

Lens Barrel Assemblies

The most common assembly method when mounting multiple lenses involves inserting them into a **metal barrel**. Assembling a system in a barrel provides protection from the environment and simplifies the system alignment. A number of factors can be considered when choosing a barrel material; favorable materials have low CTE and density (reduces weight), high stiffness, are corrosion resistant, easily machined, and can be blackened (to reduce stray light). Aluminum is the most common barrel material due to its low cost and ease of machining. Stainless steel is also popular because it has a low CTE and high stiffness. The lens system is often assembled with the barrel vertical by using a vacuum tool to pick up the lenses outside of their clear aperture and lower them into the barrel.

- The barrel is often given a 25–50- μm larger diameter than the lens outer diameter to provide room for loading the optics without jamming.
- Relief grooves or vent holes should be created in the barrel to relieve pressure when inserting elements into the barrel.
- The retaining rings and spacers should contact the lenses at the same diameter that the seats do; this avoids imparting a moment in the lens, causing distortion.
- The axial location of the lenses should not be determined by the retaining rings. Tightly fitted rings can cause stress in the lenses due to wedge error. To avoid this problem, either the fit of the retaining rings should be loose or some compliance should be provided (i.e., an O-ring). The lens position should be defined by machined seats in the barrel or by precision spacers.

After the system is assembled, it should be **sealed** to prevent dust, water, or other contaminants from entering the barrel. O-rings, adhesives, or internal pressurization in the barrel with dry gas are common sealing methods.

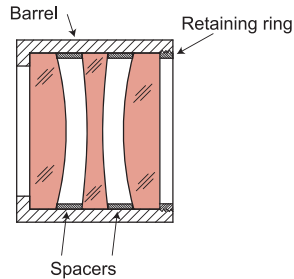
Lens Barrel Assembly Types

There are a number of ways to approach barrel mount designs, depending on system requirements; the most common barrel designs are shown below and on the next page in order of increasing accuracy and complexity.

In a **straight-barrel** design, all lenses are the same diameter and are separated by **spacers**. The assembly is typically held secure by a threaded **retaining ring** at the end.

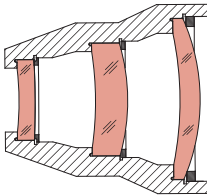
- Simple, low-cost, easy assembly
- Precision limited mainly by the precision of the elements

Common-bore-diameter barrel: uses spacers to maintain element spacing.



A **stepped-barrel design** can accommodate lenses of varying sizes and uses spacers and/or **machined seats** to hold the lenses at the proper separation. If the seats are machined into the barrel, tight tolerances are required on the wedge of each lens.

- More complex machining required than a straight barrel, easy assembly
- Precision limited by the machining: 50 μm is common, 10 μm is possible



Stepped-diameter barrel: uses machined seats to place lenses.

Lens Barrel Assembly Types (cont.)

Spacing adjustments can be included for additional precision. One method adds shims to adjust for measured errors. Another method enters as-built data into a lens-design program and then machines the spacers to compensate for errors and optimize performance.

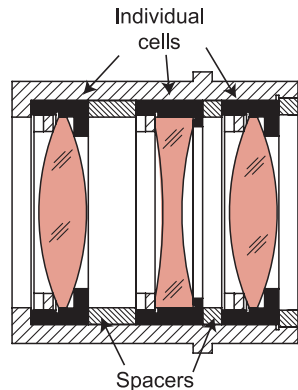
- Labor intensive
- Can achieve 25 μm easily, 5 μm is possible

Sometimes a **lateral adjustment** is included for one or more of the lenses in the barrel, providing the ability to decenter the lens during assembly to compensate for a specific aberration. The best element for this adjustment is usually determined by sensitivity analysis in a lens-design program.

- Labor intensive
- Can achieve 10 μm easily, 1 μm is possible

In **subcell mounting**, individual lenses are centered in their own subcell and fixed with adhesive. The subcells are then press (interference) fitted into a parent barrel, wherein centering is achieved by the tolerancing and form of the metal cells rather than the lenses.

Because it is easier to control the form of machined metal components than of polished optical elements, this process greatly improves the centering accuracy more than is traditionally possible. Subcell mounting has a higher cost for components and is more complex, but it is economical for assembly and for fulfilling difficult requirements; thus, it is commonly used in high-performance systems.

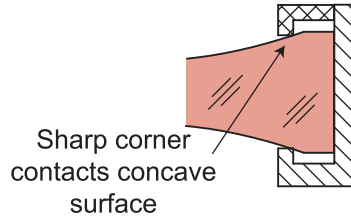


- Very labor intensive and expensive
- Can achieve 10 μm easily, < 1 μm is possible

Surface–Contact Interfaces

There are a few different ways the edges of a glass optic can interface with its mount.

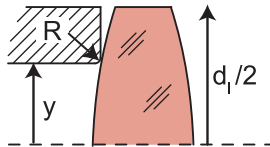
A **sharp-corner contact** occurs when the glass sits on the corner of the mechanical mount. This contact provides the highest accuracy and is the easiest to fabricate and tolerance. However, a sharp corner can create high local stresses in the glass.



In practice, a true sharp corner is rarely produced. Typically, it will have a small radius. If the retainer has a specific controlled radius in the design, it is called a **toroidal contact**. This type of contact can be used for convex or concave surfaces and is seen in many high-quality assemblies due to the reduced compressive stress from the sharp-corner contact. The **maximum compressive axial stress** σ_a a lens will experience due to a preload force F on a retainer with radius R can be estimated by

$$\sigma_a = 0.4 \sqrt{\frac{F E}{2\pi y R}}$$

where y is the height at which the retainer contacts the lens, and R is the radius of curvature of the retainer edge, typically ~ 0.05 mm.

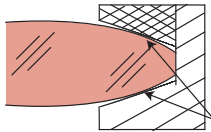


This estimation assumes that the Young's modulus values of the glass and metal are similar ($\Delta E < \sim 25$ GPa).

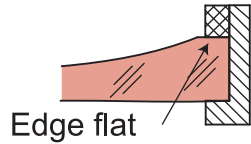
Surface–Contact Interfaces (cont.)

A **tangential contact** occurs when the mechanical mount contacts tangentially to the glass. This contact has relatively low stress and can be fabricated fairly easily. It cannot be used with concave surfaces; however, a flat can put on the edge of the glass to provide a seat for the retainer.

$$\sigma_a = 0.798 \left[\frac{\frac{F}{2\pi y d_l}}{\left(\frac{1-\nu_l^2}{E_l} \right) + \left(\frac{1-\nu_r^2}{E_r} \right)} \right]^{\frac{1}{2}}$$



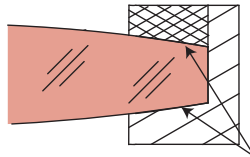
Tangential



Edge flat

Conical mount contacts tangentially to glass.

A **spherical contact** occurs when the mechanical mount and glass have the same radius. This contact has the lowest stress but is very difficult to fabricate and tolerance and thus is the most expensive option.



Spherical

Mount and glass have same radius of curvature.

When a compressive contact stress occurs at an interface, a tensile stress also occurs as a result. Experience and data show that when a retaining ring is pressed against a lens, the tensile stress field is so small that performance is not affected.