# Development of Hydrogen Transport Models for High Temperature Metal Hydride Moderators

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Prof. Jeffrey C. King, Mines

Drs. Alex Long & Erik Luther, LANL

COLORADO SCHOOL OF MINES

INL Idaho National Laboratory | OAK RIDGE National Laboratory | MRP Microreactor Program | Los Alamos NATIONAL LABORATORY | Argonne NATIONAL LABORATORY

# Project Motivation

- Minimizing core size is an important consideration in many (all?) microreactor concepts
- The incorporation of a moderator into a reactor core can reduce the amount of fissile material required for criticality
  - This can translate to reduced size or reduced enrichment
- The high temperatures expected in most microreactor design limit the use of water (the most common moderating material)
- Metal hydrides can be nearly as effective as water at elevated temperatures
- Understanding the fabrication, incorporation, and performance of high temperature metal hydride moderators is an enabling technology for the development of future microreactors
- This project will develop validated computational methods to predict the short- and long-term reactor performance impacts from thermally-driven hydrogen transport in zirconium- and yttrium-hydrides)

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# Project Objectives

- Develop neutron radiography techniques to measure time-dependent hydrogen concentrations in metal hydride moderators
- Derive updated hydrogen diffusion coefficients for metal hydride moderator materials
- Demonstrate and validate multiphysics-based reactor performance models incorporating improved models for the transport of hydrogen in metal hydride moderators

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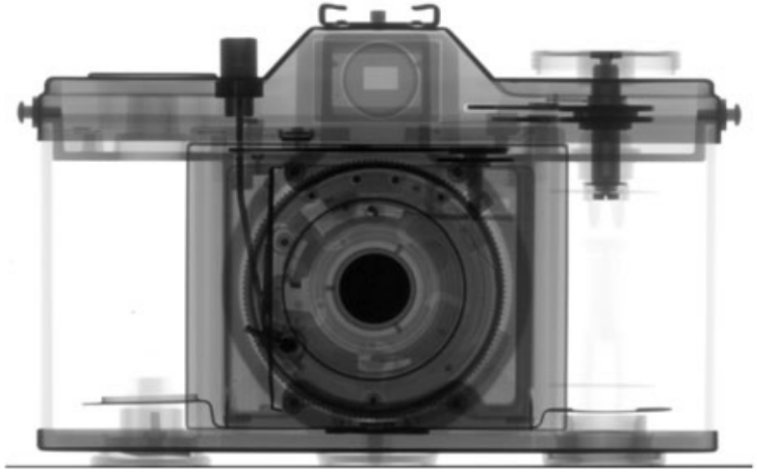
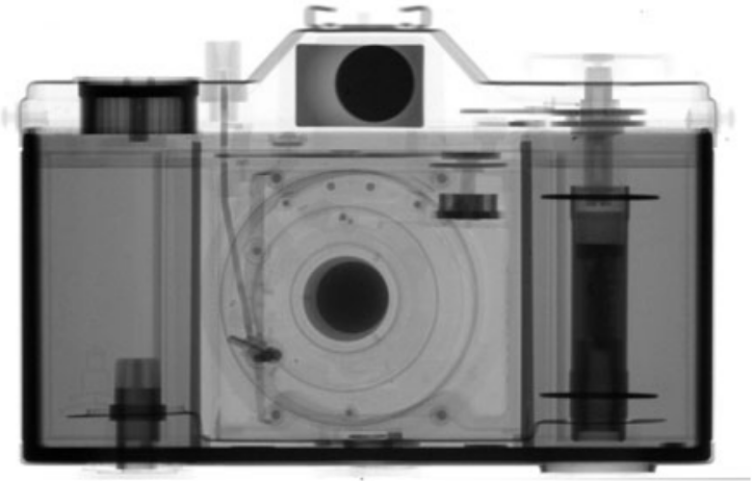
# Neutron Radiography

- Neutron radiography can be a valuable tool for studying the presence and migration of hydrogen in metal hydrides
- Neutron beams are strongly attenuated by the presence of hydrogen and only weakly attenuated by zirconium and yttrium
- The key challenge will be extracting quantitative information from the resulting images
  - This project is synergistic with parallel project sponsored by Naval Reactors that is focuses on quantifying hydrogen behavior in zirconium cladding and structural materials



**X-Ray Radiograph**



**Neutron Radiograph**

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# Project Plan

- Year 1
  - Develop neutron imaging techniques to measure hydrogen content in metal hydrides
- Year 2
  - Collect data on the diffusion of hydrogen in yttrium and zirconium hydride in response to chemical, stress, and thermal gradients
  - Derive appropriate transport models for the diffusion of hydrogen in hydride moderators
- Year 3
  - Update reactor simulation codes (BISON and GRIFFIN) with the new diffusion models
  - Demonstrate the impact short- and long-term hydrogen mobility on the performance of hydride moderated microreactors

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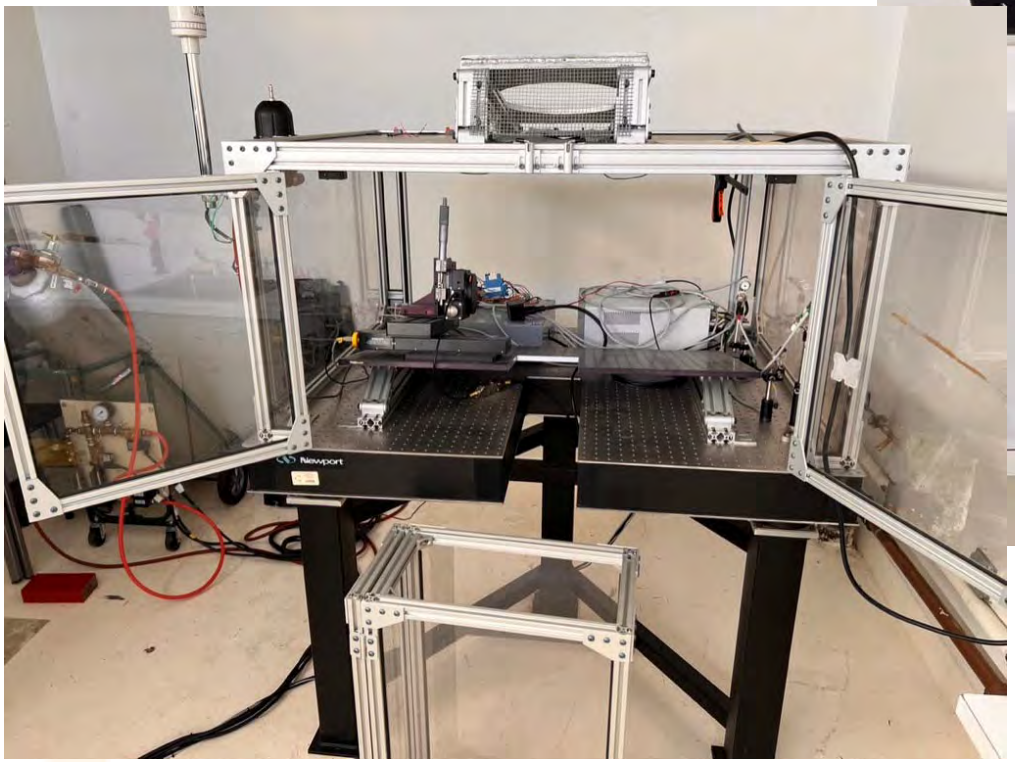
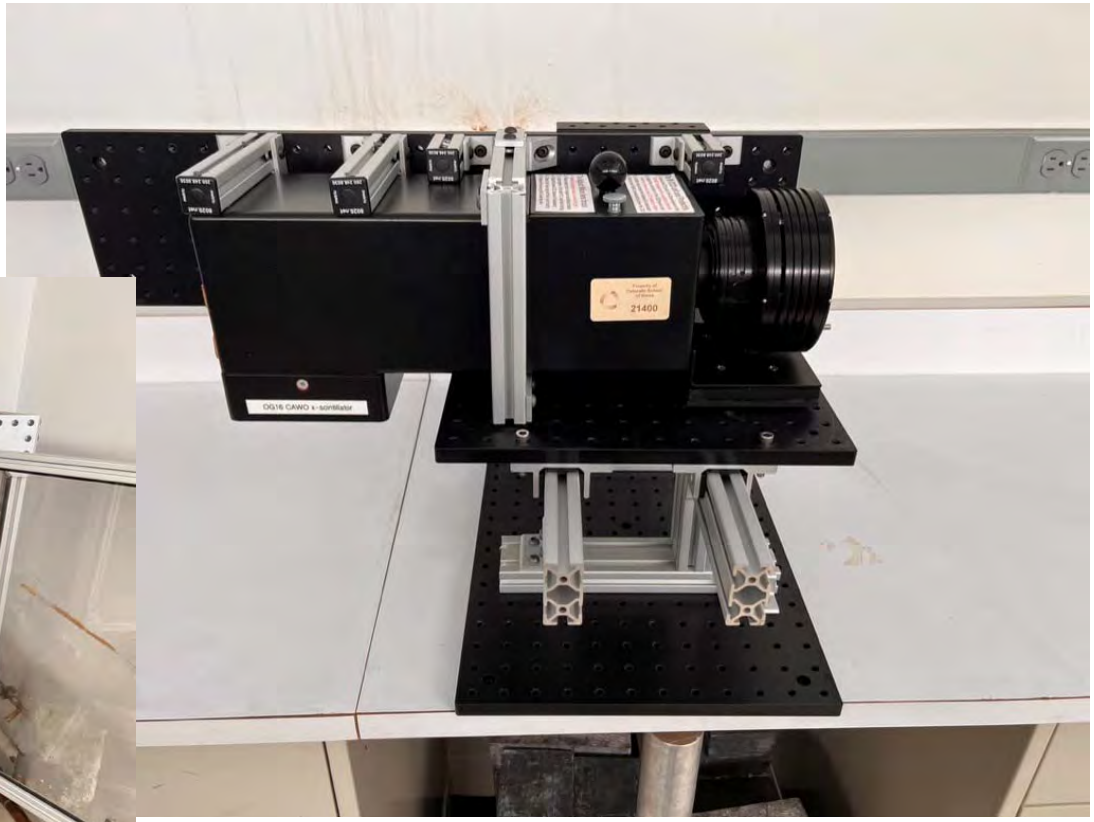
# Work in Progress - Radiography

- Reinstalling neutron beamline capabilities at the GSTR
  - Post-COVID recovery
  - Foil and film (transfer) radiography
  - Digital radiography

**Experimental Station**



**Scintillator-based Digital Imager**

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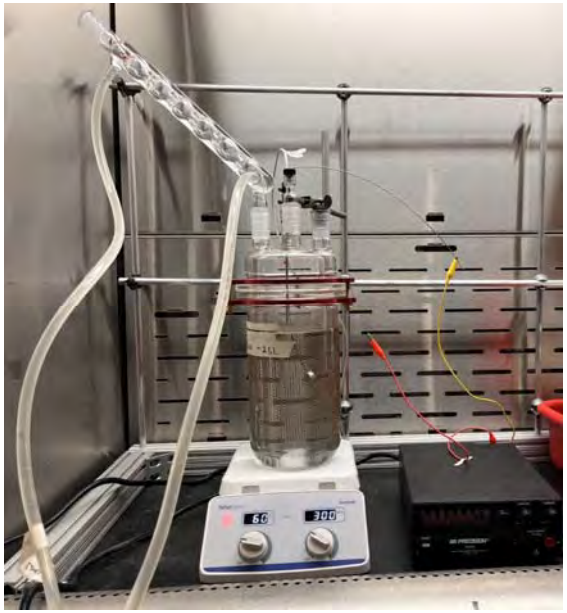
# Work in Progress – Specimen Preparation

- Developing the capabilities to produce hydrided imaging specimens at Mines, with parallel elemental analysis
- Electrolytic process
  - Primarily supports NR project (with funding from that source)
  - Calibration is ongoing
- Thermal (Sievert's) process
  - Existing vacuum tube furnace retrofit with Ar-5H atmosphere
  - To be completed over the summer



**Electrolytic Hydriding Cell**

**Cleaned (L) and Hydrided (R) Samples**

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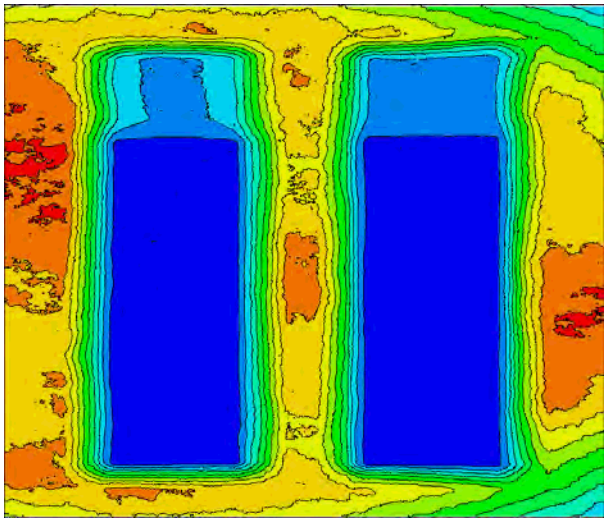
# Work in Progress – Image Simulation

- Developing the ability to accurately simulate radiography images produced at the GSTR
- Model-referencing will be important for quantitative analysis



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# Current Challenges

- Reactor Access Agreement
  - Lapsed during COVID quarantine
  - Negotiations on new agreement are taking longer than expected
- BISON/GRIFFIN Licensing
  - Also taking longer than expected

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