UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING

COLLABORATION WORKSHOP

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Pipeline Health Monitoring using Fiber-optic Sensor Technology and Ultrasonic Guidedwave

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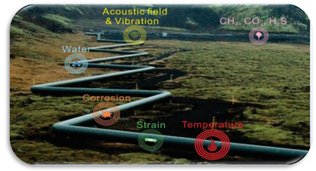


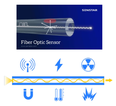
INTRODUCTION

➢ Pipelines Infrastructure Monitoring

- Natural Gas, Oil Transport & Storages
- > 300k miles of distribution network
- > 50% built after World war II
- Aging and tend to deteriorate due to corrosion etc.
- Ruptures occurs -> **Leaks** -> Explosion!!

➢ Fiber-optic Sensors (FOS) Technology

- Lightweight / embeddable in composite material
- Explosion- and electrical-proof
- Can work upto 1000 °C temperature
- Passive devices
- Point, quasi-distributed and fully-distributed sensing



➢ Fiber Sensors R&D @ Ohodnicki Lab

Custom Benchtop Interrogators

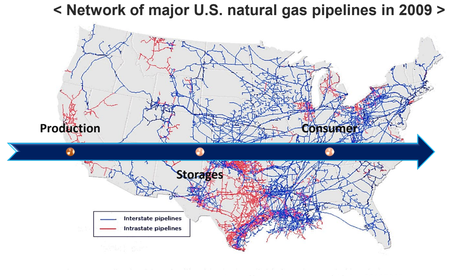
- Acoustics and Vibration -> DAS and Q-DAS
- Strain and Temperature -> OFDR and FBG sensors

Commercial Interrogators

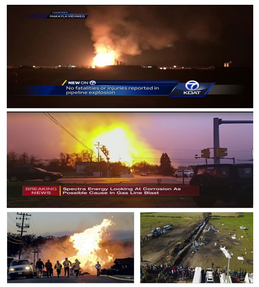
AP SENSING advanced photonics

- Distributed Acoustic Sensor (DAS)
- Distributed Temperature sensor (DTS)

< Network of major U.S. natural gas pipelines in 2009 >

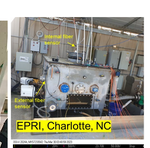


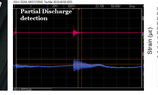
https://www.nbcnews.com/id/wbna39107965

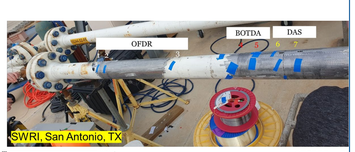


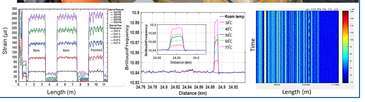
News incidents: Natural gas pipelines explosions in the US.

Field Tests



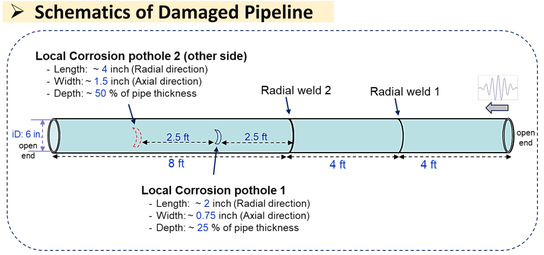




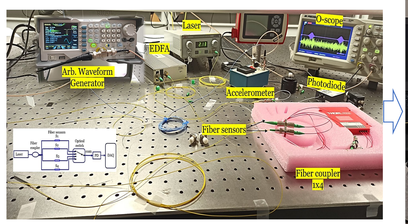


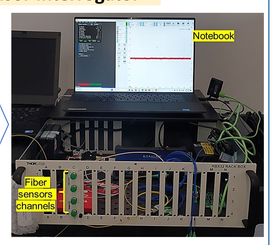
DAMAGED DETECTION OF PIPE

➢ Schematics of Damaged Pipeline

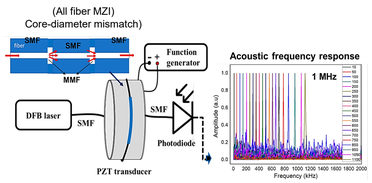


➢ Fiber-optic Quasi-Distributed Acoustic Sensor Interrogator



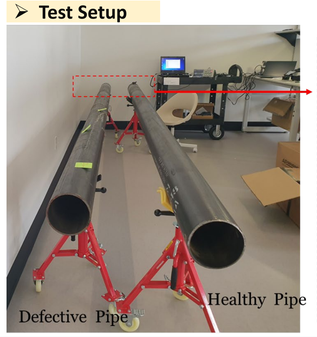


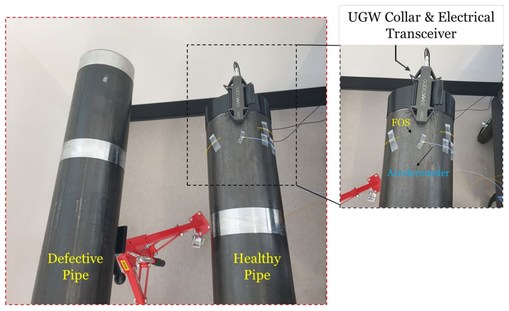
➢ Fiber-optic Acoustic Sensor



- Remote bonding technique
- Qualitative detection of acoustic event amplitude
- Freq. bandwidth > 1 MHz

➢ Test Setup



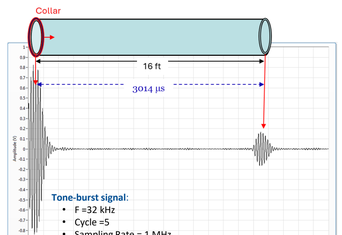


RESULTS

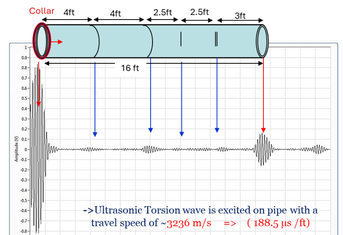
1. Ultrasonic Source: Guided wave collar

-> Torsional mode (symmetric wave) is excited by the UGW collar on the pipe surface.

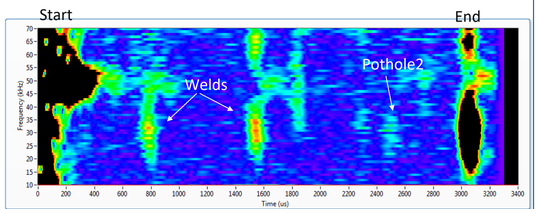
Electric Transceiver



Healthy Pipe

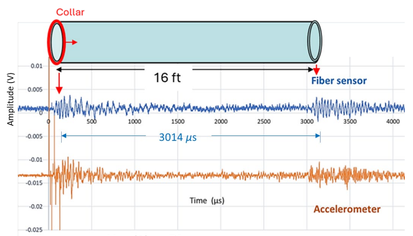


Defective Pipe

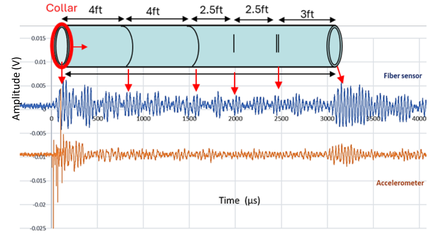


Frequency Plot

Fiber Acoustic Sensor



Healthy Pipe



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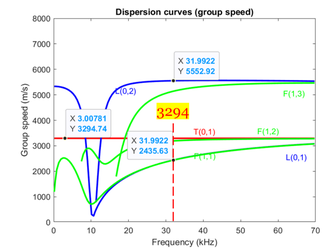
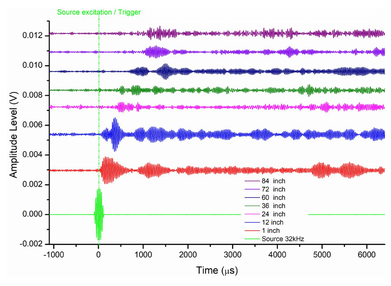
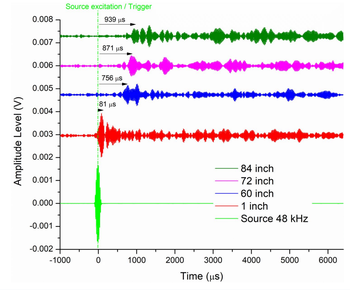
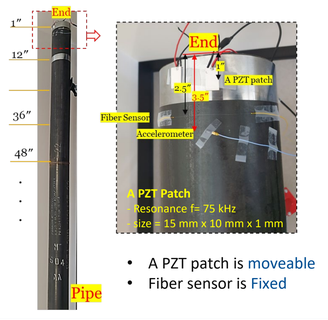


2. Ultrasonic Source: PZT patch

Fiber Acoustic Sensor







- A PZT patch is moveable
- Fiber sensor is Fixed

Acknowledgments

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NEUP Nuclear Energy University Program — U.S. Department of Energy

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2. N. Lalam,, P. Westbrook, K. Naeem et al. Pilot-scale testing of natural gas pipeline monitoring based on phase-OTDR and enhanced scatter optical fiber cable. Sci Rep 13, 14037 (2023).
3. K Naeem, N. Lalam et al., "High-sensitivity distributed pipelines infrastructure monitoring with internal deployed fibers and Rayleigh enhancement," Proc. SPIE 12532, Optical Waveguide and Laser Sensors II, 125320J (13 June 2023)
4. P. R. Ohodnicki, E. Sarcinelli, P. Zhang, K. Naeem et al., "Nuclear canister integrity monitoring using quasi-distributed fiber acoustic sensors and physics-based modeling," Proc. SPIE 12532, Optical Waveguide and Laser Sensors II, 125320I (13 June 2023)