CO_2 Detection at 2 μm using Quartz Enhanced Photoacoustic Spectroscopy

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Abstract: Sensitive carbon dioxide detection and analysis of the CO_2 relaxation process is performed using quartz enhanced photoacoustic spectroscopy and a diode laser operating at 2μm as the spectroscopic source. Sensor performance and optimization will be reported.

OCIS codes: (280.3420) Laser sensors; (300.6430) Spectroscopy, optoacoustic and thermo-optic; (300.6260) Spectroscopy, diode lasers

Photoacoustic spectroscopy has proved to be a powerful and sensitive technique used in a wide range of trace gas detection applications [1]. A new approach to detect photoacoustic signals in gas media using quartz enhanced photoacoustic spectroscopy (QEPAS) [2] will be reported. While traditional photoacoustic spectroscopy (PAS) utilizes a gas-filled resonant acoustic cavity and a microphone for photoacoustic signal detection, QEPAS takes advantage of the extremely high quality factor *Q* of quartz crystals used as convenient low cost transducers. The laser-excited sound can be detected in a non-resonant gas chamber by means of a high *Q* piezoelectric crystal element used as a resonant microphone. When employing commercially available quartz tuning forks (TF) resonating at 32.768 kHz with a quality factors of $Q > 10^4$, the QEPAS based sensors can offer quasi complete immunity to environmental acoustic noise (because a TF is only sensitive to a symmetric fundamental mode of vibrations), and the advantage of a very small sample volume required for analysis (~1 mm^3). The fundamental thermal noise of the TF is the only limiting factor of QEPAS sensitivity. Due to relatively higher frequency of the detected acoustic signals in comparison to conventional PAS, the QEPAS system shows also higher sensitivity to the time constants associated with the pertinent molecular V-T relaxation processes. In this work recent results on QEPAS-based sensitive CO_2 detection as well as a study of the CO_2 relaxation process will be presented. Feasibility experiments of a QEPAS based CO_2 sensor utilizing a new commercial distributed-feedback (DFB) diode laser (NEL model: KELD1G5B2TA) operating at 2 μm have demonstrated a normalized absorbance detection limit of 9.4×10^{-8} cm^{-1} $W/Hz^{1/2}$.

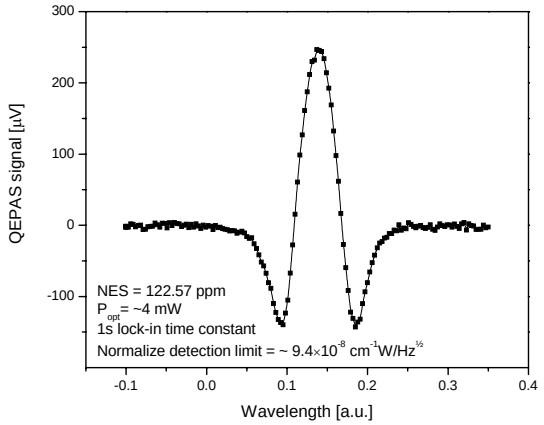

Figure 1. 2f spectrum of the CO_2 R18 line at 4991.25 cm^{-1} measured for a 1% CO_2: N_2 mixture at 60 torr.

Figure 1 depicts the CO_2 absorption line at 4991.25cm^{-1} measured for a 1% CO_2:N_2 mixture using a wavelength modulation technique and second harmonic (2f) signal detection. For sensor optimization, the influence of the H_2O content in the sample gas mixture on the CO_2 relaxation time constant was studied. The QEPAS amplitude signal measured for a 1% CO_2: N_2 mixture as a function of H_2O concentration is shown in Figure 2.

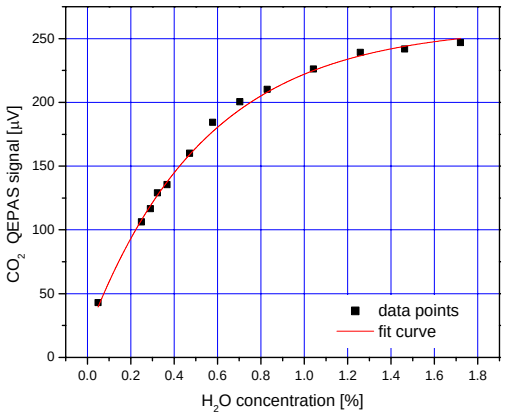

Figure 2. Influence of the H_2O content in a sample gas mixture (1% CO_2, balance N_2) on the measured amplitude of a QEPAS signal..

The overall system design and performance will be presented and future developments discussed.

References:

[1] A. Miklós, P. Hess, Z. Bozoki, „Application of acoustic resonators in photoacoustic trace gas analysis and metrology", Rev. Sci. Instrum. 72, 1937-1955 (2001)
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