Quartz tuning fork based photoacoustic spectroscopy and sensing

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Environmental monitoring, as well as safety and security, oil&gas and biomedical applications demand for real time and in-situ solutions together with unambiguous identification and quantification of the chemical analytes composing the investigated samples. Gas spectroscopy exploiting laser sources is a reliable tool providing highly selective and sensitive detection with robust and compact sensor architectures.

Quartz crystal tuning forks (QTFs) resonators are central components for timing and frequency measurements, due to their high stability, high-quality factors and low power consumptions. Thanks to their piezoelectric properties, QTFs are employed as sensitive element in many fields and systems such as atomic Force Microscopy (AFM), near-field, microwave microscopy and mass/viscosity sensor. Since 2002, QTFs are also widely used as a sharply resonant acoustic transducer to detect weak photoacoustic excitation for Quartz-Enhanced Photoacoustic Spectroscopy (QEPAS) [1, 4]

Among most sensitive optical techniques, QEPAS has been demonstrated as the leading-edge technology for addressing these application requirements, providing also modularity, ruggedness, portability and allowing the use of extremely small volumes [1-4]. QEPAS technique does not require an optical detector, it is wavelength independent, it is immune to environmental noise and can operate in a wide range of temperature and pressure. These factors, together with and its proven reliability and ruggedness, represent the main distinct advantages with respect to other laser-based techniques for environmental monitoring and in situ detection. In on-beam QEPAS the laser beam is focused on the gap between the two prongs of QTF and excites the gas molecules (see Figure 1).

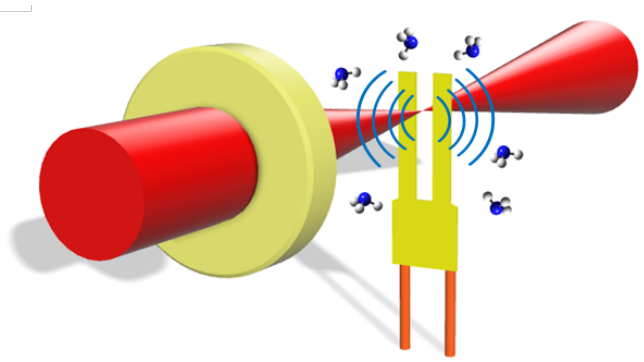

Fig. 1. Schematic diagram of a QTF, a laser and an acoustic wave in on-beam QEPAS.

QTFs have also recently demonstrated their capability to operate as sensitive and broadband infrared photodetectors for absorption spectroscopy. The photodetection process is based on light impacting on the tuning fork and creating a local temperature increase that generates a strain field. A modulation of the optical power causes periodic heating/cooling, which in turn generates a modulation of accumulated charges on the QTF surface due to quartz piezoelectricity [5-7]. To maximize the photoinduced signal, the laser beam has to focused on the quartz surface where the maximum strain field occurs, typically nearby the QTF prong based (see Fig. 2) and under these conditions the LITES signal-to-noise ratio is proportional to the product of the strain and the QTF accumulation time [6-7].

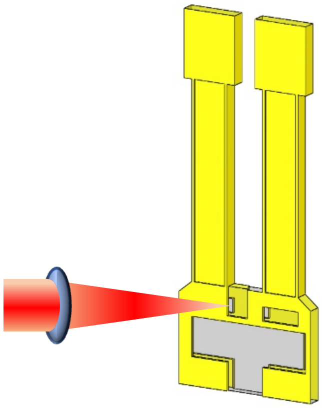

Fig. 2. Schematic of the QTF photodetection process, based on light impacting on the tuning fork.

This technique combined with the tunable diode laser absorption spectroscopy (TDLAS) approach, known as light-induced thermoelastic spectroscopy (LITES), has been explored in the last two years [3]. The typical schematic of LITES is shown in Fig. 3. The QTF can be placed far from the target gas and be sealed in a gas chamber with an inert gas or under vacuum. Therefore, LITES is a non-contact measurement method and can be used for remote and standoff gas detection.

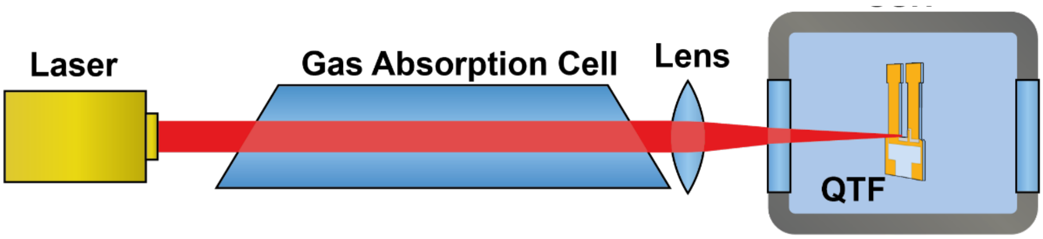

Fig. 3. LITES schematic

Starting from the basic physical principles governing the QTF physics, I will review the main results achieved by exploiting custom QTFs for QEPAS sensing and as photodetector in LITES setup, with a main focus on real-world applications. Finally, a detailed description of an innovative QEPAS shoebox sized sensor system for in-situ operations [8-10] will be provided.

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