Laser-Based Measurement Tools for Future Enrichment Plant Safeguards

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ABSTRACT

- PNNL is developing the Laser Ablation, Absorption Ratio Spectrometry (LAARS) method for destructive assay (DA) of uranium samples collected during enrichment plant inspections.
- This poster presents the LAARS measurement method, instrument design, and results of a recent assay precision study.

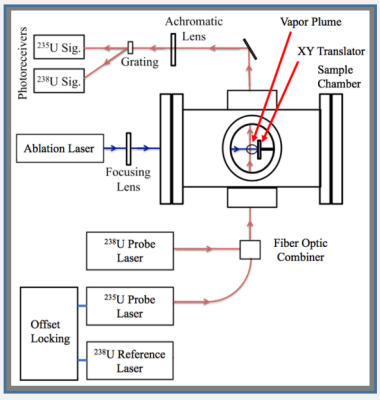
BACKGROUND

- **Value Proposition:** The IAEA has successfully leveraged many laser-based technologies for safeguards applications: 3D mapping, label scanning, tamper detection. Emerging laser technologies and measurement methods could help address gaps in enrichment plant DA safeguards.
- **Current Challenges**: On-site UF_6 DA is needed to address evolving difficulties in shipping hazardous samples. Discrepancies with operator declarations could also be addressed while inspectors are conducting physical inventory verifications. Fieldable mass spectrometers have had limited success. Combined Procedure for Uranium Concentration and Enrichment Assay (COMPUCEA) is now being used for on-site UF_6 analysis. Implementing COMPUCEA may be challenging: resource-intensive, time-consuming, and complicated sample preparation chemistry.
- **Envision Solution:** Combine sample preparation by laser ablation, with uranium isotope analysis using wavelength-stabilized diode laser spectroscopy. Laser ablation has been used for many years as a direct sampling method for trace analysis. The narrow emission linewidth and wavelength tunability provided by diode lasers has enabled stable isotope analysis for geoscience, medical, planetary exploration, and many other applications.

METHODS

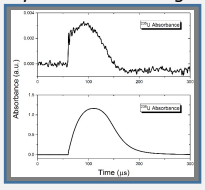
- Single-Use Destructive Assay (SUDA) sampler collects DA samples.
- Sample preparation using only a miniature pulsed Nd:YAG laser source to vaporize a pinpoint sample region (40 µm diameter).
- Two wavelength-stabilized diode lasers simultaneously measure the ^{235}U and ^{238}U atom concentrations in the vaporization plume.
- Measured absorbance signals are processed to provide direct $^{235}U/^{238}U$ ratio determinations at each vaporized point on the sample surface.
- A prototype LAARS laboratory instrument has been developed that provides assays in 30 minutes. Additional integration will lead to a fieldable system.

LAARS Instrument Schematic



SUDA Sampler Design

Isotope Absorbance Signals

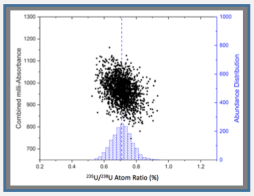


OUTCOMES

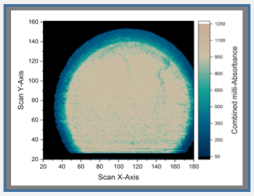
LAARS SAMPLE ASSAY

- Each LAARS assay produces 500 to 2000 ratio estimates. Each measurement is correlated spatially to the sample surface.

Sample Assay Distribution

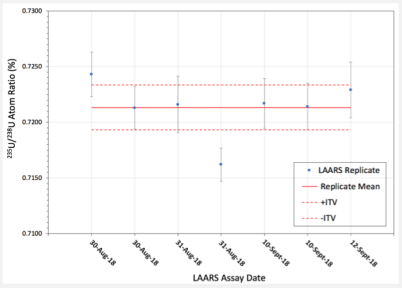


Sample Spatial Map



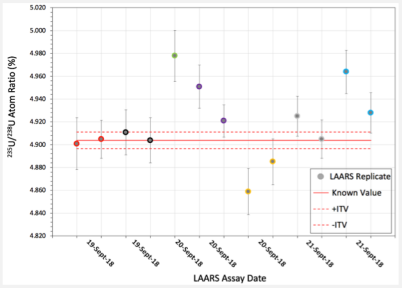
LAARS UF_6 REPLICATE ASSAY RESULTS

- Assays were conducted on individual natural uranium DA samples over a 14-day period to estimate LAARS assay precision. Samples were collected from the same source by the SUDA sampler.



The replicate $^{235}U/^{238}U$ mean and standard deviation for this study is 0.7213±0.0025% and the LAARS relative precision for NU SUDA samples is 0.35%. This performance nearly meets IAEA's 0.28% ITV goal for natural uranium DA by high-precision mass spectrometry.

- Assays were conducted on individual LEU uranium DA samples over a 3-day period to estimate LAARS short- and long-term assay precision. Samples were collected from the same source by the SUDA sampler.



The replicates study $^{235}U/^{238}U$ assay is 4.918±0.0276% and the relative precision for LEU SUDA samples is 0.56%. The <0.15% short-term precision is promising. Some effects degraded the overall replicate precision; however the LAARS performance is very promising. Future work is planned to reduce the systematic measurement errors.

CONCLUSION

- New DA technique developed to assay the $^{235}U/^{238}U$ atom ratio in samples collected during uranium enrichment plant inspections.
- A prototype laboratory LAARS instrument has been developed that can assay DA samples near the International Target Values (ITVs).
- Future work includes developing and testing a fieldable system.

ACKNOWLEDGEMENTS

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