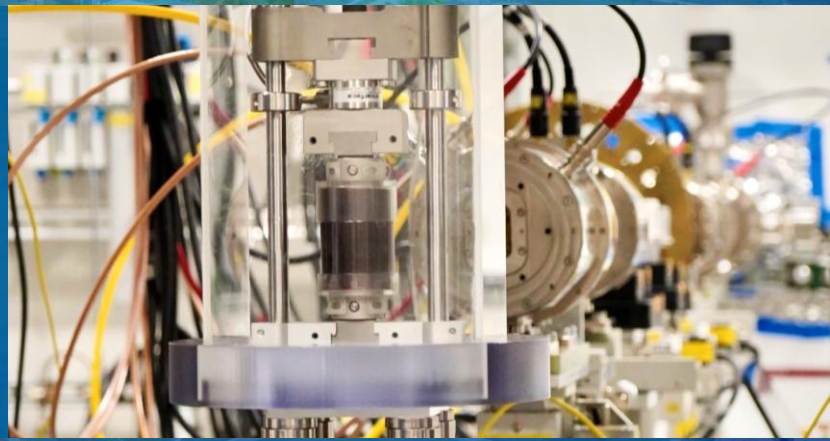
NUCLEAR SCIENCE USER FACILITIES PROGRAM REVIEW MEETING
MAY 11-13, 2026

ACTIVATED MATERIALS LABORATORY AT THE ADVANCED PHOTON SOURCE



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U.S. DEPARTMENT of ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Argonne NATIONAL LABORATORY

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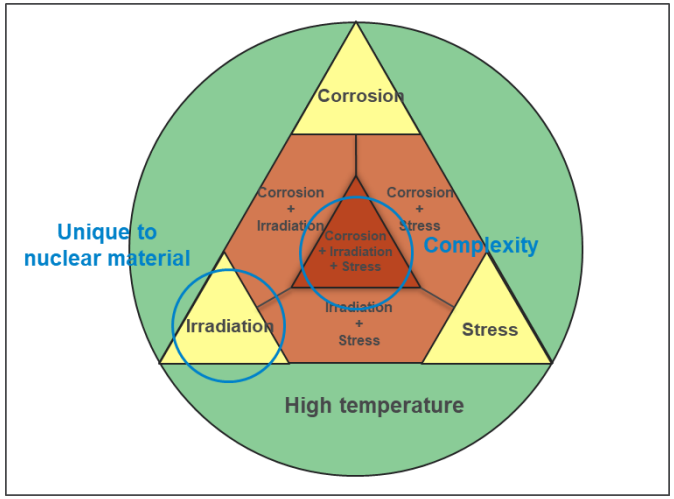
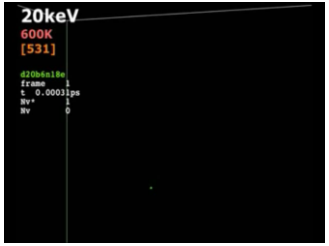
MATERIAL CHALLENGES IN NUCLEAR ENERGY

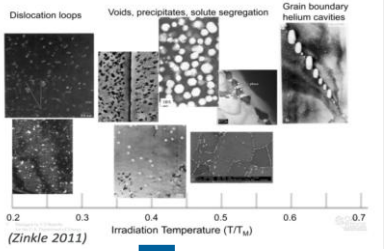
Materials used in nuclear reactors—such as structural alloys, fuel cladding, and nuclear fuels—must endure **extreme environments**, including neutron irradiation, high temperatures, mechanical stress, and corrosive conditions. These factors lead to **complex degradation mechanisms**.



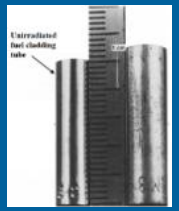
Collision cascade: A few nms, a few ps



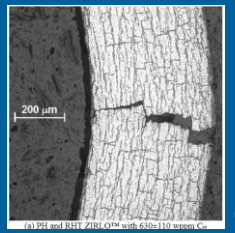
Irradiation-induced micro-scale defects



Irradiation embrittlement



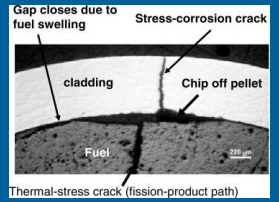
Swelling

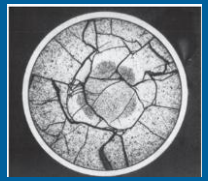


Hydriding and cracking in clad materials *(Billone 2012)*

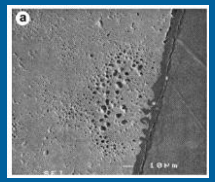
Stress corrosion cracking

Irradiation creep



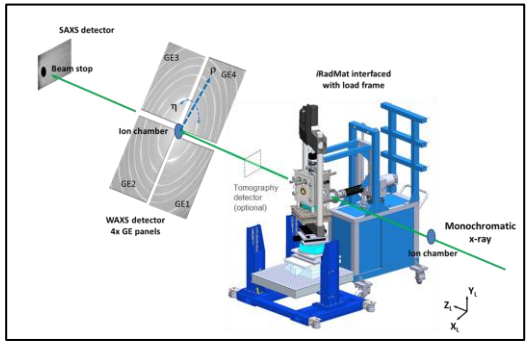


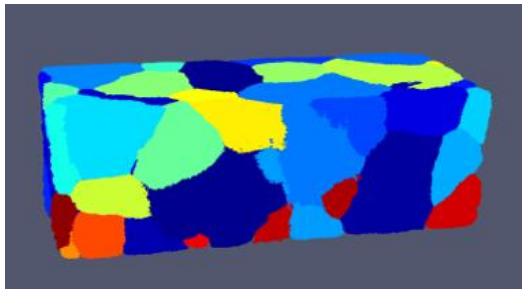
Fragmentation of fuel elements *(Ewing 2015)*

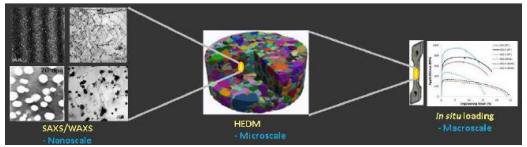


Fission gas bubbles *(Olander 2009)*

Synchrotron X-ray Techniques for Nuclear Materials







Capabilities:

1. *In situ* dynamic measurements

- *In situ* observation of materials response to external stimuli
- Complex sample environments (loading, heating, corrosion)

2. Non-destructive 3D characterization

- Mapping microstructural and micro-mechanical heterogeneity at grain level

3. Multiple length scales in one experiment

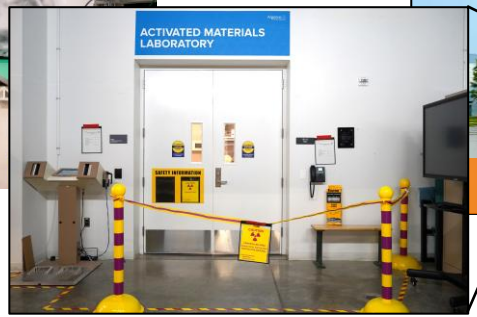
- From macro to meso to micro, with different modalities, all in one experiment

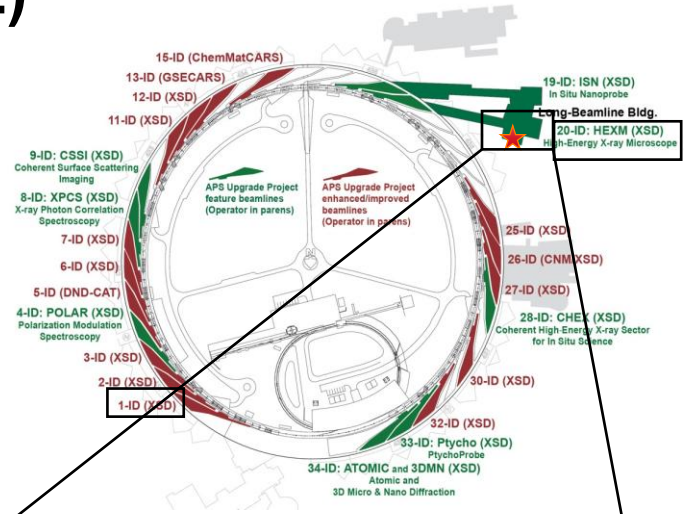
Advantages:

- Minimum sample preparation (friendly to radioactive samples)
- Sampling mm^3 volume (great statistics)
- Comprehensive sample environment
- Direct structure-property correlation
- **Real materials, real environments, non-destructive, *in situ*, 3D**

Activated Materials Laboratory (AML)

- The AML is a **Low-Activity Specimen Preparation Laboratory** next to the 20-ID **High Energy X-ray Microscope (HEXM)** beamline in the Long Beamline Building (LBB) at the APS, constructed as part of the APS-Upgrade Project
- The AML is a Nuclear Science User Facilities **(NSUF) partner user facility**, started user operation in **July 2025**
- **The AML is partnered with high-energy beamlines 1-ID and 20-ID at the APS**

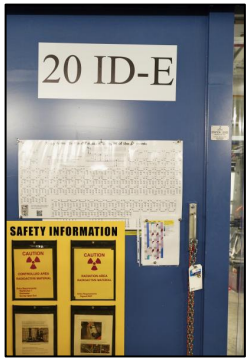




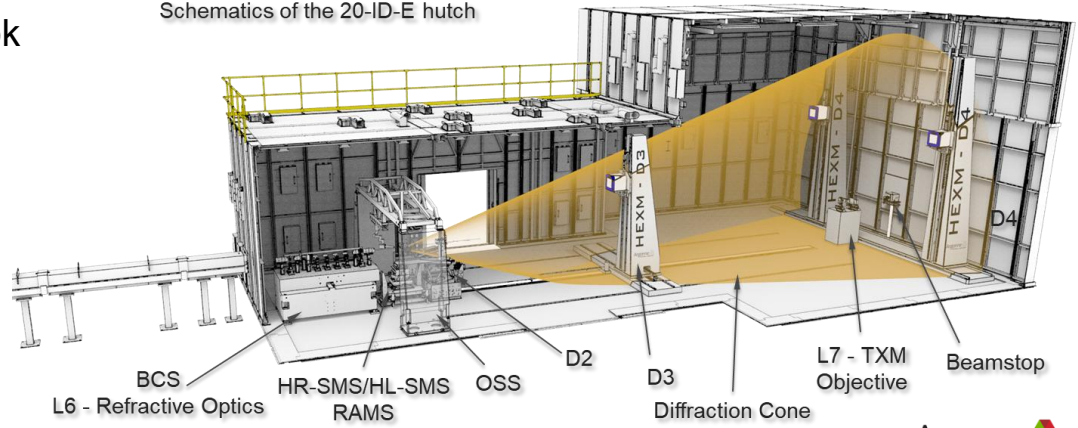
AML Partnership with APS beamlines 1-ID & 20-ID

- The **AML-APS partnership** is established through a Partner User Proposal (**PUP**), allocating a portion of the beamtime at **1-ID and 20-ID** to NSUF users
  - Both beamlines offering world-leading high-energy X-ray (35-120 keV) techniques
  - 20-ID High-Energy X-ray Microscope (HEXM) beamline is one of the two long beamlines
- **First batch of radioactive samples** arrived at the AML in August 2025
- **First NSUF beamline experiment** took place at 1-ID-E during September 25-30 (more on this later).

NSUF leadership team visting 20-ID and AML in June 2025



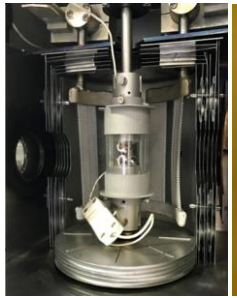
Schematics of the 20-ID-E hutch

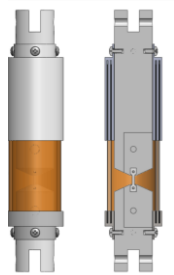
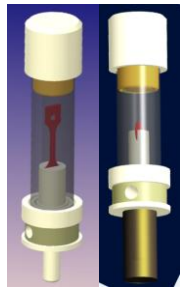


AML Scope and Function

- **A central lab** providing encapsulated rad samples **for all APS beamlines**
- **A radiological facility**
  - Radiation exposure limit: **100 mR/h at 30 cm**
  - Nuclear fuel samples will be handled inside glove boxes
  - Radiologically engineered controls/w HEPA filtered exhaust
- **A Radioactive Specimen Preparation Lab**
  - Receiving/shipping samples
  - Handle open rad samples in solid form
  - Encapsulate samples
  - Support beamline experiments
  - Interface with APS's Radioactive Sample Safety Review Committee (RSSRC)
  - Short-term sample storage



AML Components

AML fact sheet:
https://anl.box.com/s/5mwlwx22gtjdchm8xk2qpvv9cd5y7ehb

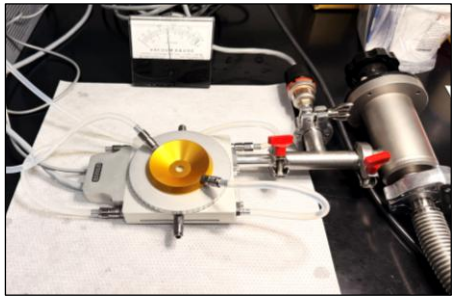
Glove boxes, fume hoods, and hoist

Lead-shielded cabinets, barriers, and cart

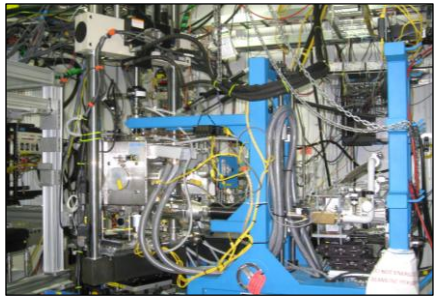
Mezzanine and basement

Shielded Keyence VHX 7000 digital

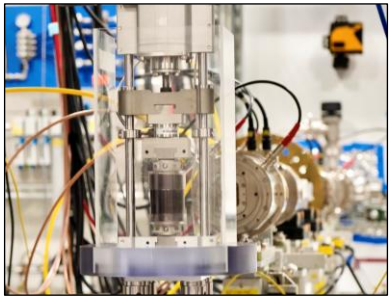
Linkam TS1500 heater (1500°C, vacuum compatible)



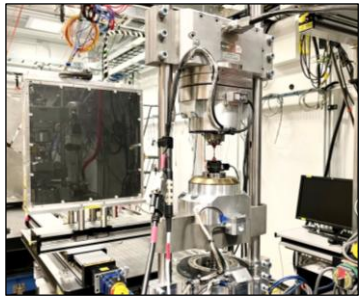
The iRadMat vacuum furnace + MTS load frame



Psylotech 4.5 kN µTS system



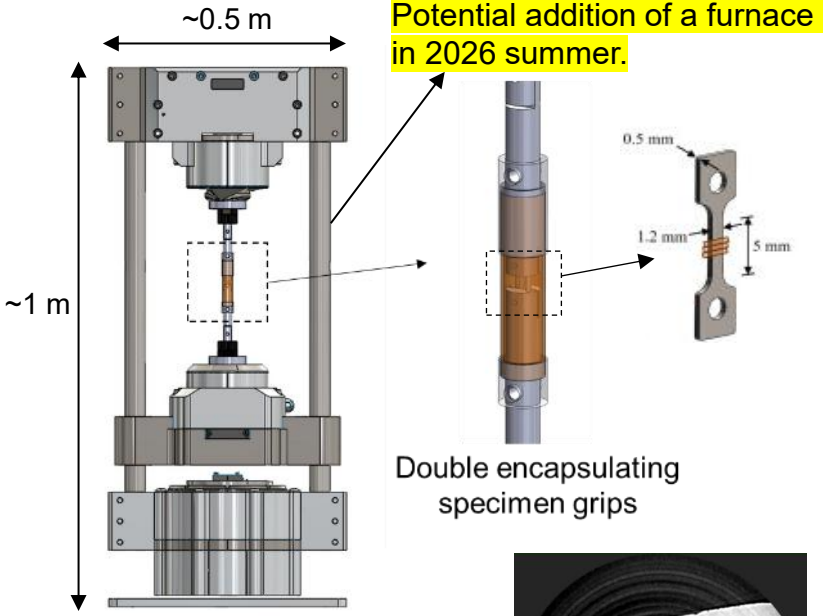
Psylotech xTS system with in-grip rotation



CAPABILITY DEVELOPMENT IN FY26

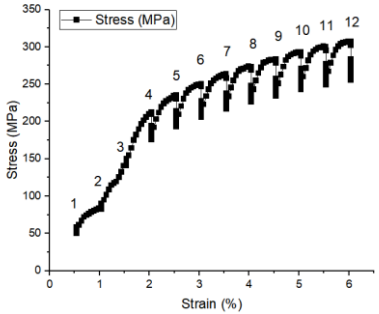
New load frame with in-grip rotation is commissioned

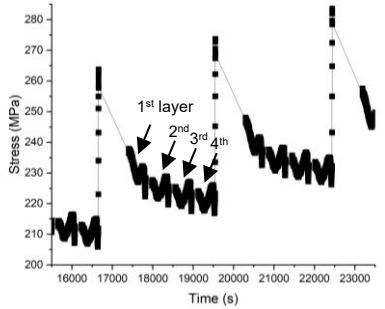
- Quasi *in-situ* 3D measurements are demonstrated in February 2026

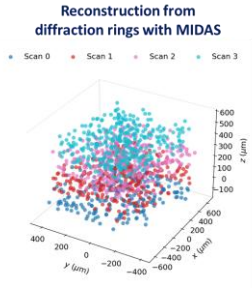


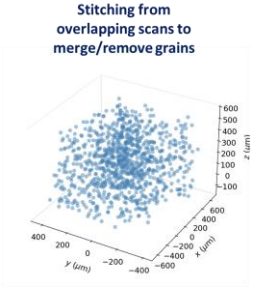
Tomography reconstruction of a 3D-printed stainless-steel **sample under 150N load**, showing micro-voids.

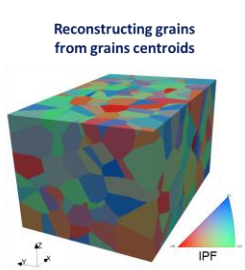
- Hand-shake between load frame and beamline control enabled unmanned operation for the entire duration of experiment (~ 10 hours)











Before stitching:
Scan 1: 603 grains
Scan 2: 666 grains
Scan 3: 780 grains
Scan 4: 792 grains

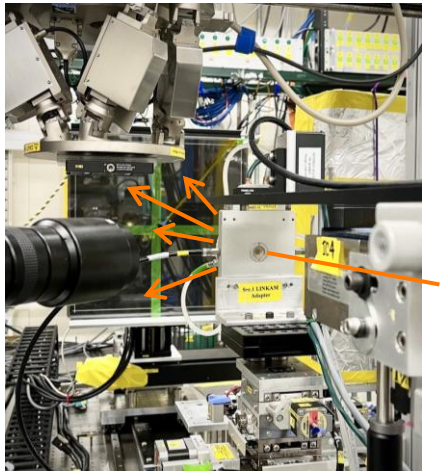
After stitching:
Merged 582 grains
Total 2208 grains
Removed 51 grains outside expected domain

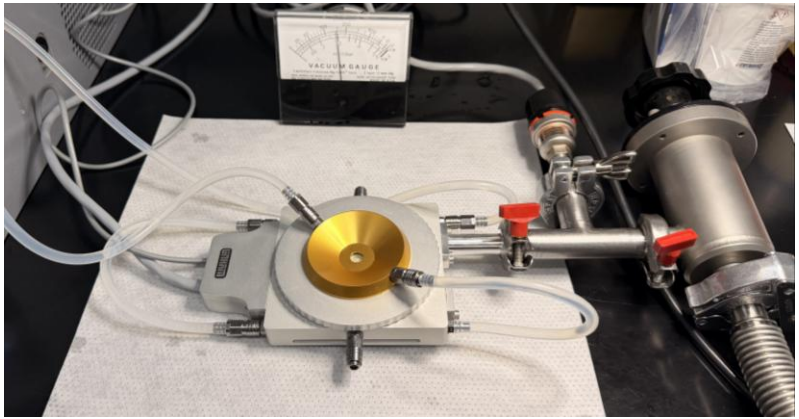
New heater with vacuum is commissioned

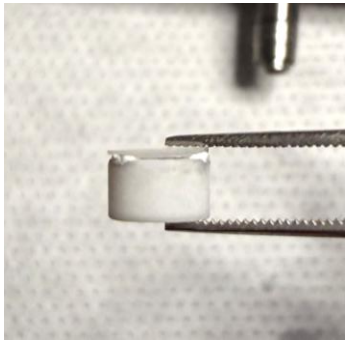
- Dummy sample heated in double-quartz encapsulation

Linkam TS1500V model

- Vacuum compatible to 0.05 Torr
- Up to 200°C /min heating rate
- Rated for 1500°C max temperature
- Practical 900°C max temperature for rad samples
- First RTE beamtime planned for summer 2026







USER PROJECTS IN FY26

DEVELOPING AML USER BASE

Seeking user input

*NSUF research supports DOE-Office of Nuclear Energy's missions. Most of the research looks at either **understanding the mechanisms of radiation on materials and fuels** to address the challenges of the current fleet of reactors, or looks at materials and fuels for the next generation. – NSUF website*

Reach out to AML and APS beamline technical contacts to discuss research scope.

NSUF Consolidated Innovative Nuclear Research (CINR) award

- Perform irradiation effects studies of **larger scope** that span multiple years.
- Annual call.

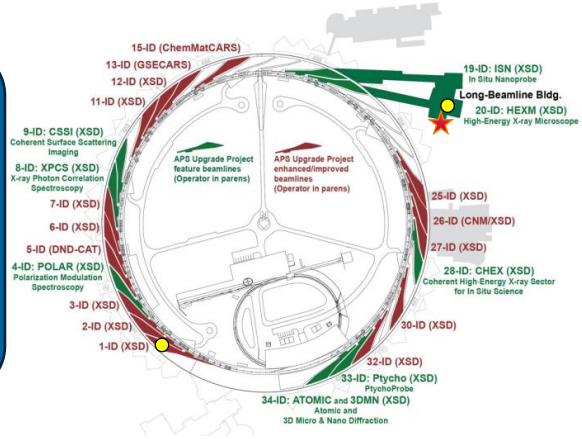
NSUF Rapid Turnaround Experiment (RTE) award

- Perform irradiation effects studies of **limited scope** on nuclear fuels and materials within 9 months of an award.
- Calls open three times a year.

Access to the AML and associated beamlines

- **Free of charge to use the facilities**
- **Experimenters cover their own travel and effort costs**

This process bypasses the APS General User Proposal (GUP) process.



Currently, the AML has 7 active projects

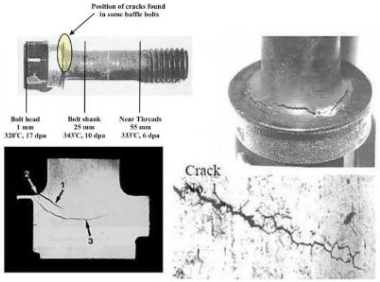
- 2 CINR, 4 RTE, 1 super RTE
- Users coming from various national laboratories and universities
- Activated samples of nuclear structural alloys & fuel cladding materials

FIRST USER EXPERIMENT (9/25-9/30/2025)

CINR 24-31412 (UIUC): Characterization Of Irradiation-assisted Stress Corrosion Cracking In 316 Stainless Steel Baffle-former Bolts Harvested From Commercial Pressurized Water Reactor

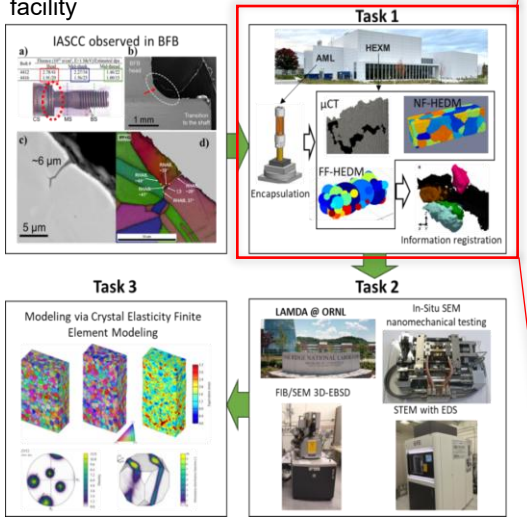
Objectives:

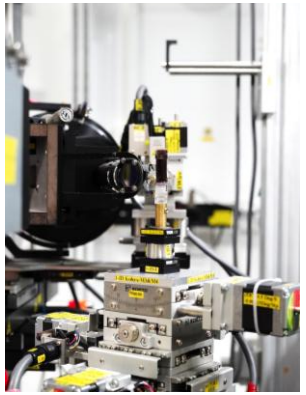
Assess the **mechanisms** for initiation and development of irradiation-assisted stress corrosion cracking (**IASCC**) in austenitic stainless steel internal components harvested from a commercial pressurized water reactor (PWR)



Logical Path:

The research will combine microstructural analysis at LAMDA-ORNL and using the AML-HEXM facilities at APS-ANL to characterize IASCC, supplemented by crystal-plasticity FEM analysis at the INL-HPC facility





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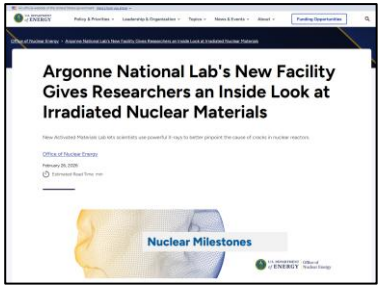
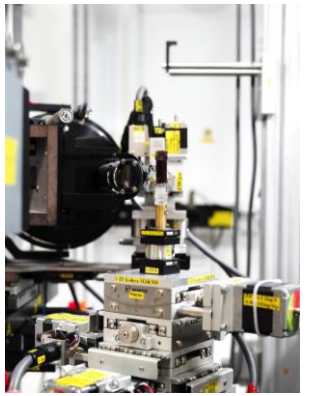


This is the **first time** in the APS history that **radioactive specimens** with beta/gamma dose rates **higher than 5 mR/h at 30 cm** were brought to an APS beamline hutch, transforming the hutch to a temporary **Radiation Area (RA)**.

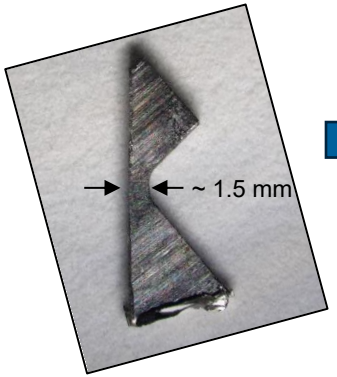
This achievement was highlighted on DOE-NE website as a **Nuclear Milestones article**. It brings a new era of nuclear materials research at the APS.

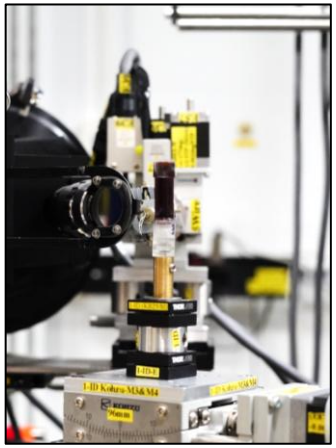


PRELIMINARY RESULTS AROUND AN IASCC CRACK

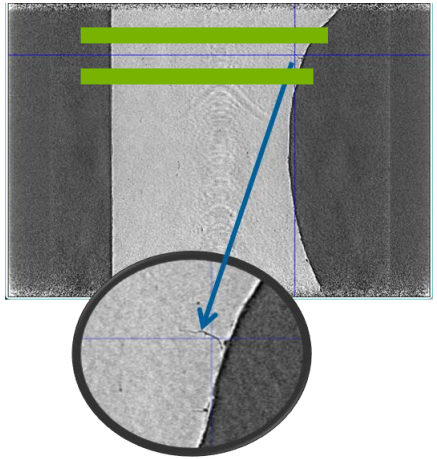
- Sample 4416-CS2-A, 29 dpa

- **Two beamtimes have been performed at 1-ID**
  - September 2025: 4 specimens, tomo & nf-HEDM on 2, identified cracks
  - February 2026: 2 specimens, tomo & nf-HEDM on 1 focusing on the crack region

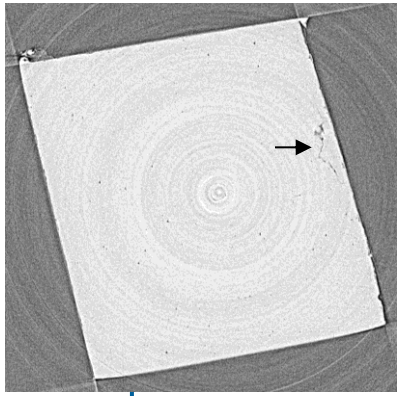




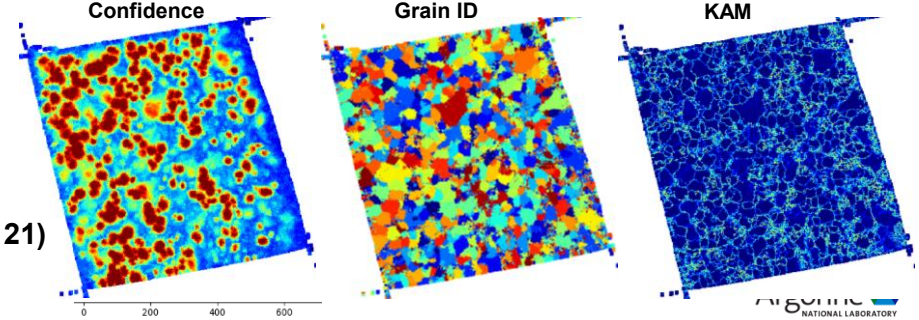
Side-view in tomo



Top-down cross-sectional view in tomo



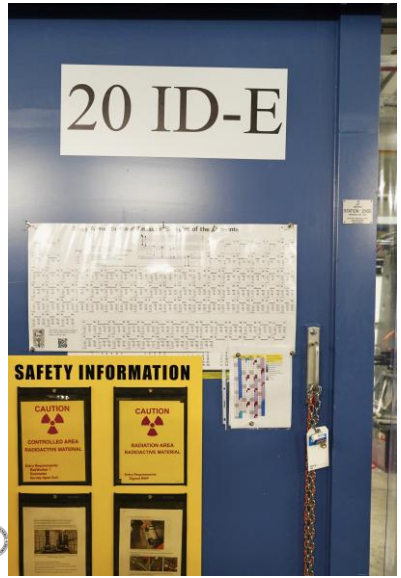
Near-field HEDM (Layer #12 out of 21)

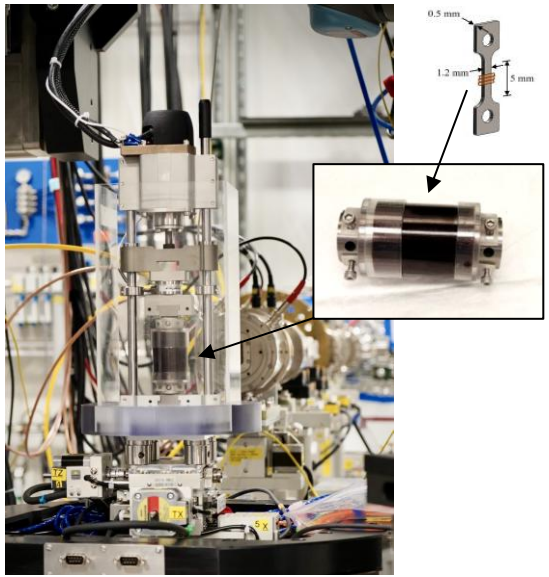


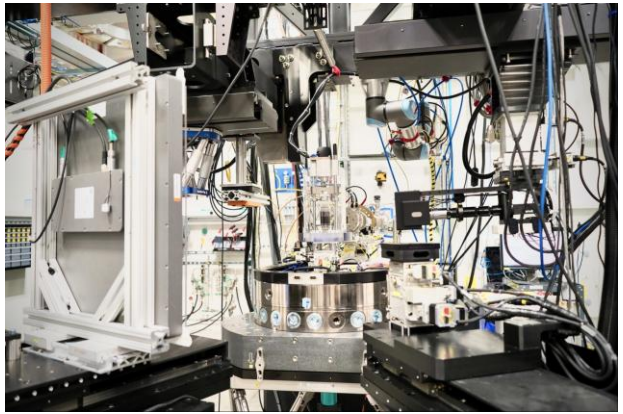
FIRST *IN-SITU* EXPERIMENT (4/16-4/19/2026)

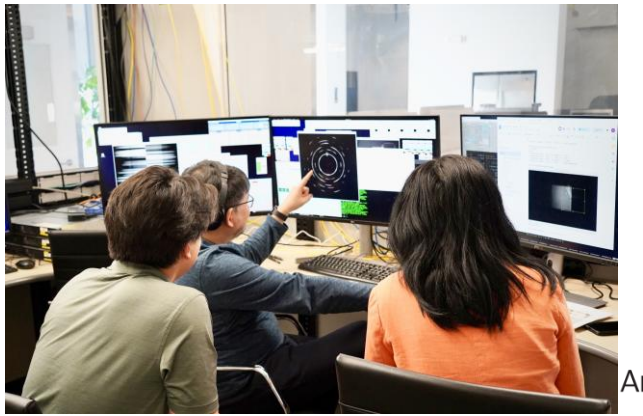
RTE 25-5409 (INL): In-Situ Synchrotron X-ray Diffraction Study During Tensile Deformation of Neutron Irradiated MA957 ODS Alloy

- Users requested 3 NFML samples (MA-957 ODS steel) which are part of irradiation experiment 08-92 (UIUC)
- Samples were subjected to slow tension tests at room temperature while x-ray diffraction data was continuously recorded
- This is the first radiological experiment in the brand-new 20-ID-E HEXM beamline; individual sample dose rate was 40 mR/h at 30 cm



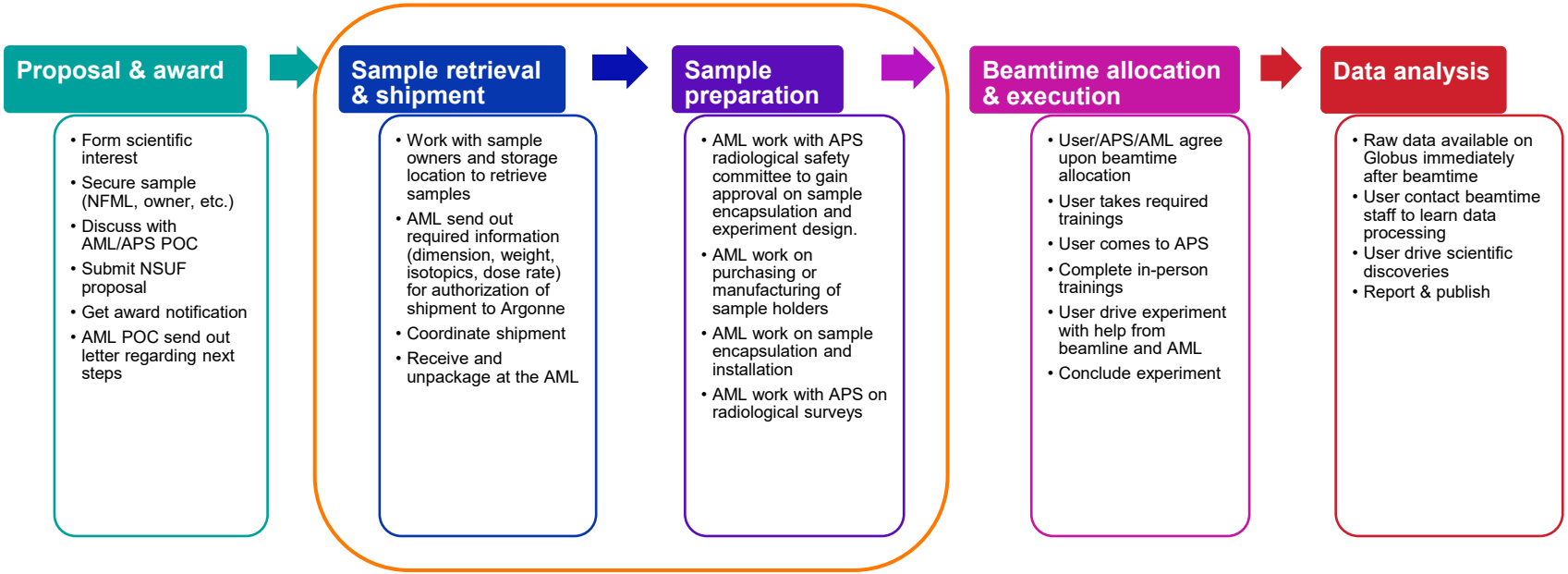






HOW AN AML PROJECT LOOKS LIKE, *FROM START TO FINISH*

- RTE 25-5409 (INL) as an example



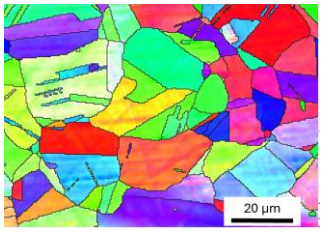
AML drives the most time-consuming and hazardous processes so users can focus on research.

A FEASIBILITY STUDY ON OTHER NFML SAMPLES

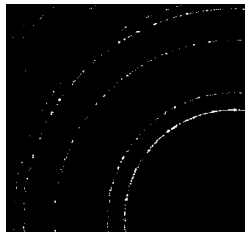
Related to RTE 25-5313 (ANL): Investigation of Elastic Interactions and Mechanical Behaviors in NF709 Using Coherence Enhanced High Energy Diffraction Microscopy

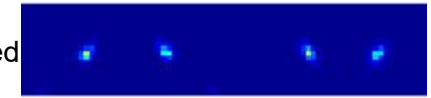
- Users requested 2 NFML samples (NF709 stainless steel) which are part of irradiation experiment 08-331 (UW-Madison)
- Ex-situ ff-HEDM measurement confirmed grainy microstructure and confirmed observable irradiation effect
- This is the second radiological experiment in the brand-new 20-ID-E HEXM beamline; individual sample dose rate was 70 mR/h at 30 cm

Reactor Name	Material Code	KGT Num	As Run Temp	As Run Total Dose
ATR	NF709 (M5)	1760	451.5	4.04

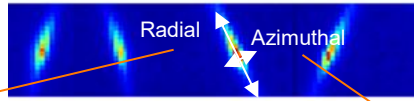


Grainy pattern

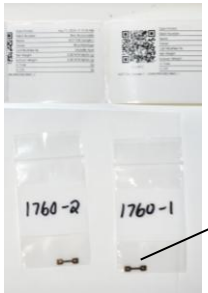


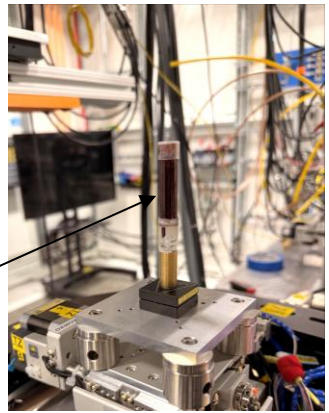


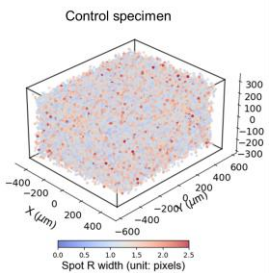
Unirradiated

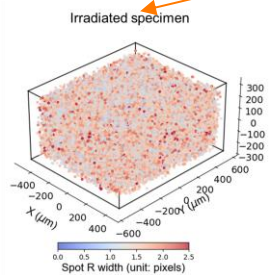


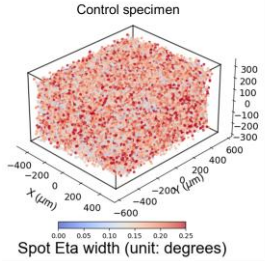
Irradiated

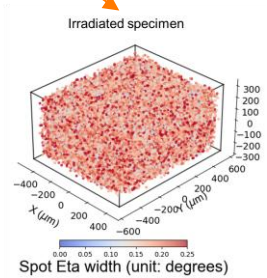












Activated Materials Laboratory (AML)

In summary, the AML has had a great start in FY26. We look forward to working with users on capability development and exciting research.

Questions?

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Argonne
NATIONAL LABORATORY
U.S. DEPARTMENT of ENERGY