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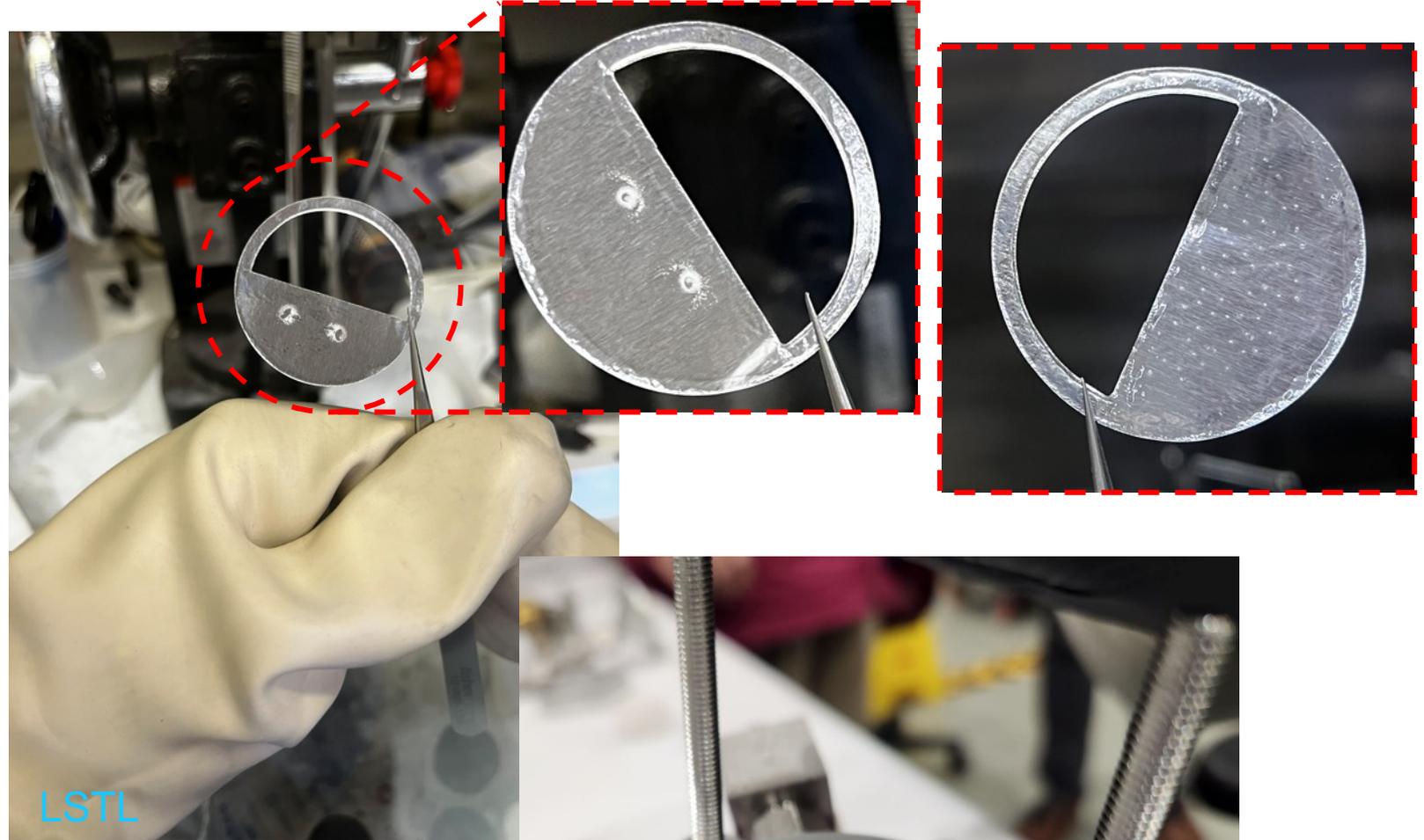
# LIBS for Elemental Monitoring of MSR Off-Gas Streams

Hunter B. Andrews  
Oak Ridge National Laboratory

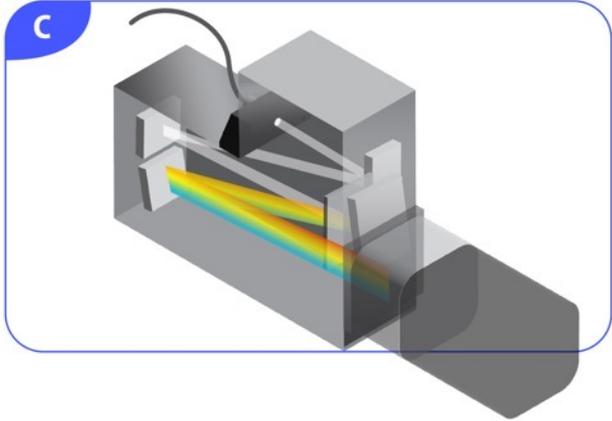
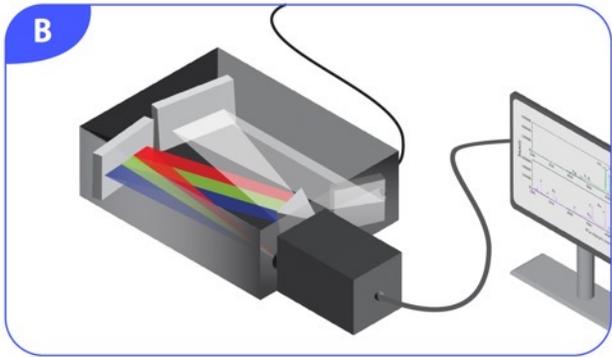
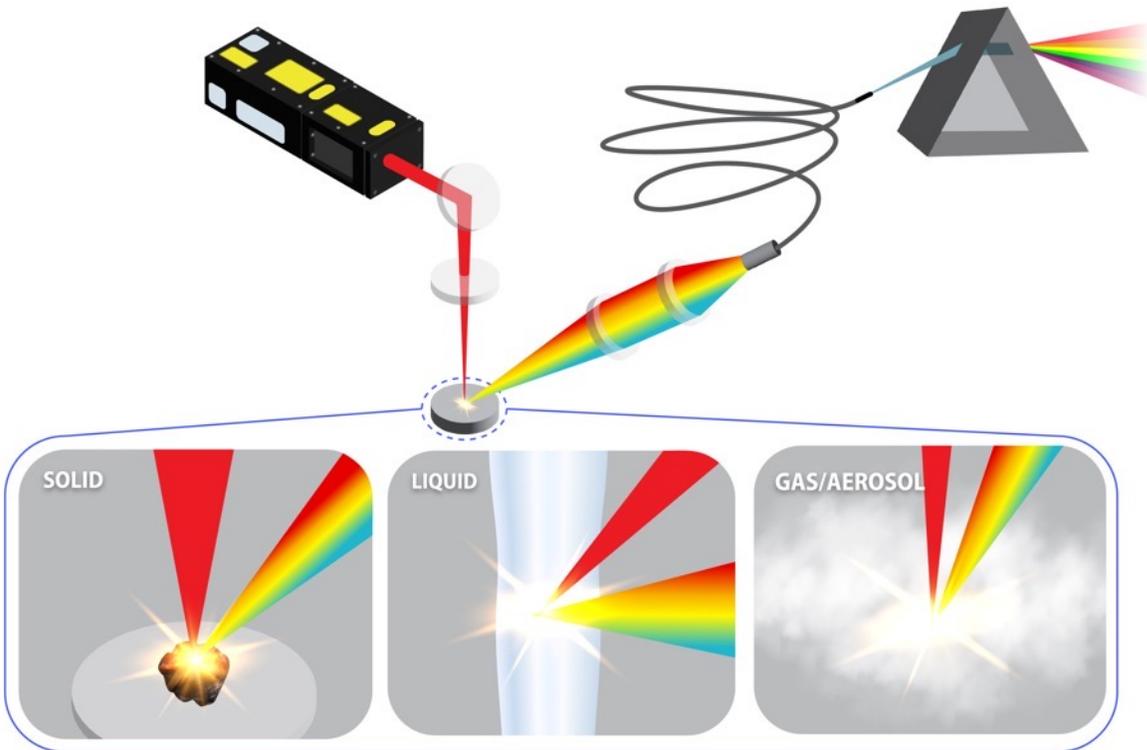
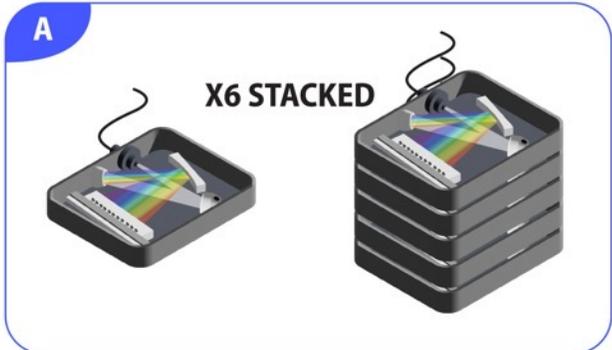
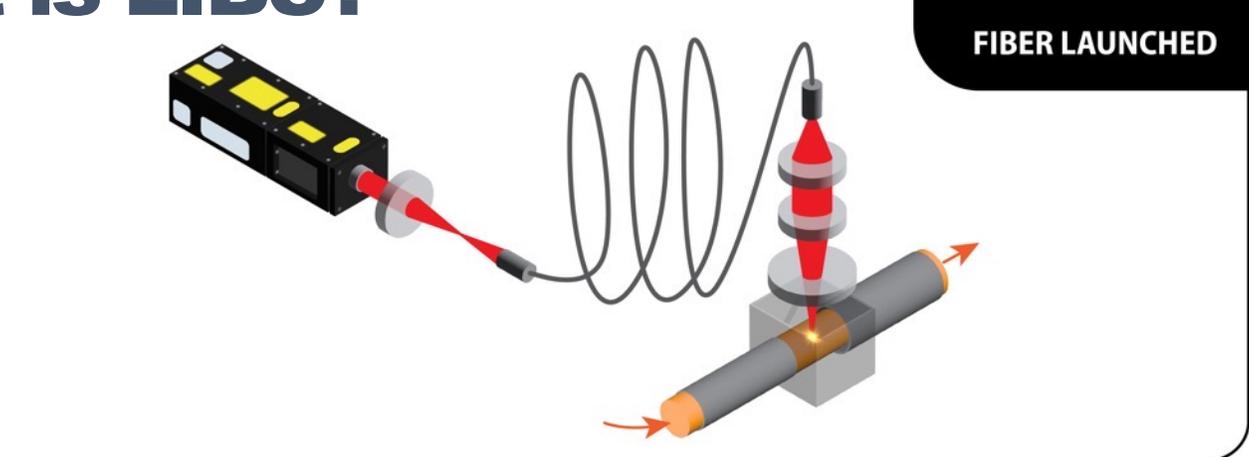
Annual MSR Campaign Review Meeting April 2024

# MSR Challenges

- Liquid fuel
- Inert environment
- Radiation
- Aerosol formation
- Changing chemistry

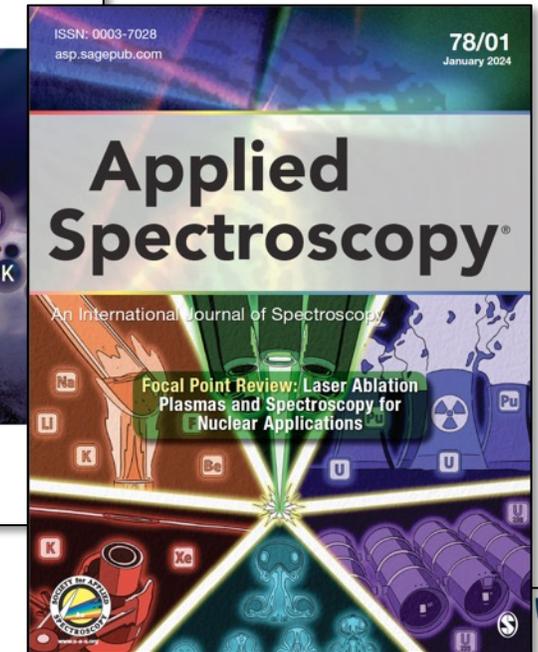
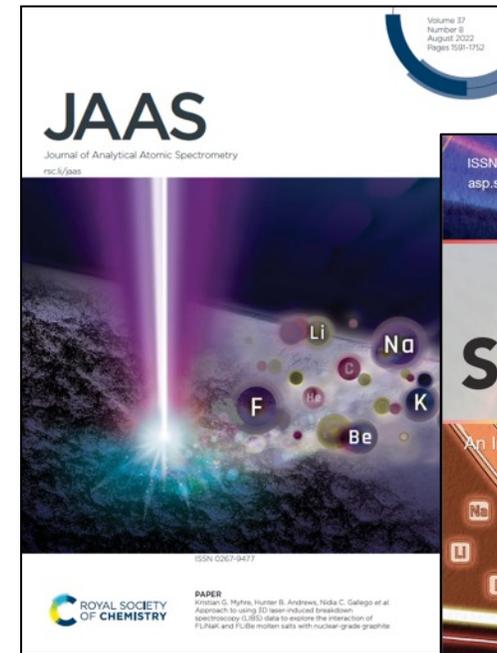


# What is LIBS?



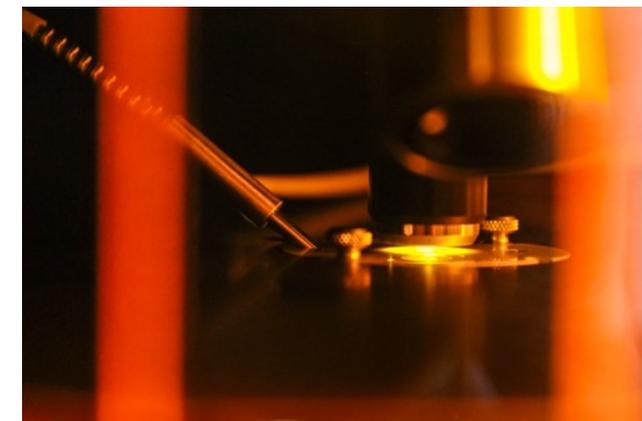
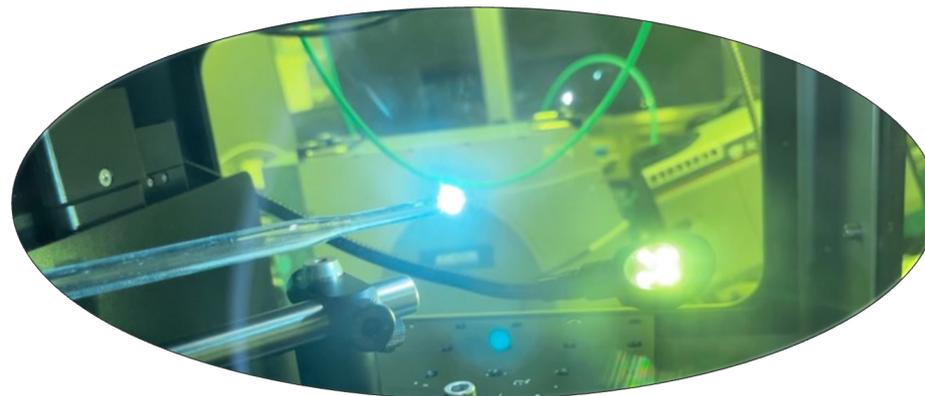
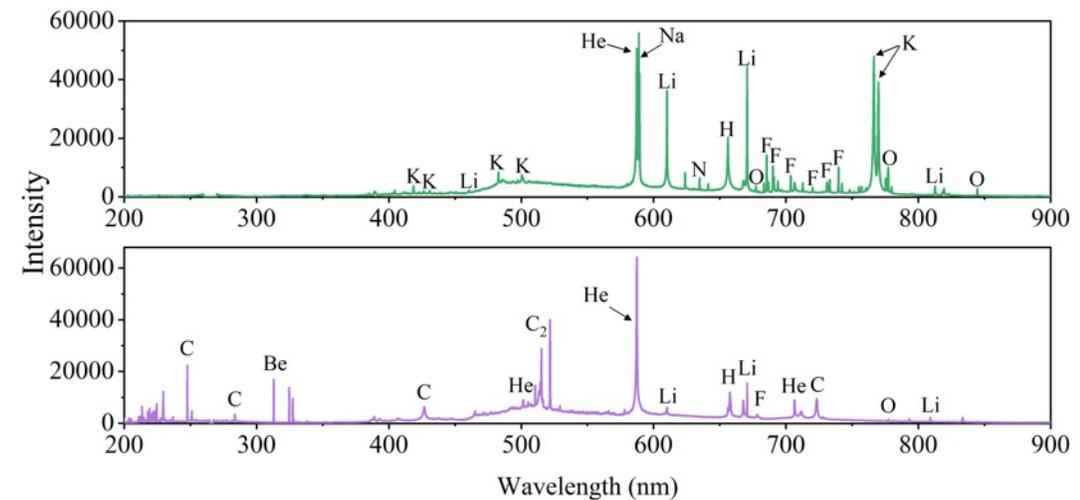
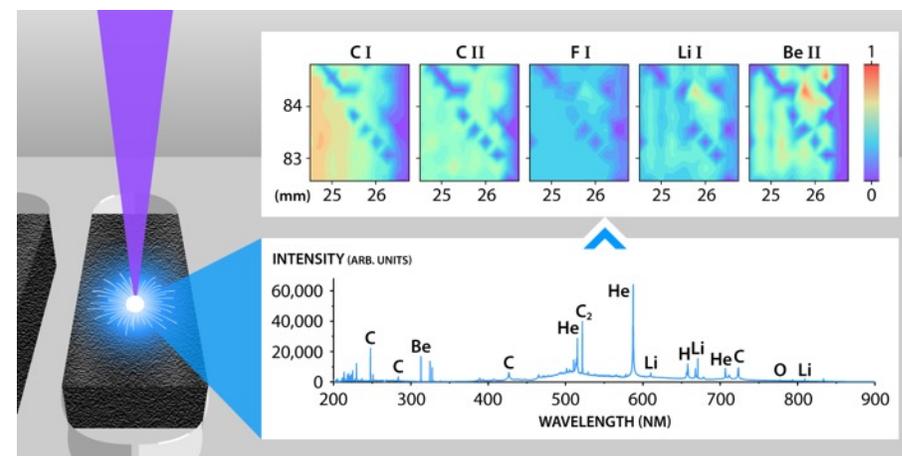
# Why LIBS?

- Sensitivity across the periodic table
- Capable of remote measurements
- Rapid analysis
- Customizable to the application
- Can monitor solids, liquids, gases, and mixtures
- Elemental (occasionally isotopic) technique

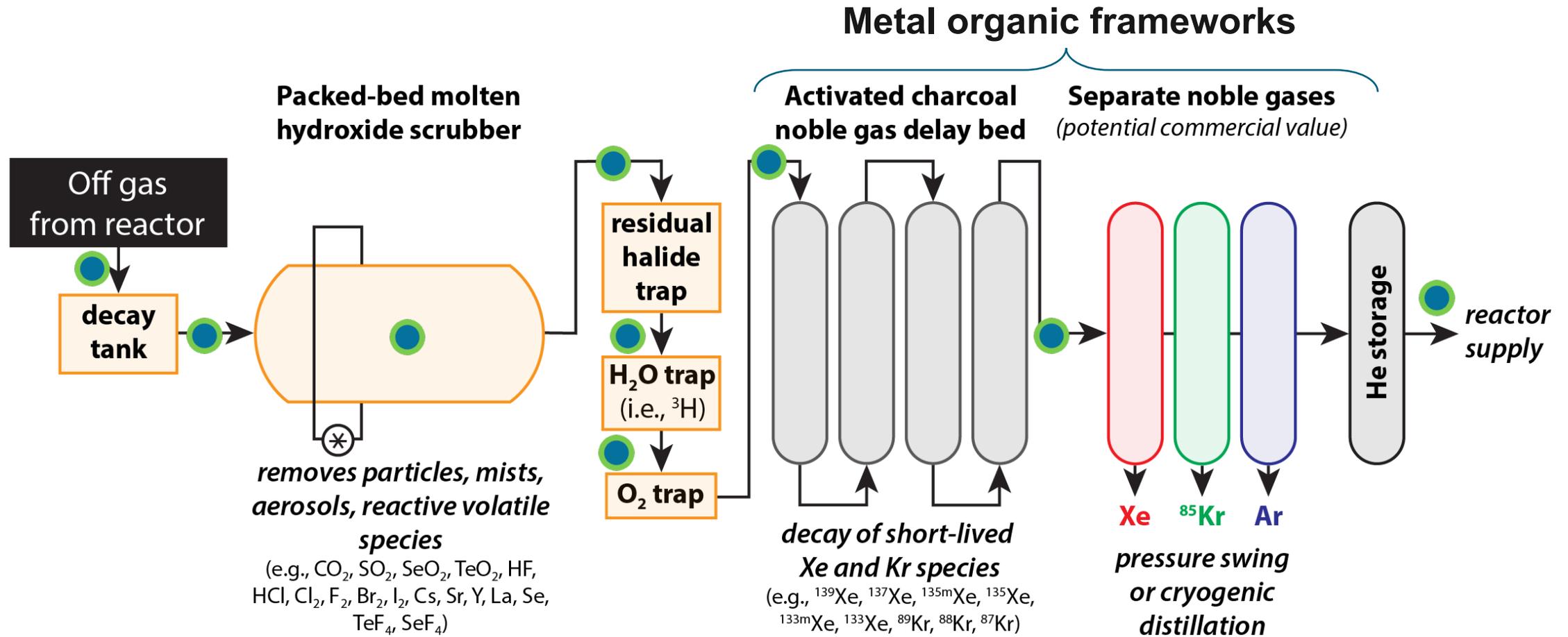


# How can LIBS be used?

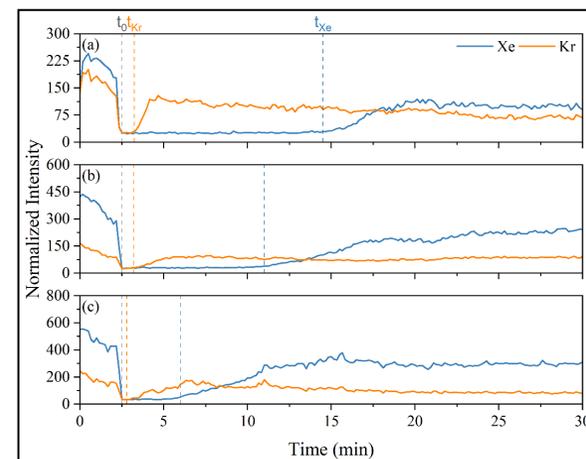
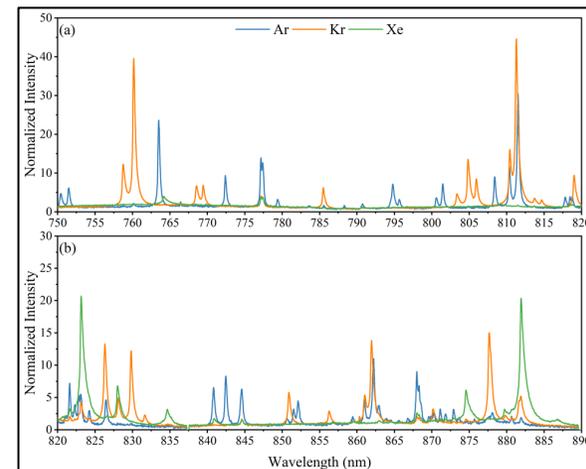
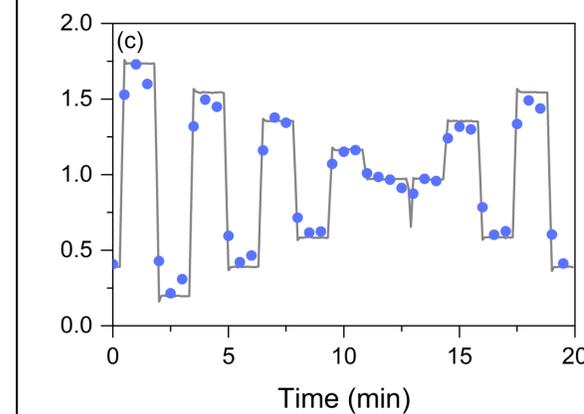
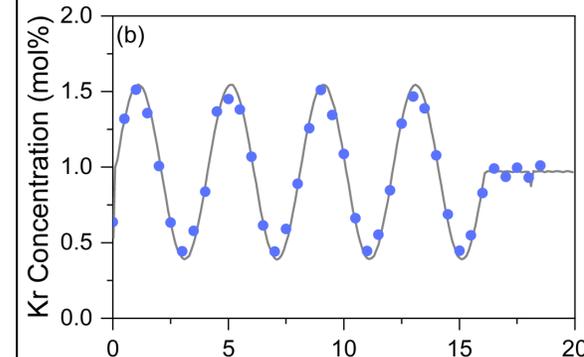
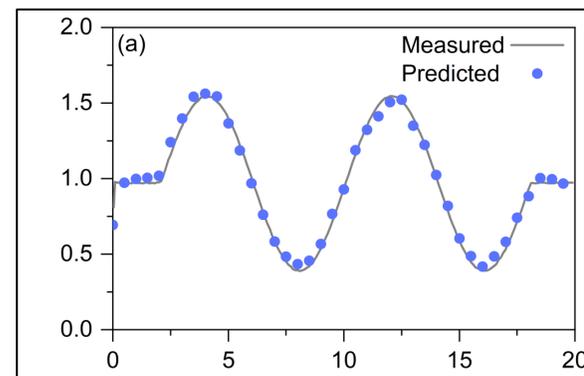
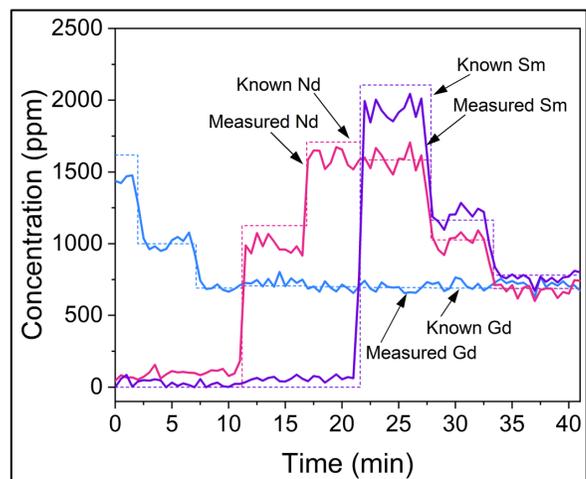
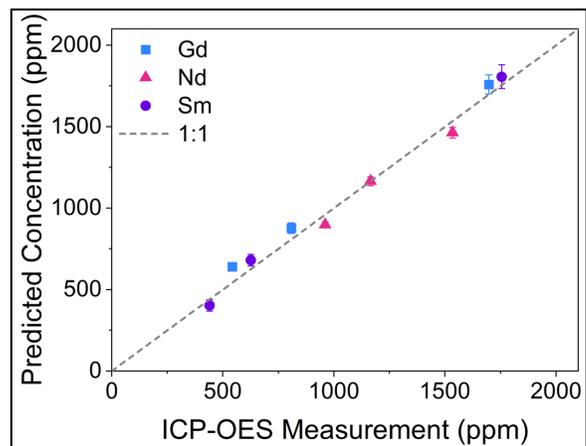
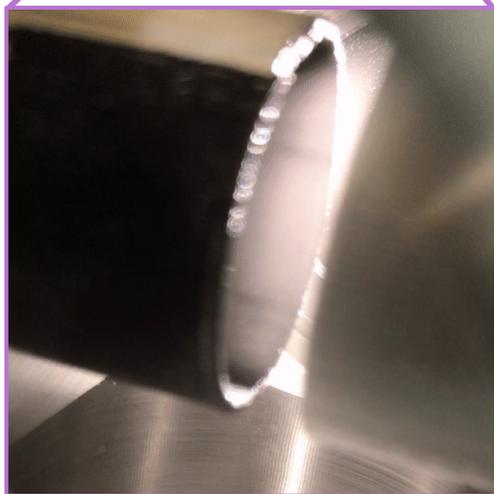
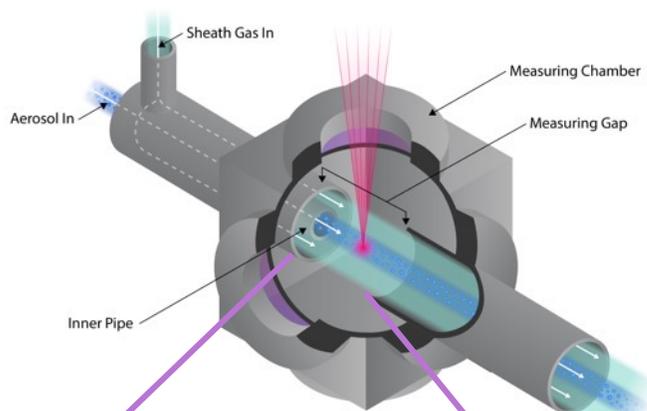
- Frozen salt analysis
  - As procured, purified, and post testing
- Investigating salt – material interactions
  - Graphite, structural materials
- Online monitoring
  - In-situ salt analysis, off-gas monitoring
- Real-time isotopic composition



# The off-gas treatment system development is critical for continued MSR development

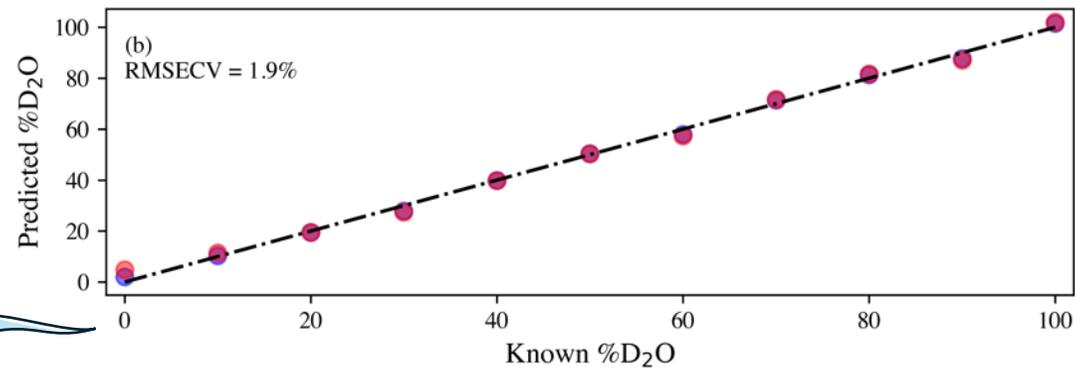
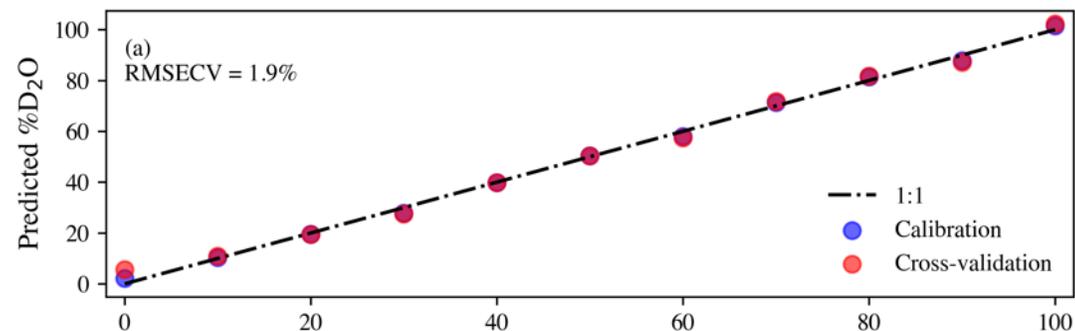
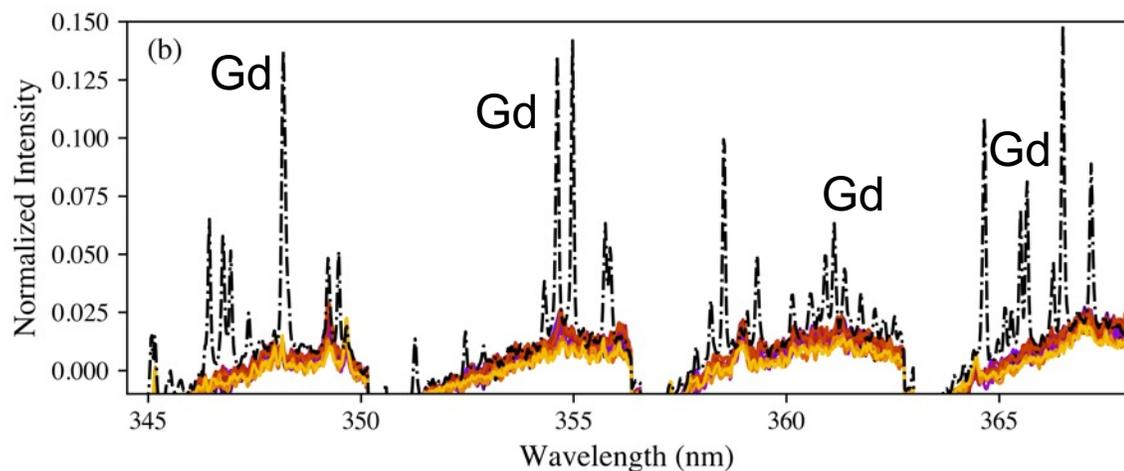
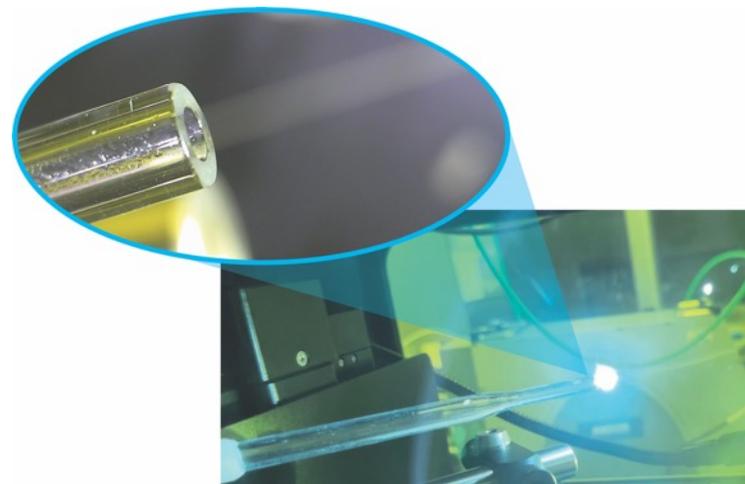
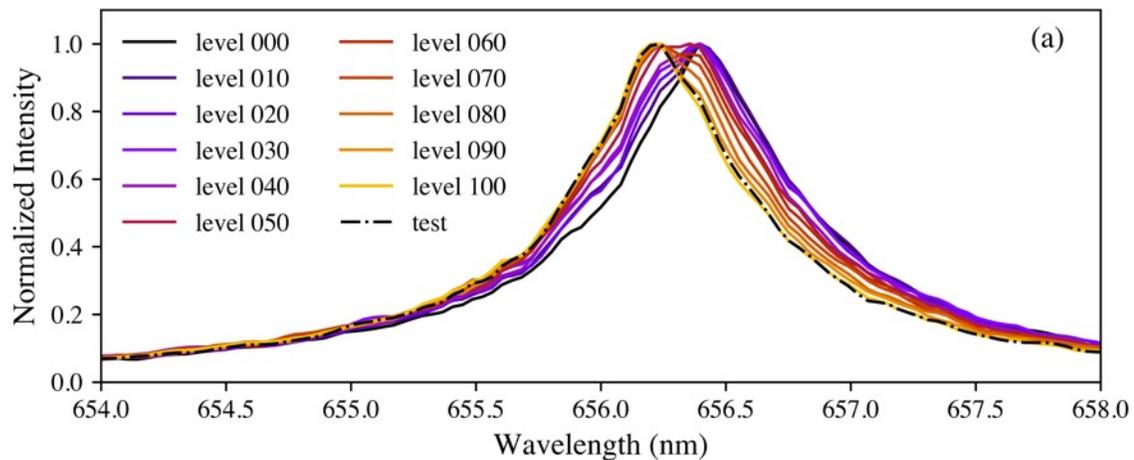


# MSR Off-gas streams can be monitored using LIBS



# LIBS can monitor isotopes relevant to MSRs

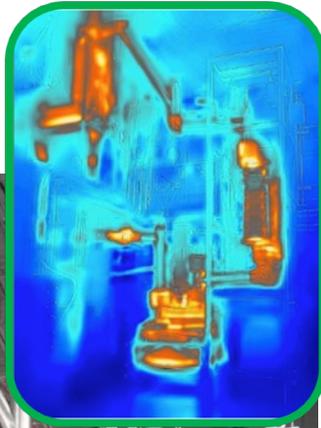
${}^2\text{D} \leftarrow {}^1\text{H}$



See talk tomorrow for more information on isotopic LIBS!

# A goal moving forward - deployment

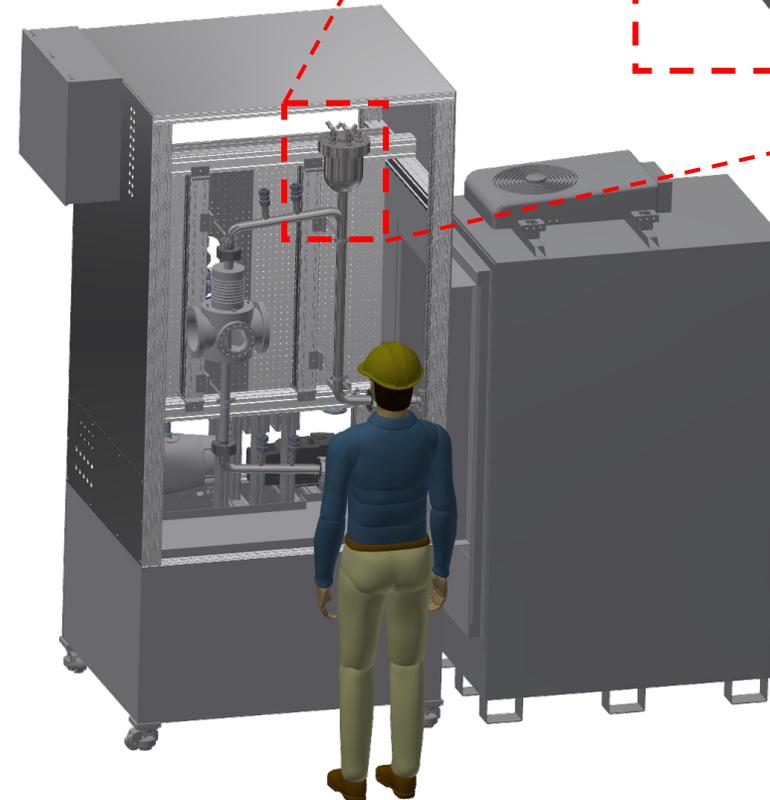
FASTR Loop



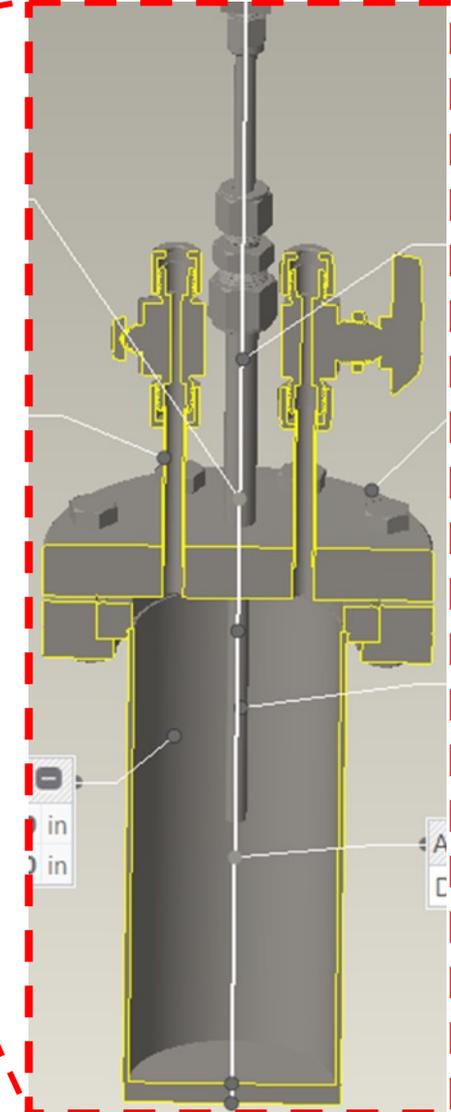
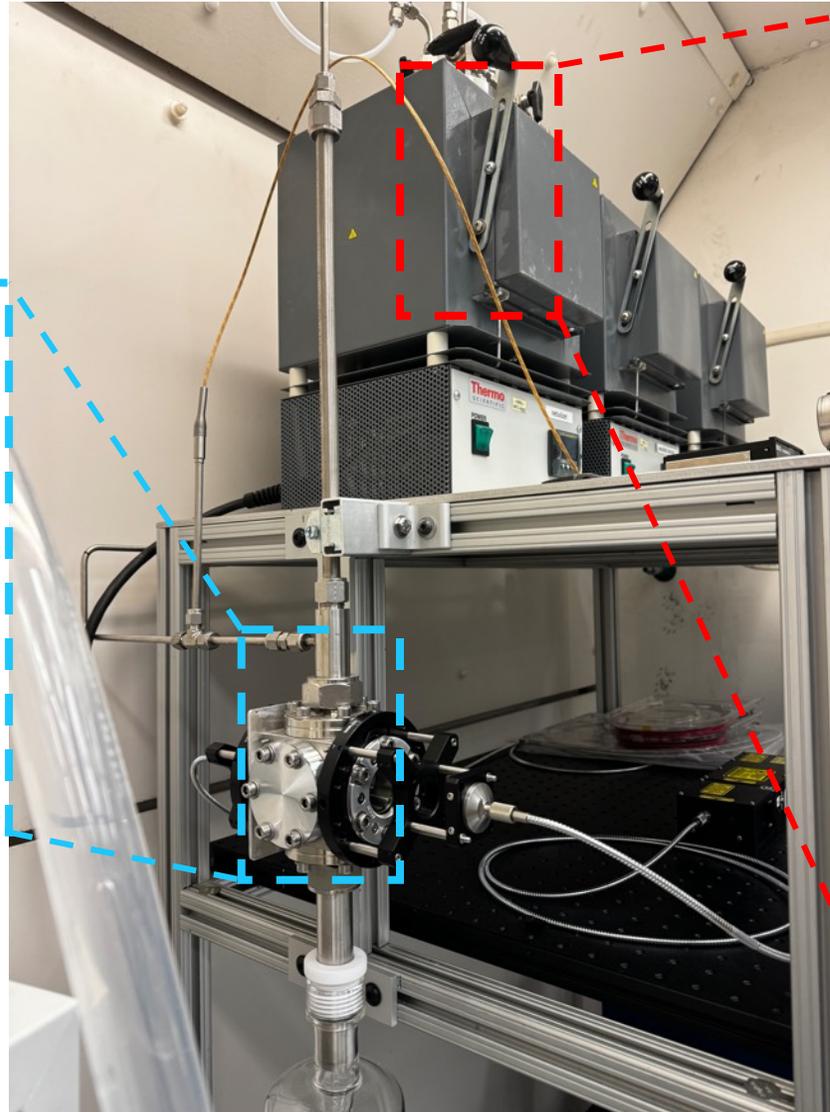
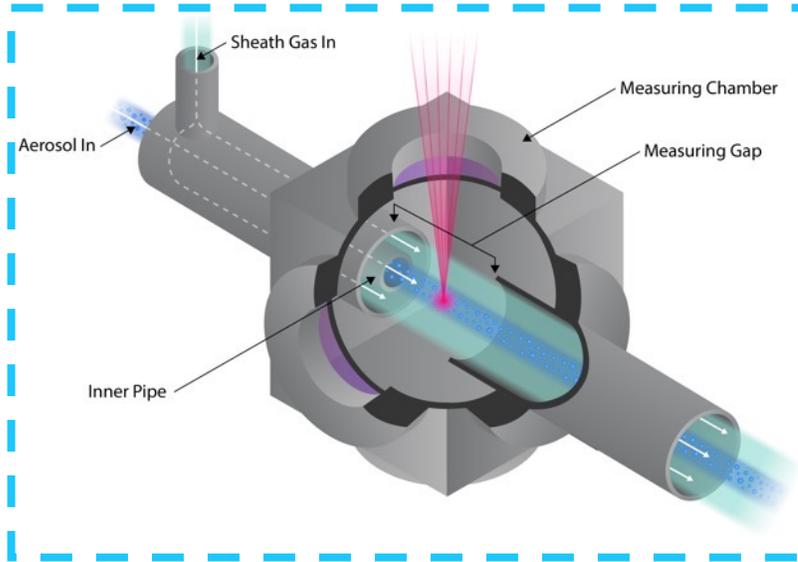
ACU MSRR



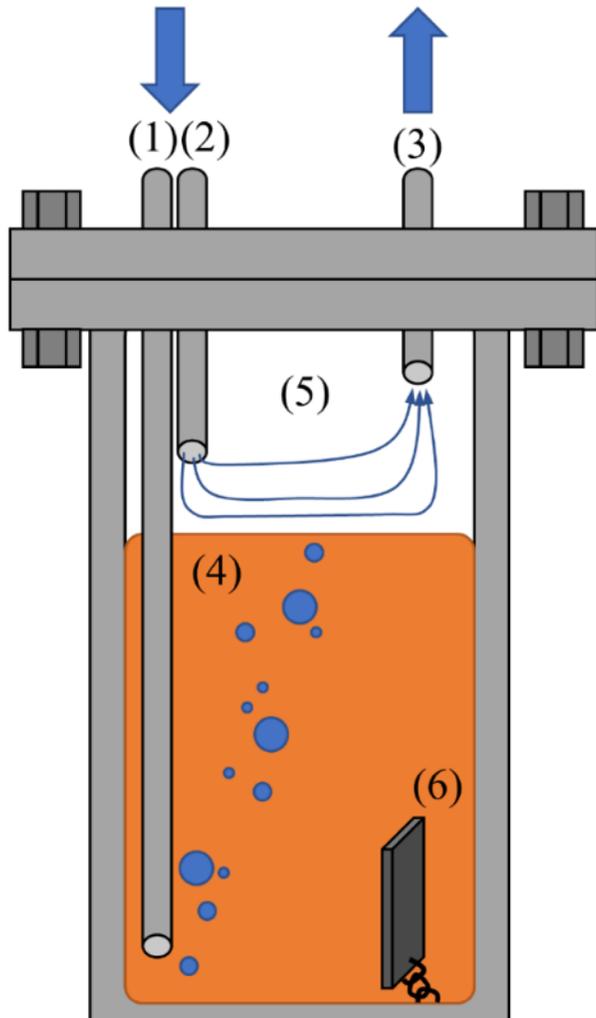
MSTTE Loop



# Molten Salt Aerosol Test Stand (MSAT)



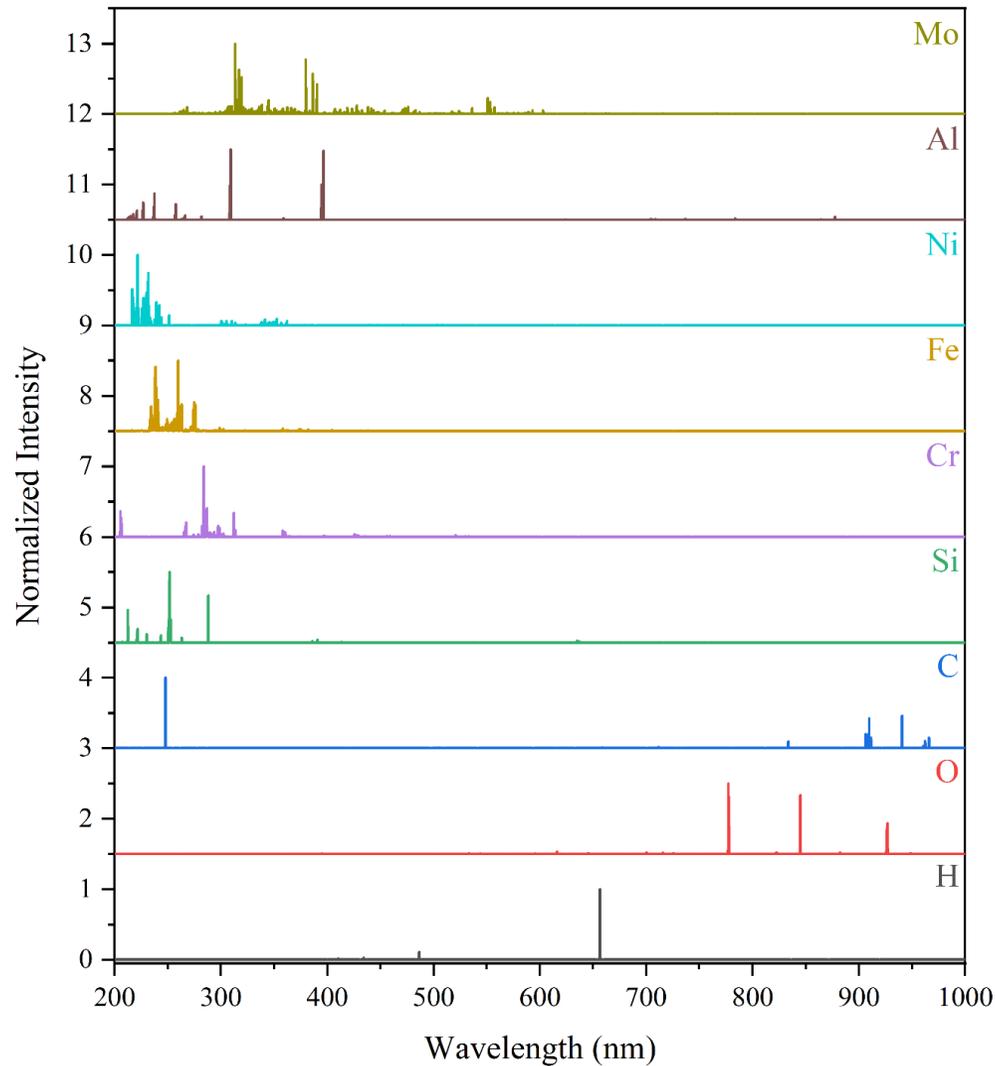
# MSAT design permits a plethora of small-scale experiments



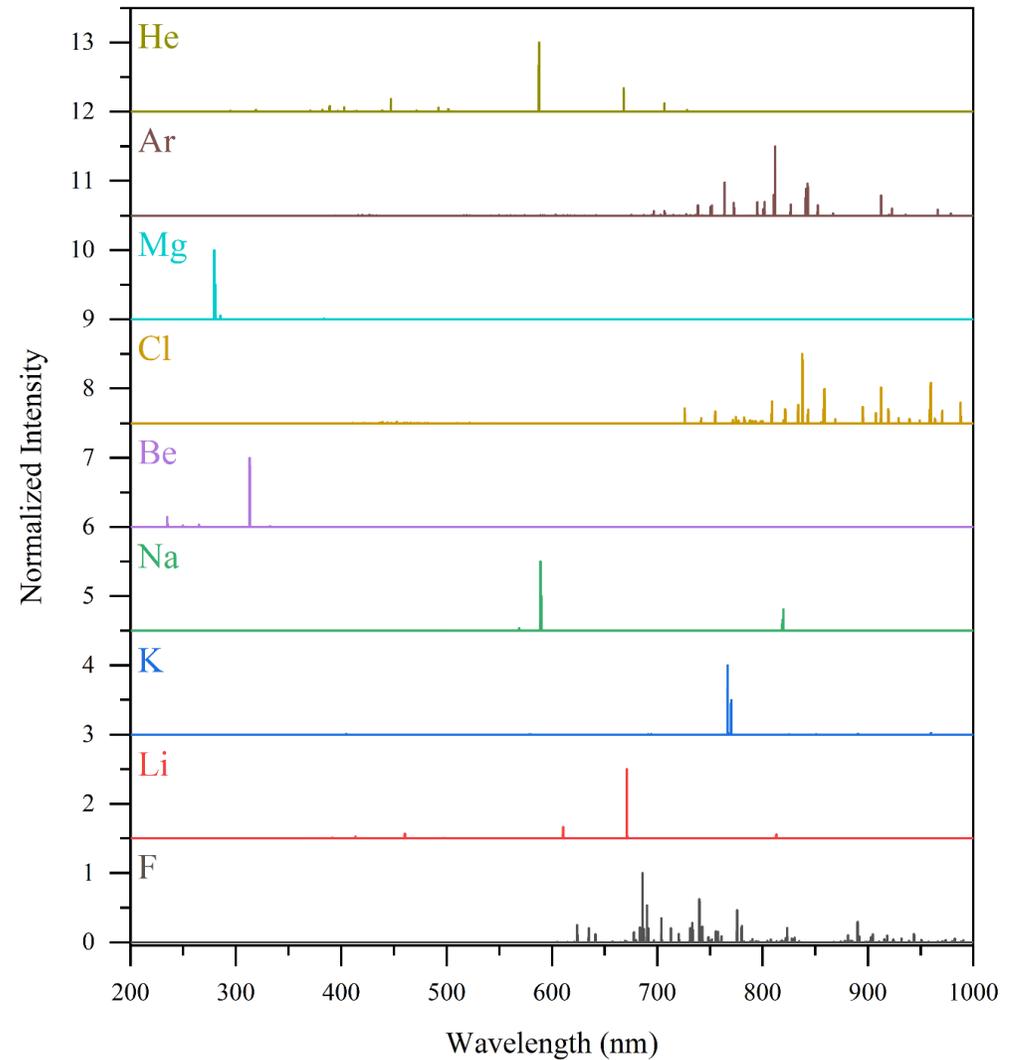
Example schematic of salt test capsule with:  
(1) sparge gas line to bubble gases through salt,  
(2) cover gas line to sweep salt gas interface,  
(3) gas outlet to send stream to inline measurement systems,  
(4) fluoride/chloride molten salt,  
(5) vessel headspace,  
(6) potential corrosion coupons or graphite samples.

# Modeled emission spectra provide insight for tests

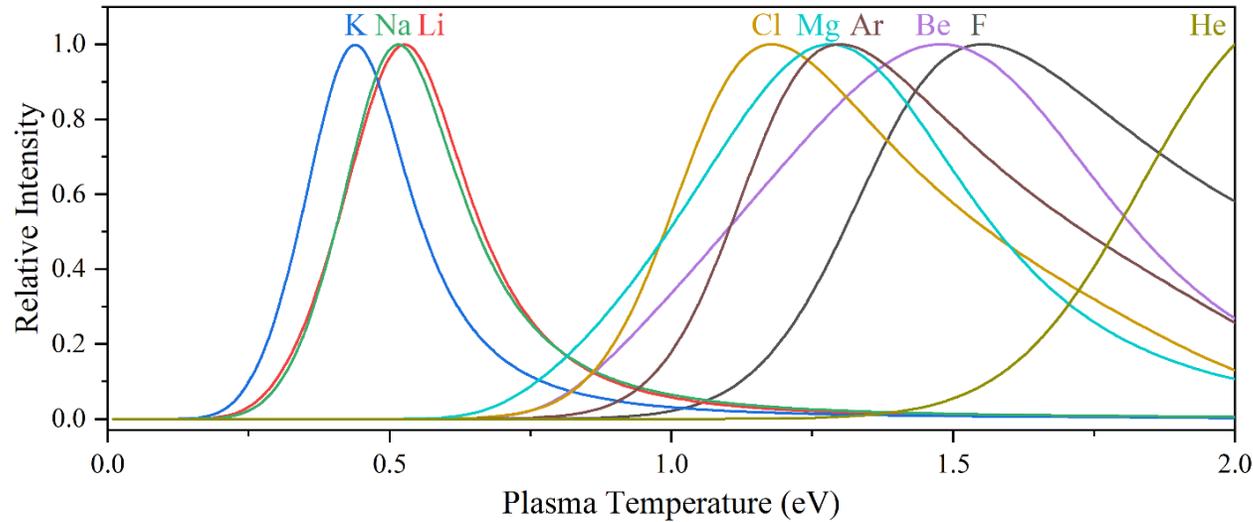
## Corrosion species of interest



## Salt species of interest

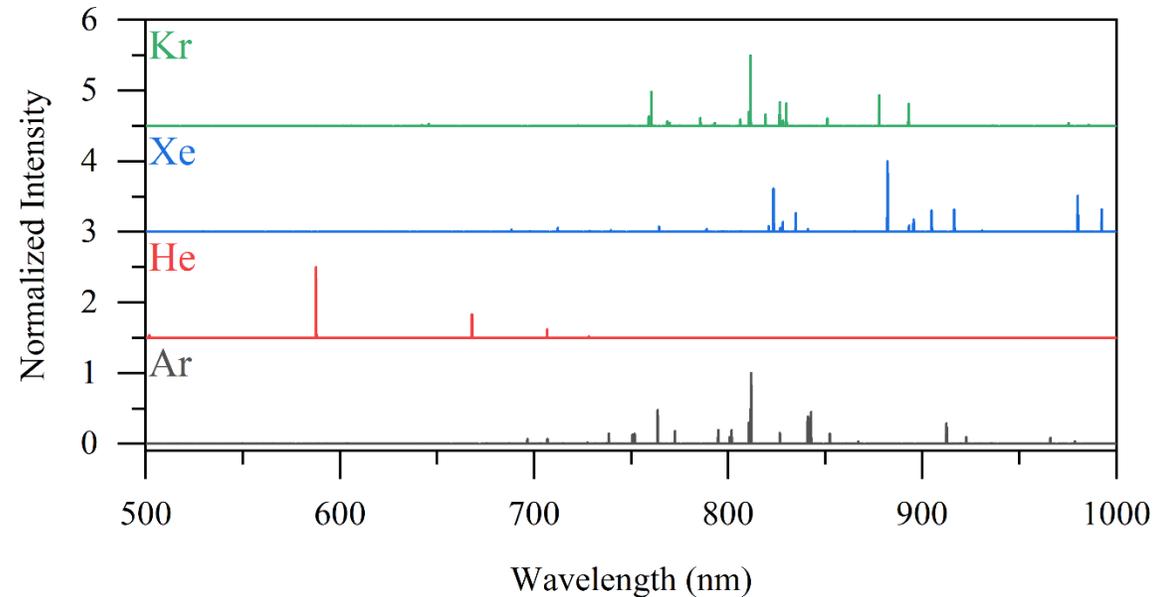


# These artificial spectra can be adjusted based on plasma temperature and density



Laser energy and time of observation impact plasma temperature

## Gaseous species of interest



# For the MSAT and looking beyond we are building a mobile LIBS cart

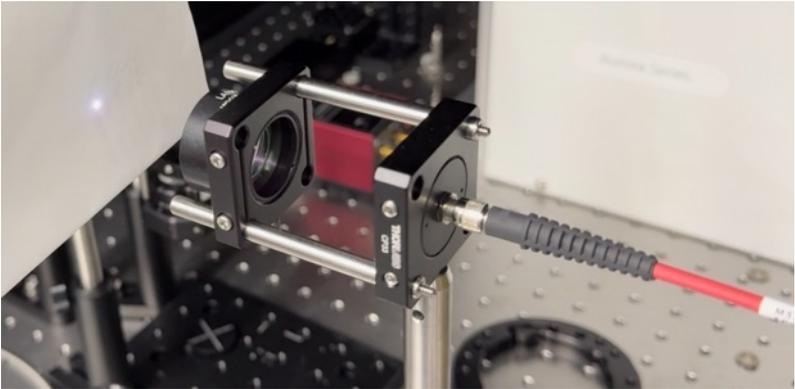
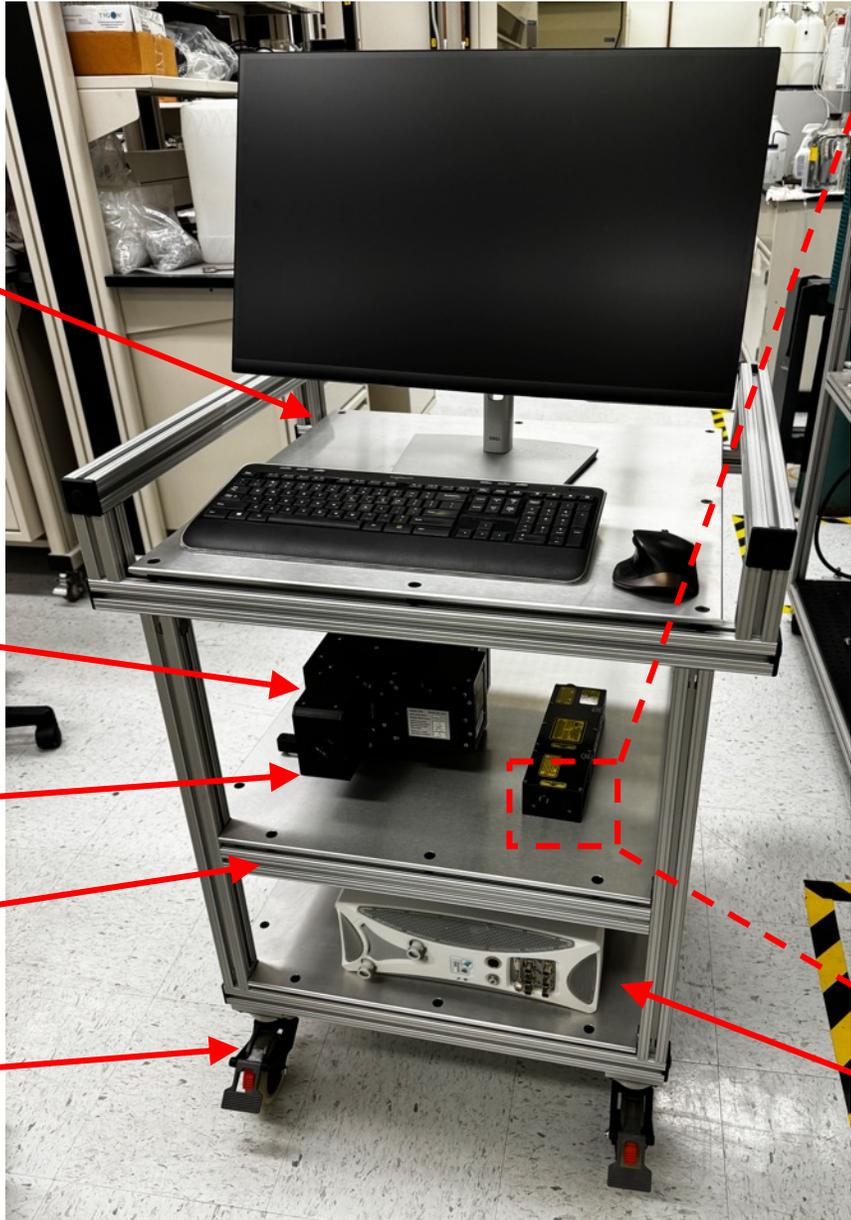
Control computer

Interchangeable spectrometer

Delay generator

Shelves with vibration dampening

Casters with locks



Fiber delivered LIBS



Fiber launched laser

Laser power system

# Coupling LIBS with MOF for Xe breakthrough tests

Open Access

Feature Paper

Editor's Choice

Article

## Monitoring Xenon Capture in a Metal Organic Framework Using Laser-Induced Breakdown Spectroscopy

by  Hunter B. Andrews <sup>1,\*</sup>  ,  Praveen K. Thallapally <sup>2</sup> and  Alexander J. Robinson <sup>2</sup>

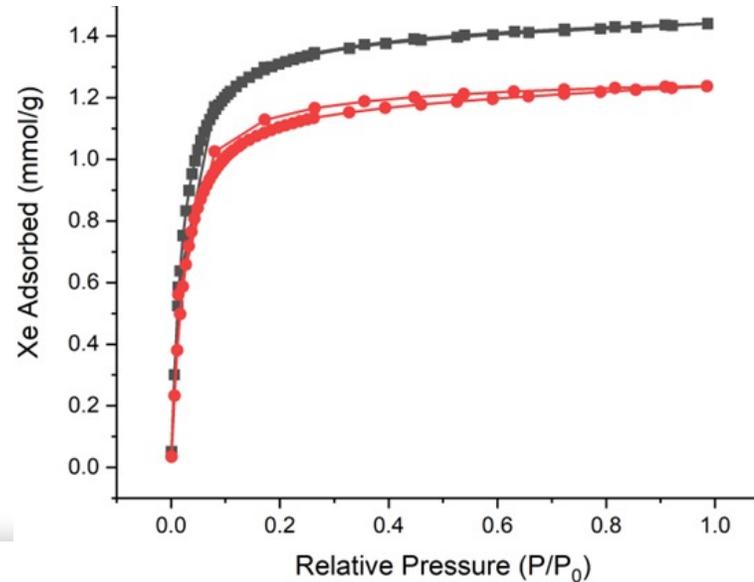
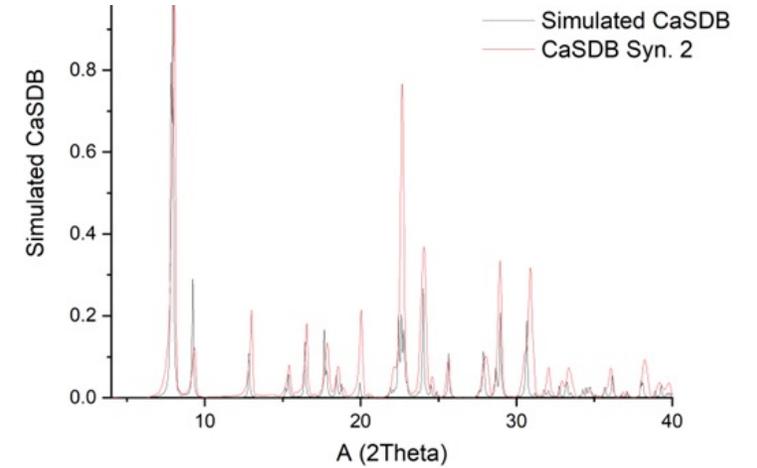
<sup>1</sup> Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA

<sup>2</sup> Pacific Northwest National Laboratory, Richland, WA 99352, USA

# MOF Synthesized at PNNL

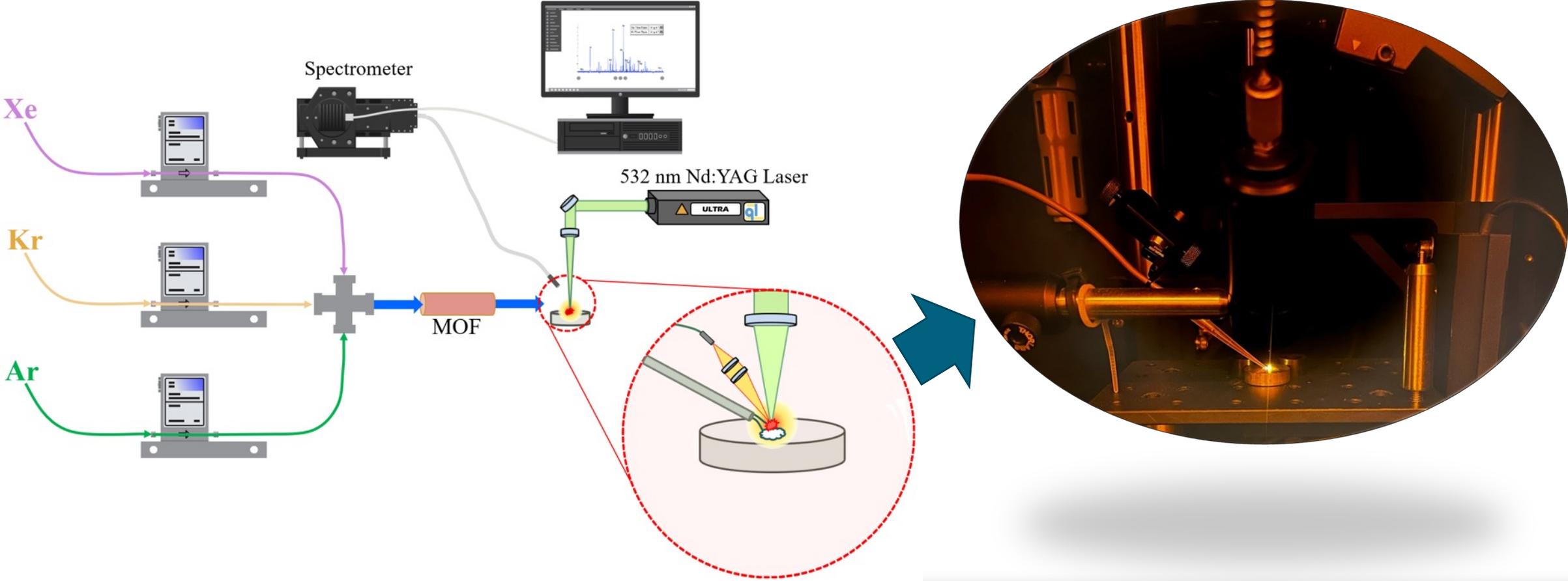


- Identical PXRD confirmed (powder to pellet)
- No amorphous phase
- Reduced BET surface area

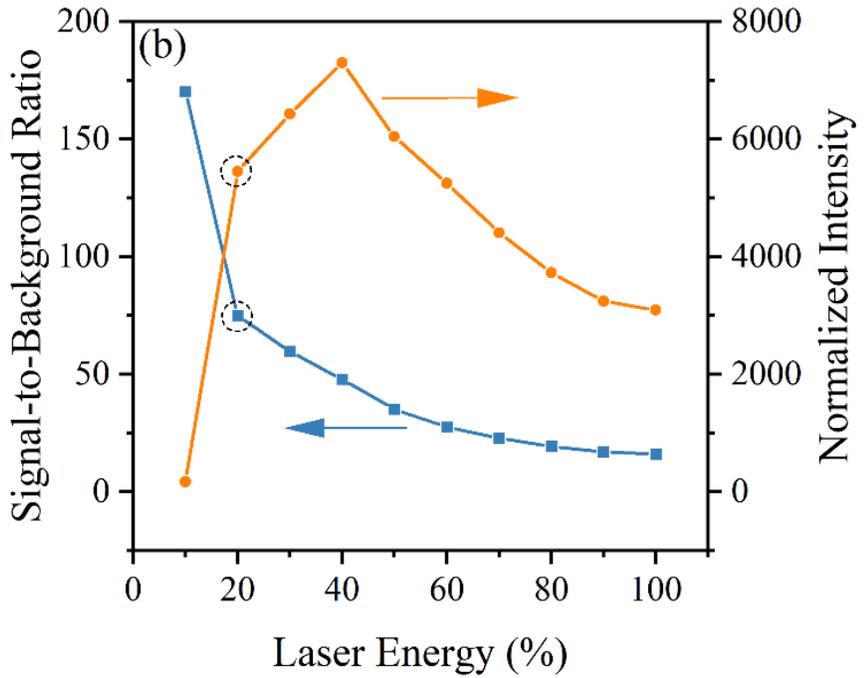
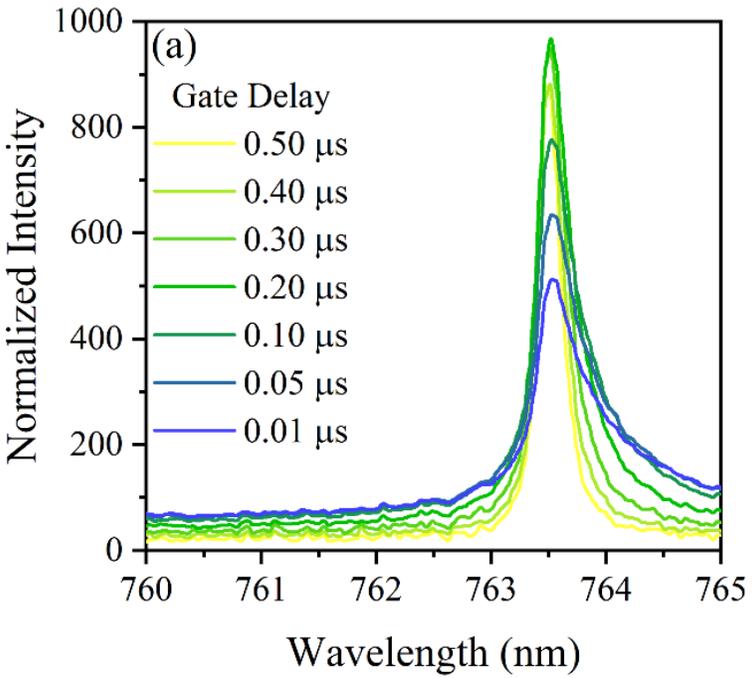


Property	Value
Pressed Pressure	2000 psi for 3 min
Size	600 – 850
BET Surface area	15 m <sup>2</sup> /g
BET Surface area, Po	120 m <sup>2</sup> /g

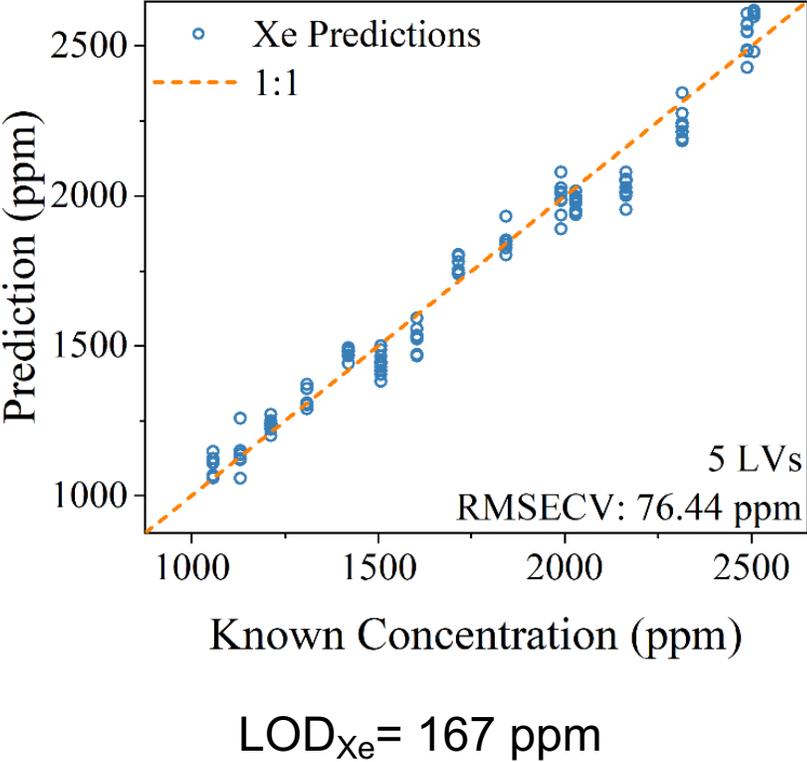
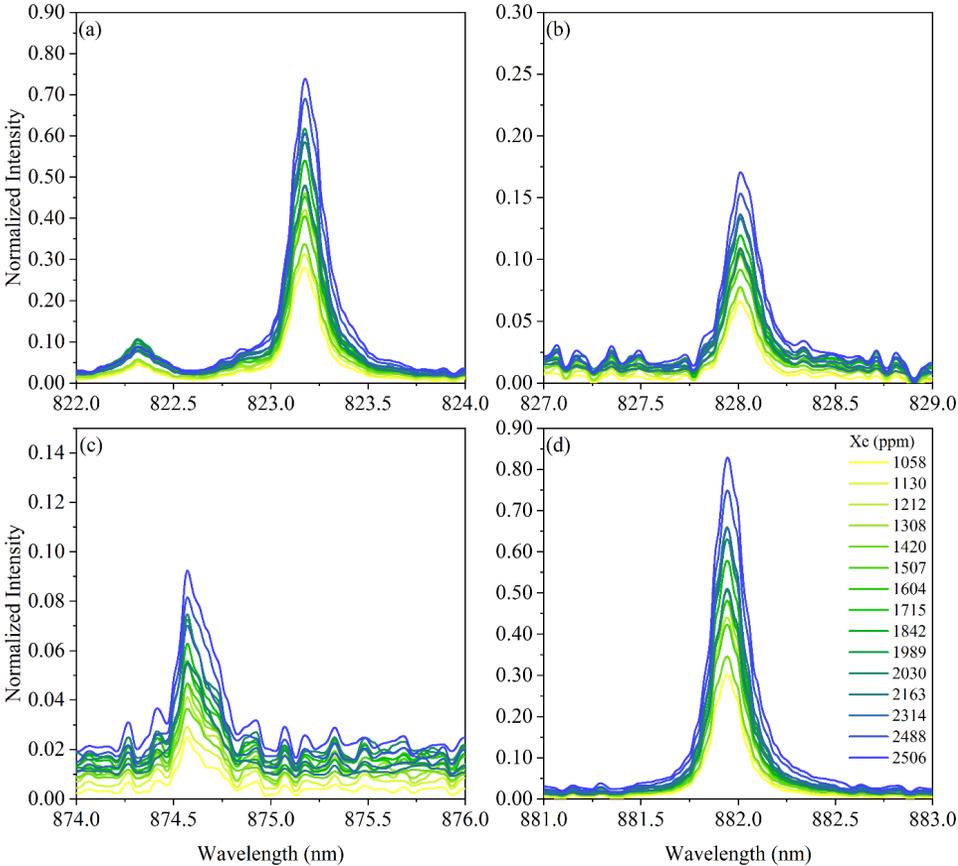
# New LIBS setup was needed to facilitate MOF size and flowrates



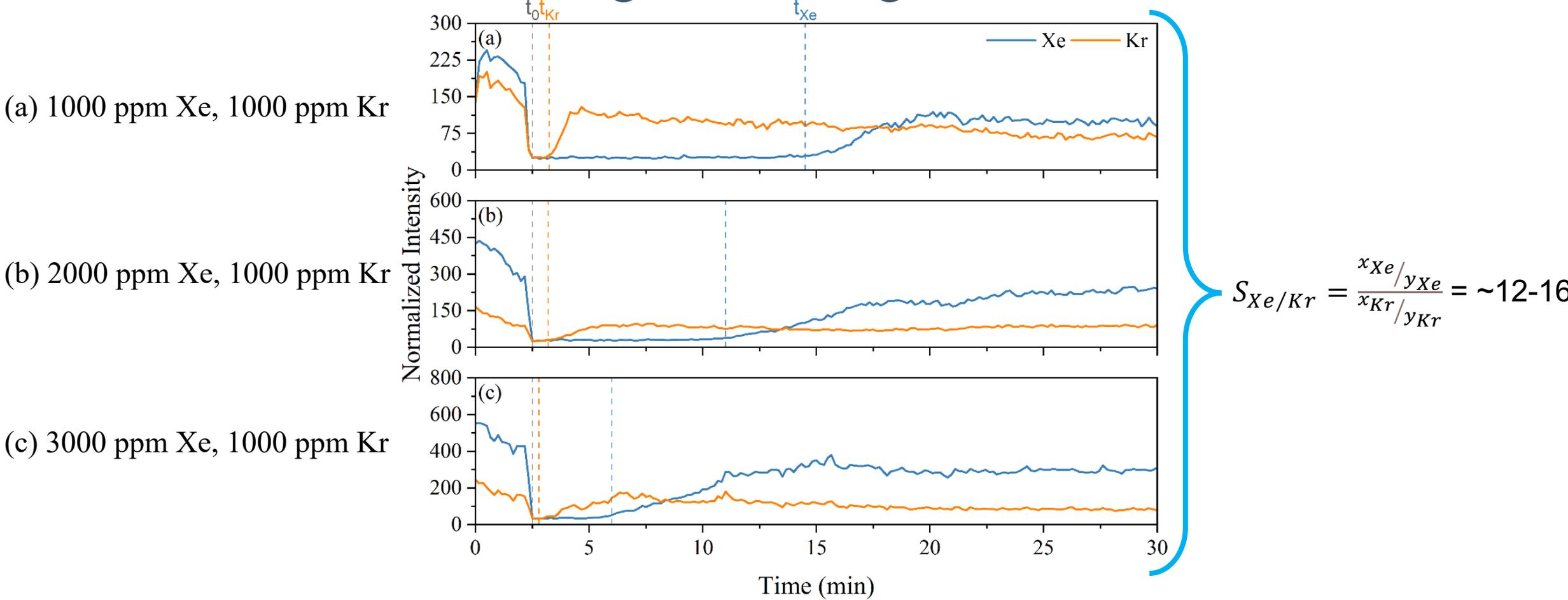
# Spectrometer gating and laser energy were optimized prior to data collection



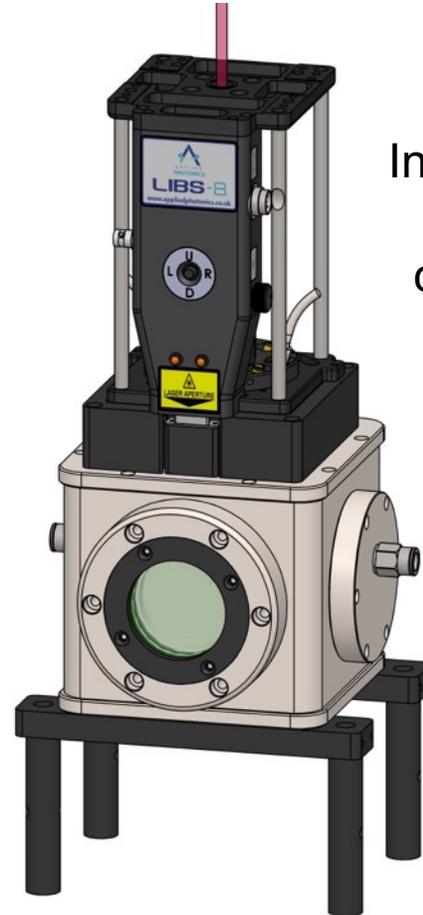
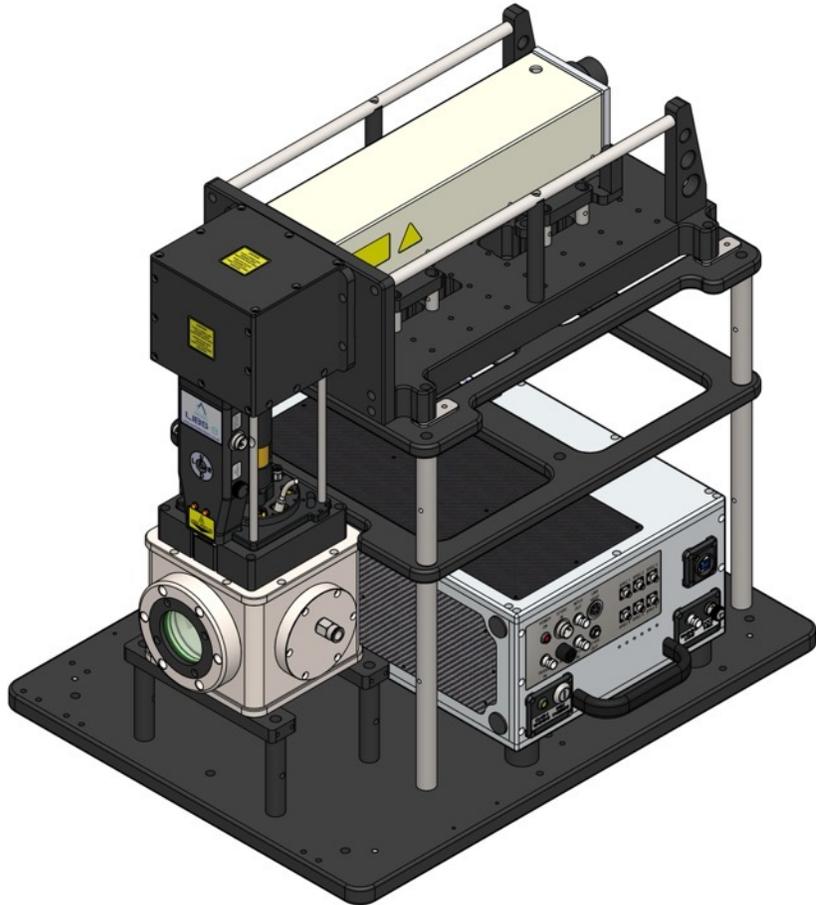
# A multivariate model was built for Xe ranging from 1000 – 2500 ppm to estimate limits of detection for the given setup



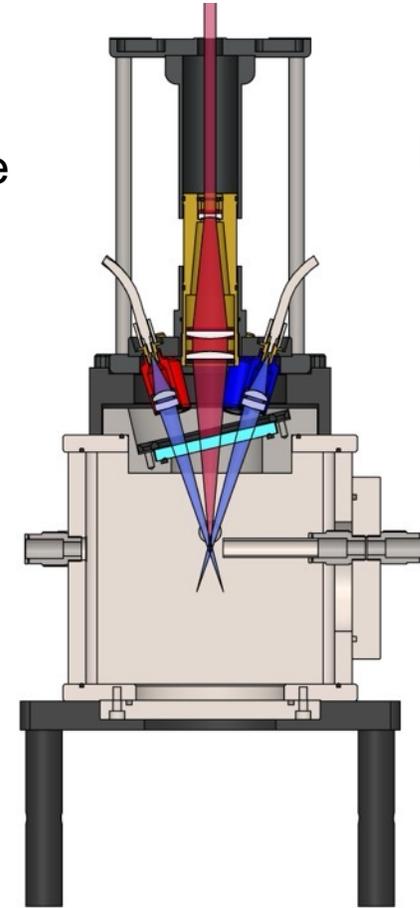
# Breakthrough tests were completed on the activated MOF with the LIBS inline for noble gas tracking



# A new system optimized for gas LIBS is being developed for future MOF tests



Interchangeable  
flanges for  
customization



Eight collection  
optics for  
multiple  
spectrometers

# Summary

- **Mobile LIBS system being developed for enhanced involvement across MSR research**
- **MSAT undergoing final construction to enable small-scale salt transport and monitoring tests**
- **New gaseous LIBS system designed for enhanced noble gas quantification and MOF testing**
  
- **All of these efforts are focused around increasing LIBS usage for MSR research.**

**Tune in tomorrow to learn more about measuring isotopes via LIBS!**



**Thank you**

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