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Project: Health Monitoring of Nuclear Fuel Pins and Pressurized Tubes Using Fiber-Optic Strain and Temperature Sensors

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Background

- Fiber optic sensors (FOS) using single mode fiber can be used to measure distributed strain and temperature on the cladding surface of a simulated fuel rod out-of-pile.
- Fiber optic sensors offer more refined spatial and distributed measurements than traditional point-to-point sensors and are small, nonconductive, and immune to electromagnetic interference.
- The technique used to make the fiber optic sensor function involves sending a pulsed laser into the fiber and collecting the intensity of the Rayleigh backscatter reflections.
- The reflected light is combined with a reference field, and external stimuli on the FOS can cause changes in the reflected spectrum, which is leveraged to create temperature or strain sensors.

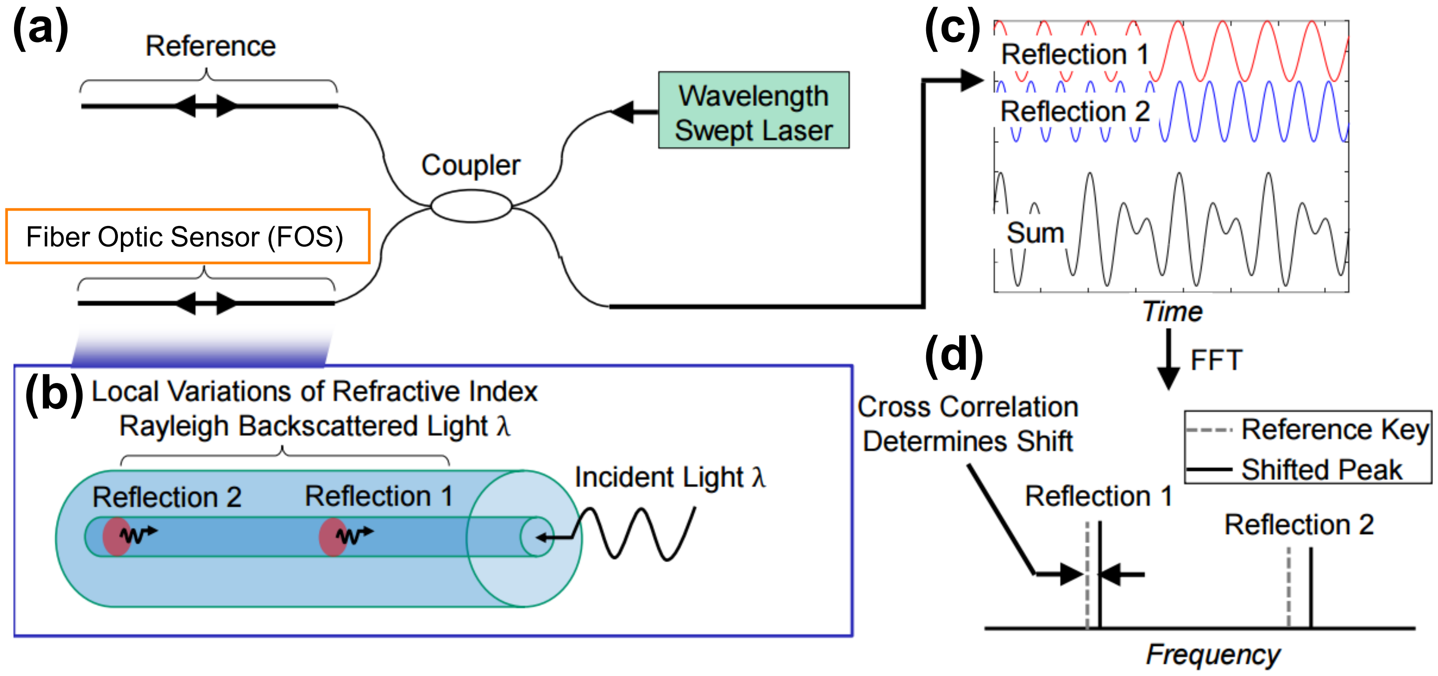

Figure 1: Optical Frequency Domain Reflectometry Illustration. **(a)** Schematic of the Interferometer; **(b)** Illustration of Rayleigh scattering in a single mode fiber; **(c)** An algorithm combines the polarized reflections from the FOS with a reference; and **(d)** A cross-correlation algorithm that determines the Rayleigh backscatter shift in terms of a spectral frequency change. The spectral shift can be correlated to temperature or mechanical strain. [1]

[1] M. T. Weathered, “Characterization of sodium thermal hydraulics with optical fiber temperature sensors,” thesis, The University of Wisconsin - Madison, Madison, 2017.

Project Goals

1. Develop a fiber optic sensor (FOS) system for obtaining distributed temperature measurements as well as local strain measurements and test the FOS in a heater rod (Fig. 2), initially under steady-state pressurized water reactor (PWR) conditions at UW-Madison.

2. Develop a methodology for bonding fiber optical sensors (FOS) onto the surface of tubes and/or embedding them in the tube walls for monitoring internal pressure.

3. Develop a methodology for collecting temperature compensated strain data in high-temperature and high-pressure environments.

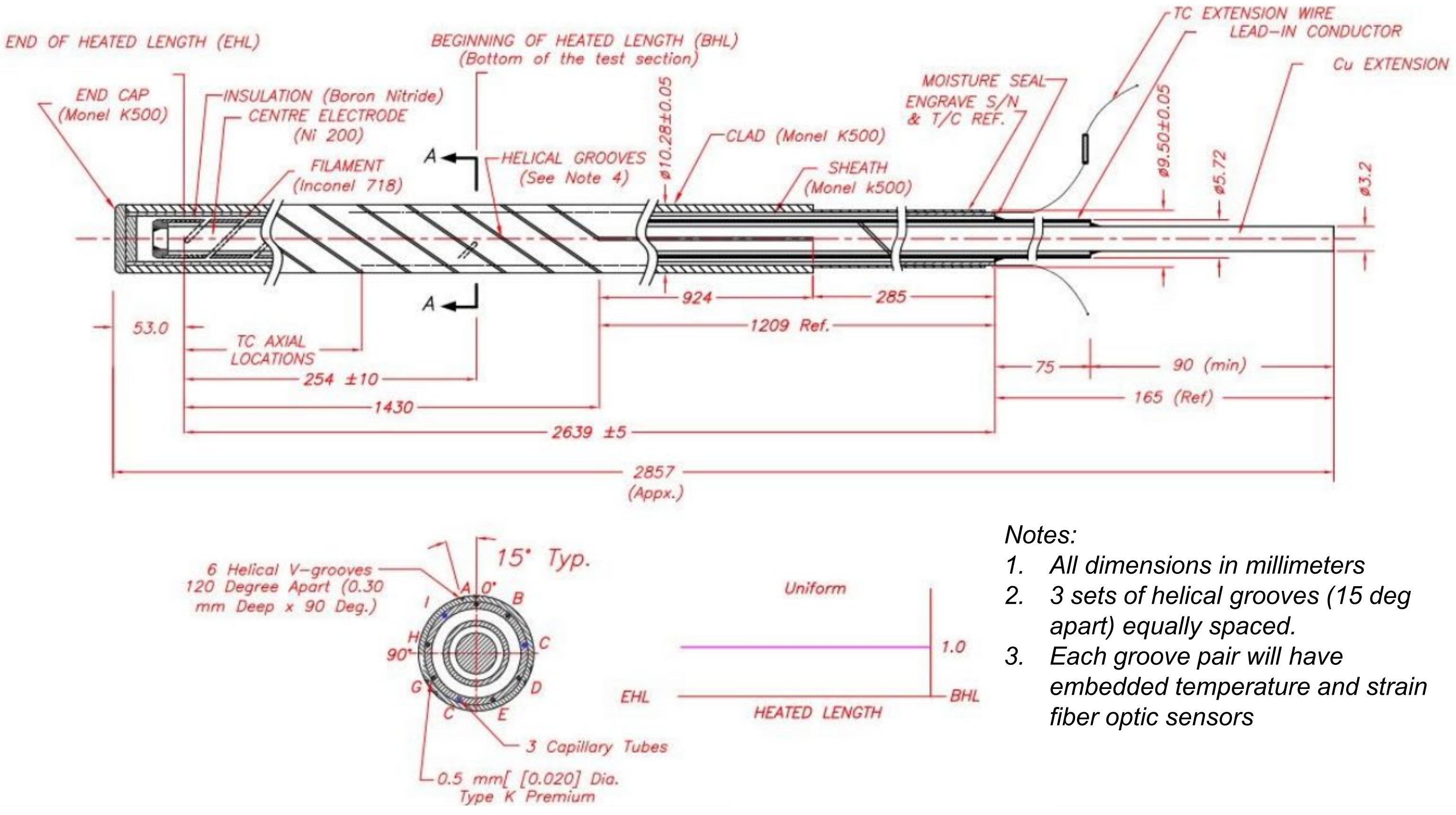

Figure 2: Heater Rod Schematic showing a uniform heat flux profile. 6 type-K thermocouples and 3 temperature fiber optic sensors (FOS) in stainless-steel capillary tubes run along the rod length under the cladding. 3 helical groove pairs (6 total grooves) are machined on the exterior heater cladding wall to accommodate temperature and strain FOS pairs along the surface.