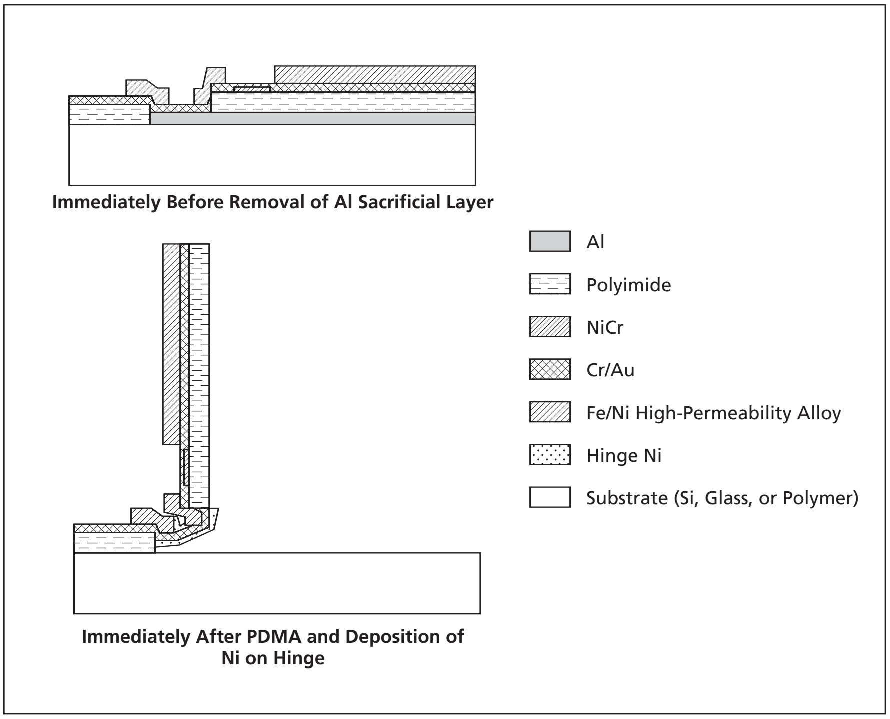


Figure 2. **The Cantilever Remains Horizontal** during most of the fabrication process. It is released by etching away the aluminum sacrificial layer, then raised to its perpendicular orientation by PDMA.

cured in a 1-torr (≈133-Pa) atmosphere of N_2 for 2 hours at a temperature of 350 °C (this is the highest temperature used in the fabrication process).

3. A 750-Å-thick layer of NiCr, intended to serve as the electrically resistive transducer in the strain gauge, is deposited by electron-beam evaporation.
4. A layer of Au/Cr 0.5 µm thick, from which the strain-gauge electrical leads and a bending hinge are to be formed, is deposited by evaporation.
5. A portion of the Au/Cr layer also serves as a seed layer for electrodeposition of a 5-µm-thick layer of a highly magnetically permeable Fe/Ni alloy. Once this alloy has been deposited, the remaining unused Au/Cr is removed by lift-off.
6. A 1.8-µm-thick polyimide film (omitted from the figure) is deposited to form a protective coat on the Fe/Ni alloy layer and the NiCr strain gauge.
7. The workpiece is placed in a basic solution for more than a day to etch away the sacrificial layer of Al.
8. The workpiece is rinsed, then placed in an electroplating bath. A magnetic field is applied to pull up on the Fe/Ni layer, thereby bending the cantilever upward at the hinge. While the magnetic field remains thus applied, Ni is electrodeposited onto the Au/Cr hinge to a thickness of ≈10 µm, thereby reinforcing the hinge and fixing the cantilever perpendicular to the substrate.

This work was done by Chang Liu and Jack Chen of the University of Illinois at Urbana-Champaign for **Goddard Space Flight Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

University of Illinois at Urbana-Champaign
Office of Technology Management
319 Ceramics Building, MC-243
105 South Goodwin Avenue
Urbana, IL 61801

Refer to GSC-14812-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Video Guidance Sensor and Time-of-Flight Rangefinder

A prior VGS would be modified to incorporate the rangefinder function.

Marshall Space Flight Center, Alabama

A proposed video guidance sensor (VGS) would be based mostly on the hardware and software of a prior Advanced VGS (AVGS), with some additions to enable it to function as a time-of-flight rangefinder (in contradistinction to a triangulation or image-processing rangefinder). It would typically be used at distances of the order of 2 or 3 kilometers, where a typical target would appear in a video image as a single blob, making it possible to extract the direction to the target (but not the orientation of the target or the distance to the target) from a video image of light reflected from the target.

As described in several previous *NASA Tech Briefs* articles, an AVGS system is an optoelectronic system that provides guidance for automated docking of two vehicles. In the original application, the two vehicles are spacecraft, but the basic principles of design and operation of the system are applicable to aircraft, robots, objects maneuvered by cranes, or other objects that may be required to be aligned and brought together automatically or under remote control. In a prior AVGS system of the type upon which the now-proposed VGS is largely based, the tracked vehicle is equipped with one or more passive targets that reflect light from one or more continuous-wave laser diode(s) on the tracking vehicle, a video camera on the tracking vehicle acquires images of the targets in the reflected laser light, the video images are digitized, and the image data are processed to obtain the direction to the target.

The design concept of the proposed VGS does not call for any memory or processor hardware beyond that already present in the prior AVGS, but does call for some additional hardware and some additional software. It also calls for assignment of some additional tasks to two subsystems that are parts of the prior VGS: a field-programmable gate array (FPGA) that generates timing and control signals, and a digital signal processor (DSP) that processes the digitized video images.

The additional timing and control signals generated by the FPGA would cause the VGS to alternate between an imaging (direction-finding) mode and a time-of-flight (range-finding mode) and would govern operation in the range-finding mode. In the direction-finding mode, the VGS would function as described above. In the range-finding mode, the laser diode(s) would be toggled between two programmed power levels, while the intensities of the outgoing and return laser beams would be sensed by two matched photodetectors. The outputs of the photodetectors would be sent to dedicated high-speed analog-to-digital converters, the outputs of which would be stored (buffered) for processing.

The DSP would execute algorithms that would determine the time between corresponding transitions of the outgoing and return signals and, hence, equivalently, the time of flight of the laser signal and the distance to the target. The algorithms would be modern ones that would enable determination of the time of flight to within a small fraction of the transition time between the two laser power levels, even if the outgoing and return laser waveforms were slow, nonlinear, or noisy. The DSP would also execute an algorithm that would determine the return signal level and would accordingly adjust the laser output and the gain of a programmable-gain amplifier.

This work was done by Thomas Bryan, Richard Howard, Joseph L. Bell, Fred D. Roe, and Michael L. Book of **Marshall Space Flight Center**. *Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 7,006,203). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31785-1.

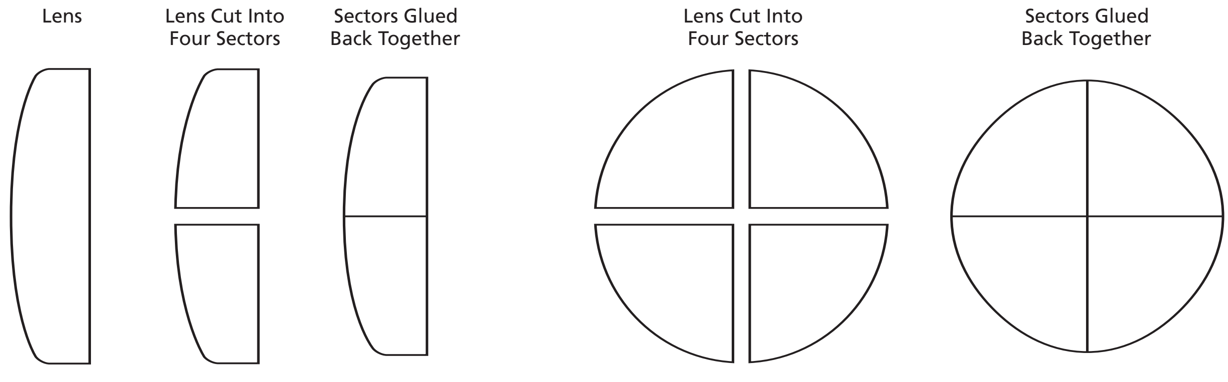
Optical Beam-Shear Sensors

Simple sensors measure radiant fluxes in beam quadrants.

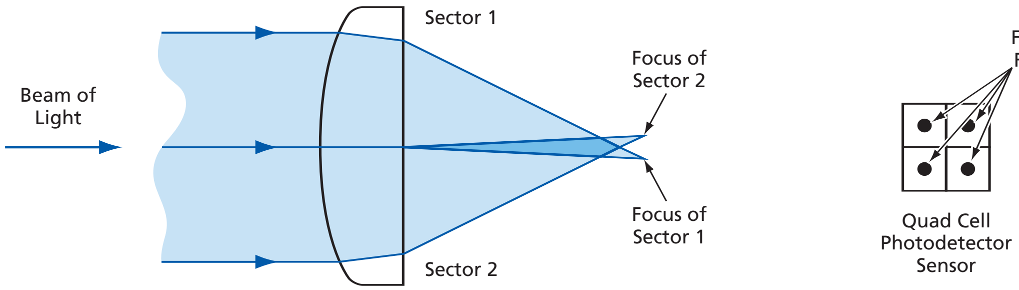
NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for measuring optical beam shear is based on collecting light from the four quadrants of the beam and comparing the optical power collected from each quadrant with that from the other three quadrants. As used here, "shear" signifies lateral displacement of a beam of light from a nominal optical axis.

A sensor for implementing this technique consists of a modified focusing lens and a quad-cell photodetector, both centered on the nominal optical axis. The modification of the lens consists in cutting the lens into four sectors (corresponding to the four quadrants) by sawing along two orthogonal diameters, then reassembling the lens follow-



MODIFICATION OF LENS



OPTICAL BEAM-SHEAR SENSOR

An **Optical Beam-Shear Sensor** can be made from a lens and a quad-cell photodetector.