2014 NETL Crosscutting
Research Review Meeting
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Pittsburgh, PA

EMBEDDED ACTIVE FIBER OPTIC SENSING NETWORK FOR STRUCTURAL HEALTH MONITORING IN HARSH ENVIRONMENTS

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Outline

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

MOTIVATION AND OBJECTIVES

Motivation

- Health condition monitoring of key materials and structures can ensure safety and minimize system shutdowns.

- Challenges from a new set of extreme physical and chemical conditions:
  - Ultrahigh temperature
  - High pressure
  - Severe chemical corrosion

Impacts

- Currently available methods:
  - X-ray defect detection
  - Ultrasonic tomography
  - Remote techniques using piezoelectric transducers
- Advantage of new fiber-based technology:
  - Can be attached or embedded
  - Multi-parameters monitoring with single sensor
  - High temperature
  - Remote, no on-site power required
  - Potential of multiplexing

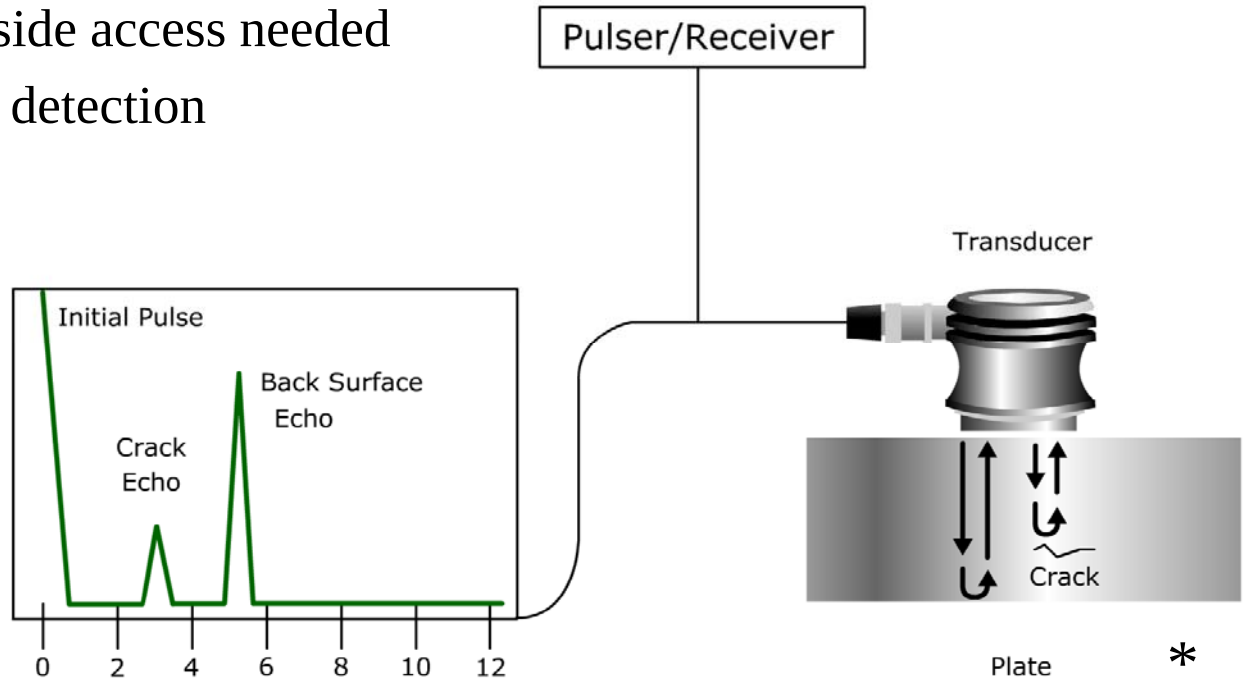
Project Overview & Objectives

- Three-year project beginning 4/1/2013.
- Objectives:
  - Develop a fiber-based multi-parameter (temperature, strain, corrosion, and defects) health monitoring sensor
  - Develop the attachment or embedment technology of the sensor to steel
  - Demonstrate the feasibility of sensor multiplexing

BACKGROUND AND FUNDAMENTAL TECHNOLOGY

Ultrasonic Non-Destructive Evaluation (NDE)

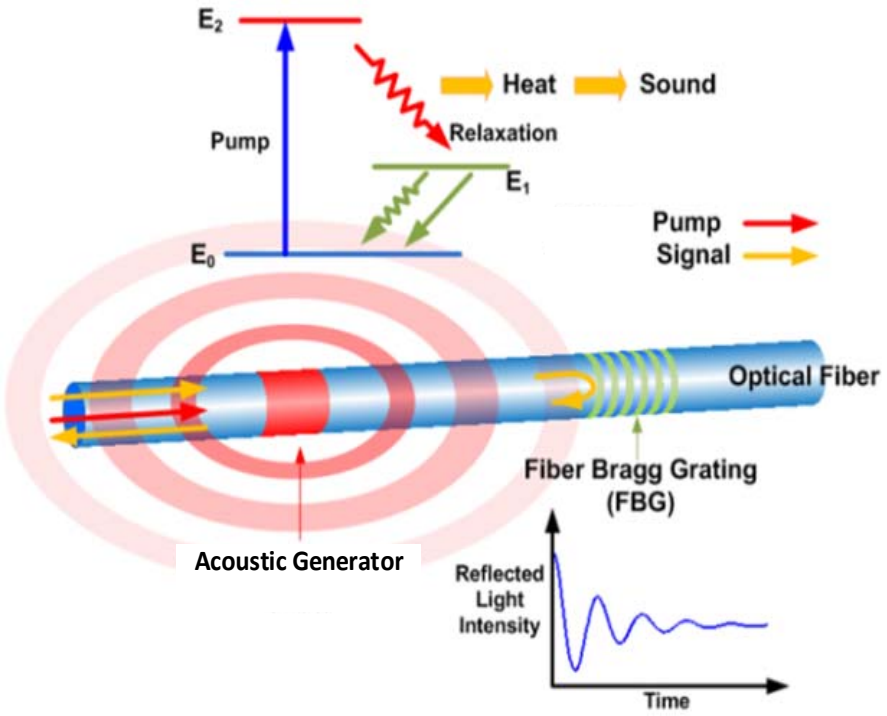
- Widely used and versatile technique of material defect detection.
  - One-side access needed
  - Deep detection



* Figure from www.ndt-ed.org

Active Fiber-Optic Non-Destructive Evaluation (FO-NDE)

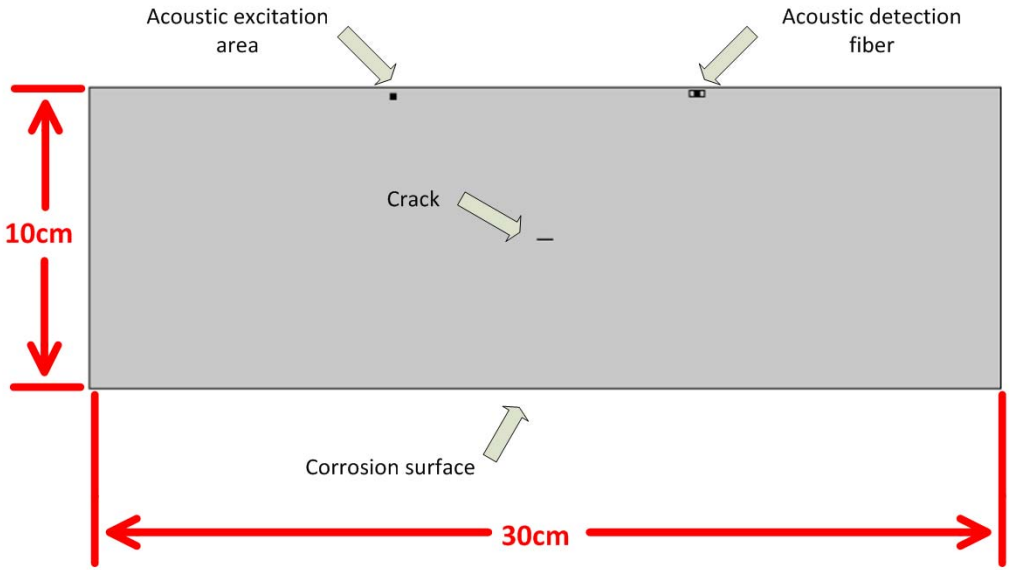
- An acoustic wave is generated to detected defects optically in a fiber.
- A Fiber Bragg Grating (FBG) is used to detect the acoustic signal modulated by the material as well as other parameters.



PROJECT PROGRESS

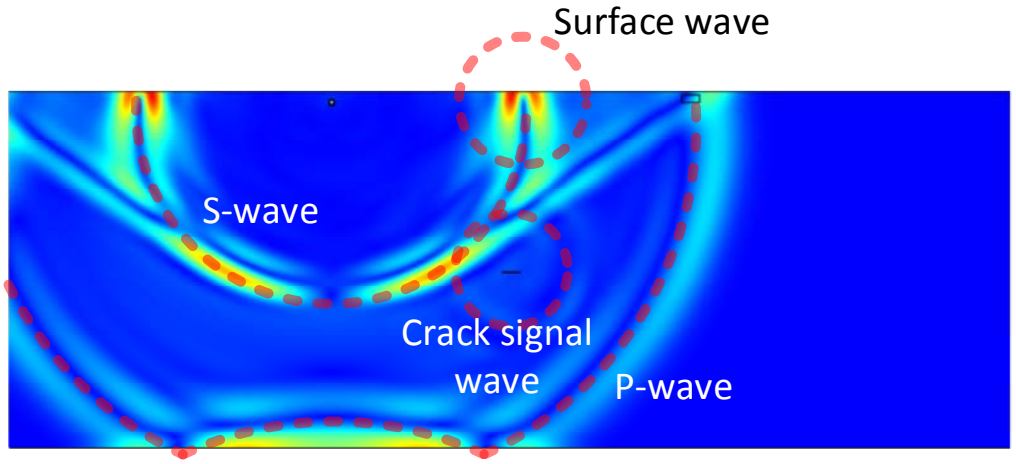
Computational Modeling

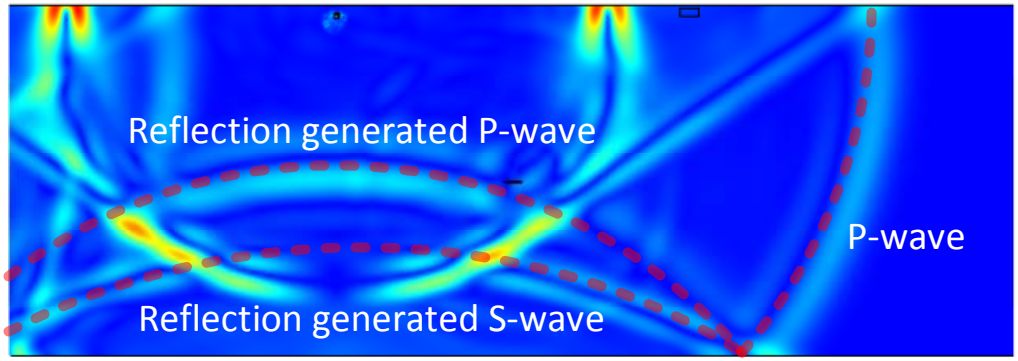
- A 2D computational model was built to simulate acoustic propagation in a bulk material.
- Cracks and corrosions were placed on the block to simulate acoustic responses of the system.



Acoustic Wave Simulation

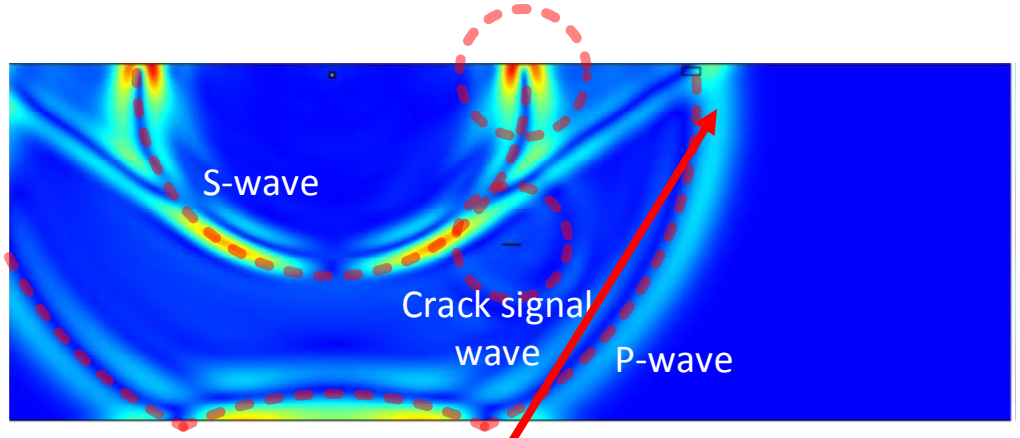
- Elastic wave propagation model
- Simulated
  - P-wave
  - S-wave
  - Surface wave
  - Reflection
- Demonstrated acoustic propagation in a specimen with crack and corrosion

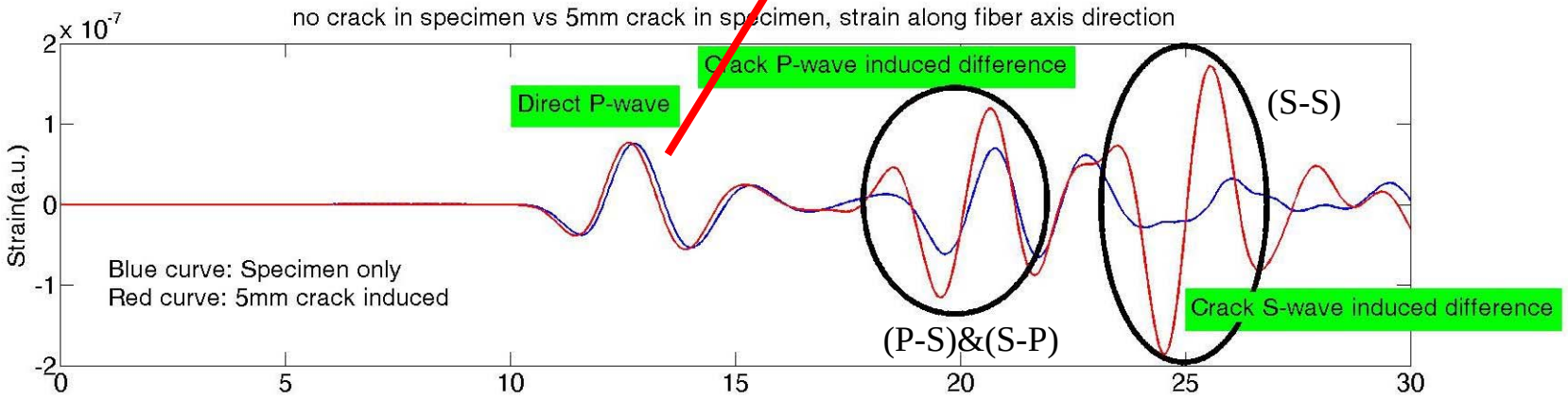




Crack Detection

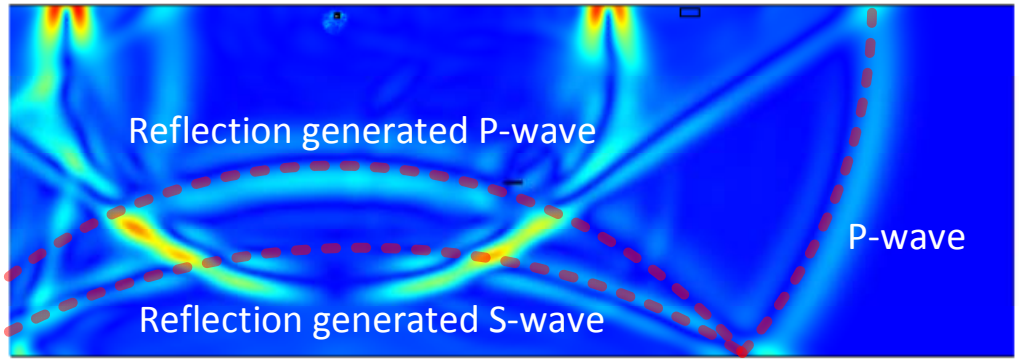
- Crack-induced acoustic signal

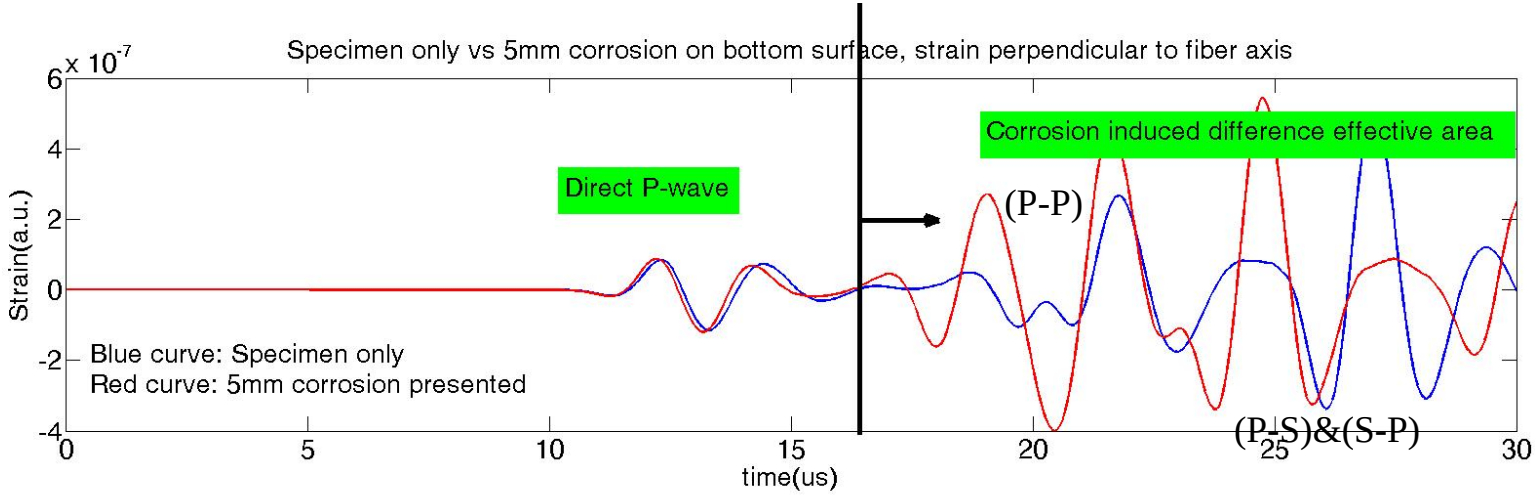




Corrosion Detection

- Corrosion induced acoustic signal change

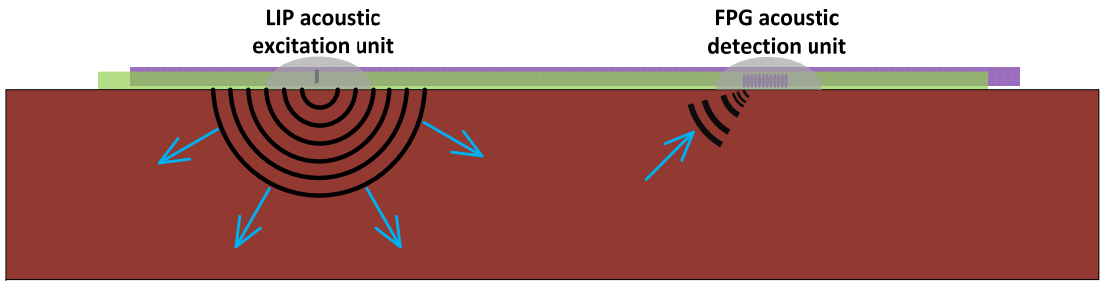




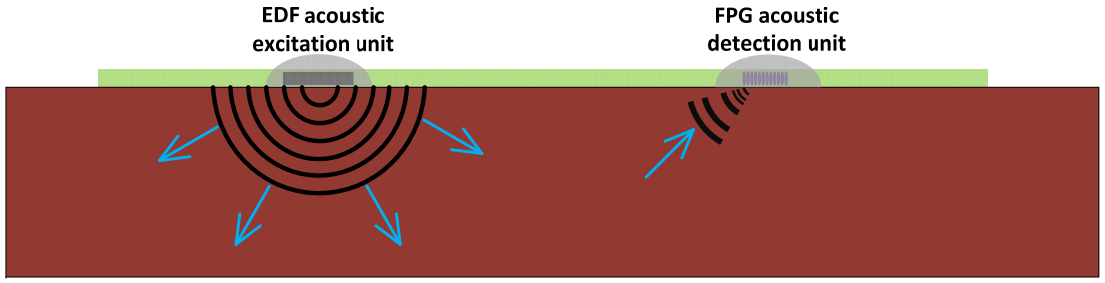
Sensor Element Design

- Two acoustic generation candidates
  - Laser Induced Plasma (LIP)
  - Erbium-Doped Fiber (EDF)

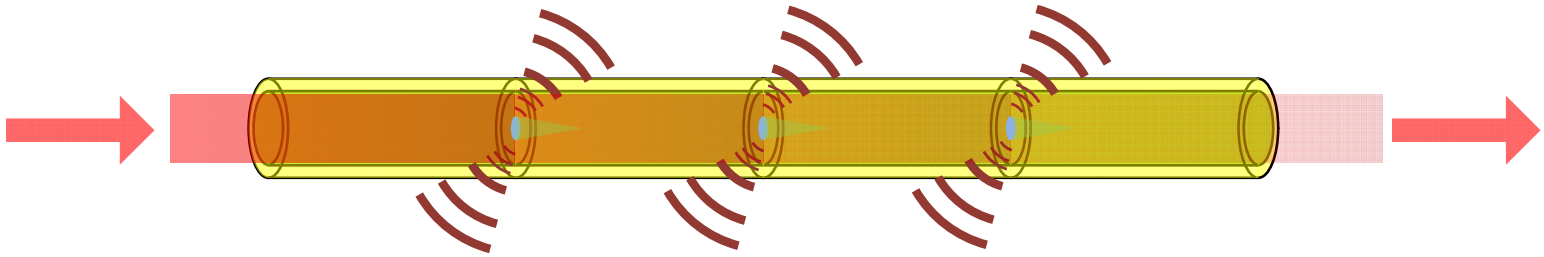
Surface attached LIP& FBG based FO-NDE element



Surface attached EDF& FBG based FO-NDE element



LIP Based Sensor Design



- Metal film embedded in multimode fiber
- Confined LIP
- Multiplexing through partial absorption on each element
- Pro: high acoustic signal level
- Con: dual fiber system, complicated sensor fabrication

LIP Based Acoustic Generator Fabrication

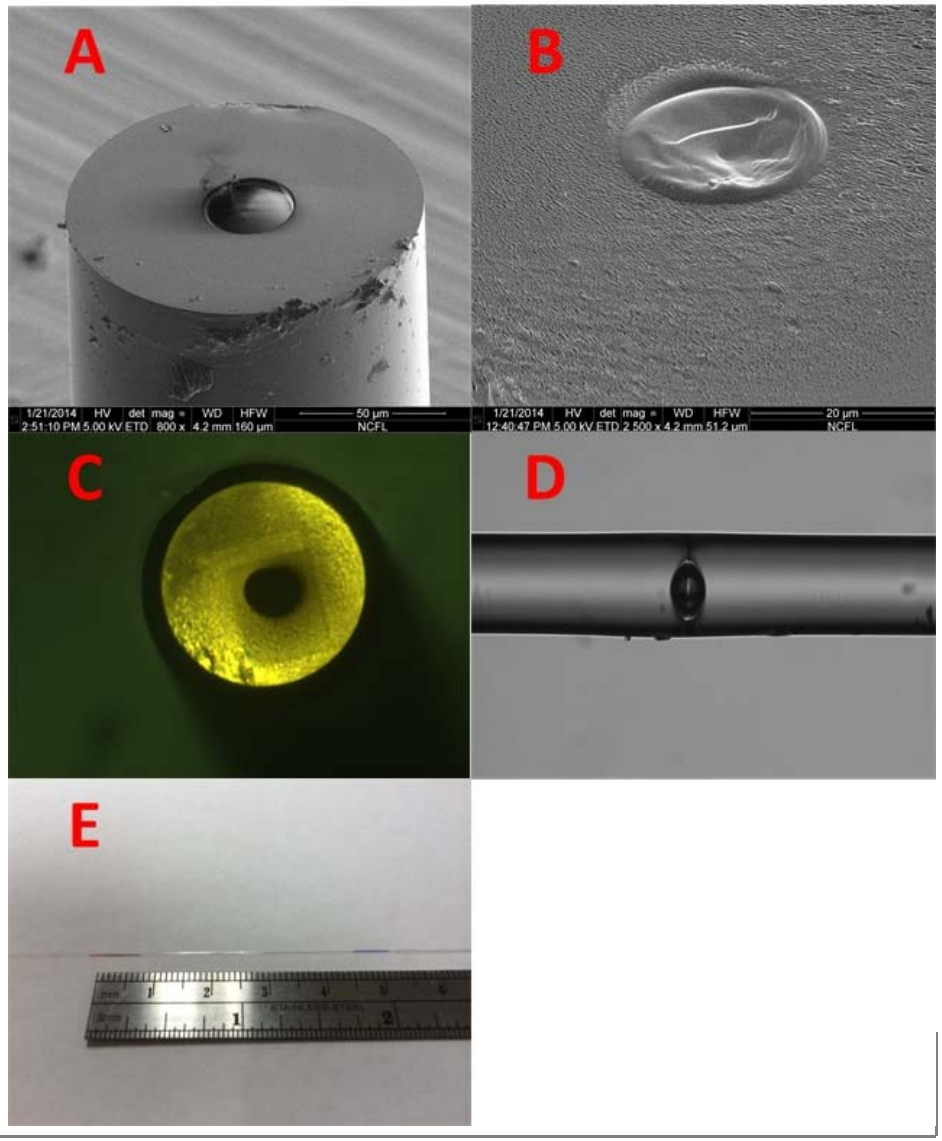
A. Well drilled on fiber end;

B. Well filled with platinum using Focused Ion Beam (FIB);

C. Microscope image;

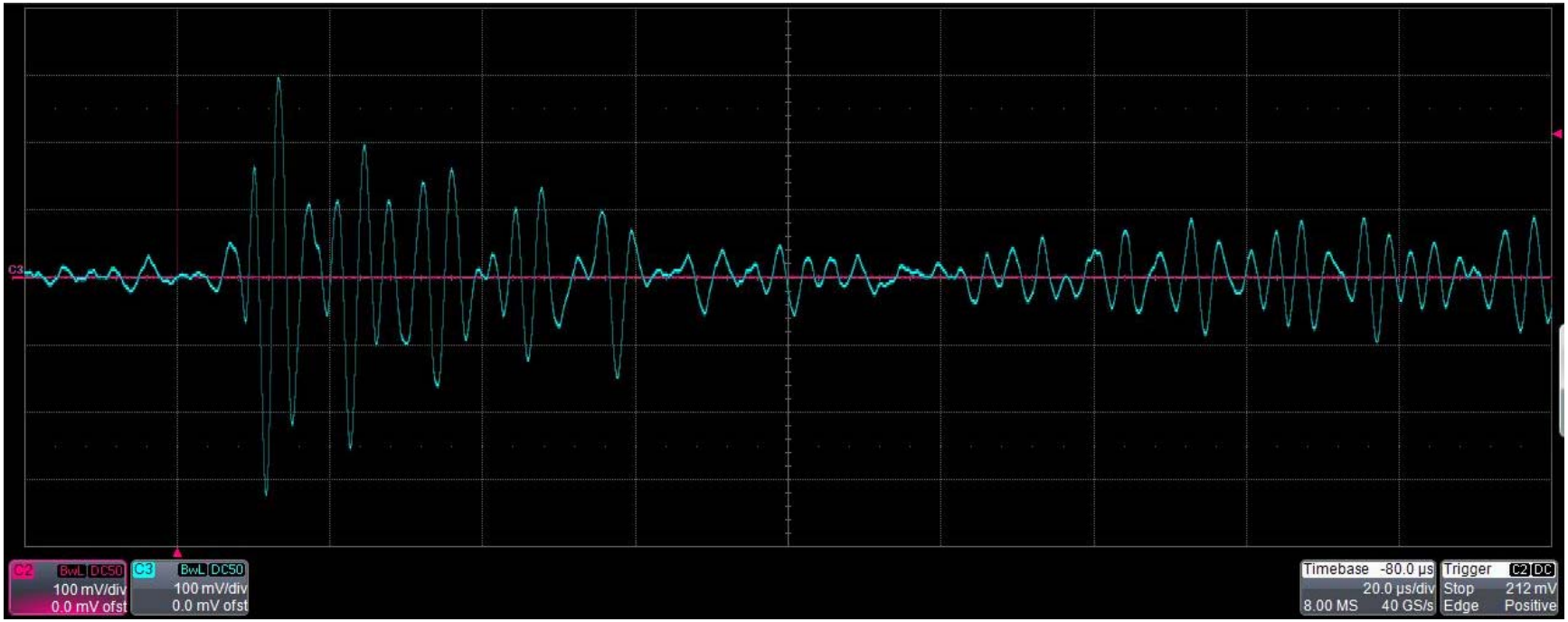
D. Splicing;

E. Completed unit.

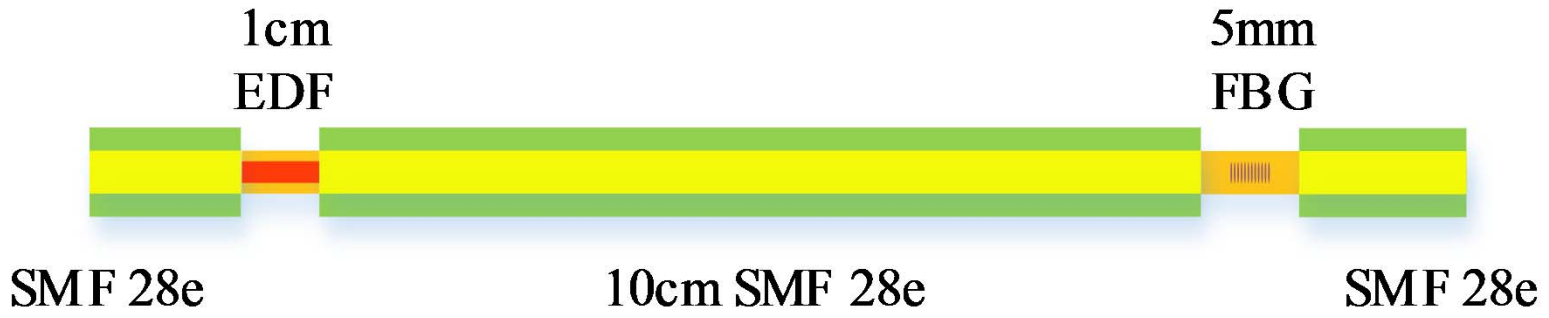


LIP Based Sensor Preliminary Test

- Strong acoustic wave generated by single unit in water



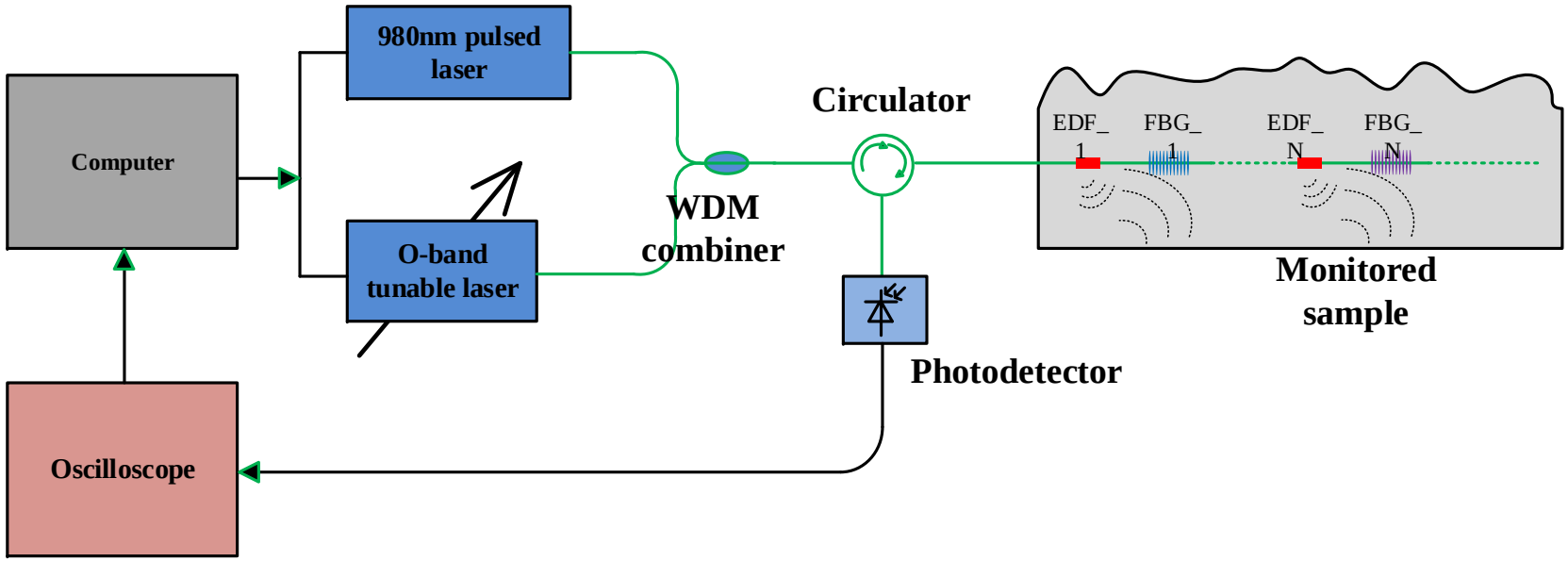
EDF Based Sensor Design



- Using the absorption and thermal relaxing of EDF for acoustic generation
- Pro: easier fabrication, single fiber structure
- Con: weak acoustic signal

EDF Based System Design

- Wavelength Division Multiplexing (WDM) technique for signal demodulation in a multiplexed system



Next Steps

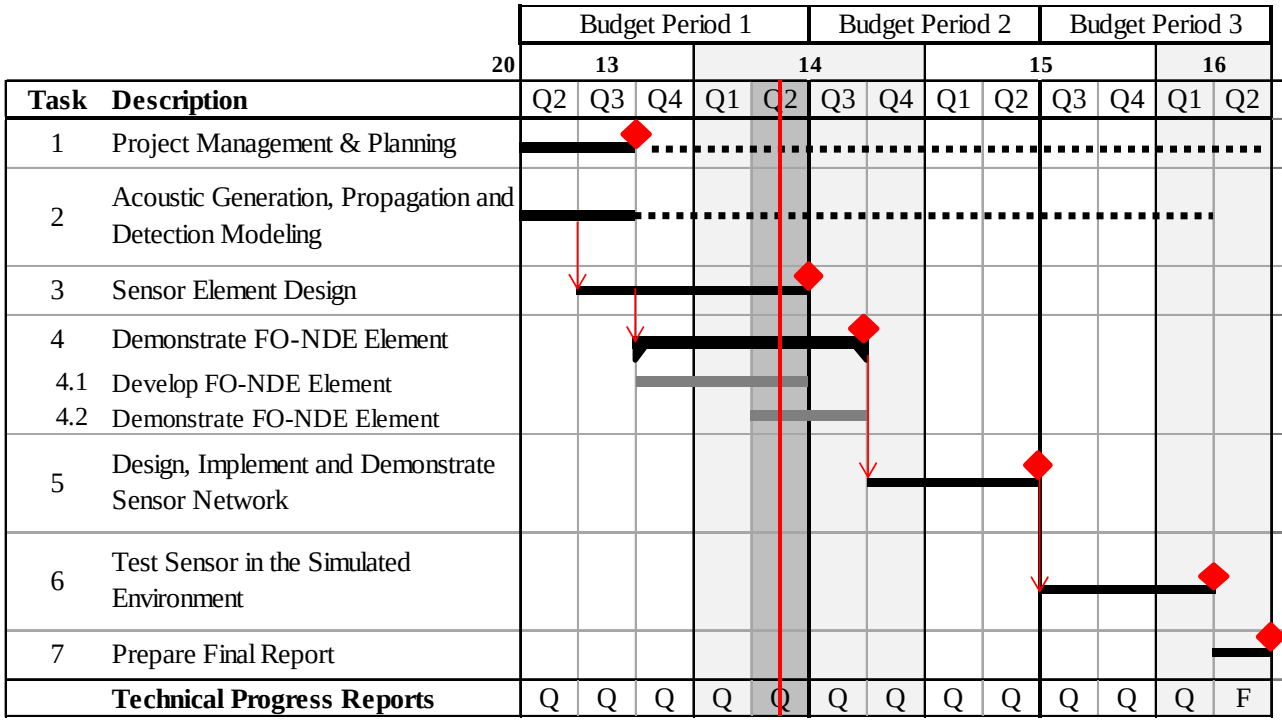
- Develop of both LIP and EDF based acoustic generation units, and compare their performance and choose one for the final scheme
- Fabricate and demonstrate a complete single FO-NDE unit
- Develop fiber sensor embedding technique in target metal
- Demonstrate sensor unit multiplexing

SUMMARY

Task Status

1. Project Management & Planning
2. Acoustic Generation, Propagation and Detection Modeling
3. Sensor Element Design
4. Demonstrate FO-NDE Element
5. Design, Implement and Demonstrate Sensor Network
6. Test Sensor in the Simulated Environment
7. Prepare Final Report

Project Progress Summary



Task	Description	Start Date	End Date	Cost
1	Project Management & Planning	2013/4/1	2016/6/30	$112,000.00
2	Acoustic Generation, Propagation and Detection Modeling	2013/4/1	2016/3/31	$118,000.00
3	Sensor Element Design	2013/7/1	2014/6/30	$132,706.00
4	Demonstrate FO-NDE Element	2013/10/1	2014/9/30	$324,000.00
4.1	Develop FO-NDE Element	2013/10/1	2014/6/30	$150,000.00
4.2	Demonstrate FO-NDE Element	2014/4/1	2014/9/30	$174,000.00
5	Design, Implement and Demonstrate Sensor Network	2014/10/1	2015/6/30	$347,285.00
6	Test Sensor in the Simulated Environment	2015/7/1	2016/3/31	$436,221.00
7	Prepare Final Report	2016/4/1	2016/6/30	$24,502.00
	Technical Progress Reports			

Reports: Q - Quarterly F - Final

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THE END