FAST, NON-CONTACT DETECTION OF BIOMATERIALS DURING DAYLIGHT WITH “STANDOFF BIOFINDER”

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Introduction: Searching for biosignatures on other planets with conventional instruments onboard landed missions can be very challenging and time consuming. Deciding which samples are important and should be collected and analyzed is a difficult choice to make for a mission and its science team. To further expand the NASAÕs capabilities to look for signs of past and present life on a planetary surface we are developing a novel instrument known as ñStandoff Biofinderò. The Standoff Biofinder is able to detect biomolecules from a collection of rocks and minerals in a large area of 500 cm^2 with detection time of 0.1 s [1-4]. During a planetary mission, the system would be able to scan a 300 m^2 area in 10 minutes for biosignatures. The Standoff Biofinder takes advantage of the short lifetime (less than 50 ns) of bio-fluorescent materials [5] to obtain real-time images showing the locations of biological materials among luminescent minerals in a geological context. One of the important features of the biofinder instrument is its capability to separate out bio-fluorescence from mineral luminescence which have relatively longer life times of the order of micro-seconds to milli-seconds. The interference from mineral luminescence has been an issue for detecting biological materials [6].

Fig. 1: Outdoor testing of Standoff Biofinder on a sunny day in Hawaii. The bio-images were collected from a collection of rocks as seen towards the right of the system at 3 m distance.

Here, we demonstrate the capability of a ñStandoff Color Biofinderò to successfully detect biological materials in daylight during an outdoor test on a sunny day in Hawaii.

System description and experimental details: The Standoff Biofinder uses an expanded and diffused nano-second pulse laser to illuminate a large geological region. A gated detector such as an ICCD equipped with a focusing lens is used to record time-resolved fluorescence images. The timing of the detector is synchronized with the pulsed laser. An optical filter (either notch or long pass filter) is used in front of the focusing lens to block the laser wavelength. The schematic diagram and working principle of the biofinder system are discussed in detail [3]. The data presented here were recorded from a target distance of 3 m (Fig. 1), with a 355 nm Nd-YAG pulsed laser (10 mJ/pulse, 20 Hz, 10 ns pulse width). The laser beam was expanded to a diameter of 60 cm to illuminate an area with lava rocks and small plants (Fig. 2a).

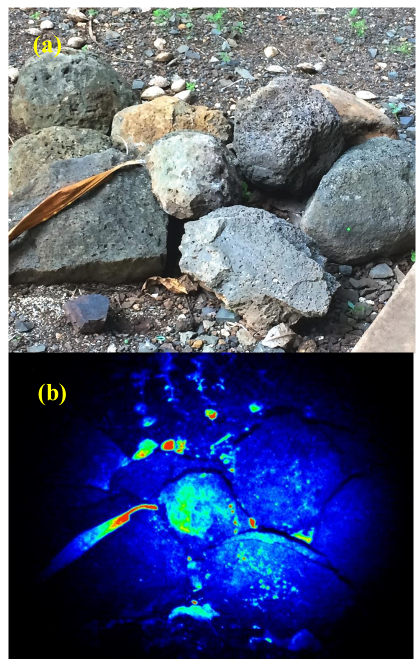

Fig. 2: (a) Picture of sample area captured using a regular color camera. (b) False-color bioimage of the target area using the Biofinder with 1 s integration time. The red areas indicate stronger fluorescence signal than the blue areas. Biological materials are detected on the lava rocks which appear to be free from bioactivity in the image (a).

Results and discussion: Figure 2 (a) shows the close up view of collections of rocks on the ground. This color image was taken by a regular digital camera. The sample set contains Hawaiian basaltic lava rocks, green leaf plants, soil, dry leaf, fallen seeds from tropical almond (Terminalia catappa) tree, stones etc. Presence of natural biological material such as microbes, algae on the lava rocks is not obvious.

Figure 2(b) shows the bio-fluorescence image taken by the biofinder system during daylight. The false colored image, with red color indicating higher intensity, shows the location of biological materials. It is shown that all lava rocks have significant amount of biological material on their surfaces.

Figure 3 shows time resolved remote fluorescence spectra of lava rock using a remote fluorescence system with 355 nm laser excitation with 50 ns time steps. The fluorescence spectra of the rock shows a life time of less than 50 ns confirming the presence of biological material. Biological materials on the rocks are presumably microbes.

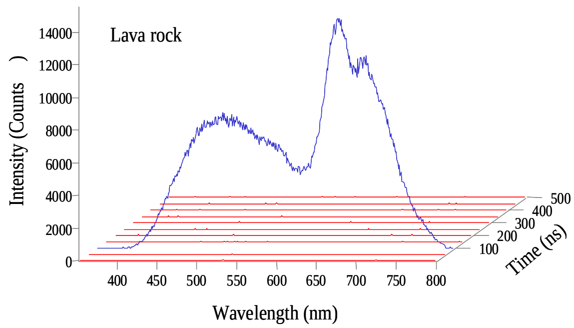

Fig. 3: Time resolved remote fluorescence spectra of lava rock with 355 nm excitation and 50 ns gate width separation. The fluorescence spectra predict presence of biological material on the rock.

Figure 4 shows remote fluorescence spectra of almond seed, brown dry leaf, green leaf plants, lava rock, and soil. All materials showed bio-fluorescence signal with life times less than 50 ns. The relative intensities of the fluorescence spectra are in good agreement with the intensities of the fluorescent images in Fig 2(b).

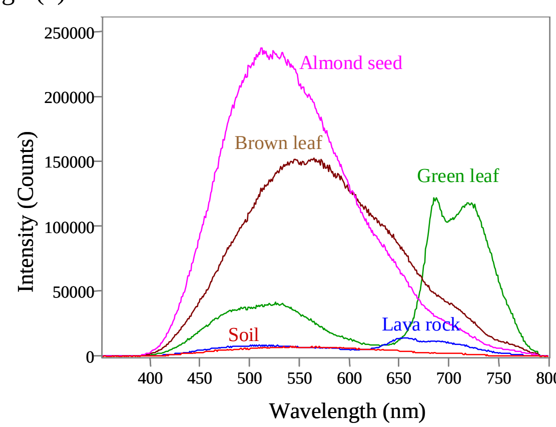

Fig. 4: Remote fluorescence spectra of various objects shown in Fig 2(a) with 355 nm excitation and 50 ns gate width.

The biofinder system was also used to make a color fluorescence image. Using Bayer RGB filters, three fluorescence images (red, green and blue) were recorded and used to generate a color fluorescence image shown in Fig 5. One of the advantages of the color biofinder is the ability to differentiate multiple biological materials in a target area by providing their fluorophore colors, along with morphologies. For example, green leaf plants are seen as bright red due to strong red fluorescence from chlorophyll. The biological materials on the lava rocks shows diverse microbial presence with colors ranging from red, green, blue, purple, and white.

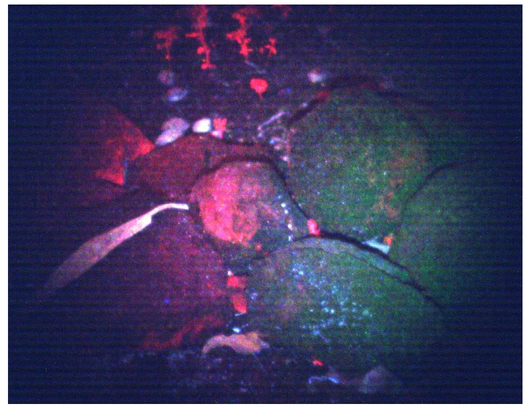
Fig.5: Color fluorescence image showing presence of biological diversity in the target area. Green leaf plants are seen as bright red due to intense chlorophyll fluorescence. Microbial diversity on the lava rocks are seen as various colors (red, green, purple, blue, white).

Summary: The standoff color biofinder instrument was successfully tested to detect biological materials outdoor during daylight from a 3 m distance and with 1 s integration time. The instrument is especially of interest to future NASA missions to Europa and other moons for rapid detection of biological materials in water and ice. Previously we have demonstrated detection of biological materials which are submerged in ice and water at the depth of several centimeters [4]. The biofinder system provides a fast non-destructive approach to detect important biological targets from a standoff distance which can help accelerate search for life missions.

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