Real-time in-situ CO_2 Monitoring (RICO_2M) Network for Sensitive Subsurface Areas in CCS

Project Number DE-FE0012706

Sensor Development

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Sensor Field Validation and Modeling

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U.S. Department of Energy

National Energy Technology Laboratory

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Outline

- Benefit to the Program
- Technology
- Project Overview
- Technical Status
- Summary – Accomplishments to Date
- Synergy Opportunities
- Appendix
- Acknowledgments

Benefit to the Program

- Carbon Storage Program goal being addressed:
  - Develop and validate technologies to ensure 99% storage permanence.

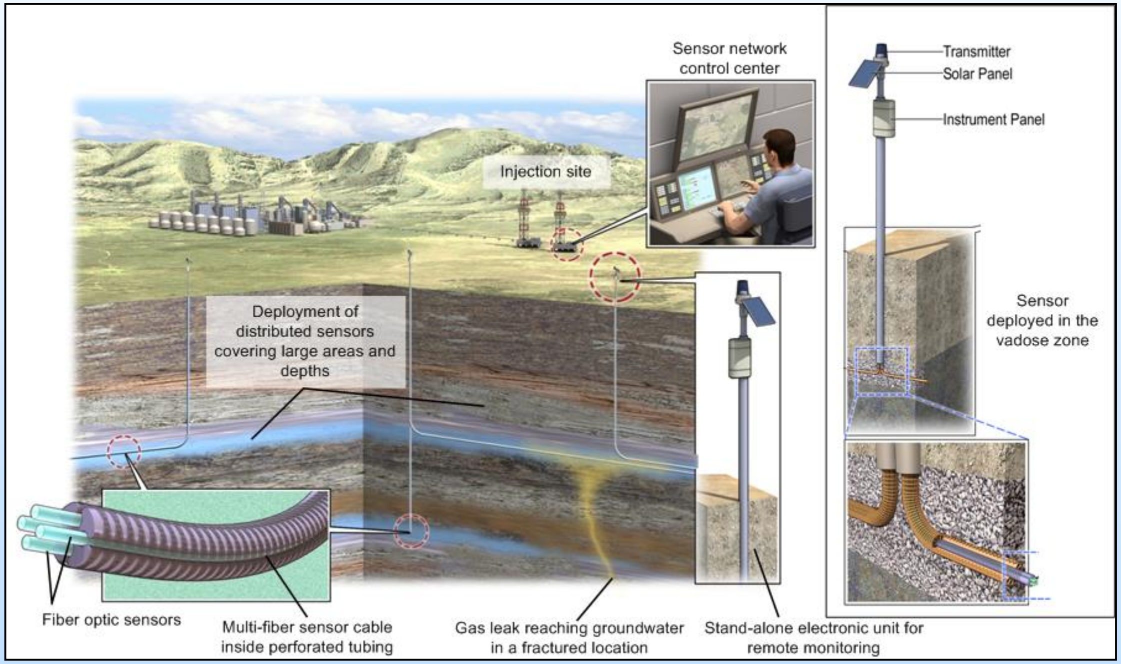
- Benefits Statement:
  - The project will develop a **sensor network based on distributed fiber optic sensors for in-situ, real-time monitoring of geochemical parameters in groundwater.** The system will be capable of covering large areas and measuring very low concentrations of CO_2 with high resolution, detecting small changes from background concentrations in sensitive areas. This technology contributes to the Carbon Storage Program's effort of ensuring 99% CO_2 storage permanence (Goal).

Technology

Distributed Intrinsic Fiber Optic Chemical Sensors

Unique Characteristics

- Long segments of optical fiber are the sensor
- Direct detection of dissolved CO_2
- A single cable may include CO_2, pH, salinity and temperature sensors.



Project Overview – Goals and Objectives

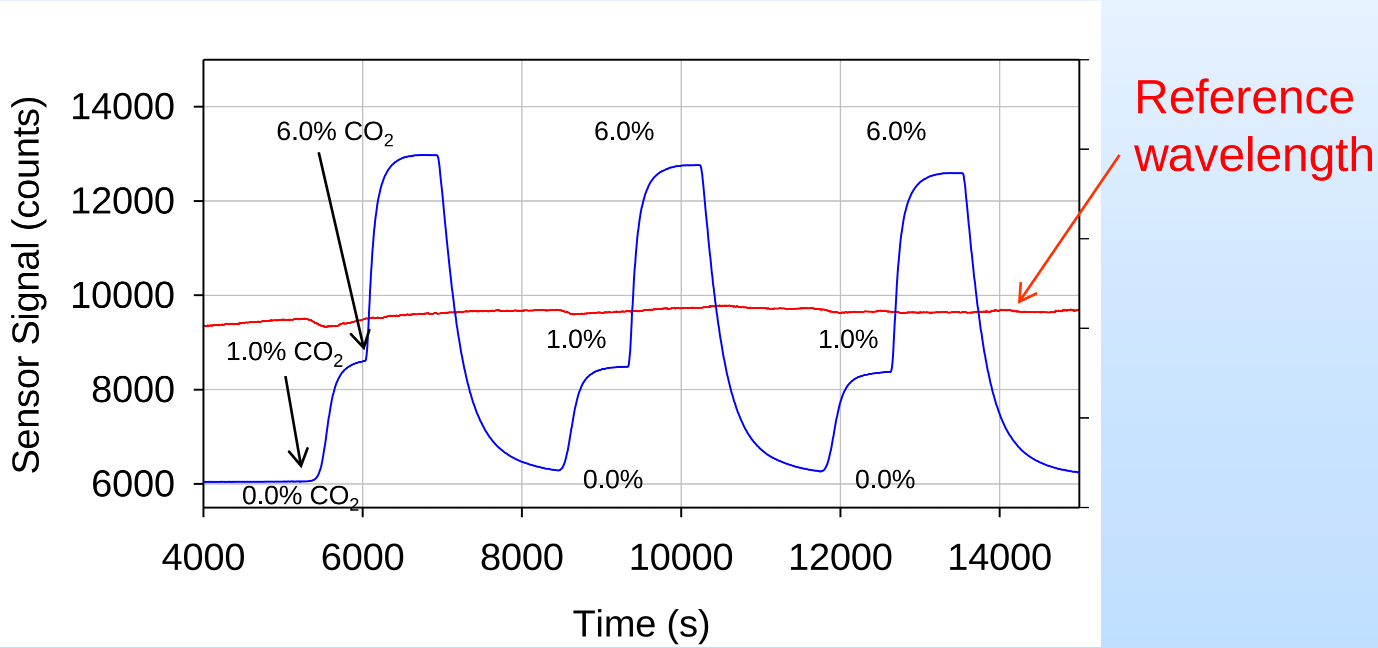
- **Phase I Objective:** **Develop a multi-parameter system** for highly sensitive and accurate detection of CO_2 in groundwater.

- **Phase II Objective:** Perform large-scale **field deployment and demonstration** of intelligent real-time, in-situ monitoring (RICO_2M) network.

Technical Status – Sensor Fabrication

Sensitive Material

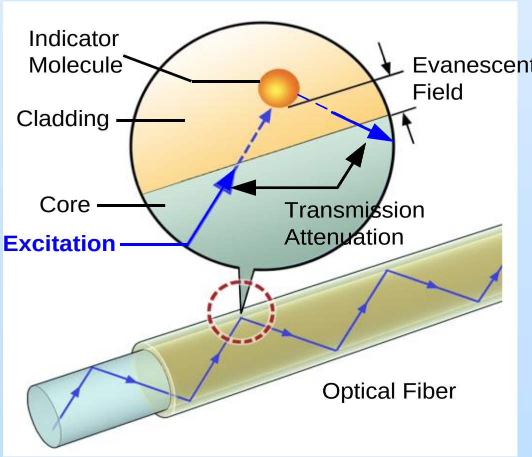
- A doped polymer whose absorption at a specific wavelength changes upon exposure to CO_2.
- The absorption change is proportional to the concentration of CO_2, and is reversible.

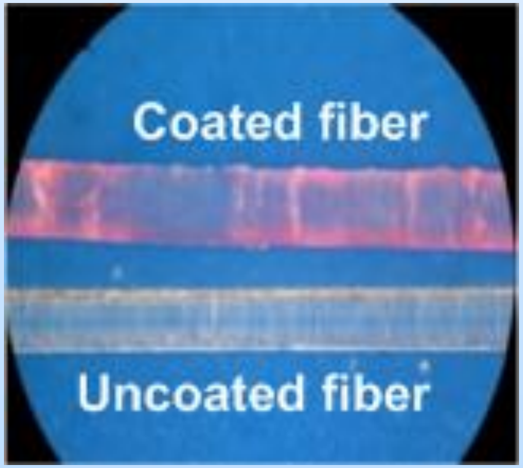


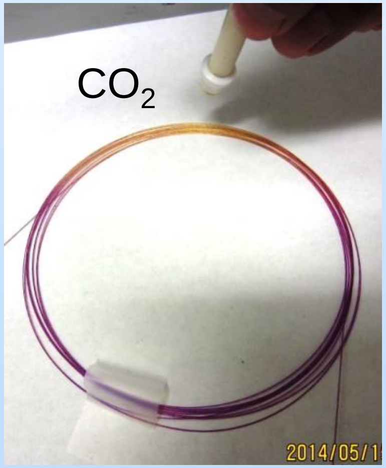
Technical Status – Sensor Fabrication

Evanescent Wave-based Approach

- A silica glass core fiber is coated with the sensitive material. Upon exposure of any segment of the fiber, the CO_2 diffuses into the cladding and changes color.
- Due to the evanescent field, the light transmitted through the fiber at wavelengths absorbed by the indicator varies with the concentration of CO_2.



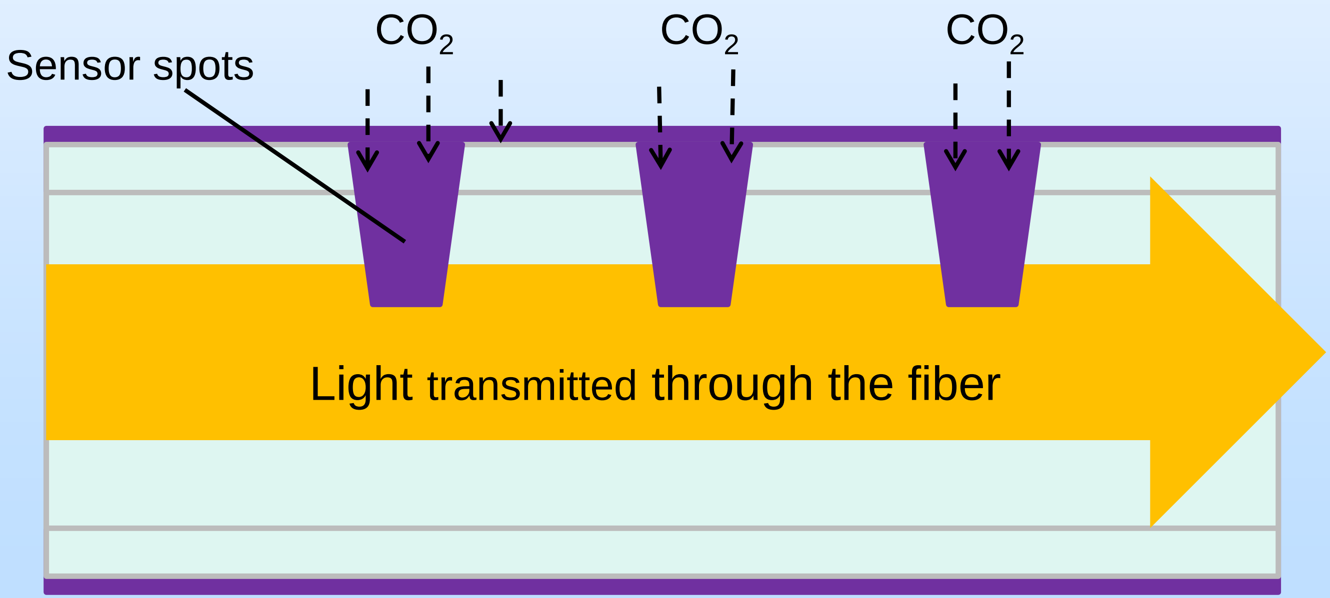




Technical Status – Sensor Fabrication

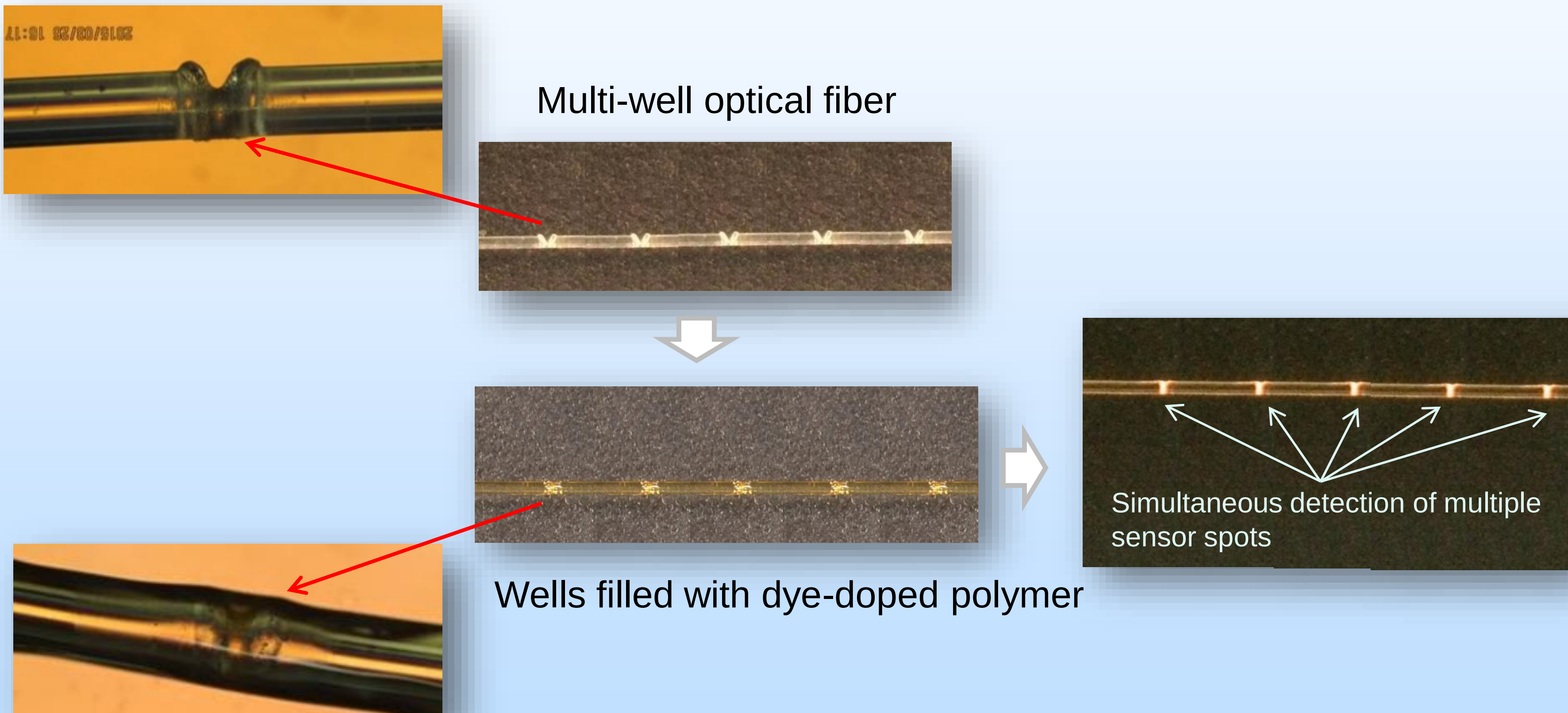
Multi-Sensor Spot Approach

- The cladding and core of an optical fiber are precisely removed at multiple spots by means of a laser beam, creating a sequence of wells along a selected segment of the fiber.
- The wells are subsequently filled with the sensitive material, which places that material in the path of the light transmitted through the fiber.



Technical Status – Sensor Fabrication

Multi-Sensor Spot Approach

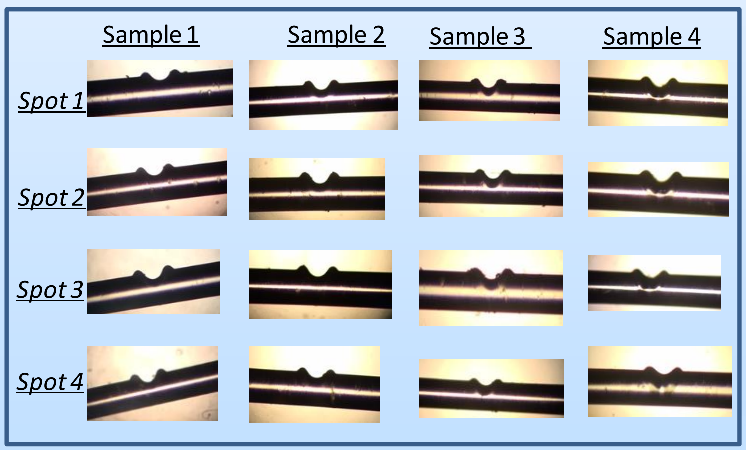


Technical Status – Sensor Fabrication

Multi-Sensor Spot Approach

With this approach, we are able to tune:

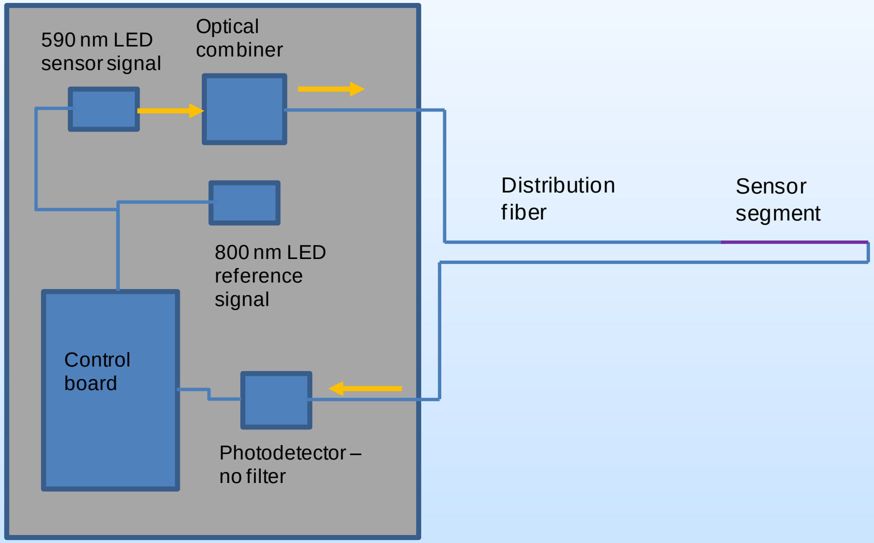
- Depth of wells
- Number of wells
- Distance between wells
- Length of the sensorized segment, according to the sensor application.



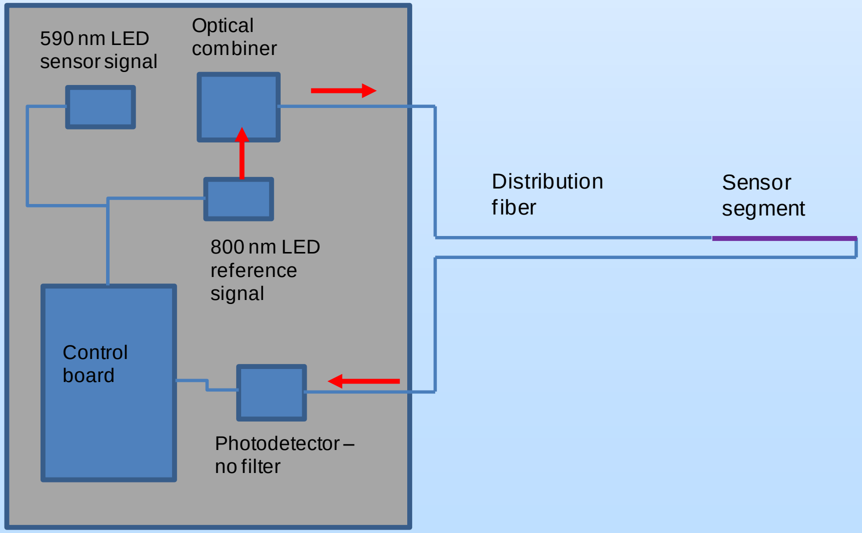
Technical Status – Optoelectronic Unit

Dual LED Approach

1. Sensor signal (absorption peak at 590 nm)



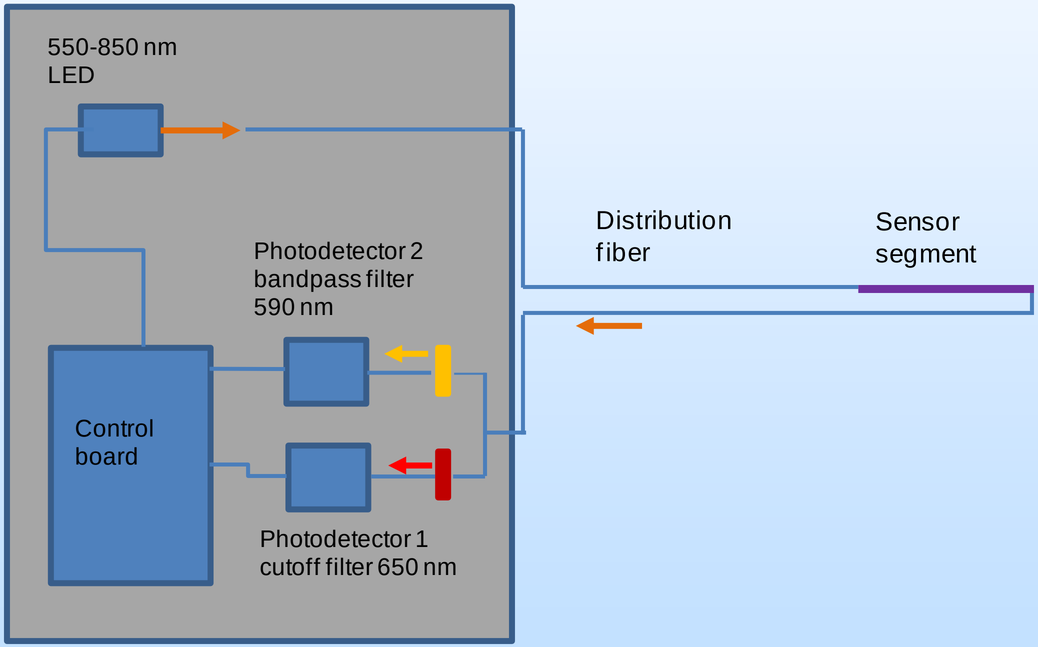
2. Reference signal (above 700 nm)



Technical Status – Optoelectronic Unit

Dual Photodetector Approach

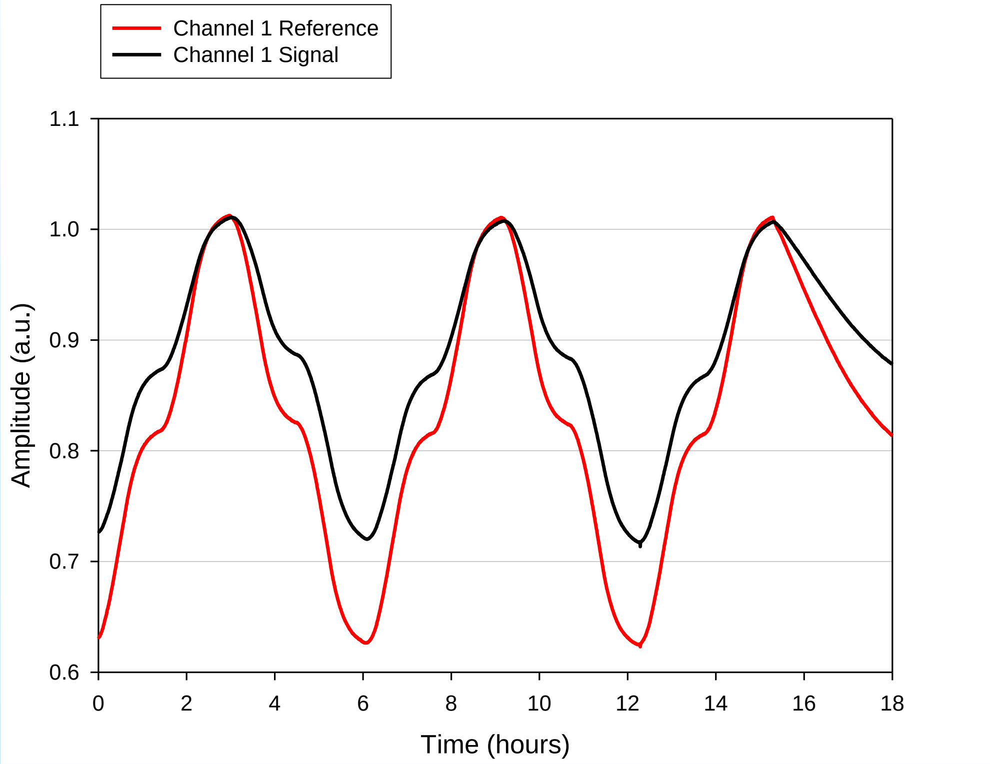
Dual Photodetector System



Technical Status – Optoelectronic Unit

Dual Photodetector Approach

Temperature Effect



Technical Status – Field Validation

Dual Photodetector Approach

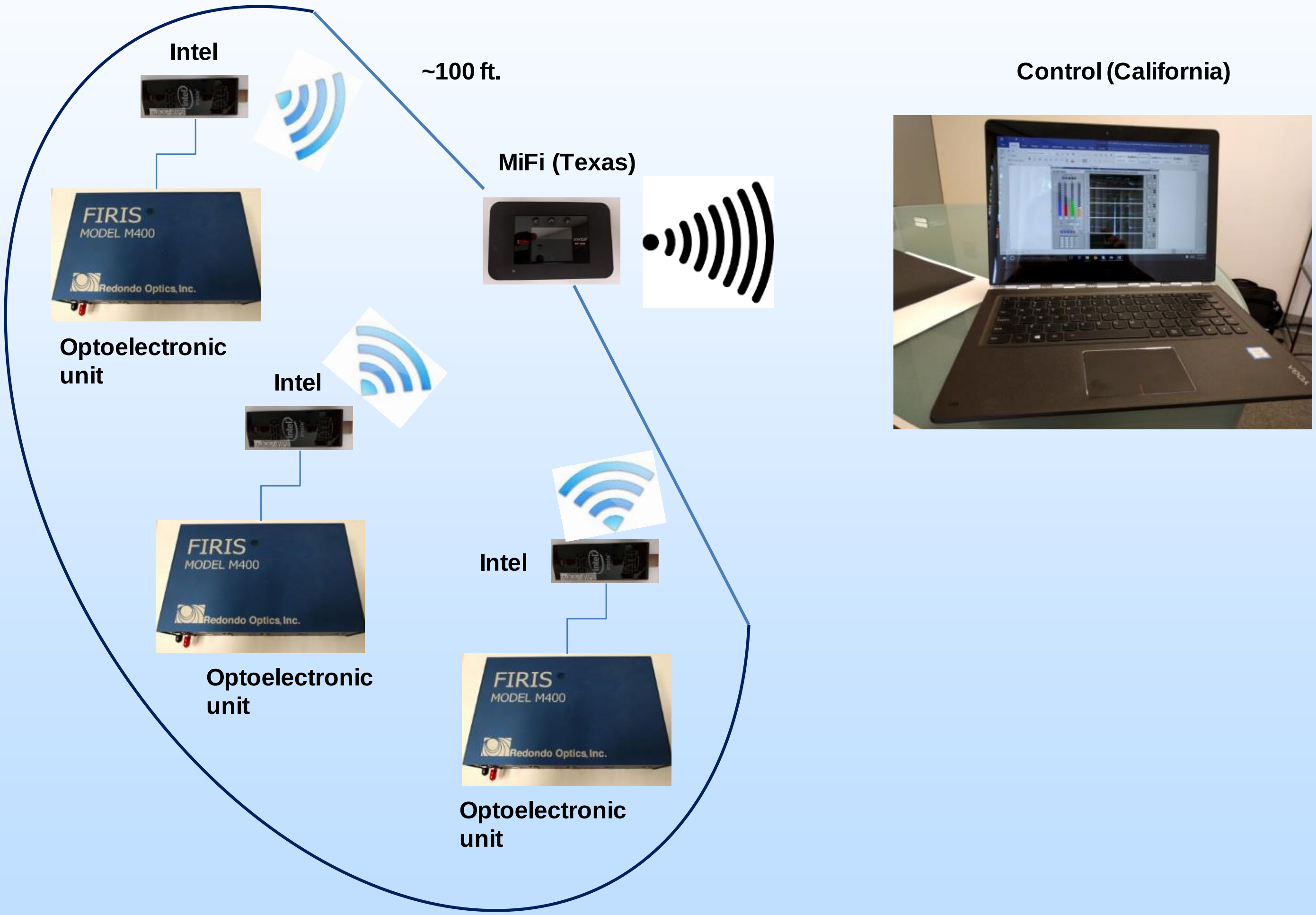
RICO$_2$M v3.0 PN005

Dual LED Approach

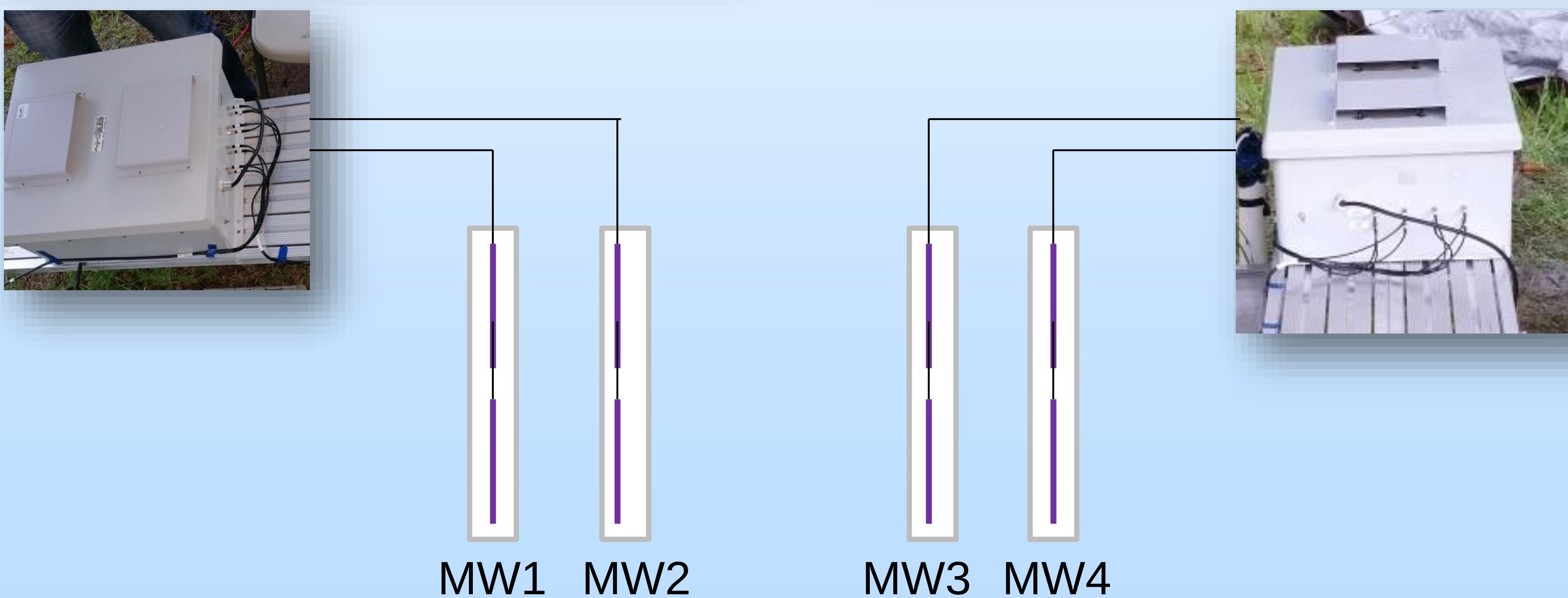
RICO$_2$M v2.0 PN003

Chassis integrates temperature control module.

Technical Status – Field Validation

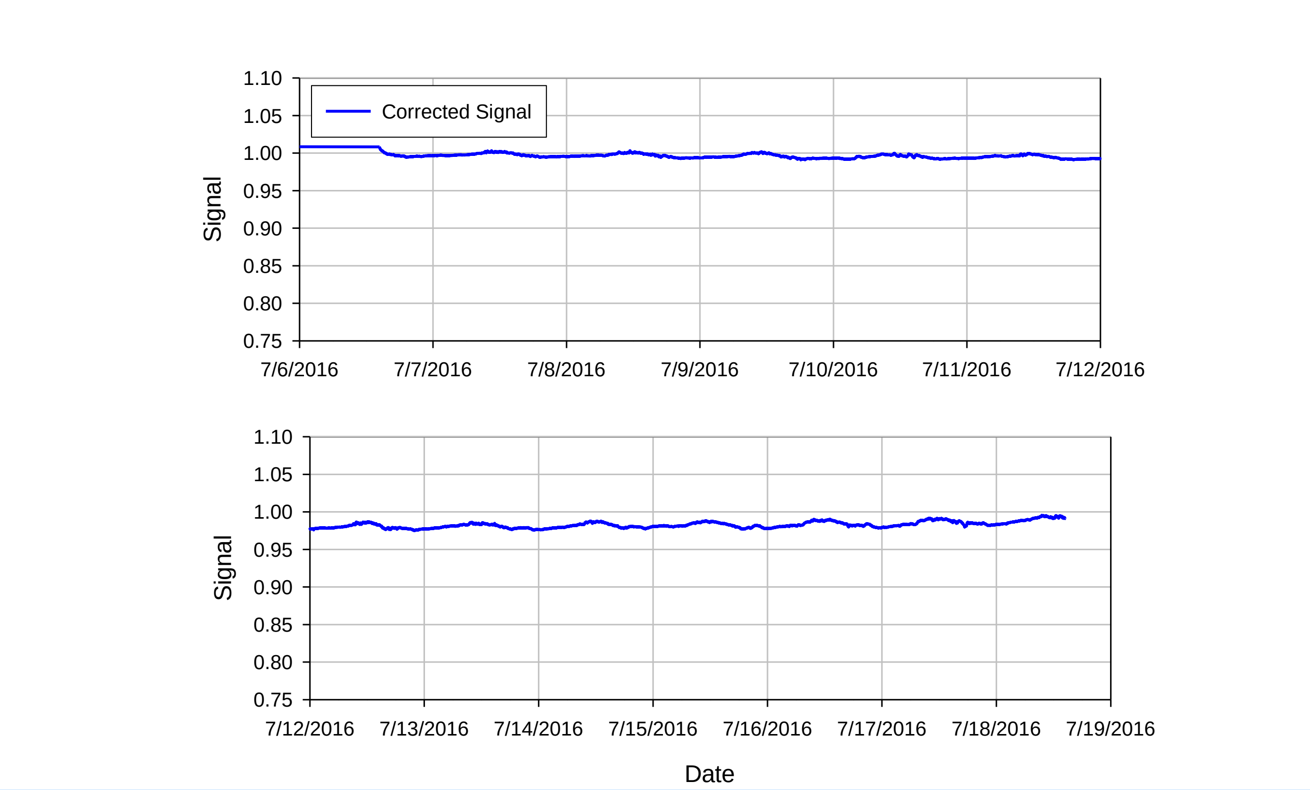


Technical Status – Field Validation



Technical Status – Field Validation

Dual Photodetector Approach

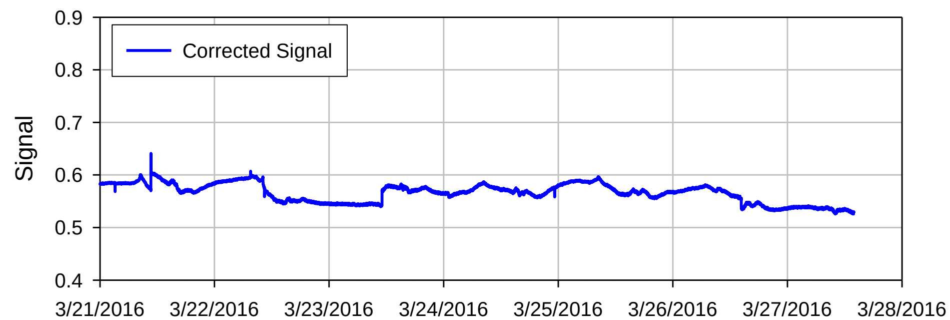


- Correction functions determined in the laboratory did not provide proper signal correction.
- Correction functions were adjusted based on the data collected in the field.

Technical Status – Field Validation

Dual LED Approach

Chassis integrates temperature control module.



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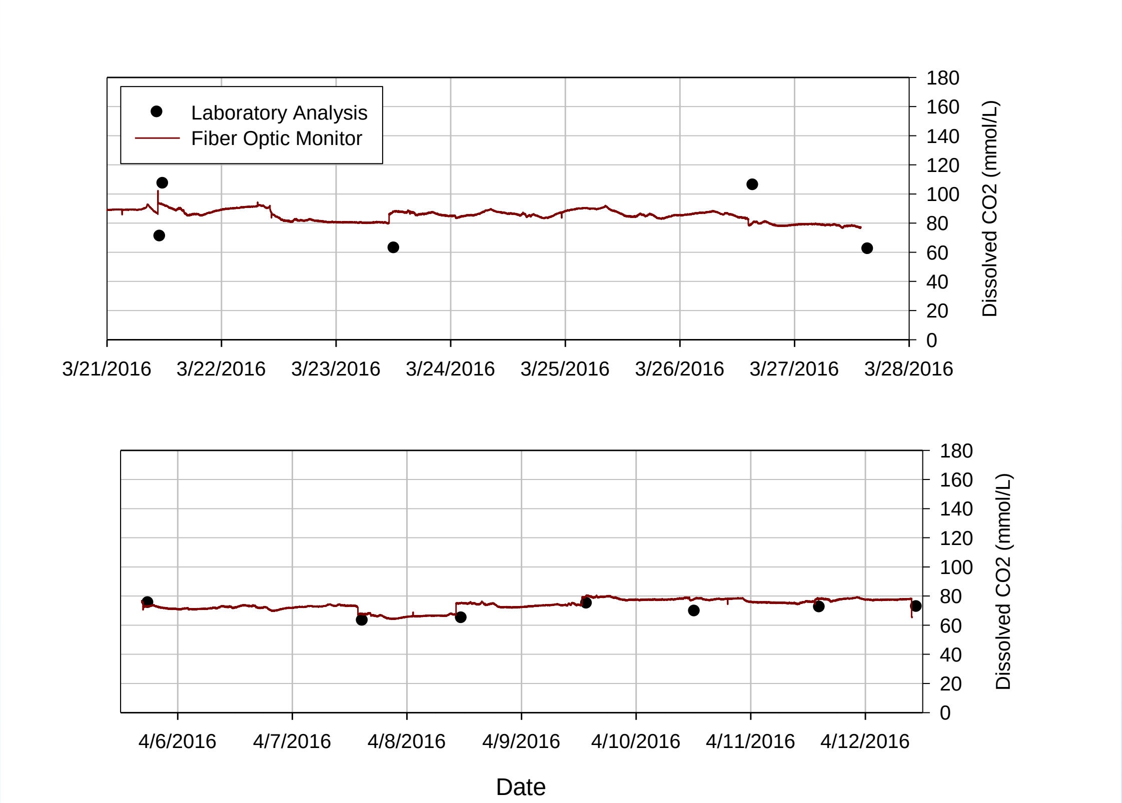
Technical Status – Field Validation

Dual LED Approach



- Pre-calibration did not provide good comparison with laboratory analysis.
- Offset adjustment using the data provided by the laboratory was performed.

Summary – Accomplishments to Date

- Designed, fabricated, and integrated the first version of the optoelectronic unit for the fiber optic multi-parameter monitor, and performed initial field studies, including controlled CO_2 release.
- Developed multi-sensor spot sensor technology in order to reduce fabrication cost and calibration effort, and to facilitate sensor deployment.
- Assembled and deployed in the field the second and third generation RICO_2M system.
- Identified and implemented the required system adaptations for field operation.
- Validation by comparison with laboratory analysis is ongoing.

Synergy Opportunities

Intrinsic Fiber Optic Chemical Sensors for Subsurface Detection of CO_2

Project Number DE-FE0010318

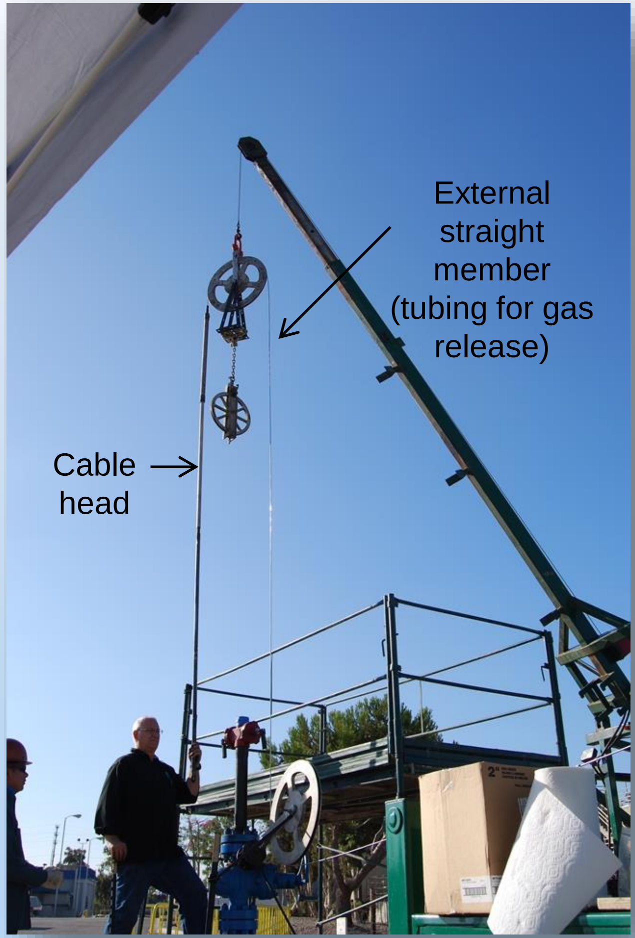
DOE Technical Monitor: *Barbara Carney*

Intelligent Optical Systems, Inc.

Jesús Delgado Alonso, Ph.D.

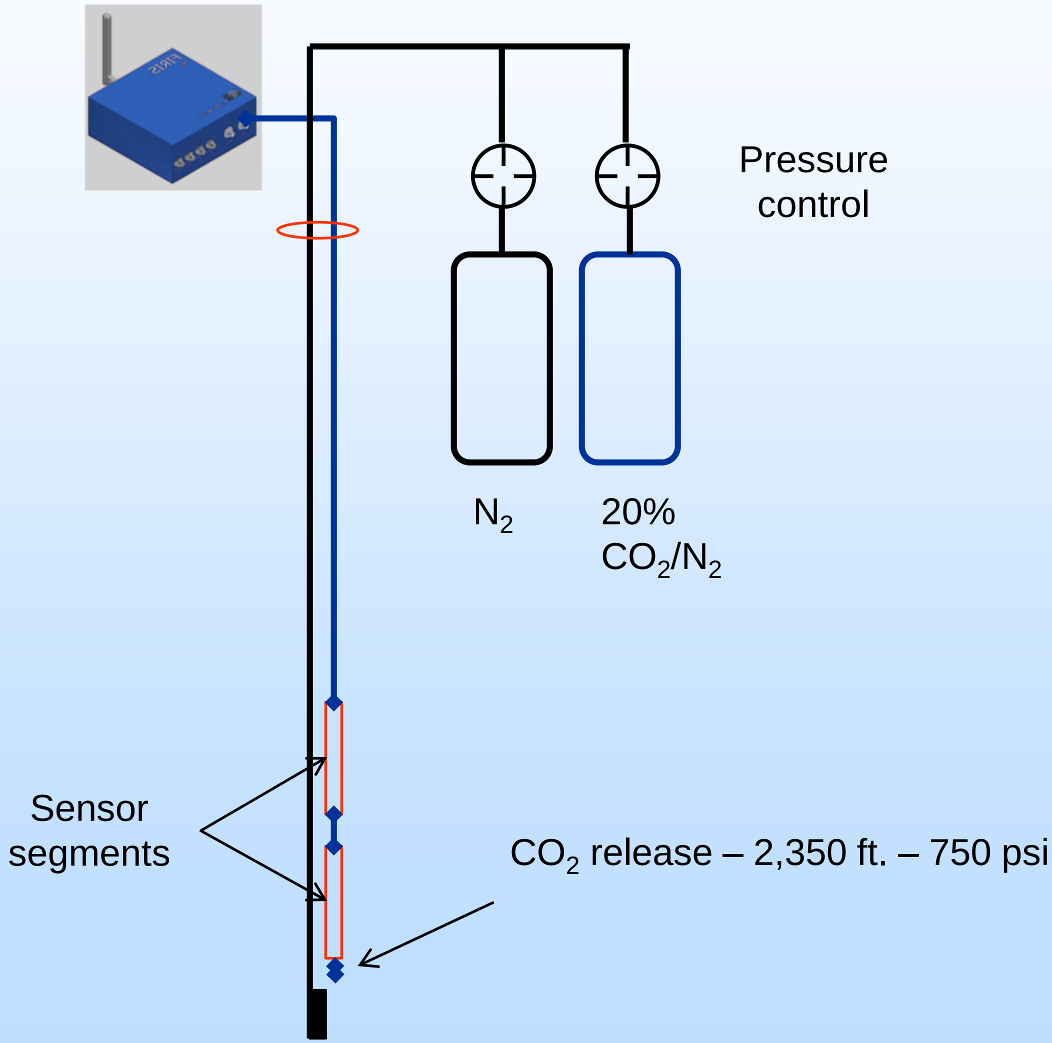
Synergy Opportunities

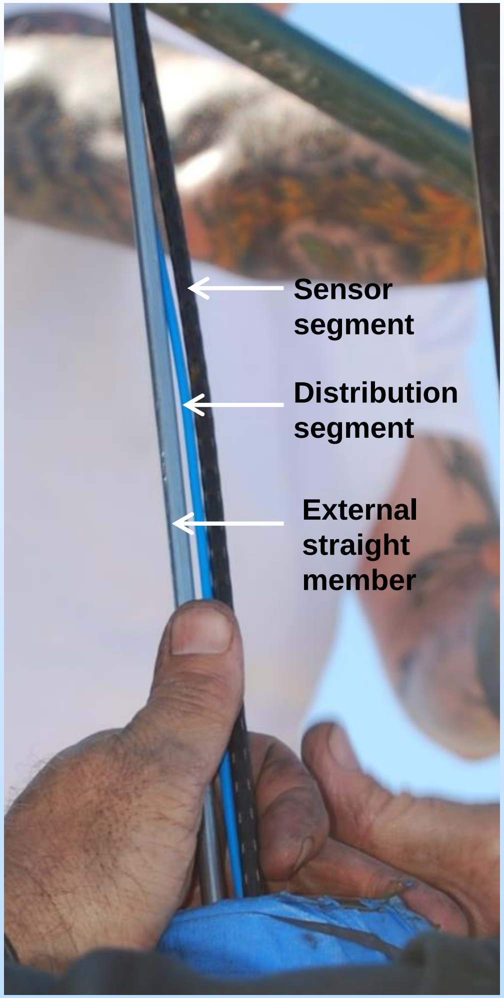
Deep Well Monitoring – Field Validation



Synergy Opportunities

Deep Well Monitoring – Field Validation

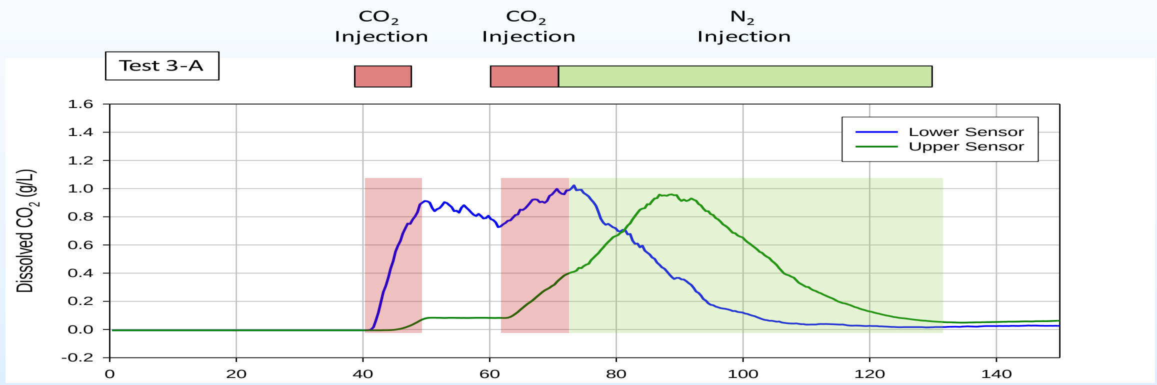




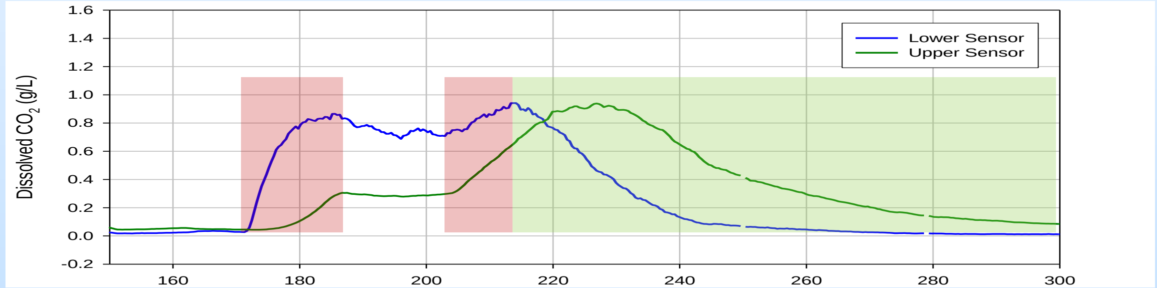
Synergy Opportunities

Deep Well Monitoring – Field Validation

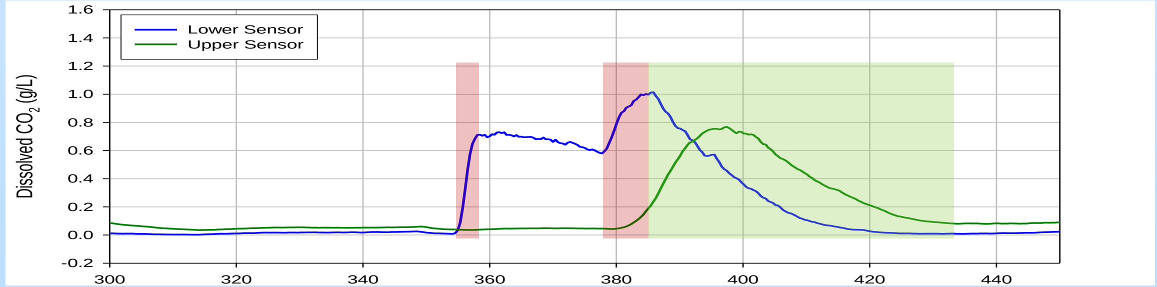
- Test 3A



- Test 3B



- Test 3C



Acknowledgments

NETL Department of Energy

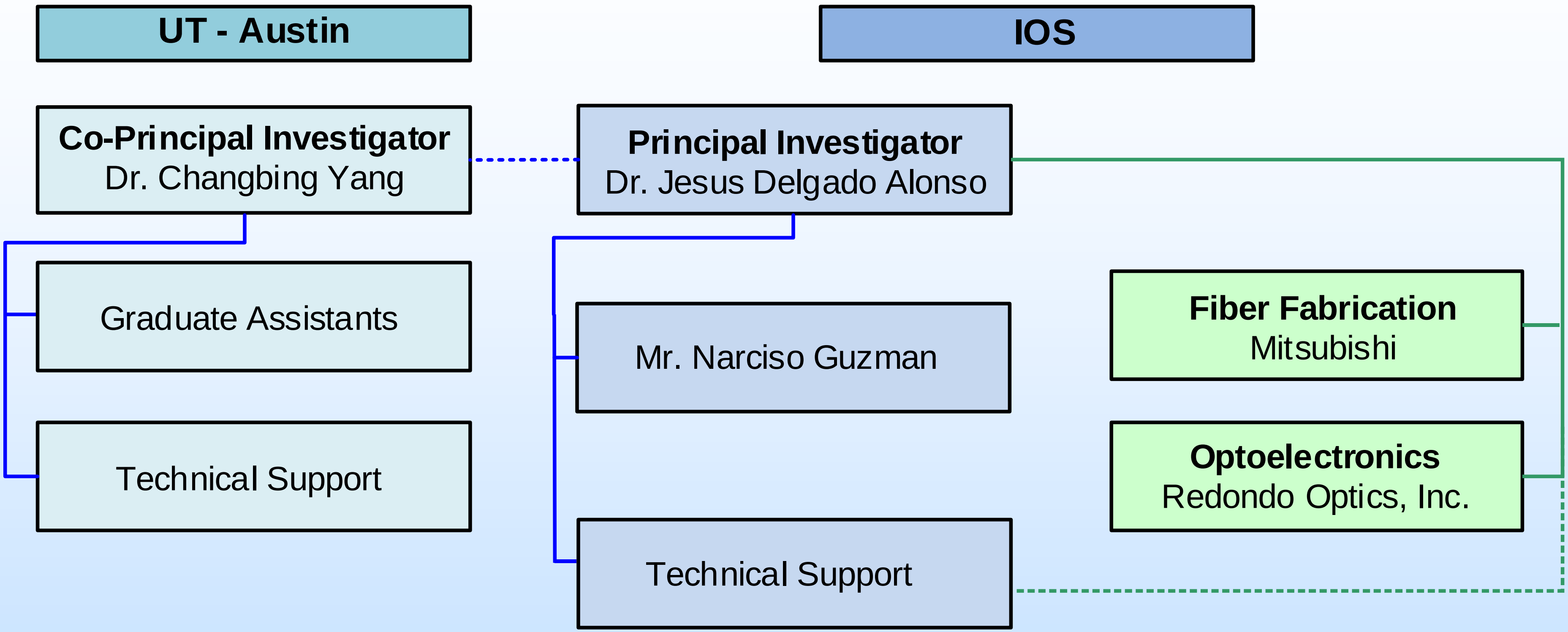
Joshua Hull

Robie Lewis, Robert Noll, Barbara Carney

Appendix

- Organization Chart
- Project Schedule

Organization Chart



- As the prime contractor for this project, IOS will carry out all activities related to the design, fabrication, and testing of the distributed CO_2 sensor network, and will provide field support to the University of Texas at Austin (UT-Austin) throughout the system Phase II field trials.
- UT-Austin will manage all aspects of CO_2 sensor system field testing, and will provide valuable technical guidance in Phase I, assuring that the system design meets the rigorous demands of the subsurface environment found at the CCUS test site.

Organization Chart

Intelligent Optical Systems, Inc.

INTELLIGENT OPTICAL SYSTEMS, INC.

Maven Biotechnologies Polaron Reader™

Laser Ultrasonic Noncontact Structural Inspection

Founded in 1998

- Spun-off from Physical Optics Corporation

Focus areas:

- Chemical optical-based sensors
- Rapid diagnostic assays (LFAs)

Several million dollars invested in equipment

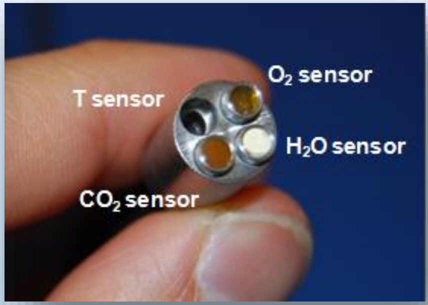
11,500 square foot facility in Torrance, CA

Several spin-off companies with >$22M in private funding

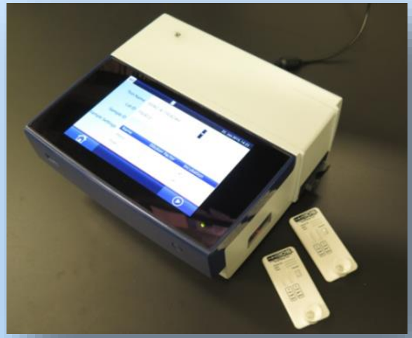
Commercial technology developed or acquired

- Laser ultrasound for non-destructive examination
- Light-emitting diode incapacitator for law enforcement
- Biochip reader

Cell Phone-based LFA Reader



Multi Sensor Probe



LFA Multi-Panel Reader

DICAST® Chemical Sensor Cables

Organization Chart

University of Texas at Austin

Bureau of Economic Geology (BEG)

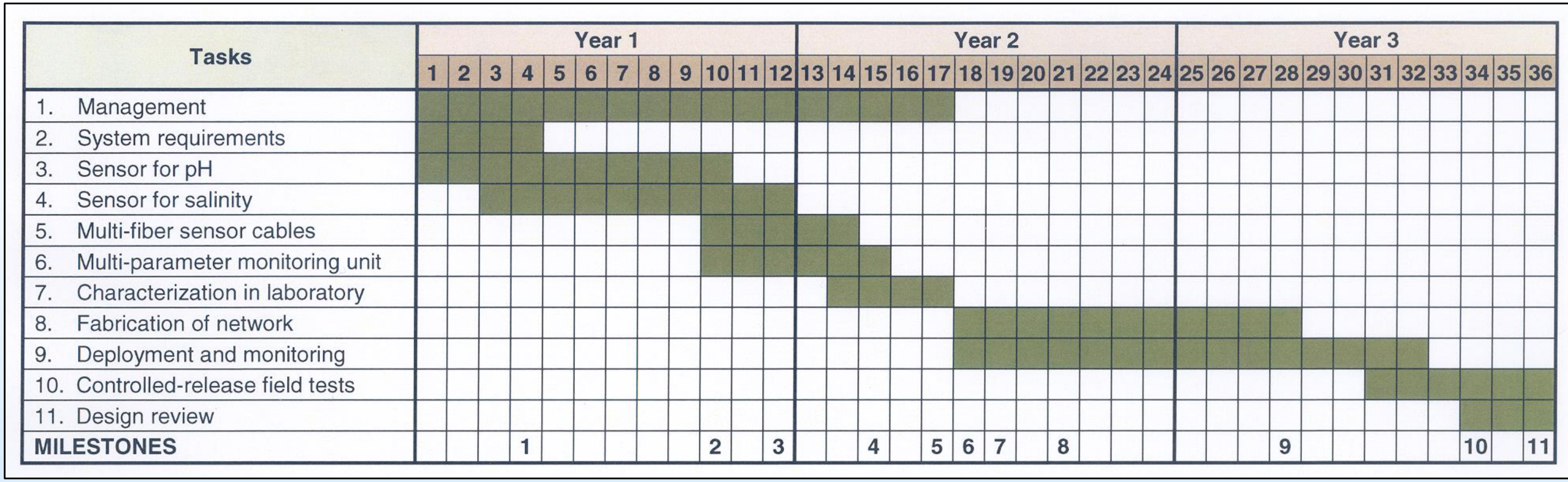
- Established in 1909, BEG is the oldest research unit at The University of Texas at Austin.

- Provide research and advice related to energy and environmental issues, and perform State Geological Survey functions as requested by the State Legislature.

Gulf Coast Carbon Center (GCCC)

- Seeks to impact global levels of atmospheric carbon dioxide by:
  - ✓ Conducting studies on geological sequestration of CO_2 in the deep subsurface
  - ✓ Educating the public about risks that might limit deployment of geological sequestration and measuring the retention of CO_2 in the subsurface
  - ✓ Enabling the private sector to develop an economically viable industry to sequester CO_2 in the Gulf Coast area.

Project Schedule



PHASE I: Develop a multi-parameter system

Milestone 1. System Functional Requirement Document (FRD) generated.

Milestone 2. Fiber optic distributed sensor for pH fabricated and characterized in the laboratory.

Milestone 3. Fiber optic distributed sensor for salinity fabricated and characterized in the laboratory.

Milestone 4. Monitoring system assembled and system operation verified in accord with FRD.

Milestone 5. Multi-parameter monitoring system characteristics established.

PHASE II: Perform large scale field validation

Milestone 6. Groundwater chemistry survey, using the traditional method, conducted.

Milestone 7. First series of multi-parameter monitoring system fabricated.

Milestone 8. First Intelligent Real-time in-situ CO_2 Monitoring Network ("RICO_2M Net") deployed.

Milestone 9. Revised multi-parameter monitoring systems fabricated and deployed.

Milestone 10. RICO_2M Net detects presence (or absence) of CO_2 in sensitive subsurface locations.

Milestone 11. System design reviewed.