Standoff Laser Ablation Mass Analyzer (LAMA) for Lunar Surface Analysis

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Abstract

Lunar exploration is central to addressing key questions about the origin and evolution of the Solar System while supporting the development of sustainable human presence beyond Earth. Future missions will require rapid, high-resolution chemical and isotopic analyses of diverse lunar materials *in situ*, at fine spatial scales, and with minimal sample preparation. The Laser Ablation Mass Analyzer (LAMA) is a novel instrument designed to meet this need by combining the efficiency of pulsed laser ablation sampling with the sensitivity and accuracy of time-of-flight mass spectrometry (TOF-MS) for operation in the lunar vacuum. LAMA integrates a Q-switched Nd:YAG laser (1064 nm) with a heritage TOF-MS design derived from Phobos-Grunt and Luna Resurs missions and introduces a unique standoff analysis mode that enables compositional measurements over adjustable target ranges from 5 cm to more than 30 cm. This approach, achieved through dynamically tunable ion optics employing shape-changing lenses made of optical fluids and polymer membranes, eliminates the need for bulky mechanical components, allowing for a compact, few-kilogram payload with low power demands ideally suited for robotic landers, rovers, or astronaut-deployed platforms. Laboratory testing with lunar analog materials demonstrates ppmw detection limits for many rock-forming and trace elements, semi-quantitative determination of elemental ratios within ±10% relative standard deviation, and fine-scale (micron to millimeter) resolution suitable for heterogeneous samples. High-intensity laser operation enables correlated detection of H^+ and O^+ ions for water ice prospecting, supporting both scientific investigations and resource prospecting for human exploration. Furthermore, LAMA can operate semi-autonomously to locate and characterize high-priority phases across an exploration area and can be used within astronaut habitats for detailed follow-up studies of collected samples, complementing other instruments. By enabling chemical, isotopic, and mineralogical analyses directly on the lunar surface without sample handling, LAMA significantly advances the ability to provide ground truth for orbital observations and identify resource-rich regions critical for sustained exploration. This instrument represents a transformative step in standoff mass spectrometry for planetary missions, offering a much-needed capability for efficient, high-resolution, and non-destructive surface analyses that directly address priority lunar science and human exploration objectives of the coming decade and beyond.

Biography - Xiang Li

Xiang Li received his Ph.D. in Physical Chemistry from the Johns Hopkins University in 2009. He is a mass spectrometry scientist at NASA Goddard Space Flight Center. His research focuses on the detection of trace element and astrobiologically relevant organic molecules in planetary systems, such as Mars, Europa and Titan. He is especially interested in the instrument development of time-of-flight and ion trap mass spectrometers with various ionization and ion gating techniques.

Keywords

LAMA, Standoff, Lunar surface