INL/MIS-20-60288-Revision-0

High Fluence Active Irradiation and Combined Effects Testing of Sapphire Optical Fiber Distributed Temperature Sensors

November 2020

Changing the World's Energy Future

Joshua E Daw, Kelly M McCary

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

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Advanced Sensors and Instrumentation Annual Webinar

October 29, November 5, November 12 , 2020

Joshua Daw

Idaho National Laboratory

Project Overview

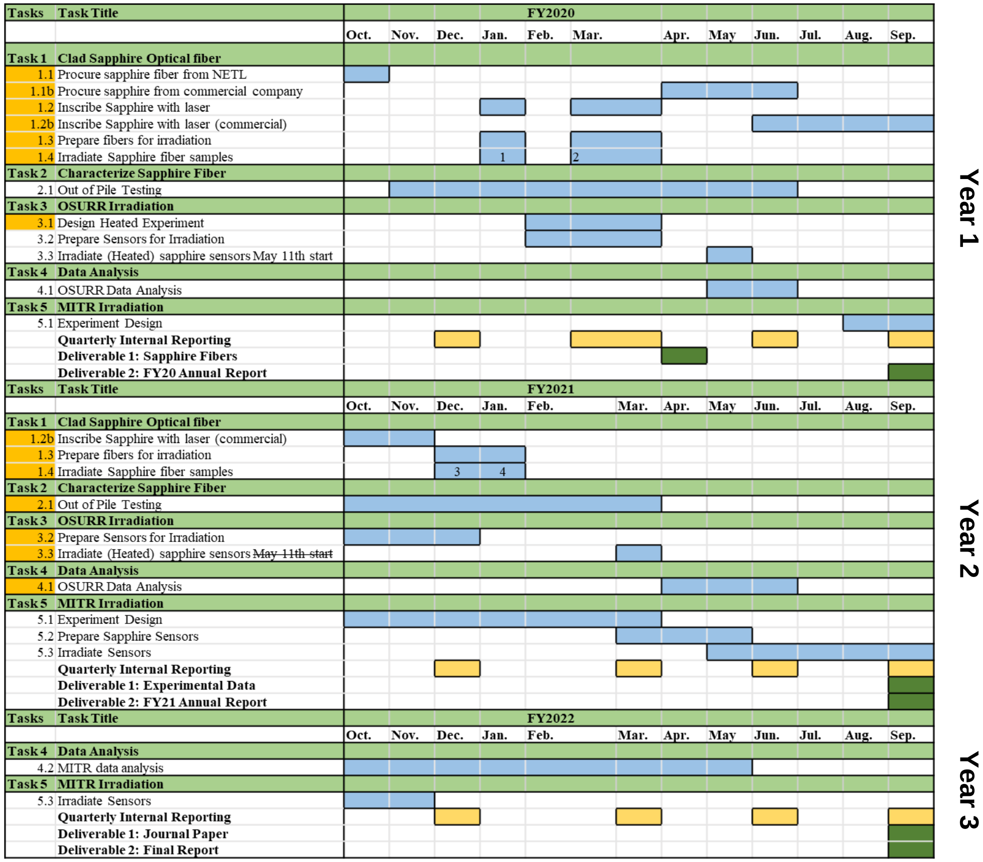
- Goals and Objectives

Investigate the in-pile performance of sapphire optical fiber temperature sensors and to develop clad sapphire optical fibers for in-pile instrumentation. Evaluate the distributed sensing performance of the sensors through optical backscatter reflectometry under combined radiation and temperature effects, and high fluence.

– Objective 1: Fabricate sapphire optical fiber sensors.
– Objective 2: Evaluate the clad sapphire fiber to verify single-mode behavior and determine and characterize light modes supported by optical fibers.
– Objective 3: Characterize in-pile temperature sensing of sapphire optical fiber and combined temperature and irradiation effects.
– Objective 4: Evaluate the lifetime and sensing performance of the sensor under irradiation to high neutron fluence.

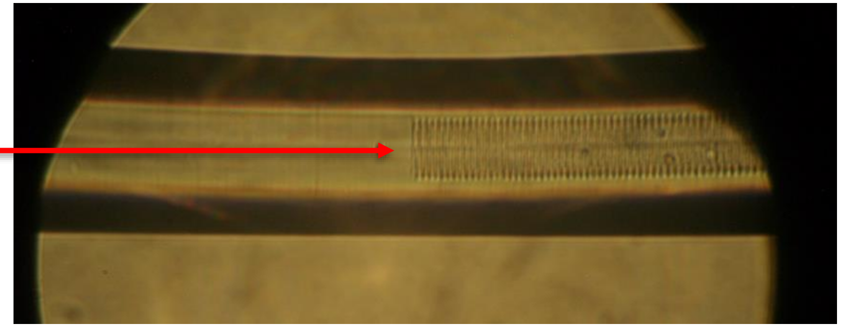
- Participants (2020)
  - Idaho National Laboratory: Lead organization
    - Dr. Joshua Daw, Kelly McCary
  - The Ohio State University
    - Dr. Thomas Blue, Josh Jones, NRL
  - The Massachusetts Institute of Technology
    - NRL
  - National Energy Technology Laboratory
    - Dr. Michael Buric
  - Oak Ridge National Laboratory
    - Dr. Christian Petrie
  - Luna Innovations and the University of Pittsburgh

- Schedule



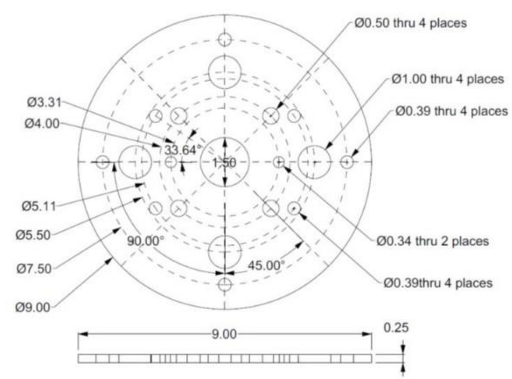
Accomplishments

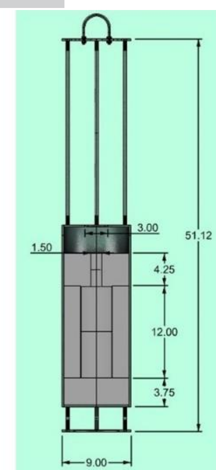
- Fiber procurement
- FBG inscription
- Fiber cladding irradiations



Quantity of Fibers	# of Gratings	Inscribed by	Fiber Supplier	OD (um)	Length (inches)	Clad (Y/N)	Location
2	2	U-Pitt	Micromaterials	100	~14	Y	OSU
4	1	U-Pitt	Micromaterials	100	~14	Y	OSU
1	0	N/A	Micromaterials	100	~18	Y	OSU
1	13	FemtoFiber Tec	Micromaterials	75	~24	Y	OSU
8	0	N/A	Micromaterials	100	1 m	N	INL

- Heated irradiation designed and furnace procured



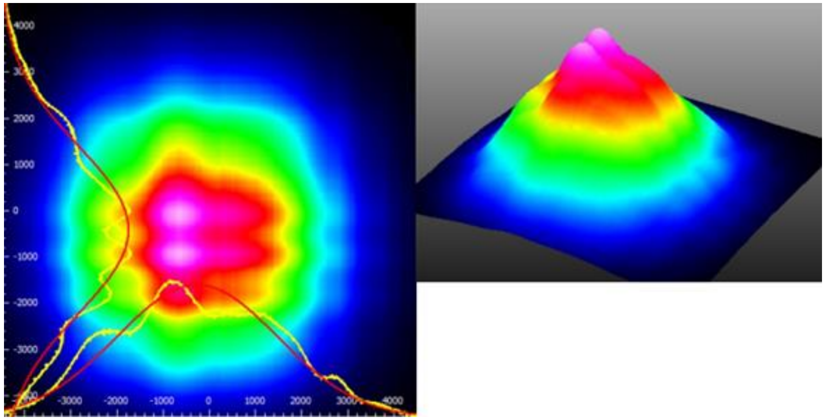


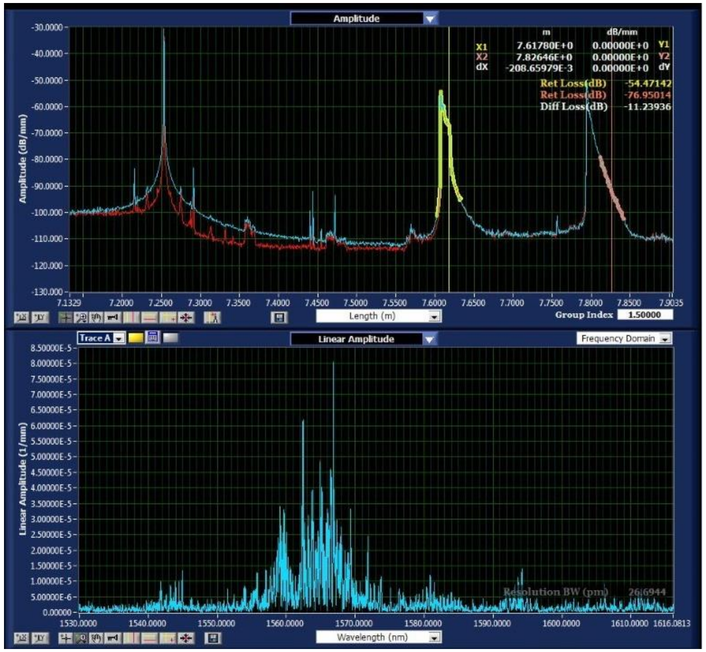
Technology Impact

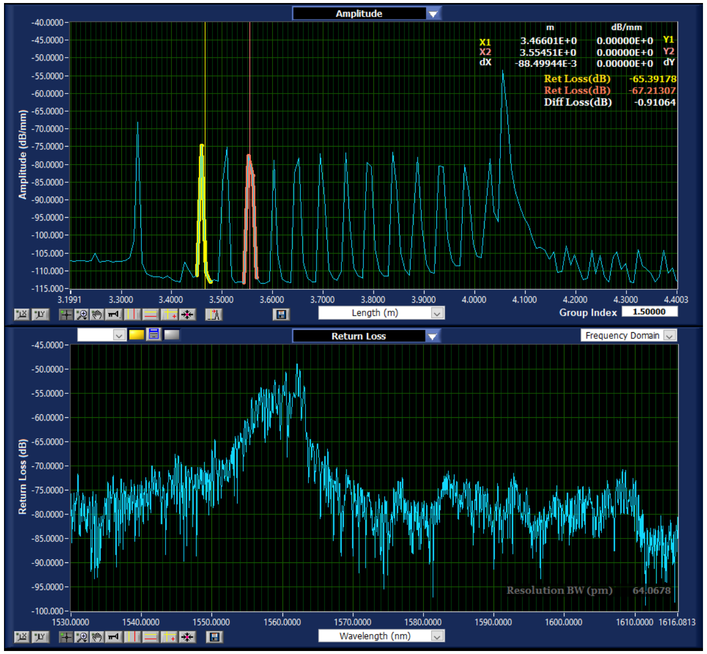
- This research advances nuclear technology by characterizing and demonstrating a sensor technology with the potential to make measurements with unprecedented spatial and temperature resolution at higher temperatures than prior optical sensors. This technology can also be applied to measurements other than temperature.
- This research supports the DOE-NE research mission by enabling high fidelity measurements in irradiation experiments in more extreme conditions than previously possible.
- Impacts the nuclear industry by decreasing the time to qualification of new reactor concepts, fuels, and structural materials.
- Commercialization is underway by Luna Innovations. This research represents the opportunity to close technology gaps and demonstrate the potential of sapphire optical fibers.

Accomplishments (1/2)

- Pre-clad characterization of fibers
  - OBR scans
  - Microscope pictures
  - IR imaging





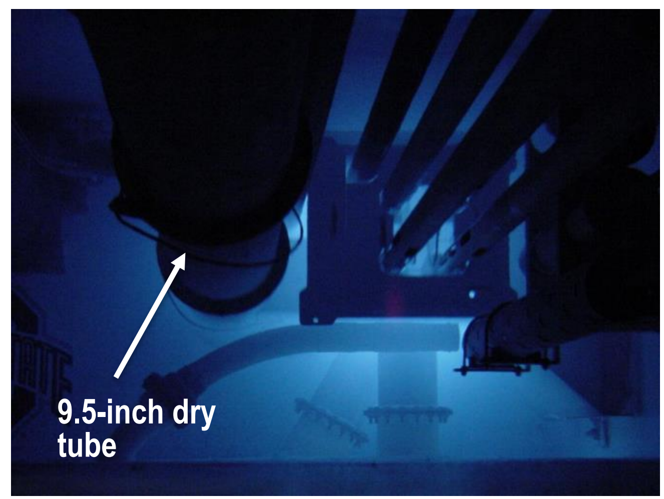


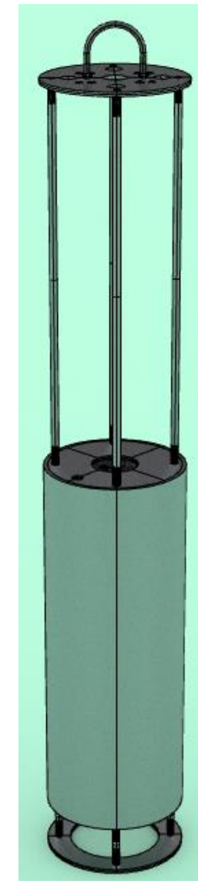
Accomplishments (2/2)

- Heated Irradiation at OSURR:
  - $MoSi_2$ heating elements, capable of up to 1500 C
  - Fits in the 9.5-inch dry tube at OSURR
  - 1.5-inch ID for samples
- OSURR Dry Tubes:
  - 6.5-inch and 9.5-inch ID
  - Next-to-core position: neutron flux up to ~10^{12} n/cm^2/s
  - The shielding plug for each tube has a cableway that allows cabling out of the dry tube to enable in-situ measurements from instrumented experiments
  - Cryogenic up to 1600 C

Table 2: NRL Irradiation Facility Dimensions

Facility	Inner Dimension
CIF	1.3" Diameter
AIF	2.4" Diameter
Rabbit	1.1" Diameter *
6.5" Movable Dry Tube	6.6" Diameter
9.5" Movable Dry Tube	9.5" Diameter
Beam Port #1 (BP1) Sample Holder Position	2.0" Diameter x 3.7" Height
Function Test Vessel in BP1	Phenolic mounting board
Beam Port #2 (BP2) External Beam Line Facility	~30 mm Diameter
Thermal Column	4" x 4" Square/Stringer





reactor.osu.edu

Conclusion

Year one progress was limited to procurement, inscription, and cladding of single mode sapphire FBG sensors for out-of-core characterization and heated irradiation tests. The design of the heated irradiation was also completed. This research closes a technology gap limiting optical fiber use for high temperature, high fluence irradiations. This will provide a valuable new capability which will help expedite qualification of new fuels, materials, and advanced reactor designs.

- *Questions?*
- *joshua.daw@inl.gov*