Air pollutants detection with QEPAS sensors

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In this work we report on two multi-gas sensors based on QEPAS technique for environmental monitoring purposes. Both sensors have been validated and calibrated using certified concentrations of gas sample, in controlled pressure, flow and humidity conditions. Then, the sensors have been demonstrated by analysing laboratory air samples.

Background – Gas detection has a great impact in a wide range of applications. For example, the use of high sensitivity gas detectors is widespread in atmospheric science to measure different gas species, including greenhouse gases, and detect harmful gases leaks. Laser absorption-based gas sensors can provide highly sensitive and selective detection, with fast response time. In particular, quartz-enhanced photoacoustic spectroscopy (QEPAS) has been demonstrated as a powerful tool for trace gas detection [1,2].

Methods – QEPAS technique consists in: i) exciting the target gas molecules with a modulated laser light matching an absorption feature of the selected molecules and; ii) detecting the sound waves generated by the non-radiative molecules' energy relaxation using a quartz tuning fork (QTF), usually coupled to a pair of micro-resonator tubes to further amplify the sound waves [3]. Pressure waves hitting the QTF deflect its prongs and put them in vibration. These vibrations are mainly damped by air- and support-related losses [4]. The prongs mechanical stress causes piezoelectric charges accumulate on the QTF surface that can be collected by gold electrodes. QEPAS signal depends on the target molecules absorption coefficient, the laser optical power, the QTF quality factor, and the generated the vibrational-to-vibrational and vibrational-to-translational energy relaxation paths.

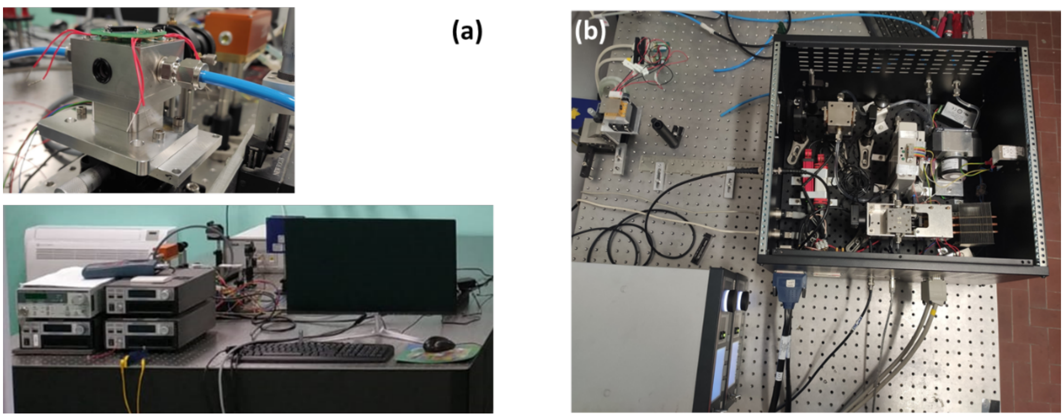

Fig. 1. Picture of the QEPAS sensor for carbon monoxide, nitrous oxide, carbon dioxide, and water vapor **(a)** and for methane, nitric oxide, and water vapour detection **(b).**

The first QEPAS sensor exploits a Vernier-effect quantum cascade laser to detect carbon monoxide, nitrous oxide, carbon dioxide, and water vapor. This innovative laser behaves as a switchable, multicolour, electrically tunable light source with an extended tuning range, ranging from 2100 cm^{-1} to 2220 cm^{-1} [5]. A picture of the developed setup is shown in Fig. 1(a).

The second QEPAS sensor exploits two distributed-feedback quantum cascade lasers to detect methane, nitric oxide, and water vapor. Here, the realization of the QEPAS sensor required the design of an innovative box sensor architecture and a dedicated LabVIEW-based software driving the devices and processing the QTFs signal. The sensor architecture is shown in Fig. 1(b).

Results – Both sensors were validated and calibrated using gas cylinders with certified concentration of the target gas in nitrogen. The detection limits achieved with the two allowed multi-gas detection test on laboratory air samples. The retrieved concentrations matched the typical values of the amount of these gas species in air.

Conclusions

In this work we presented two recent QEPAS sensors developed for atmospheric detection of air pollutants. The sensors operation was demonstrated by measuring the concentration of carbon monoxide, nitrous oxide, carbon dioxide, and water vapor or methane, nitric oxide, and water vapor in the air of our laboratory.

References

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