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DISTRIBUTED FIBER OPTIC SENSOR FOR ON-LINE MONITORING OF COAL GASIFIER REFRACTORY HEALTH

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Motivation

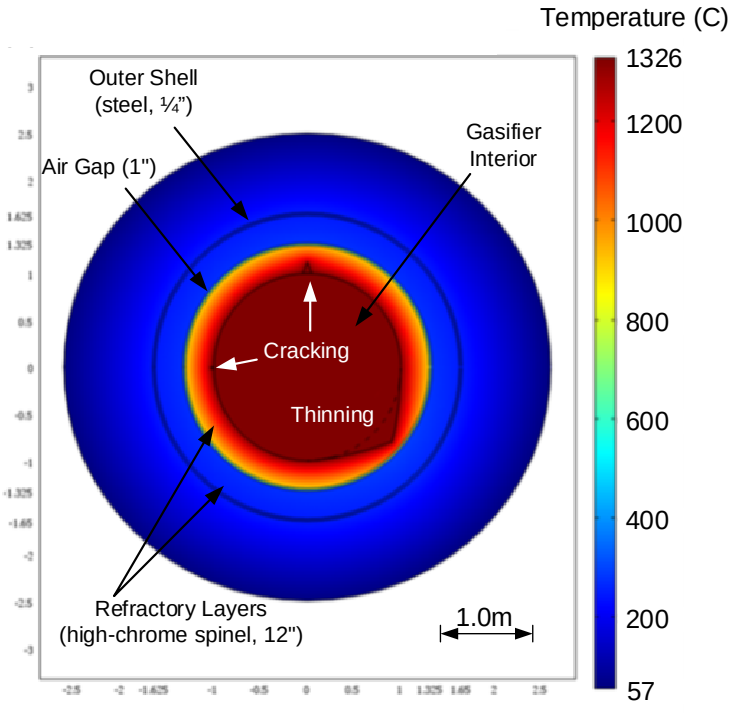
- Refractory health monitoring in slagging coal gasifiers:
  - Rapid corrosion of refractory materials.
    - High-temperature reducing environment.
  - Difficult to predict remaining refractory life.
    - Localized thinning, spallation and cracking.
  - Expensive to shut down gasifier for repair.

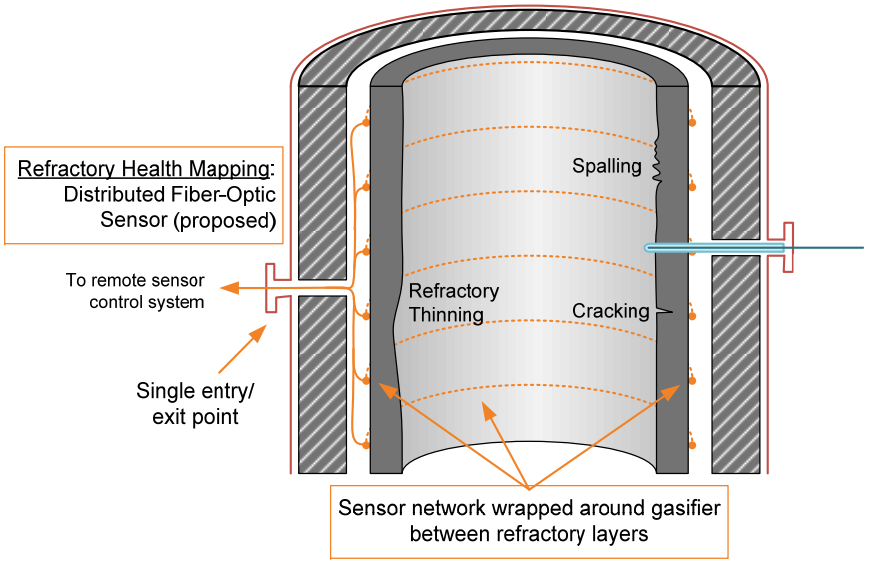
Impacts

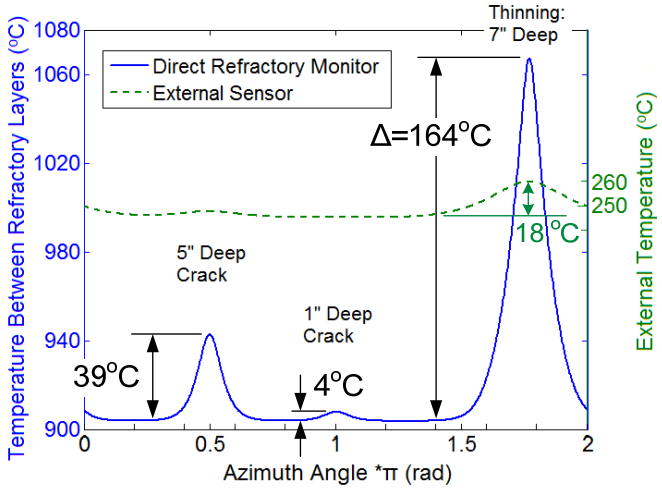
- Current gasifier operation strategy:
  - Scheduled inspection & replacement of liners.
    - Conservatively short intervals – increased downtime
    - Difficult to predict wear rate.
  - Re-bricking takes up to 3 weeks and $1-2M, and downtime costs even more.
- New technology will enable:
  - Early detection & location of hot-spots.
  - Estimation of remaining lifetime.
  - Allow condition-based maintenance model.
  - Reduced downtime & cost savings.

Gasifier Refractory Health Monitoring

- Refractory defect monitoring by temperature mapping

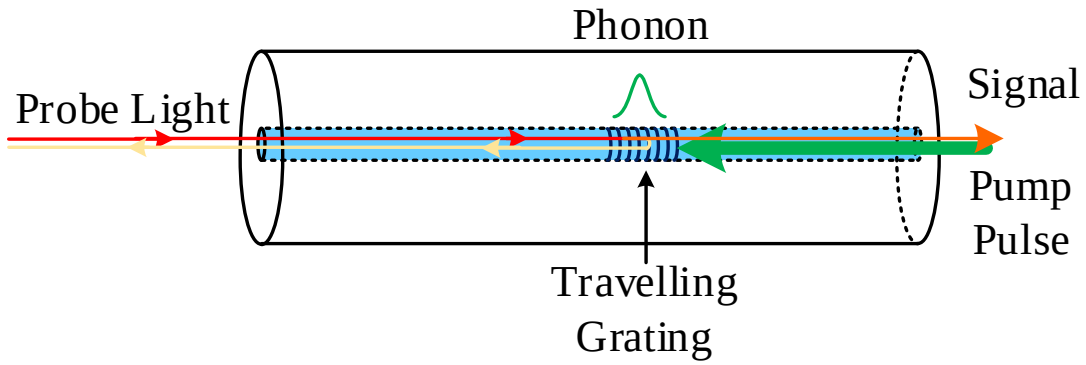




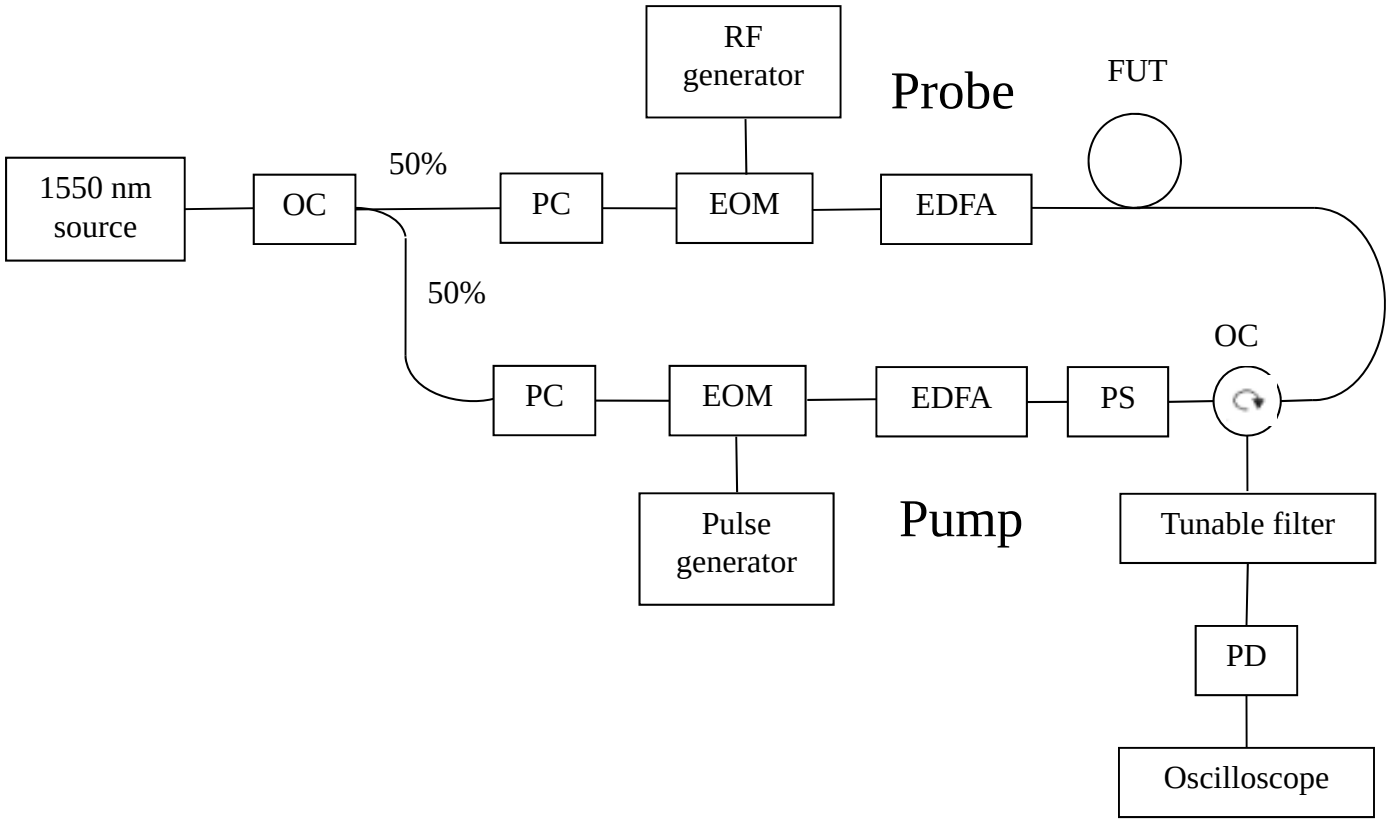


Sensing Mechanism

- A strong pulsed light as pump and a weak CW light as probe are injected into the sensing link, counter-propagating.
- The beat note of the pump induces a transient grating which scans along the sensing fiber via electrostriction effect.
- The signal light probes the travelling fiber grating and translates the temperature distribution along the fiber from spectral shift changes in time domain.

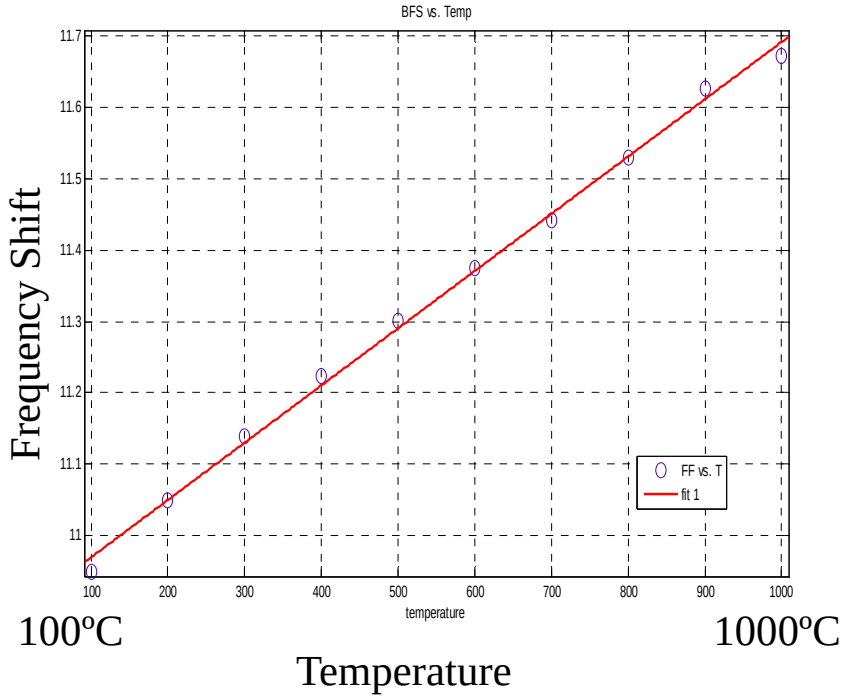


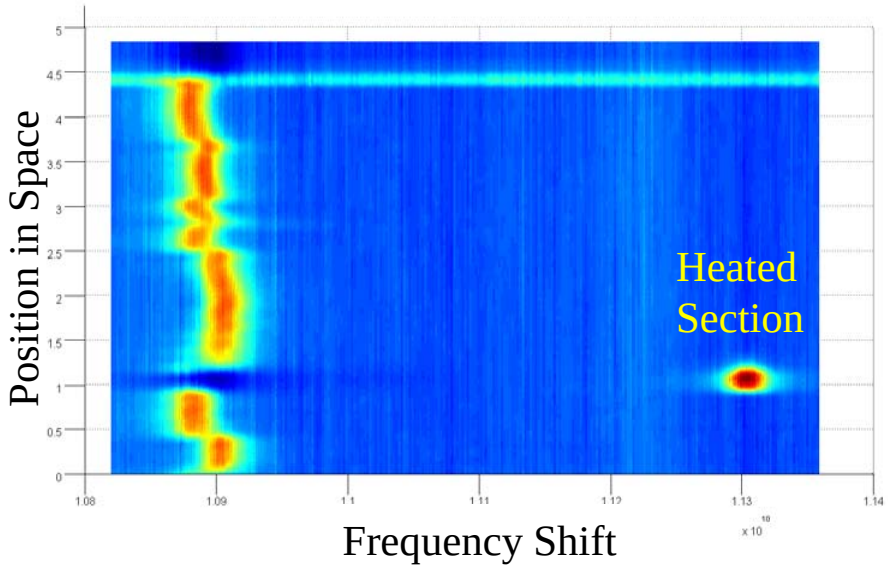
Optical Sensing System Designing



First Demonstration

- First demonstration of temperature sensing
- 5m spatial resolution and 10ºC temperature resolution achieved at 500ºC





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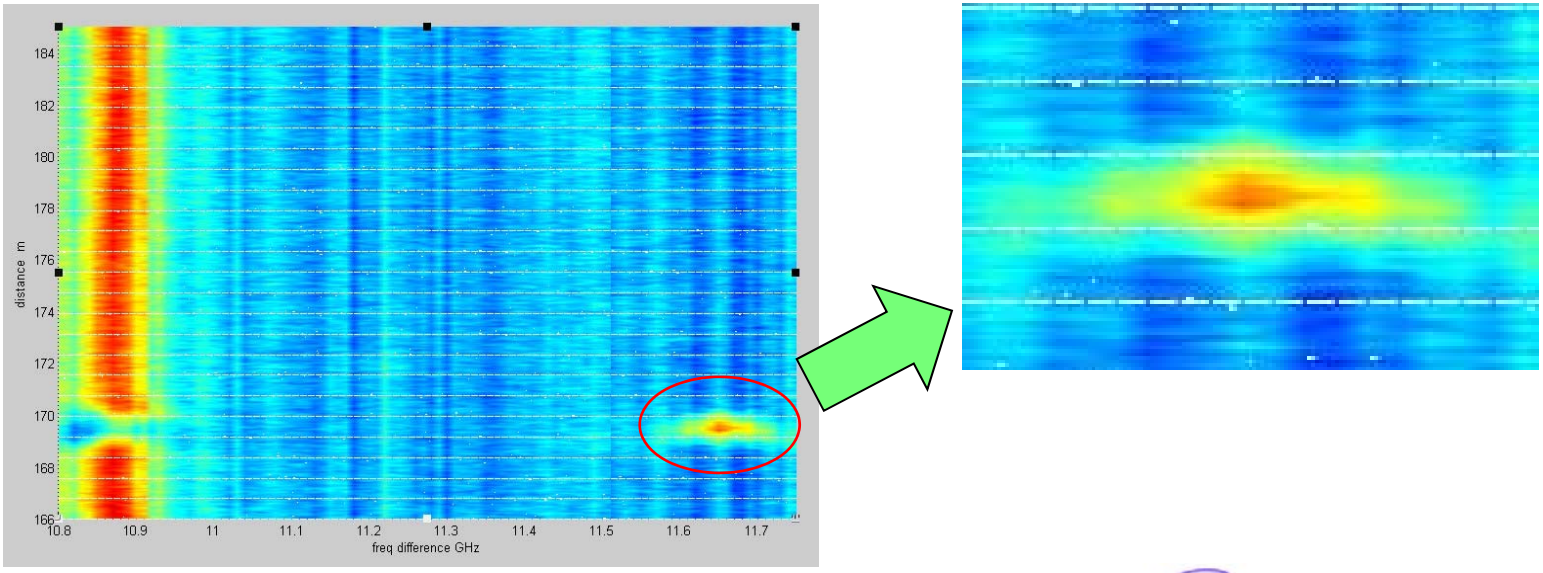
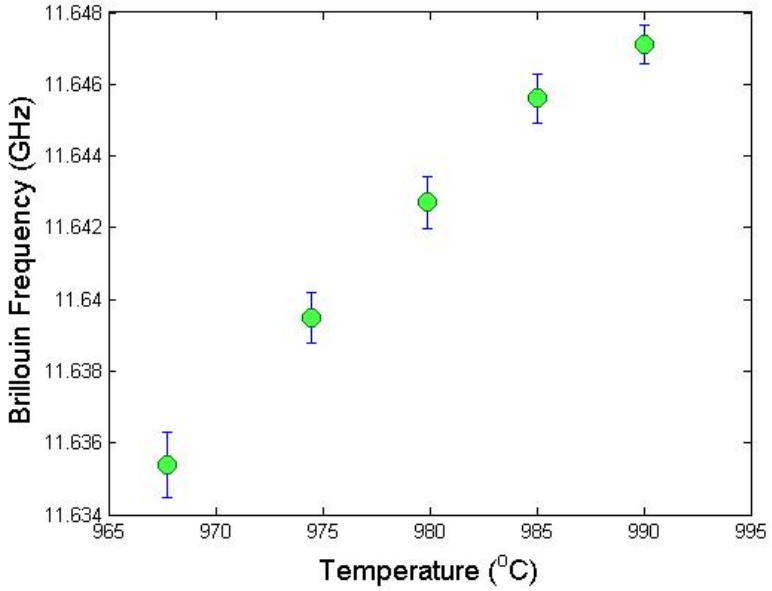
Sensitivity Optimization: Spatial Resolution

- Width of pump pulse and intensity of probe light optimized with the help of theoretical analysis
- Spatial resolution improved from 5m to 1m (over the span of 230m, at 1000°C)



Sensitivity Optimization: Temperature Resolution

- Temperature demodulation algorithm improved
- Test environment temperature stabilized
- Temperature resolution of 2.5°C achieved near 1000°C with 1m spatial resolution.



Challenges

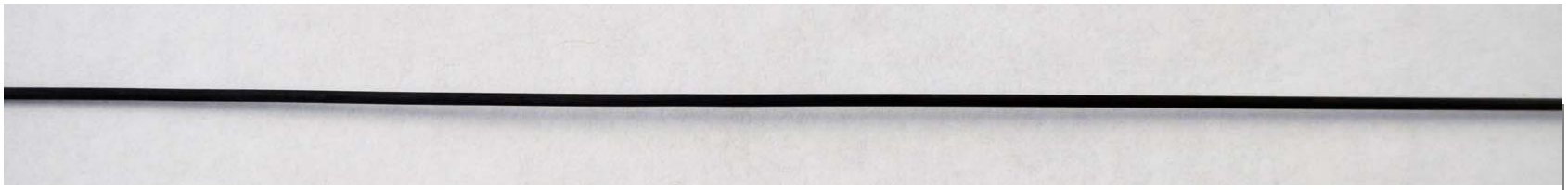
- Fiber type: silica fibers
  - Must be single-mode fiber
- Silica devitrification at extremely high temperatures
  - Weaken in mechanical strength
  - Optical transmission loss increase
  - Refractive index and acoustic property change

Challenge 1: Packaging

- Inconel 600 alloy tubes
  - No deformation
  - Oxidation on surface only

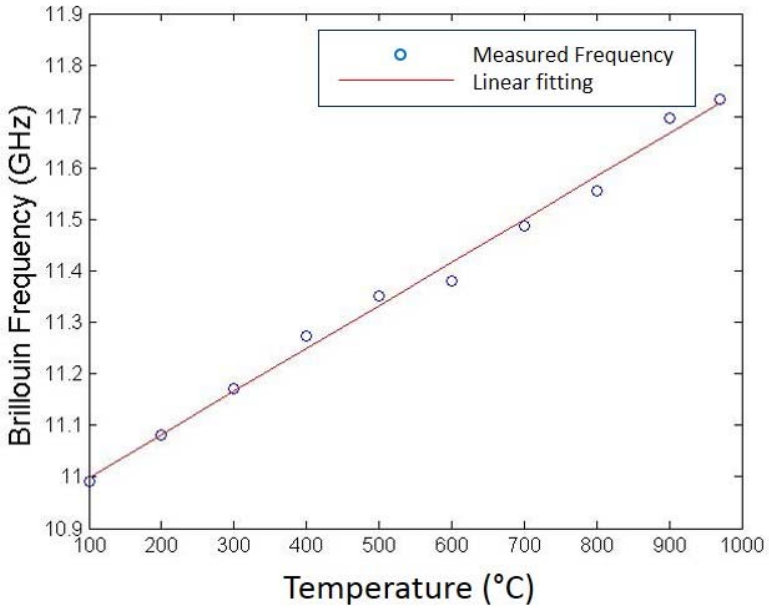
Before annealing

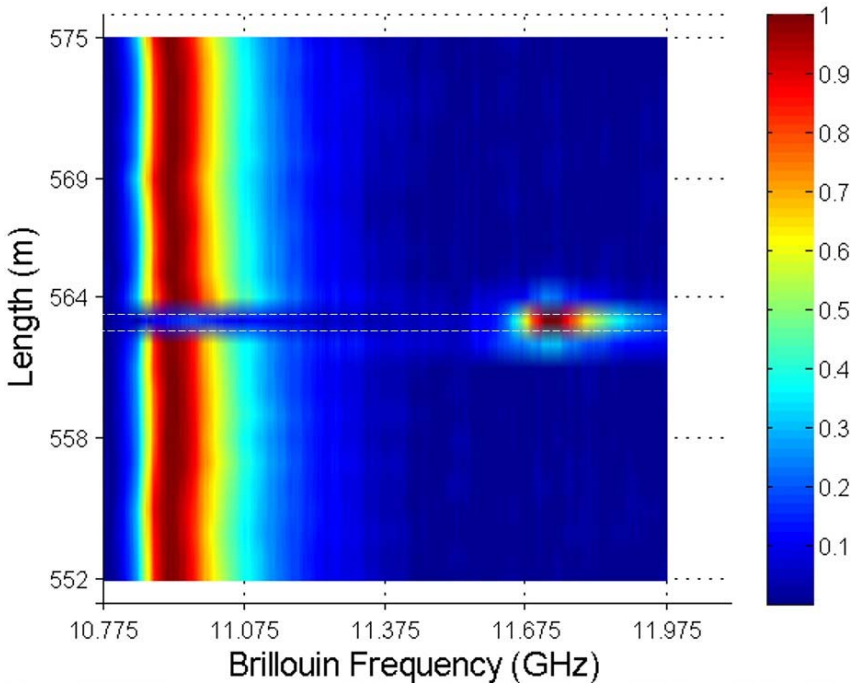
After 1000ºC annealing



Preliminary Packaged Sensor Test

- 1m spatial resolution over the span of 600m achieved at 1000ºC
- Sensor passed 36h annealing test at 1000ºC





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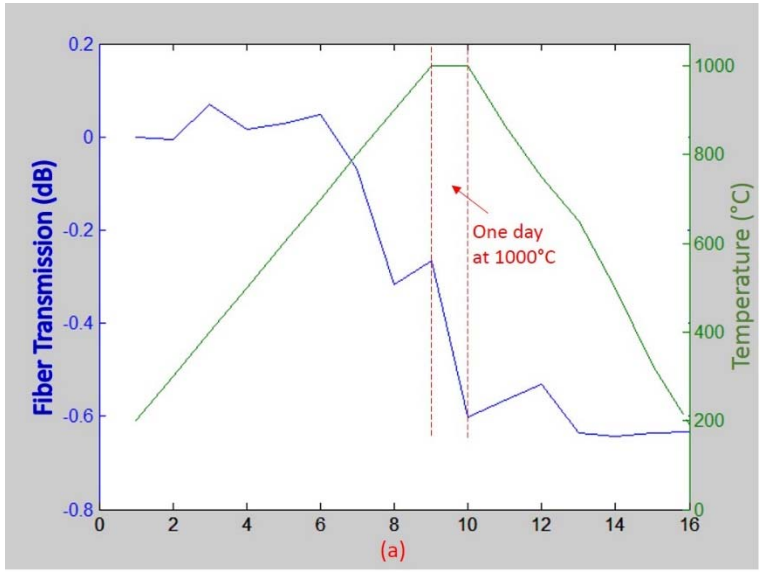
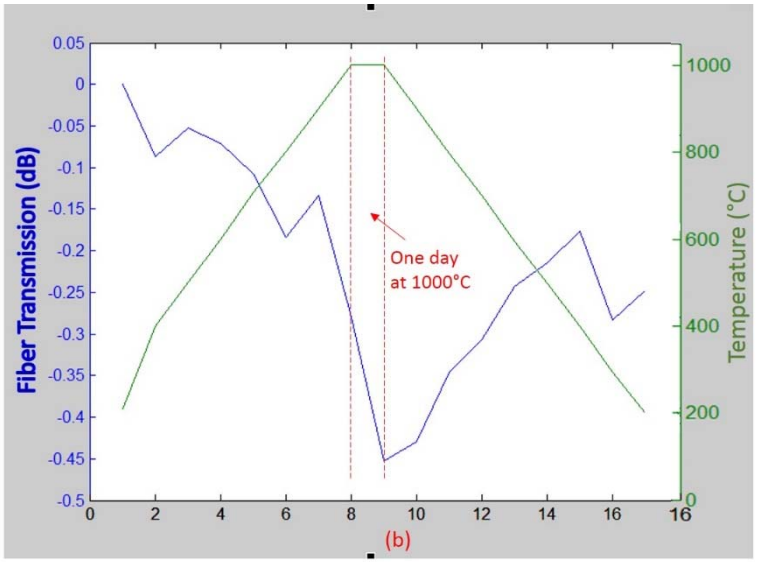
Challenge 2: Fiber Loss

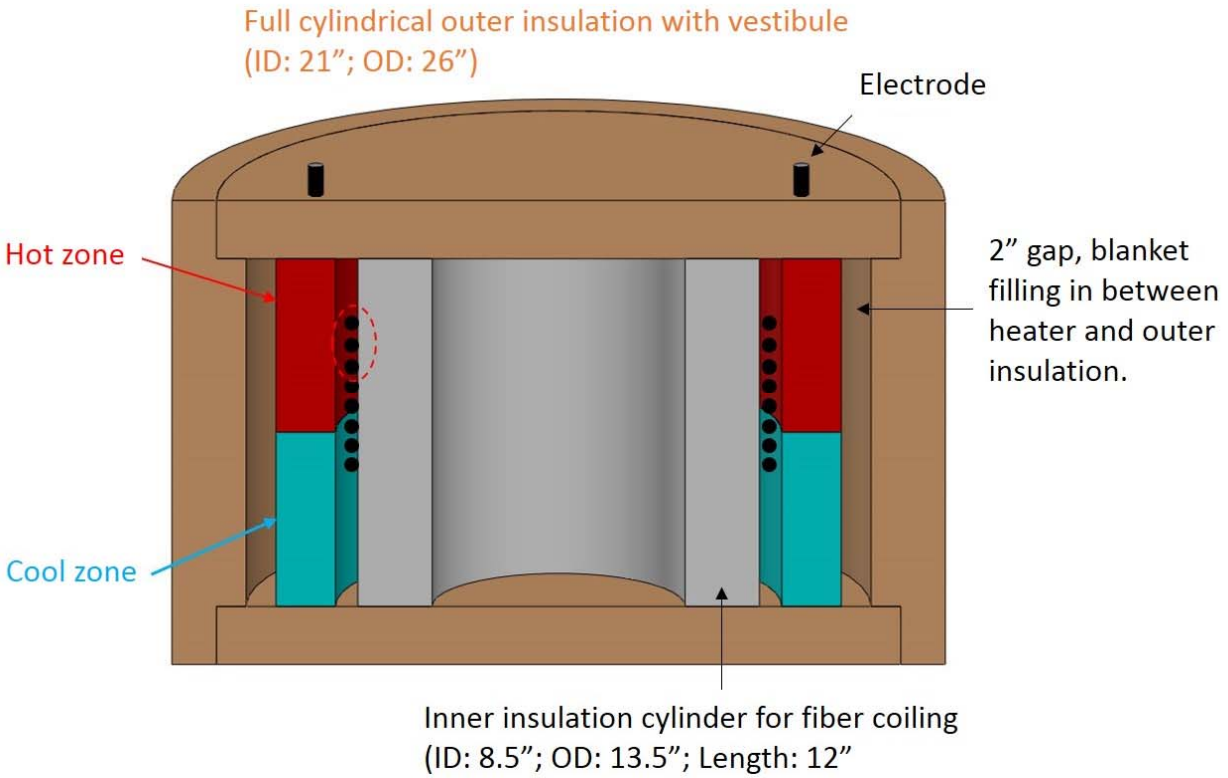
- Minor loss increases over time when fiber is kept at temperatures at 1000ºC
- Increasing rate measured to be ~0.1dB/m/day for a properly packaged fiber at1000ºC





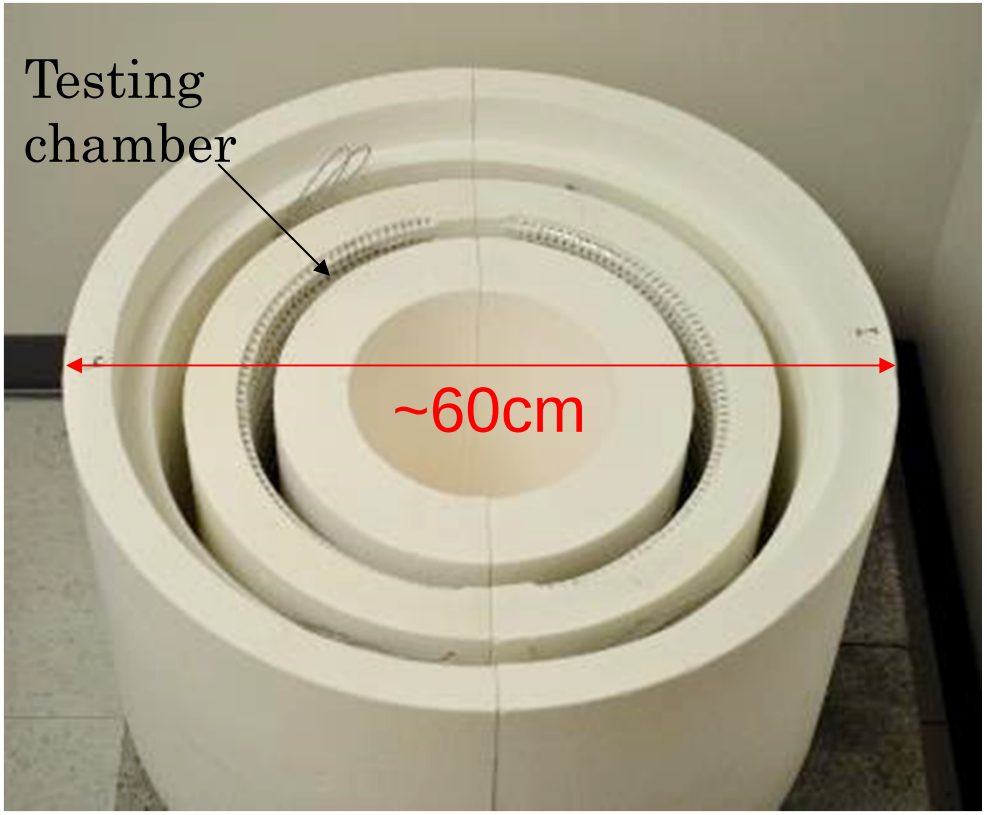
Lab Test Environment Design

- Independent dual heating zone for temperature gradient simulation



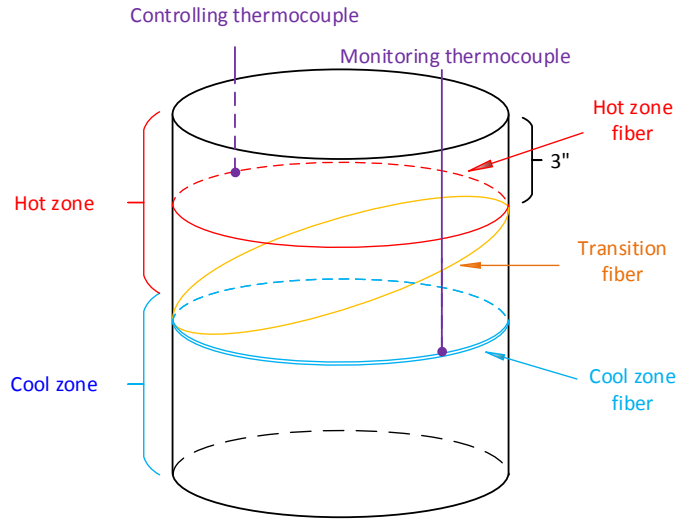
Lab Test Environment Building

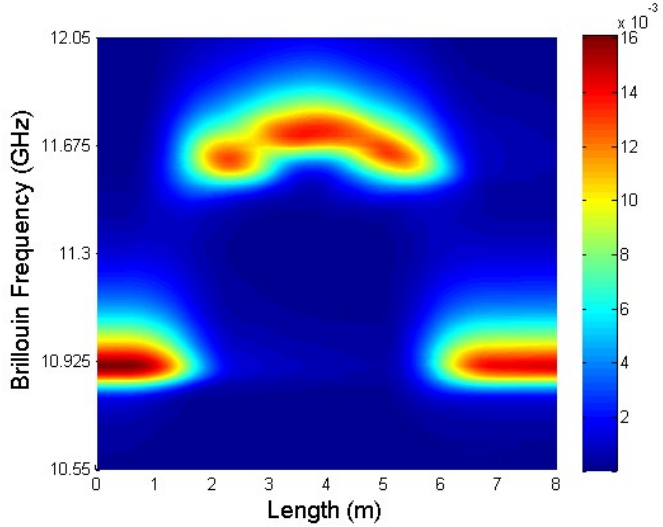
- Finished furnace assembly

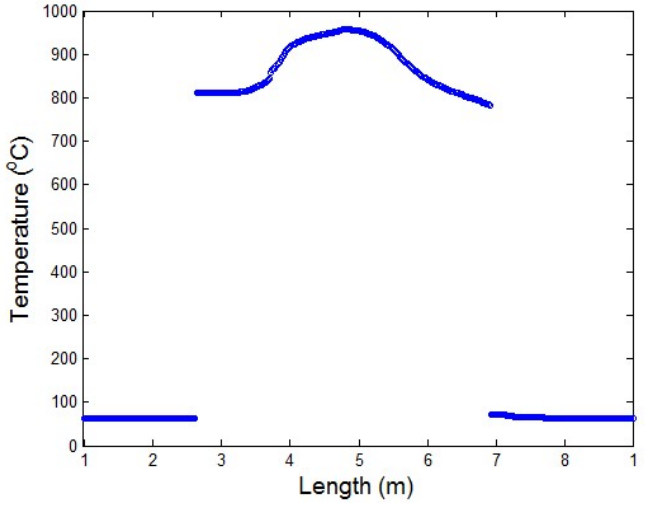


Performance Demonstration: Spatial Resolution

- Fiber installing scheme designed to simulate a hot spot on the furnace inner-wall
- 1m spatial resolution over 550m measurement range







What's Next

- Temperature resolution demonstration of packaged sensor in simulation environment
- Proposing of possible sensor installation schemes

THE END
THANK YOU!