Highly Selective Toluene Detection using Quartz Enhanced Photoacoustic Spectroscopy at λ = 13.71 µm

Kumar Kinjalk[1,2], Giansergio Menduni[2], Andrea Zifarelli[2], Marilena Giglio[2], Roland Teissier[3], Alexei N. Baranov[1], Angelo Sampaolo[2]

[1]IES, University of Montpellier, CNRS, 34095 Montpellier, France

[2]PolySense Lab, Dipartimento Interateneo di Fisica, University and Politecnico of Bari, Bari, Italy

[3]MirSense, 34095 Montpellier, France

Among anthropogenic and natural volatile organic compounds (VOCs), benzene, toluene, ethylbenzene, and xylene isomers (commonly called BTEX) are the main sources of air pollution. The World Health Organization has classified BTEX compounds as highly aggressive cancer-causing agents, and therefore there is a high interest in developing efficient techniques for their detection.

Although optical sensors proved high performances in terms of sensitivity and selectivity, there is a lack of suitable sources emitting in the 13-15 µm wavelength range, where BTEX exhibits strong absorption features. This work demonstrates a custom-built InAs-based QCL operating at 13.71 µm and its employment in a quartz enhanced photoacoustic spectroscopy (QEPAS) sensor for detecting toluene. The fabricated QCL allowed the excitation of the absorption lines of toluene at 729.39 cm^{-1} (see Fig 1). The QEPAS sensor employs a quartz tuning fork (QTF) excited by sound waves generated via a photoacoustic effect to detect gas traces. The QTF has a fundamental resonance frequency of $f_0 = 12.457\ kHz$ and a quality factor $Q = 22{,}197$ at $200\ Torr$. A 2f-wavelength modulation detection scheme is implemented by modulating the QCL current with a frequency of $f_0/2$ and acquiring the f_0 component of the QTF using a lock-in amplifier [1]. Starting from the obtained calibration curve and the measured noise level, a minimum detection limit of 592 ppb at 0.1s of integration time is achieved. Using the Allan deviation analysis, a detection limit of 150 ppb can be obtained at 10 s of integration time (see Fig 2). Furthermore, the study of gas mixtures revealed no spectral interference from benzene or ethylbenzene (see Fig 3).

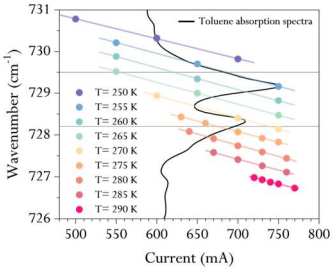

Fig. 1 Wavenumber as a function of current at different temperatures.

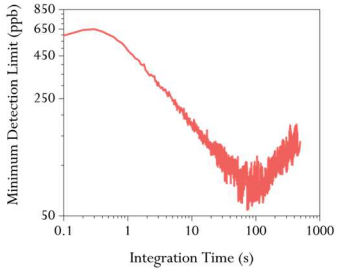

Fig. 2 Minimum detection limit as a function of Integration time.

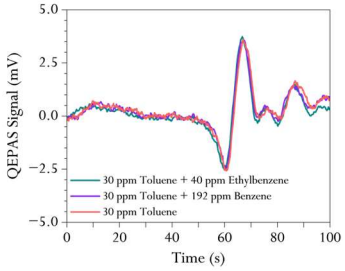

Fig. 3 QEPAS signal of toluene in different gas mixtures.

[1] A. Sampaolo et al., "Quartz-enhanced photoacoustic spectroscopy for multi-gas detection: A review," Anal Chim Acta, vol. 1202, p. 338894, Apr. 2022, doi: 10.1016/j.aca.2021.338894

[+] Author for correspondence: kumar.kinjalk@umontpellier.fr