Quartz enhanced photoacoustic spectroscopy exploiting beat frequency approach for environmental monitoring of pollutants

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Fast and accurate monitoring of pollutant gases in the environment is critical to safeguard public health. Among different sensing solutions, quartz enhanced photoacoustic spectroscopy (QEPAS) is a highly sensitive optical technique, implementing quartz tuning forks (QTFs) to convert sound waves, produced by gas molecules when modulated light is absorbed, into an electric signal. The slow signal acquisition speed depends on the long scan time of the gas absorption feature, requiring few minutes. Furthermore, the real-time monitoring of the QTF resonance frequency (f_0) and quality factor (Q) cannot be carried out during the laser tuning range scan. In this work, the beat frequency-QEPAS (BF-QEPAS) approach [1] was employed to both overcome these limitations and detect NO, using an interband cascaded laser emitting at a central wavelength of 5.263 µm and a 12.4 kHz custom QTF. In BF-QEPAS, a staircase ramp with a rising time of ~1s and a sinewave detuned with respect to f_0 allow exciting the QTF with an acoustic pulse. Considering the BF-QEPAS signal shown in Figure 1 [1], i) the gas concentration is retrieved from the value of P1, ii) f_0 is measured from the time difference between the five peaks, and iii) Q is determined by the decay time, evaluated with an exponential fit of the five peaks. We achieved a minimum detection limit and a normalized noise equivalent absorption of 180 ppb at 5 ms of the lock-in time constant and $2.5\cdot10^{-9}$ $cm^{-1}WHz^{-1/2}$, respectively. Furthermore, the BF-QEPAS signal allows determining the f_0 with an accuracy of 0.1 Hz and the Q with a relative error of ~1%.

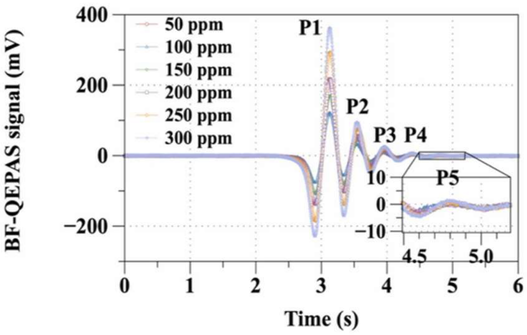

Figure 1 BF-QEPAS spectral scans measured for different NO concentrations in standard air [1].

[1] B. Li, G. Menduni, M. Giglio, et al., Photoacoustics, 100479 (2023), In press.

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