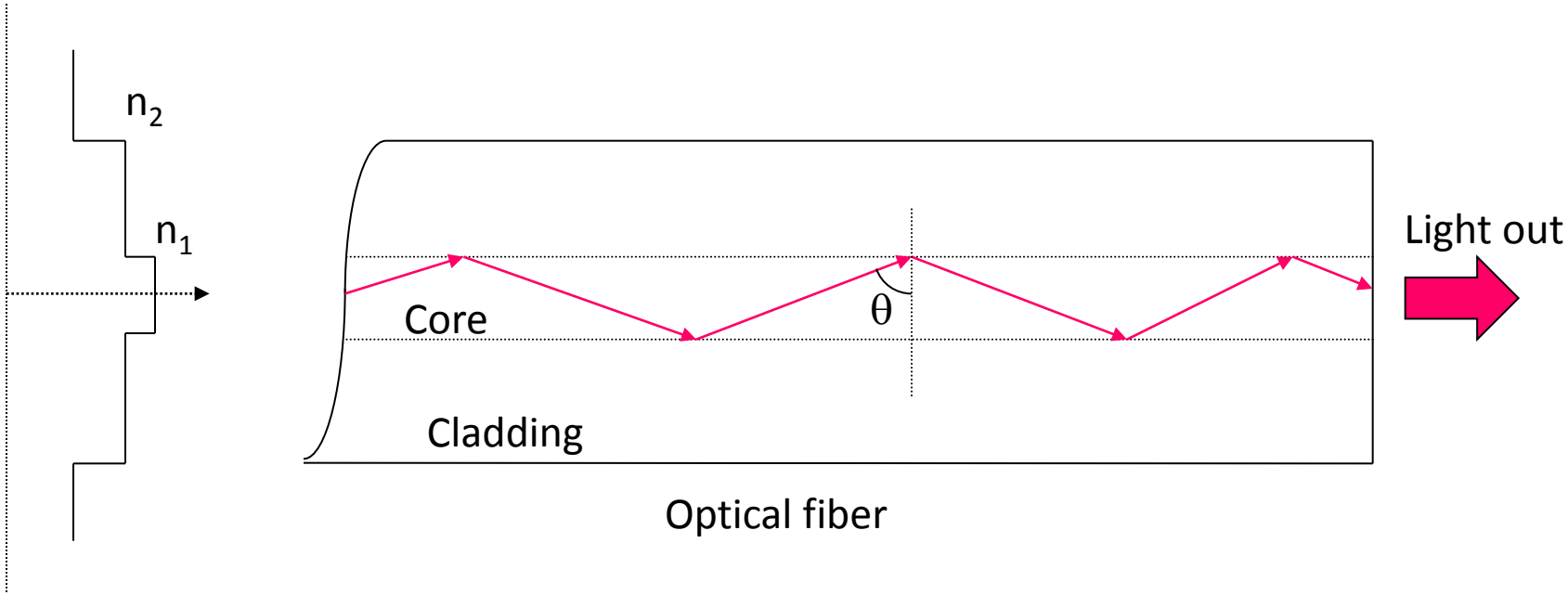
Overview of Fiber Optic Sensing for Energy Applications

Anbo Wang
Center for Photonics Technology
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0111
Tel: (540)231-4363 E-mail: awang@vt.edu

Principle of an optical fiber

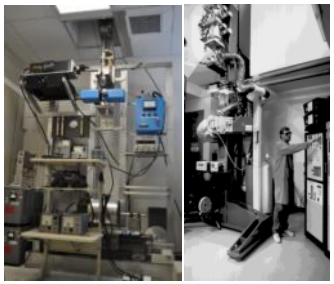


When θ is greater than $\theta_c=\sin^{-1}(n_2/n_1)$, the light can be guided.

Why fiber sensors attractive?

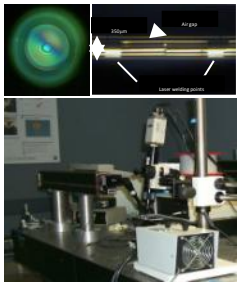
- High temperature capability
- Chemically inert
- Remote operation
- Immunity to electromagnetic interference
- Non-electrically conducting
- Sensor multiplexing/distributed measurement

Overview of CPT Sensor Research

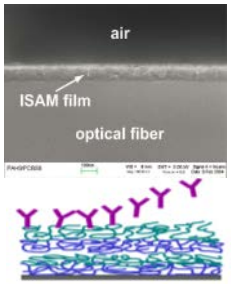


Fiber Fabrication

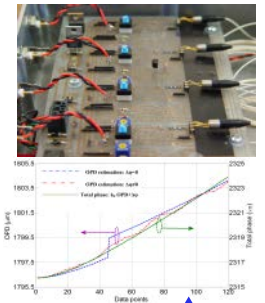
Micro-Fabrication



Epoxy-Free Bonding



Nano-Film Assembly



Signal Processing

Distributed Sensing

Fabrication and instrumentation

PHOTONIC SENSORS

Applications

Gasifier Temperature Monitoring

Sapphire fiber temperature sensor testing in TECO coal gasifier

Oil Downhole Measurement

Pressure and temperature sensors tested in Chevron oil well

Partial Discharge Detection

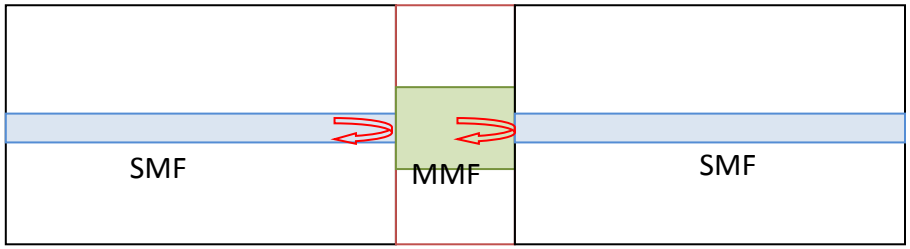
Acoustic sensors (70-250kHz) tested in Northfleet 400kV transformer

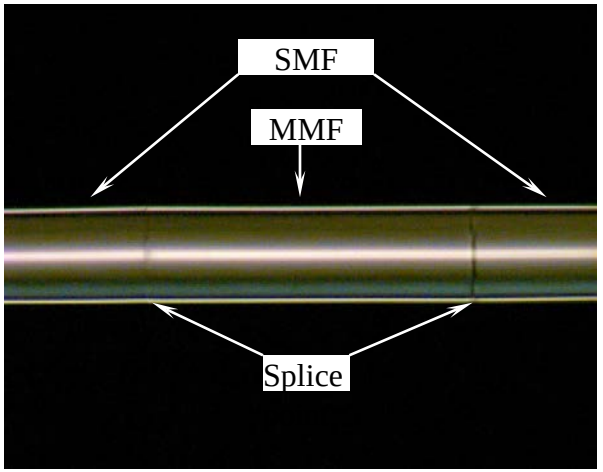
Dynamic Engine Pressure Monitoring

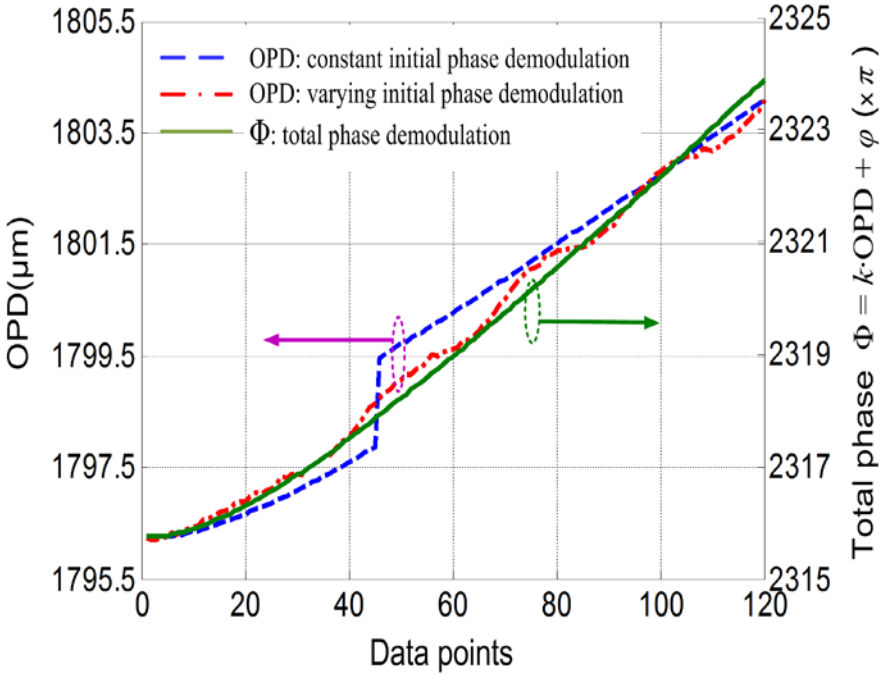
Pressure sensors tested on Virginia Tech Engine

Gallery of the CPT Sensors

Intrinsic Fabry-Perot Sensors







$$\Delta\varphi = \frac{2nL}{\lambda}\cdot 2\pi + \varphi_o$$

λ is the light wavelength in vacuum and φ_o is a constant.

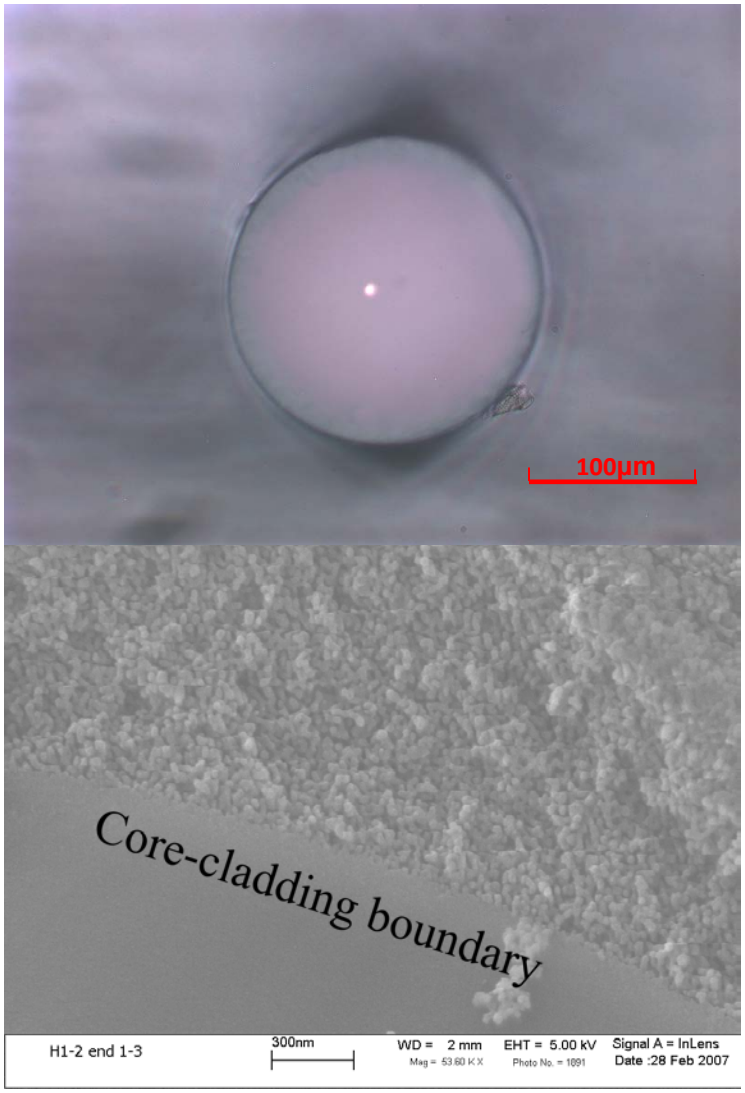
$$\Delta\varphi = \frac{2nL}{\lambda}\cdot 2\pi + \varphi_o + \Delta\varphi(L,n,\lambda)$$

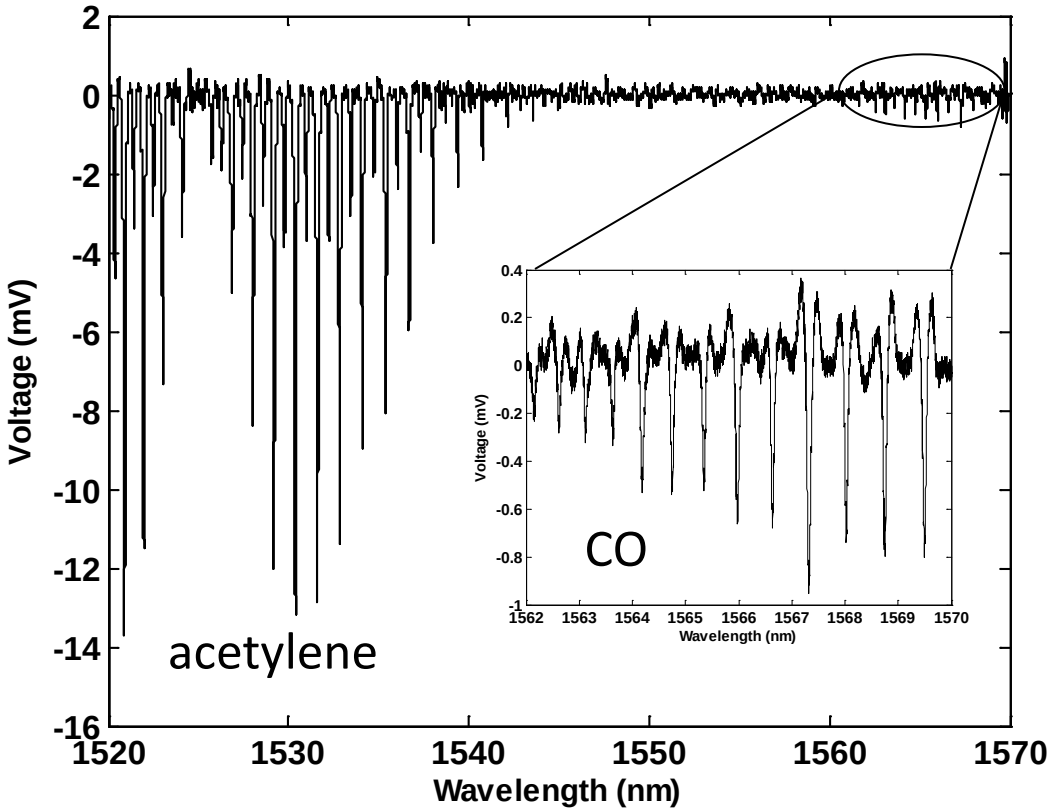
"Decoding the spectra of low-finesse extrinsic optical fiber Fabry-Perot interferometers," Opt. Express, 24, 23727-42 (2011).

"Toward eliminating signal demodulation jumps in optical fiber intrinsic Fabry-Perot interferometric sensors," J. Lightwave Tech. 29 (13), 1913-9(2011)

"Phase Term in the Spectrogram of SMS-IFPI Fiber Sensor and Its Influence on White-Light Interferometry Based Sensor Signal Demodulation," *Appl. Opt.*, 49, 4836 (2010).

Porous Clad Optical Fiber for High Temperature Fast Gas Sensing





Transmission Spectrum

Single-Crystal Sapphire Fiber Sensors

Silica Fiber Limitations

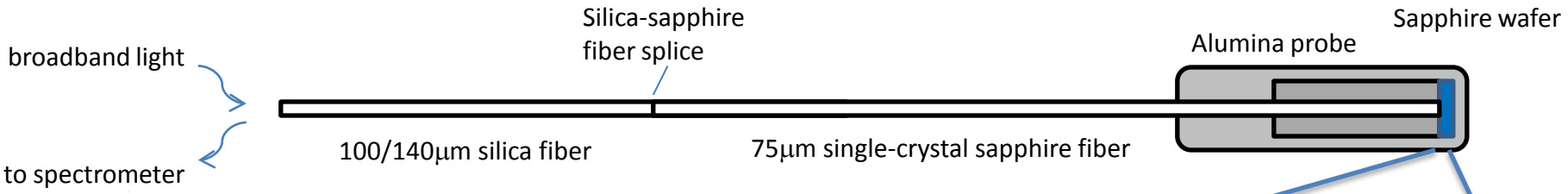
1) Thermal diffusion of germanium dopant
2) Glass creep under stress at elevated temperatures
3) Max temperature is usually between 800 and 900C.

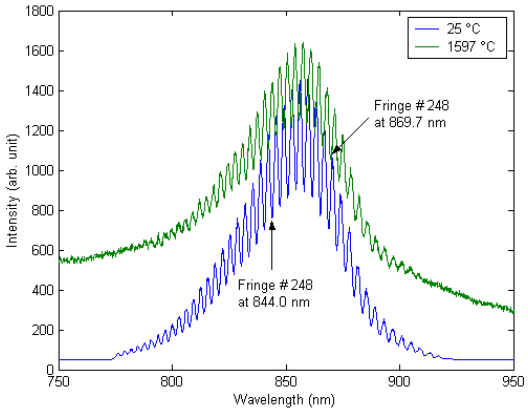
For higher temperatures, different fibers are needed.

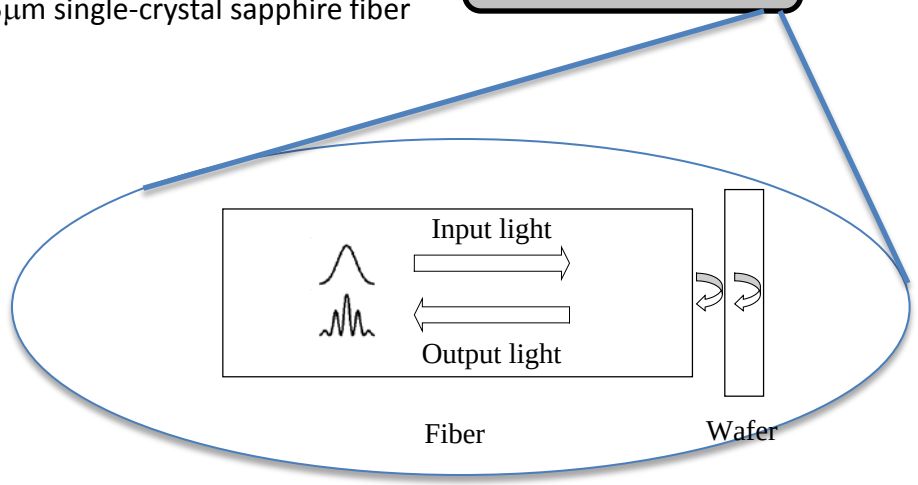
Sapphire Properties

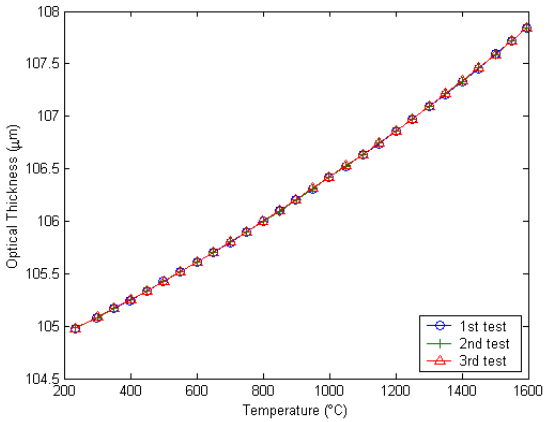
1) High melting point (2045C)
2) Excellent optical transparency from near UV to several microns
3) Commercial availability

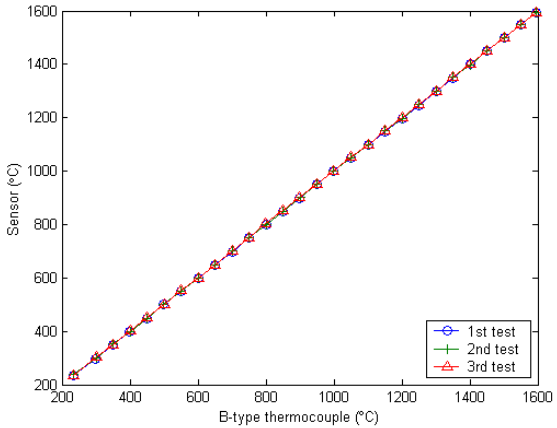
Sapphire Fiber Temperature Sensor





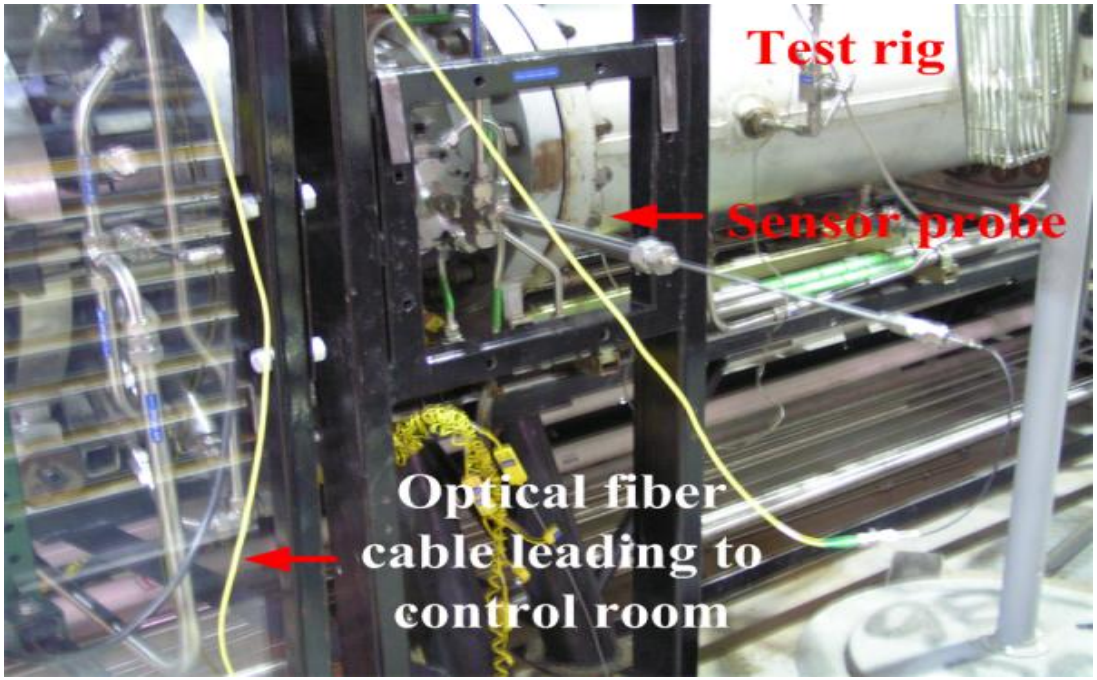


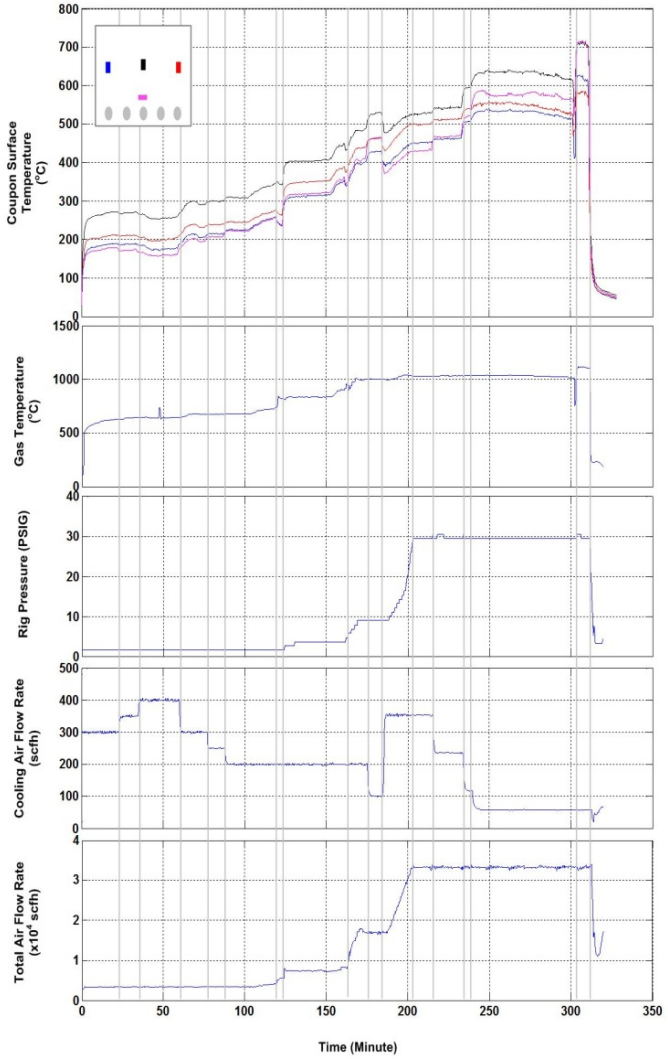




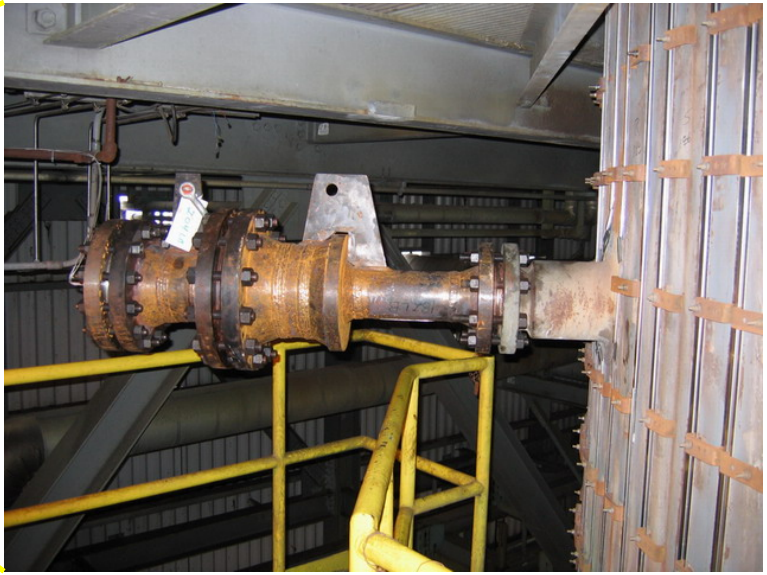
Virginia Tech

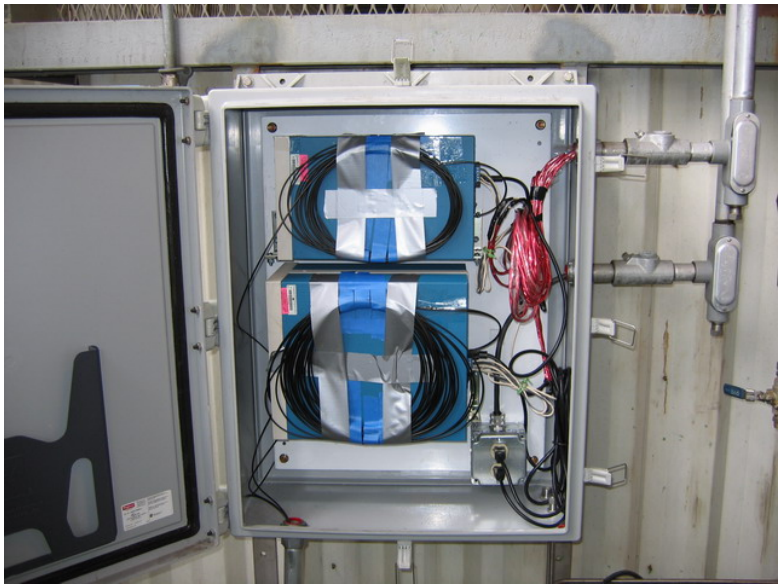
IFPI Sensor Test on NETL Engine Rig

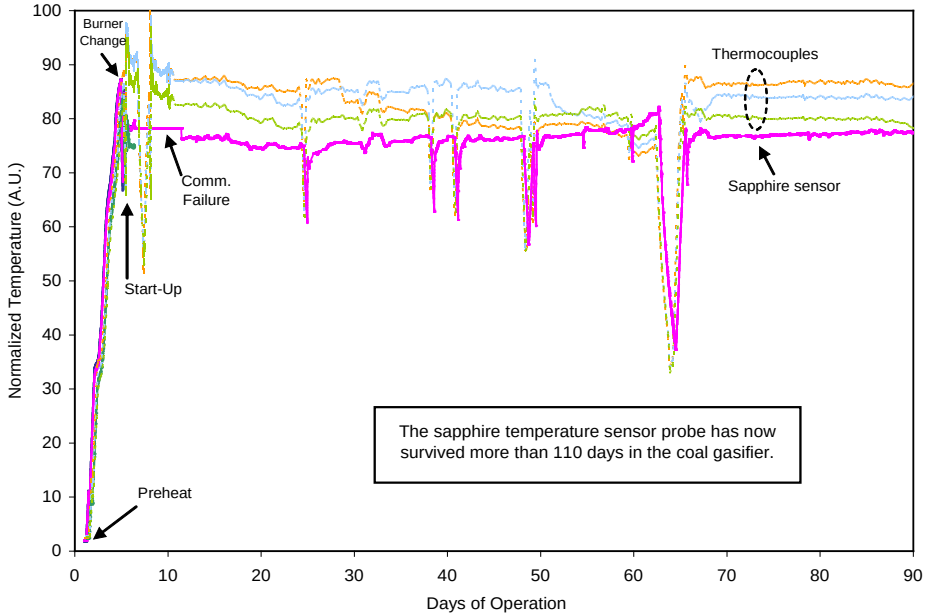




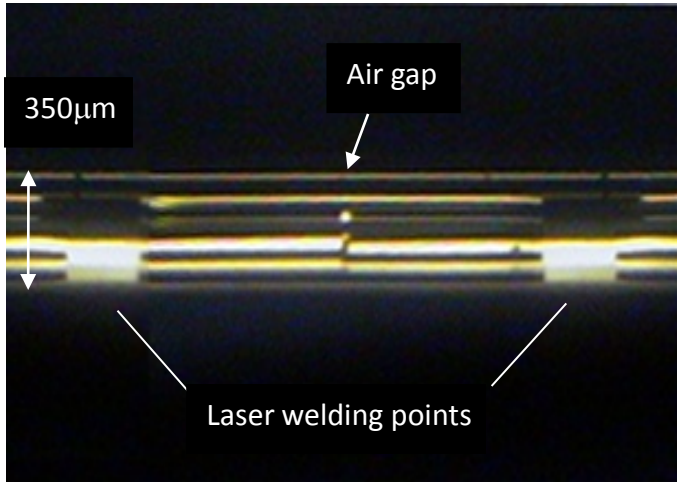
Field Test at Tampa Electric Corporation

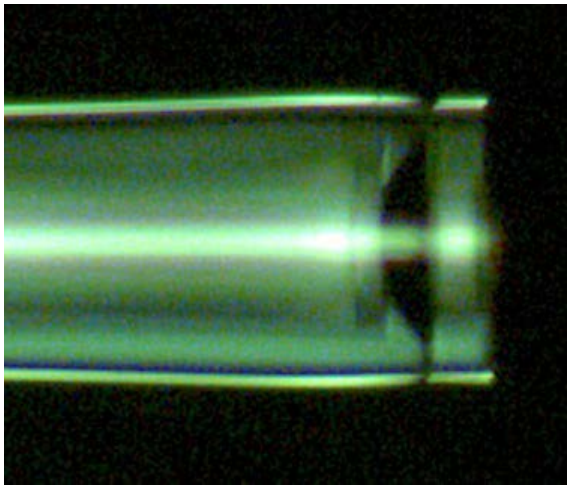


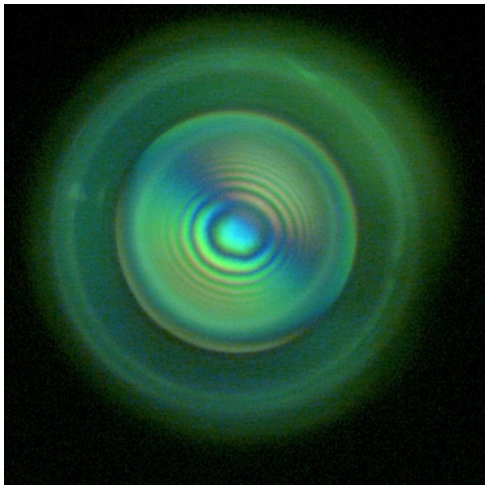


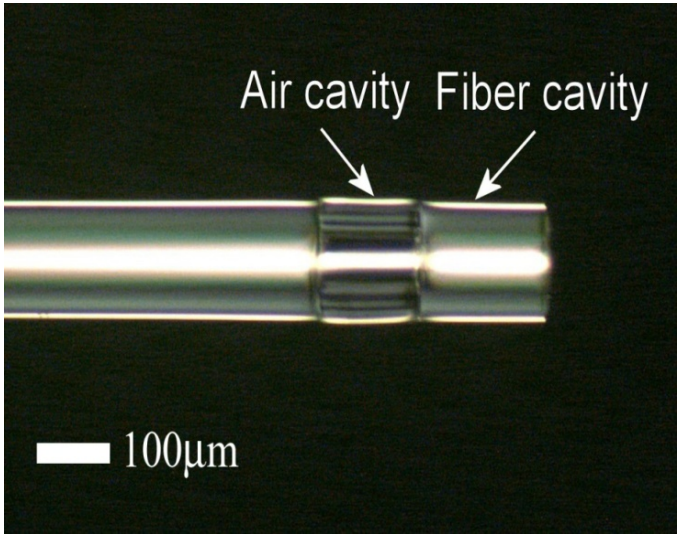


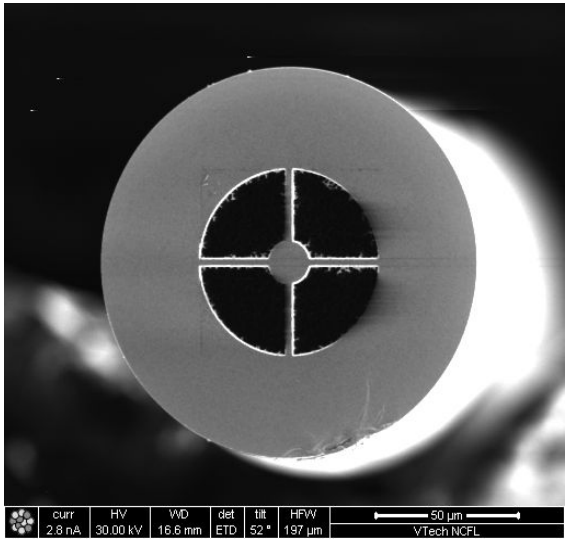
Example Sensors

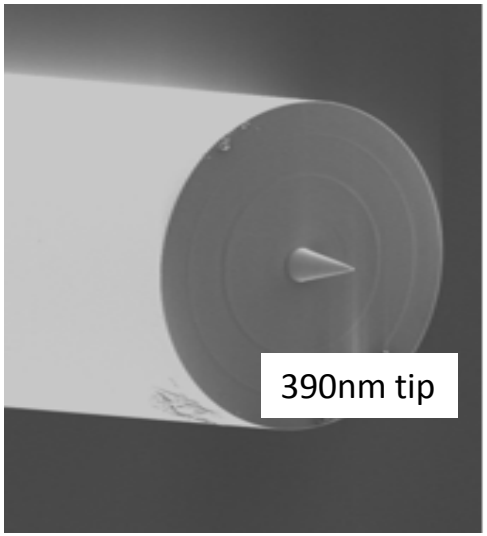




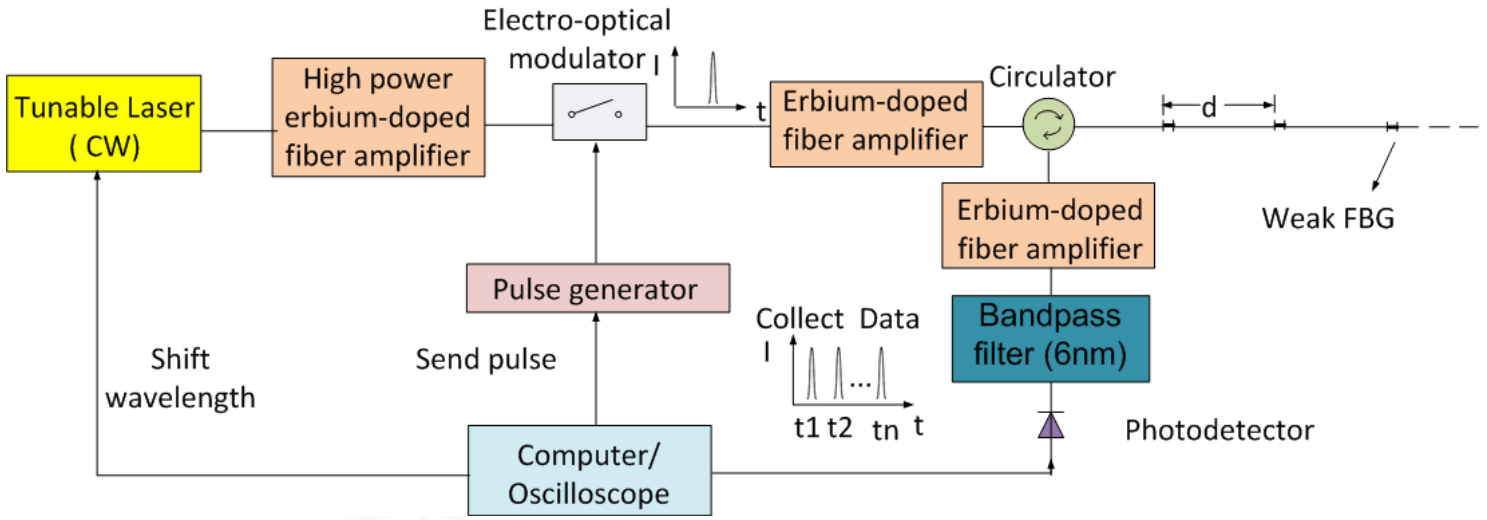


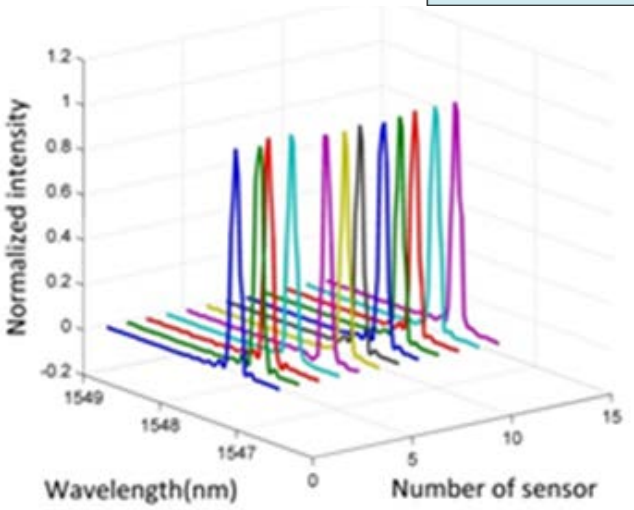


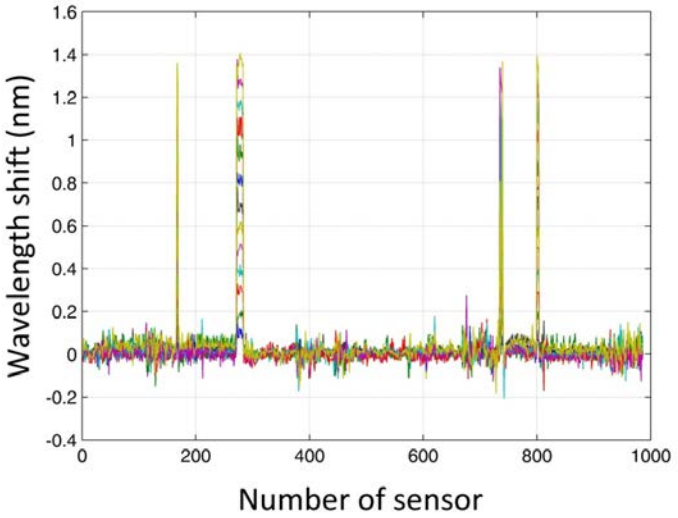




Wavelength-Scanning TDM







Important Feature: Use weak IDENTICAL FBGs.

Acknowledgement

Thanks go to CPT faculty, staff and graduate students who were involved in the presented research.

We are also grateful to DOE NETL for their support to the presented research.