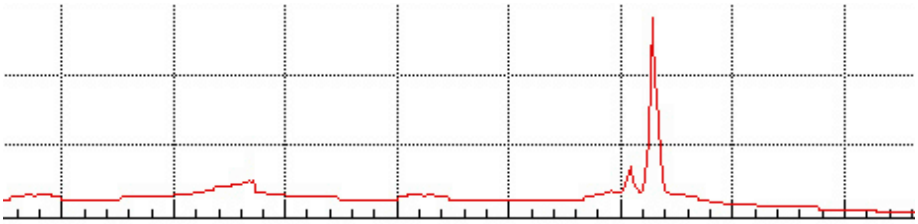
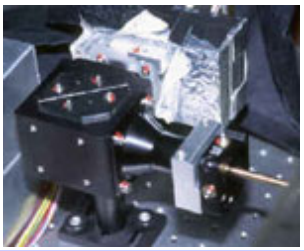


Life´s Chemical Fingerprints

By Lee Siegel

Perhaps in 2008, a rover on Mars will press its robotic arm against a rock. A probe at the end of the arm will scan the rock, repeatedly zapping the surface with a microscopically thin laser beam, probably green or ultraviolet.



A prototype of the Mars Microbeam Raman Spectrometer. *Credit: Haskin Research Group.*

As the laser light hits the rock, it will "scatter" (be deflected) in random directions. Most of that light will stay the same color, but a tiny fraction will be shifted just slightly to a different color, a phenomenon called the Raman effect. That slight shift will reveal whether the rock harbors the chemical signatures of life, either microbes now alive or the remains of organisms that lived in the past. The "Raman−shifted" light also can detect any minerals indicating whether Mars once was conducive to life.

In the more distant future, a spacecraft hardened against Jupiter´s intense radiation may land on the icy moon Europa, then melt its way downward to a vast ocean below. The interplanetary submarine will activate a Raman probe, analyzing the water for mineral evidence of seafloor hot springs and life that might thrive there.

Thanks to miniaturization of devices that once were as big as beds, researchers are developing "Raman spectrometers" small enough to look for evidence of life on Mars and Europa. They hope green or ultraviolet Raman instruments or perhaps both might be launched toward Mars in 2007.

Prototypes of the green−laser Mars Microbeam Raman Spectrometer which excels at identifying minerals were built by a team led by Larry Haskin, a professor of Earth and planetary sciences at Washington University in St Louis. His team includes researchers from the University of Alabama at Birmingham, Cornell University and NASA´s Jet Propulsion Laboratory (JPL) in Pasadena, California. Dr. Alian Wang of Washington University, a member of Haskin´s team, first conceived and designed the miniature instrument.

Michael Storrie−Lombardi, a member of the NASA Astrobiology Institute, works at JPL´s Center for Life Detection. He is principal investigator of a second team, which builds devices that use ultraviolet lasers to

perform Raman spectroscopy highly sensitive to organic materials.

The Raman effect was named for its discoverer, Chandrasekhra Venkata Raman (1888−1970). *Credit: the Nobel Foundation.*

Scientists believe Raman spectroscopy is more likely to find minerals indicating conditions conducive to life than it is to find unambiguous evidence of life itself, past or present.

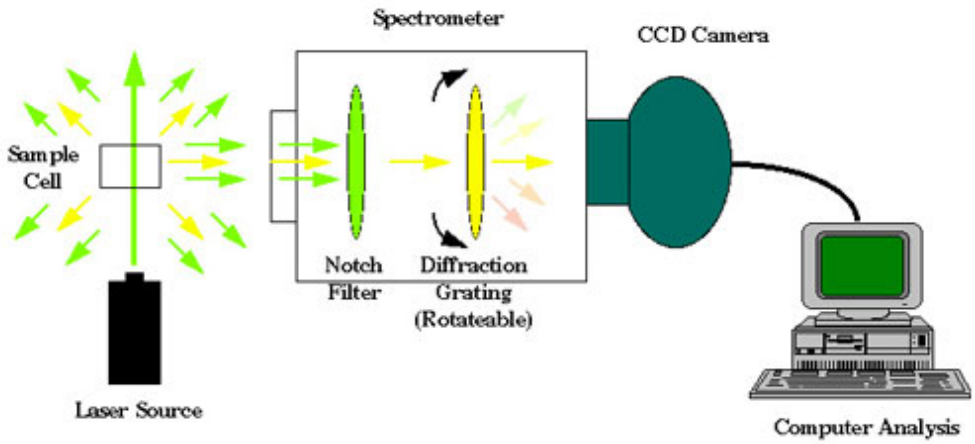
"No instrument can tell you life yes or no so you can be sure about it," said Tom Wdowiak, a member of the Haskin group and a physicist at the University of Alabama at Birmingham. But a Raman spectrometer "is the best instrument we have in the pipeline for selecting samples on Mars to answer the question of whether or not life ever could have existed on that world or if conditions are such that life could exist there now."

"If there were life forms or residues of life and we encountered them with the [Raman] instrument, of course we would see them," Haskin said. "But our chances of running into it [life] are extremely low."

Raman spectroscopy was named for Chandrasekhra Venkata Raman, a University of Calcutta physicist who won the Nobel Prize in physics in 1930 for his discovery of the Raman effect.

When a laser beam of a specific wavelength or color hits a target material, most of the light that bounces off the material stays the same wavelength, or color. But a small portion of the laser light, from one−in−one−thousand to one−in−one−trillion photons (light particles), changes wavelength. The precise shift in wavelength is determined by the molecular makeup of the targeted material. Each different type of molecule has a unique signature.

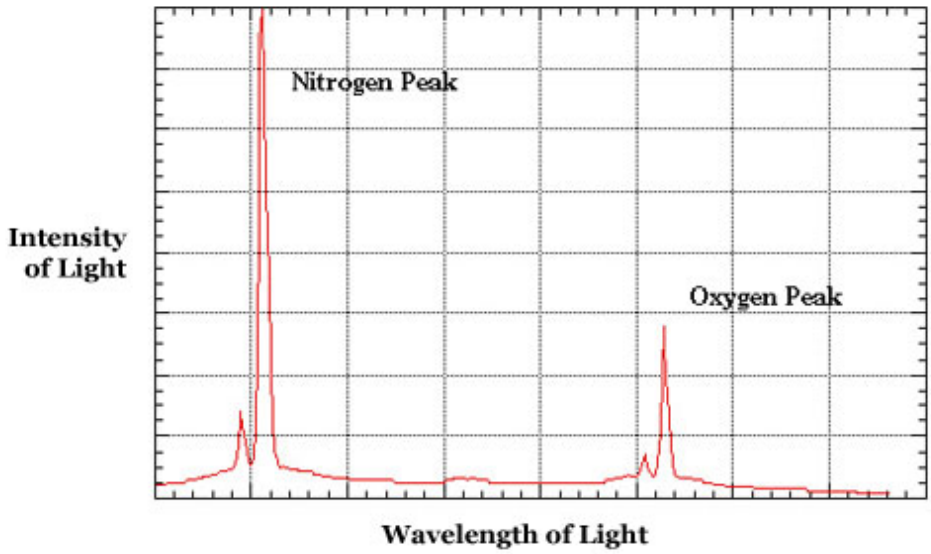
As a result, Raman spectroscopy determining the wavelengths of Raman−shifted light can characterize minerals, detect trace amounts of organic substances and identify biological substances such as proteins,DNA,amino acids and plant pigments. The method often is used in medicine, for tasks that range from analyzing genes to detecting microbes, Storrie−Lombardi said.



The basic process of Raman spectrometry. The mineral sample to be studied is illuminated by a laser beam. Scattered light is collected by the spectrometer. A filter removes any light that is the same color as the laser beam, letting only the light that has changed color (Raman−shifted light) pass through. The diffraction grating separates the light by color (wavelength). The different wavelengths are collected by a charged couple device (CCD) camera. A computer creates a graph showing the intensity of light at each wavlength. *Credit: University of Utah, Center of Excellence for Raman Technology.*

A planetary Raman spectrometer would press a probe against a sample, or perhaps plunge a fiber−optic cable into the soil, then fire the laser repeatedly as the probe scanned the sample. A special filter would remove scattered light that had not changed color. Raman−shifted light would pass through the filter, then pass through a grating and bend according to wavelength.

The light would hit an electronic camera. A computer would convert the data collected by the camera into graphs showing the "spectra" or wavelengths of the Raman−shifted light. Organic substances and minerals can be identified by the "peaks" they create at certain wavelengths on these graphs.



When illuminated by a laser, chemicals and minerals scatter light. The specific

wavelengths of the light identifies the composition of the chemical or mineral. This Raman spectrograph of ordinary room air shows that air is composed of nitrogen and oxygen. *Credit: University of Utah, Center of Excellence for Raman Technology*.

Wdowiak said a Raman spectrometer could look not only for life and organics, but also for minerals in which organisms might have fossilized. The Raman device also could detect minerals that formed in the presence of water, which is needed for life, and minerals that indicate energy use in living organisms.

Haskin and Wdowiak said the green laser Raman spectrometer was bumped from NASA´s 2003 Mars launch program when the mission evolved into a pair of rovers.

Animation: the Smart Lander seeks a landing spot. The spacecraft could carry a raman spectrometer to Mars as early as 2007. (Requires QuickTime player.) *Credit: NASA.*

"The best prospect now for the Raman spectrometer to go to Mars," Wdowiak said, "is in 2007, because the 2005 mission is going to be an orbiter."

The Haskin team´s latest green Raman spectrometer is an L−shaped device that fits in an outstretched hand. Storrie−Lombardi´s most recent ultraviolet Raman spectrometer is "about the size of a carry−on suitcase," he said. "Were aiming to get it down to a tenth of that size" or smaller.

Storrie−Lombardi said the green laser Raman device is first in line for Mars. But he also would love to send his ultraviolet instrument, which is more sensitive for detecting signs of life.

William Hug of Photon Systems in Covina, CA, developed the miniaturized ultraviolet laser used in Storrie−Lombardi´s Raman instrument, which can identify DNA (the genetic material of life) and detect three of the 20 amino acids that build proteins in living organisms.

Not only could the ultraviolet device use the Raman effect to look for those signs of life, it also could make "black−light" and visible−light photographs of extraterrestrial samples. Protein glows fluorescently in ultraviolet light, Storrie−Lombardi said, just as blood glows under black lights used by crime−scene investigators.

Storrie−Lombardi´s prototype has detected bacteria, DNA, protein and other organic materials in laboratory experiments.

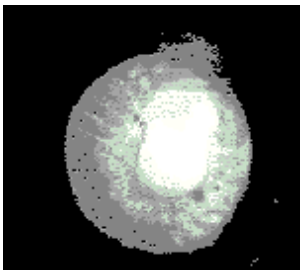
"The first thing we scanned was coffee grounds. Clearly organic," he joked. "We´ll be able to tell if there is Starbucks on Mars."

Raman analysis revealed an organic wax and fossilized bacteria in this billion−year−old basalt rock. Click here to enlarge. *Credit: Haskin Research Group..*

Haskin said that as his Raman device scanned a 1.1−billion−year−old volcanic basalt from Minnesota, "all of a sudden, we got a beautiful organic spectrum, which turned out to be a wax," produced by microscopic lichens on the rock. Wdowiak used Raman spectroscopy to detect 2−billion−year−old fossilized bacteria in rock.

Storrie−Lombardi´s ultraviolet light illuminated algae and fungi when it was tested on rocks from Antarctica. According to D. D. Wynn−Williams of the British Antarctic Survey, modern cyanobacteria in harsh Antarctic deserts produce chlorophyll and other pigments detectable by Raman spectroscopy. The pigments have been found in 3.5−billion−year−old fossilized cyanobacteria.

Wynn−Williams suggested a spacecraft could use a fiber−optic cable to extend a Raman probe into martian soil to look for such pigments, which would provide "evidence of former surface life on Mars."



This microorgansim was found in the above sample of basalt rock.*Credit: Haskin Research Group..*

Wdowiak doubts such "biomarkers" will be found on Mars, however, because the surface environment is so harshly oxidizing it destroys any life.

Haskin said he hopes a Raman device on Mars will "find minerals that require water and warm conditions for

their formation." Finding such minerals on Mars would indicate conditions hospitable to life once existed there.

A Raman spectrometer on Europa´s icy surface could identify any minerals or organic material that welled up from the moon´s purported ocean and broke or percolated through the ice, he added.

Darcy Gentleman and colleagues at Arizona State University have suggested using a submersible Raman instrument to look for organic materials around undersea hot springs on Earth and Europa. Earth life may have begun near undersea hydrothermal vents, which "might be places to look elsewhere in the solar system for life," Gentleman said.

According to Storrie−Lombardi, though, such a mission is unlikely before the 2020s.

What Next?

Beyond Mars and Europa, he said he would like to see a Raman device look for signs of life on Jupiter´s moon Callisto.

Storrie−Lombardi said Raman spectrometers not only can explore other worlds, but also can screen spacecraft to ensure they are not carrying Earth microbes to other planets. They also can be used to protect Earth from extraterrestrial contaminants hitchhiking on returning spacecraft.

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