U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Advanced Sensors and Instrumentation

Deployment and In-Reactor Test of an Instrument for Real-Time Monitoring Thermal Conductivity Evolution of Nuclear Fuels

Advanced Sensors and Instrumentation (ASI)
Annual Program Webinar
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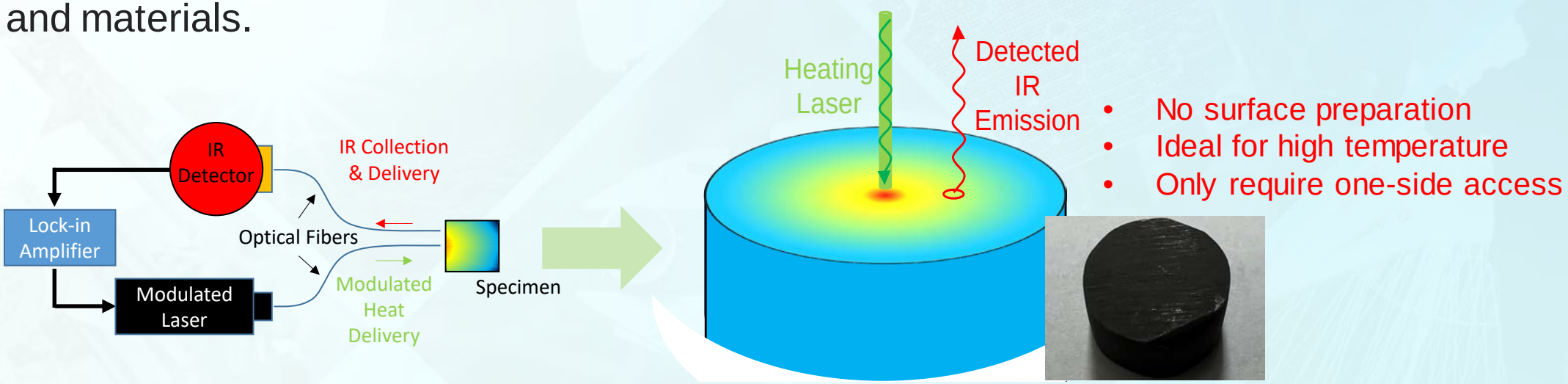
Zilong Hua, Caleb Picklesimer, Austin Fleming, David Hurley (INL)
Michael Short, Weiyue Zhou (MIT), David Carpenter (MITR)

Project Overview

Motivation:

- Thermal conductivity varies significantly in extreme reactor environments
- PIE characterization after reactor shutdown does not capture the defect medicated thermal conductivity under irradiation due to significant defect annealing
- Experimental capability for in situ measurements is currently lacking

In this project, we will deploy and test a photothermal radiometry (PTR) based instrument in MITR. This fiber-based PTR instrument will enable real-time, in-pile thermal conductivity measurements of nucleal fuels and materials.



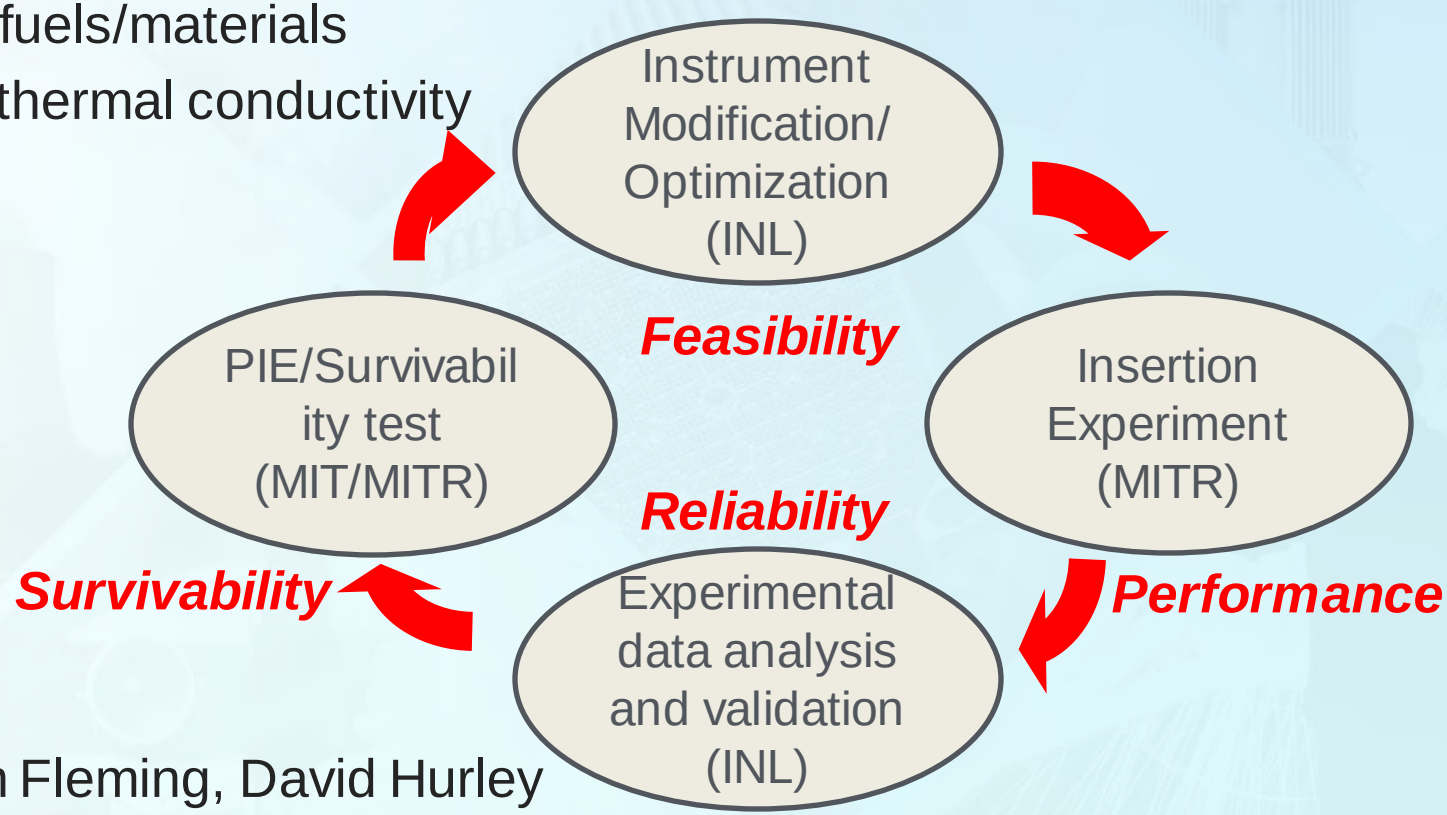
Project Overview

Objectives:

- Test the performance and survivability of the instrument
- Collect real-time experimental data and monitor the thermal conductivity change of reference samples and nuclear fuels/materials
- Develop a user protocol for routine in-pile thermal conductivity measurements

Schedule:

- FY22-24
- Irradiation round #1 (2022/11)
- Irradiation round #2 (2023/04)



Participants:

- INL: Zilong Hua, Caleb Picklesimer, Austin Fleming, David Hurley
- MIT: Michael Short, Weiyue Zhou; MITR: David Carpenter

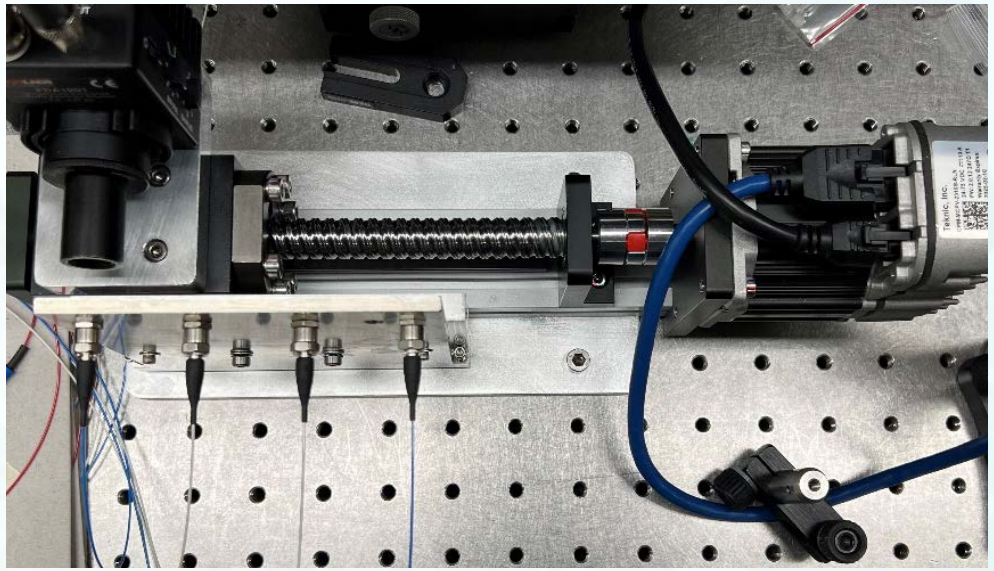
Technology Impact

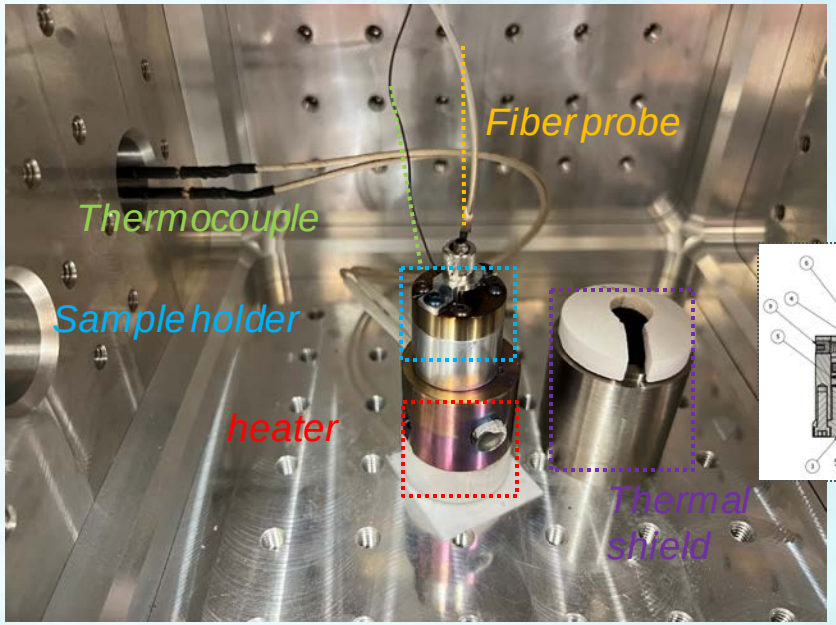
- The instrument, user protocol and user-friendly interface are expected to make regular in-reactor thermal conductivity measurements of nuclear fuels and related materials feasible
- Real-time, in-reactor thermal conductivity data will
  - Capture dynamic features of microstructure defect generation and evolution
  - Generate tremendous experimental data for computational scientists to validate and verify the advanced fuel performance codes
  - Boost the development of advanced fuels

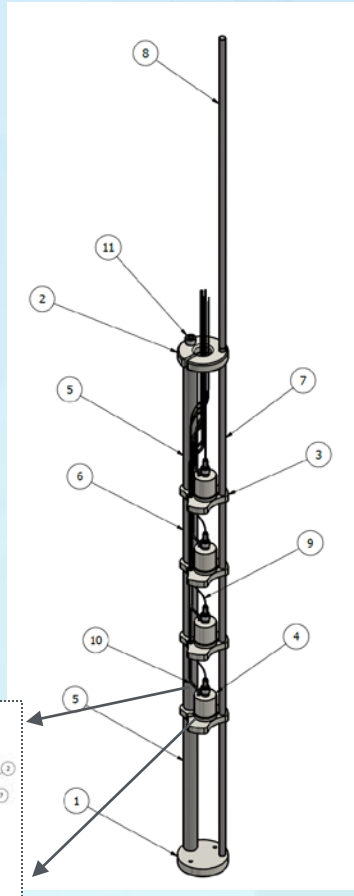
Results and Accomplishments

- Instrument design completed
- Thermal and neutronic analysis completed
- Instrument assembled and shipped to MITR for the irradiation experiment

- More high temperature testing completed (up to 730°C)







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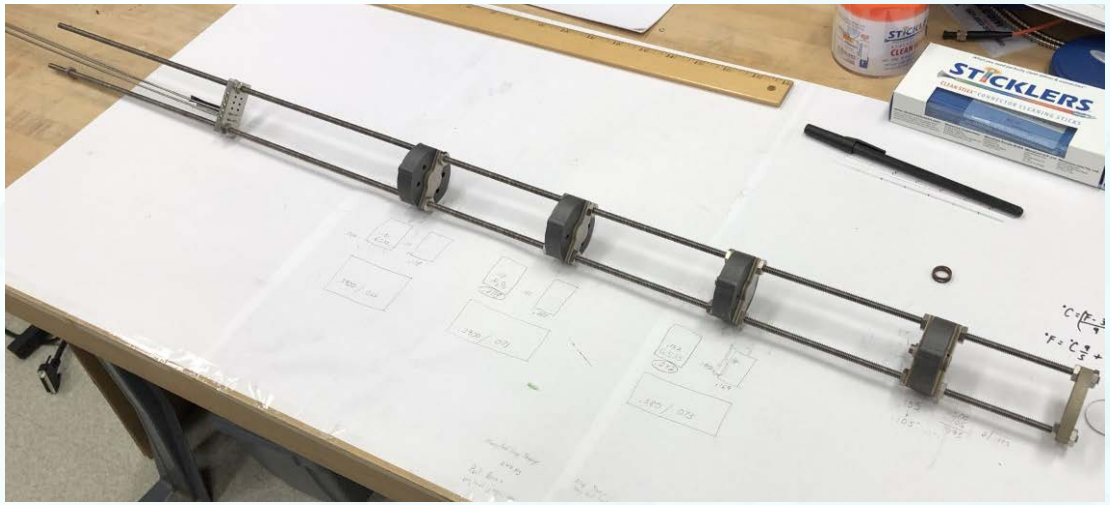

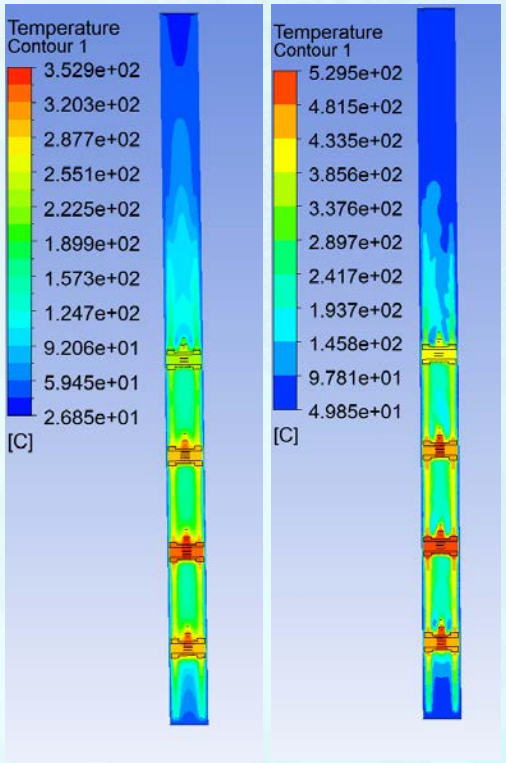

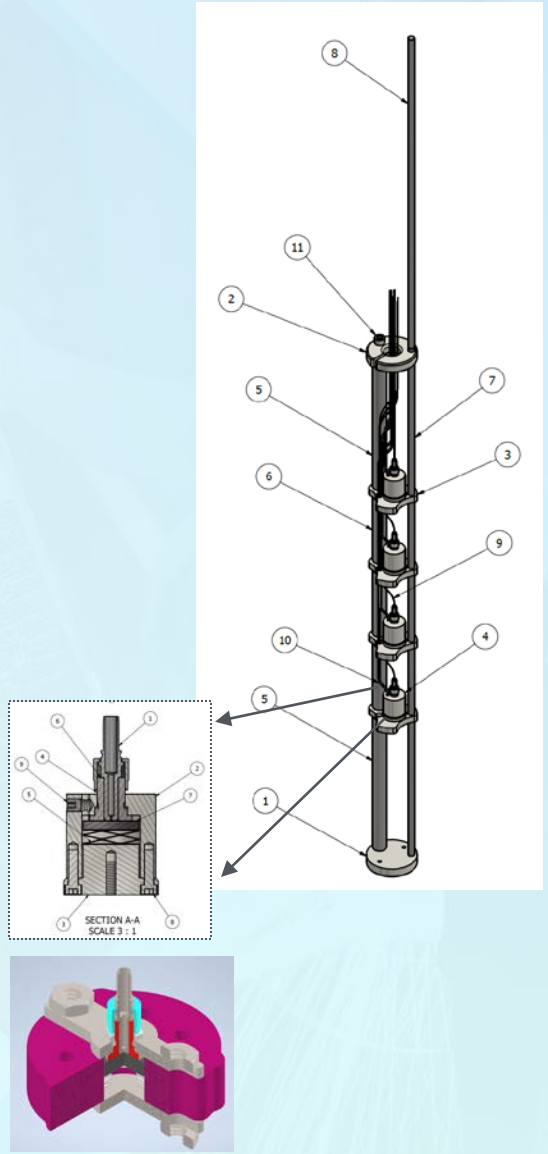

Results and Accomplishments

Challenges:

- Personnel change and manpower shortage
  - co-PI Cody Dennett left INL; Robert Schley retired from INL
  - MITR engineer for thermal and neutronic analysis left
  - Caleb Picklesimer (INL) and Weiyue Zhou (MIT) joined the team
- Long lead time of externally fabricated parts and overpriced reference samples
  - Adapted design for the sample holder; splicing fiber to overcome the short supply
  - INL/IRC machine shop helped fabricate parts
  - INL/IRC Advanced Manufacturing group (Jorgen Rufner and Arin Preston) helped fabricate samples
- Schedule adjustment
- In situ testing in the vacuum chamber observed zinc evaporation/contamination

Concluding Remarks

Summary

- Instrument fabricated, assembled, and shipped to MITR for the irradiation experiment

Future work

- Irradiation experiment is scheduled in 2022/11
- Real-time data collection
- PIE is scheduled after irradiation experiment in 2023/01
- Second round of irradiation experiment is tentatively scheduled in 2023/04
- Latest results will be presented in MRS 2022 and TMS 2023
- One journal publication is planned to summarize the instrument design and data collected in the first-round irradiation experiment

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Thank You