# Portable Spectroscopic Carbon Dioxide Monitor for Carbon Sequestration Applications

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**Abstract:** A portable sensor for $CO_2$ monitoring based on QEPAS technology and using a DFB diode laser operating at $\lambda$=1.57 μm will be described. The sensor is primarily intended for studies of $CO_2$ penetration through soil.

**OCIS codes:** (280.3420) Laser sensors; (300.6340) Spectroscopy, infrared; (140.5960) Semiconductor lasers

Most scientists currently believe that the observed global warming of the Earth's climate is caused mostly by the anthropogenic carbon dioxide ($CO_2$). Therefore, international efforts are made to reduce $CO_2$ emissions into the atmosphere. One of the proposed methods toward this goal is pumping the industrially generated carbon dioxide into natural underground reservoirs. However, there is no full confidence that $CO_2$ stored in such a way will not leak back into the atmosphere. The work reported here is supported by the Department of Energy and has the goal of designing and field testing of a portable $CO_2$ sensor to detect leaks from underground carbon dioxide storage facilities.

The problem of detecting $CO_2$ leaks is complicated by the ~350 ppmv background of atmospheric $CO_2$, which also exhibits large variations caused by plants breathing, bacteria activity, automotive traffic and other factors. Therefore, we designed a sensor with two sensing modules which can be positioned up to 4 meters apart and thus indicate the difference in $CO_2$ concentrations which can be caused by underground leaks, especially near $CO_2$ injection wells (Fig. 1).

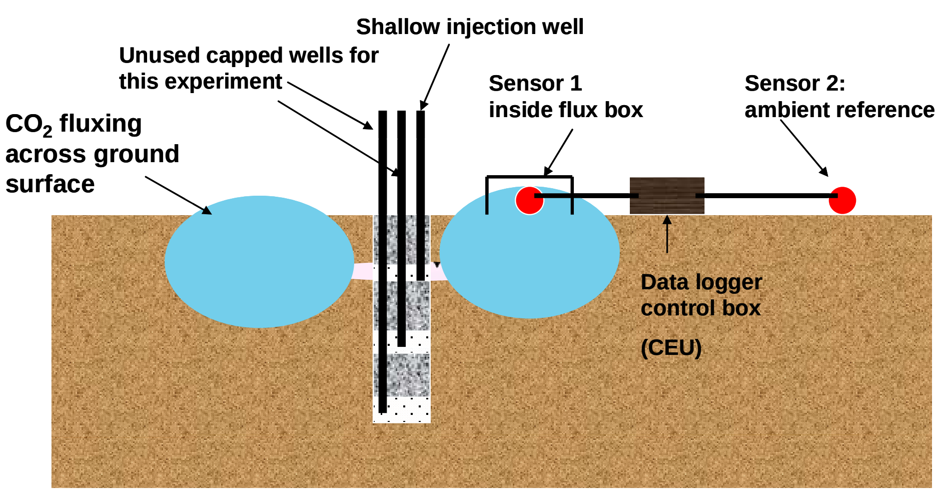


Fig. 1. One of the possible arrangements of the developed sensor field test for detecting $CO_2$ leaks through soil. "CEU" stands for Comtrol Electronics Unit.

The sensor platform utilized a quartz enhanced photoacoustic spectroscopy (QEPAS) approach [1]. A DFB diode laser emitting at 1.57 μm and coupled to a single mode optical fiber was used as an excitation source, accessing weak $CO_2$ absorption lines in this spectral region. The sensor architecture schematic is shown in Fig. 2(a). The laser source was integrated into the control electronics module (CEU). Its radiation is alternately directed to one of the compact spectrophones (SPh) as shown in Fig. 2(b) by means of an electronically controlled, MEMS based optical switch. The measurement time for each SPh can be programmed with 1 minute increments. For power efficiency and reliability, the system does not include active air sampling. Instead, each SPh is covered by a porous teflon film which stops dust and water droplets but allows ambient air diffusion into a SPh. In addition, each SPh is mounted on a thermoelectric element to keep its temperature constant at +35ºC and thus prevent water condensation (dew) during the daily temperature cycle.

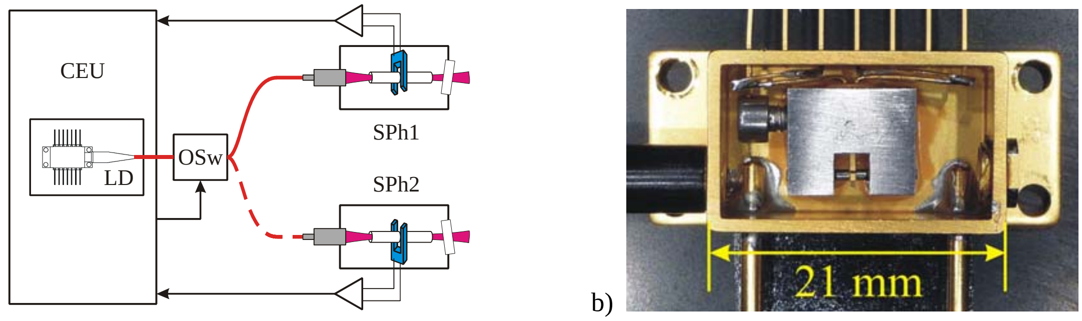


Fig. 2. Schematic of the QEPAS based $CO_2$ sensor with two spectrophones (SPh). Radiation of the laser diode (LD) located inside the control electronics unit (CEU) is alternately directed to SPh1 or SPh2 by means of electronically controlled, MEMS based optical switch (Osw). (a). A photograph of one of the two compact spectrophones used in this sensor (b).

During the laboratory testing period the detection sensitivity of this device was determined to be ~15 ppmv in 1s. The Allan variance plots show that averaging can be performed up to 400s, resulting in ~1 ppmv standard deviation in $CO_2$ concentration. The device is equipped with temperature, pressure, and relative humidity sensors. Their readings are logged into the CEU memory every 10s along with the SPh signals. QEPAS sensitivity to $CO_2$ depends on the $H_2O$ vapor concentration in air, rapidly growing in the 0% to 0.2% $H_2O$ vapor concentration range (Fig. 3), but becomes practically constant at higher humidity levels.

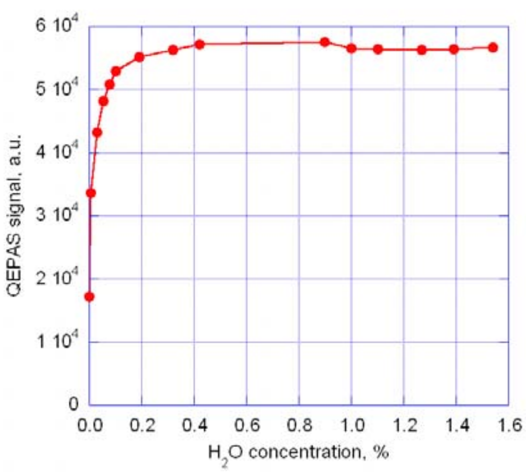


Fig. 3. Water vapor effect on the QEPAS signal generated at a constant $CO_2$ concentration.

Both laboratory and field test results will be reported.

## References

[1] A. A. Kosterev, F.K. Tittel, D.V. Serebryakov, A. L. Malinovsky, I. V. Morozov, "Applications of quartz tuning forks in spectroscopic gas sensing," Review of Scientific Instruments, 76, 043105 (2005).