The Potassium–Argon Laser Experiment (KArLE): Design Concepts
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1. Background

◆ When were they formed?

![Image of Mars stratigraphy]

- Beautiful stratigraphy observed by Curiosity on Mars. Nobody knows exactly when these layers were formed. Knowing the absolute ages is important to understand the processes that caused these deposits.

- An important goal of the science community is to measure the age of various key geologic units to reconstruct Martian history and correlate it with other Solar System events.

2. In situ K–Ar dating

- Schematics of KArLE measurements. Spot-by-spot analyses yield the isochron age of target rocks, enhancing the reliability and accuracy of the K–Ar age measurement.

- K–Ar dating with LIBS–MS approach

K–Ar age $t = \frac{1}{\lambda} \left( \frac{\Delta^{40}Ar}{\Delta^{39}Ar} - 1 \right)$

1. Laser ablates a target rock in vacuum chamber
2. K contents measured with LIBS (e.g., ChemCam)
3. Released Ar measured using mass spectrometry (e.g., SAM)
4. K and Ar related by volume of the ablated pit using optical measurement (e.g., MAHLI)

- Use TRL 9 components to achieve new science
  1. Payload synergy
  2. Reasonable cost
  3. Low risk
  4. Near-term implementation

3. KArLE breadboards

- KArLE breadboard at MSFC
- Breadboard in Japan / Field test at Izu island

4. KArLE flight concepts (examples)

- KArLE enables various configurations, because
  1. KArLE is a partner-provided instrument suite, agnostic to specific analysis providers
  2. KArLE allows for flexible implementation with multiple sample delivery systems (e.g., core, pebble, and slab)
  3. KArLE-specific hardware is mechanically simple sample handling system (SHS), which provides vacuum sealing and laser pits observation

- Curiosity-like configuration. The mast mounted LIBS measures the sample in the KArLE chamber. The chamber could be mounted on the deck or inside the rover body. The gas processing system and the mass spectrometer is stored in the rover body.

- Point design for candidate KArLE flight configuration

- KArLE Sample Handling System (SHS). The SHS must be capable of ingesting a sample, achieving a vacuum seal, and enabling the measurements to be performed on the enclosed sample. A SAM-like elevator actuator seats the chamber. Samples are introduced into and ejected from the chamber by a spoon-like manipulator.

- The amount of residual $^{40}K$ when different elastomeric O-rings are used under various ambient conditions. Silicon O-rings can maintain an Ar pressure of 600 psi.

5. Results of LIBS experiments

- Emission spectrum of a standard sample
- Calibration curve at the laser pulse energy of 30 mJ. Best-fitting curve and to prediction bands are shown.

6. Obtained Isochrons

- K–Ar isochron for the hornblendite-biotite gneiss. The data points follow one regression line well, supporting the viability of isochron measurements with the LIBS–MS approach. The slope and intercept yield a K–Ar age of 750±190 Ma and an initial $^{40}Ar/^{39}Ar$ ratio of 440±290, respectively.

- $^{40}Ar$–$^{39}Ar$ plot for (a) hornblendite-biotite gneiss and (b) pyroxene gneiss samples. The 'isochron' slopes agree with the K–Ar ages determined for biotite separates with conventional methods.

7. Performance of K–Ar dating

- Compiled K–Ar dating results published from multiple labs. Results from multiple laboratories yield whole-rock ages within error of accepted ages and precision close to theoretical.

- TRL 4 (validation in the laboratory)

8. Work in progress

- Using the laboratory breadboard to measure Mars and Moon analog materials
- Characterizing and optimizing the performance of the components
- Pursuing funding for construction and test of the flight concepts

References

[Insert list of references related to the experiment and methodology]