Opto-Mechanical Hardware Types

Opto-mechanical components can be separated into two general categories: fixed components and adjustable components. The most basic fixed components simply hold either an optical element or another hardware component. Examples of fixed components include simple lens mounts, posts, pillars, and adaptor plates. Adjustable components, essential to any optics laboratory, include translation stages, rotation stages, and adjustable mirror and optics mounts. Adjustable mounts typically have an adjustment screw for positioning and springs to preserve alignment and remove backlash. Often these mounts are automated with powered actuators which replace manual adjustment screws. For ease of setup, virtually all opto-mechanical components are designed to be mounted to optical tabletops directly or via threaded posts. Proper selection of fixed and adjustable components can improve experimental measurements and provide years of productive service.

ADJUSTABLE OPTICAL COMPONENT MOUNTS

Adjustable optical component mounts include mirror and beamsplitter mounts as well as prism tables.

Three linear and three angular motions are necessary to describe fully the motion and position of a solid body in space. Figure 7.1 identified the six degrees of freedom in the Cartesian frame of reference. When each of these degrees of freedom is singularly constrained by a hardware mount, the mount is defined as kinematic. Kinematic mounts offer simple and economical positioning. Typical construction includes a cone, groove, and flat in the front plate of the mount to constrain unwanted motion (see figure 7.8). The cone constrains motion in the x, y, and z axes. The groove constrains motion in θy (pitch) and θz (yaw). The flat constrains motion in θx (roll). All six axes are constrained but only once, making this design kinematic. This principle is used for mirror mounts and mounting plates. In the mirror mount, angular adjustment is accomplished with drive screws pushing against the groove and flat. Springs pull the plate against the drive screws.

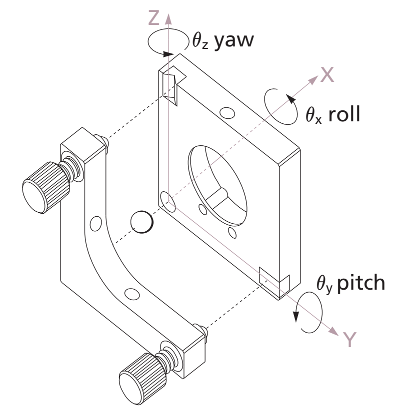


Figure 7.8 **Kinematic mount with a cone, groove, and flat**

Flexure mounts differ from kinematic mounts in that they use solid springs to constrain the mirror mounting plate. These springs, like leaf springs on automobiles, constrain the motion to up and down while limiting twist. The constraint on twist (front to back plate shear) offers improved positioning control and stability. Spring flexures are superior to traditional kinematic designs. The weight of the mirror and mirror plate is supported directly by the flexures, which eliminate all in-plane motion, leaving the drive threads free to control the remaining three degrees of freedom. In traditional kinematic designs, unless the mirror mount is pointing vertically, gravitational pull and resultant torque must be accommodated by the drive threads. Consequently, any play, no matter how small, results in pointing error and wobble. Mounts using flexures are not affected by this torque.

To achieve maximum performance from a flexure system, care is required when mounting and clamping the flexing element. The flexure merely constrains motion so that the resulting stage moves in the desired direction. In the two orthogonal directions, the flexure is rigid. The rigidity of the flexure in directions orthogonal to the axes of motion can be made as great as required by strapping or stiffening the flexure to produce a rigid link with small regions of flexibility near the clamping points. If this semi-rigid link is wide enough, resistance to twisting becomes enormous. Using a suitable return (coil) spring allows the flexure stage to be preloaded against the drive.

Kinematic and flexure mounts offer economical, precise positioning. Some cross-coupled motions, however, occur because the rotational axes are not centered on the surface of the mounted optic. Gimbal mounts provide angular adjustment without translation. The axes of rotation for gimbal mounts are orthogonal, noninteracting, stationary, and centered on the optic. Gimbal mounts are used for the most precise optical beam control applications. A comparison of kinematic, flexure, and gimbal mounts is shown in figure 7.9.

LENS HOLDERS

A variety of holders and mounts are available for holding lenses of all shapes and characteristics. Depending on the application, the optical element itself, the degree of precision required, and the number of directions along which adjustments need to be made, one type of lens holder might be preferrable to another. Cost considerations are also important, particularly in experimental setups in which a large number of optical components are mounted on holders.

The fixed-lens holder with a single screw retainer is a simple type of edge-mounting lens device. Its principal advantage is its low cost; its disadvantage is the fact that it has no mechanism for dealing with centration error. Additional hardware may have to be used to correct for optical axis tilt. This type of lens holder is suitable primarily for use with long-focal-length lenses in which centration error is not critical and applications in which wavefront distortion caused by tilt can be tolerated.

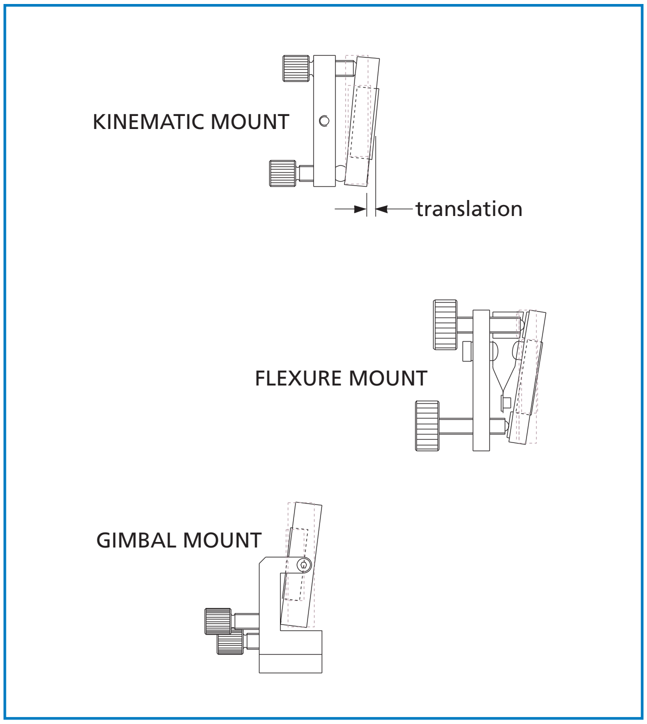


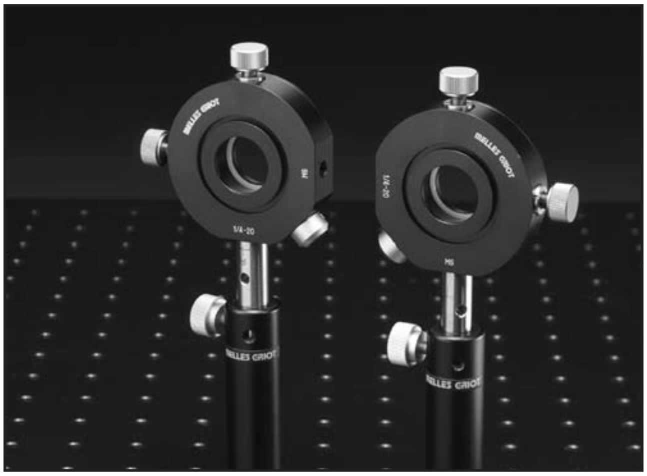
Figure 7.9 **Kinematic, flexure, and gimbal mounts**

The fixed-lens holder with a retaining ring can be used for a variety of applications in which a moderate degree of precision is required. Because it uses the surface-mounting technique, it does not suffer from the problems caused by centration error. Its major disadvantage is that each mount can be used only with a lens of a specific diameter. As a result, to hold lenses of various diameters, one would need an assortment of these holders, each with a different diameter.

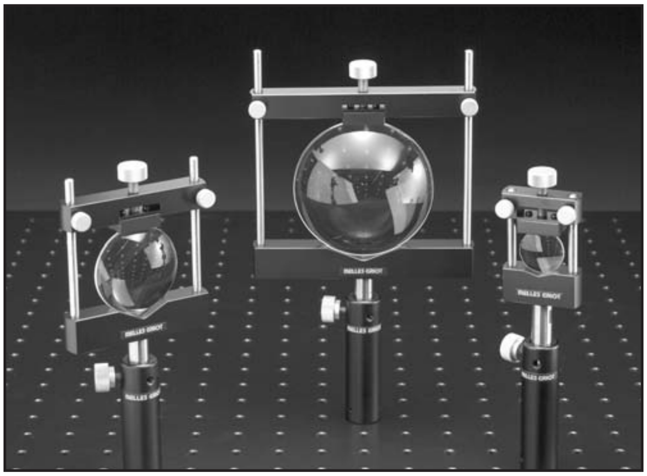
The two-axis lens holder is essentially a fixed-lens holder with a retaining ring which is also equipped with a mechanism for adjusting the vertical and horizontal positions of the optical element. The advantage of this type of holder is that it is a single, compact piece of hardware which provides precision positioning in the plane perpendicular to the optical axis. Its disadvantage is that one needs a variety of different size lens holders to hold lenses of varying diameters.

The universal lens holder, a versatile piece of optical hardware, can be used to hold lenses of various diameters. These lens holders are available in a variety of styles. One uses a mechanism in which three radial screws, placed 120 degrees apart with respect to one another, grip the lens at three different points. The screws are loosened to open up the holder in order to place the lens in place and then they are tightened to hold the lens securely in place.

Fixed-lens holders with retaining ring



Two-axis lens holders



Universal lens holders

Another mechanism used is a combination V-block and vertically sliding clamp which works together to hold the lens in place. Both of these lens holders are useful because they allow easy removal and replacement of lenses. The disadvantage of this type of lens holder is that it suffers from the centration-error problems associated with edge-mounting lens holders. Another disadvantage is that the lower part of these lens holders has a fixed position with respect to the optical axis of the experiment. This means that when a different diameter lens is inserted into the holder, the holder height must be readjusted to maintain the optical axis.

The self-centering lens holder can easily hold lenses of different diameters, and, regardless of the size of the lens, the center of the lens is always aligned to the optical axis of the experimental setup. The holders use a special chuck with three flexible jaws which make it quite easy to load and unload lenses in applications in which one must regularly change lenses. The main disadvantages of these lens holders are those associated with edge-mounting holders. Due to the additional complexity of the mechanism, the self-centering lens holder can be more expensive than simpler lens holders.

Self-centering lens holders

MIRROR MOUNTS

The mounting and holding of mirrors are fundamentally different from the mounting and holding of lenses. Unlike a lens, which typically has curved surfaces, a mirror has a flat surface. Consequently, it is not necessary to adjust the position of the piece in the y or z directions. However, it is often necessary to tilt the object and adjust its position along the θy and θz directions. In some cases this angular adjustment could be 180 degrees or more (up to 360 degrees for beam-folding applications).

Unlike lenses, mirrors are not subject to centration error. However, when a mirror is fixed in place using only a radial screw, it very likely will be subject to asymmetrical stresses which can distort the surface of the mirror resulting in distortion of the optical wavefront. This could be the cause of significant error in optical applications requiring wavefront quality of $\lambda/10$ or higher. The solution to this problem is to hold the mirror with a symmetrical clamping mechanism, such as a retaining ring, which applies pressure uniformly from all directions and thus minimizes the possibility of surface distortion.

The key parameters characterizing the performance of a mirror mount are range, resolution, repeatability, and stability. The term *range* refers to the total angular range of motion that the mount can move along each axis. *Resolution* refers to the smallest adjustment increment. *Repeatability* refers to the ability of the optical piece of the hardware to return to its original position following a specific movement or adjustment. *Stability* is a measure of how unchanging the form and shape of the hardware are with respect to time and when the hardware is subjected to mechanical or thermal stresses.

Mirror mounts are offered in three main styles: kinematic mounts, flexure mounts, and gimbal mounts. These three fundamental mirror-mount designs result in pieces of optical component hardware that demonstrate different performance characteristics and are suitable for different applications.

In a ***kinematic mirror mount***, the mirror is mounted on a movable plate. The angle of this front plate is adjusted relative to a fixed back plate. The adjustments are made using two adjustment screws which are mounted on the opposite corners of the mount. The plate is preloaded against these screws and against a fixed ball bearing by a single coil spring. The arrangement of the hardware pieces in this type of mount is based on a common mechanical design referred to as the cone, groove, and flat arrangement. In this fashion it is possible to perform tip and tilt adjustments, but over a limited range only. Kinematic mirror mounts are also available with three adjustment screws. The third adjuster allows linear adjustment, typically focus, to be made in addition to tip and tilt.

As shown in figure 7.10, the center of rotation of a kinematic mount is outside of the plane of mirror. As the angular position of the mirror is adjusted, the optical beam not only is angularly adjusted but also undergoes a slight

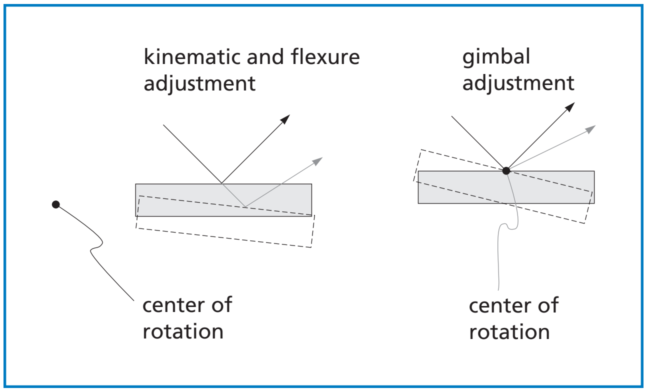


Figure 7.10 **Center-of-rotation comparison for kinematic, flexure, and gimbal adjustments**

translational displacement as well. Furthermore, because the tip and tilt adjustments are not truly orthogonal, the magnitude of this undesirable translation effect is not constant and varies as the mount is adjusted. The combined effect of beam translation and nonorthogonality creates a situation in which several adjustment iterations may have to be made when performing optical alignment in an experimental system using one or more kinematic mirror mounts. Additional disadvantages of kinematic mirror mounts include a relatively limited range of motion, typically between 5 and 10 degrees, as well as limitations in the resolution and repeatability characteristics of the mount.

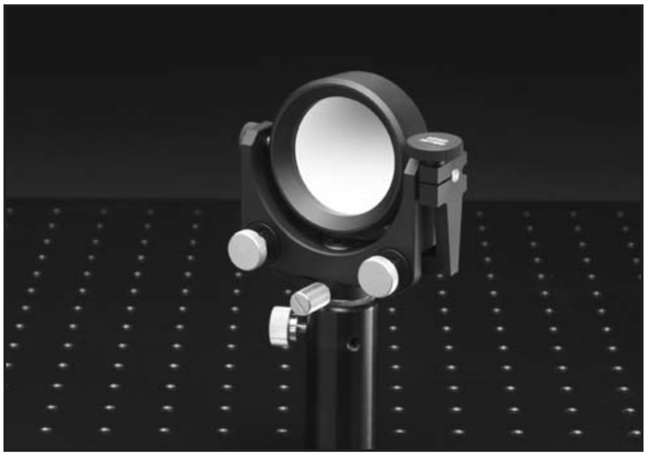
In spite of these disadvantages, because of their simple construction, kinematic mounts can be very cost effective in many applications and are used widely.

Flexure mirror mounts come in a variety of configurations. Some configurations offer performance and cost comparable to those of kinematic mirror mounts. Other configurations offer resolution and repeatability of a few arc seconds.

In a flexure mirror mount, the motion of the mirror-mounting plate is constrained through the use of leaf-style springs, which are a form of solid spring mechanism. As a result of this arrangement, both twist and shear motions, with respect to the fixed back plate, are minimized. Consequently, the repeatability and stability of the entire mechanism are greatly improved. An additional benefit is that flexure mirror mounts can handle much heavier loads than kinematic mounts, and there is therefore much less chance of deformation. However, similar to kinematic-style mirror mounts, flexure mirror mounts have their center of rotation located outside of the surface of the mirror, and, as a result, the tip and tilt adjustments are not truly orthogonal. Consequently, as the optical beam undergoes an angular change of direction, it also gets slightly shifted in a translational direction.

Gimbal mirror mounts solve the two major problems associated with kinematic and flexure mirror mounts by placing the surface of the mirror at the center of rotation, thus eliminating any translation as the mirror is rotated, and by eliminating cross-coupling between the θy and θz axes. In general, gimbal mirror mounts offer a higher degree of resolution, repeatability, and stability than either flexure or kinematic mounts.

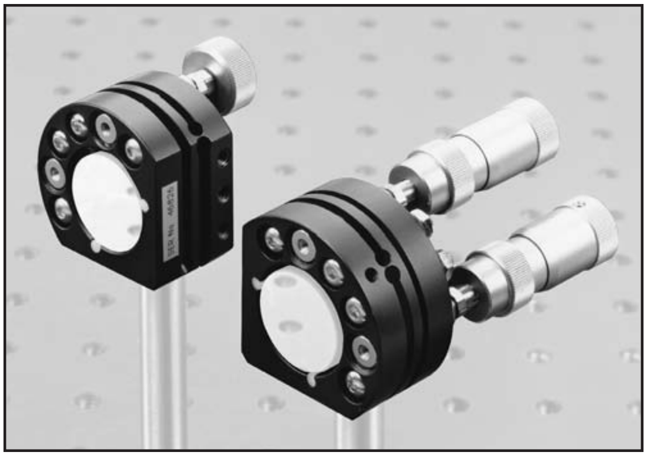
Gimbal mounts are available in a wide variety of configurations, but their increased complexity and associated manufacturing costs result in their being more expensive than either flexure or kinematic mirror mounts.



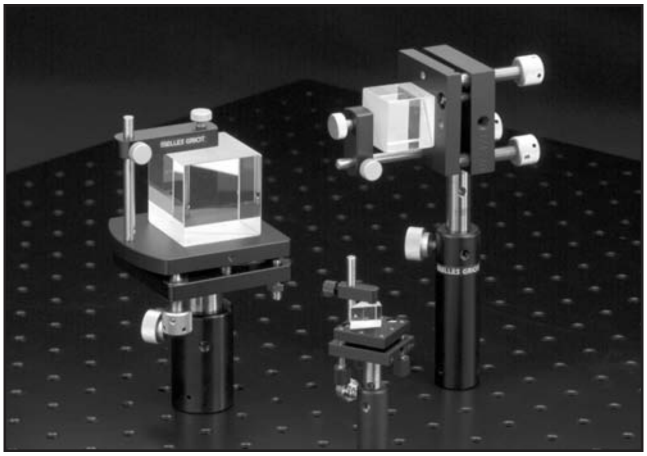
Gimbal mirror mount

PRISMS AND CUBE BEAMSPLITTER HOLDERS

A convenient and economical method of mounting and positioning prisms, cube beamsplitters, and similar components which require adjustment in angular axes (θx, θy, θz) is the prism/beamsplitter table. These devices are kinematic mounts with three adjusters which provide angular adjustment in θx and θy. Adjustment in θz is obtained by rotating the table on its mounting post. Moving all three adjusters together in the same direction and in the same amount provides a small amount of vertical translation. The optic can be held on the table by gravity or by a clamping mechanism.



Flexure mirror mounts



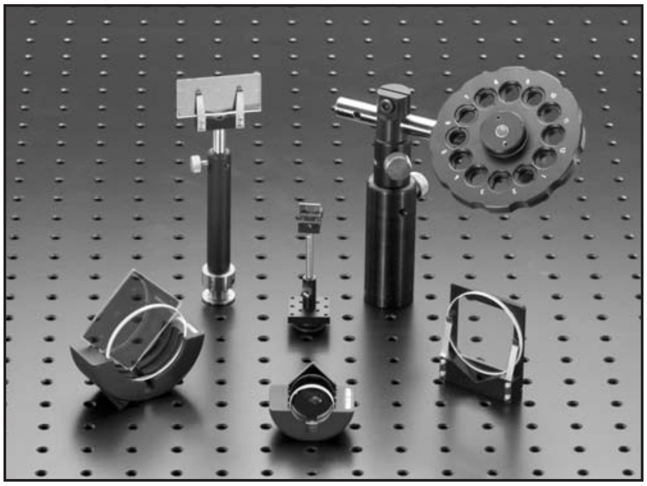
Prism/beamsplitter tables

Introduction to Opto-Mechanical Hardware

FILTER HOLDERS

Filter holders are used to mount filters on posts. Holders which retain the filter with a spring clip can hold either square or round filters. Holders which retain the filter with nylon-tipped screws protect the edges from damage are typically used only with square filters. Multiple filter holders are ideal for stacking several filters in a beam path. In these devices, the filter is held in place by gravity.

Special holders are required for circular-wedge variable neutral-density filters because the holder must allow for precise rotation or translation of the filter. The circular filter holder consists of two assemblies. One is the outer knurled ring and the other is the central hub. The outer ring allows one to rotate the filter without touching the optical element. The central hub holds the filter securely in place while allowing rotation about its axis. Typically a magnetic system allows firm yet easy adjustment with positive retention of the selected angle.

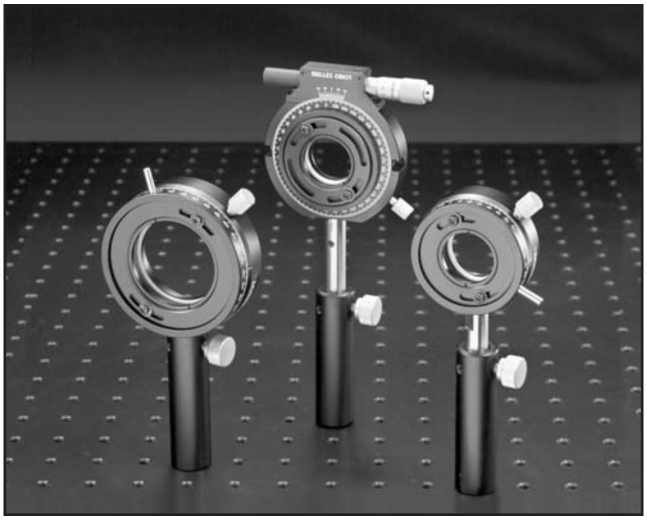


Filter mount options

ROTARY POLARIZER HOLDERS

Rotary polarizer holders are designed to mount and rotate optical elements such as dichroic sheet polarizers, infrared polarizers, calcite prism polarizers, and quartz or mica retardation plates. Alignment of the polarizer or retardation plate to the engraved scale is accomplished by first mounting the optical element in the adaptor so that its line of orientation is near the zero shown on the engraved scale.

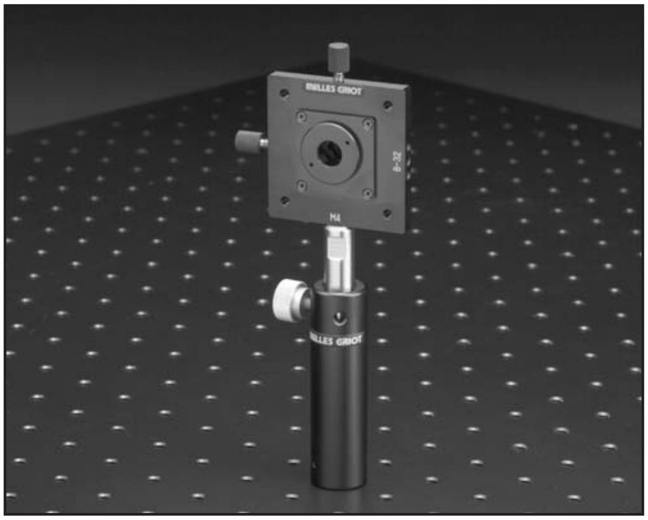
Standard rotary polarizer holders provide 360 degrees of rotation with a resolution of 1 degree. Precision rotary polarizer holders combine the 360 degrees of manual rotation with approximately 15 degrees of high-resolution micrometer-driven adjustment to provide a resolution of 5 arc minutes.



Rotary polarizer holders

PINHOLE AND SLIT HOLDERS

Pinholes and slits, typically used for spatial filtering and optical beam attenuation, are essentially tiny openings that have been very accurately drilled or cut in thin stainless steel substrates. Pinholes come in a variety of sizes ranging from about 1 to 1000 μm. Similarly, slits are available in widths ranging from 5 to 200 μm. Because of the small size and delicate nature of these elements, special holders are required to mount and position them. In a pinhole mount, the precision slit or pinhole is held securely in place by a retaining ring within a recess with a diameter that matches the size of the stainless steel pinhole substrate. Pinhole/slit positioners are used to move and position the mounted pinhole or slit about its optical axis.



Pinhole/slit positioner and holder

FIBER-OPTIC HOLDERS

The opto-mechanical devices used to hold an optical fiber are commonly referred to as fiber chucks. Fiber chucks, which come in a variety of configurations, are typically designed to hold standard diameter fibers. Collet and side-loading fiber chucks hold bare optical fibers with a standard cladding diameter of 250 μm. Universal fiber chucks are designed to hold both bare and jacketed fibers with diameters ranging from 125 μm to 3.9 mm.

V-groove fiber holders are ideal for holding bare, single-mode optical fibers with diameters as small as 125 μm. The main advantage of this type of fiber holder is the ease with which a fiber can be mounted and removed. Typically manufactured from magnetic stainless steel, they usually use magnetic clamps to hold the fiber in place. The clamp mechanism must provide a secure, yet delicate grip ensuring that the optical fiber is not crimped or deformed.

Chucks for holding optical fibers

CYLINDRICAL LASER HOLDERS

Most helium-neon lasers and many diode laser assemblies used in laboratory applications come in a cylindrical housing with an outside diameter of 45 mm or less. A variety of components are available to facilitate the mounting of these lasers to tabletops, posts, or rod systems and to align them to the optical axis. Most of the holders provide ± 4 degrees of angular adjustment with a resolution of approximately 0.4 arc minute. Models are available with or without micrometer drives for angular adjustments.

Cylindrical laser holders