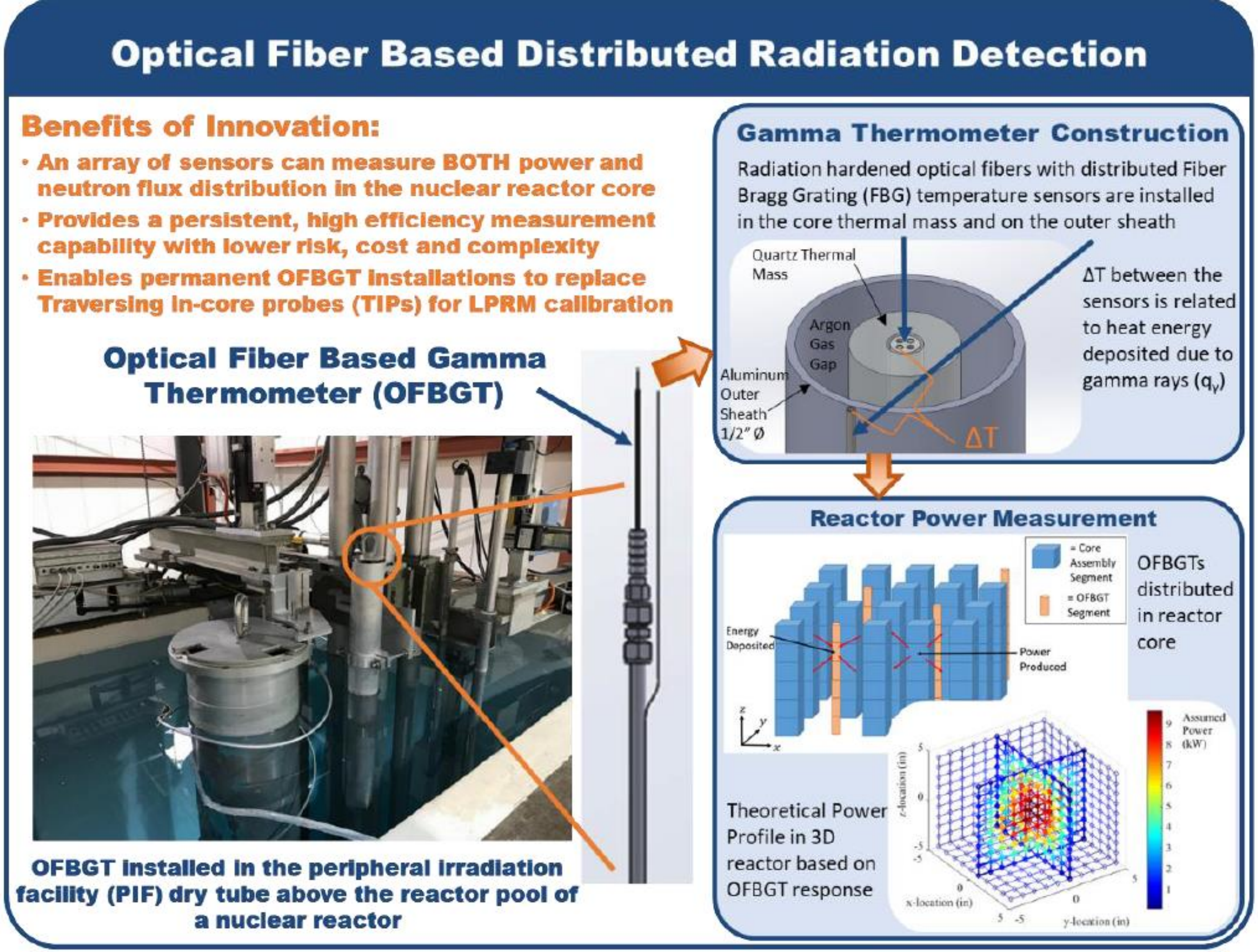
DOE – Phase I STTR program

Optical Fiber Based Distributed Radiation Detection

Chris Westcott – Luna Innovations

Period of Performance – 7/10/23 through 4/9/24

Program Concept Overview



University Partner:

Dr. Thomas E. Blue at The Ohio State University

THE OHIO STATE UNIVERSITY

Program Objectives

OVERALL GOAL

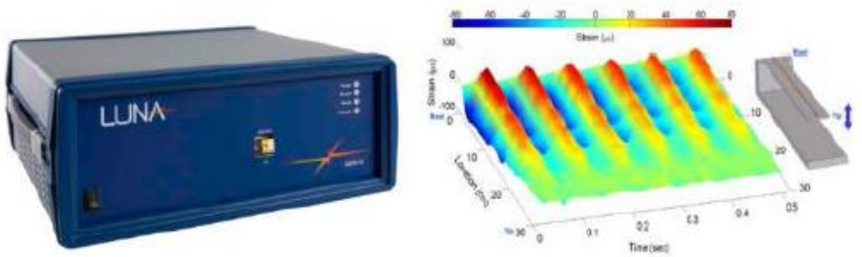
Transition earlier work by others on Optical Fiber Based Gamma Thermometers (OFBGT's) into a commercial product.

PHASE I OBJECTIVES – 9 month program from July 2023 – April 2024

- Develop early commercial prototype sensors with increased TRL
- Test sensors in the OSU reactor to demonstrate power measurement
- Expand sensor capability to include both gamma and neutron flux measurements
- Characterize accuracy and repeatability of sensors
- Determine longevity over temperature and radiation exposure/fluence

Luna Enabling the future with fiber

- Luna is a global leader in fiber optic sensors and instrumentation with a focus on distributed sensing.
- Luna instruments have been used in the prior research and development efforts for OFBGT's and many other sensors.
- As a public company with extensive production and engineering capabilities, Luna is uniquely qualified to transition new sensor technologies into commercial applications.

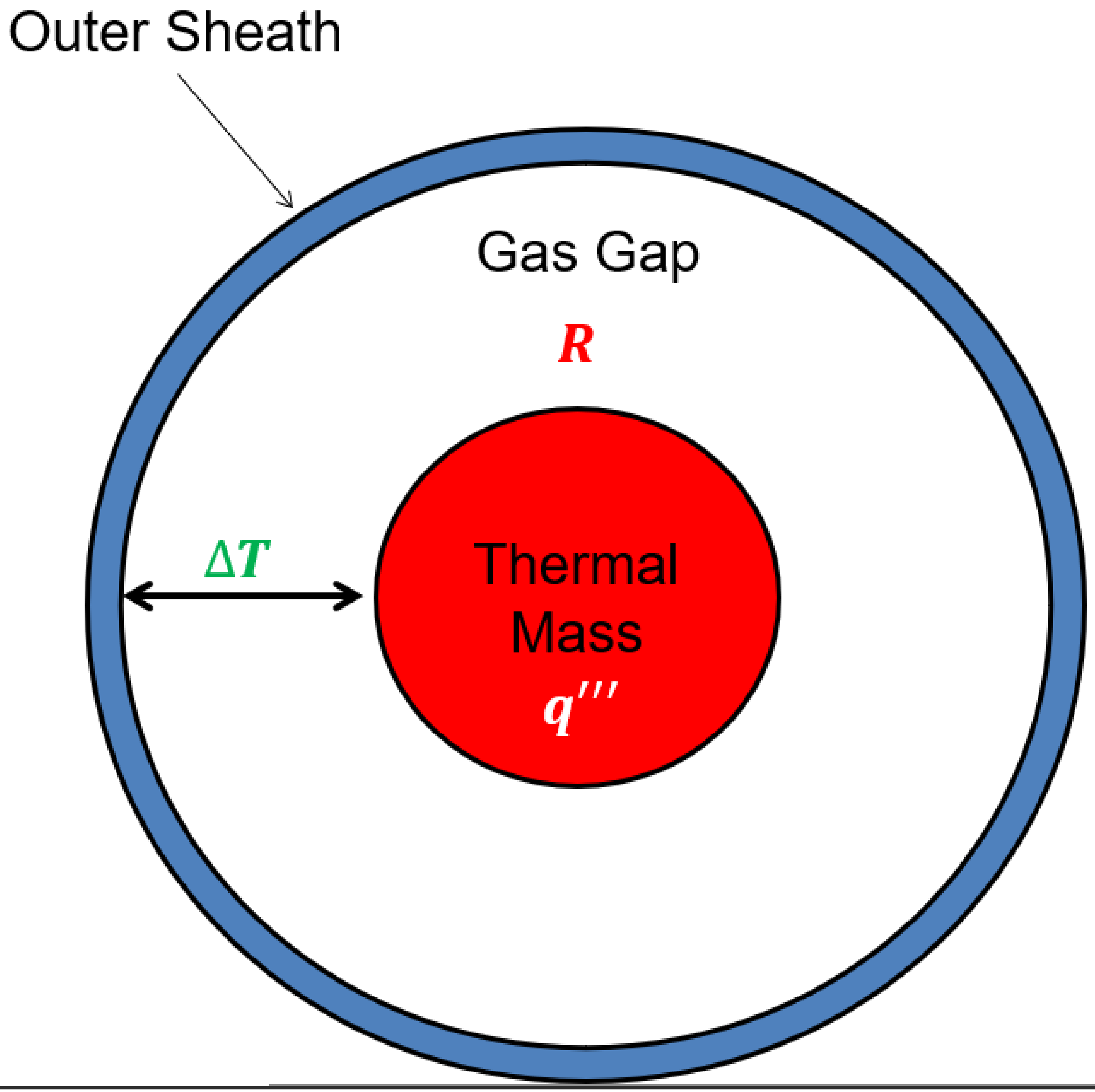


The ODISI-B recording the time response of the strain of a cantilever beam oscillating at its natural frequency.

The ODISI 6100 instrument (top), temperature data on a car radiator shown with point cloud visualization.

What is a Gamma Thermometer?

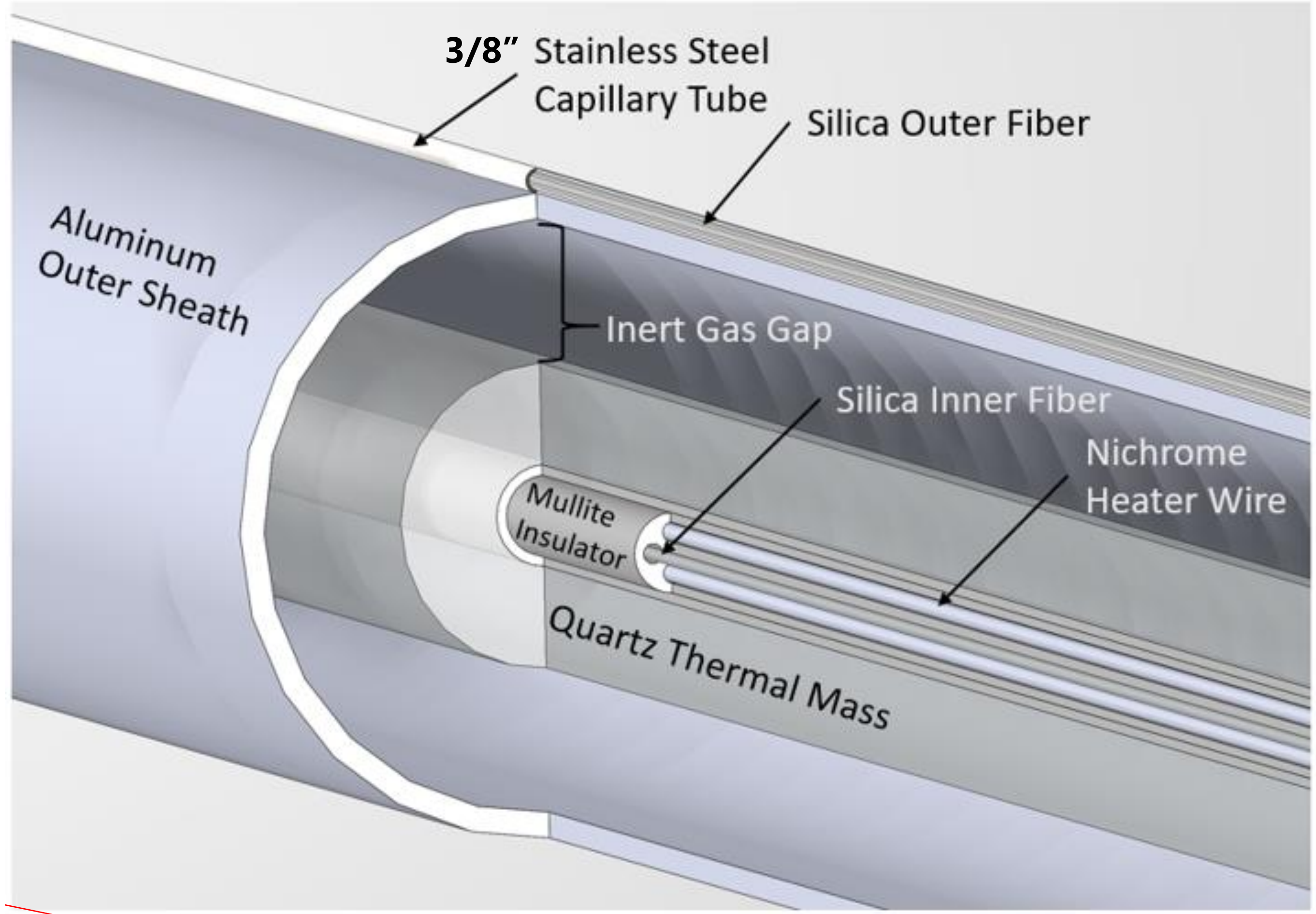
- A gamma thermometer consists of:
  - Thermal mass, in which heat energy is deposited due to gamma rays (q''')
  - Outer sheath, which contains the thermal mass
  - Gas gap, which is responsible for a thermal resistance (R) between the thermal mass and outer sheath, thus resulting in a ΔT
- If one measures ΔT, and the relationship between q''' and ΔT is known, then one can determine q''' ($q''' = \Delta T / R$)

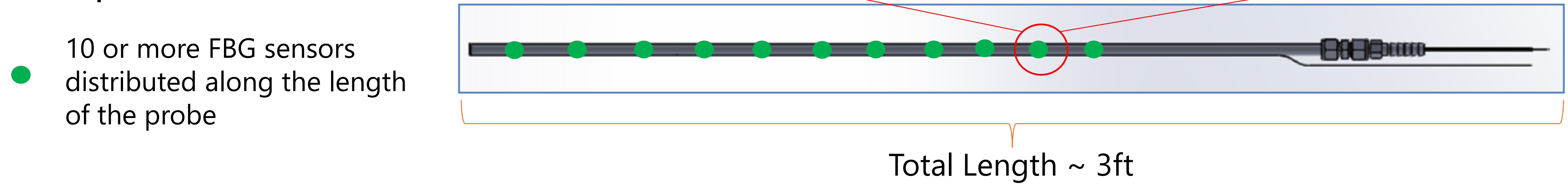


Sensor Design

- Active sensor region consists of a thermal mass, inert gas gap, and an aluminum outer sheath

- Fibers are inscribed with customized FBGs to create a strong OFDR signature that is robust to radiation exposure



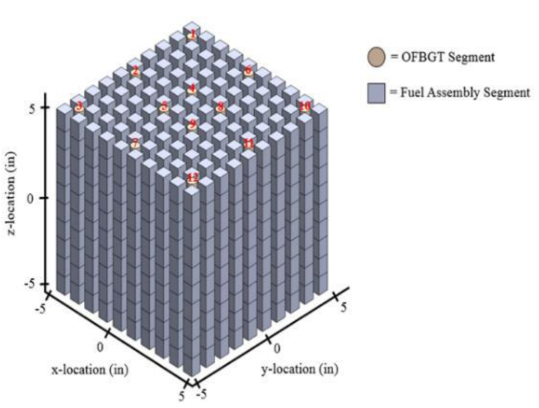


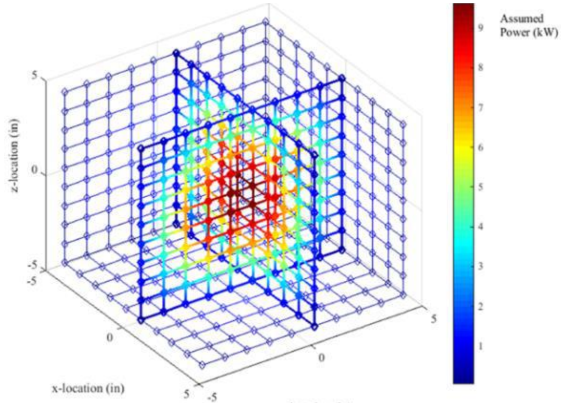
Preliminary Target Performance Criteria

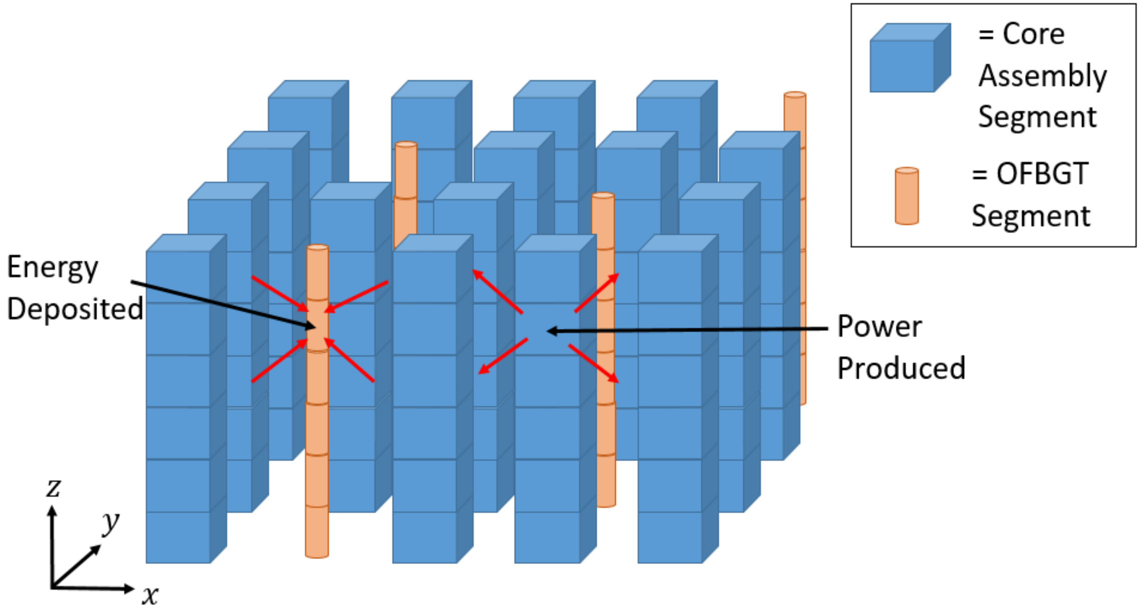
Specification	Phase I Goal	Overall Project Goal
Temperature Range	0 - 300°C	0 - 800°C
Number of FBG temperature sensors in an OFBGT	10	20+
Measurement Rate	1 Hz	10 Hz
Temperature Resolution	1.0°C	0.1°C
Temperature Accuracy	2% F.S.	1% F.S.
Reactor Power Accuracy	5%	1%
Neutron Flux Accuracy	Best effort	5%
OFBGT length	3 ft.	10 ft.

Benefits of the technology

- OFBGTs could simply be used to calibrate LPRMs
  - Because an OFBGT is a distributed sensor, one could perform this calibration with less wiring with an OFBGT than with a chain of thermocouple-based GTs. Improvement over TIP’s.
- However, because of the distributed sensing capability of the OFBGT, it presents the opportunity for power inferencing
  - An array of OFBGTs in a reactor core could provide 100s to 1000s of data points
  - If one considers a segmented core, one could use response function equations between OFBGT segments and reactor core segments to obtain a power distribution of 100s to 1000s of segments
  - Using different materials can create a neutron sensitive probe, which would allow for co-located gamma and neutron measurements to be made.







Tasks and completion

1. **Determine target system performance criteria**
    - 100 % complete
2. **Model and simulate performance of OFBGT sensors for measurement of reactor power and neutron flux**
    - 25% complete, work in progress at Luna and Ohio State
3. **Fabricate OFBGT sensors**
    - 35% complete, bare sensors and most materials are in hand.
4. **Test and calibrate OFBGT sensors in the laboratory**
    - 10% complete – began testing with bare sensors at Luna
5. **Test OFBGT sensors in nuclear reactor**
    - Planned for March 4th , 2024
6. **Data Analysis**
7. **Program Management, Commercialization and Phase II Planning**

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