DOE-ARRA Geologic Sequestration Training and Research
2011 Yearly Review Meeting

Project DE-FE0001858
Title: Development of a 1 x N Fiber Optic Sensor Array for Carbon Sequestration Site Monitoring

Montana State University
Presenter: Dr. Kevin Repasky, Electrical and Computer Engineering
February 24-26, 2011

Project Participants

- Kevin Repasky, Electrical and Computer Engineering, Montana Staet University, (PI)
- John Carlsten, Physics, Montana State University, (Co-I)
- Geoffrey Wicks, Graduate Student, Physics
- Benjamin Soukup, Undergraduate Student, Physics
- Laura Dobeck, Zero Emission Research and Technology (ZERT) Field Site Manager, Montana State University
- Lee Spangler, Director ZERT and Big Sky Carbon Sequestration Partnership, Montana State University

Introduction

- Near surface monitoring of sequestration sites is needed to ensure the sequestration site integrity and public safety.
- The proposed 1 x N fiber sensor array provides a potentially low cost reconfigurable instrument for large area monitoring for sequestration sites.

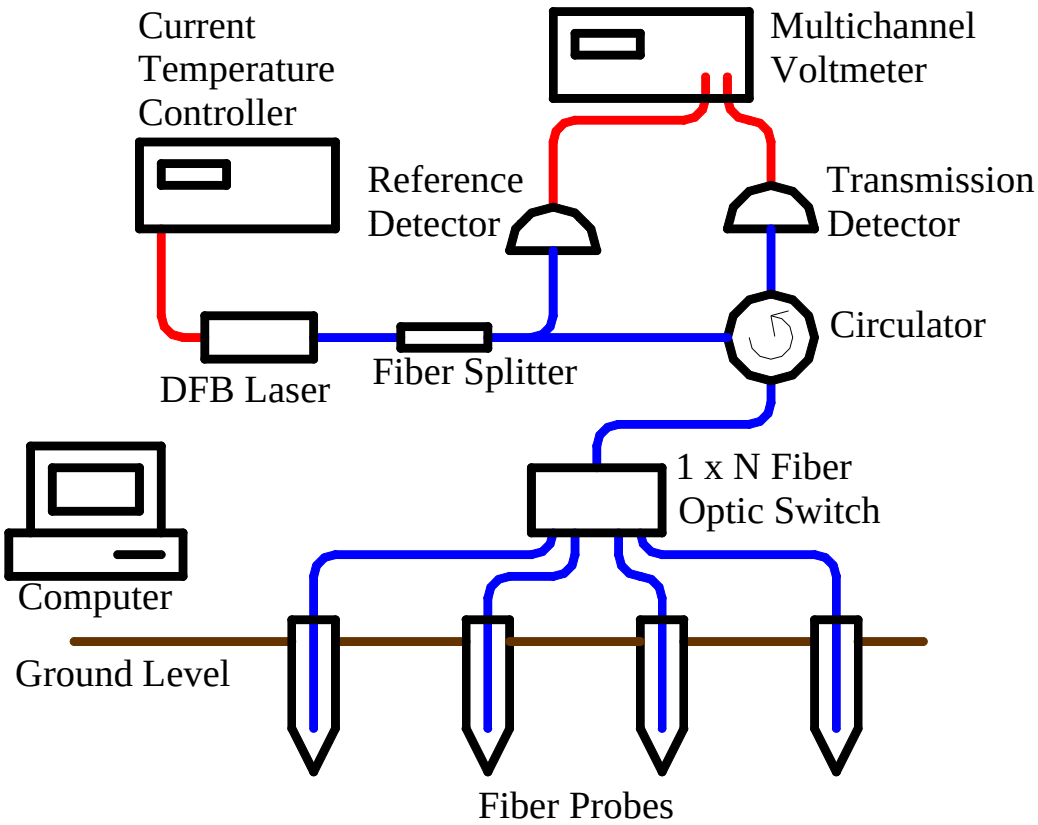
Project Objectives

- The objective of the proposed work is to develop and demonstrate a 1 x N fiber sensor array for near surface sequestration site monitoring.
- Provide educational opportunities for undergraduate and graduate students in carbon sequestration.

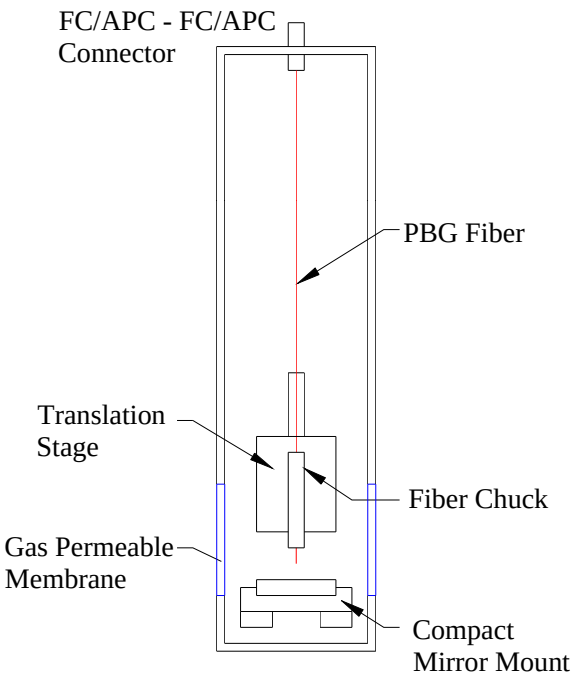
Project Funding

- Total Project Cost: $299,203
- DOE Share: $299,203
- Non-DOE Cost Share: $0

Highlights of Project to Date

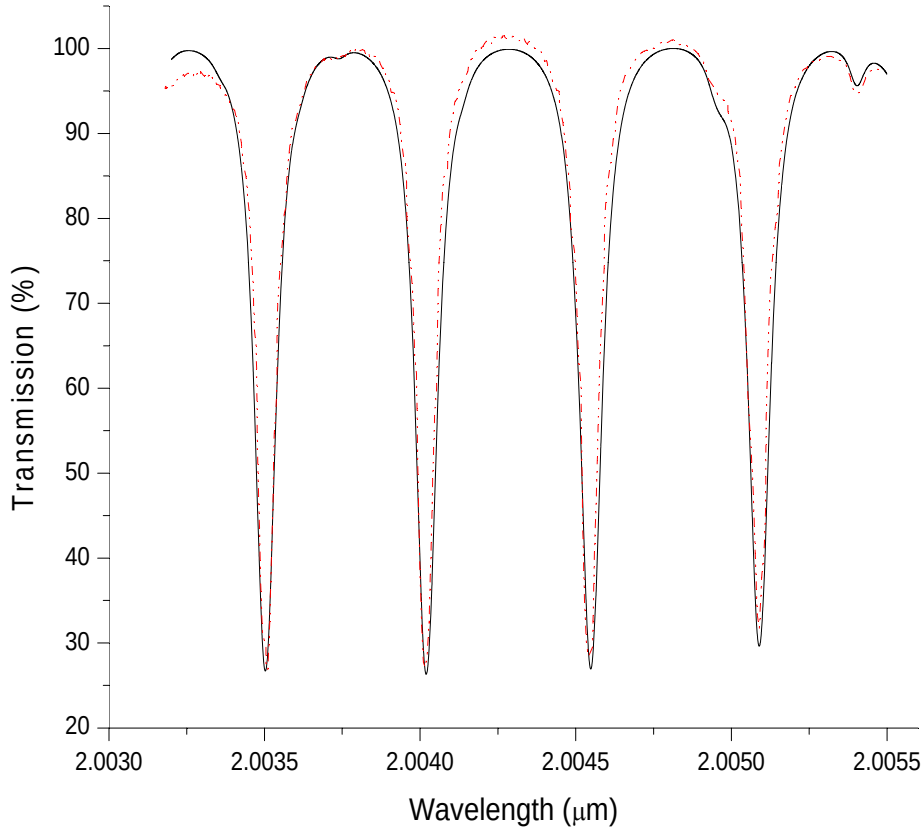


Schematic of the 1 x N fiber sensor array



Schematic of the fiber sensor probe.

Highlights of Project to Date

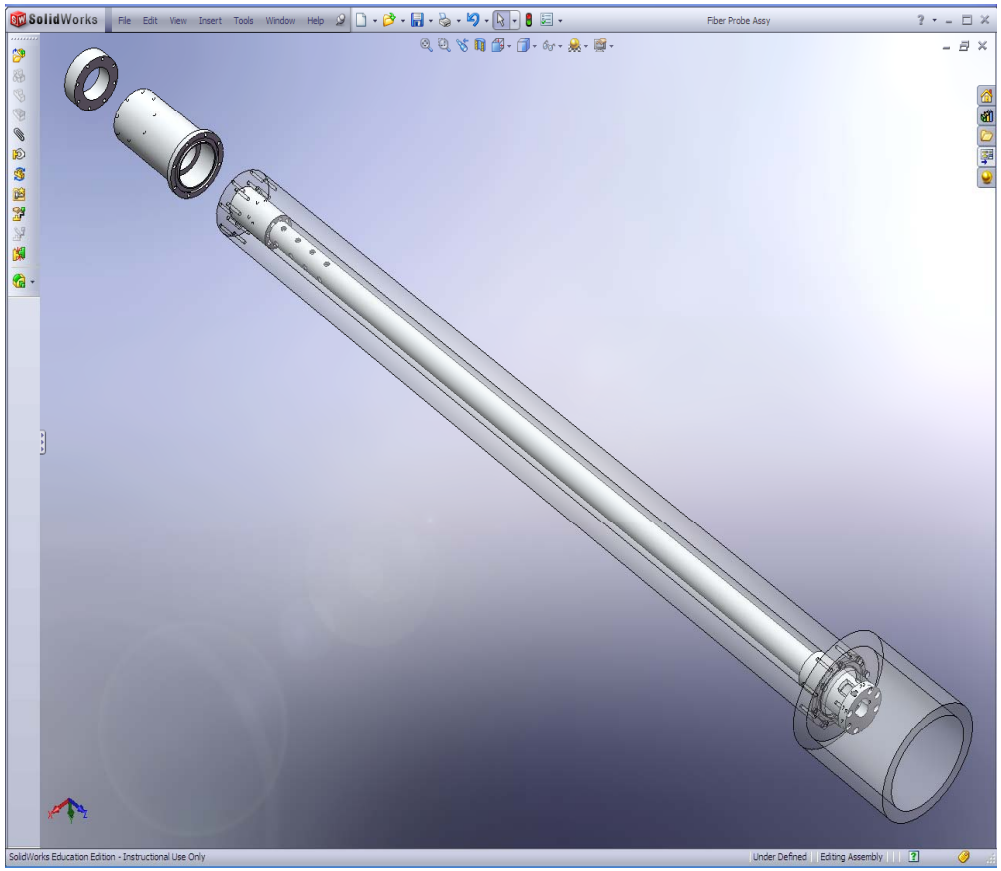


The black line represents the expected transmission as a function of wavelength while the red line represents the measured transmission as a function of wavelength for CO_2 absorption features near 2 μm.

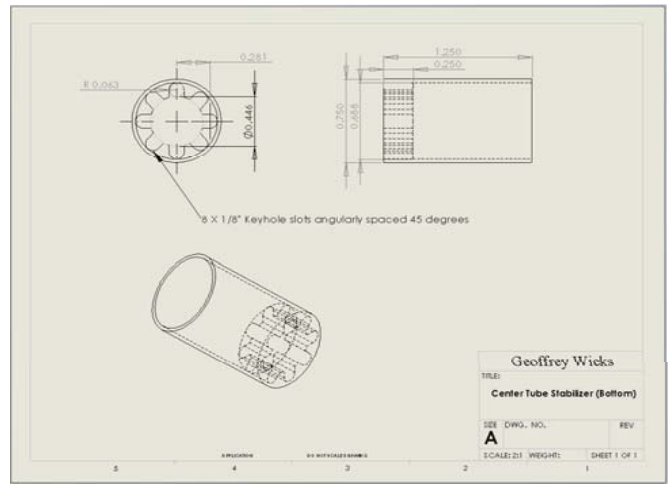
$$C = \frac{P_a}{P_T} = \frac{-\ln(T)}{Sg(v - v_0)N_L\left(\frac{296}{T_a}\right)P_T L}$$

The concentration, C, can be calculated by measuring the transmission, T.

Highlights of Project to Date

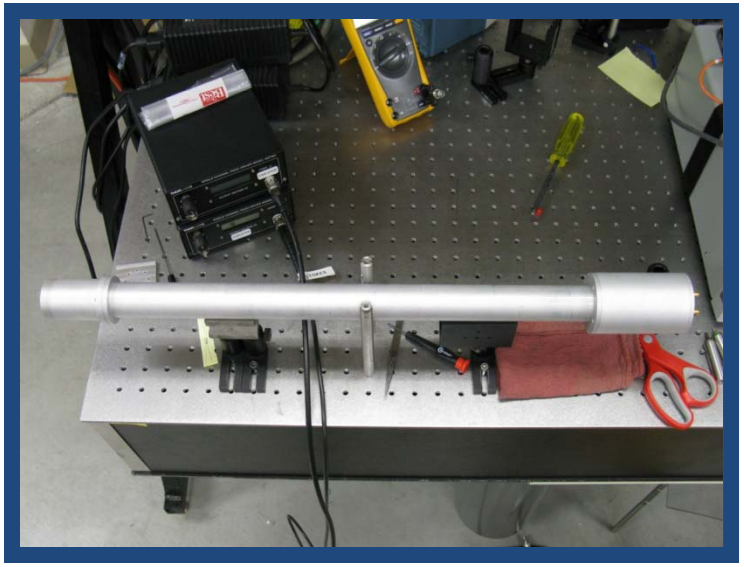


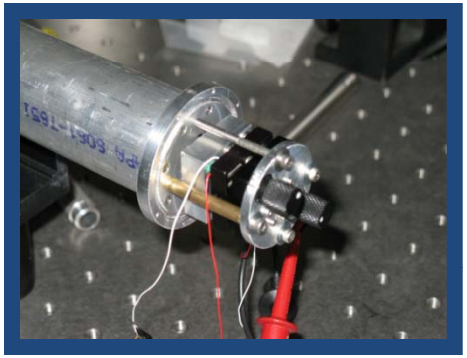
The exploded assembly drawing of the 1st generation fiber probe.

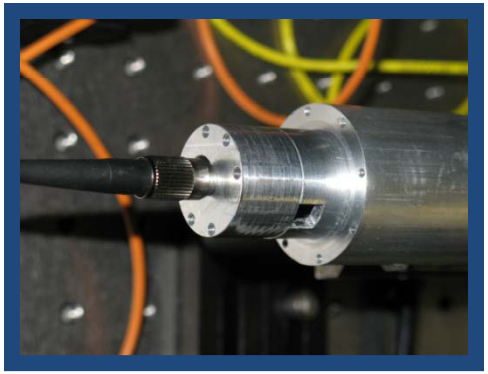


Machine Drawings for the 1st generation fiber probe

Highlights of Project to Date

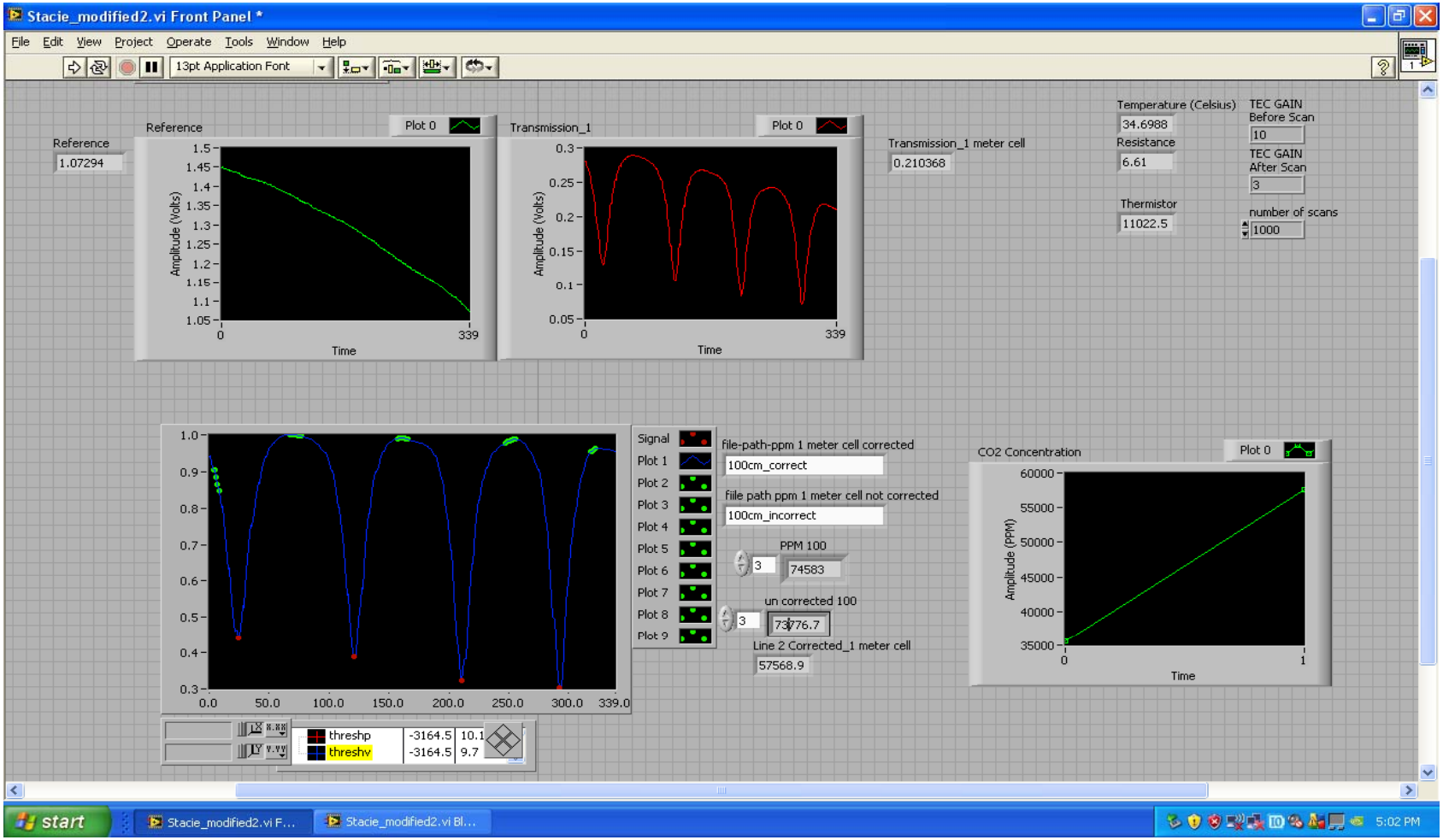






Machined, assemble, and aligned first generation fiber probe

Highlights of Project to Date

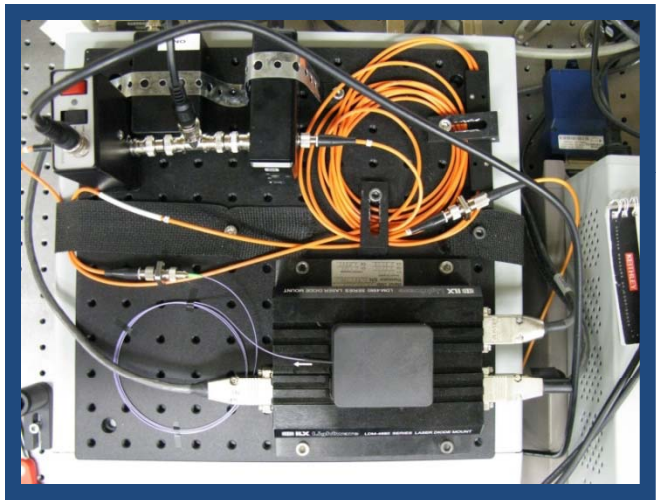


Front panel of the Labview program for operating the fiber sensor.

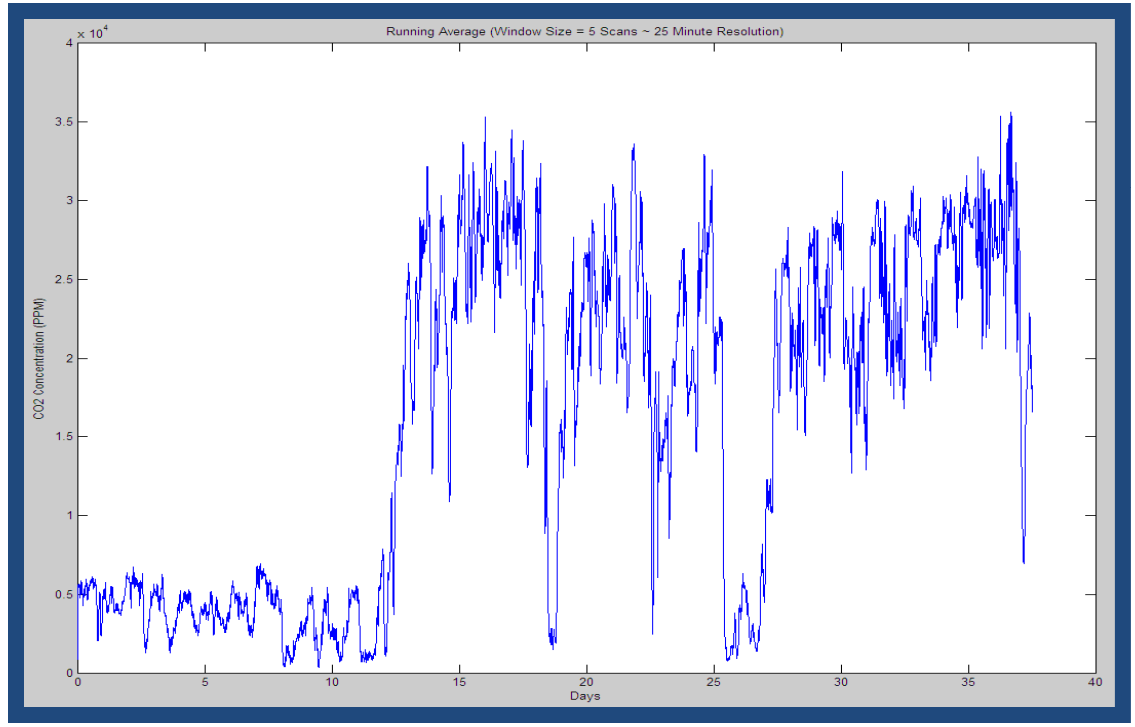
Highlights of Project to Date

Aerial view of the ZERT controlled underground release facility for testing near surface and surface monitoring instrumentation.

Highlights of Project to Date

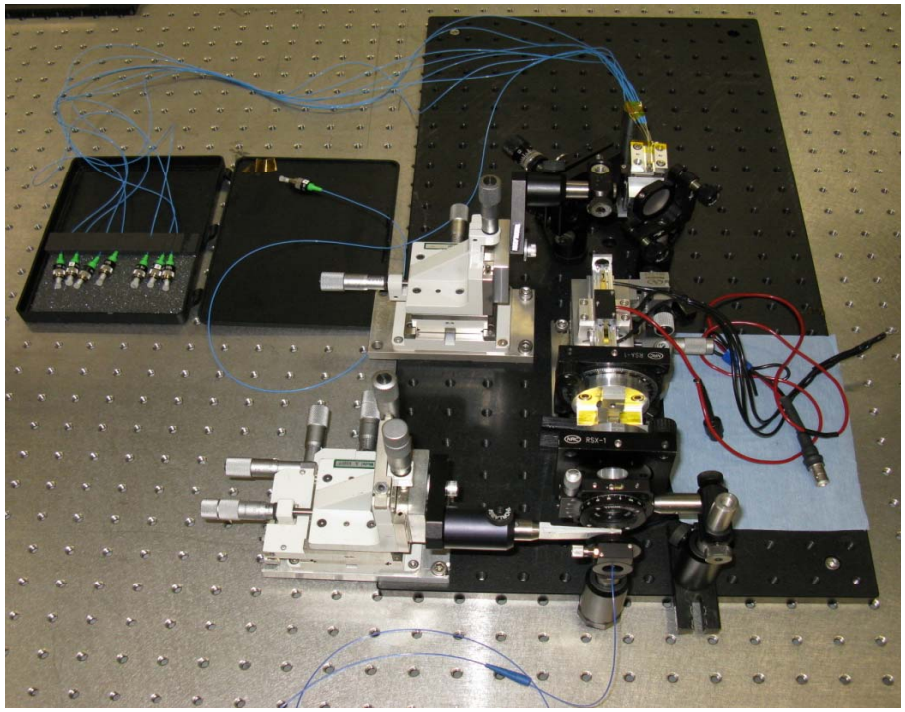


Laser,detectors, and computer housed in a weatherproof field deployable box.



CO_2 number density as a function of time for the 2010 summer controlled thirty day release.

Highlights of Project to Date



1 x 100 Electro-Optic switch under development

Commercialization Efforts

- Phase I EPA SBIR with ADVR, a Bozeman Montana based Photonics Company
- Phase II EPA SBIR is Pending

Tasks – Overview

Task No.	Task Description	Task Duration	Task Funding
1	Project Management and Planning	12/01/2009 – 11/30/2012	$27,407
2	Develop a single channel fiber sensor	12/1/2009-11/30/2010	$108,856
3	Develop a 1 x 4 fiber sensor array	12/1/2010-11/30/2011	$75,677
4	Field testing of the fiber sensor array	12/1/2011-11/30/2012	$87,263

Project Schedule

Project Milestone Description	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Planned Start Date	Planned End Date	Actual Start Date	Actual End Date
Project Managerment Plan	x	x	x	x	x	x	x	x	x	x	x	x	1-Dec-09	30-Nov-12	1-Dec-09	
Negotiate Management Plan	x												1-Dec-09	28-Feb-10	1-Dec-09	28-Feb-10
Prepare Reports	x	x	x	x	x	x	x	x	x	x	x	x	1-Dec-09	30-Nov-12	1-Dec-09	
Develop a Single Channel Fiber Sensor	x	x	x	x									1-Dec-09	30-Nov-10	30-Dec-10	30-Sept-10
Develop CAD drawings	x	x											1-Dec-09	30-Jul-10	1-Dec-09	28-Feb-10
Construction of the fiber probe		x	x										1-Mar-10	29-Oct-10	1-Feb-10	30-Sep-10
Develop control software			x	x									1-Jun-10	28-Dec-10	1-Mar-10	30-Sep-10
Laboratory Testing of Single Channel Fiber Sensor				x									1-Sep-10	30-Dec-10	1-Mar-10	30-Sep-10
Develop 1 x 4 Fiber Sensor Array					x	x	x	x					1-Dec-10	30-Nov-11	1-Sep-10	
Modify CAD drawings					x	x							1-Dec-10	28-Jun-11	1-Sep-10	1-Dec-10
Construction of the four fiber probes						x	x						1-Mar-11	31-Aug-11	1-Oct-10	
Develop control software for the 1 x 4 fiber sensor array							x	x					1-Jun-11	28-Nov-11		
Laboratory testing of the 1 x 4 fiber sensor array								x								
Field Testing of the Fiber sensor Array									x	x	x	x	1-Dec-11	30-Nov-12		
Field Testing of the Fiber sensor Array									x	x	x	x	1-Dec-11	30-Nov-12		

Discussion – Task 2

- Task Name/Goal: Develop a single channel fiber sensor
- Key Subtasks:
  - Develop CAD drawings
  - Construction of the fiber probe
  - Develop control software
  - Laboratory testing of the single channel fiber sensor
- Responsible parties (including students): Kevin repasky, John Carlsten, Geoffrey Wicks, Benjamin Soukup
- Task Status: 100% complete
- Major accomplishment: Demonstrated single channel fiber sensor over a thirty seven day period.
- Major issues/problems: None

Discussion – Task 3

- Task Name/Goal: Develop the 1 x 4 fiber sensor array
- Key Subtasks:
  - Modify CAD drawings
  - Construction of the four fiber probes
  - Development of the control software for the 1 x 4 sensor
  - Laboratory testing of the 1 x 4 fiber sensor array
- Responsible parties (including students): Kevin repasky, John Carlsten, Geoffrey Wicks, Benjamin Soukup
- Task Status: 25% complete
- Major accomplishment: CAD drawings complete and machine is finished.
- Major issues/problems: None

Project Milestones

Milestone	Planned Completion Date	Actual Completion Date
1. Development of CAD drawings of the proposed sensor probe and detector equipment.	7/30/2010	3/31/2010
2. Construction of the single fiber sensor probe.	10/29/2010	9/30/2010
3. Development of the computer code to operate the detector system.	12/28/2010	9/30/2010
4. Construction and laboratory testing of the single channel fiber sensor and probe in the call/return geometry.	12/30/2010	12/30/2010
5. Modify the CAD drawings for the four second generation fiber probes	6/28/2011	Active

Project Milestones

Milestone	Planned Completion Date	Actual Completion Date
6. Construction of the Four fiber sensor probes and detection system.	8/31/2011	Active
7. Modify the computer code to operate the detector system for four probes.	11/28/2011	
8. Construction and laboratory testing of the 1 x 4 fiber sensor array.	12/30/2011	
9. Testing the 1 x 4 fiber sensor array at the ZERT field site.	11/30/2012	

Anticipated Efforts for the Coming Year

- Activity 1: Modify CAD drawings for the four fiber sensor probes.
- Activity 2: Construction and alignment of the four fiber probes.
- Activity 3: Modification of the software to operate the 1 x 4 fiber sensor array.
- Acivity 4: Laboratory testing of the 1 x 4 fiber sensor array.
- Activity 5: Pursue avenues of commercialization.

PI Contact Information

- If you have any questions or would be interested in collaboration please contact
- repasky@ece.montana.edu (for instrument development and deployment)
- dobeck@chemistry.montana.edu (for information regarding the ZERT sub-surface controlled release facility.
- Spangler@montana.edu (for information regarding ZERT and the Big Sky Carbon Sequestration Partnership.