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Capabilities of the OSU Research Reactor (OSURR) Irradiation Facilities

ASI Webinar, 2023-11-02

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OSU-NRL History

Origin

- Facility built in 1960; first critical in 1961
- 10 kW training reactor w/ HEU MTR-type fuel

Conversion

- Analysis for LEU fuel and higher license limit in 1980s
- Fuel conversion to LEU in 1988
- Power uprate in 1992

Present

- 500 kW research reactor - multiple dry tubes, 2 beam facilities, thermal column
- Also, have multiple gamma irradiators and a gamma spectroscopy counting lab

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103A Reactor

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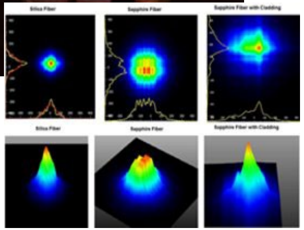
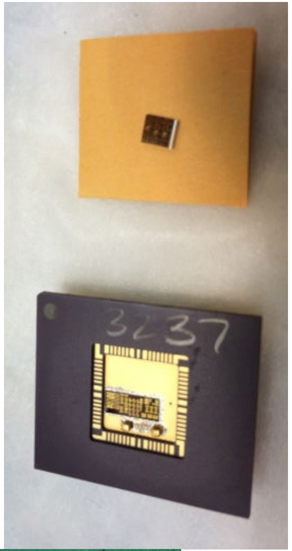
OSURR Research Strengths



Radiation sensor studies and testing

- Prototype sensors for next-gen reactors
  - Fiber-optic based detectors
  - Solid-state based detectors and materials
  - Scintillator detectors
  - *Unique capability for high-temperature testing*
- Ionization chambers for current-gen reactors
- Off the shelf sensors for fusion, accelerator use



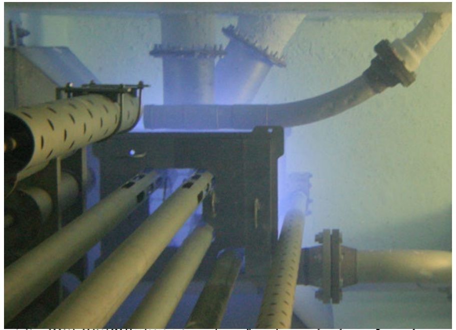
Electronics damage studies

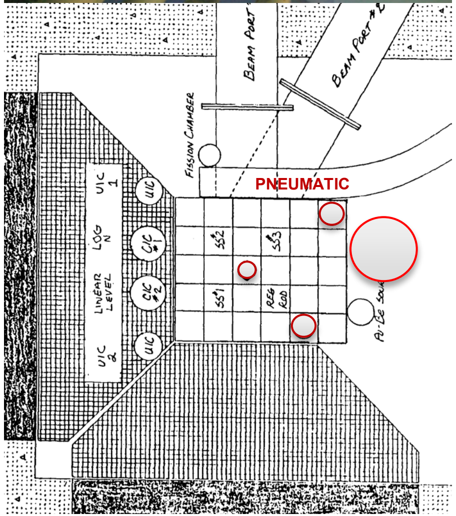
- Characterize response of electronics to radiation for use in nuclear industry, spacecraft

Phase 1 investigations

Research Capabilities

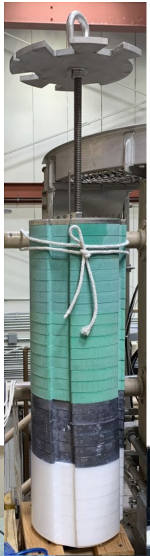
- Multiple vertical dry tubes used for irradiating experiments and samples with neutrons
  - 2 vertical dry tubes (1.3” I.D., 2.4” I.D.), 1 wet tube (2.4” I.D.) in core
  - Any one of 3 large moveable dry tubes (6.5” I.D., 6.5” I.D., 9.5” I.D.) can be positioned next to core
- Two beam facilities
  - Fast beam facility (FBF): reactor spectrum neutron beam; can filter thermal neutrons; 1.25” diam beam
  - Thermal beam facility (TBF): 98.5% thermal, 1.25”
- Pneumatic “rabbit” tube
- Thermal column facility

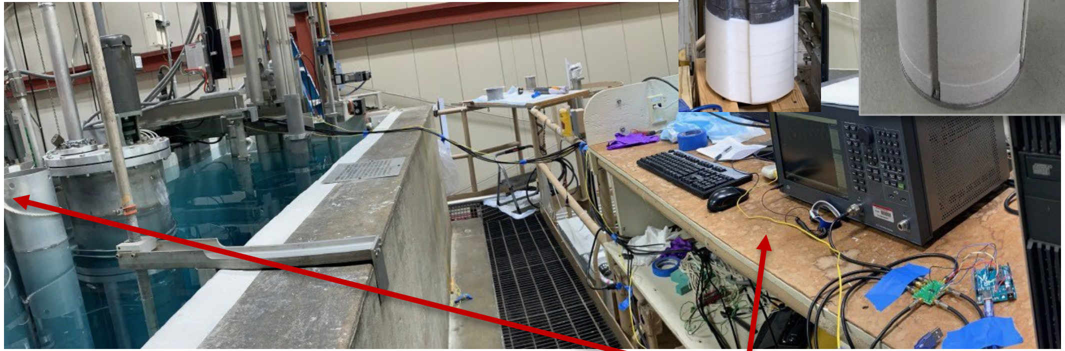




Research Capabilities

- Instrumented experiments
  - Capability for real-time, in-situ measurements in n + γ field
  - Dry tubes open to atmosphere (with shielding plugs)
  - Essential for sensor and sensor materials research
- Large experiment capability
  - Position any one of three large dry tubes next to core
- Flexible operations
  - Great flexibility for experiments with different power levels and power transients (non-pulse)
  - Experimenters control their own approved experiments

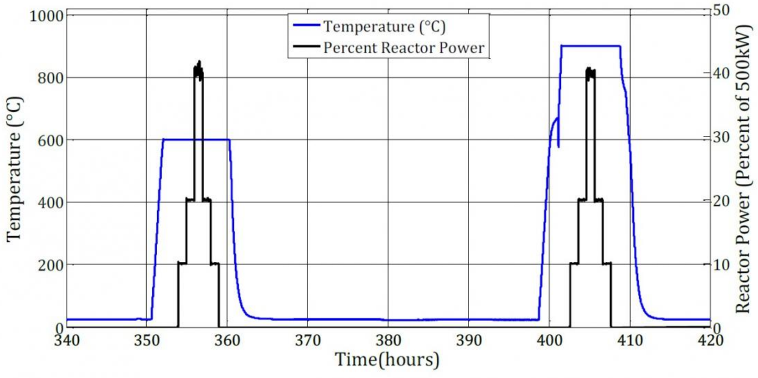


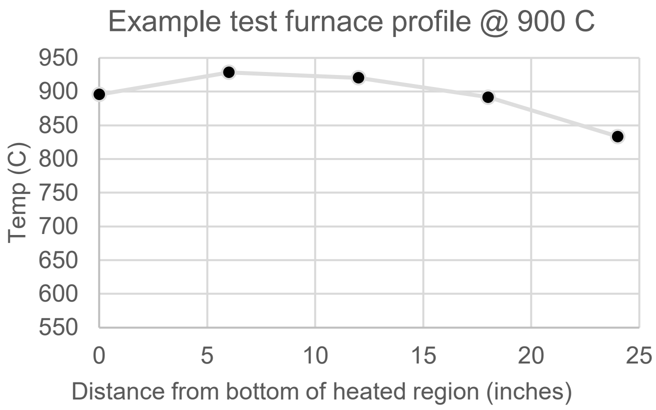


Experiment equipment space

Research Capabilities

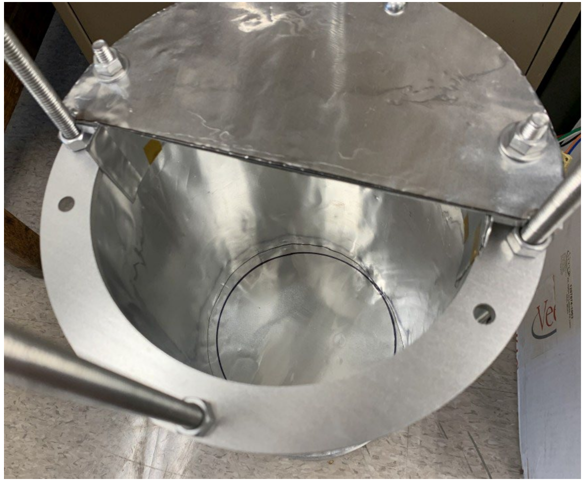
- **High-temperature irradiation experiments**
  - Unique high-temperature, in-situ experiment capabilities utilizing moveable external dry tube next to core.
  - Custom furnaces have been created to investigate material effects in sensors and sensor materials in a high-temperature radiation environment, enabling reactor-based research thus far up to 1500° C in a 1”-I.D. space. (Up to 800° C or 1200° C more typical)



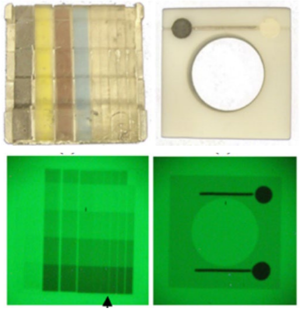


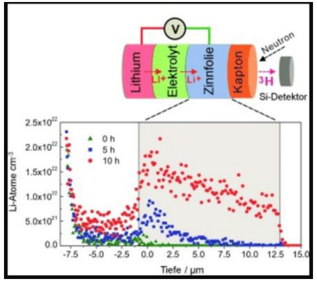
Research Capabilities

- Non-thermal neutron irradiation
  - In-situ experiment capabilities utilizing Cd-shielded rig in 9.5”-I.D. moveable external dry tube next to core.
  - Useful for testing components for displacement damage
  - Reduce thermal neutron flux 99%



Research Capabilities





Thermal neutron imaging

- Max thermal flux ~ $3x10^6$ n/cm^2/s

Neutron depth profiling

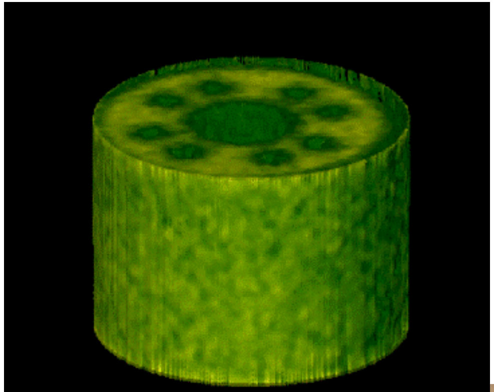
- Measure distribution of specific light elements (Li, B) near sample surface
- Useful for optimizing batteries by studying Li distribution

Neutron transmission testing

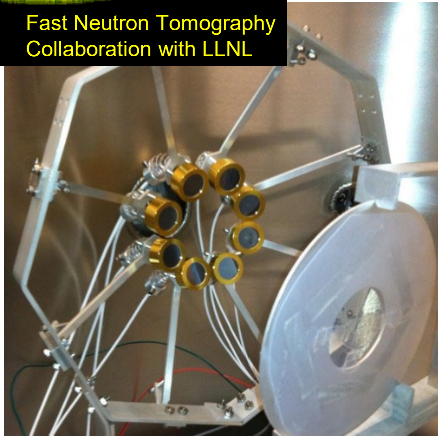
- Measure neutron absorption of materials using standards-based method

Fast neutron imaging

- Reactor-spectrum beam; thermal neutrons can be filtered
- Max flux ~ $2x10^7$ n/cm^2/s



Fast Neutron Tomography
Collaboration with LLNL

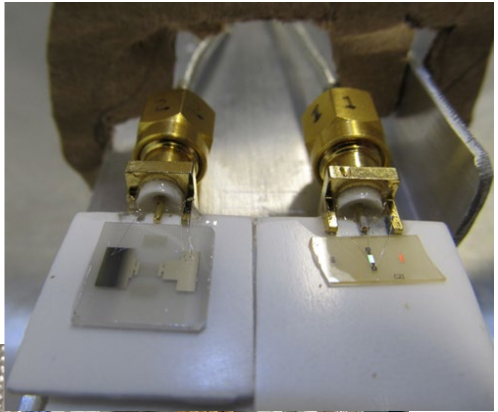


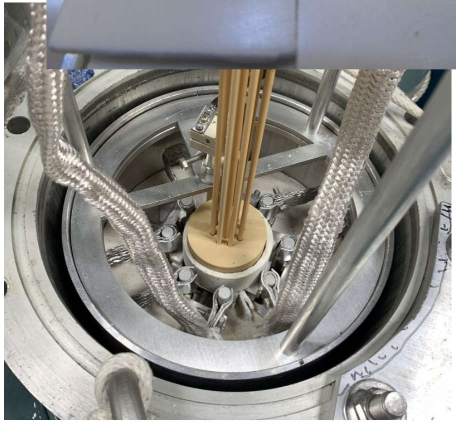
OSURR NSUF Support

Joined NSUF in 2017

OSURR NSUF Consolidated Innovative Nuclear Research (CINR) awards:

- High Fluence Active Irradiation and Combined Effects Testing of Sapphire Optical Fiber Distributed Temperature Sensors (Daw)
- Irradiation of Optical Components of In-Situ Laser Spectroscopic Sensors for Advanced Nuclear Reactor Systems (Jovanovic)
- Irradiation behavior of piezoelectric materials for nuclear reactor sensors (Khafizov)





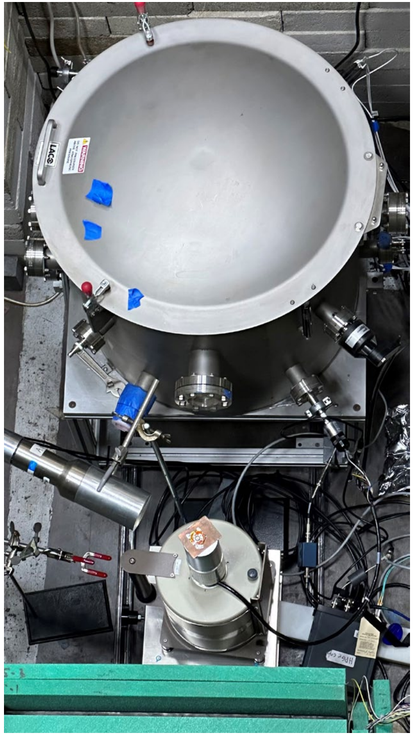
OSURR NSUF Support

Present OSURR NSUF Rapid Turnaround Experiment (RTE) awards:

- RTE 4513 (Jovanovic): Measurement of 254-eV Nuclear Recoils in Germanium
- RTE 4530 (Lanza): Irradiation of Radiation-hard GaN Transistors for Mixed Gamma and Neutron Field Under High Temperature
- RTE 4603 (Hutchins): Neutron Irradiation of Updated In-Pile Steady State, Extreme Temperature Experiment (INSET)
- RTE 4652 (Yu): Irradiating a novel thin-film scintillator for neutron radiography
- RTE 4683 (Edgar): Neutron Detection Via Defects Created in Hexagonal Boron Nitride
- RTE 4730 (Di Fulvio): Testing of ex-core monitoring configurations at the Ohio State University Research Reactor
- RTE 4745 (Pereira da Cunha): In-Situ Irradiation and RF Characterization of Langasite-Based Surface Acoustic Wave Sensors for Advanced Nuclear Reactor Applications
- RTE 4750 (Harper): Time-Resolved Neutron Damage Characterization using In Situ Positron Annihilation Spectroscopy
- RTE 4754 (Ray): Characterization of the Total-Dose Effect on State-of-the-Art Static Random-Access Memory

Recent examples

- INL - characterize miniaturized neutron sensors designed for incorporation into reactor experiments where space is at a premium.
    - Testing performed at different reactor powers at both ambient and elevated temperatures that correspond to advanced reactor operating temperatures
- UM – Measuring germanium nuclear recoils

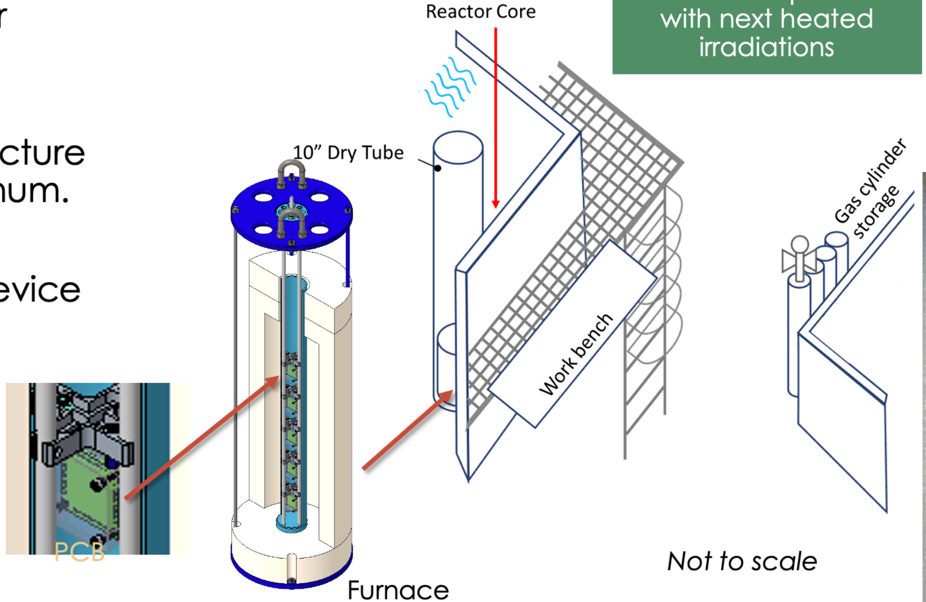


Recent examples

Gallium Nitride-based 100-Mrad Electronics Technology for Advanced Nuclear Reactor Wireless Communications, ORNL/OSU

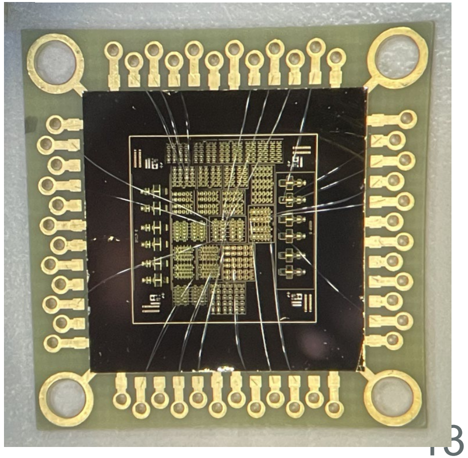
OSU Research Reactor Irradiation Plan

- Testing E-mode and D-mode devices under irradiation at room temperature.
- Mechanical infrastructure composed of Aluminum.
- Materials analysis completed at the device and board level.
- Devices wire bonded on PCB and cabled to DAQ system in safe area.



Irradiating with furnace (off) for direct comparison with next heated irradiations

Bonded E-Mode device



Recent examples

INSET Nuclear Thermal Propulsion (NTP) Testing, ORNL

INSET is a low-cost, modular irradiation test vehicle for evaluation of materials and sensors in a prototypic NTP environment or other high-temperature, radiation environments. It is a vacuum furnace capable of reaching temperatures of 2000° C and above while also being compatible for insertion into nuclear reactors. The majority of INSET is composed of low-activation materials (graphite and aluminum), and with a diameter of 8”, it can be placed in any reactor with a drywell port of at least that size.

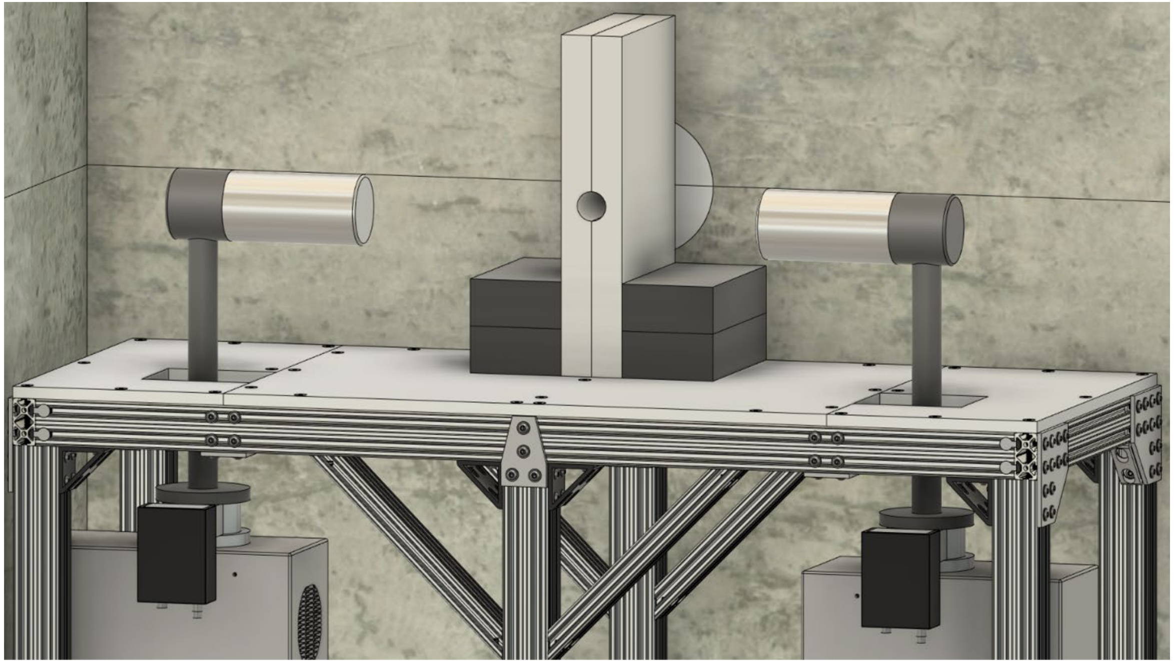
Electrical Specifications

INSET is electrically heated using DC power to resistively heat a graphite heating element

- 2 kW Power Rating
- 40 Amps
- 50 Volts DC
- 240 Volts AC from the wall

Recent examples

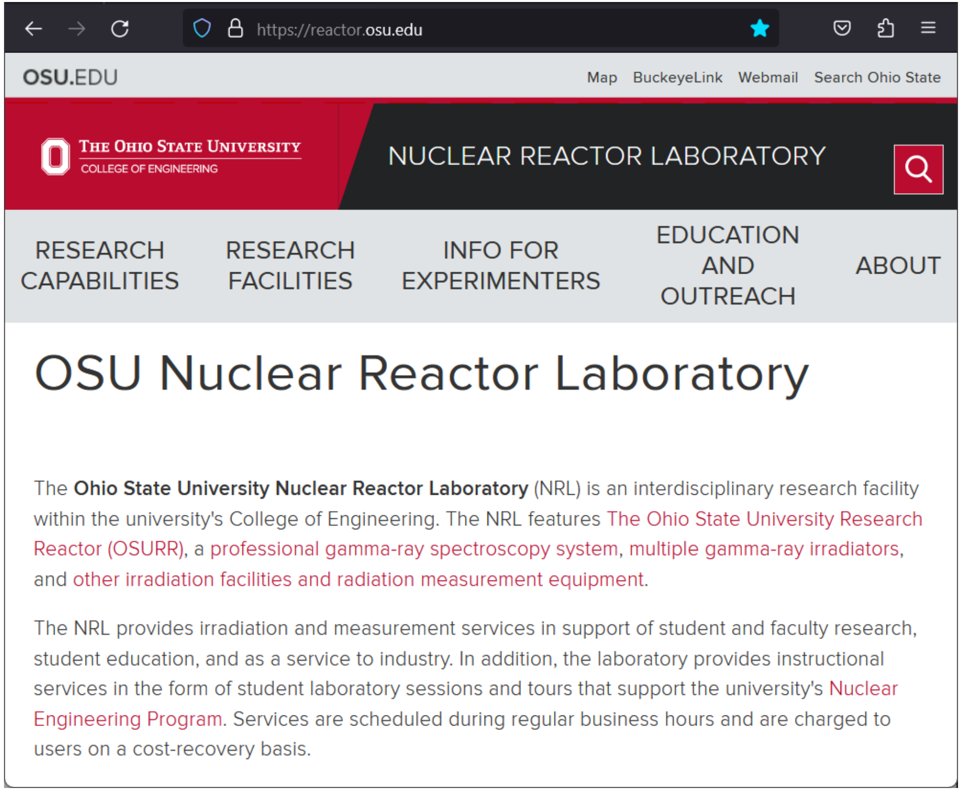
Neutron Induced Positron Annihilation Spectroscopy (INL)



Measure how point defects, specifically vacancies, are generated and evolve at the onset of irradiation damage in nuclear fuels and materials

Important for predicting material behavior and operating life in extreme environments

Additional resources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NUCLEAR REACTOR LABORATORY

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OSU Nuclear Reactor Laboratory

The **Ohio State University Nuclear Reactor Laboratory** (NRL) is an interdisciplinary research facility within the university's College of Engineering. The NRL features The Ohio State University Research Reactor (OSURR), a professional gamma-ray spectroscopy system, multiple gamma-ray irradiators, and other irradiation facilities and radiation measurement equipment.

The NRL provides irradiation and measurement services in support of student and faculty research, student education, and as a service to industry. In addition, the laboratory provides instructional services in the form of student laboratory sessions and tours that support the university's Nuclear Engineering Program. Services are scheduled during regular business hours and are charged to users on a cost-recovery basis.

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Table 1: NRL Irradiation Facility Neutron Fluxes and Neutron & Gamma Dose Rates

Facility	Total Neutron Flux (n/cm²/s)	Percent Thermal (%)	Thermal Neutron Flux (n/cm²/s)	epi-Cd Neutron Flux (n/cm²/s)	1.0 MeV Eq Neutron Flux (n/cm²/s)	Neutron Dose Rate in Si (rad-Si/hr)	Gamma Dose Rate in Si (rad-Si/hr)
			(E_n<0.5 eV)	(E_n>0.5 eV)	$F_{D,1.0 MeV,Si}$ = 95 MeV•mb $F_{D,1.0 MeV,GaAs}$ = 70 MeV•mb (Ref: ASTM E722-14)		
1.3" CIF	2.7E13[*]	60	1.6E13[*]	1.1E13[*]	5.6E12 (Si)[†] 6.0E12 (GaAs)[†]	1.6E06[‡]	8.7E07[§]
2.4" AIF	1.1E13[**]	54	6.0E12[**]	5.2E12[**]	2.3E12 (Si)[†] 2.5E12 (GaAs)[†]	6.9E05[‡]	3.8E07[§]
Pneumatic Transport System (PTS) / Rabbit	3.4E12[††]	69	2.3E12[††]	1.1E12[††]	5.5E11 (Si)[†] 6.0E11 (GaAs)[†]	1.6E05[‡]	not measured
6.5" External Dry Tube	1.9E12[‡‡]	75	1.4E12[‡‡]	4.9E11[‡‡]	2.7E11 (Si)[†] 3.0E11 (GaAs)[†]	8.5E04[‡]	7.6E06[§]
9.5" External Dry Tube (Flux Box Evacuated)	1.1E12[§§]	74	8.0E11[§§]	2.9E11[§§]	1.6E11 (Si)[†] 1.8E11 (GaAs)[†]	4.8E04[‡]	4.4E06[§]