Recent Advances In Quartz-Enhanced Photoacoustic Sensors Employing Custom Tuning Fork Operating At The First Overtone Flexural Mode

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Quartz tuning forks (QTFs) have been successfully employed as piezoelectric optoacoustic transducers in a quartz enhanced photoacoustic spectroscopic sensor (QEPAS) for sensitive and selective gas sensing applications. Stainless tubes are acoustically coupled with the QTF and act as an acoustic micro-resonator (AmR) to confine the acoustic waves and enhance the QEPAS signal [1]. Very recently, we realized custom QTFs with fundamental resonance frequency of a few KHz [2] in order to approach the typical energy relaxation time of gases, while maintaining a high resonator quality factor. However, lowering the fundamental resonance frequency reduces also the overtone frequencies, leading to their use in QEPAS.

Here we compare the photoacoustic performance of custom-made QTFs, with prong sizes designed to provide fundamental resonance frequencies of a few kHz and the first overtone mode of ≤ 50 kHz. We implemented the QTFs in a different QEPAS sensor systems operating in the near-IR spectral range in order to evaluate the custom-made QTFs acousto-electric transduction efficiency. A detailed analysis of the dependence of the QTFs first overtone mode quality factor on the prongs' geometry will be reported. An appropriate design of the QTF prong geometry can provide a higher Q factor for the 1st overtone flexural mode resonance with respect to the fundamental mode [3,4]. The 1st overtone mode is characterized by two antinode point, i.e., positions of the focused laser providing a maximum QEPAS signal as shown in Fig. 1a. Hence, it is possible to excite the two-antinode points singularly or simultaneously using one laser source. Based on these consideration we will describe two QEPAS sensors, one exploiting a single-tube microresonator configuration [5] (see Fig. 1b) and another implementing a double antinode excited configuration (see Fig. 1c), using two sets of acoustic micro-resonators assembled at two separated 1st overtone antinode points [6].

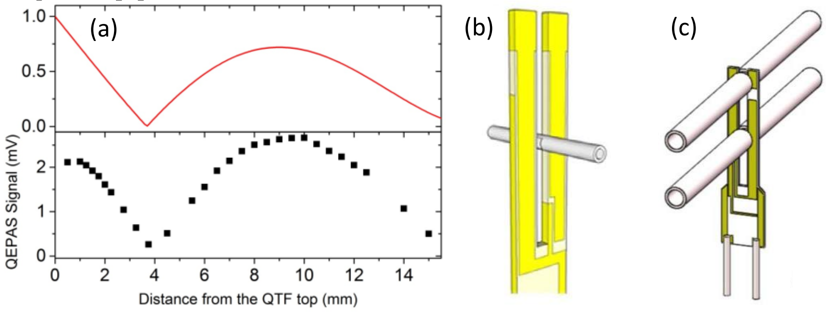

Fig. 1 (a) Normalized transverse displacement of the prong and the corresponding QEPAS signal for a QTF operating at the overtone resonance frequency of 17789 Hz as a function of the distance from the QTF top. The laser beam position was scanned along the symmetry axis of the QTF. (b) Sketch of a single-tube QEPAS spectrophone. (c) Sketch of the double antinode excited QEPAS spectrophone.

These two configurations provide QEPAS signal enhancements of more than two orders of magnitude with respect to that measured for the bare QTF operating at the fundamental mode.

References

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