3,
ed. William Taylor (Jan 1983)

Opti-521 Report#2
Michihisa Onishi
Dec. 14, 2007

Introduction

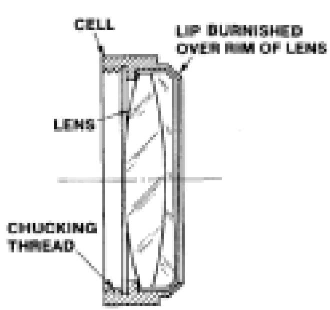
Lens mounting techniques are one of the key techniques for optical system. Optical engineers should well understand the basic concepts of lens mounting techniques even though not working on this field. In this paper, a variety of techniques used for mounting rotationally symmetric lenses in the size of approximately 0.5 to 10 inches diameter are discussed. The discussion is progressed from simple design to more higher precision version.

Permanent mounting individual lenses

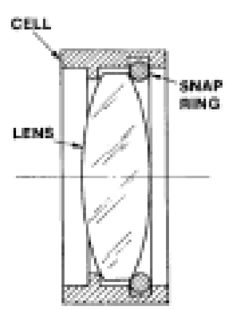
Burnishing the lens permanently is usually accomplished by deforming the cell lip after the lens is inserted. The cell material should be malleable. Aluminum and brass are commonly used for this purpose. **[Fig-1]** shows the lens burnished into a cell made of a malleable metal. A radial clearance between lens and cell is usually 0.001 to 0.005 inch. This technique is inexpensive and requires no extra parts.

A snap ring can be used to hold lenses in a cell. The ring drops into a groove in the inside surface of the cell. **[Fig-2]** shows an example of such designs with a ring of circular cross section. Rectangular section snap rings can be used also. Variations in lens thickness as well as in groove location and depth and snap ring cross section dimensions affect the interface between the lens and the ring.

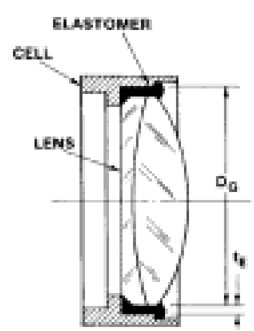
Another simple mounting technique is using resilient materials. **[Fig-3]** shows an example where a radial spacing is allowed between the lens and cell and the annular void filled with resilient material such as RTV. Positioning o the lens in the center of the cell cavity can be accomplishes by mechanical fixturing or by using three narrow plastic shims of suitable thickness to center the lens temporarily.



[Fig-1] Lens Burnished into a cell



[Fig-2] Snap Ring Technique



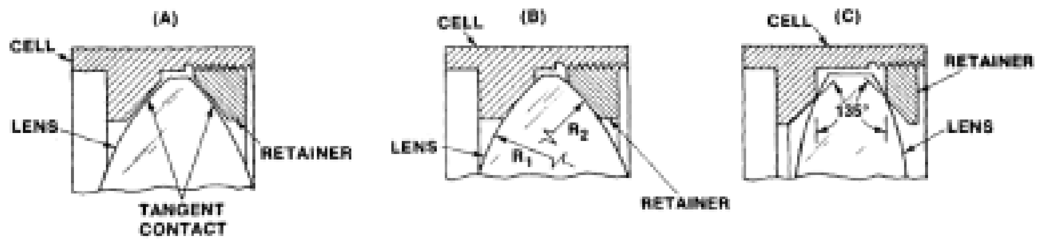
[Fig-3] Holding Lens by Elastomer

Retainer

The techniques listed above are rather permanent assembly technique. The other method for mounting an individual lens or mirror with rotationally symmetry is to secure it against a shoulder in a cell with a threaded retaining ring as shown in [Fig-4]. This type of design has many advantages as listed below;

a) It gives a firm mounting that can be assembles and disassembled relatively easily.
b) It compensates for axial thickness variations of the element.
c) It lends itself easily to environmental sealing with an elastomer or O-ring.
d) It is compatible with mounting multiple elements in the same cell or housing.

The retaining ring loads the element axially against an annular seat which may be (A) cut square to the axis, (B) tangent to the radius of curvature of the element or (C) cut and lapped to the same radius of curvature as the lens surface. **[Fig-4]** shows those three types of configurations.



[Fig-4] Three Configurations for glass-to-metal interface

The square configuration is the most commonly used type and easiest to machine. But a care should be taken since the contacting edge is left sharp; usually results in a minute chamfer or radius. For the tangential contact configuration, the contact should occur midway between the lens clear aperture and its outside diameter. An error in annular radius of contacting point could misposition the lens axially. A typical tolerance on that angle is 1^o. The tangential contact is hard to make accurately and, hence, expensive. In case (C), the corner that contacts the glass is obtuse. That would prevent line contact over a full circle.

Axial Stress in the Interface – Worst Case

To select the proper seat, spacer, and/or retaining ring configuration for a specific design, the worst-case axial compressive stress or preload, imparted to the glass by tightening the retainer and, additionally, by differential thermally induced contractions, should be cared. The models used here for the estimation of those stresses are rather simple. The lenses are modeled as circular cylinder and the contacting surfaces or edges are modeled as cylinder or flat plane. The dimensions are assumed to be as follows;

radius of curvature of lens: 60 inches	metal edge radius: 0.004 inch
height of line contact on lens: 1 inch	half diameter of lens: 1 inch
change in temperature: 148^oF	load per unit: 0.5 lb/in
glass: BK7	metal: Aluminum (wall thickness: 0.125 inch)

For the case (A), the stress induced by load is estimated to be 21,636 ib/in^2 and thermal stress to be 7500lb/in^2. the total stress induced would be 29,136 ib/in^2 that is about 60% of the safe value of 50,000 ib/in^2 for BK7 glass. The stress imparted to the glass surface can be greatly reduced by changing the design to tangent contact. The preload stress with tangent contact is reduced to 177 lb/in^2. The total would be 7677 lb/in^2 which is about 1/6 of the danger value. We could then consider the tangential contact design as acceptable from a low temperature survival viewpoint.

Radial Stress – Worst Case

Some lens assemblies are designed with very little radial clearance between glass and metal. Nominal clearance as small as a few the thousands of an inch might be provided and tolerances specified so the maximum clearance does not exceed 0.0005 inch. In such design, it is important to match the coefficient of thermal expansion of the cell material closely to that of the glass. Using the values provided in previous section, the estimated value of thermal radial stress is 1000lb/in^2 for this case that is much below the yield stress of BK7.

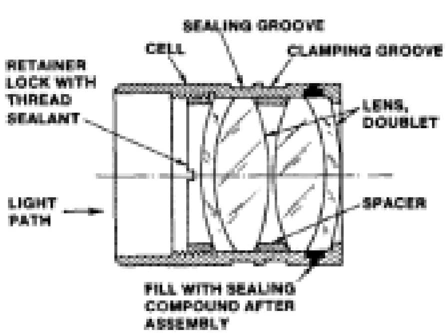
Stress under Operating Conditions

The operating temperature range for an optical instrument is more benign than its survival range. The change in mounting stress due to lesser temperature changes would not be catastrophic but rather ones that affect performance of the optics. Since he limited his consideration to effects within the lens mounting, the two effects of interest are birefringence and surface deformation. A generally accepted criterion for compressive stress that does not introduce noticeable birefringence is about 500 lb/in^2. if we assume that the operating temperature range is +-5^{o}F, using the same conditions, the thermally induced compression stress would be only 253 ib/in^2 that is about one half the total allowable stress from birefringence viewpoint. In the case of laser interferometer, polarimeter and so on, special care should be exerted. The balance could be allocated to preload stress.

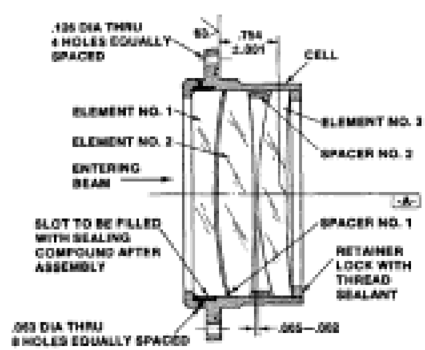
Analytical method for predicting the deformations of surfaces under mounting stresses include solution of closed-form equations and finite element analysis – both these method are beyond the focus of this paper.

Multi-Element Mounting Configuration.

Stack-mounted assemblies are those in which the lenses are inserted in sequence into the cell or lens barrel with spacer rings to separate them by the proper airspaces. A single retainer usually holds all these parts in place. A fixed focus eyepiece subassembly for a military telescope is shown in **[Fig-5]**. Both lenses and the spacer fit into an internal bore in an aluminum cell with typically 0.003 inch diameter clearance. The first inserted lens resisters against the squared seat. The spacer is of the square configuration as is th threaded retainer that holds both lenses in place. The doublets are generally edged after cementing, so both elements have the same outside diameter.



[Fig-5] Example of a fixed focus eyepiece

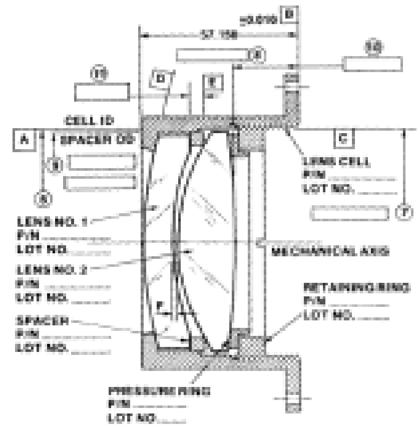


[Fig-6] a high performance telescope objective

Another example of an opto-mechanical configuration of a multiple-element objective for a relatively high performance military telescope intended to withstand a severe shock and vibration environment is illustrated in **[Fig-6]**. The three singlets have the same outside diameter and fit into a stainless steel cell with normally 6um diametrical clearance. All lenses are inserted from right side. The wedge tolerances on the lenses and spacers are 10 arc seconds and the maximum edge thickness variation is about 10um. At assembly, the lens elements are phased by rotation about the axis for maximum symmetry of the on-axis image.

Lathe assembly techniques

In this type of mounting, elements are radially positioned by the inside diameter (ID) of the mating cell or housing. The outside diameter (OD) of each element must be precision machined to fit that specific element. In multi-element designs, the axial positions of the various elements are established by properly locating the machined seats while cutting the IDs. Since this machining process is traditionally done on a lathe or similar machine tool spindle, it has come to be known as "lathe assembly". In a high performance lens assembled in this manner, nominal diametrical clearance between the OD of the element and the ID of the metal part may be as small as 0.0002 inch.



[Fig-7] an example of lathe assembly

[Fig-7] shows the actual lathe assembly process. Two lens elements are to be hard-mounted into a cell woth a small radial clearance between metal and glass parts. Both lenses are constrained by a single threaded retaining ring acting through a pressure ring.

Conclusion

Even though all of the designs discussed in this paper were very fundamental and previously developed methods, they suggest us a most basic concept we have to be familiar with. Many modern assembly methods have been developed by expanding those basic ideas. Reviewing the most basic lens mounting method tells us a very important sense that all on the optical engineer need to fully understand.