SLIMERS:
Searching for Life on Icy Moons with Excitation and Raman Spectroscopy.

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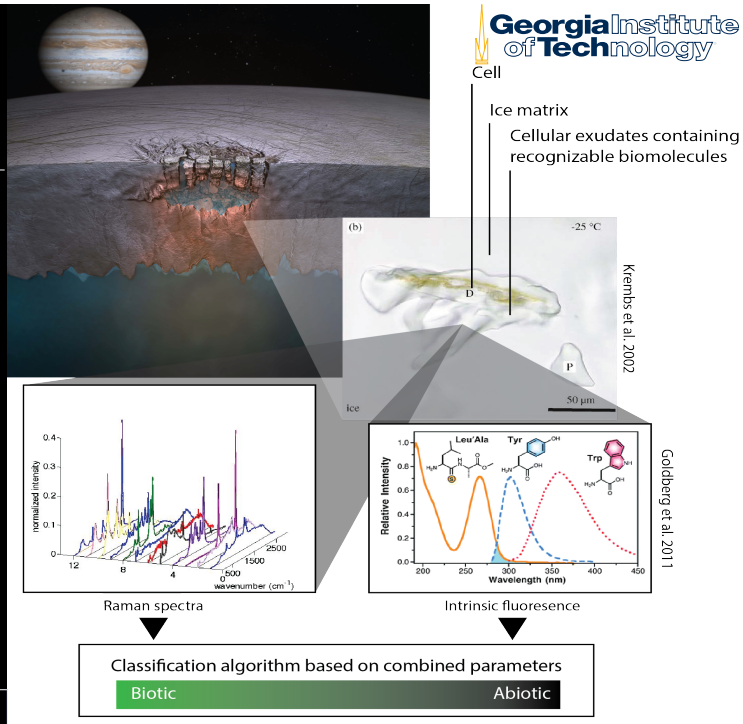
Table 1. SLIMERS Capability Justification

NASA Strategic Objective	SMD Division Science Goals	Decadal Survey Priority	SLIMERS Science Capability
Planetary Science – Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere.	1. Explore and observe the objects in the solar system to understand how they formed and evolve. 2. Advance the understanding of how the chemical and physical processes in our solar system operate, interact and evolve. 3. Explore and find locations where life could have existed or could exist today.	b. Planetary Habitats—search for the requirements for life (3, 4) c. Workings of Solar Systems—reveal planetary processes through time (1, 2, 5)	1. Collect the fluorescence spectra of samples excited at multiple wavelengths (248.6, 405, and 532 nm) with 0.5 nm wavelength resolution from 350 nm to 650 nm for *biomarker detection*. 2. Collect Raman spectra of samples irradiated at multiple wavelengths (248.6, 405, 532, 785 nm) with 0.5 nm wavelength resolution from 250 nm to 1100 nm for *life detection*. 3. Collect SERS spectra of samples irradiated at multiple wavelengths (405, 532, 785 nm) with 0.5 nm wavelength resolution from 425 nm to 1100 nm for *life detection*.



Life detection is a complex goal requiring multiple lines of corroborating evidence. For sampling systems, this is a particularly difficult constraint since multiple instruments are needed to make convincing detections but discreet samples cannot easily be passed through multiple instruments. This is especially true when destructive techniques are used, i.e. GCMS. To realize the capability to run many tests on a single source, we will adapt and test a miniaturized optical suite with non-destructive techniques that combine multiple lines of evidence for more robust life detection within discrete samples. By obtaining information on organic molecules and a range of potential biosignatures with high resolution and sensitivity, we can quantitatively assess the composition and structures of organic materials in a given sample and make a preliminary classification of the material as biotic or abiotic. This instrument (SLIMERS): Searching for Life on Icy moons and Mars with Excitation and Raman Spectroscopy) is based on our experience finding and characterizing life in low-biomass environments, including the Arctic, Antarctic and other extreme environments on Earth. SLIMERS integrates a multi-channel fluorescence spectrometer and a Raman spectrometer with a surface enhanced mode to obtain information from samples. By characterizing the chemical complexity, we can classify individual samples as potentially biotic or abiotic.

SLIMERS will be a prototype life detection system that includes fluorescence and surface-enhanced Raman analysis. This system will:

1) Collect the fluorescence spectra of samples excited at multiple wavelengths (248.6, 405, and 532 nm) with 0.5 nm wavelength resolution from 350 nm to 650 nm and identify diagnostic features and sensitivity limits.

2) Collect Raman spectra of samples irradiated at multiple wavelengths (248.6, 405, 532, and 785 nm) with 0.5 nm wavelength resolution from 250 nm to 1100 nm and identify diagnostic features and sensitivity limits.

2) Collect surface-enhanced Raman spectra of samples irradiated at multiple wavelengths (405, 532, and 785 nm) with 0.5 nm wavelength resolution from 425 nm to 1100 nm and identify diagnostic features and sensitivity limits.

This instrument suite is primarily geared to address high priority science goals for the detection of biomarkers of extinct or extant life on the surface and in the sub-surface of planets: these coupled techniques can be used for ocean world targets including Europa, Enceladus and Titan, as well as for searching for life within water or ice samples on Mars. The same techniques can be applied to characterize organics within ices liberated by plumes and comet comae, and thus could be applied on missions seeking to understand the generation of the building blocks of life on small bodies throughout the solar system. Our compact, multi-technique instrument will be compatible with obiters and landed platforms, including stationary, roving, buoyant or submersible platforms—any system that can deliver ice or aqueous samples to the instrument.

Figure 3. Programmable Microfluidic Architecture: (A) Valve operation is unchanged, but (B) the rectilinear array pattern enables complex mixing operations. (C) A photograph of a 4x4 core.

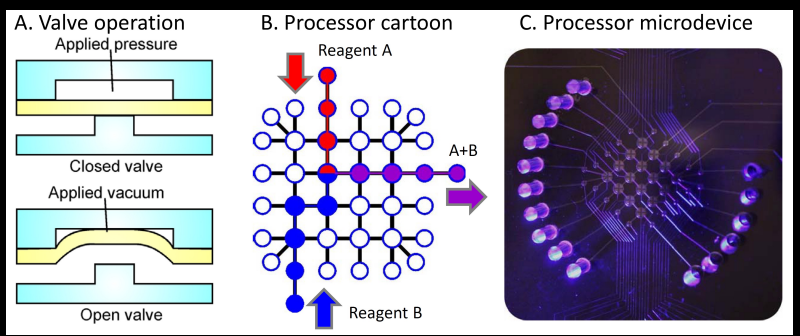


Fig. 1 Our proposed optical techniques are highly complementary, and also can be conducted using a single optical instrument by implementing the optical elements along a microfluidic system enabled by the training algorithm. Therefore, the SLIMERS instrument will incorporate these three optical measurements for the first time in a single instrument, in a microfluidic device to enable the use of small samples passed from one technique to the other with minimal change and loss. The flow rate is controlled by the user – from a dead stop through nL/min to mL/min. These high throughput rates mean that SLIMERS can accomplish a nearly infinite number of analyses on the initial sample and is ultimately constrained by the lifetime of the lander. Our preliminary design system is 5-10 kg with power of less than 1 W. Once these analyses are run, Raman can be run on a subset of the samples and then the SERS analyses is expected to run 24 analyses (i.e. one a day) as that will use a consumable to mark the high priority particles.

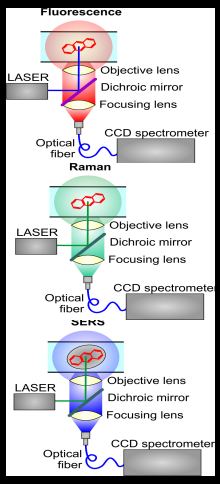


Figure 2. (left) SLIMERS integrates a multi-channel fluorescence spectrometer and a Raman spectrometer with a surface enhanced mode to obtain information from discrete samples. By obtaining quantitative spectral information on organic molecules and potential biosignatures with high sensitivity, we can make a preliminary classification of materials as biotic or abiotic, and detect biomarkers and life within a single discreet sample.

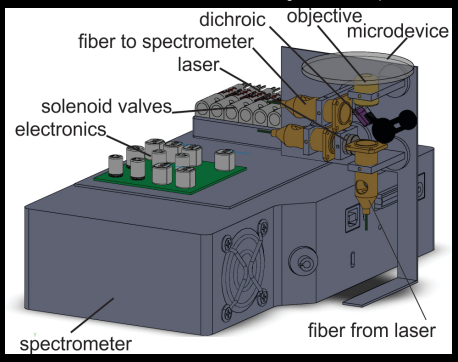


Figure 4. (above right) An initial, single-wavelength design of the 405 nm excitation fluorescence, Raman, and SERS optical detection subsystem of the SLIMERS prototype. While deep UV lasers (and even 405 and 532 nm lasers) can degrade the chemicals under investigation, particularly those that exhibit weak bonds (e.g., peroxides, perchlorates), our unique PMA architecture allows for the facile incorporation of Surface Enhanced Raman Spectroscopy (SERS). SERS can typically be induced by the addition of suspended silver (Ag) or gold (Au) nanoparticles, nanorods, nanoshells, or nanostars as well as Raman reporter molecules (molecules with large resonance/absorption cross-sections) attached to the surface of the nanoparticles, often within a polyethylene glycol (PEG) or SiO2 protective layer to form Raman tagging agents. Thus, these agents can be introduced to our sample mixture to enhance the signal prior Raman analysis. The size of the nanoparticles as well as the specific Raman reporter used can be tailored for specific excitation wavelengths. The detection limits utilizing SERS with or without additional Raman tagging demonstrate impressive enhancement factors (up to 1011) covering wide classes of molecules of interest from a biomolecular viewpoint, Our set-up will likely reach enhancement factors of 106 to 108, which are regularly achievable without elaborate set-ups. Raman is also suited to elucidate the bulk compositions of Europa and Enceladus and Titan where compositions from ppm are readily identified.