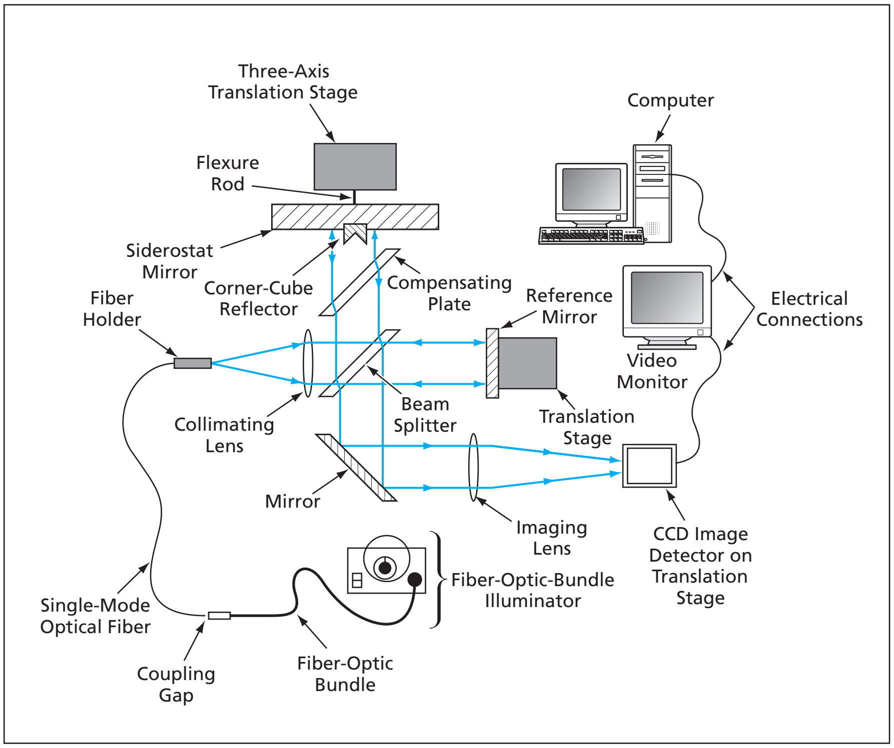
Gauges for Highly Precise Metrology of a Compound Mirror

High precision is achieved through careful attention to details of complex designs.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three optical gauges have been developed for guiding the assembly and measuring precisely the reflecting surfaces of a compound mirror that comprises a corner-cube retroreflector glued in a hole on a flat mirror. In the specific application for which the gauges were developed, the compound mirror is part of a siderostat in a stellar interferometer. The flat-mirror portion of the compound mirror is the siderostat mirror; the retroreflector portion of the compound mirror is to be used, during operation of the interferometer, to monitor the location of the siderostat mirror surface relative to other optical surfaces of the interferometer. Nominally, the optical corner of the retroreflector should lie precisely on the siderostat mirror surface, but this precision cannot be achieved in fabrication: in practice, there remains some distance between the optical corner and the siderostat mirror surface. For proper operation of the interferometer, it is required to make this distance as small as possible and to know this distance within 1 nm. The three gauges make it possible to satisfy these requirements.



The **White-Light Assembly Interferometer** is one of three gauges designed specifically for use in aligning and measuring the alignment of the corner-cube retroreflector relative to the siderostat mirror to which it is bonded.

The first gauge is denoted the white-light assembly interferometer and is illustrated schematically in the figure. This is a Michelson type-interferometer with improvements over the basic Michelson design to make the attachment of the corner-cube retroreflector to the siderostat mirror as easy and accurate as possible. The initial alignment of the interferometer is performed soon after slow-curing glue has been applied to hold the corner-cube retroreflector in the siderostat mirror. For initial alignment of the interferometer, light is supplied by a laser diode; for subsequent observations, cool white light is supplied by a fiber-bundle illuminator. In either case, the supplied light is fed to the input end of a single-mode optical fiber, which, in turn, transmits a portion of the light to the input collimator of the interferometer. A reference mirror lies in one of the arms of the interferometer, while the siderostat and corner cube lie in the other arm. A digital micrometer on the reference-mirror translation stage is used only for calibration.

The output of the interferometer is reflected through a lens that images the siderostat-mirror/corner-cube assembly onto a monochrome charge-coupled device (CCD) image detector. The CCD output is digitized by a frame grabber and the digitized image data are processed in a personal computer running special-purpose software. After initial alignment of the interferometer, the interferometer is operated in a special high-tilt mode while the special-purpose software executes a very fast algorithm that analyzes the white-light interference fringes to locate the corner-cube and siderostat mirror surfaces relative to each other. If the measurement indicates excessive error, the corner cube can be removed or else its position adjusted before the glue sets hard. Experiments have shown that the use of the white-light assembly interferometer makes it possible to achieve a final optical corner/siderostat-mirror-surface distance of only about 50 nm, whereas heretofore, the final distance has typically been of the order of microns.

The second gauge, denoted the three-fiber gauge, is used to measure the deviations from flatness of (1) nominally flat optical components that are used in the assembly of highly precise retroreflectors and (2) other nominally flat optical components used to measure the optical-corner/siderostat-mirror-surface distance to within 1 nm or less. The three-fiber gauge is based partly on the idea that the wave front emitted by a highly polished, single mode, polarization-maintaining optical fiber is nearly perfectly spherical, and when such wave fronts emitted by two perfectly matching fibers are interferometrically combined by a beam splitter at exactly equal distances from the tips of the fibers, the resulting fringe pattern can be used to deduce the deviation of the beam splitter from flatness.

In practice, the wave fronts from different fibers do not match perfectly, and this gives rise to complications that are addressed in the design and operation of the three-fiber gauge. The design and operation are extremely complex. The following are a few major features:

- The three-fiber gauge is so named because it utilizes laser wave fronts emitted by three optical fibers. (There is also a fourth fiber, which is used for monitoring power.)

- Two of the fiber optical paths include delay lines containing electro-optical modulators.
- In operation, the modulators are used to create phase shifts that alter the interference fringes in ways that aid the extraction of the desired information.
- Images of the phase-shifted interference fringes are captured, digitized, and then analyzed by use of a very robust fringe-tracking and phase-unwrapping algorithm developed specifically for this gauge.
- The final product of the analysis is a map, accurate to 1 nm or less, of the deviation from flatness of the component under test.

The third gauge is denoted the split-fiber-beam, single-fiber interferometer. This gauge utilizes a reference optical flat that has been calibrated by use of the three-fiber gauge for measuring the optical-corner/siderostat-mirror-surface distance. A single laser beam is delivered by an optical fiber, and is split in half and collimated by two off-axis paraboloidal reflectors. The collimated first half beam is aimed at the siderostat/retroreflector assembly. The light reflected from the assembly is sent back toward the fiber by the same paraboloid that collimated it. This light is then reflected from the tip of the optical fiber and interferes with the second half beam coming out of the fiber. The resulting two divergent beams are intercepted and collimated by the second paraboloidal reflector, then focused by a third paraboloidal reflector onto an image detector for analysis of interference fringes. For the purpose of shifting phases in order to shift interference fringes to aid the extraction of the required information, the siderostat/retroreflector assembly is mounted on a closed-loop, three-axis piezoelectric transducer that moves the assembly in controlled steps that can be resolved to 1 nm.

This work was done by Yekta Gursel of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30804

Improved Electrolytic Hydrogen Peroxide Generator

Energy efficiency exceeds that of a prior electrolytic H_2O_2 generator.

Lyndon B. Johnson Space Center, Houston, Texas

An improved apparatus for the electrolytic generation of hydrogen peroxide dissolved in water has been developed. The apparatus is a prototype of H_2O_2 generators for the safe and effective sterilization of water, sterilization of equipment in contact with water, and other applications in which there is need for hydrogen peroxide at low concentration as an oxidant. Potential applications for electrolytic H_2O_2 generators include purification of water for drinking and for use in industrial processes, sanitation for hospitals and biotechnological industries, inhibition and removal of biofouling in heat exchangers, cooling towers, filtration units, and the treatment of wastewater by use of advanced oxidation processes that are promoted by H_2O_2.

The apparatus is an electrochemical cell in which the electrodes are located on opposite sides of a commercially available polymeric membrane, which separates the electrolytes of the two electrolytic half-reactions. One of the half-cells produces the biocidal aqueous H_2O_2 product; the product of the other half-cell restores the biocidal solution to potability. The apparatus is designed to process water that is neutral (in the sense of neither acidic nor alkaline) or nearly neutral, to consume minimal energy, and to operate without need to supply nonregenerable material(s) other than the small proportion of water that is electrolyzed.

The energy efficiency of the cell is increased through improved microscopic mixing of the electrolytes near the electrodes without need for large bulk electrolyte flow rates: this is accomplished by rotating the electrodes relative to the rest of the cell (in contradistinction to forcing electrolyte flow over stationary electrodes). Even though the design of this prototype cell is unoptimized, the total energy consumption per unit of product was found to be 60 percent less than that of a common planar H_2O_2-generating cell in operation at similar Faradaic and production rates.

This work was done by Patrick I. James of Eltron Research, Inc., for **Johnson Space Center**. *For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.*
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High-Power Fiber Lasers Using Photonic Band Gap Materials

PBG materials would be exploited to increase power levels and efficiencies.

NASA's Jet Propulsion Laboratory, Pasadena, California

High-power fiber lasers (HPFLs) would be made from photonic band gap (PBG) materials, according to the proposal. Such lasers would be scalable in the sense that a large number of fiber lasers could be arranged in an array or bundle and then operated in phase-locked condition to generate a superposition and highly directed high-power laser beam. It has been estimated that an average power level as high as 1,000 W per fiber could be achieved in such an array.

Examples of potential applications for the proposed single-fiber lasers include welding and laser surgery. Additionally, the bundled fibers have applications in beaming power through free space for autonomous vehicles, laser weapons, free-space communications, and inducing photochemical reactions in large-scale industrial processes.