to the shop floor, something that was not practical to do before with large products such as external tanks, space shuttle main engines, and solid rocket boosters. From label scanning to material analysis, the vacuum enhanced XRF is a welcome addition to the NASA toolbox of capabilities.

This work was done by Harry F. Schramm of **Marshall Space Flight Center** *and Bruce Kaiser of Keymaster Technologies, Inc. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.nabors@msfc.nasa.gov.*

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:

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Refer to MFS-31898, volume and number of this NASA Tech Briefs *issue, and the page number.*

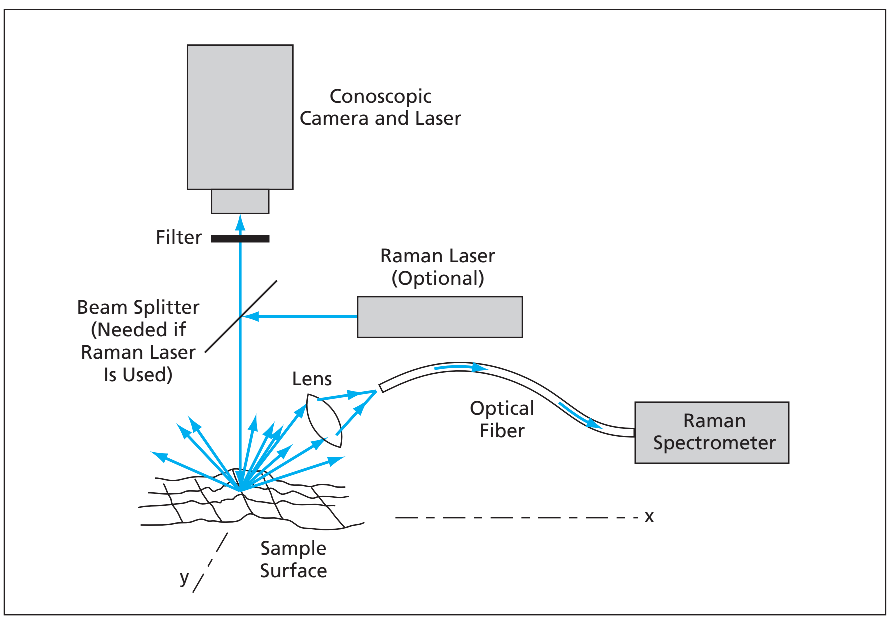
Simultaneous Conoscopic Holography and Raman Spectroscopy

Both the topography and the chemistry of surfaces would be mapped.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new instrument was developed for chemical characterization of surfaces that combines the analytical power of Raman spectroscopy with the three-dimensional topographic information provided by conoscopic holography. The figure schematically depicts the proposed hybrid instrument. The output of the conoscopic holographic portion of the instrument is a topographical map of the surface; the output of the Raman portion of the instrument is hyperspectral Raman data, from which the chemical and/or biological composition of the surface would be deduced. By virtue of the basic principles of design and operation of the instrument, the hyperspectral image data would be inherently spatially registered with the topographical data.

In conoscopic holography, the object and reference beams of classical holography are replaced by the ordinary and extraordinary components generated by a single beam traveling through a birefringent, uniaxial crystal. In the basic conoscopic configuration, a laser light is projected onto a specimen and the resulting illuminated spot becomes a point source of diffuse light that propagates in every direction. The laser beam is raster-scanned in two dimensions (x and y) perpendicular to the beam axis (z), and at each x,y location, the pattern of interference between the ordinary and extraordinary rays is recorded. The recorded interferogram constitutes the conoscopic hologram. Of particular significance for the proposed instrument is that the conoscopic hologram contains information on the z coordinate (height) of the illuminated surface spot. Hence, a topographical map of the specimen is constructed point-by-point by rastering the laser beam in the x and y directions and correlating the x and y coordinates with the z information obtained from the interferograms. Conoscopic imaging is an established method, and conoscopic laboratory instruments for surface metrology are commercially available.



A **Spot on a Specimen Would Be Illuminated** by a laser beam (or by two coincident laser beams) that would be raster-scanned across the surface in x and y. Laser light back-scattered from the surface would be used to map the surface height (z) and chemical composition as functions of x and y.

In Raman spectroscopy of a surface, one measures the spectrum of laser light scattered inelastically from a laser-illuminated spot on the surface. The wavelengths of the inelastically scattered light differ from that of the incident laser beam by amounts that correspond to the energies of molecular vibrations. The resulting vibrational spectrum can be used to identify the molecules. Raman spectroscopy is a standard laboratory technique for identifying mineralogical, biological, and other specific chemical compositions.

In the design and construction of the proposed instrument, a commercially available laboratory conoscopic holographic imaging system would be integrated with a Raman spectrometer (see figure). The on-axis back-scattered laser light would be used by the imaging system to generate the conoscopic hologram of the illuminated spot. Part of the off-axis back-scattered laser light would be collected by a lens, which would couple the light into an optical fiber, which, in turn, would feed the collected light to the Raman spectrometer. The lateral (x,y) resolution of the instrument would typically be of the order of microns, the exact value being determined primarily by the size of the laser-illuminated spot on the specimen. In one of two configurations, the Raman-excitation and conoscopic-holography beams would be generated by two different lasers and would be aligned and focused together on the same spot on the specimen. In a simpler configuration that would entail less weight, complexity, size, and cost, the same laser beam would be used for both conoscopic holography and Raman spectroscopy. The two-laser configuration would be preferable in cases in which the illumination needed for Raman excitation significantly exceeds that needed for conoscopic holography and, hence, it becomes necessary to alternate between conoscopic and Raman analysis of each scan spot.

The proposed instrument would be capable of mapping topography and chemical composition at lateral scales from microns to meters, with nanometer height resolution. Thus, the instrument could provide information on composition, roughness, porosity, and fractal dimension of specimens ranging from fine dust to large rocks, without need for any preparation of the specimens. The instrument would be mechanically noninvasive in that there would be no need for mechanical contact between a solid probe and a specimen. Because the probe would be a narrow laser beam, it would be possible to profile features at the bottoms of steep, narrow holes — for instance, crevices in a rock. The proposed instrument could also be combined with other optical spectroscopic instruments.

This work was done by Mark S. Anderson of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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:

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Refer to NPO-30751, volume and number of this NASA Tech Briefs *issue, and the page number.*

Adding GaAs Monolayers to InAs Quantum-Dot Lasers on (001) InP

Modifications enable long-wavelength lasing at higher temperatures.

NASA's Jet Propulsion Laboratory, Pasadena, California

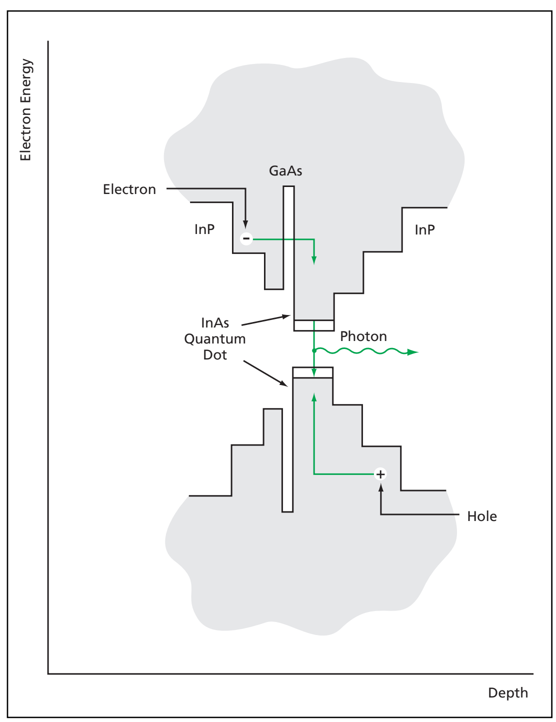
In a modification of the basic configuration of InAs quantum-dot semiconductor lasers on (001)InP substrate, a thin layer (typically 1 to 2 monolayer thick) of GaAs is incorporated into the active region. This modification enhances laser performance: In particular, whereas it has been necessary to cool the unmodified devices to temperatures of about 80 K in order to obtain lasing at long wavelengths, the modified devices can lase at wavelengths of about 1.7 μm or more near room temperature.

InAs quantum dots self-assemble, as a consequence of the lattice mismatch, during epitaxial deposition of InAs on $In_{0.53}Ga_{0.47}As$/InP. In the unmodified devices, the quantum dots as thus formed are typically nonuniform in size. Strain-energy relaxation in very large quantum dots can lead to poor laser performance, especially at wavelengths near 2 μm, for which large quantum dots are needed. In the modified devices, the thin layers of GaAs added to the active regions constitute potential-energy barriers that electrons can only penetrate by quantum tunneling and thus reduce the hot carrier effects. Also, the insertion of thin GaAs layer is shown to reduce the degree of nonuniformity of sizes of the quantum dots.

In the fabrication of a batch of modified InAs quantum-dot lasers, the thin additional layer of GaAs is deposited as an interfacial layer in an InGaAs quantum well on (001) InP substrate. The device as described thus far is sandwiched between $InGaAsP_y$ waveguide layers, then further sandwiched between InP cladding layers, then further sandwiched between heavily Zn-doped (p-type) InGaAs contact layer.

Once a wafer comprising the layers described above has been formed, the wafer is processed into laser diodes by standard fabrication techniques. Results of preliminary tests of experimental modified quantum-dot lasers have been interpreted as signifying that these devices lase at wavelengths from 1.60 to about 1.74 μm. The devices were found to be capable of continuous-wave operation at temperatures up to 260 K and pulse operation (duration 1 ms, repetition rate 1 kHz) at temperatures up to 280 K. It is anticipated that future such devices containing multiple stacks of quantum dots (instead of single stacks in these experimental devices) would be able to lase, at a wavelength of 2 μm. In addition, the multiple-stack devices are expected to perform better at room temperature.

This work was done by Yueming Qiu, Rebecca Chacon, David Uhl, and Rui Yang of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40243



This Energy-Band Profile of a modified $In_xGa_{1-x}As$/InP quantum-dot structure shows the energy effect of the additional thin GaAs layer.