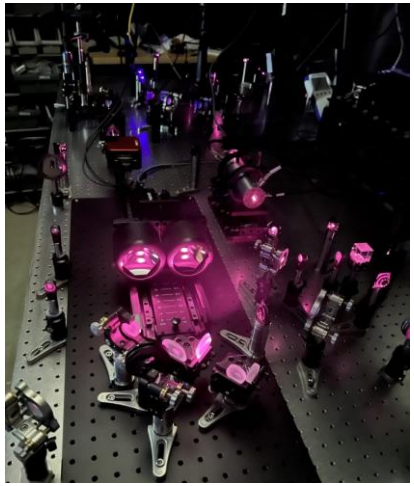
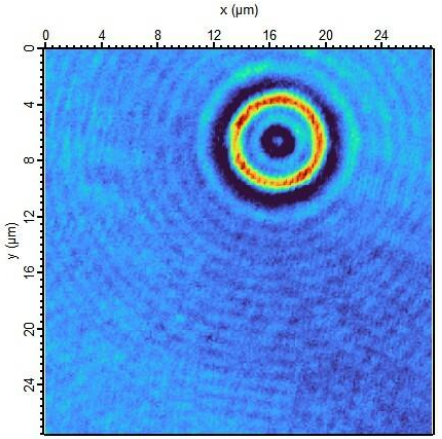
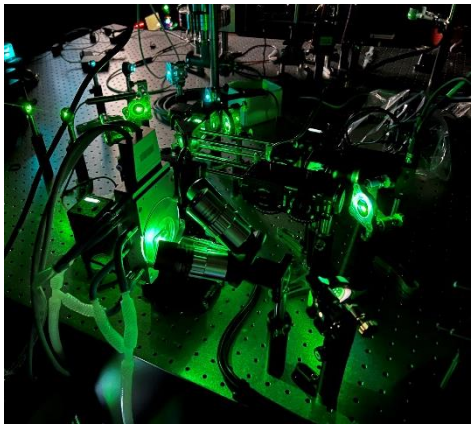


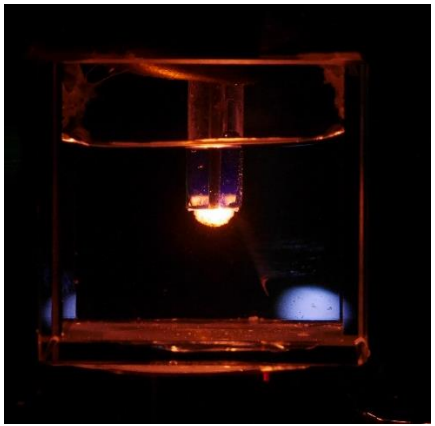
# An Integrated Elemental and Isotopic Detector for Real-Time Molten Salt Monitoring

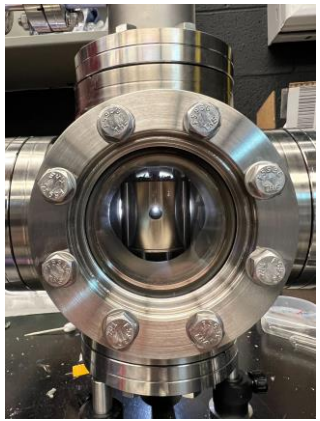
Prof. Alex Bataller
Department of Nuclear Engineering
North Carolina State University

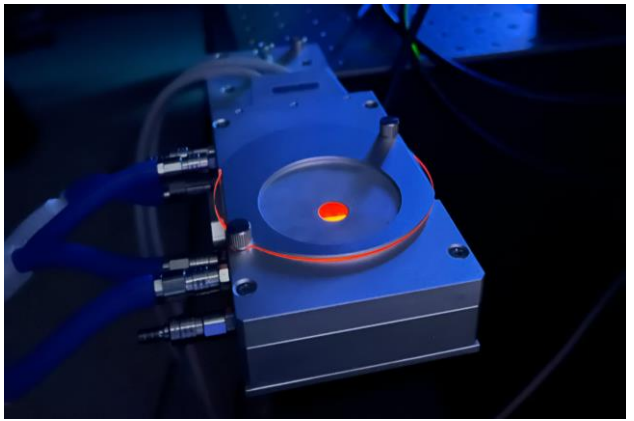
ARSS Fall Program Review, 2:40 pm Nov. 2nd 2023









U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

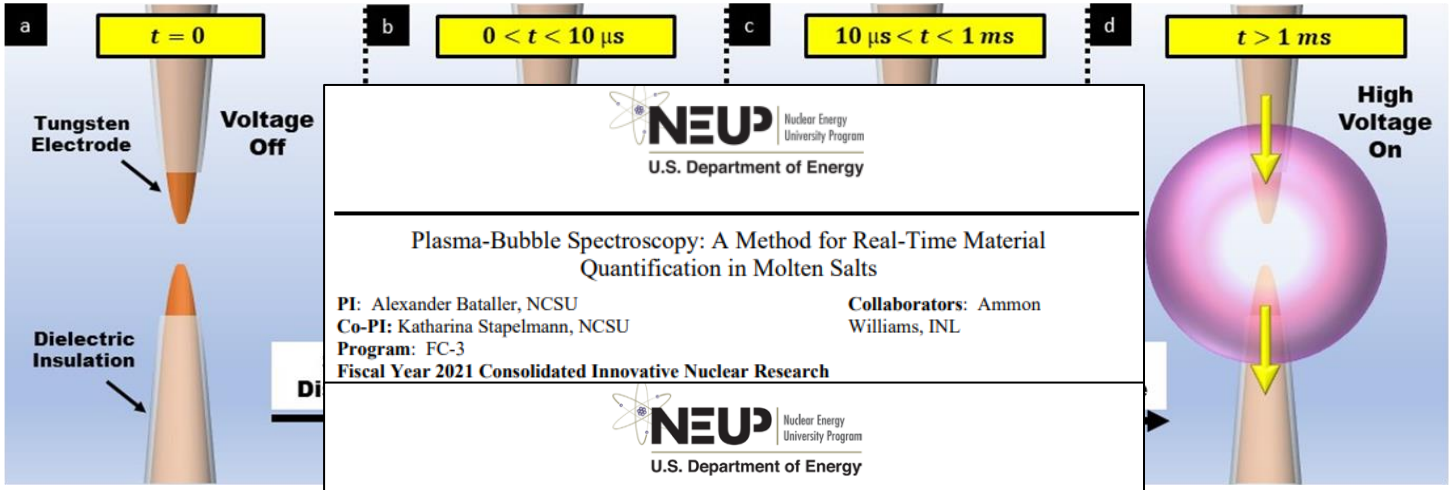
# What's in the salt?

NNSA
National Nuclear Security Administration

- **MSR Processing:** Many future MSR designs feature online chemical processing for continuous removal of neutron-absorbing fission products, corrosion-causing impurities (e.g., oxygen and water), and breeding fuel.
- **MSR Refueling:** Many MSR designs also require some level of periodic refueling, which will change both the quantity of fissile material and its isotopic concentration.
- **MS-Cooled Contaminants:** Salt-cooled reactors might also require process monitoring for contaminants and verifying <ppm uranium.
- **Pyroprocessing:** Commercial-scale processing of used nuclear fuel must also have adequate process monitoring for controlling the rate of actinide removal.
- **MPACT:** Unique mobility of flowing nuclear molten salts is problematic for material protection, accounting, and control

**A critical challenge facing the future utilization of molten salts is the necessity of an online elemental sensor that can operate in extreme molten salt environments.**

# Plasma Bubble Spectroscopy




NEUP Nuclear Energy University Program
U.S. Department of Energy

Plasma-Bubble Spectroscopy: A Method for Real-Time Material Quantification in Molten Salts

**PI**: Alexander Bataller, NCSU
**Co-PI:** Katharina Stapelmann, NCSU
**Program**: FC-3
**Collaborators**: Ammon Williams, INL
**Fiscal Year 2021 Consolidated Innovative Nuclear Research**

NEUP Nuclear Energy University Program
U.S. Department of Energy

**An Integrated Elemental and Isotopic Detector for Real-Time Molten Salt Monitoring**

**PI**: Alexander Bataller – NCSU
**Collaborators**: Ammon Williams, INL
Aslak Stubsgaard, Copenhagen Atomics

**Program**: LS-3, Advanced reactors and fuel cycle facilities materials accountancy, control, and physical protection

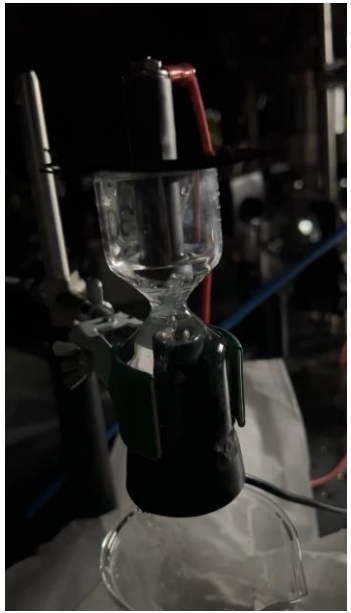
elemental
for molten salt

de a molten salt
enables emission
spectroscopy and isotopic differentiation

NC STATE UNIVERSITY
Department of Nuclear Engineering

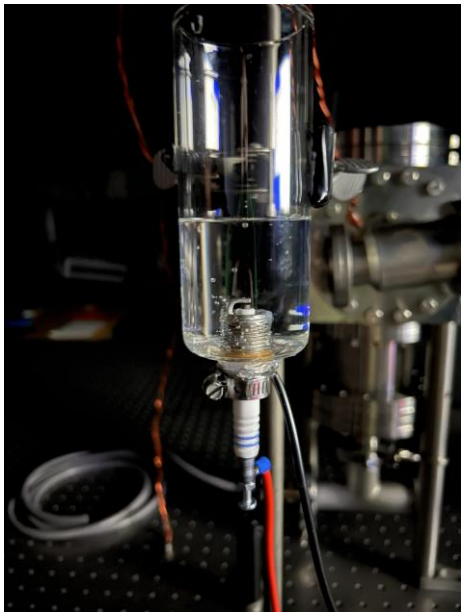
# Plasma Bubble Spectroscopy

Exploration of discharge geometries in saline solutions during year 1 has greatly facilitated molten salt experiments for year 2

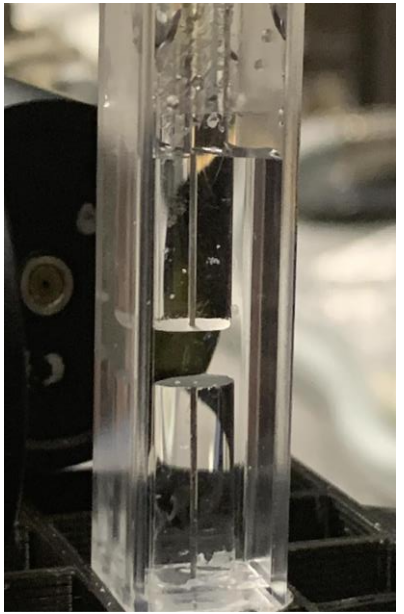


Hourglass

Point-to-Point

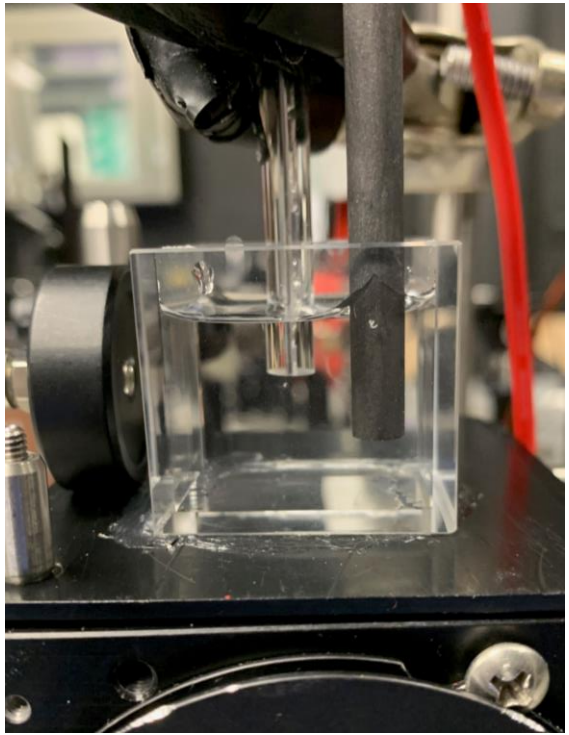


Spark Plug

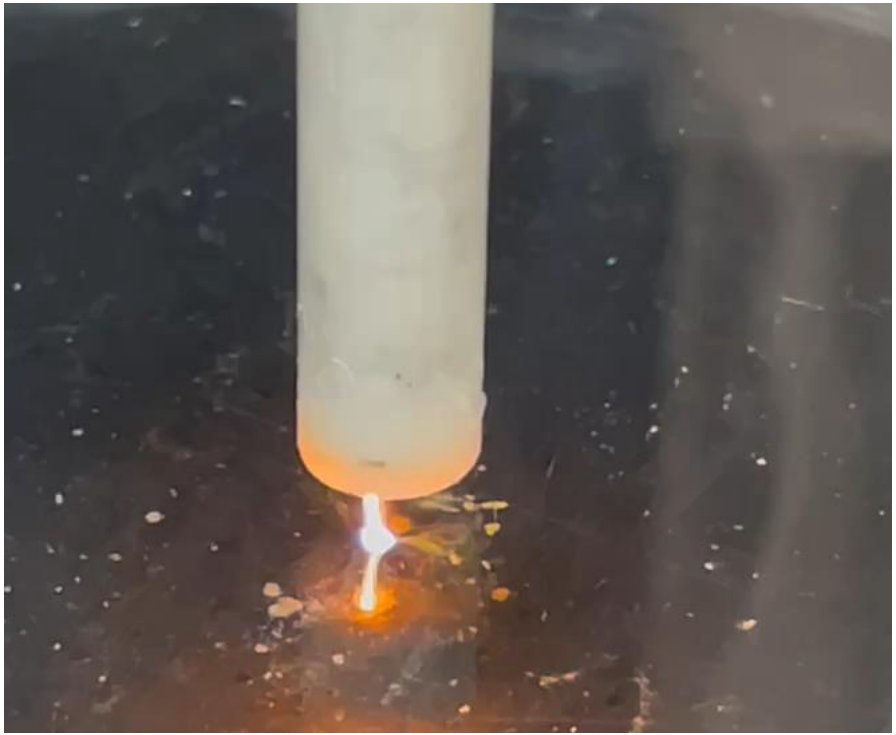


Insulated P2P

**Best overall performing geometries were the:**
**Contact Glow Discharge Electrolysis (CGDE) & Atmospheric-Pressure Glow Discharge (APGD)**

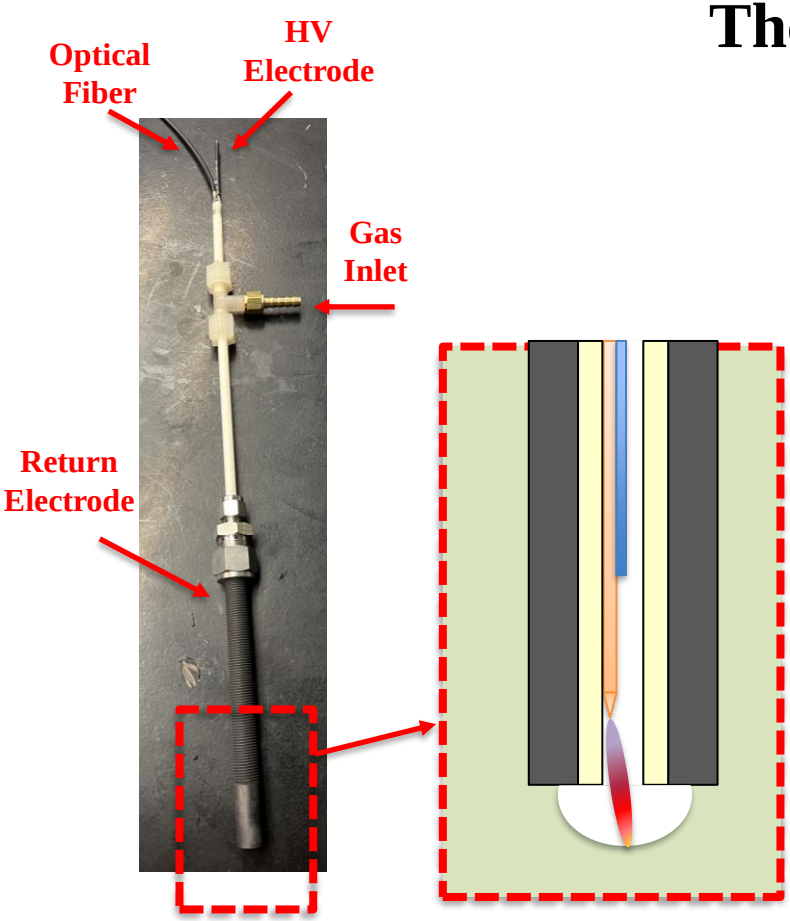


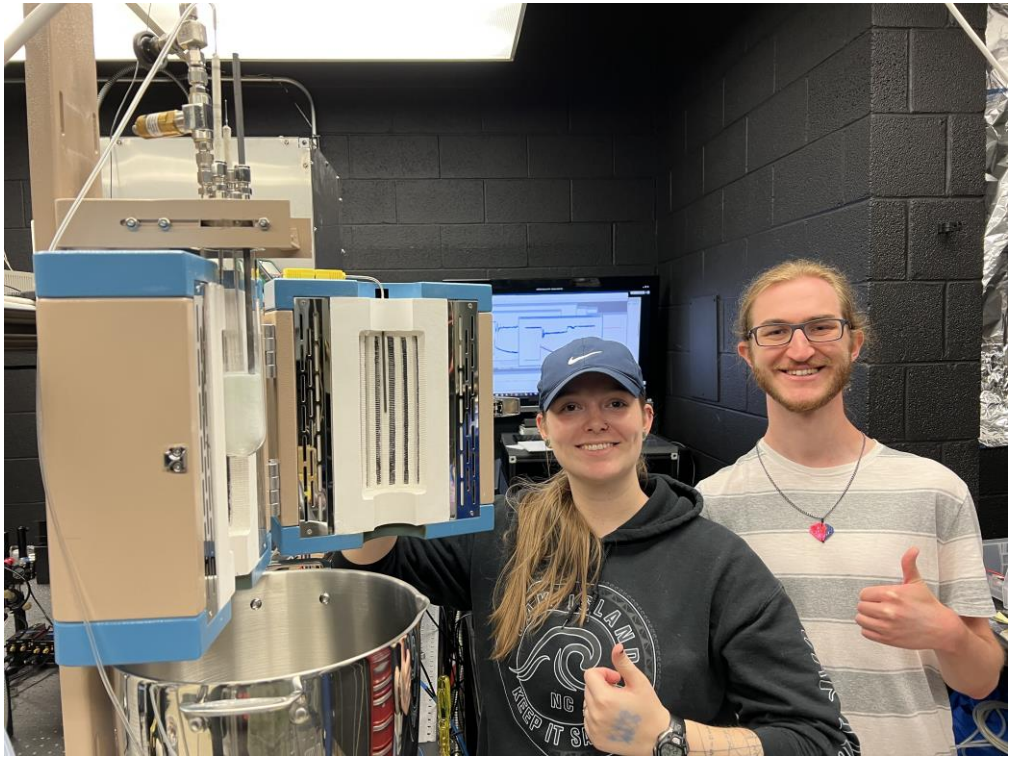
CGDE – Pulsed Circuit



APGD – DC Circuit

# The Arc Bubbler

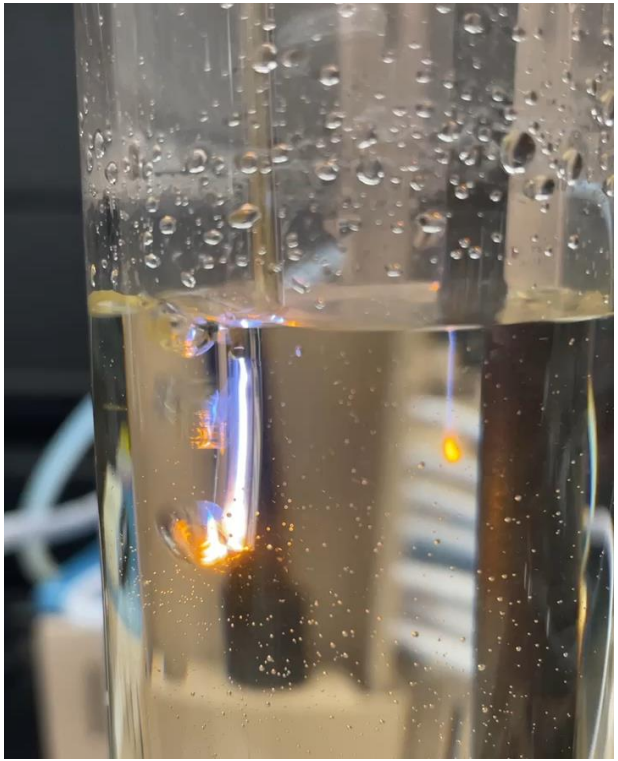


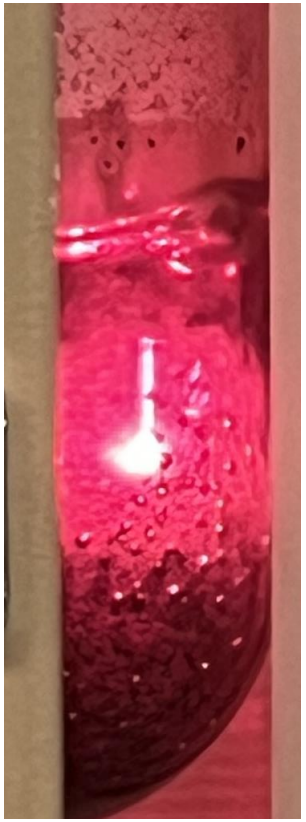
NC STATE UNIVERSITY
Department of Nuclear Engineering

# The Arc Bubbler

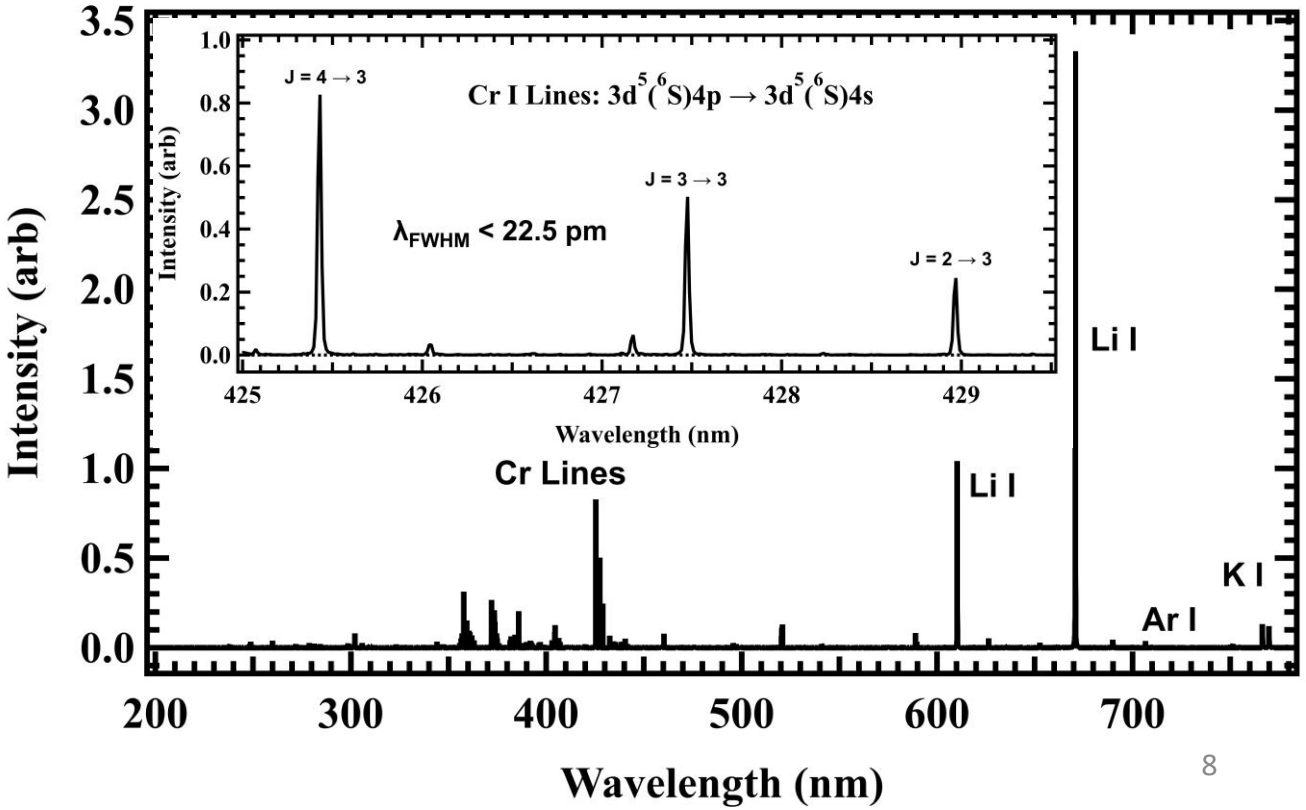
APGD submerged protects the electrode while producing stable plasma of the analyte



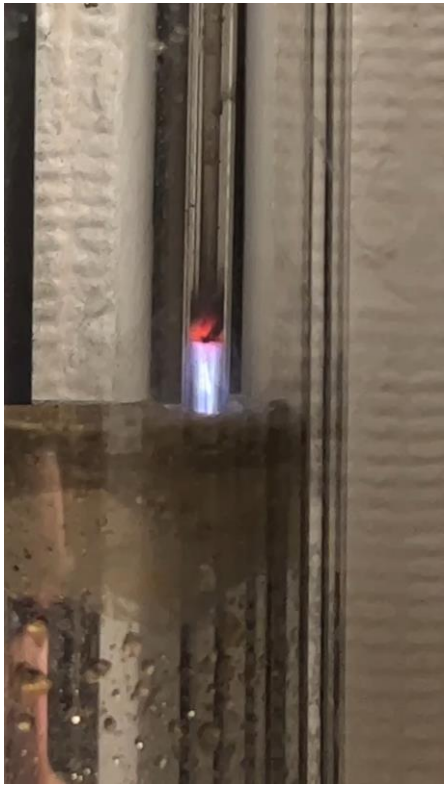
# The Arc Bubbler: Molten salts



$LiCl\text{-}KCl\text{-}CrCl_3$



# The Arc Bubbler: Liquid metals

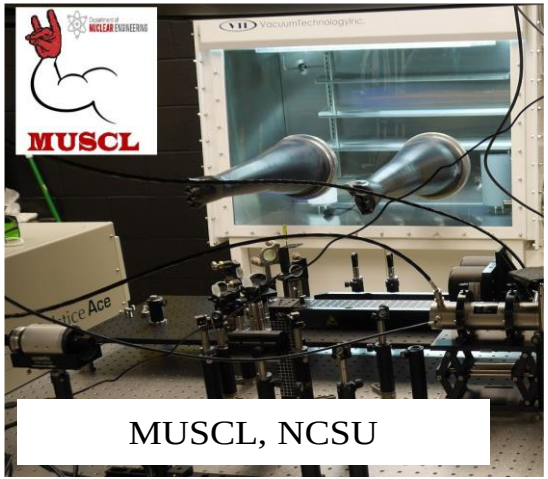


# NEUP R&D 2023-2026

Sensor demonstration for Longevity, Limits, and Latency

PI: Alex Bataller  Collaborators: Ammon Williams (INL) & Aslak Stubsgaard (CA)

## "Longevity"
Device Robustness




MUSCL, NCSU

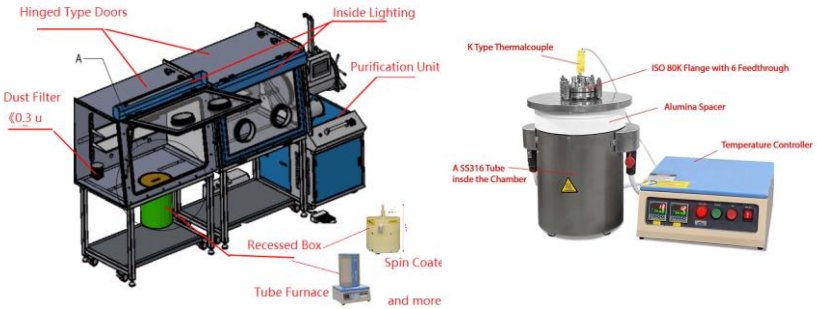
## "Limits"
Complex Fuel Salts

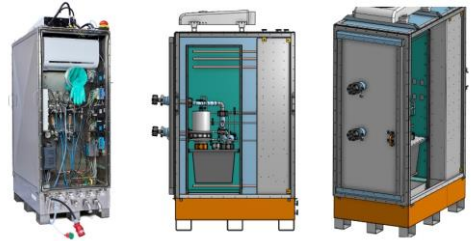
Hot Fuel Examination Facility, INL

## "Latency"
Process Monitoring

CA Pumped Loop

| Milestone Timetable | | Year 1 | | | | Year 2 | | | | Year 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quarter | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **Research Task 1 – Develop PBS detectors: CGDE and GDE** | | | | | | | | | | | | | |
| 1.1 | Develop CGDE electrode with fiber optic feedthrough | | | | | | | | | | | | |
| 1.2 | Calibrate CGDE detector | | | | | | | | | | | | |
| 1.3 | Develop GDE electrode with fiber optic feedthrough & gas line | | | | | | | | | | | | |
| 1.4 | Calibrate GDE detector | | | | | | | | | | | | |
| 1.5 | Develop automation software for CGDE and GDE detectors | | | | | | | | | | | | |
| **Research Task 2 – Develop and procure molten salt furnaces and loop** | | | | | | | | | | | | | |
| 2.1 | Develop molten salt furnaces for Longevity experiments (NCSU) | | | | | | | | | | | | |
| 2.2 | Develop molten salt furnaces for Limits experiments (INL) | | | | | | | | | | | | |
| 2.3 | Procure molten salt pumped loop | | | | | | | | | | | | |
| 2.4 | Develop plumbing and detector port for Latency experiments | | | | | | | | | | | | |
| **Research Task 3 – Perform Longevity experiments** | | | | | | | | | | | | | |
| 3.1 | CGDE: Assemble in fume hood | | | | | | | | | | | | |
| 3.2 | CGDE: Perform Longevity experiments on LiCl-KCl-$UCl_3$ | | | | | | | | | | | | |
| 3.3 | CGDE: Perform Longevity experiments on FLiNaK-$ThF_4$ | | | | | | | | | | | | |
| 3.4 | GDE: Assemble in fume hood | | | | | | | | | | | | |
| 3.5 | GDE: Perform Longevity experiments on LiCl-KCl-$UCl_3$ | | | | | | | | | | | | |
| 3.6 | GDE: Perform Longevity experiments on FLiNaK-$ThF_4$ | | | | | | | | | | | | |
| **Research Task 4 – Perform Limits experiments** | | | | | | | | | | | | | |
| 4.1 | Phase 1: Test PBS detector/s with surrogate salt at EIL | | | | | | | | | | | | |
| 4.2 | Phase 1: Determine minimum salt volume to minimize dose | | | | | | | | | | | | |
| 4.3 | Phase 2: Setup PBS detectors and furnace in ARL | | | | | | | | | | | | |
| 4.4 | Phase 2: Perform Limits experiments with ER salt | | | | | | | | | | | | |
| **Research Task 5 – Perform Latency experiments** | | | | | | | | | | | | | |
| 5.1 | Install PBS detector/s in molten salt loop and test functionality | | | | | | | | | | | | |
| 5.2 | Procure purified salts and test loop ingot loading capability | | | | | | | | | | | | |
| 5.3 | Perform Latency experiments on FLiNaK-$ThF_4$ | | | | | | | | | | | | |



Portable Molten Salt Loop with research ports on side wall (Copenhagen Atomics)