Laser-based Downhole CO_2 Sensor and Leak Detector

Physical Sciences Inc.

20 New England
Business Center,
Andover, MA 01810

Who we are

- A growing 46 year-old company of ~180 talented scientists, engineers and administrative personnel
- Headquartered in Andover, MA, with eight satellite locations in the U.S.
- Three wholly-owned subsidiaries, Q-Peak, Research Support Instruments, Faraday Technology, with complementary capabilities
- A diverse Research, Development, and Manufacturing organization with annual revenues exceeding $70M
- Employee-owned through an Employee Stock Ownership Trust

What we do

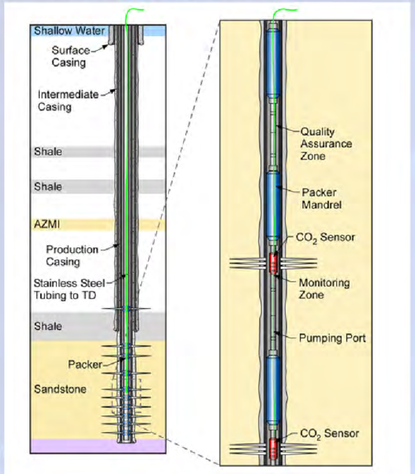
- Applied contract research and development for all major agencies of the U.S. government
- Technology development under contract to both industry and government
- Prototype product development for industry and commercial applications
- Components, systems, and instrumentation for industry and government sales
- Technology and product licensing

PSI Industrial Sensors

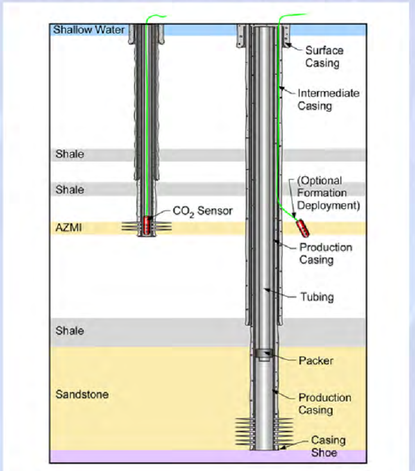
- Interdisciplinary combination of science and engineering skills with specific strengths in development and commercialization of photonic sensors and instrumentation
- Product development from concept to manufacturing prototype
- Go to market via direct sales, strategic partnerships, pilot scale manufacturing, and licensing
- Developing strong interactions with the oil & gas and broader energy industries since 1994

Deployment Concepts

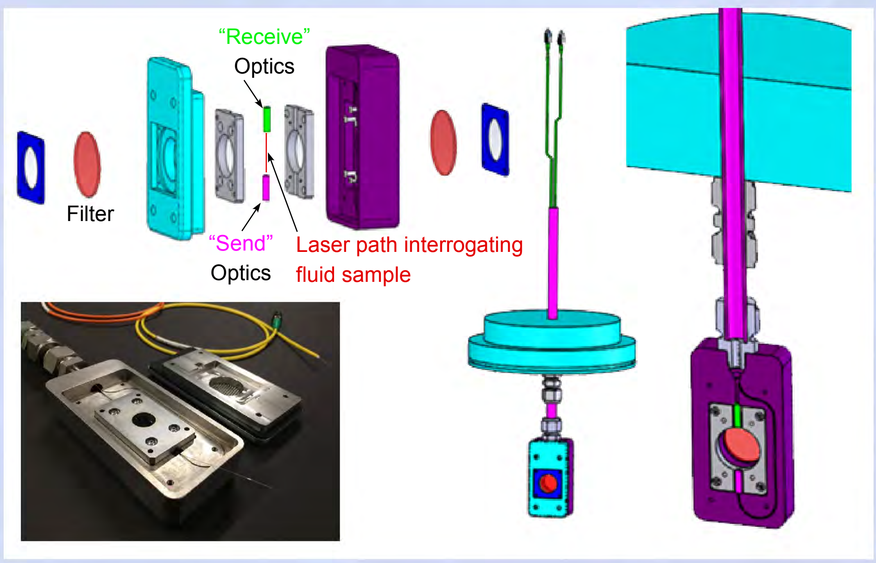
A) In monitor well; potentially multiple depths with single cable



B) In porous "leak-monitoring" layer (above-zone monitoring interval (AZMI))

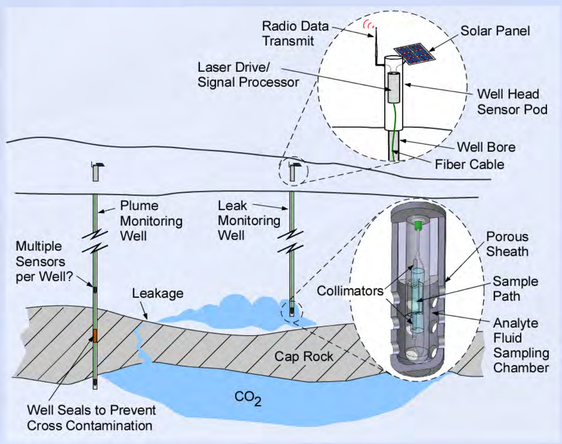


Sensor Head Prototype



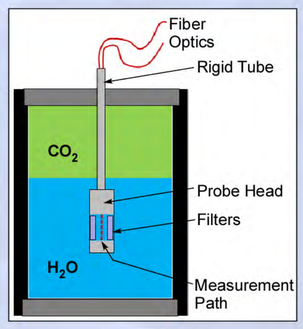
Downhole Fluids Sensor

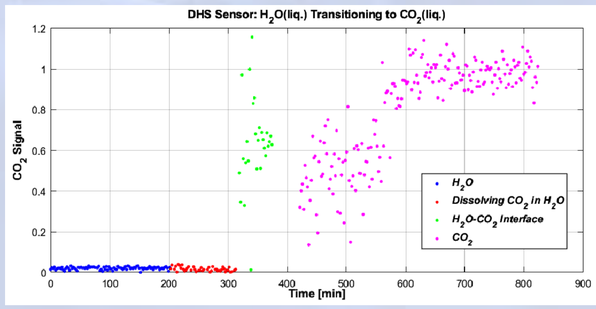
- Laser-based sensor for continuous and autonomous *in situ* measurement of supercritical and gaseous CO_2 in fluids within and around sequestration reservoirs
  - Deploys a passive optical sensor head at depth
  - Coupled via optical fiber cable to the laser source and electronics at the surface
- Supports GCS MVA by detecting and characterizing leakage from GCS sites at all depths
- Can advance GCS fluid transport modeling by monitoring CO_2 plume progress



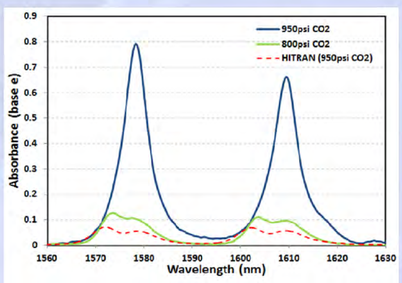
Lab Tests of Prototype

High-pressure vessel (up to 3000 psi) employed to access 100% H_2O, 100% CO_2, and CO_2/H_2O mixtures/solutions

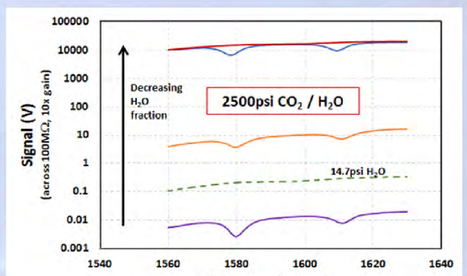




Measurement Principles



Absorbance signals for pure CO_2 vs. pressure near phase change boundary. For reference, a calculation for high pressure gas is also included.

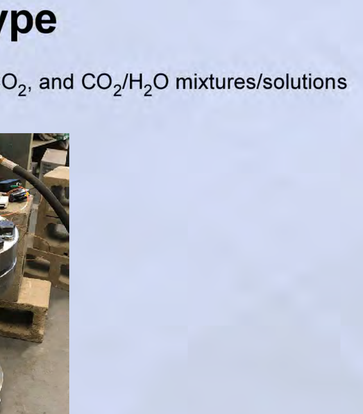


Temporal signal traces versus wavelength for varying CO_2 / mixtures.

- **Tunable Diode Laser Absorption Spectroscopy (TDLAS)** is a common technique for measuring trace gases
  - CO_2 absorbs infrared light in specific spectral wavelength (color) bands
  - A color-tunable laser repetitively scans its wavelength across the CO_2 bands
  - High-sensitivity signal processing deduces CO_2 concentration even when dissolved in H_2O
- The broad spectral band of liquid CO_2 feature (~6nm FWHM vs. 0.25nm for gas) demands **a novel laser tuning approach implemented in the DFS**

Field Tests Plans

- **Carbon Management Canada (CMC) / U Calgary – Priddis Well**
  - Closed foot system with coiled tubing integrated to inject CO_2 at the bottom
  - 2-3 day test focused on deployability, functionality, and performance.
- Seeking collaborations for long-term test deployments in GCS and other applications including:
  - Enhanced oil recovery (EOR)
  - Enhanced (natural) gas recovery (EGR) and CO_2-based hydraulic fracturing
  - Logging while drilling
  - Monitoring natural CO_2 reservoirs
  - Other supercritical CO_2 applications
    - CO_2 as extracting solvent (coffee decaffeination, botanical oils...)
    - Oxy-combustion



Acknowledgments

This material is based upon work supported by the Department of Energy under Award Number DE-SC0011876

Contact

Dr. Mickey Frish
(978) 738-8252
frish@psicorp.com

Dr. Shin-Juh Chen
(978) 738-8284
schen@psicorp.com