Multi-species QEPAS based gas sensing using a wavelength-programmable diode laser source

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Abstract: Quartz-enhanced photoacoustic spectroscopy (QEPAS) was combined with a wavelength-programmable near-IR tunable laser source to realize a compact prototype chemical gas sensor for multi-species analysis. The best QEPAS sensitivity achieved to date is ~4×10^{-8} cm^{-1} W/√Hz.

OCIS codes: (300.6430) Spectroscopy, optoacoustic and thermo-optic; (280.3420) Laser sensors

Photoacoustic spectroscopy (PAS) is an established method of experimental physics [1]. It is based on detection of sound waves produced in an absorbing medium when the medium is illuminated by modulated radiation. A common approach used to detect the acoustic signal generated by modulated laser radiation in a weakly absorbing gas utilizes an acoustic resonator filled with the gas sample. Recently, a novel approach to PAS called Quartz-enhanced photoacoustic spectroscopy (QEPAS) was introduced [2]. QEPAS takes advantage of the extremely high quality factor Q of quartz crystals, which serve as resonant microphones. At the present state of development, standard clock tuning forks (TF) are used in QEPAS. These crystals resonate at f~32768 (2^{15}) Hz, and possess a Q of up to 13000 at atmospheric pressure (Q in a gas depends on particular TF dimensions). A true background-free detection can be achieved when the laser is wavelength-modulated at $f/2$ and the TF signal is detected at f. This approach eliminates photoacoustic signals resulting from nonselective absorbers such as dust or the TF itself. The basic schematic of QEPAS gas sensor is shown in Fig. 1. A reference cell contains a gas mixture with high concentration of the species to be detected. A photodiode signal demodulated at $3f/2$ frequency is used to lock the laser frequency to the center of an absorption line.

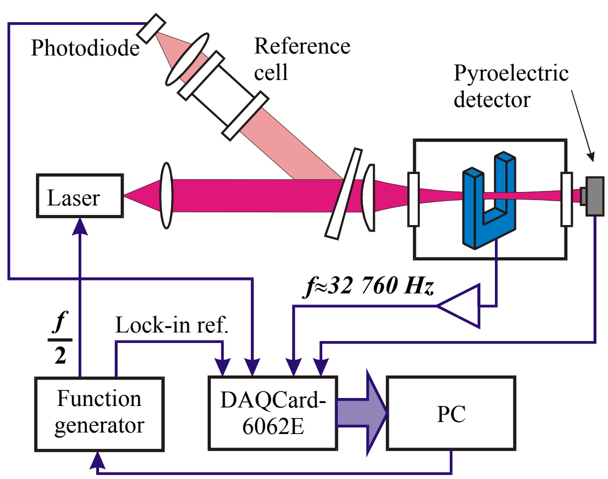

Fig. 1. Simplified schematic of QEPAS laboratory setup. Triangle represents a one-chip transimpedance preamplifier with a 10 MΩ feedback resistor followed by a SR560 low-noise amplifier (Stanford Research Systems). Pyroelectric detector is used as an auxiliary means for laser beam alignment and as a transmitted laser power monitor.

The principal advantages of QEPAS as compared to the conventional PAS are:

- Ultrasmall gas sample volume required to perform a species detection (V<1 mm^3)
- Immunity to environmental acoustic noise

The best QEPAS sensitivity achieved to date is ~4×10^{-8} $cm^{-1}W/\sqrt{Hz}$, which approaches the conventional PAS results [3, 4].

Photoacoustic spectrophones, including a TF based sensors, are detecting the energy absorbed in the gas and therefore can operate with a laser source in any spectral region. This feature makes QEPAS suitable for multispecies analysis. We shall report performance of a prototype multi-species QEPAS gas sensor with a wavelength-programmable tunable diode laser source based on sampled-grating distributed Bragg reflector technology [5] (Altowave 3500 from Intune Technologies). A preliminary selection of 20 target gas absorption lines was made in the 1528-1564 nm range. Corresponding laser operating parameters were then implemented in the laser module memory. The wavelength can be switched from one channel to another with a 1 GHz accuracy via a RS232 communication interface. A frequency scan of ±15 GHz around a selected channel can be performed allowing wavelength modulation spectroscopy to be carried out. The laser wavelength can be locked to an absorption line using a reference cell in the same manner as described above. Approaches to improve the detection limit of the QEPAS sensor will be discussed.

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