Photonic Tools for the Lab

Optical Mounts: Ignore Them at Your Peril

Optomechanical mounts may seem like insignificant design elements, but they can make or break a photonic application.

by Peter Griffith
and Donn Silberman

In any optical system, no matter how simple or complex, each optical element must be mounted in some way. Furthermore, system performance depends on the precision of the optics, their mounts and their positioning accuracy. Thus, designers should pay the same attention to optomechanical mount selection as to tolerancing individual optical elements.

Typically, the most important parameters in determining the performance of mounts are adjustment range, resolution, repeatability, orthogonality of motion, stability, thermal drift and cost. Understanding these parameters and individual mount mechanisms can help a designer select the right mounts for a given application.

Factors to consider

Six major factors affect the cost and performance of optomechanical mounts for mainstream applications:

Range is the total angle or linear distance over which the mount can be adjusted. A designer who needs a very large adjustment range may combine a mount with positioners, such as translation and rotation stages, to extend the range of travel. This also can add degrees of motion that are not inherently present in the mount. Increasing the range typically increases the mount cost, so low-cost OEM mounts may permit only a small amount of "tweaking" around the nominal position.

Resolution is the minimum movement that the mount can make. For example, consider a simple case: A mirror reflects a light ray, which travels a distance, *D*, to a surface (Figure 1). Let us assume that the application requires positioning the beam with resolution, *r*, at this distance. For small angles, the relationship between beam displacement and mirror angular movement is $r \cong D\Theta$. However, because a given mirror rotation causes the reflected light to move through twice that angle, the mount's angular resolution must be $\Theta/2$, or $r/2D$. This means that achieving a given ray positional resolution requires better angular resolution at larger distances.

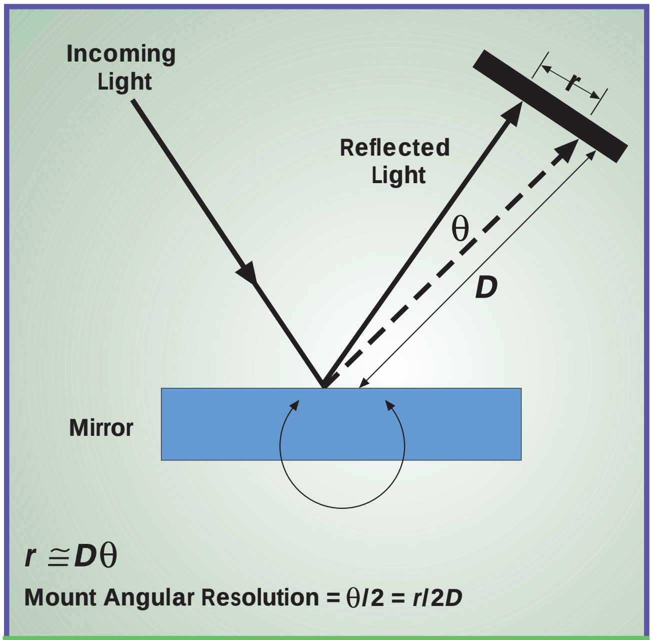


Figure 1. If a mirror is to reflect a ray of light onto a point on a surface, it must have adequate angular resolution to position the ray. An application that needs more space between the mirror and the surface also needs a mount with better angular resolution.

Repeatability measures how closely the mount returns to the same position for a given adjustment. Repeatability is required most often in laboratory setups, where a set of conditions must be accurately replicated several times during data collection. Repeatability is required less commonly in OEM applications in which mounts are adjusted and then fixed in place.

Orthogonality describes the independence of the degrees of motion. For example, it would address whether an adjustment in Θ_x causes small changes in Θ_y. In some types of mounts, angular adjustments also produce small translations.

Stability specifies how well a mount remains in a position over time. Instruments in the field, such as a medical laser system, often employ locking mechanisms that can disturb the mount position. Stability also is critical in research applications such as time-resolved spectroscopy using ultrafast laser pulses. The adjustment mechanisms and mount materials influence mount stability.

Newport Corp. recently evaluated several locking mechanisms by mounting a mirror and using a laser diode autocollimator to measure any shift. One common locking mechanism uses a set screw to clamp the threaded collet

Reprinted from the September 1998 issue of PHOTONICS SPECTRA **© Laurin Publishing Co. Inc.**

Figure 2. Three types of mounts with angular adjustments have advantages for different applications. "Cone, groove and flat" mounts (left) combine adjustment range and stability, and can be very economical. Flexure mounts (center) have more limited adjustment range but are compact, with excellent stability. Gimbal mounts have wide adjustment (up to 360°) and a high load-bearing capacity.

that holds the adjustment screw. Tightening a standard micrometer screw produces hundreds of arc-seconds of motion because the mount's springs load the screw in the forward direction.

As a result, Newport developed a device in which a collet is slotted *perpendicular* to the direction of the screw. Opening this changes the pitch of the threads in the collet, locking the screw in place. This action loads the screw in the same direction in which it is already loaded. These new locking actuators reduce lock error by an order of magnitude, according to our tests.

Thermal drift measures the shift in mount position as the temperature changes. Mount design and materials influence thermal drift. Achieving high thermal stability increases mount cost. This parameter is typically not a concern for lab applications, which occur in temperature-controlled environments. However, in portable or airborne applications, it can have a critical impact. This factor also must be taken into account when mounting intracavity optics in a thermally loaded laser.

In some applications, users may also need to consider vacuum compatibility, weight, load capacity and vibrational stability. In addition, users should consider very real-world considerations such as access to optical surfaces for cleaning and the location of adjustment screws or micrometers.

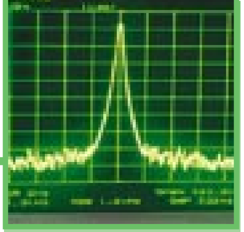
Adjusting the angles

Optomechanical mounts that provide 2° of angular (tip/tilt) adjustment come in three basic designs (Figure 2):

- The most common type of kinematic mount uses a cone, groove and flat arrangement (Figure 3). A steel ball (or spherically tipped actuator) rests in a cone at the corner of two plates that are attached by springs; this ball acts as a pivot point and constrains translational motion. A spherically tipped actuator pushes into a groove providing Θ_x (tip) adjustment, but constraining any Θ_z (azimuthal) motion. The second spherically tipped actuator pushes against a flat for Θ_y (tilt) movement. Thus, each degree of freedom is constrained in only one manner.

These mounts offer an excellent combination of adjustment range and stability, and can be very economical. They do not offer complete orthogonality of motion, however, and angular adjustment results in some beam translation and "crosstalk" between axes.

- Flexure mounts consist of pairs of plates connected by stiff leaf springs. Using three plates with flexures acting at right angles to each other allows actuators to provide tip/tilt motion that is constrained in all other dimensions. Flexure mounts typically offer more limited adjustment range than kinematic mounts. Like the kinematic mount, flexure mounts are not truly orthogonal. However, flexure mounts are compact, and offer exceptional



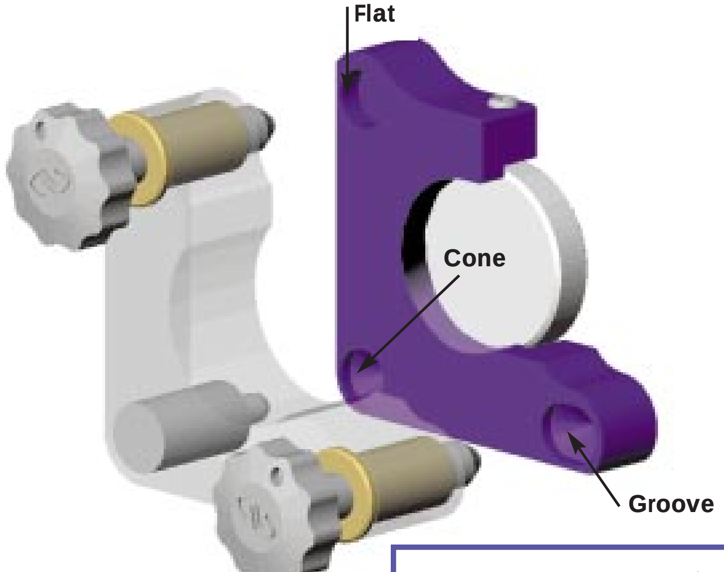


Figure 3. In a typical kinematic mount, the corner "cones" create a pivot point to constrain translational motion.

mechanical and thermal stability.

- In a typical gimbal mount, the part that contains the optic rides in two pairs of bearings, placed at right angles to one another. This allows tip/tilt adjustment. The primary advantage of the gimbal mount is that it delivers truly orthogonal motion (Figure 4). Gimbal mounts place the center of rotation at the front surface of the optic, so rotational adjustments do not cause any beam translation. Because gimbal mounts do not suspend the optical element on a spring, they have a high load-bearing capacity; this makes them the typical mount of choice for very large components. Gimbal mounts also can be designed to provide full 360° motion in both axes.

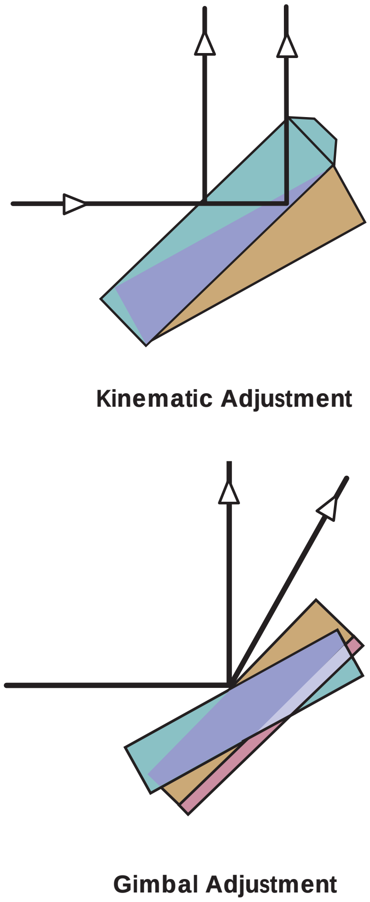


Figure 4. Kinematic mounts are not truly orthogonal; they allow some (slight) beam translation when they rotate. Gimbal mounting uncouples rotation and translation.

Flow cytometry

A wide range of optomechanical mounts are available on the market. Newport alone makes well over 100 different mounts, and many of these have numerous options in terms of manual or motorized actuators and optional attachments. Because many mounts overlap in terms of performance, it is difficult to give definitive answers about which mount is optimal for a specific application. Instead, by looking at two simplified, generalized cases, we hope to explain how to read manufacturers' printed specifications and make intelligent purchasing decisions.

Abbott Diagnostics of Santa Clara, Calif., manufactures clinical blood cell analyzers using the principles of flow cytometry. In cytometry, the suspended cells pass single file through a flow cell, where a focused laser beam (HeNe or argon-ion) illuminates them. Sometimes the system tags the cells with fluorescent probes that preferentially bind to selected cells. As the cells pass through the interrogation zone, they scatter light and/or generate fluorescence signals that the system detects for analysis.

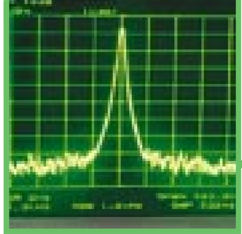
In the Abbott instruments, the beam path includes two plane folding mirrors. Tip/tilt adjustment of these mirrors controls beam position and angle at the flow cell. In this application, the illumination beam must be positioned with a resolution of a few microns at the flow cell, and with high long-term stability. Compact size and low cost were also important concerns in this OEM application.

Suresh Mehta, principal engineer at Abbott, said that because the instrument iteratively aligns the mirrors to maximize signal, "we don't need perfectly orthogonal adjustments, just a stiff, low-cost mount with a resolution of about 10 arcsec of the beam."

The designers chose an off-the-shelf flexure mount (Newport MFM-075). To minimize drift, they use a Loctite product to increase adjustment screw friction without permanently bonding.

In a second example, consider a system that will test the high-resolution, multifunction focal plane arrays that image visible and IR radiation for the latest missile guidance and tracking systems. In testing these arrays, all-reflective optics direct focused light from a blackbody source onto each micron-size detector element.

The need to focus a significant amount of light onto tiny pixels dictates the use of large (12 in.) optics



with high numerical aperture. Furthermore, because the mirror must steer the 12-in. “beam” through as much as 90°, it must have an overall clear aperture of 17 in.

Such a test system needs a mount with an angular resolution of 0.0001° (0.36 arcsec). The mirror also must move under programmable, motorized control at speeds of up to 50°/s in vacuum.

The need to address a rectangular array of pixels necessitated true orthogonality, making a gimbal mount the best choice. The tight angular resolution also required a very rigid structure, meaning a thick mount of heavy construction.

Newport developed a series of very large gimbal mounts (Figure 5) for this application and now offers them as standard products.

With a mounted optical element, the entire gimbal assembly can weigh more than 250 lb, a factor that dominated the design of the mount. For example, to ensure that frequency harmonics would not cause the mount to “ring,” the entire structure was designed using finite element analysis.

Also, the assembly uses special bearings to support the load while providing vacuum compatibility. G

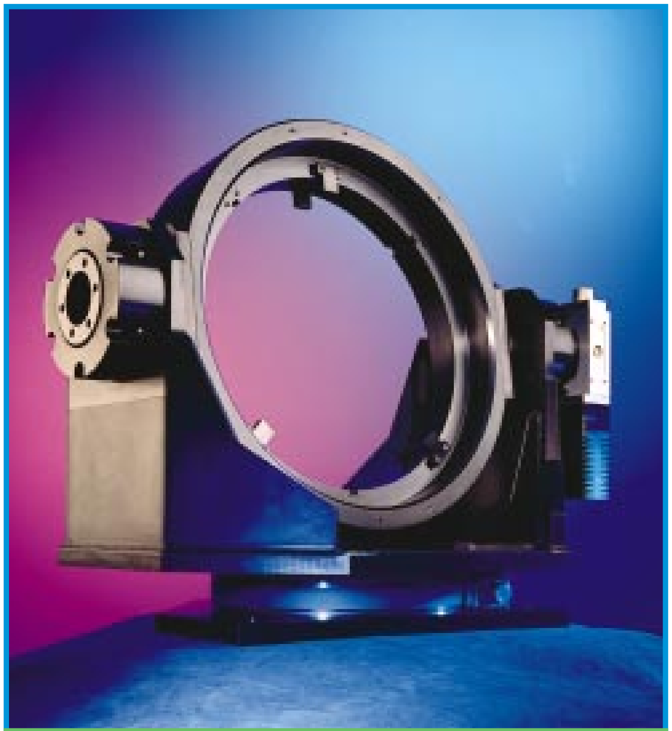


Figure 5. Testing infrared focal plane arrays requires a large, rigid gimbal mount.

Meet the authors

Peter Griffith is the optics product line manager at Newport Corp. in Irvine, Calif. He has a bachelor's degree in optics from the University of Rochester.

Donn Silberman is an opto-mechanical product marketing engineer at Newport. He graduated from the University of Arizona with honors in engineering physics and received a masters of science in technology management from Pepperdine University.