2014 NETL Crosscutting
Research Review Meeting
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Pittsburgh, PA

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

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Outline

- Motivation and Objectives
- Background and Fundamental Technology
- Project Progress
- Summary

MOTIVATION AND OBJECTIVES

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 conditions-based maintenance model.
  - Reduced downtime & cost savings.

Project Overview & Objectives

- Three-year project beginning 5/1/2011.
- Industrial collaborator Eastman Chemical Co. assists in developing technical requirements.
- Objectives:
  - Develop a first-of-a-kind distributed high-temperature sensing platform.
  - Demonstrate potential for coal gasifier refractory health monitoring.
    - Potential operation at the back side of inner-most gasifier refractory wall.
    - Direct mapping of temperature profile.

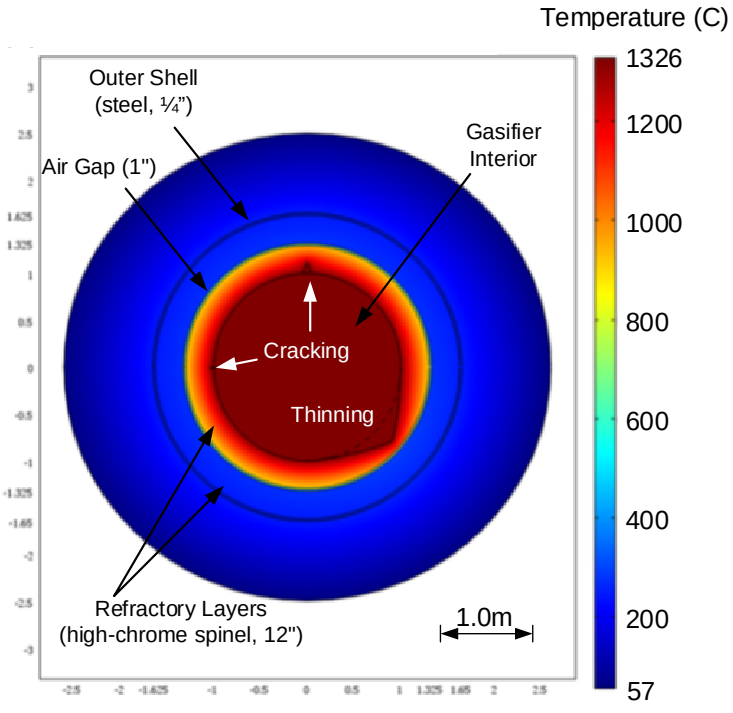
BACKGROUND AND FUNDAMENTAL TECHNOLOGY

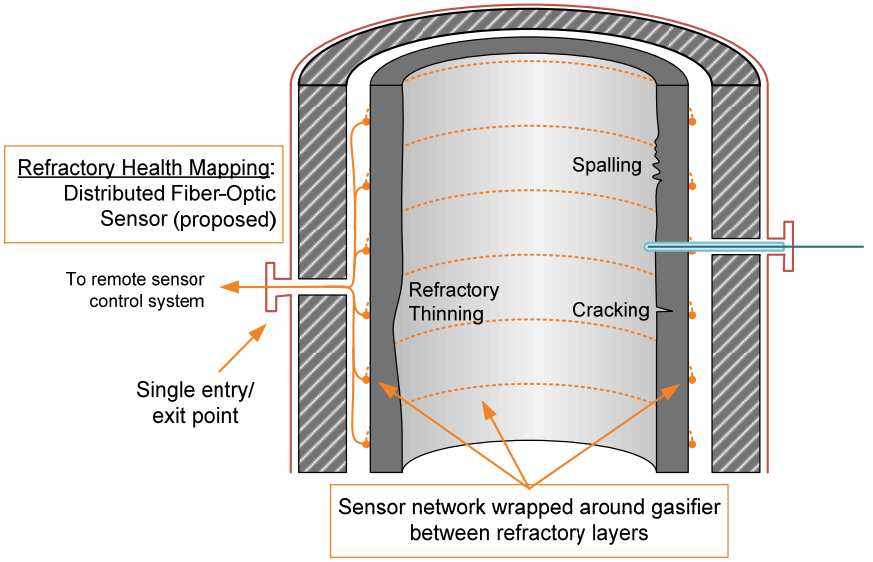
Light-induced Traveling Fiber Grating

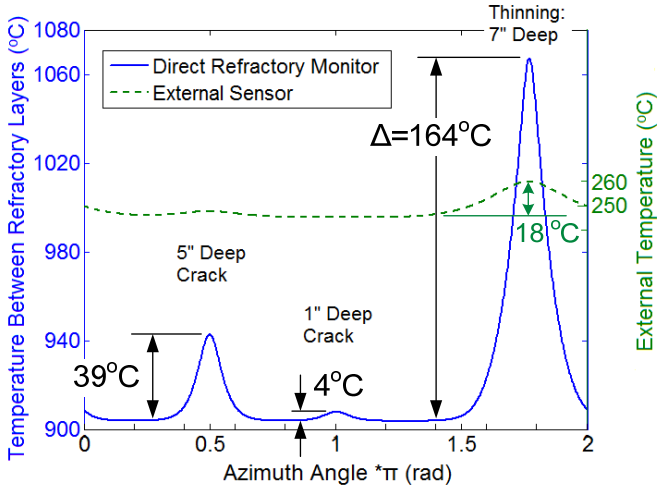
- A strong pulsed light as pump and a weak CW light as probe are injected into the sensing link, counter-propagating.
- The beat note of the pump induces a transient grating which scans along the sensing fiber.
- The signal light probes the travelling fiber grating and translates the temperature distribution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

Gasifier Refractory Health Monitoring

- Refractory defect monitoring by temperature mapping



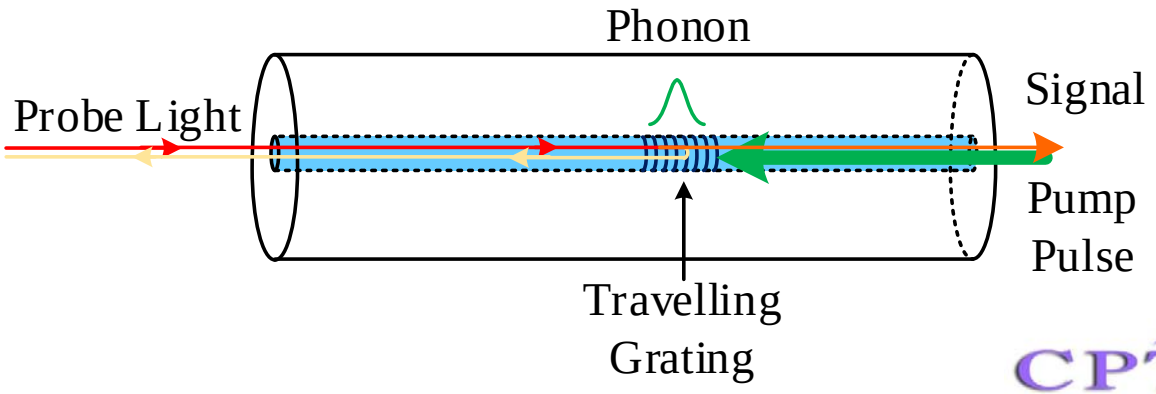




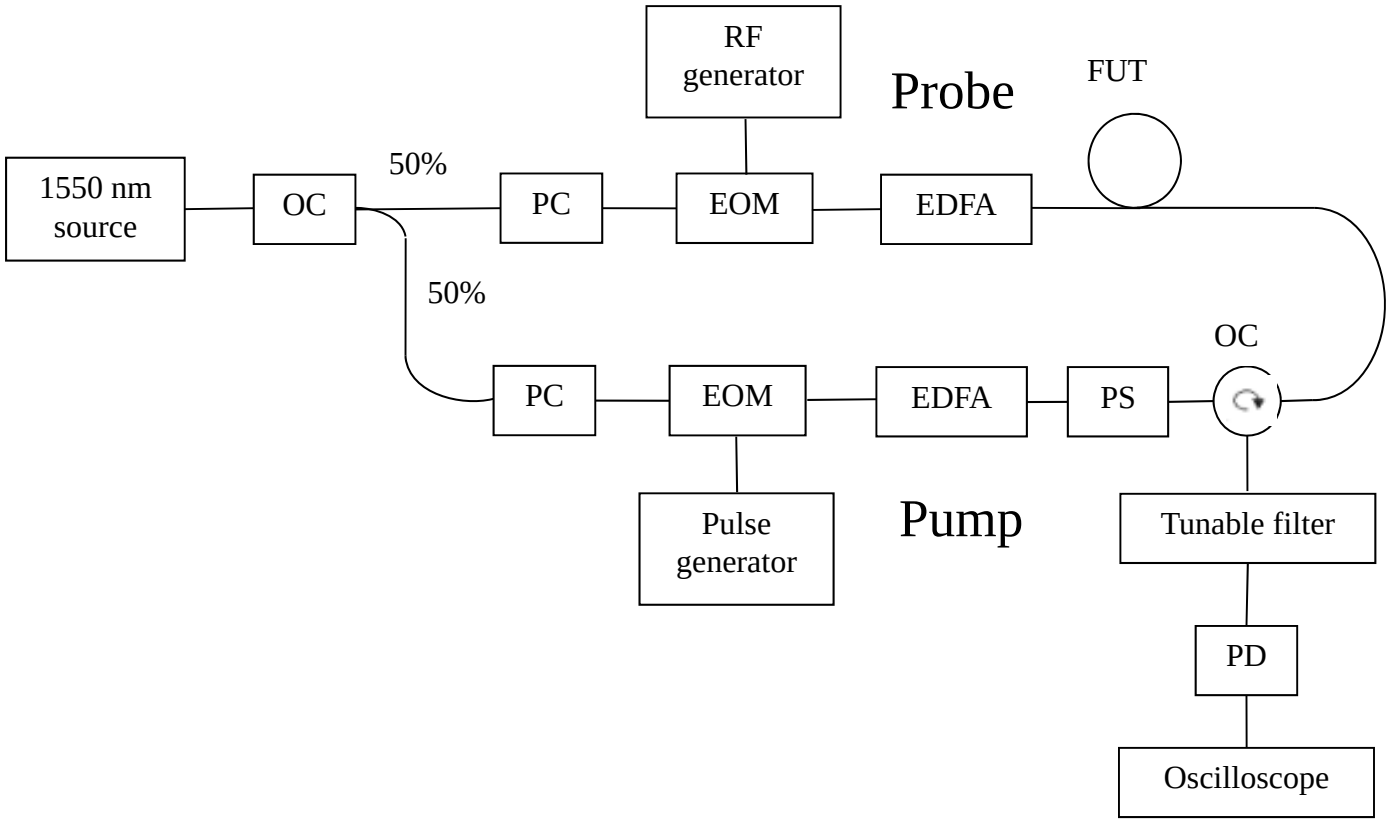
PROJECT PROGRESS

Sensing Mechanism

- Electrostriction phonon induced transient periodic refractive index change is chosen as the mechanism to generate the travelling fiber grating.
- With an intense pulsed light, the pulses generates acoustic gratings as they propagate along the sensing fiber, also known as Stimulated Brillouin Scattering (SBS) effect.

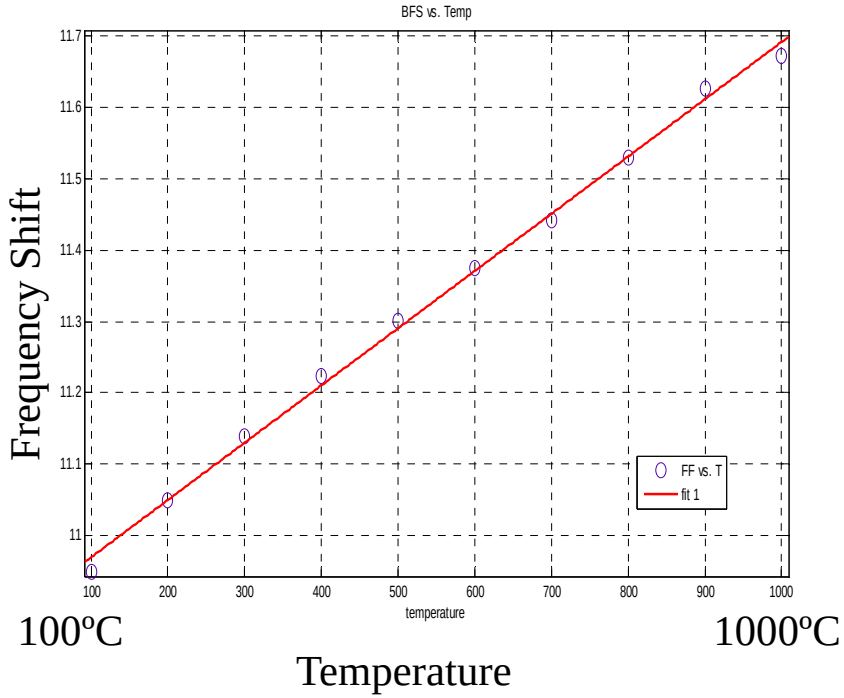


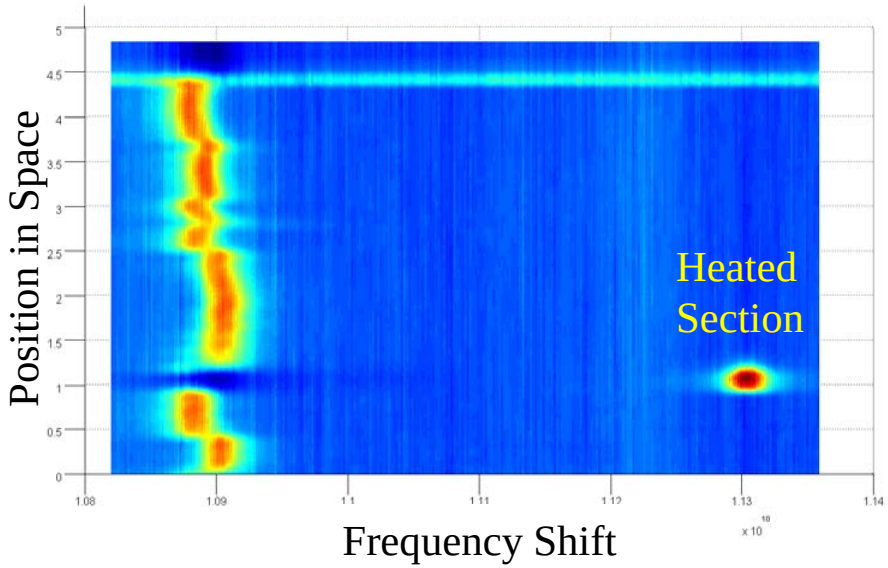
Optical Sensing System Designing



First Demonstration

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





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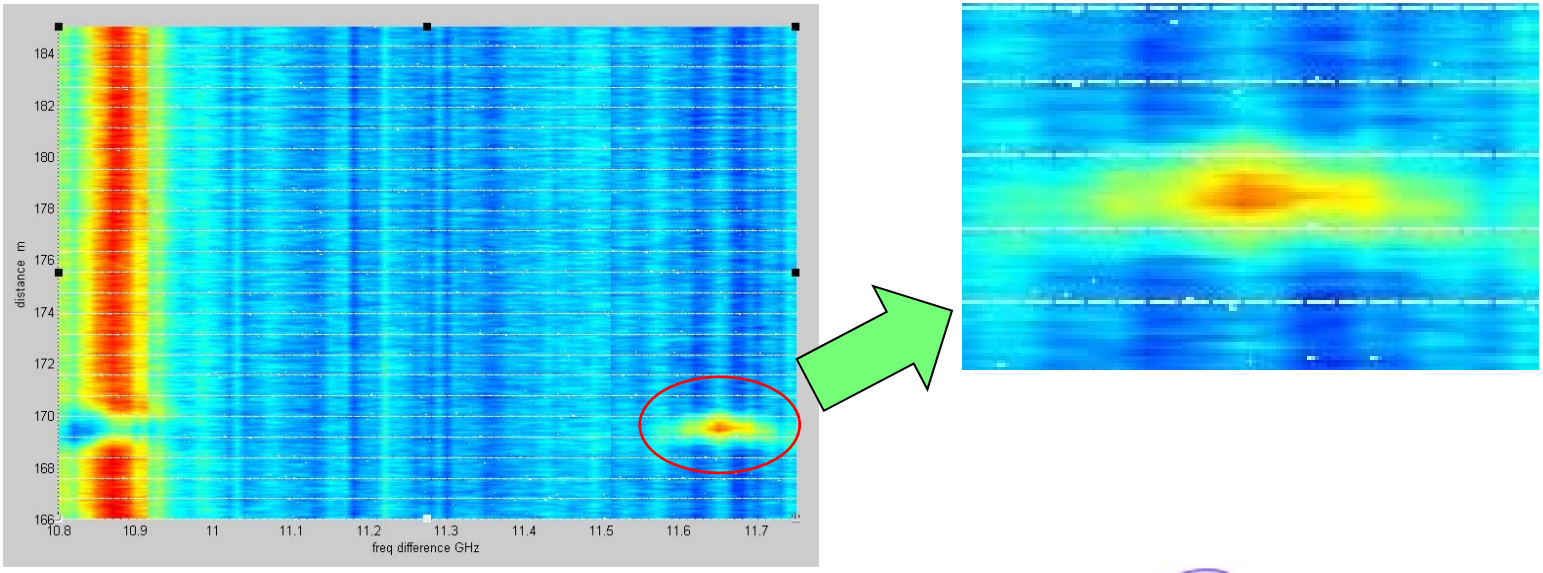
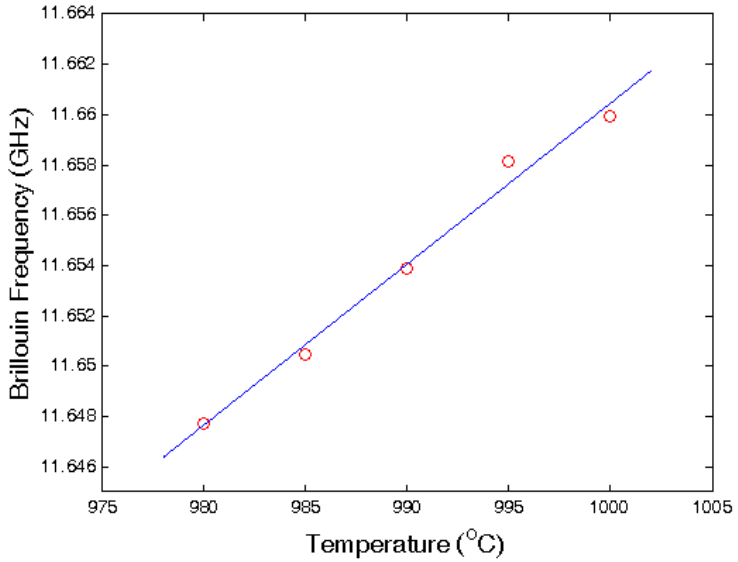
Sensitivity Optimization: Spatial Resolution

- 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 5°C achieved at 1000°C with 1m spatial resolution.



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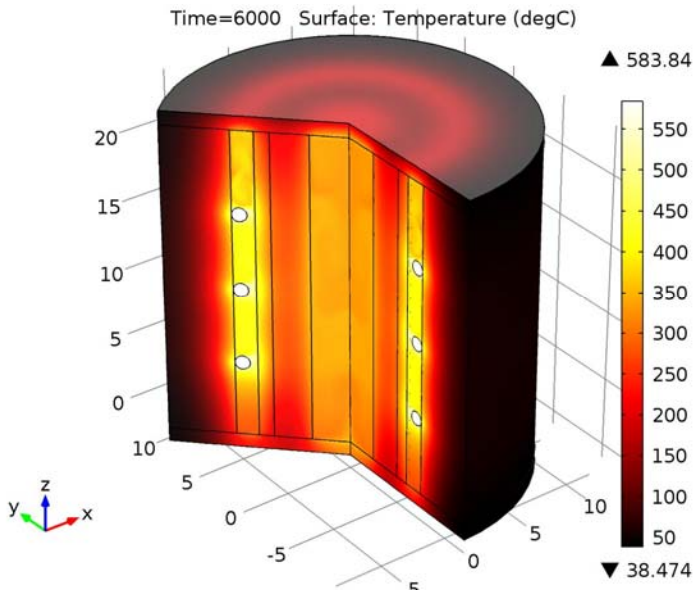
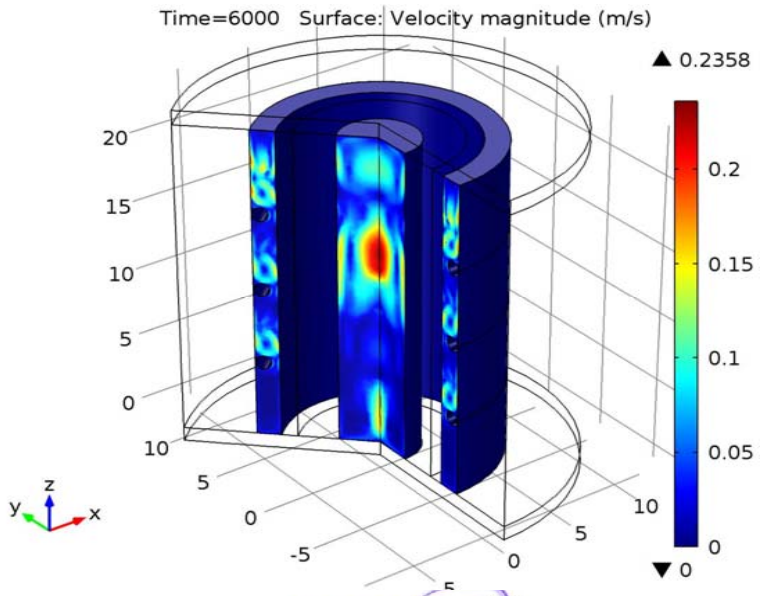
Lab Test Environment Design

- Simulation for key parameters of
  - Furnace geometry
  - Power consumption
  - Heating element arrangement





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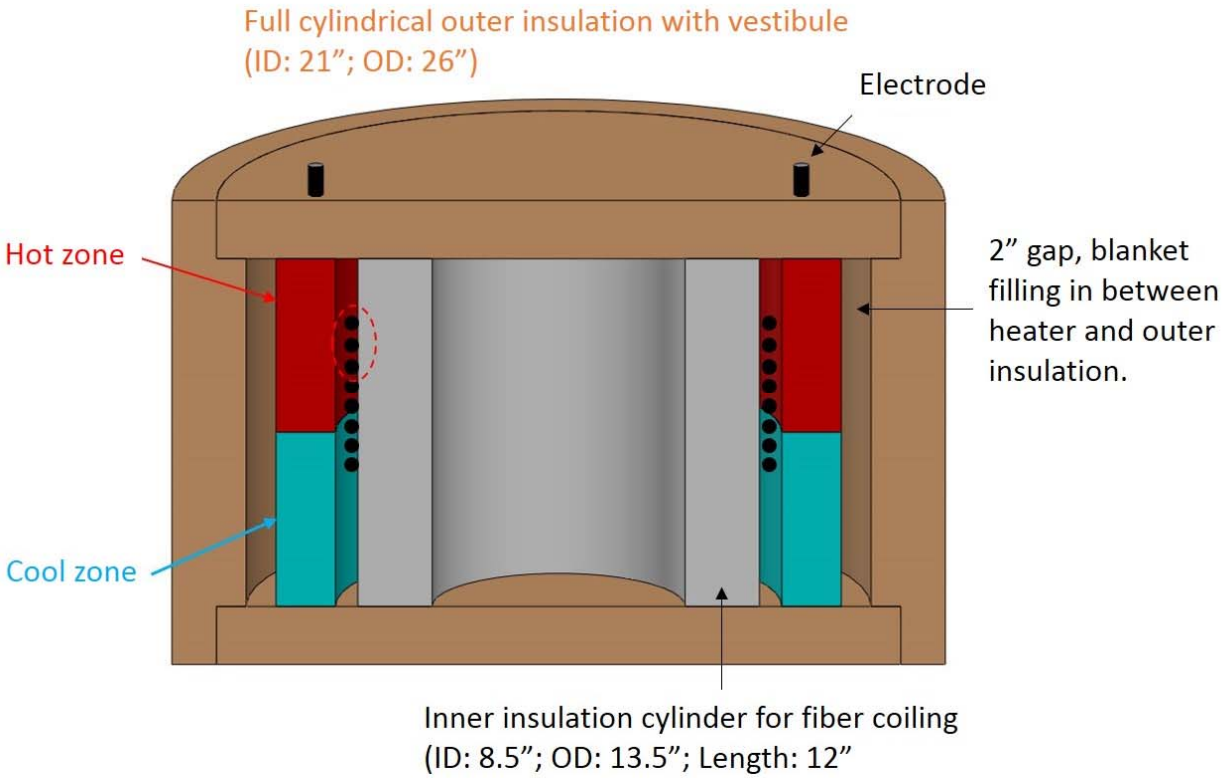
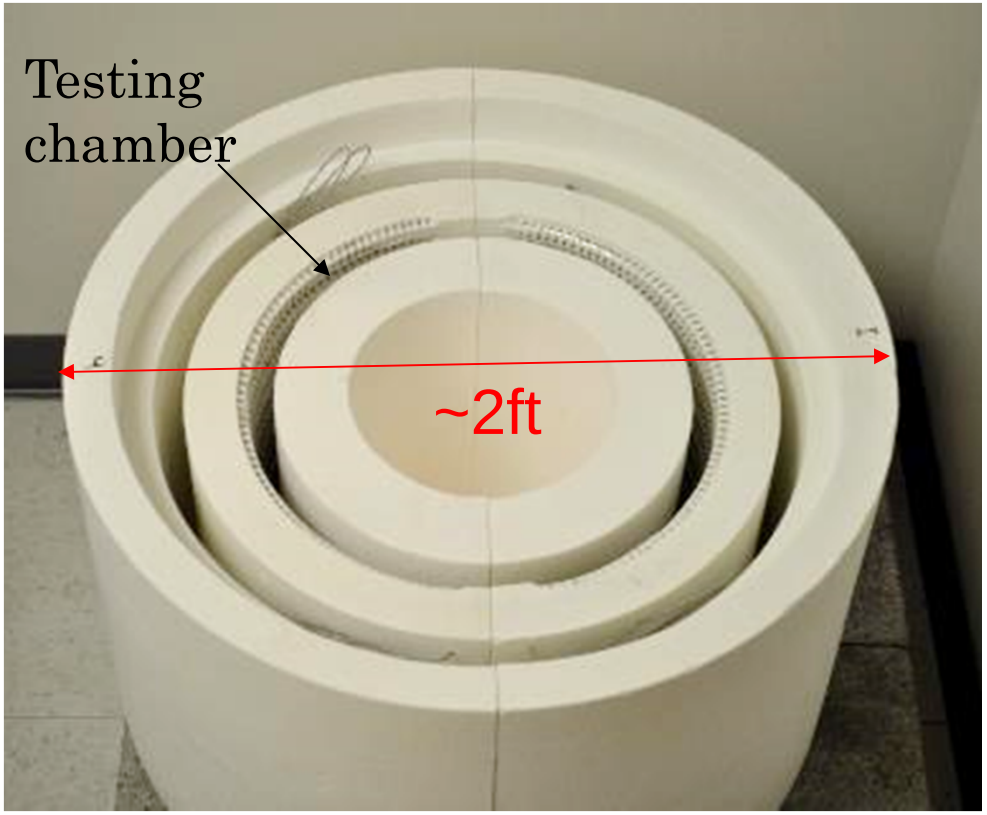
Lab Test Environment Design

- Independent dual heating zone for temperature gradient simulation



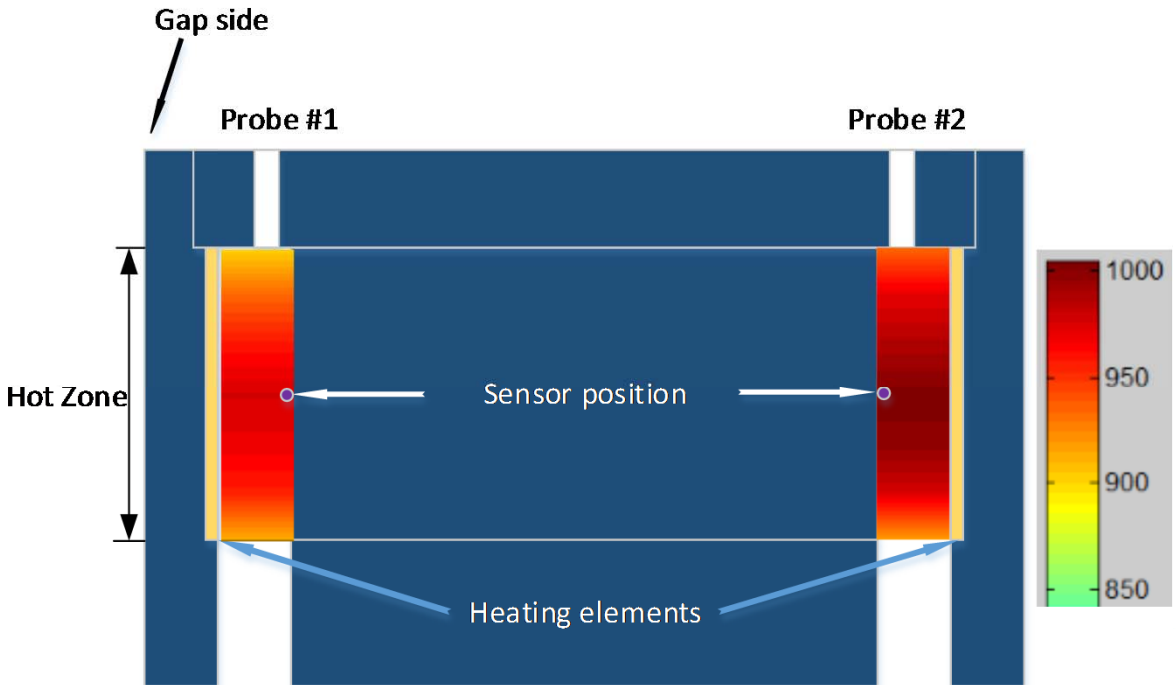
Lab Test Environment Building

- Finished furnace assembly



Lab Test Environment Characterization

- Minor temperature difference observed due to a gap reserved for sensor leading-in and leading-out.
- ~2°C temperature stability at 1000°C

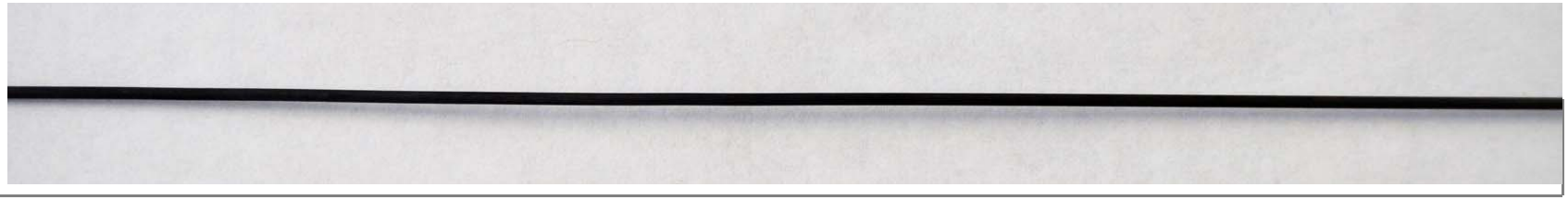


Sensor Packaging: Alloy Tubing

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

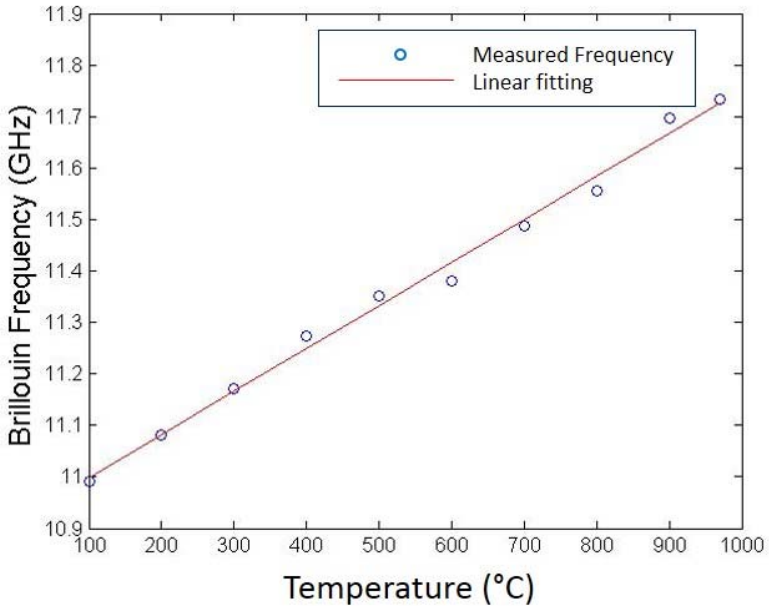
Before annealing

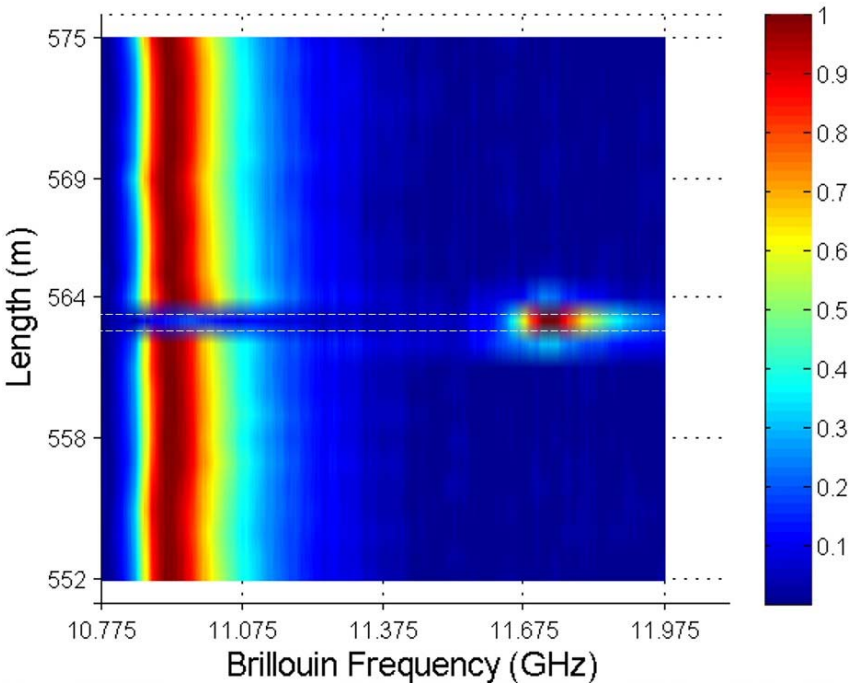
After 1000ºC annealing



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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Next Steps

- Demonstrate temperature gradient measurement in the lab testing environment
- Improve sensor temperature response linearity

SUMMARY

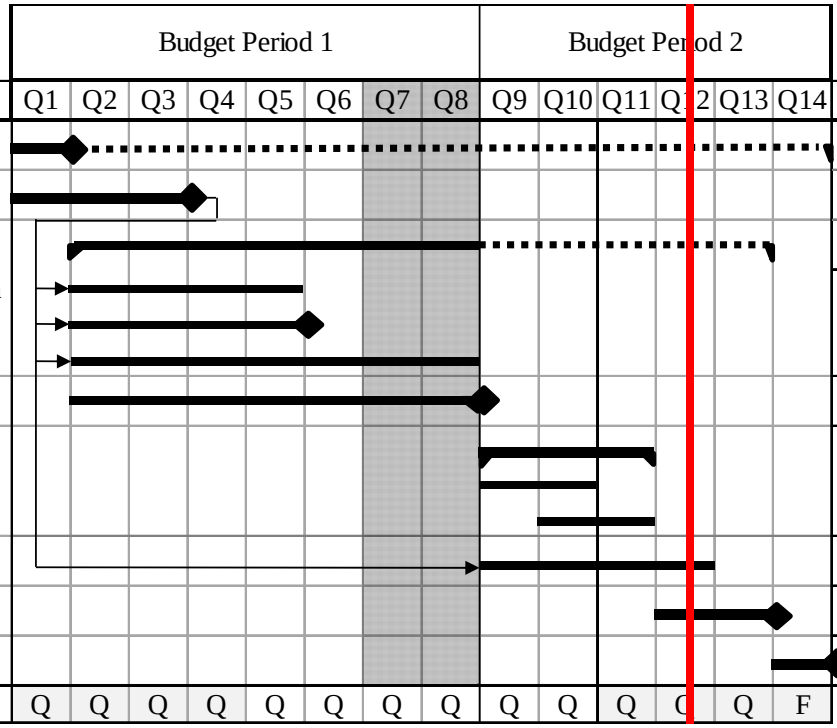
Tasks

1. Project management and planning
2. Determine sensor technical requirements
3. Sensor design and refractory performance modeling
4. Demonstrate the chosen mechanism
5. Develop distributed sensor prototype
6. Design and build test environment
7. Test sensor and evaluate performance
8. Prepare final report

Project Progress Summary

Project Start Date: 5/1/2011
Project End Date: 12/31/2014

Task	Description	Start Date	End Date
1	Project Management & Planning	2011/5/1	2011/9/30
2	Determine Technical Specifications	2011/5/1	2012/3/31
3	Sensor Design & Refractory Model	2011/10/1	2013/6/30
3.1	Investigate various sensing mechanism	2011/10/1	2012/9/30
3.2	Develop sensor design	2011/10/1	2012/9/30
3.2	Develp refractory model	2011/10/1	2013/6/30
4	Demonstrate the Choson Mechanism	2011/10/1	2013/6/30
5	Develop Sensor Prototype	2013/7/1	2014/3/31
5.1	Construct prototype sensor	2013/7/1	2013/12/31
5.2	Calibrate & verify basic operation	2013/10/1	2014/3/31
6	Design & Build Test Environment	2013/7/1	2014/6/30
7	Test & Evaluate Sensor	2014/4/1	2014/9/30
8	Prepare Final Report	2014/10/1	2014/12/31
	Technical Progress Reports		



Project Milestone
Linked Tasks: Application Info.
Umbrella Task
Task Continuation
Budget Period
No cost extension

Reports: Q - Quarterly F - Final

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THE END