Fiber-optic Sensor System for Multipoint Pressure and Temperature Measurement

Advanced Sensors and Instrumentation (ASI) Annual Program Webinar

October 30 – November 2, 2023

Senior Research Scientist: Qiwen Sheng, Ph. D.

Key Personnel: Ming Han, Ph. D.

Nusenics, LLC

Program Manager: Daniel Nichols, Ph. D.

Department of Energy

Project goal and technology

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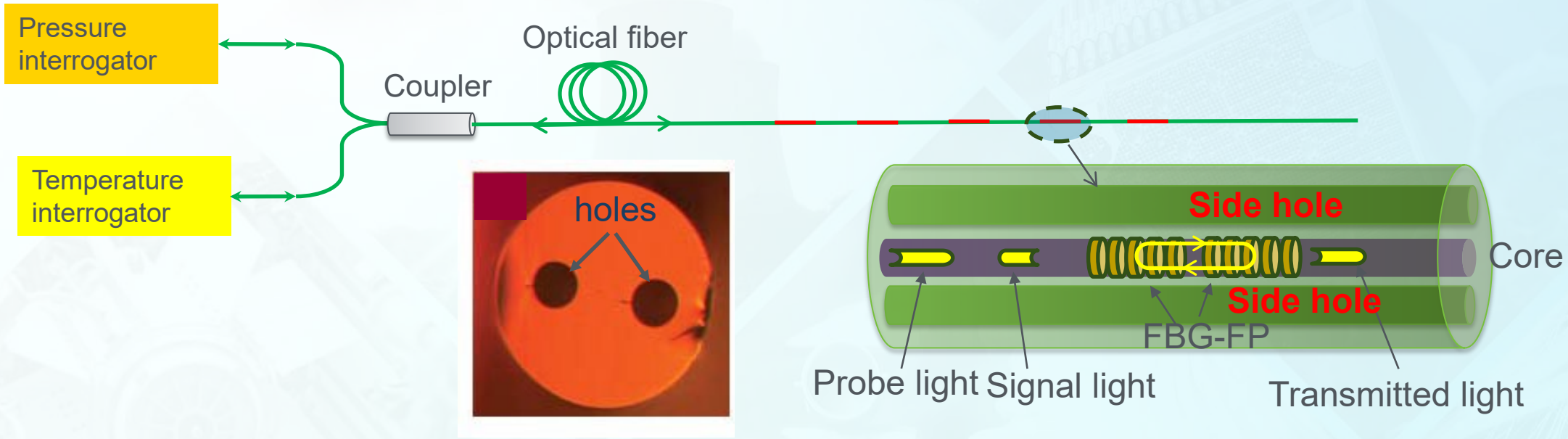
The goal of this project is to develop a quasi-distributed fiber-optic sensor system for multipoint pressure and temperature measurement in nuclear power plants.



Project schedule and Participants

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Project Schedule		1 J	2 A	3 S	4 O	5 N	6 D	7 J	8 F	9 M	10 A	11 M	12 J
T1	Design and obtain side-hole fibers												
T2	Fabricate FBG-FP sensors on side-hole fibers												
T3	Construct sensor interrogator and perform laboratory test												
T4	Study an in-situ pressure sensor calibration method												
T5	Perform radiation testing on sensors												
T6	Prepare Phase II proposal and write final technical report												

Participants:

- PI: Dr. Qiwen Sheng (Senior Research Scientist)
- Key Personnel: Dr. Ming Han (President of Company and Professor at Michigan State University)
- Research Scientist: Hasanur R. Chowdhury (will start on 1/1/2024)

P/T Sensors for Nuclear Power Plants

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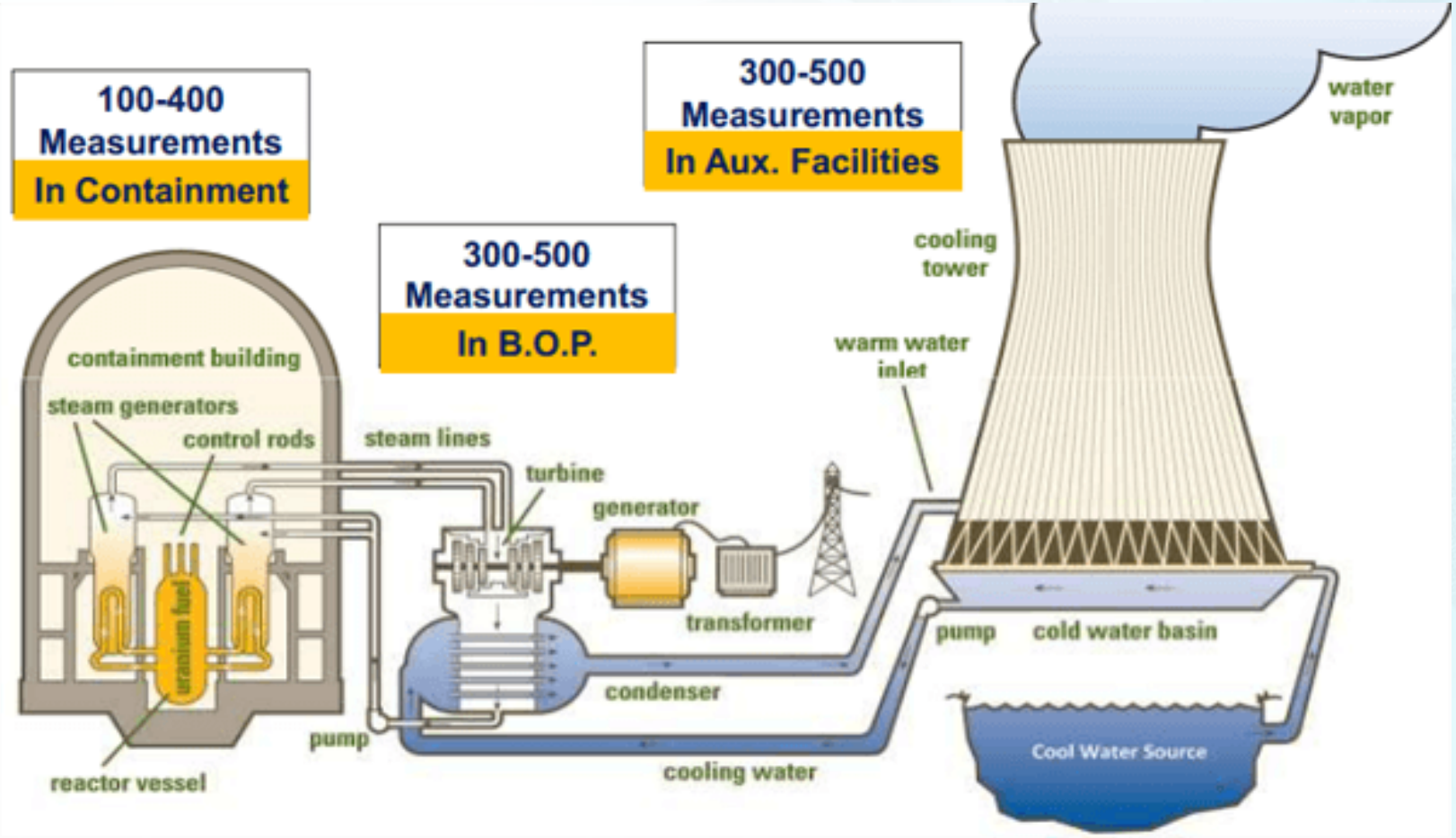
Pressure/temperature measurement – increase safety, improve efficiency, and reduce cost.



Typical nuclear power plant *(https://www.emersonautomationexperts.com/)*

Advantages of Fiber-Optic Sensors

- Intrinsically immune to EMI
- Small footprint/light weight
- Long distance signal transmission
- Chemically inert
- High-temperature capability
- Multiplexing and multi-modal capability (minimizing # of feedthroughs; reducing assembly time)

Fleming, Austin, et al. *Research plan for the development of optical fiber pressure sensors for nuclear applications.* No. INL/EXT-18-45711-Rev000. Idaho National Lab.(INL), Idaho Falls, ID (United States), 2018.

Fiber-Optic P/T Sensor – FBG-FP + Side-Hole Fiber

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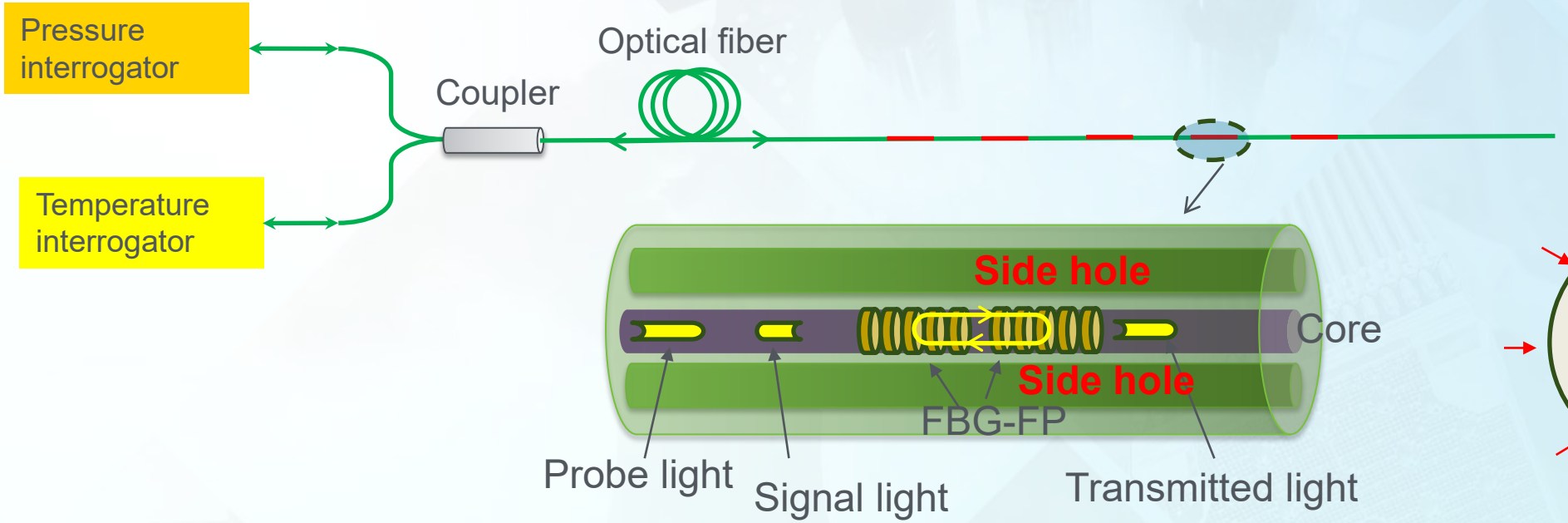

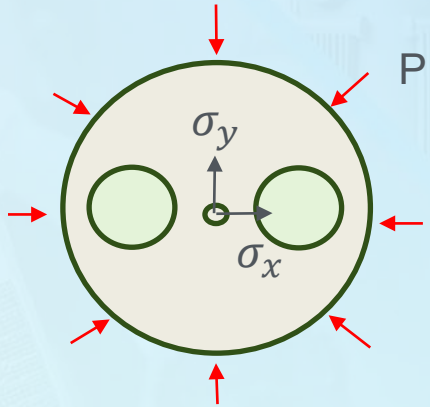

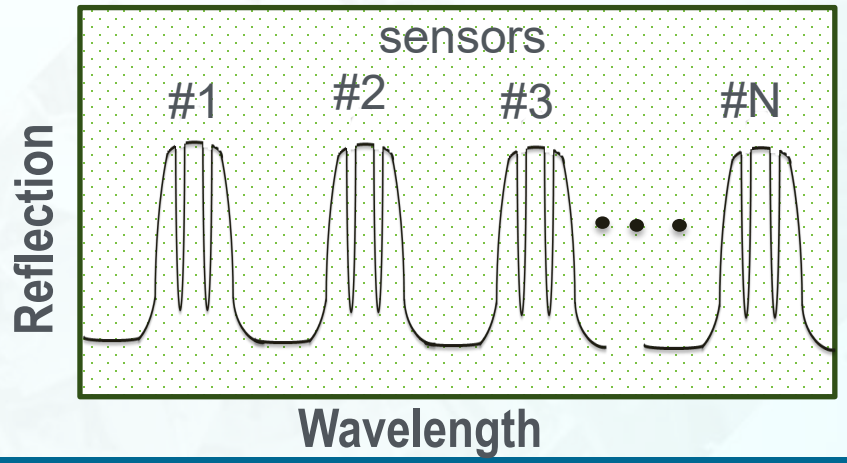

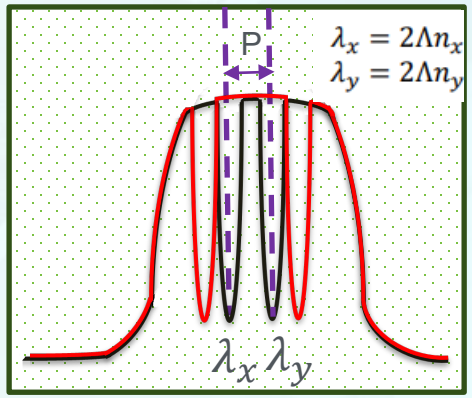

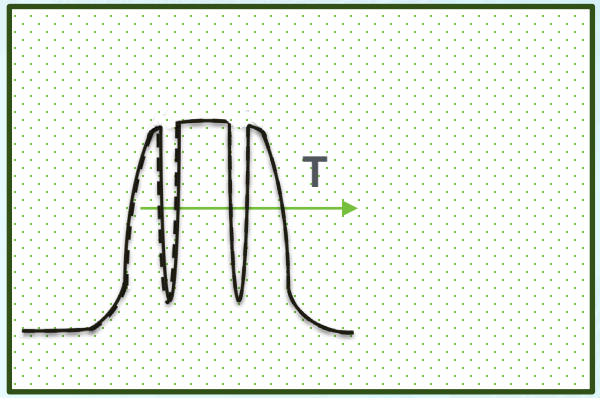

Fiber-Optic P/T Sensor – Preliminary Results

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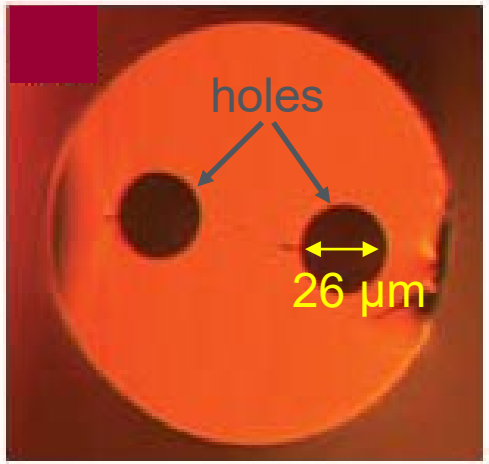

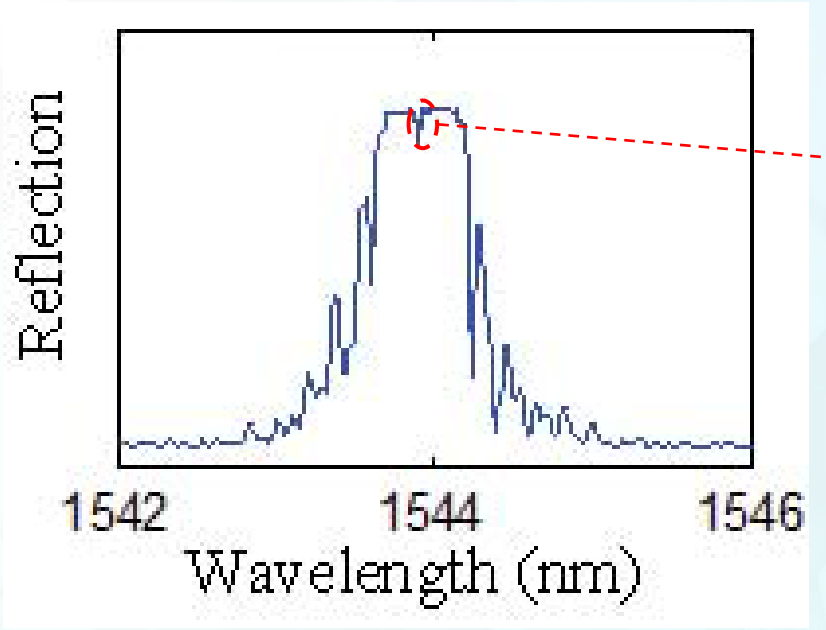

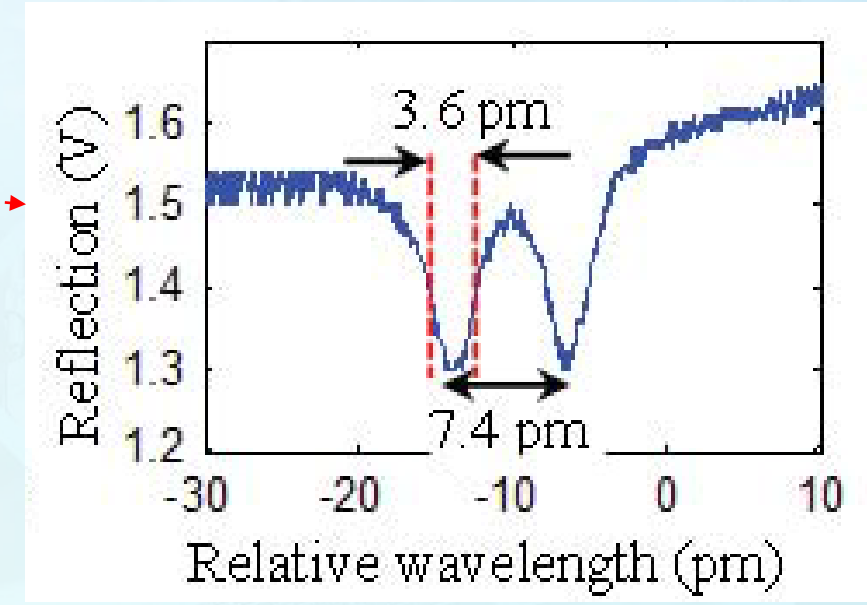

Qi Zhang, et al. Fiber-optic pressure sensor based on pi-phase shifted fiber Bragg grating on side-hole fiber. *IEEE Photonics Technology Letters* VOL. 24, NO. 17, 2012.

Fiber-Optic P/T Sensor – Preliminary Results

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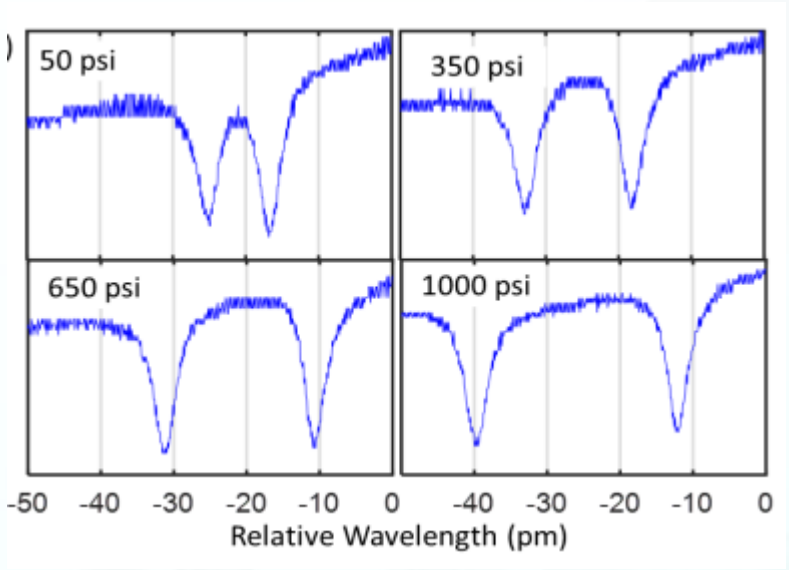
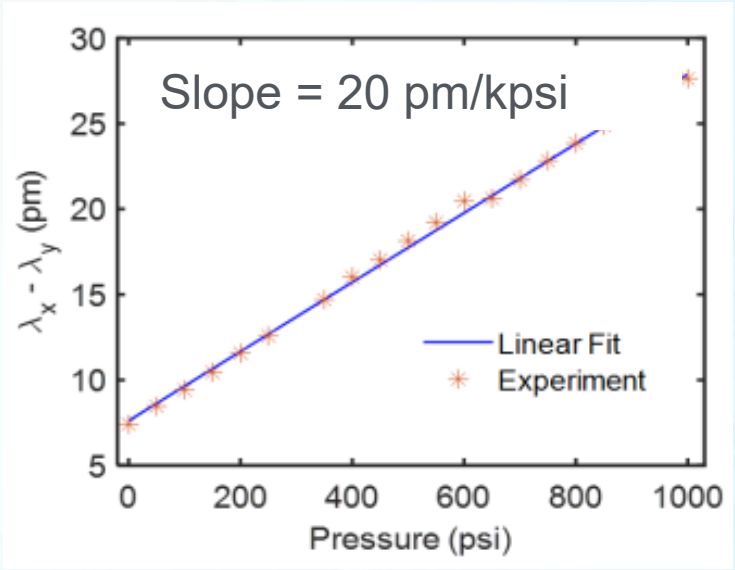
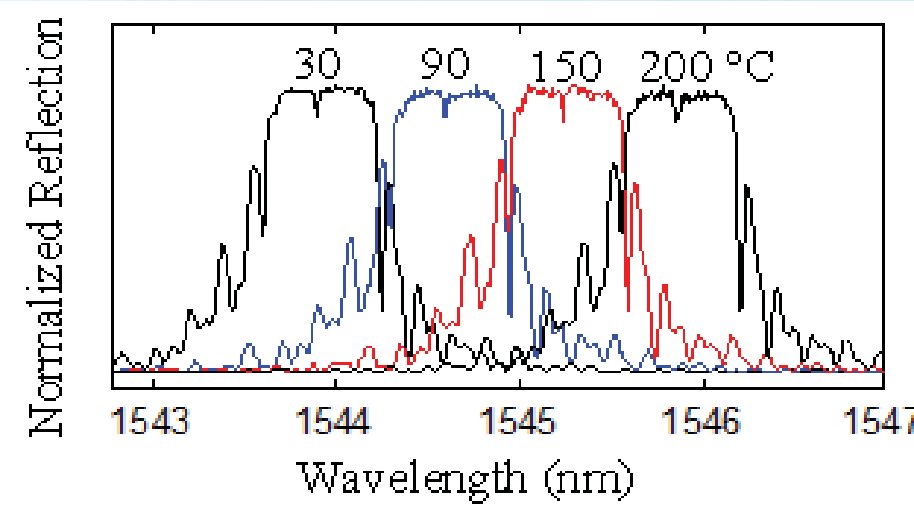
Response to Pressure





Response to Temperature



- Research needs toward practical applications & Commercialization
  - Low-cost, high-precision, high-accuracy interrogation
  - Effects of radiation and their mitigation

Qi Zhang, et al. Fiber-optic pressure sensor based on pi-phase shifted fiber Bragg grating on side-hole fiber. *IEEE Photonics Technology Letters* VOL. 24, NO. 17, 2012.

Project Tasks and Schedule

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1. Design and obtain side-hole fibers (100%)
2. Fabricate FBG-FP sensors on side-hole fibers (30%)
3. Construct sensor interrogator and perform laboratory test (30%)
4. Study an *in-situ* pressure sensor calibration method (0%)
5. Perform radiation testing on sensors (0%)
6. Prepare Phase II proposal and write final technical report (0%)

Task 1: Design and obtain side-hole fibers

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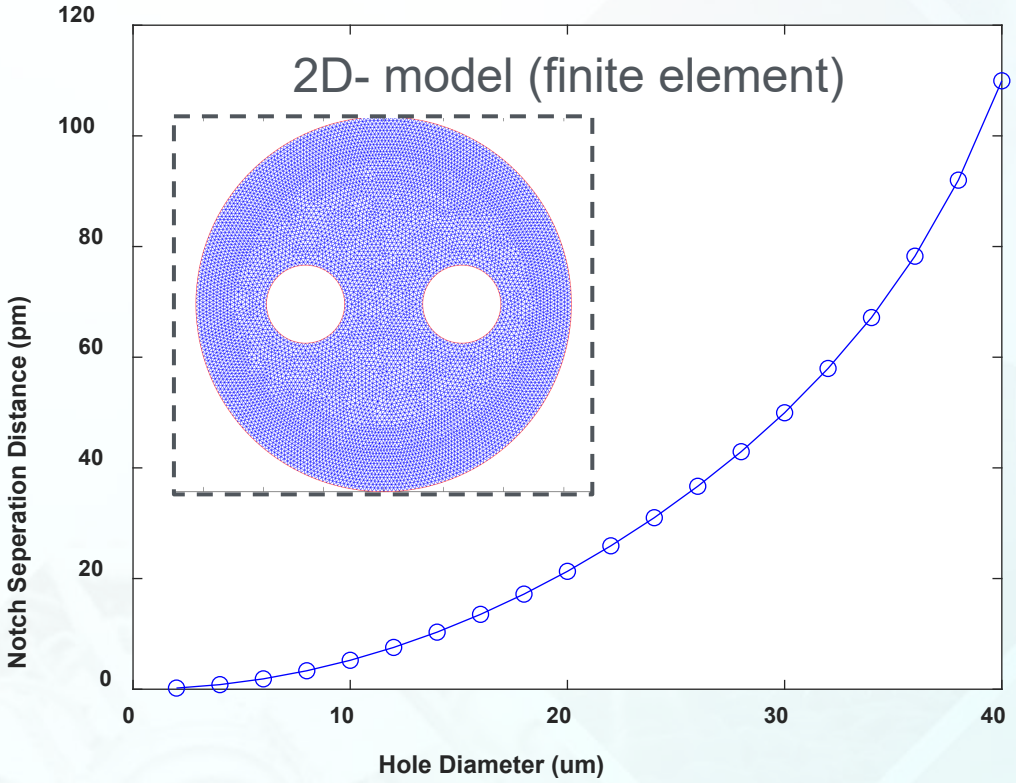

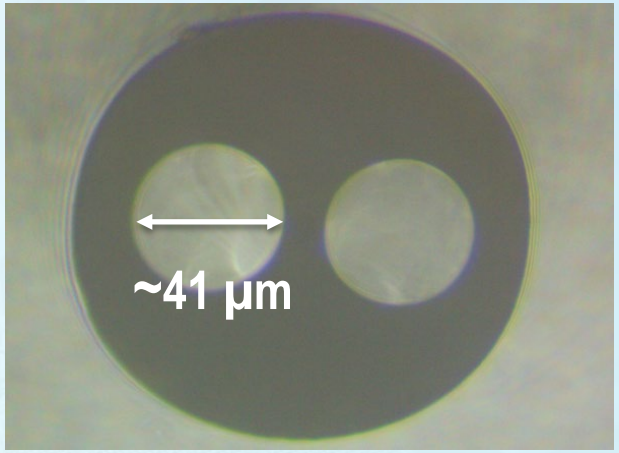

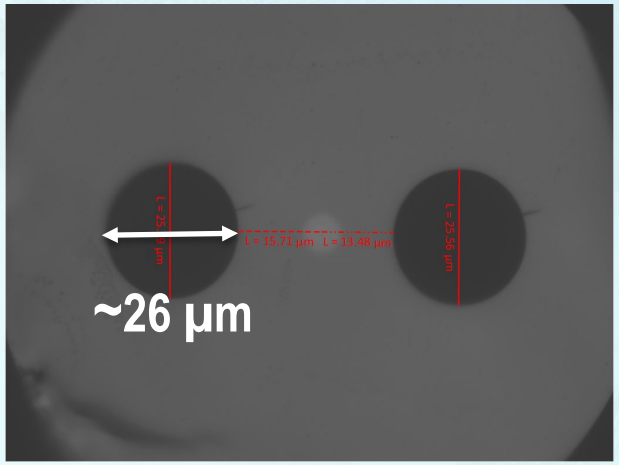

Sensitivity to pressure as a function of hole diameter

Task 2: Obtain FBG-FPs on side-hole fibers

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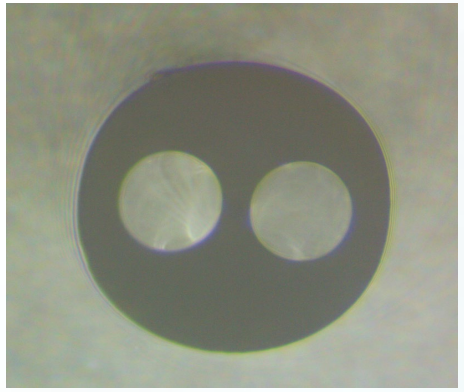
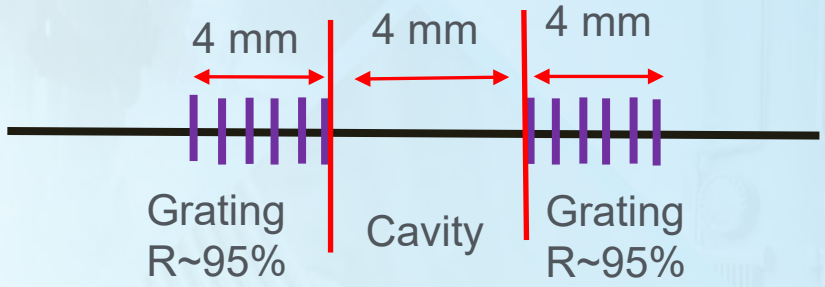
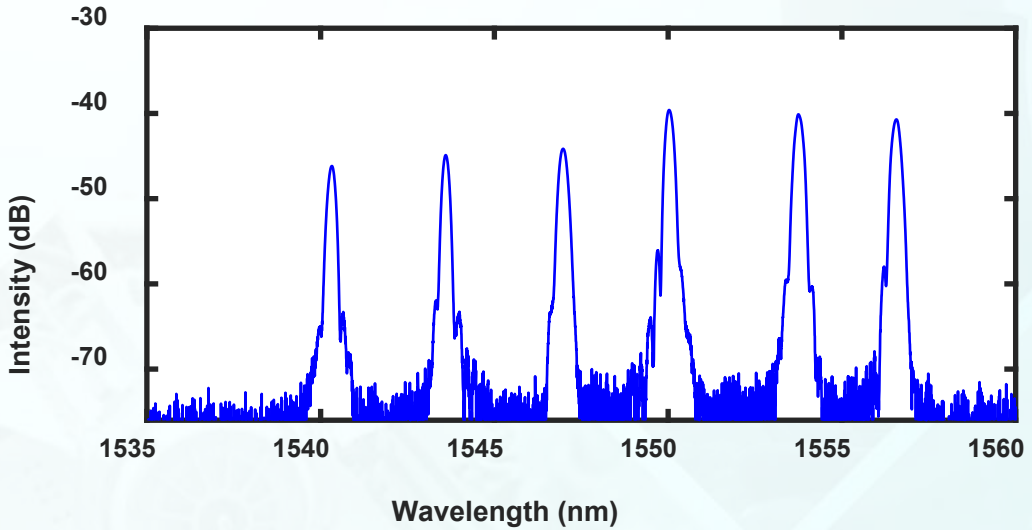
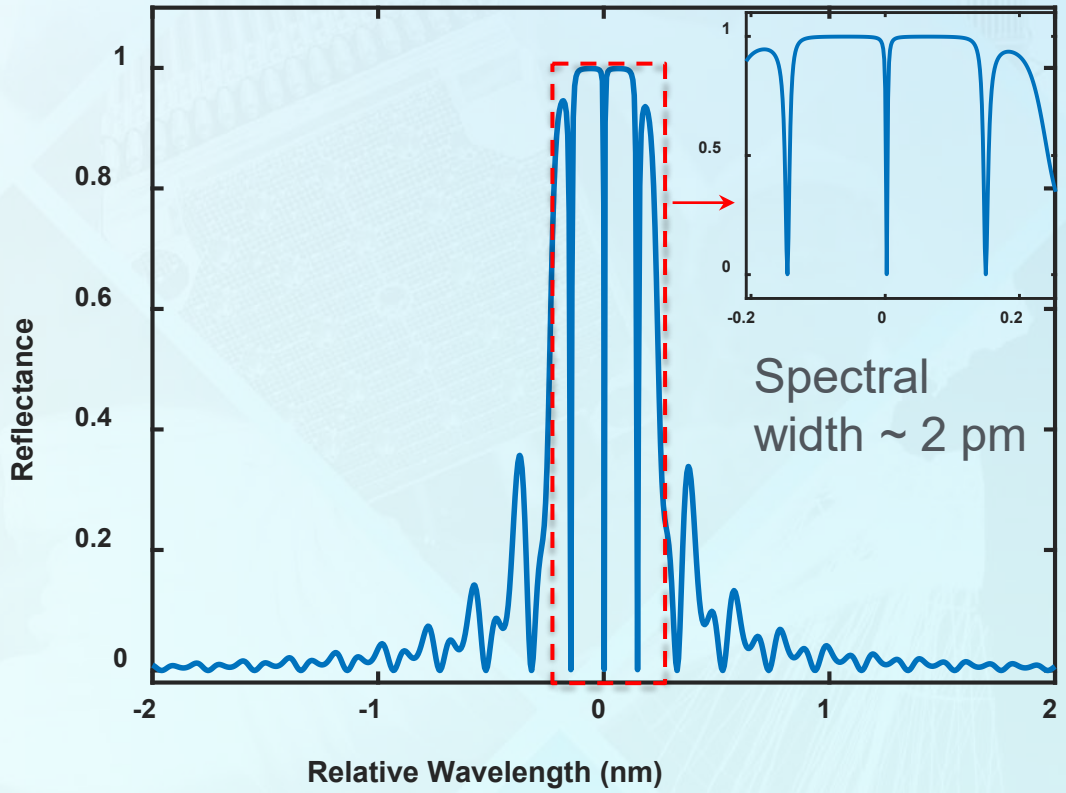


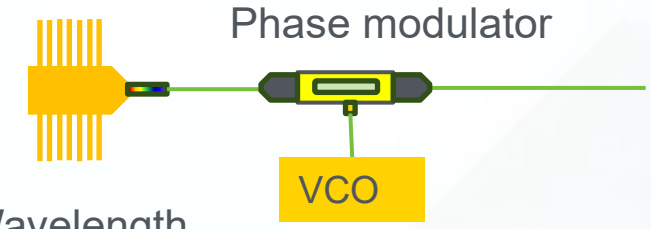




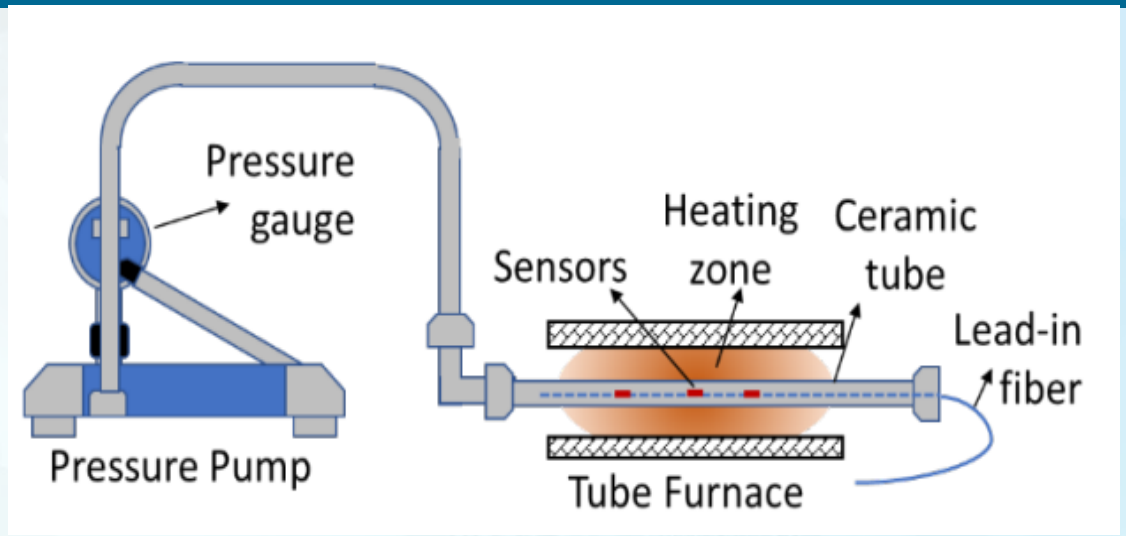


Multiple regular FBG sensors were successfully obtained on a single side-hole fiber

Task 3: Sensor interrogation and Laboratory Test



Wavelength
Tunable Laser



High temperature and pressure tests

Wavelength tunable laser

Pneumatic pressure pump ~ 1000 psi

Tube oven > 1100 °C

Future Tasks/Work

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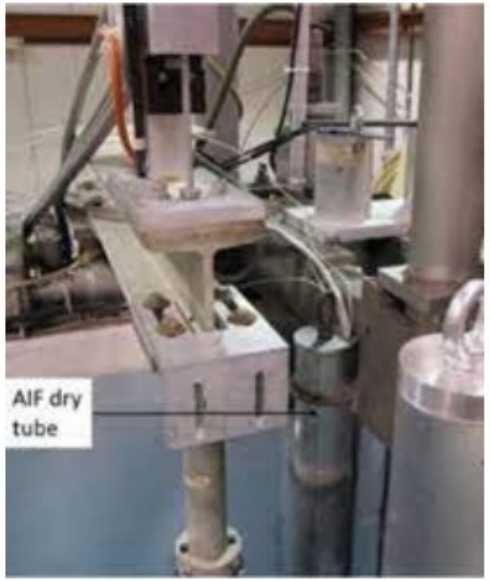
Task #4: Study in-situ pressure sensor calibration

Task #5: Perform Radiation testing

Beyond Phase I:

- Increase radiation hardness:
  - pure-silica core fiber
  - fs-laser FBGs
  - Pre-irradiation of fibers
- Sensor package
- High dose radiation test
- Prototype development



γ-radiation dose rate 0.38 MGy/hr for 7 hours at OSU-NRL

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Thank You