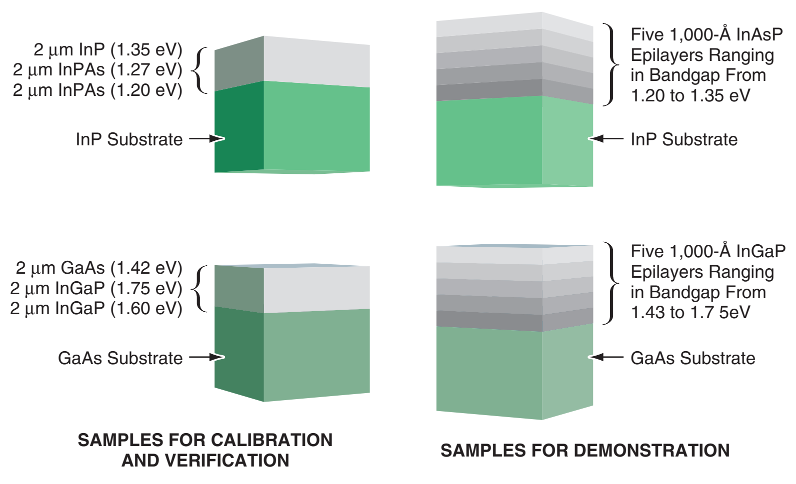


Figure 2. **Heterostructures** containing single and multiple III-V epilayers are to be evaluated by use of STORM.

fects of deterioration of the tip and interactions with the illumination.

Initially, in a proposed demonstration, a prototype STORM apparatus would be used to measure the local bandgaps on well-characterized metal/organic chemical-vapor-deposited epilayers composed of elements from periods III and V of the periodic table ("III-V epilayers"). $InAs_{1-x}P_x$ and $In_{1-x}Ga_xP$ can be grown with extremely precise stoichiometry so as to provide a range of bandgaps that are accessible to the wavelength range of a tunable solid-state laser included in the proposal.

In principle, the optical bandgap of $InAs_{1-x}P_x$ should vary from 0.36 to 1.35 eV and the optical bandgap of $In_{1-x}Ga_xP$ should vary from 1.35 eV to 2.27 eV as x is raised from 0 to 1. In practice, lattice mismatches make it impossible to achieve these ranges. However, it is possible to provide a set of samples having bandgaps ranging from 1.2 to 1.75 eV. It is planned to grow initial single control epilayers of these materials (see left side of Figure 2) and characterize them by use of standard techniques. Single-crystal x-ray diffraction (and scanning electron microscopy with energy-dispersive spectroscopy) will be used to determine the stoichiometric coefficients of these samples. The relationship between the stoichiometry, lattice parameters, and optical bandgaps in these materials has already been established to a high degree of certainty. In addition, Hall-effect and four-point probe measurements will be performed to determine the electrical properties of the materials. These materials will constitute, in effect, a calibration set for initial qualification of the proposed STORM apparatus. The optical bandgaps measured by use of STORM on cleaved cross sections of the individual epilayers will be compared to their known values.

Subsequently, the individual epilayers of the calibration set would be incorporated into multilayer heterostructures (see right side of Figure 2). The entire cross-sectional surfaces of these multilayer stacks would be scanned by STORM and the "turn-on" wavelength of each layer would be determined by the spectroscopic illumination technique of STORM. It is planned to grow several analogous structures with decreasing layer thicknesses for use in studying how the turn-on characteristics and optical bandgaps of the individual layers vary with decreasing thickness and comparing them with quantum-mechanical theoretical estimates based on the bulk properties of the materials.

It is also planned to use STORM to measure the size dependencies of the optical bandgaps of isolated nanocrystals. Two specific types of systems that will be studied are semiconducting quantum dots and high-purity single-wall carbon nanotubes. These systems are the foci of several current projects at Glenn Research Center.

This work was done by Sheila Bailey and Dave Wilt of **Glenn Research Center**, *Ryne Raffaelle and Tom Gennett of Rochester Institute of Technology, Padetha Tin of the National Center for Microgravity Research NASA GRC, and Janice Lau, Stephanie Castro, Philip Jenkins, and Dave Scheiman of Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland Ohio 44135. Refer to LEW-17344.

The Micro-Arcsecond Metrology Testbed

Optical-path measurements must be precise to within tens of picometers.

NASA's Jet Propulsion Laboratory, Pasadena, California

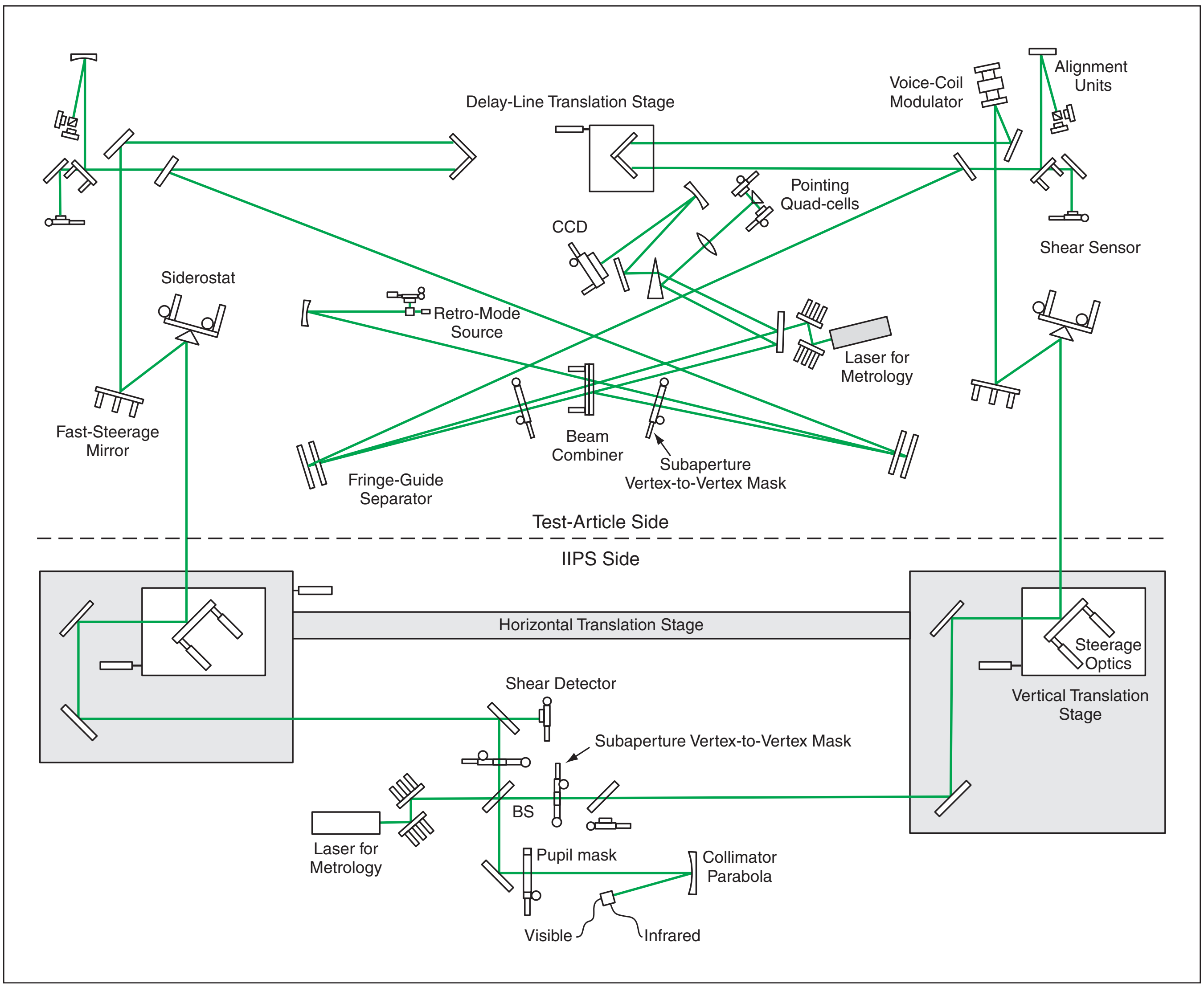
The Micro-Arcsecond Metrology (MAM) testbed is a ground-based system of optical and electronic equipment for testing components, systems, and engineering concepts for the Space Interferometer Mission (SIM) and similar future missions, in which optical interferometers will be operated in outer space. In addition, the MAM testbed is of interest in its own right as a highly precise metrological system.

The designs of the SIM interferometer and the MAM testbed reflect a requirement to measure both the position of the starlight central fringe and the change in the internal optical path of the interferometer with sufficient spatial resolution to generate astrometric data with angular resolution at the microarcsecond level. The internal path is to be measured by use of a small metrological laser beam of 1,319-nm wavelength, whereas the position of the starlight fringe is to be estimated by use of a charge-coupled-device (CCD) image detector sampling a large concentric annular beam. For the SIM to succeed, the optical path length determined from the interferometer fringes must be tracked by the metrological subsystem to within tens of picometers, through all operational motions of an interferometer delay line and siderostats. The purpose of the experiments performed on the MAM testbed is to demonstrate this agreement in a large-scale simulation that includes a substantial portion of the system in the planned configuration for operation in outer space. A major challenge in this endeavor is to align the metrological beam with the starlight beam in order to maintain consistency between the metrological and starlight subsystems at the system level.

The MAM testbed includes an optical interferometer with a white light source, all major optical components of a stellar interferometer, and heterodyne metrological sensors. The aforementioned subsystems are installed in a large vacuum chamber in order to suppress atmospheric and thermal disturbances. The MAM is divided into two distinct subsystems: the test article (TA), which is the interferometer proper, and the inverse interferometer pseudo-star (IIPS), which synthesizes the light coming from a distant target star by providing spatially coherent wavefronts out of two mirrors, separated by the MAM baseline, that feed directly into two siderostats that are parts of the TA. The two feed mirrors of the IIPS are articulated (in translation and tilt) in order to simulate stars located at different orientations in space, while still illuminating the TA siderostats. The spectrum of the simulated starlight of the IIPS corresponds to that of a blackbody at a temperature of about 3,100 K.

The figure schematically depicts the optical layout of the MAM testbed. A beam splitter is used as central main beam combiner that brings together light from the two arms of the interferometer to produce interference. A CCD camera records the white-light interference fringes. A delay line is used to adjust the steady component of the optical-path difference (OPD) between the two interferometer arms, while a voice-coil modulator superimposes an oscillating OPD component to scan the OPD for fringe fitting. In addition to the white light source, the IIPS contains a number of auxiliary light sources at different wavelengths that are used as beacons for aligning the optics. One of the auxiliary light sources makes it possible to perform an alternative metrological test in which a full-aperture beam (instead of a pencil beam) is used.

In the MAM testbed as in the SIM interferometer, the starlight beams (in this case, the simulated starlight beams) propagate in annuli that fill most of the apertures of the siderostats. The metrological laser beams propagate concentrically with



The **MAM Testbed** is designed to demonstrate concepts for a highly precise optical interferometer and especially to test for agreement between measurements of metrological and white-light interferometer path lengths. At the time of reporting the information for this article, agreement to within 150 pm had been demonstrated.

these annuli within subapertures that are obscured to the starlight beams. The metrological beams are directed to small reference corner-cube reflectors at the centers of the siderostats. The differences between the optical footprints of the metrological and starlight beams put a premium on precise optical alignment.

MAM has recorded and processed data that show agreement between the metrological and starlight paths to better than 150 picometers, using the SIM narrow-angle (1 degree) astrometry observation scenario. This result is consistent with the basic requirement for astrometry on SIM at the 3-microarcsecond level for planet detection around nearby stars.

This work was done by Renaud Goullioud, Braden Hines, Charles Bell, Tsae-Pyng Shen, Eric Bloemhof, Feng Zhao, Martin Regehr, Howard Holmes, Robert Irigoyen, and Gregory Neat of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP* *(see page 1)**.*
NPO-30897