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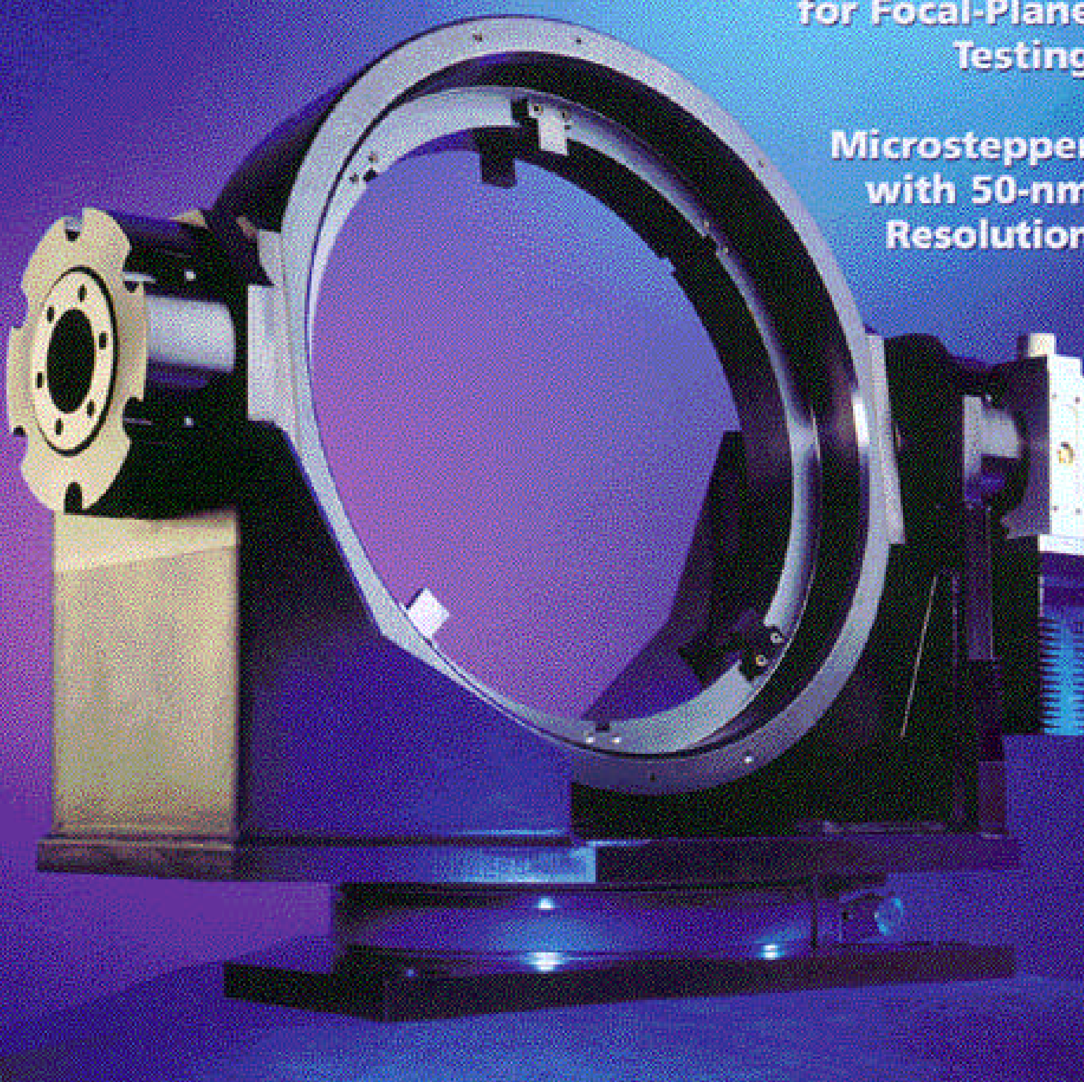
Motion Control Tech Briefs

Large Gimbal Mount for Focal-Plane Testing

Microstepper with 50-nm Resolution



Large Gimbal Mount Enables Focal-Plane Testing

A motorized gimbal mount has been developed to scan and position large, heavy optics (up to 17" in diameter) with high angular resolution (0.0001°).

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The latest missile guidance and tracking guidance systems deliver unprecedented performance, in terms of range, precision, and the ability to function in very unfavorable atmospheric conditions. These systems rely on a new generation of high-resolution, multifunction focal plane arrays to image visible and IR radiation. In testing these arrays, the focused light from a blackbody source must be sequentially directed onto each individual pixel using all-reflective optics. Accomplishing this requires panning and tilting a 17"-diameter mirror at a resolution of 0.0001° under programmable, motorized control. This brief describes a novel, 2-axis gimbal mount that was designed to successfully meet this and other demanding specifications.

How did these specifications arise? Focusing the blackbody radiation onto individual micron-sized pixels dictates the use of large (12"), high-numerical-aperture optics. However, since the mirror must steer the 12"-diameter blackbody "beam" through as much as 90°, it must have a clear aperture of 17". Illuminating individual pixels at a distance of 2 feet translates into an angular resolution of 0.0001° (0.36"). Holding these specifications in actual operation also requires the mirror to be very rigid, meaning it is thick and very heavy. In addition, this application requires moving the mirror under vacuum at speeds of up to 50°/second.

Figure 1 shows the assembled gimbal mount. The first step in development was designing the passive components—the primary bracket (or cradle mount) and the mounting ring. This involved a tradeoff to provide the nec essary rigidity at a reasonable mass. Using 5/8"-thick 6061T-6 aluminum alloy proved to be the optimum way to meet these goals.

In addition to static rigidity, trial designs were also analyzed and optimized for dynamic behavior, *i.e.* resonances. Successfully rotating the gimbal at constant velocity means avoiding low-frequency flexure modes. Fortunately, the design team had extensive experience using finite element analysis (FEA) to address the same issues in the design of vibration isolation systems. Table 1 shows the success of this optimization: the first resonance of the assembled gimbal does not occur until 63 Hz.

With a mounted optic, the entire gimbal assembly can weigh more than 250 lb. This was obviously a major factor influencing the choice of bearings and rotation stages. For example, the shaft on each side of the mounting ring was mated to the main bracket using *two* sets of angular contact bearings. To support operation in a cryochamber, these bearings include Teflon spacers and a special lubricant to provide vacuum compatibility (to 10^{-6} torr).

Vibrational Mode	Resonant Freq. (Hz)
1	63
2	150
3	162
4	212
5	283

Table 1. **Vibrational Modes and Resonant Frequencies** of the assembled gimbal mount.

Automated motion is enabled by the use of motorized rotation stages. The mounting ring (elevation) is driven by a Newport RTM160CC rotation stage. The entire gimbal is rotated azimuthally by a Newport RTM350CC stage. Both stages are equipped with brush DC motors to provide the smoothest possible motion.

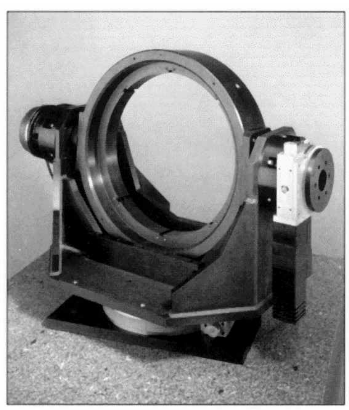

Figure 1. The 17" **Gimbal Mount,** including its rotation stages.

The required 0.0001° resolution is ten times higher than the normal, closed-loop operation of these motorized rotation stages. Therefore Heidenhain RD optical encoders were integrated to directly measure the rotation of the gimbal axes, thus providing feedback signals to the system controller.

Verifying the performance of this high-resolution gimbal mount is an important step in production, and represents something of a challenge in and of itself. To perform the test, the output of a Newport LAE 500 laser diode autocollimator is reflected off the surface of a plane mirror at the gimbal point (the point in space at which the two rotation axes intersect). This instrument can measure beam deviations as small as 0.2", which corresponds to a gimbal motion of 0.1" (0.00003°).

Since their successful development, these gimbal mounts have found several other important uses. For example, their high load-bearing capability has proven to be an asset in the testing of a missile guidance system. In this case, the missile's entire detection system is mounted on the gimbal to test its tracking accuracy over a long line of sight. The gimbal's high resolution is also proving useful for steering large laser beams. In one experiment it has been used to evaluate the practicality of disabling satellites and incoming missiles with ground-based lasers.

To summarize, a difficult set of design goals for a large, two-axis rotation mount was met by bringing together several different disciplines. These included finite element design and analysis, precision machining and assembly of the subcomponents, the availability of high-performance rotation stages to drive the motion, and the ability to measure/calibrate the performance. The successful design not only meets the high-resolution needs of the original application, but is now benefiting other uses as well.

This work was done by a team led by Beda Espinoza, Lee Green, and Warren Booth at **Newport Corp.,** *Irvine, CA. For more information, contact Booth at (949) 253-1670; fax (949) 253-1841; E-mail: wbooth@newport.com.*

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