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High Speed Data Acquisition For Fiber Optic Pressure Sensor

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Changing the World's Energy Future

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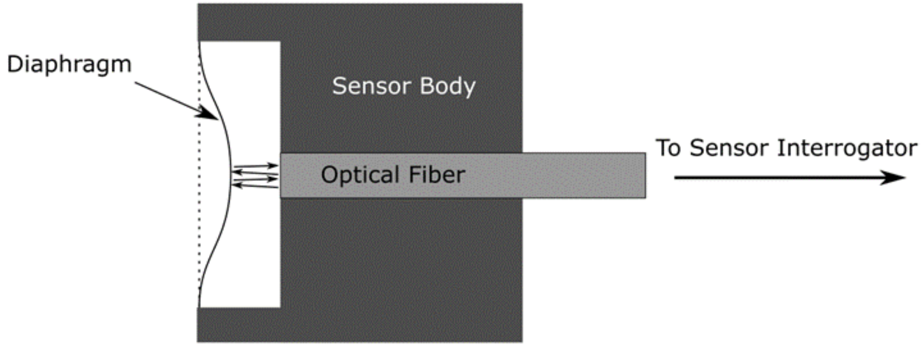
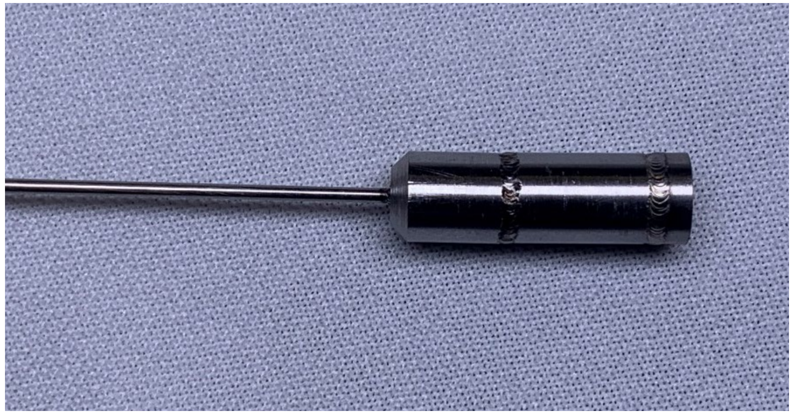
Pressure Sensor Motivation

- **Motivation:** Pressure is an extremely important parameter for thermodynamic and structural considerations
    - Heat Transfer
    - Phase Change
    - Structural Integrity (cladding/primary containment)
    - Coolant Flow (measurement/control)
- **Background:** Fiber Optic Fabry Perot Pressure Sensors
    - Widely documented in literature
    - Limited commercial availability
    - Based on light interference spectrum
    - Small Footprint
    - Relatively High Temperature
    - Customizable Pressure Range



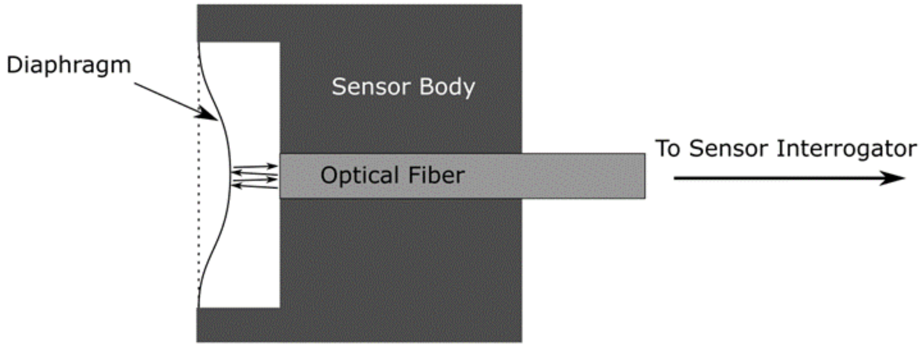


Pressure Sensor Design

- **Design Considerations:**
  - Diaphragm Diameter & Thickness
  - Sensor Material
  - Nominal Cavity Length
  - Fabrication Techniques
  - Design Rating
  - Desired performance
    - Drift
    - Hysteresis
    - Temperature compensation
    - Accuracy

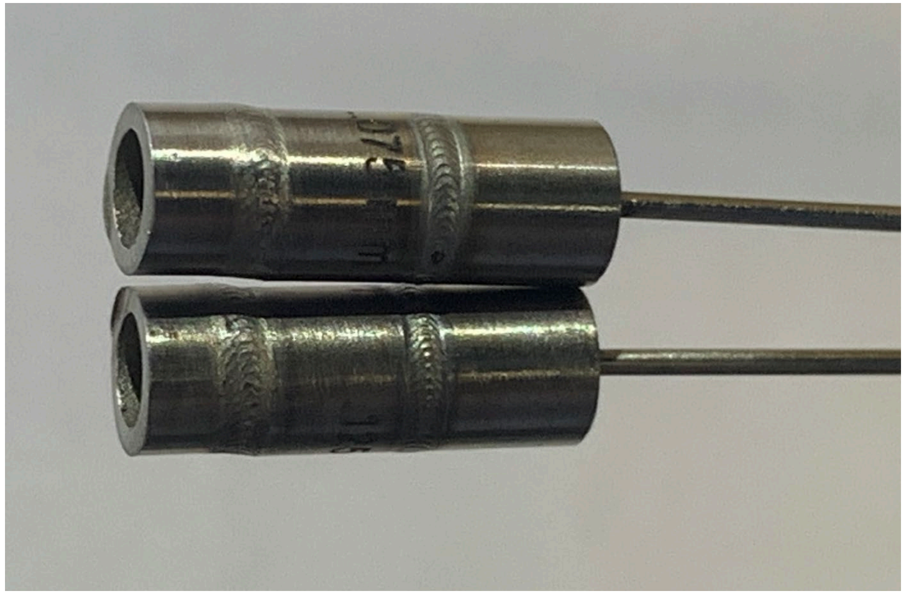
$$y_0 = \frac{3(1-\nu^2)P\,r_0}{16E\tau^3}$$

y_0 - displacement
ν - Poisson ratio
P - Pressure
r_0 - Diaphragm radius
E – Modulus elasticity
τ – Diaphragm Thickness



Targeted Applications

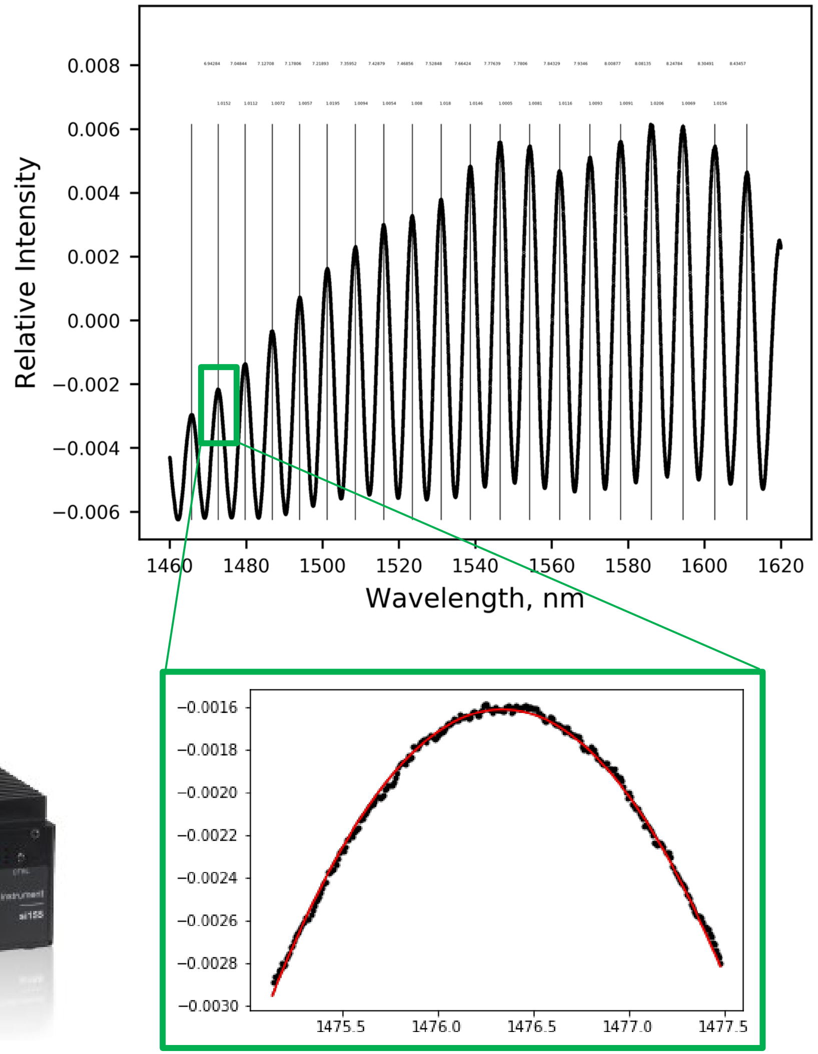
- Pressure measurements are required for many data objectives across nuclear energy applications. Specifically including characterizing:
  - Thermal Hydraulic Conditions
  - Pressure changes during Loss of Coolant Accidents
  - Pressure waves induced from Radiation Initiated Accidents
  - Fission as Release
  - Fuel Cladding lift-off



Previous Data Acquisition Limitations

- A high-resolution spectrum is obtained using an optical interrogator utilizing a swept laser
- The wavelengths in which interference peaks are located are identified
  - The cavity length is calculated using each adjacent peaks (λ_1 and λ_2) through this equation (right)
  - The mean of these calculated cavity lengths is then used to determine the pressure through a calibration curve
- This technique is referred to as period tracking
  - This technique uniquely identifies cavity length
  - Full high resolution spectrum data acquisition times are generally slow. The system we're using is limited to 10 Hz

$$L = \frac{\lambda_1 \lambda_2}{2n(\lambda_2 - \lambda_1)}$$

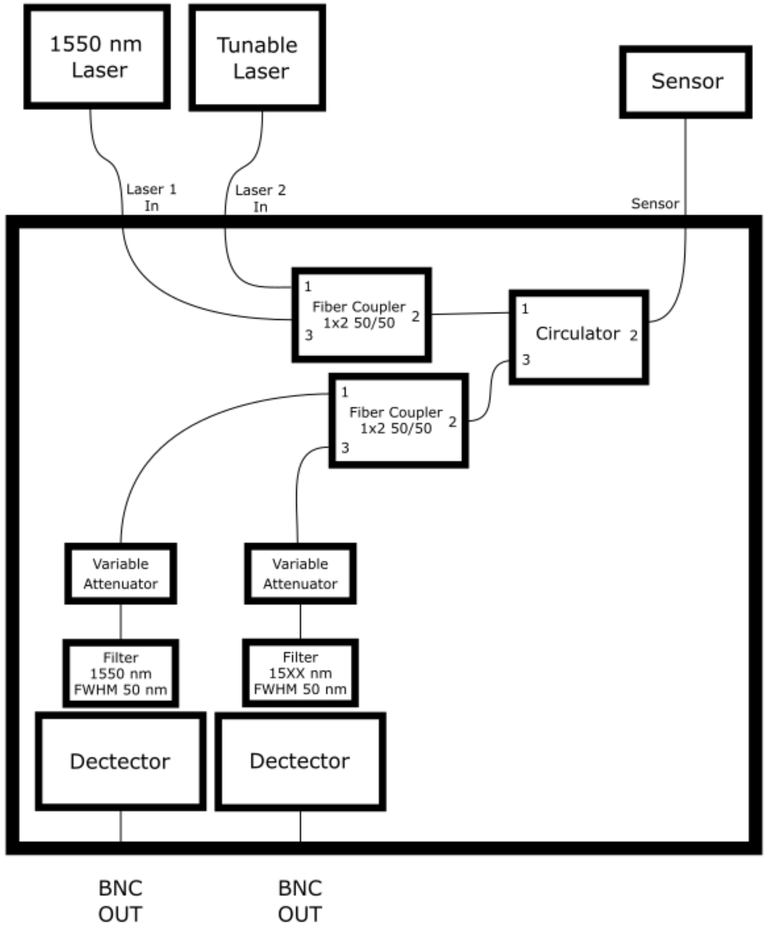


Conceptual Design of New System

- The interference spectrum peaks “move” with respect to wavelength as the cavity length changes
  - This can be used to determine the cavity length changes and is referred to as phase tracking
  - This can be accomplished by monitoring the intensity of light at a single wavelength
    - If only one wavelength is used the tracking becomes ambiguous at any peak or trough
    - If two wavelengths are used which are separated by a quarter wavelength enables unique determination of phase

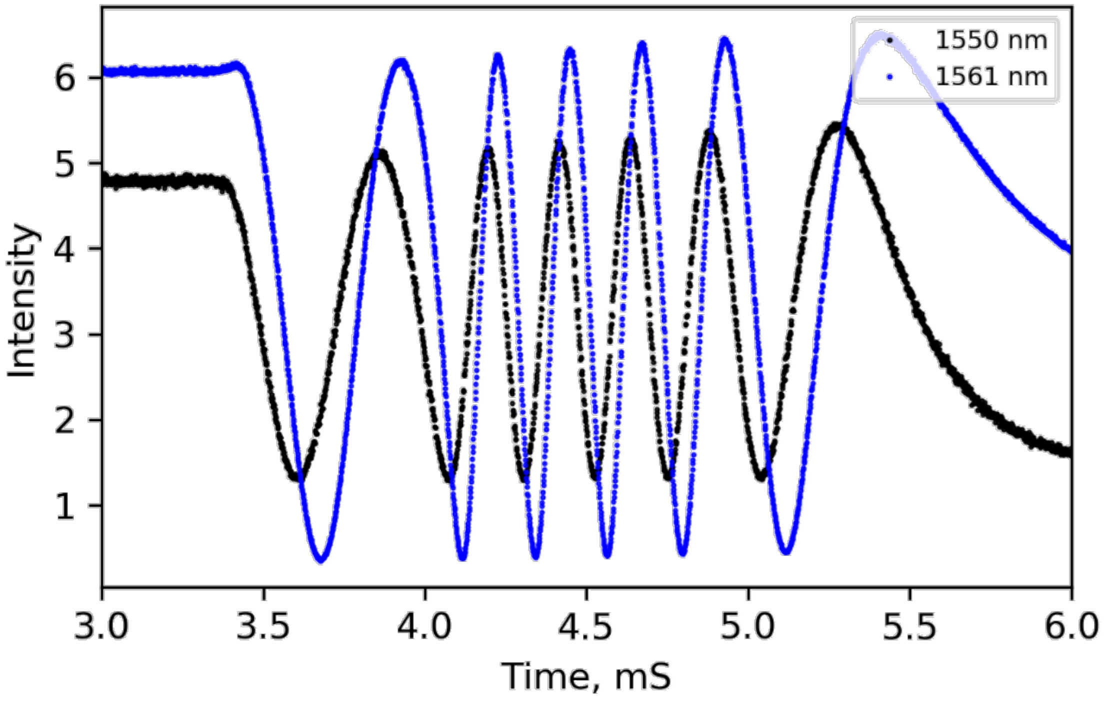
Data Collection

- A diagram of the system design is provided to the right
  - A fixed wavelength laser used and a tunable laser is tuned to either ¼ or ¾ of the interference spectrum period away from the fixed wavelength at 1550 nm
  - Those two lasers are combined using a 50/50 fiber coupler and routed to the pressure sensor through a fiber circulator
  - The reflected light from the sensor re-enters the circulator and passed into another 50/50 fiber coupler with splits the intensity
  - Each split channel is fed through a variable a band pass filter which corresponds to the two interrogation wavelengths.
  - The light that is passed through each of these filters is measured with high speed photo detectors



Data Collection (continued)

- The output from each photodetector is measured using a National Instruments cDAQ system
  - The data collection speed for the system has been set at 1 kHz, which was been the standard DAS speed for Transient Reactor Test (TREAT) Facility experiments. However, DAS and photo detectors can operate orders of magnitude faster.
- An example of data collected during a pressure ramp is given to the right
  - Very good signal to noise ratios are obtained
  - Modulation from interference spectrum is clearly observed



Summary & Conclusion

- A high-speed interrogation system for the fiber optic pressure sensor has been designed, built, and tested
  - This system is easily capable of operating at higher speeds than what is required for any of the nuclear energy applications that have been identified
- A known limitation of phase tracking is the cavity length is not determined absolutely.
  - If an interruption of data occurs, it is not possible to uniquely determine the cavity length
- Future work could incorporate a hybrid method between phase tracking and period tracking to provide the unique/absolute cavity length determination of period tracking but maintain the high-speed capability of phase tracking.