



## Relative-Motion Sensors and Actuators for Two Optical Tables

Relative motions can be suppressed or imposed on demand.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optoelectronic sensors and magnetic actuators have been developed as parts of a system for controlling the relative position and attitude of two massive optical tables that float on separate standard air suspensions that attenuate ground vibrations. In the specific application for which these sensors and actuators were developed, one of the optical tables holds an optical system that mimics distant stars, while the other optical table holds a test article that simulates a spaceborne stellar interferometer that would be used to observe the stars.

The control system is designed to suppress relative motion of the tables or, on demand, to impose controlled relative motion between the tables. The control system includes a sensor system that detects relative motion of the tables in six independent degrees

of freedom and a drive system that can apply force to the star-simulator table in the six degrees of freedom.

The sensor system (see Figure 1) includes (1) a set of laser heterodyne gauges and (2) a set of four diode lasers on the star-simulator table, each aimed at one of four quadrant photodiodes at nominal corresponding positions on the test-article table. The heterodyne gauges are used to measure relative displacements along the x axis.

The most innovative part of the sensor system is the quadrant-photodetector subsystem, which differs from commercial quadrant-photodetector relative-position-measuring systems. The active area of each quadrant photodiode is 1 cm in diameter. The 635-nm-wavelength output of each laser diode is coupled via an optical fiber to a collimator, which focuses the laser beam to a spot centered

at the nominal center of the corresponding quadrant photodiode. The laser spots on two of the quadrant photodiodes are 5 mm in diameter; these quadrant photodiodes provide low-resolution, high-dynamic range measurements of relative displacements and tilts in the y-z plane. These measurements are used to bring the tables into coarse alignment. The laser spots on the remaining two quadrant photodiodes are 0.55 mm in diameter; these quadrant photodiodes provide high-resolution, low-dynamic range measurements of relative displacements and tilts in the y-z plane, thereby enabling finer alignment. This quadrant-photodiode subsystem offers two advantages over commercial quadrant-photodetector relative-position-measuring systems: it is much quieter (its position noise output is about a hundredth of that of a typical com-

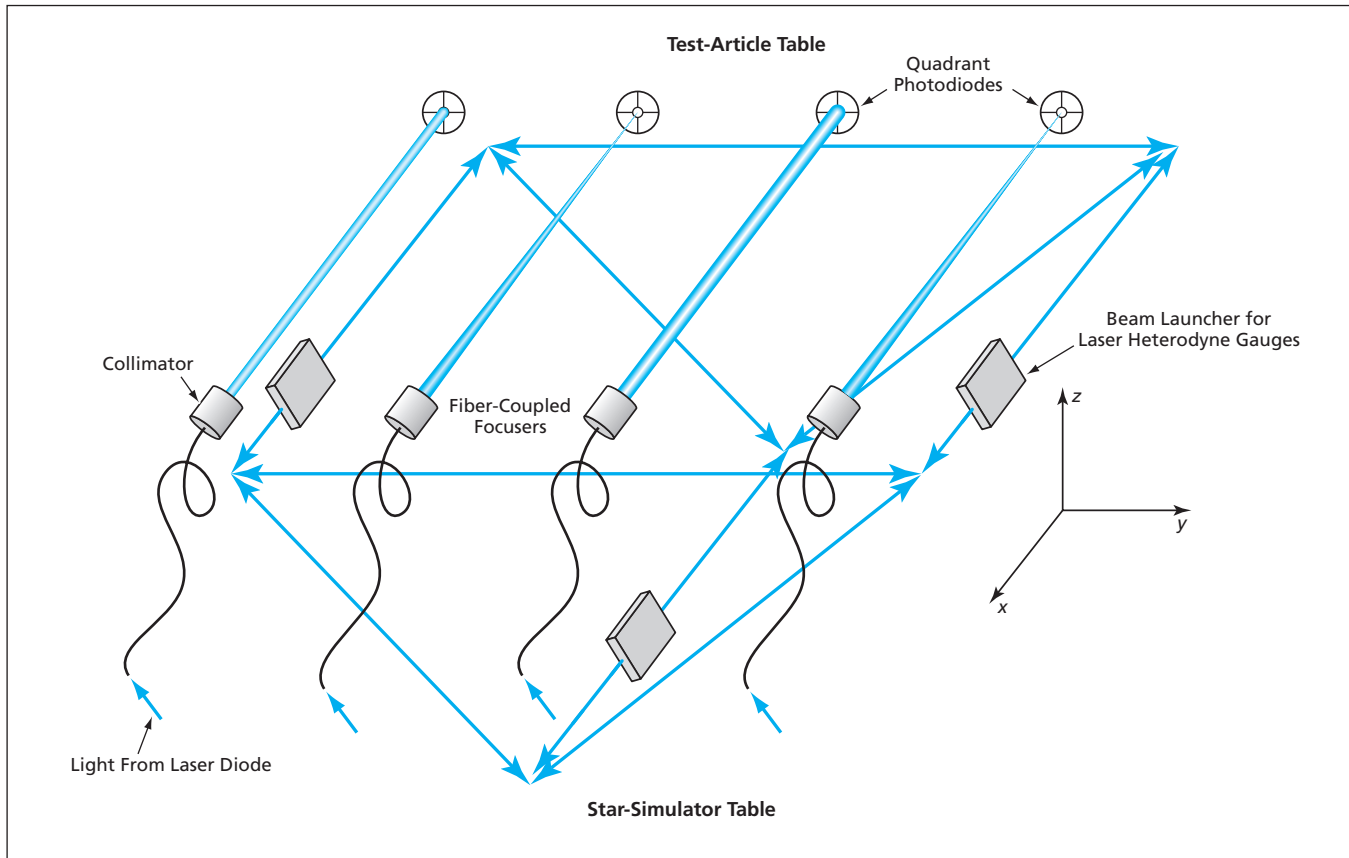


Figure 1. Two Optoelectronic Sensor Subsystems use collimated laser beams to measure relative motions of the star-simulator and test-article tables.

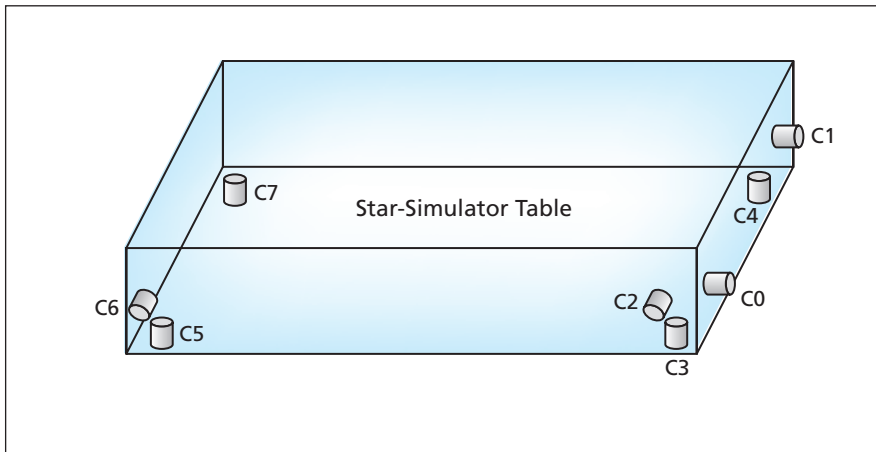


Figure 2. **Eight Linear Magnetic Actuators**, partly similar to traditional voice-coil actuators, apply forces to the star-simulator table to control its position and attitude in all six degrees of freedom. The actuators are represented by the cylinders labeled C0 through C7.

mercial system) and it can be constructed at relatively low cost.

The drive system includes eight magnetic linear actuators — two more than the minimum of six needed for the six

degrees of freedom. Each actuator partly resembles a traditional voice-coil actuator in that it includes a permanent magnet, upon which an axial force is exerted by a nominally concen-

tric electromagnet coil. The force exerted by each actuator depends on the current applied to its coil and typically lies in the range of  $\pm 10$  N (for some degrees of freedom, the typical range is  $\pm 40$  N). Unlike a traditional voice-coil actuator, which cannot withstand a lateral displacement of more than 0.1 mm without breakage, each of these magnetic actuators can withstand a displacement of  $\pm 5$  mm in any direction without breakage. The electromagnet coils are wound on aluminum forms that contain water cooling channels to remove excess heat from the coils when necessary. The motions of the permanent magnets in the aluminum forms also provide eddy-current damping of rapid motions (e.g., vibrations) of the table.

*This work was done by Yekta Gursel and Elizabeth McKenney of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30805*

## Improved Position Sensor for Feedback Control of Levitation

In this application, an incandescent light bulb is preferable to a laser.

Marshall Space Flight Center, Alabama

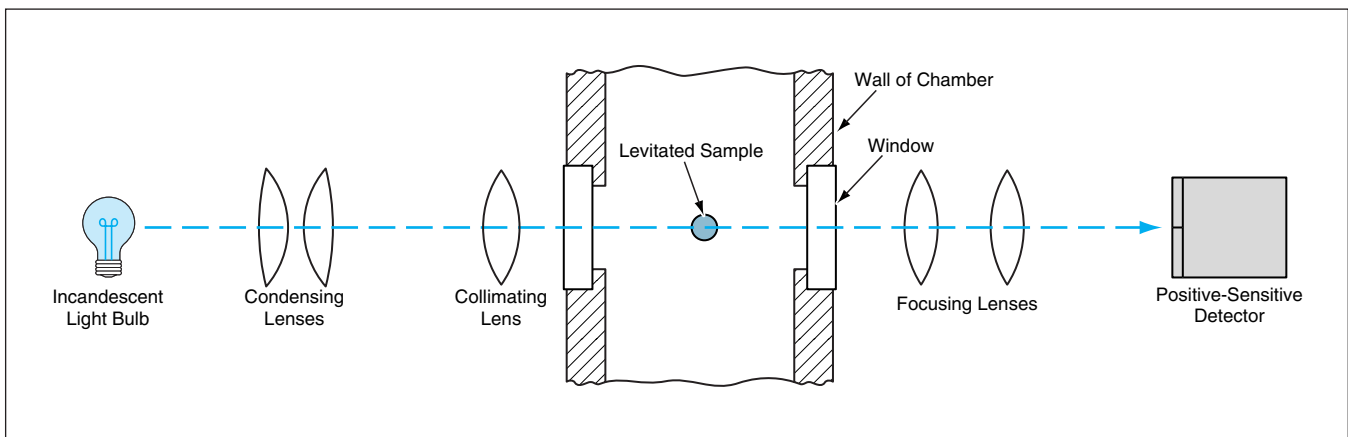
An improved optoelectronic apparatus has been developed to provide the position feedback needed for controlling the levitation subsystem of a containerless-processing system. As explained below, the advantage of this apparatus over prior optoelectronic apparatuses that have served this purpose stems from the use of an incandescent lamp, instead of a laser, to illuminate the levitated object.

In containerless processing, a small object to be processed is levitated (e.g.,

by use of a microwave, low-frequency electromagnetic, electrostatic, or acoustic field) so that it is not in contact with the wall of the processing chamber or with any other solid object during processing. In the case of electrostatic or low-frequency electromagnetic levitation, real-time measurement of the displacement of the levitated object from its nominal levitation position along the vertical axis (and, in some cases, along one or two horizontal axes)

is needed for feedback control of the levitating field.

In a typical prior position-measuring optoelectronic apparatus for levitation control, a laser beam is aimed through the nominal levitation position to a position-sensitive photodetector, so that the levitated object casts a shadow on the detector face. The output of the position-sensitive detector circuitry is a voltage proportional to the displacement of the shadow from a nominal



An **Incandescent Light Bulb** and some lenses are used to illuminate a levitated object in a processing chamber so that the object casts a shadow on a position-sensitive detector.