Auto-Focusing Raman Fiber Optic Probe for Remote Measurements

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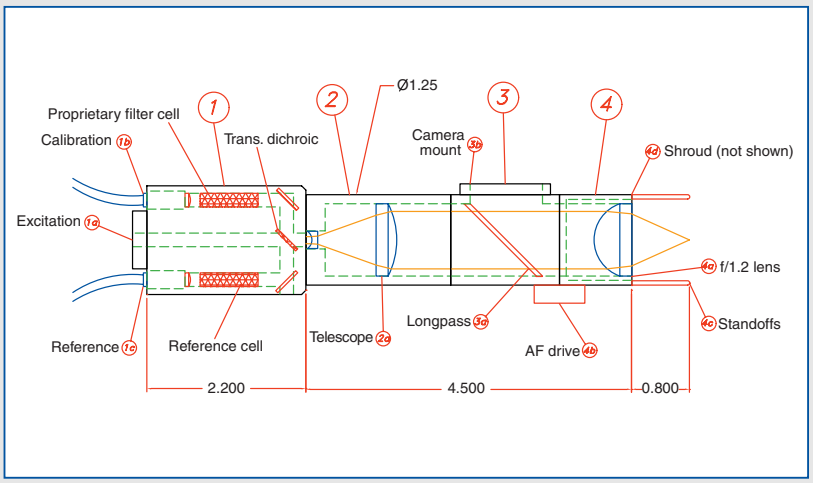
Introduction

Focused Raman fiber optic probes enable semi-micro analysis of samples with a spot size typically 100 – 200 µm. Proper focusing on the desired area can usually be achieved by eye. True remote sensing applications require an adjustable focus to accommodate irregularly shaped samples. A new Raman fiber optic probe has been developed enabling computer-controlled focal adjustment based on a visual image. This probe was built as a prototype for an instrument under consideration for a future Mars Rover mission.



Schematic of the "Mars Probe", a Raman fiber optic probe with adjustable focus and sample visualization. Dimensions shown are in inches.

The "Mars Probe" was specified for the measurement of irregularly-shaped mineral samples. InPhotonics' commercially-available fiber optic probes usually have a final focusing lens that is fixed in place. In routine laboratory studies, the probe and sample are positioned such that the surface of the sample is at the probe focus; this is generally easy to achieve by eye since the depth of field is 1 – 2 mm. The Mars Probe was prototyped for exploration of the planet surface, and the probe would be mounted on a vehicle with relatively coarse positioning capabilities. Fine focus of the laser/collection spot on mineral samples would be facilitated via computer-controlled adjustment of the probe lens rather than movement of the probe or sample. The prototype was designed with future miniaturization in mind.

Probe Design

The probe housing was constructed in four sections such that component modules could be exchanged in the future according to changes in optical requirements. The interface and filtering optics inside section (1) were based upon InPhotonics' commercial RamanProbe™ design utilizing micro-optics. The "excitation" channel (1a) contained optical filters to remove silica background from the incoming fiber. The "collection" channel (1b) contained the laser-blocking filters. The custom "reference" channel (1c) incorporated a natural calcite ($CaCO_3$) sample for frequency calibration of the complete Raman system, along with an additional set of laser-blocking filters. The telescope (2) was used to increase the beam size to the desired clear aperture. The camera cell (3) incorporated a mounting flange for the visual camera, and contained a custom filter to transmit the laser/scattered radiation while reflecting the visible image to the focusing lens assembly (4). Various lenses were tested as the final op-

tic. An aspheric lens was considered for its low image distortion, however chromatic aberrations prevented a simulaneous focus of the visible and NIR wavelengths. Since the visible image would determine the focus position, these chromatic aberrations were undesirable. A Hastings triplet provided excellent image quality, but its size and weight were not feasible for future miniturization. In the end, an achromat was selected as the final focusing lens.

Spectroscopic tests on the probe showed greater than 50% signal compared to our commercial probes. This is excellent considering the increased number of optical components and larger clear aperture.

Mars Probe Specifications

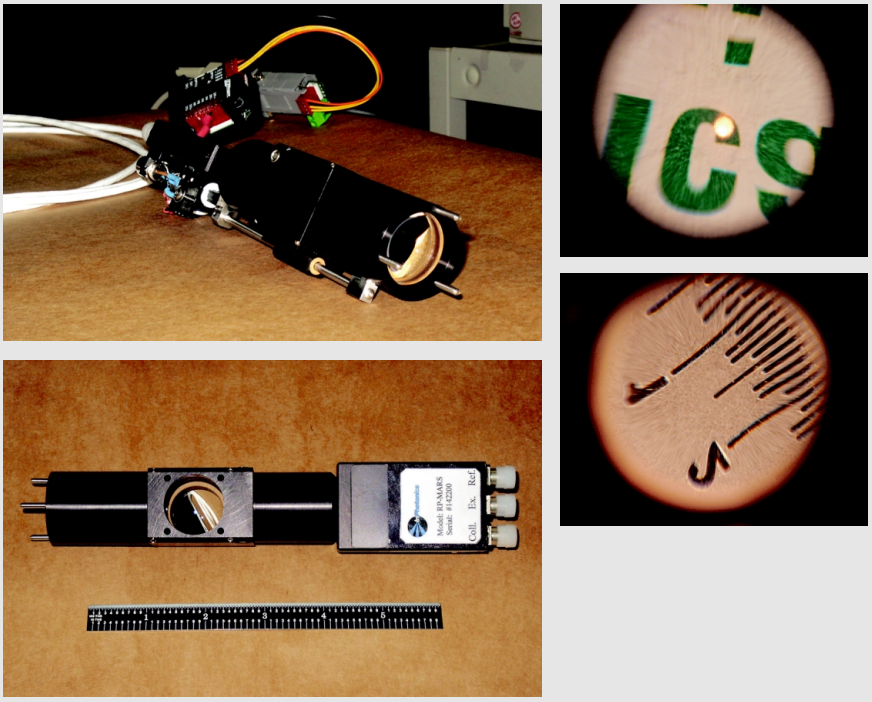
Laser λ:	785 nm +/- 1 nm
Spectral Range:	150 – 3500 cm^{-1}
Rayleigh Filter:	> 10^8 blocking at laser line
Camera Mount:	Camera optical path collinear with Raman optical path, 1" clear aperture
Front Lens:	f/1.2, 25 mm clear aperture, resulting in laser spot size ca. 180 μm
AF Drive:	Adjustable in 10 μm steps, focus range of 10 mm (2.5 sec total travel time), end-of-travel sensor to set "home" point, serial communication
Exc. Channel:	Accepts 100 μm fiber
Col. Channel:	Focus into fiber bundle < 400 μm in diameter
Int. Calibrant:	Includes reference channel with internal calcite target and laser filter, focused into additional fiber bundle
Physical:	Prototype; reasonable size, weight, and robustness with possibility for future minimization

Future Applications

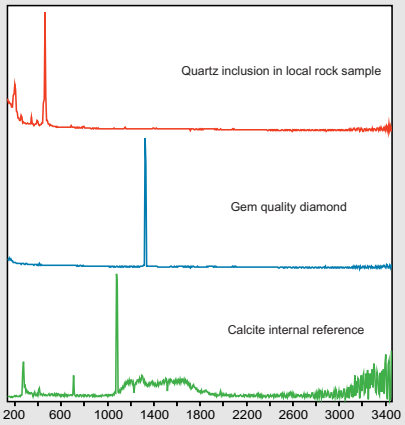
The autofocus RamanProbe can be used for a variety of remote sensing applications, either in its current size or after proposed miniaturization:

- Analysis of artifacts and artwork,
- Laboratory or on-site forensic analysis (e.g. fibers or spots),
- Measurements in hazardous environments where manual focusing is not possible.

A probe can also be constructed with only the viewing capabilities and a fixed front lens.



Left: Front and top views of the Mars Probe. The probe has three FC couplers for the excitation, collection, and reference optical channels, along with two electrical connectors for the stepper motor. Right: Images through the probe, showing the 180 μm laser spot within the 5 mm field of view.



Test spectra measured with the Mars Probe and the RS2000 spectrometer (InPhotonics, Inc.)

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