

## Luminescence Imager for Exploration

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**Relevant Technology Showcase Abstract:** Enceladus Orbilander objective to search for cell-like morphologies.

**Introduction:** The Luminescence Imager for Exploration (LiFE) is an automated bright-field and epifluorescence microscope designed to identify and characterize morphological and textural indicators of life and to identify, resolve, and characterize microscale structural features indicative of cells and cell fragments. To achieve these objectives, LiFE uses visible light to image organic and inorganic structures with submicron resolution, combined with, deep ultraviolet (DUV), ultraviolet (UV), and visible-light excitation for autofluorescence characterization of sample organic and mineral content. LiFE also autonomously manipulates samples to stain key molecular and structural indicators of microbial life (e.g., proteins, lipids, and nucleic acids) for fluorescence microscopic detection.

**LiFE Microscope:** LiFE is a high-resolution optical microscope (Fig. 1) that can spatially resolve structures smaller than 0.5  $\mu\text{m}$  in size using bright-field imaging. Light Emitting Diodes with wavelengths centered near: 265, 370, 470, and 530 nm are used to excite autofluorescence. The use of multiple excitation wavelengths not only allows for the detection of different molecular species, but also their rough classification. Excitation at 265 nm allows for the detection of smaller polycyclic aromatic hydrocarbons (PAHs; 1-5 rings), aromatic amino acids, and proteins with little to no interference from mineral fluorescence with proper emission band selection. 370 and 470 nm light excites increasingly larger PAH structures (e.g., coronene) and larger aromatic biomolecules that may be present (e.g., protective pigments). Similarly, inorganic fluorescence can be characterized and separated from organic fluorescence, allowing the recognition, and in some cases, classification, of minerals and other abiotic particles.

**LiFE Sample Processing:** After receiving an ice-rich sample, it is melted and then pumped to a rotary sample stage that is used to filter and isolate particles for processing and imaging. A stepper-motor positions the stage and directs the sample to a set of high-porosity silicon-nitride particle-capture filters as it aligns each filter set beneath the microscope objective. The in-line filter-set captures successively smaller particle sizes on 10, 1.0, and 0.2  $\mu\text{m}$  pore-size filters for imaging. Incremental stage rotation provides microscope alignment with the filters, permitting the microscope to be mechanically fixed except for piezo-driven z-motion normal to the sample stage that is used for autonomous z-stack focusing. A fluidics manifold connected to the rotary sample stage stores freeze-dried buffer, reconstituted using ultrahigh purity water before sample analysis and used to establish a circumneutral pH for cell staining. Fluorescence stains are stabilized and preserved in lyophilized form on porous-polymer support structures in the manifold and reconstituted with buffer at time of use. Four stain sets each contain 3 separated, lyophilized dyes for co-staining of proteins, lipids, and nucleic acids. Characterizations are performed using embedded sensors (pH, redox potential, conductivity, pressure) located on the fluidics manifold for sample-processing automation and control and also to provide information related to environmental habitability.

**Acknowledgements:** ELM is based upon work supported by NASA issued through the SMD Concepts for Ocean worlds Life Detection Technology (COLDTech), Instrument Concepts for Europa Exploration-2 (ICEE-2), and Maturation of Instruments for Solar System Exploration (MatISSE) programs.

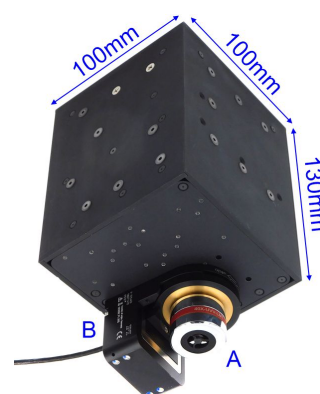


**Fig. 1.** Photo of the LiFE microscope. (A) Custom objective (B) piezo stage.

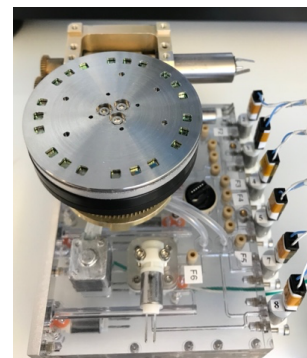


**Fig. 2.** LiFE rotary sample stage with integrated fluidics manifold underneath (9 x 8 x 4 cm).