A closed-loop software algorithm is used to control the forces applied by the nano-probes. These support forces are determined by finite element analysis (FEA) to have an acceptable and known effect on the mirror distortion. If necessary, distortions created by the nano-probes can later be analytically removed based on the correlated FEA.

The mirror is hung from strings in the suspension metrology mount (SMM) fixture. Nano-probes mounted to the fixture in optimized locations extend to stabilize the mirror. The software closed-loop force control algorithm is run to adjust the forces to pre-determined levels. Once stabilized and in a known force configuration, the mirror is measured with an interferometer.

The novel feature of this invention is the ability to measure and control the forces supporting an object whose shape must be precisely known. The advantage of this invention over prior art in the field is that a flexible object may be over-constrained without causing unknown distortions. Also, imperfections in kinematic type mounts can be measured and controlled. Using this invention, mirrors have been measured and their figures have been correlated with the figures predicted by FEA.

Automated Lab-on-a-Chip Electrophoresis System

Robotic analysis in defense or security operations that require sample handling or dilution can utilize this technology.

NASA's Jet Propulsion Laboratory, Pasadena, California

Capillary electrophoresis is an analytical technique that can be used to detect and quantify extremely small amounts of various biological molecules. In the search for biochemical traces of life on other planets, part of this search involves an examination of amino acids, which are the building blocks of life on Earth. The most sensitive method for detecting amino acids is the use of laser induced fluorescence. However, since amino acids do not, in general, fluoresce, they first must be reacted with a fluorescent dye label prior to analysis. After this process is completed, the liquid sample then must be transported into the electrophoresis system. If the system is to be reused multiple times, samples must be added and removed each time. In typical laboratories, this process is performed manually by skilled human operators using standard laboratory equipment. This level of human intervention is not possible if this technology is to be implemented on extraterrestrial targets.

A multi-layer glass wafer device was designed that is capable of performing all necessary steps of the analysis. The device consists of bonded layers of Borofloat glass wafers and a flexible polydimethylsiloxane (PDMS) membrane (254-µm thick). This flexible polymeric material was used to open and close liquid junctions in order to perform valving operations. At the base of the stack, a microfluidic channel (20×50 µm cross-section) was used for electrophoretic separations and a 405-nm laser was employed for fluorescence detection at the end of the channel.
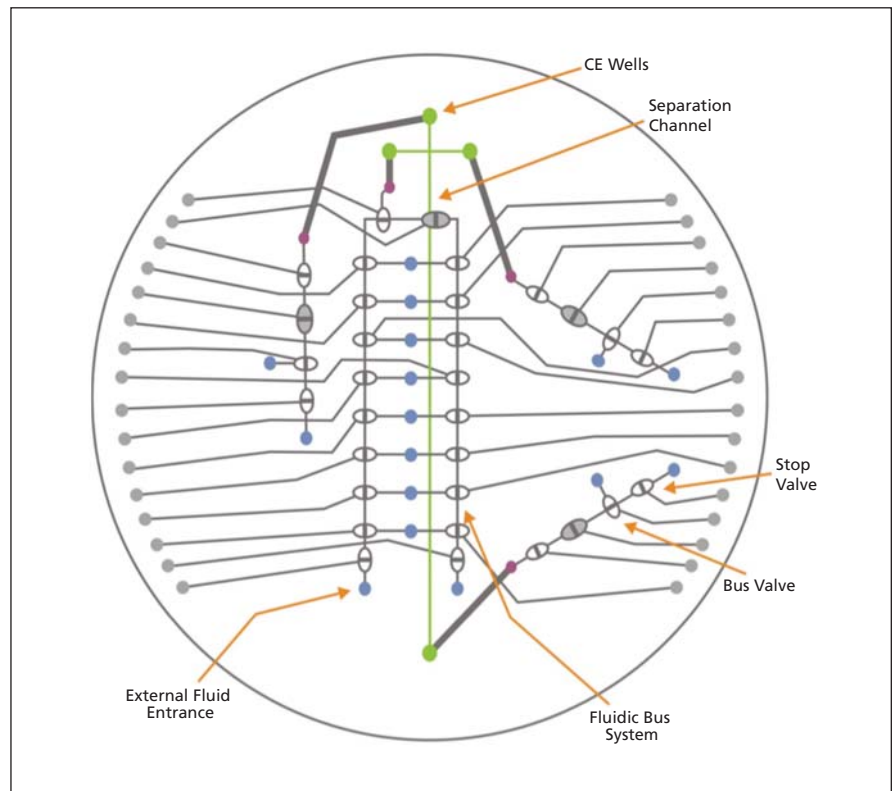
Shown here is the **Layout of a Chemistry "Circuit"** designed for the purpose of performing automated analyses of amino acids. Experiments have been performed in which a sample of amino acids is placed on the surface of a chip. All subsequent sample handling processes are performed by the microfluidic circuit shown here.

Microchip capillary electrophoresis (CE) combined with laser induced fluorescence detection (LIF) was selected as an extremely sensitive method to detect amino acids and other compounds that can be tagged with a fluorescent dye. It is highly desirable to package this technology into an integrated, autonomous, *in situ* instrument capable of performing CE-LIF on the surface of an extraterrestrial body. However, to be fully autonomous, the CE device must be able to perform a large number of sample preparation and analysis operations without the direct intervention of a human. While some of this functionality

— in particular, the routing of samples and other liquids on chip — has been demonstrated previously, the vast majority of the steps required for CE must still be done by laboratory researchers who manually perform the necessary activities off chip. This work represents the demonstration of a fully automated end-to-end CE-LIF analysis.

All of the critical functions of a future *in situ* instrument including mixing, dilution, derivatization, and separation of samples have been successfully performed on a chip. This technology and the experimental protocols developed to use it will be the heart of any future lab-on-a-chip based instruments for *in situ* life detection on the surface of a ex-

traterrestrial body, but can be readily adapted to a number of biological and defense applications.

Techniques for Down-Sampling a Measured Surface Height Map for Model Validation

NASA's Jet Propulsion Laboratory, Pasadena, California

This software allows one to down-sample a measured surface map for model validation, not only without introducing any re-sampling errors, but also eliminating the existing measurement noise and measurement errors.

At present, the surface map of an optic is measured using an interferometric instrument such as a Zygo interferometer. In such a case, the measured surface map has a high resolution and needs to be down-sampled before using it in model validation software. The software tool of the current two new techniques can be used in all optical model validation processes involving large space optical surfaces.

Down-sampling of a surface map is accomplished by using the analytical ex-

pressions of Zernike-polynomials of the given surface map for a low-spatial frequency component and the spectrum or the power spectral density (PSD) data of the given surface map for mid-spatial frequency component. The challenge is to decrease the matrix size of a measured optical surface height map to match it with a model validation software tool.

During the down-sampling of a surface map, this software tool preserves the low-spatial frequency characteristic of a given surface map through the use of Zernike polynomial fit coefficients, and maintains mid-spatial frequency characteristics of the given surface map by the use of the spectrum or the PSD data of the given surface map calculated

from the mid- and the high-spatial frequency components of the original surface map.

These new methods do not introduce any aliasing and interpolation errors as is done by the conventional interpolation and FFT-based spatial-filtering method. Also, they automatically eliminate the measurement noise and other measurement errors such as artificial discontinuity.

Multi-Component, Multi-Point Interferometric Rayleigh/Mie Doppler Velocimeter

Langley Research Center, Hampton, Virginia

An interferometric Rayleigh scattering system was developed to enable the measurement of multiple, orthogonal velocity components at several points within very-high-speed or high-temperature flows. The velocity of a gaseous flow can be optically measured by sending laser light into the gas flow, and then measuring the scattered light signal that is returned from matter within the flow. Scattering can arise from either gas molecules within the flow itself, known as Rayleigh scattering, or from particles within the flow, known as Mie scattering. Measuring Mie scattering is the basis of all commercial laser Doppler and particle imaging velocimetry systems, but particle seeding

is problematic when measuring high-speed and high-temperature flows.

The velocimeter is designed to measure the Doppler shift from only Rayleigh scattering, and does not require, but can also measure, particles within the flow. The system combines a direct-view, large-optic interferometric setup that calculates the Doppler shift from fringe patterns collected with a digital camera, and a subsystem to capture and re-circulate scattered light to maximize signal density. By measuring two orthogonal components of the velocity at multiple positions in the flow volume, the accuracy and usefulness of the flow measurement increase significantly over single or non-

orthogonal component approaches.

The subject architecture can be combined with CARS (coherent anti-Stokes Raman spectroscopy) to provide temperature and composition of the measured flow. The system is also capable of characterizing high-velocity flames, up to 2,400 K, which is useful in analyzing high-speed combustion in fighter jet engines, scramjet engines, and even potentially in gas turbines.