STANDOFF COMPACT COLOR BIOFINDER IMAGER FOR FAST, NON-CONTACT DETECTION OF ORGANICS AND BIOLOGICAL MATERIALS. T. E. Acosta-Maeda[1], A. K. Misra[1], J. Porter[1], M. Sandford[1], M. J. Egan[1], S. K. Sharma[1], D. G. Garmire[2], J. Zhou[2], T. Oyama[2], C. P. McKay[3], P. J. Gasda[4], R. C. Wiens[4], S. M. Clegg[4], and M. N. Abedin[5], [1]Hawaii Institute of Geophysics and Planetology, Univ. of Hawai'i at Mānoa, Honolulu, HI 96822, USA; [2]Department of Electrical Engineering, Univ. of Hawai'i at Mānoa, Honolulu, HI 96822, USA; [3]NASA Ames Research Center, Moffett Field, CA 94035, USA; [4]Los Alamos National Laboratory, Los Alamos, NM 87545, USA; [5]NASA Langley Research Center, Hampton, VA 23681, USA. tayro@hawaii.edu

Introduction: One of the goals listed in NASA's solar system exploration reports is the search for evidence of life. Confirmation of present or extinct life relies in the detection and characterization of biosignatures. At the University of Hawai'i we have developed a standoff compact color Biofinder instrument (shown in Figure 1 during outdoor test) that is able to detect biosignatures in a geological setting with short detection times (<0.1s). The compact color Biofinder takes advantage of the short fluorescence lifetime of biological materials to generate real-time images showing a wide image in which biomolecules are highlighted among abiotic rocks and ices. Furthermore, the color capability makes the system able to differentiate multiple biological materials in a target area which may contain a mixture of biological species in various concentrations, based on their fluorophore colors. The instrument works both in daylight and nighttime and also produces regular images which provide textural and morphological context to the bio-fluorescence images. The compact color Biofinder is suitable to locate fluorescent polyaromatic hydrocarbons (PAH), amino acids, proteins, bacteria, biominerals, photosynthetic pigments, and diagenetic products of microbial life both on dry landscapes as well as on Ocean Worlds such as Europa. The instrument is compact and light, being currently just under 2 kg, and can help a lander find biomolecules in the surface or subsurface of ices without sample collection, with fast detection times. The compact color Biofinder has been recently tested to detect biological materials down to ppm levels, including all microbial colonies on lava rocks, during sunny outdoor tests in a 2800 cm^2 area from a 2.5 m standoff distance, and to detect dead coral, fossils millions to billions years old and other biogenic samples embedded in water ice from a 2.5 m standoff distance.

System: The University of Hawai'i team developed the first version of a Standoff Biofinder in 2012 [1-2]. Since then, we have significantly miniaturized the system and successfully tested it to detect and highlight biogenic materials, biominerals such as coral or eggshell, as well as PAHs. Figure 1 shows the latest version of the Biofinder instrument: the "Standoff Compact Color Biofinder". Currently, the system is fitted with a small diode pumped laser and a small gated sensitive CMOS color camera as main components.

Figure 1: Daytime testing of the compact color CMOS detector from 2.5 m distance during daytime.

The color Biofinder instrument uses a compact conductively cooled, diode pumped, ns pulsed laser providing 355 and 532 nm to illuminate and excite the native fluorescence from the subject area. The subject area must then be imaged with a synchronized color camera to capture the short-lived fluorescence arising within ns time frames of the incident laser pulse. The

Figure 2: Fluorescence image (below) from 2.5 m distance showing presence of biological materials. Single laser pulse excitation and detection.

laser optics converts the collimated laser beam into a controlled diverging beam with uniform illumination. The imaging C-mount lens is coupled with optical filters to form the high resolution image on the CMOS detector. The optical filter blocks any Rayleigh scattering or reflection from the laser illumination and allows for only the fluorescence signal to be transmitted.

Standoff compact color Biofinder capability: In previous years we presented at this Lunar and Planetary Science Conference the detection of biosignatures of leaves, seeds, branches, bacterial colonies, dead coral embedded in seawater ice, and billion years old fossils with color images [3-5]. Figures 2 through 4 show more recent data. The photographs are shown on the top and fluorescence images in the bottom. Figures 2-3 show the Biofinder capability during an outdoor testing in Honolulu, Hawai'i obtained from a distance of 2.5 m and 3 m respectively.

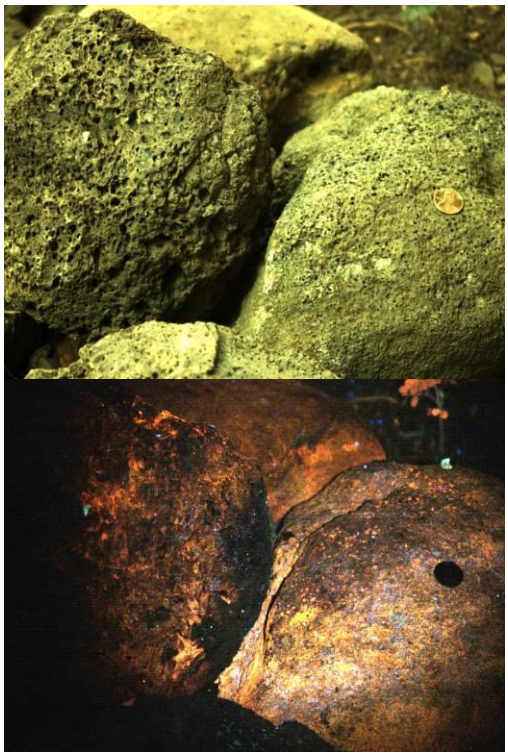

Figure 3. Top: photograph from 3 m. Bottom: Biofinder image. Single laser pulse excitation and detection. Penny for scale.

In figure 2 leaf plants are seen as red because of strong red fluorescence from chlorophyll. Their fluorescence differs from that of the dry leaves and the one of the hand of one of the authors. In Figure 3, the presence of natural biological materials such as bacteria, fungi or plant debris on the lava rocks is highlighted in the biofluorescence image. The color capability allows differentiation of multiple biological materials in the rocks by providing their fluorophore colors ranging from red, orange, yellow, green, blue and white. The microbes on lava rocks are not detected by the naked eye; the rock appears to be free from biological activity in the photograph.

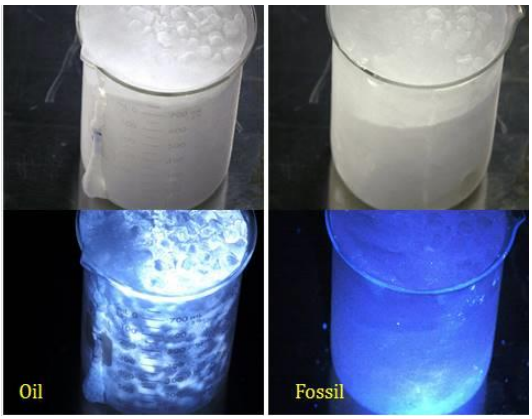

Figure 4: Photographs (top row) and color fluorescence images (bottom row) of biogenic samples frozen in polycrystalline ice. Imaged from 2.5 m distance.

With the goal of detecting biosignatures on Ocean Worlds such as Europa, we tested the color Biofinder with biogenic materials embedded in water ice. Figure 4 shows the photographs and color Biofinder images of a small amount of crude oil (10 µl) and a pisolites fossil (Captain's Reef formation, NM, USA, Permian, 299-252 Ma old) frozen inside tap water ice. While the photographs only show polycrystalline ice, the Biofinder images show the presence of biogenics embedded in the ice. The illuminating laser penetrates the ice, exciting the fluorophores in the samples, which in turn illuminate the surrounding ice from the inside. This capability of detecting biogenics or PAHs inside ice will help an Ocean Worlds lander to select important samples for further analysis.

Summary: The color Biofinder provides photographs coupled with color short-lived fluorescence images that can be used to quickly detect bacteria, fungi and biological debris on inorganic rocks and biogenics, PAHs and fossis embedded in water ice. Such abilities are of interest for planetary exploration and planetary protection programs.

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