

A PORTABLE AOTF IR REFLECTANCE POINT SPECTROMETER FOR IN SITU BIOSIGNATURE DETECTION. K. Uckert¹, N. J. Chanover¹, D. Voelz², X. Xiao², P. Boston³, ¹New Mexico State University (Department of Astronomy, Las Cruces, New Mexico 88003; kuckert@astronomy.nmsu.edu), ²New Mexico State University (Klipsch School of Electrical and Computer Engineering, Las Cruces, New Mexico 88003), ³New Mexico Institute of Mining and Technology (Department of Earth & Environmental Sciences, Socorro, New Mexico 87801)

Introduction: Characterizing the mineralogy of a planetary surface is essential to understanding its geologic and chemical evolution, which can be used to infer the past habitability of a region. Spectral signatures consistent with several important mineralogical and biogeochemical absorption features are located in the near infrared (NIR) spectral region, and thus offer a convenient wavelength range to probe for geologic and astrobiological investigations of planetary surfaces.

We developed the Portable AOTF Spectrometer for Astrobiology (PASA) to characterize the mineralogy of geologic samples and identify spectral signatures consistent with biologic influence. We demonstrated the detection of biosignatures and mineralogical characterization of geologic samples with PASA *in situ* in two subterranean environments on Earth to determine the feasibility of identifying life on other Solar System bodies. Caves provide convenient entrances for accessing the potentially habitable subsurface on other planetary bodies [1], and our demonstration of this *in situ* technique in cave environments establishes PASA as an effective instrument in characterizing the astrobiologic value of samples for eventual use on other planetary surfaces.

Instrument Development and Specifications:

AOTFs are low power devices that operate on the principle of diffraction in a birefringent crystal, and recent development by our group has demonstrated their versatility and portability [2,3,4]. We originally developed an AOTF NIR reflectance spectrometer to be paired with a laser desorption/ionization mass spectrometer to detect and characterize biosignatures in geologic samples through NASA's Astrobiology Science and Technology Instrument Development

(ASTID) program. We developed a NIR AOTF point spectrometer to measure the NIR reflectance spectrum of geologic samples in the 1.6 - 3.6 μm range with a resolution of $\lambda / \Delta\lambda \approx 250 - 400$. A detailed

Table 1: PASA Specifications

Mass (g)	~2,000
Dimensions (cm)	11.4 x 12.7 x 4.1
Wavelength Range (μm)	1.6 - 3.6
Resolution ($\lambda / \Delta\lambda$)	250 - 400
Spot Size (mm)	<2.0
Operation time (s)	0.1 - 30

description of the development and operation of this device is presented elsewhere [2,5,6].

We identified the need for a portable, stand-alone IR reflectance spectrometer, and developed PASA to demonstrate the capabilities of an AOTF NIR spectrometer *in situ* in remote, extreme field sites. Technical specifications for PASA, and the optical design are provided elsewhere [4,7], and summarized in Table 1. A photograph of the optical head is presented in Figure 1.

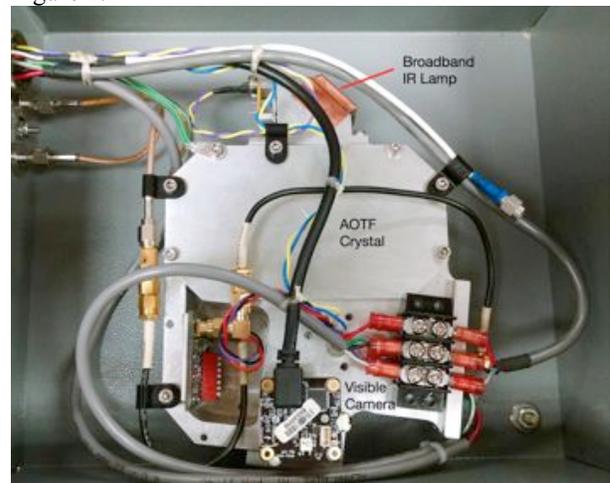


Figure 1: An annotated photograph of the aluminum case housing the optical head of PASA.

Measurements: We demonstrated the operation of PASA *in situ* in two subterranean environments, Fort Stanton Cave located in central New Mexico, and Cueva de Villa Luz located in Tabasco, Mexico. These field sites represent two geologically distinct extreme environments. Fort Stanton Cave formed millions of years ago through carbonic acid dissolution, and today is primarily decorated by carbonate minerals. Cueva de Villa Luz is actively forming through sulfuric acid dissolution, and is rich in hydrogen sulfate speleothems, which are influenced by the diverse microbial ecosystem. Figure 2 shows PASA in operation in Fort Stanton Cave.

To operate PASA, we place the aperture of the steel case housing the optical head at the focal point, approximately 1.5 mm above a geologic region of interest identified using a visible light context camera. We initiate a scan using the laptop control software, which commands an RF signal to be applied to the

AOTF crystal in a sweep mode over a specified frequency range. A calibration target, a Lambertian infrared plate, is measured as a reference spectrum prior to each sample measurement.



Figure 2: PASA operating in Fort Stanton Cave. The steel box containing the optical head (A), the electronics box (B), and the ruggedized laptop (C) are labeled. Here, we measured the IR spectrum of a gypsum star shown in Figure 3. Photo credit: Wayne Walker.

Results: Characteristic absorption features of common mineral classes and basic organics lie within the 1.6-3.6 μm region probed by PASA, allowing for the identification of the major mineral constituents of a geologic sample [2,8]. We have demonstrated that the biogenicity of a sample can be identified using multivariate analysis techniques [3]. We use principal component analysis to characterize the spectral variability between samples with and without organic biofilms (verified using independent techniques), and find that the IR spectra of biogenic calcite samples, for example, have broader carbonate absorption features and deeper hydration features [3,9].

Figure 3 shows the spectrum of a gypsum star measured *in situ* with PASA in Fort Stanton Cave. A gypsum crystal collected from the same passage six months earlier and measured in the lab with PASA is also presented for comparison. The surficial H_2O features at ~ 1.75 and $1.95 \mu\text{m}$ are much stronger in the *in situ* measurements due to the persistent humid environment. Once these gypsum samples are transported to the relatively arid lab, the surficial water features rapidly diminish and the subsequent reflectance spectrum is no longer representative of the mineral collected. These spectra demonstrate the value of collecting measurements *in situ*, particularly in environments with unique or stable environmental conditions.

Conclusions and Future Work: PASA is a ruggedized, portable NIR reflectance spectrometer based on AOTF technology capable of the rapid geologic characterization of a sample, with practical applica-

tions for *in situ* geologic and astrobiologic investigations of planetary surfaces. We have demonstrated the operation of PASA in two extreme subterranean environments, characterized the mineralogy of several distinct geologic samples, and identified biosignatures within them. We are considering several improvements to the design of PASA, including: additional miniaturization of the optical head, reducing the required power, lengthening the focus, and redesigning the exit pupil for more consistent measurements.

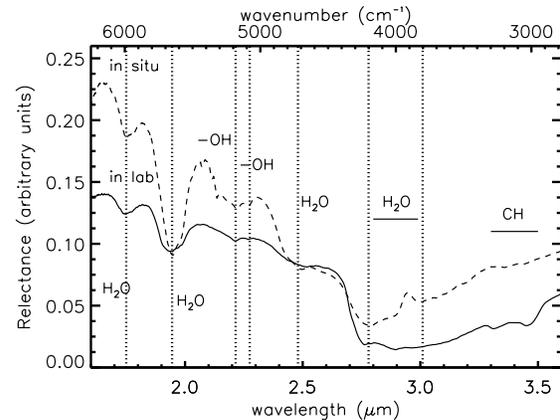


Figure 3: A gypsum star measured *in situ* and in the lab. Both spectra represent an average of 256 scans. The surficially bound H_2O features are significantly deeper in the spectrum collected *in situ*.

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