Recent advances of quartz-enhanced photoacoustic spectroscopy sensor technology

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Quartz-enhanced photoacoustic spectroscopy (QEPAS) sensor technology is based on a new approach to photoacoustic detection which employs a quartz tuning fork (TF) as a resonant acoustic transducer [1,2]. A QEPAS sensor detects the weak acoustic pressure wave that is generated when optical radiation interacts with a trace gas. The weak pressure wave excites a resonant vibration of a TF which is then converted into an electric signal by the piezoelectric effect. Subsequently, the electric signal, which is proportional to the concentration of the gas, is measured by a transimpedance amplifier. Merits of QEPAS compared to conventional resonant photoacoustic spectroscopy include QEPAS sensor immunity to environmental acoustic noise, a simple absorption detection module design, and its capability to analyze trace gas samples of ~1 mm^3 in volume.

This poster reports recent improvements of spectraphone design and QEPAS based sensor performance In order to enhance the amplitude of the photoacoustic signal, it is advantageous to place a TF within a microcresonator composed of two thin tubes, so that the microresonator yields a signal gain from 10 to 20. To-date, we have investigated the sensor performance with l=4mm, 4.4mm and 5mm long metal tubes with ID=0.4 mm, 0.5 mm, 0.58 mm, 0.6 mm, 0.76 mm and 0.084 mm. A near-infrared fiber-coupled distributed feedback (DFB) diode laser (JDS Uniphase model CQF935/908-19600) was used as the QEPAS excitation source. The diode laser output was split into a 1:99 ratio by means of a fiber beam splitter (ThorLabs 10202A-99-APC). A small fraction of the laser light was sent to a commercial fiber-coupled reference gas module (Wavelength References, Mulino, OR) containing a sealed cell filled with a mixture of 5 Torr C_2H_2 and 145 Torr N2, a fiber collimator, and a photodiode. The remaining laser power was directed to a spectrophone consisting of the TF and two tubes forming the acoustic microresonator. The spectrophone was placed into a vacuum-tight enclosure (the inner gas volume is V ~1 cm^3 when the spectrophone is installed) equipped with two sapphire windows and gas inlet and outlet. C_2H_2 in N_2 (10 ppmv) was used as a convenient target gas whose flow was set to 100 ccm. A control electronics unit was employed to measure the f_{TF} and Q-factor of the TF, to modulate the laser current at $f_L = 1/2\, f_{TF}$, to lock the laser wavelength to the targeted absorption line and to measure the current generated by the TF in response to the photoacoustic signal. For a specific length tube configuration, we varied the gas pressures by means of a pressure controller (MKS Type 649) to obtain signal amplitudes for different gas pressures.

The sensor performance was evaluated based on the SNR with a calibrated C_2H_2 gas mixture. In Ref. [3] it was shown that the TF noise is inversely proportional to the square root of the equivalent resistor R of the TF. Therefore, the SNR is proportional to the product of signal amplitude and $\sqrt{R}$ of the TF. The optimal microresonator parameters are l=4.4mm and ID=0.5mm, with the two gaps between TF and the microresonator tubes set to between 30μm and 50μm.

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