**STANDOFF BIO-FINDER FOR PLANETARY EXPLORATION WITH FAST DETECTION:** A. K. Misra[1], S. K. Sharma[1], T. E. Acosta[1], D. E. Bates[1], S. M. Clegg[2] and R. C. Wiens[2], [1]Hawaii Institute of Geophysics and Planetology, Univ. of Hawaii, Honolulu, HI 96822, USA (anupam@hawaii.edu); [2]Los Alamos National Laboratory, P.O. Box 1663 MS J565, Los Alamos, NM 87545, USA.

**Overview:** Finding evidence of life on other planets using rovers and landers is one of NASA's top priorities signified by the prominence of the Astrobiology Program. The task of finding a small amount of biological material or bio-minerals from a large collection of rocks and minerals on planetary surface can be a very time consuming process for rovers/landers. To significantly improve the capability of a rover/lander to find bio-minerals and other bio-markers from a standoff distance, we have developed a standoff laser-based instrument which is able to locate biological materials and biomarkers from standoff distances ranging from 1 m to >10 m with fast scanning speed (<1 s) in an area of ~500 cm$^2$. Such an instrument will be useful for a lander or rover for locating biological material in its vicinity. After an area of interest is identified, the instrument when combined with remote Raman and LIBS technique can assay the chemical composition of the target material from a standoff distance during both daytime and nighttime operations. In this presentation, we will demonstrate the standoff bio-finder capability of the instrument using remote time gated fast fluorescence spectroscopy.

**Background:** Most of the biogenic and organic materials give strong fluorescence signals when excited with UV and visible lasers [1-4]. Planetary minerals and rocks containing transition metal and rare-earth ions when excited with UV and visible lasers produce fluorescence spectra that in some cases overlap with the fluorescence spectra of biogenic and organic compounds. However, the fluorescence decay time or lifetime of biogenic and organic compounds is much shorter (<1 to 100 ns) than the μs to ms fluorescence decay time of of the transition metal ions and rare-earth ions in minerals and rocks [5-7]. The standoff bio-finder exploits the short bio-fluorescence lifetime to locate a biological material.

Figure 1 shows the combined spectra of time resolved (TR) laser-induced native fluorescence (LINF) and Raman spectroscopy of chicken eggshell excited with a 532 nm pulsed laser from a distance of 9 m and measured over sequential 10 ns time intervals [5]. Because inelastic Raman scattering caused by the vibrational modes of crystals is also a very fast (life-time ~$10^{-13}$ s) phenomenon, the Raman signals are simultaneously observed along with the bio-florescence signal in nanosecond time frames. The sharp Raman lines 156, 282, 711, and 1085 cm$^{-1}$ are characteristic of calcium carbonate in calcite structure. The lifetimes of the strong fluorescence band at ~564.7 nm, 633.3, and 672.4 nm are, respectively, 20, 60 and 40 ns. The presence of fluorescence features with short (tens of ns) lifetime of egg-shell indicates biological origin of the $CaCO_3$ in the eggshell [5]. These data show that a combination of time-resolved Raman and fluorescence spectroscopy can distinguish between a biogenic material and a non-biogenic material even when the structures and chemical composition of the mineral phases are the same.

Time-resolved fluorescence spectroscopy (TRFS) is extremely sensitive and ideally suited to rapidly surveying planetary surfaces to find regions of high organic content. TRFS is one of the most sensitive techniques for detecting polyaromatic hydrocarbons (PAHs) and biomolecules since these species contain aromatic structures, which have high fluorescence quantum yields.

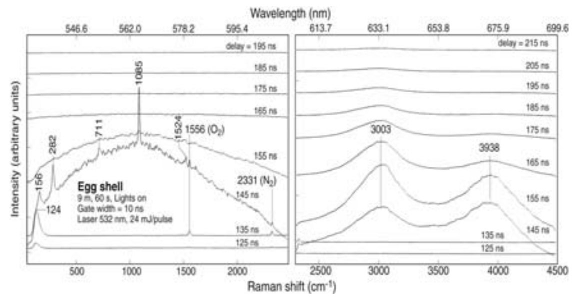


Fig 1. Time-resolved Raman and fluorescence spectra of a chicken eggshell from a distance of 9 m measured with the Univ. of Hawaii's 5-inch stand-off Raman system in gated mode. Delays on the curves are the time in nanoseconds after the Q-switch of the laser is triggered. Laser: 532 nm, 24 mJ/pulse, 20 Hz; gate width 10 ns [5].

**Experimental set-up:** Figure 2(a) shows the prototype bio-imaging system mounted on a portable trolley with a pan and tilt scanner looking down toward the targets which can be seen in Fig. 2(b). The standoff bio-imager consists of a regular 85 mm Nikon camera lens, a 532 nm notch filter and a gated ICCD camera. A small diode-pumped 532 nm YAG pulse laser with 0.1 mJ/pulse energy operating at 10 kHz was used to excite the targets placed at 2 m distance. A diverging lens was used to expand the laser beam diameter to 25-cm at 2-m distance where a variety of minerals and biological targets were excited with the expanded beam. All images were recorded with 0.1 second integration time with all the room lights turned on. Figure 2(b) shows the actual experimental setup

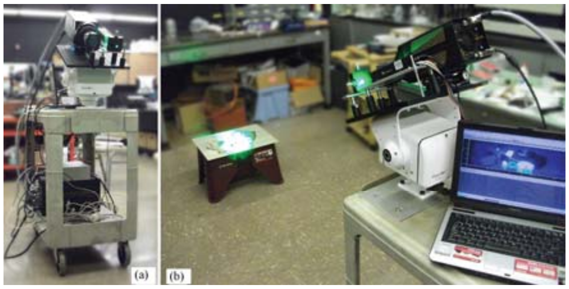


Fig 2: (a) A prototype standoff bio-imaging system utilizing an ICCD camera, a 532 nm pulsed laser (0.1 mJ/pulse) mounted on a portable trolley with a pan and tilt scanner. Fig 2(b) shows the front view of the system in action looking down towards several targets placed at 2 m distance.

where live images (at 10 frames/s) showing locations of biological materials in the 500 $cm^2$ target area could be easily detected. The frame rate indicates that rapid scanning capability of the system.

**Results:** Figure 3 (a) shows the whitelight photo taken from a regular digital camera of various minerals and biological targets placed together at a distance of 2-m from the bio-finder system. Figure 3(b) shows the photograph taken from the bio-finder system with 0.1

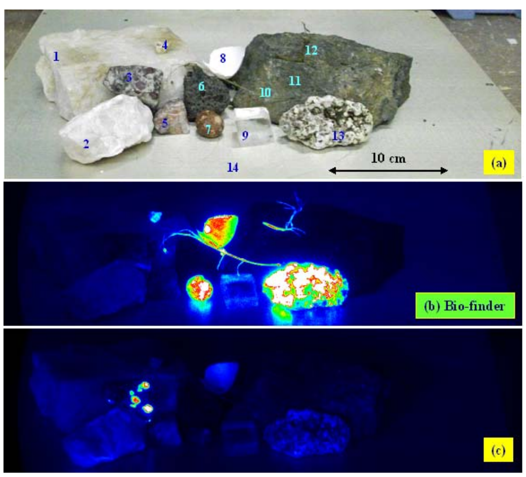


Fig. 3: Standoff Bio-finder capability to detect all biological objects with 0.1 s detection time in a target area of 500 $cm^2$ from a 2 m distance. The targets shown in white-light photograph (a) consist of (1) quartz, (2) gypsum, (3) ruby embedded in alkaline basaltic rock, (4) broken white sea shell on top of quartz rock, (5) dolomite, (6) Hawaiian basalt with olivine and pyroxene, (7) brown sea shell, (8) broken chicken egg shell, (9) calcite, (10) dry green plant twig, (11) augite (pyroxene) rock, (12) dry brown plant stick on top of augite rock, (13) marine-coral with algae residue, (14) aluminum metal base plate. The false color image (b) shows the result of bio-finder in the fast LINF imaging mode where all biological targets showing strong signals could easily be identified from the similarly colored minerals. The ruby minerals with longer LINF decay-time are shown in (c). Scale = 10 cm.

second integration time using the fast fluorescence mode with a gate width of 100 ns and ICCD gain of only 10%. The image clearly identifies all the biological targets (4, 7, 8, 10, 12, 13) which show very bright images in comparison to the non-biological samples. The long-lived fluorescence from the minerals is shown in Fig. 3 (c) which shows the very strong signal from ruby embedded in an alkaline basaltic rock. A further rapid identification of various types of biomaterials based on the position of fluorescence bands [2-4] in the bio-image can be done by simply installing a filter wheel consisting of several selective bandpass filters.

Remote time resolved fluorescence spectroscopy is a common surveying tool for trace detection of bioresources and minerals. Oceanic lidars detect the distribution of phytoplankton in surface seawater by monitoring fluorescence from chlorophyll-*a*, and for biomass assessments (e.g., [8,9]), and for monitoring of pollution [10]. A similar approach can be used to detect biogenic materials on planetary surfaces. Time-resolved fluorescence spectrometry provides a powerful tool for the analysis of complex mixtures of biomolecules because of its inherent sensitivity and selectivity. For these reasons fluorescence is suitable for detecting organic molecules of the type that might indicate life past or present on Mars.

**Summary:** A new instrument "standoff bio-finder" is shown here to detect various biological materials from a collection of samples in a 500 $cm^2$ area from a standoff distance of 2-m using fast fluorescence mode with 0.1 s speed providing live images at 10 frames/s. The biomaterials standout as bright objects due to strong fluorescence and are easily identified. The system also separates out inorganic minerals with strong fluorescence (e. g., ruby) from bio-materials using fluorescence lifetime.

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**References:** [1] Smith, H.D. (2009), Ph.D. Dissertation, Utah State Univ. http://digitalcommons.usu.edu/etd/614. [2] Storrie-Lombardi, M.C and Sattler, B. (2009), *Astrobiology*, 9, 659-672. [3] Storrie-Lombardi, M.C. et al. (2009) *Astrobiology*, 9, 953-964. [4] Bhartia, R. et al. (2008), *Appl. Spectrosc.*, 62, 1070-1077. [5] Sharma, S. K. (2007), *Spectrochim. Acta, A***68**, 1008-1022. [6] Gaft, M. et al. (1998) *Spectrochim. Acta*, A54, 2163-2175. [7] Gaft, M. et al. (2001), *Phys. Chem. Minerals,* 28, 347-363. [8] Hoge, F. E. et al. (1981), *Appl. Optics* 20, 3197-3205. [9]. Gauldie, R. W. et al. (1996) *Canadian J. Fisheries & Aquat. Sci.* 53, 1459-1468. [10]. Barbini, R. et al. (1998) *J. Marine Sci.* 55, 793-802.