Development of the Potassium-Argon Laser Experiment (KArLE) instrument for *in situ* geochronology measurements

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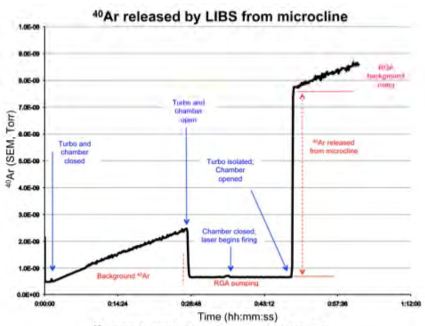
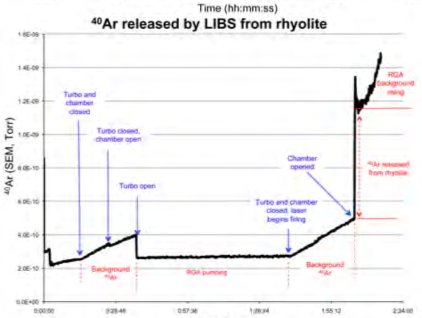
Motivation

- Absolute dating of planetary samples is an essential tool to establish the chronology of geological events, including crystallization history, magmatic evolution, and alteration
- Other in situ instruments to measure rock ages have been proposed, but none have reached TRL 6, because isotopic measurements with sufficient resolution are challenging
- KArLE is a new development effort under the NASA Planetary Instrument Definition and Development Program (PIDDP) begun in late 2011
- The aim of KArLE is to determining the age of several kinds of samples to ±100 Myr, sufficient to address a wide range of problems in planetary science
- Additional benefits derive from the fact that each KArLE component achieves analyses common to most planetary surface missions, such as elemental analysis and imaging

Quadrupole mass spectrometry (QMS)

- Measurement goal: ≤ 2% absolute ^{40}Ar abundance

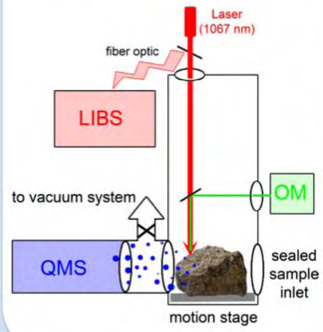


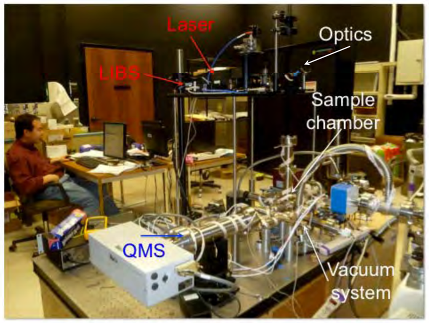


***^{40}Ar abundance in microcline and rhyolite test samples**. The mass spectrometer magnetic field was set to the ^{40}Ar peak position and run in continuous measurement mode during the LIBS measurements. ^{40}Ar buildup from background is small compared to the amount released from the sample. The microcline measurement is the total release from 200 laser shots and the rhyolite from 370 laser shots.*

KArLE Concept of Operations

- Unprepared sample (~2 cm) introduced by the spacecraft
- Infrared laser ablates a pit in the rock
- K measured using laser-induced breakdown spectroscopy (LIBS)
- Liberated Ar measured using quadrupole mass spectrometry (QMS)
- K and Ar related by volume of the ablated pit using optical measurement (OM)
- Testbed verification used two samples: rhyolite and microcline





KArLE Breadboard	Flight Equivalent
Hiden HAL/3F 51 Residual Gas Analyzer	MSL Sample Analysis at Mars (SAM) mass spectrometer

KArLE Breadboard	Flight Equivalent
Keyence VK-X200 Laser Confocal Microscope KLA/Tencor MicroXAM Vertical Scanning Interferometer	Phoenix Atomic Force Microscope

Development Path

Task 1: Construct vacuum chamber and integrate LIBS and QMS
Task 2: Conduct end-to end tests on analog samples
Task 3: Verify optical requirements and integrate into operations
Task 4: Integrate SAM/ChemCam spares (if available)
Task 5: Produce candidate flight design and requirements for PIDDP step 2

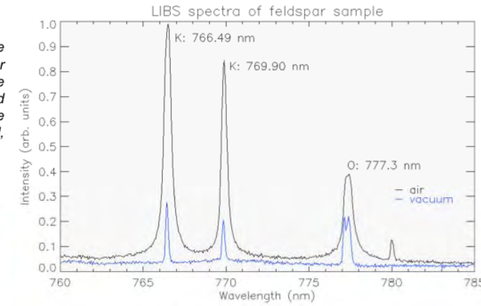
PIDDP 2011-2014	PIDDP 2014-2017	Mission 2017-?
Breadboard (component tests and trades) TRL 1-4	**Brassboard** (integration and environment tests) TRL 4-6	**Flight Unit** (flight unit build and qualification) TRL 6-9

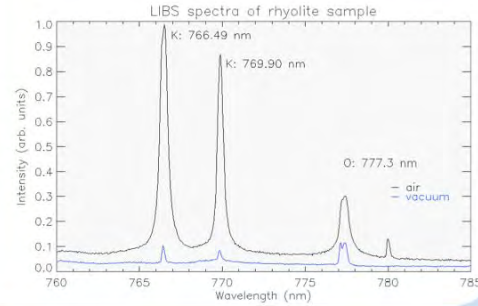
Laser Induced Breakdown Spectroscopy (LIBS)

- Measurement goal: ≤ 10% relative K abundance

KArLE Breadboard	Flight Equivalent
Ocean Optics LIBS 2500+	MSL ChemCam (without telescope)

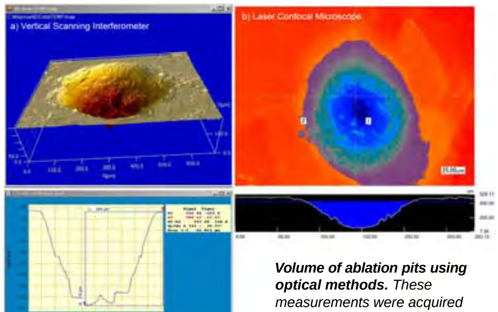
***LIBS Spectra of microcline and rhyolite test samples**. Both sample spectra in air were acquired with 100 shots each. The feldspar spectrum in vacuum was acquired with 200 shots, and the rhyolite spectra in vacuum with 370 shots. Each spectrum was acquired individually and averaged during post processing. Backgrounds were taken each day consisting of at least 100 blank runs and averaged, then subtracted from the averaged sample spectra.*





Optical measurement

- Measurement Goal: 2% in ablation volume
- Volume x rock density yields the ablated sample mass - necessary to relate absolute Ar and relative K measurements
- Evaluating existing optical methods for accuracy and precision before integrating chosen optical method into KArLE



***Volume of ablation pits using optical methods.** These measurements were acquired using two different optical methods on samples different from the LIBS/MS samples so are not directly comparable. However, they show the suitability of either method for measuring pit volume.*