“Color Biofinder” for fast, non-contact detection of biomaterials in Ocean Worlds

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Introduction: We have developed an instrument called Standoff Biofinder which is able to detect biomolecules and bio-markers from a collection of rocks and minerals in a large area with detection time of 0.1 s [1-3]. The Standoff Biofinder takes advantage of the short lifetime of bio-fluorescent materials [4] to obtain real-time images showing the locations of biological materials among luminescent minerals in a geological context. The instrument works in daylight as well as nighttime conditions and its bio-detection capability is not affected by the background light. One of the important features of the biofinder instrument is its capability to separate out bio-fluorescence from mineral luminescence. The interference from mineral luminescence has been an issue for detecting biological materials [5].

System description and experimental details: The standoff biofinder instrumentation uses a nano-second pulse laser to illuminate distant target materials. The laser beam is expanded to illuminate a large sample region. A gated detector equipped with a focusing lens is used to record time-resolved fluorescence images. The timing of the detector is synchronized with the pulsed laser. A notch filter is used in front of the focusing lens to reject the laser wavelength. The schematic diagram of the standoff biofinder instrument using a mini-ICCD detector is shown in Figure 1. The working principle of the biofinder system is discussed in detail in Misra et al., 2016 [3]. Since bio-fluorescence signals are very strong, biofinder system can be developed using compact color CMOS detector. Figure 2 shows a gated color CMOS detector used for taking data for this abstract. The entire detector unit with 10 diameter imaging lens and filters has dimension of 12 x 4.3 x 2.9 cm3 and weighs 147 g. The data presented in this abstract were recorded from a target distance of 50 cm with single laser pulse illumination using a Nd-YAG pulsed laser capable of simultaneously generating 355 nm and 532 nm pulses. Laser beam was expanded to a diameter of 12 cm, and samples were excited with total pulse energy of 1.6 mJ @ 355 nm plus 10.8 mJ @ 532 nm.

Results and discussion: Figure 3 (top image) shows a coral sample submerged inside 1000 ml of ocean water from the Pacific Ocean inside a glass beaker at a depth.
of 8 cm. The top image was taken by the color CMOS camera without any laser excitation from a 50 cm distance. The bottom image shows the bio-fluorescence image taken by the same camera from the same distance using a single laser pulse for fluorescence excitation with room lights on and fast gating of the detector. With the color bio-fluorescence imaging it is possible to detect several biological species based on their fluorophore color along with the morphologies. Because the blue green wavelengths can travel through depth of several meters in clear water, it is possible to look for biological materials in ocean and rivers using the biofinder system. It will be also useful for detecting bioresidues in the submerged soil and rocks in shallow water.

For icy planets, such as Europa, it will be possible to look through several centimeters of ice to locate submerged biological materials and their residues. Figure 4 shows standoff detection of submerged biological materials inside ice using biofinder system from 50 cm distance. Top image: White light image showing frozen ice and submerged corals and sea plants. Bottom image: Biofinder image (bottom image) showing the location of submerged bio-fluorescent materials inside ice as bright areas. (Ice diameter = 12 cm). Single laser pulse excitation and detection.

**Summary:** The standoff color biofinder instrument is especially of interest to future NASA missions to Ocean Worlds for rapid detection of biological materials in water and ice. Due to penetration of blue green laser light in water and semi-transparent ice, it is possible to detect biological materials which are submerged in ice and water at the depth of several centimeters with detection time less than 1 ms. The color standoff biofinder system will be a suitable search of life instrument for non-destructive, day operation, and fast detection, of biological materials for planetary exploration, without sample collection.

**Acknowledgments:** This work has been supported by NASA EPSCoR grant NNX13AM98A, NSF grant Đike Wai and Mars 2020 mission.