KN4

QUARTZ-ENHANCED PHOTOACOUSTIC DETECTION OF HYDROCARBONS FOR OIL EXPLORATION AND ENVIRONMENTAL MONITORING

A. Sampaolo[1], M. Giglio[1], A. Zifarelli[1], G. Menduni[1,2], A. Elefante[1], V. Passaro[2], P. Patimisco[1], F.K. Tittel[3], V. Spagnolo[1]

[1]PolySense Lab - Dipartimento Interateneo di Fisica, Politecnico and University of Bari, CNR-IFN, Bari, Italy
[2]Photonics Research Group, Dipartimento di Ingegneria Elettrica e dell'informazione, Politecnico di Bari, Italy
[3]Rice University, Department of Electrical and Computer Engineering, Houston (TX), USA

Oil exploration represents a wide research field in which science & technology mainly focus their efforts on two critical tasks: improvement of the drilling sequence efficiency and management of environmental impact. Hydrocarbon detection in the gas phase is a powerful tool for guiding downstream operations as well as providing a constant monitoring of the ambient air around the well site. Indeed, a gas sensor-assisted drilling would avoid an uncountable number of unnecessary holes for dry wells, which results in a huge money saving and a more sustainable impact on the seabed. A swarm of drones equipped with hydrocarbon sensors can be trained to detect and report natural gas leaks along the pipelines to avoid explosions and pollution.
The main advantage in employing laser-based spectroscopic sensors is their capability to target gas species with high selectivity and detection sensitivity. Most of the spectroscopic techniques rely on multi-pass absorption cells or resonant optical cavities to enhance the interaction pathlength between the laser radiation and the absorbing molecules or to boost the available laser power. In both cases, such sensors can be bulky and require the use of optical detectors, which in turn are inadequate for working in harsh environments where the temperature can change sharply.
In this context, we report quartz-enhanced photoacoustic spectroscopy (QEPAS) as a valuable candidate for natural gas analysis in the oil & gas field. The core element of any QEPAS system is the quartz tuning fork, employed as a high quality-factor optoacoustic transducer, capable of operating in a wide range of temperature and pressure [1,2]. The robustness and compactness of these sensors, together with the possibility to avoid the use of optical detectors, represent the basis for the development of a new generation of small-sized gas spectrometers to be potentially i) employed downhole for source rock characterization and estimation of oil & gas reserves, and ii) mounted on drones to constantly monitor the air composition around the well site.

KN4

In this presentation will be given an overlook on shoe-box sized QEPAS systems capable of: i) selective detect methane and ethane in the parts-per billion range, and propane in the parts-per-million range, by employing a single interband cascade laser emitting at 3.345 µm [3]; ii) selective detection of $^{12}CH_4$ and $^{13}CH_4$ isotopes at the parts-per-billion sensitivity level by employing a quantum cascade laser operating around 7.73 µm. Representatives QEPAS spectra measured for methane and ethane are shown in Fig. 1.

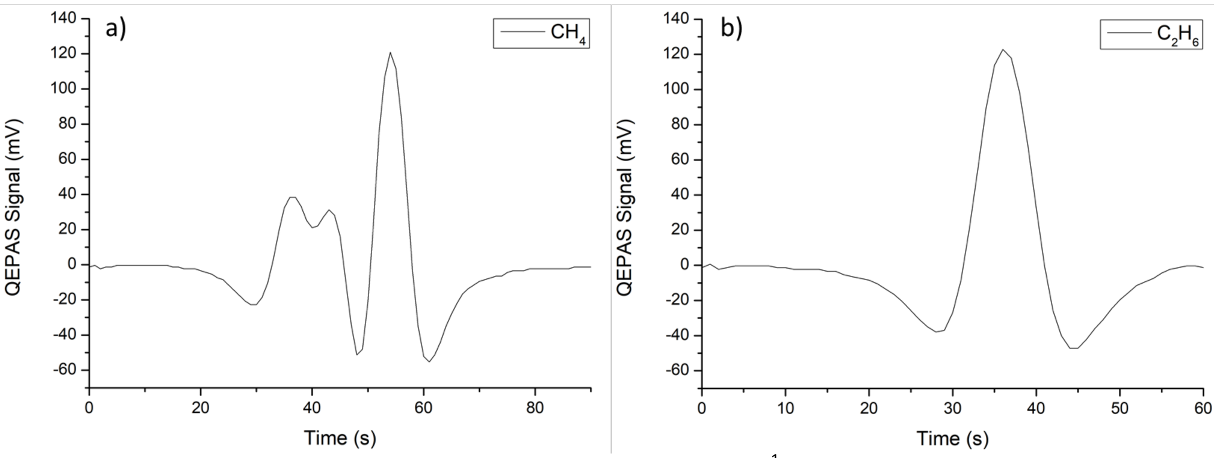

Figure 1. a) QEPAS signal due to methane absorption at 2988.8 cm^{-1} and b) QEPAS signal due to ethane absorption @ 2986.2 cm^{-1} for a mixture of CH_4-900 ppm, C_2H_6-100 ppm in pure N_2 at atmospheric pressure.

An alternative lightweight and low power consumption prototype will be presented as the most compatible with the drone technology state of the art. Two laser diodes beams are combined in a single fiber and its output coupled with the acoustic detection module for simultaneous near-IR detection of methane/ethane or methane/water vapor in the parts-per-million sensitivity level.

References

[1] Patimisco P., Sampaolo A., Dong L., Tittel F. K., Spagnolo V., App. Phys. Rev. 5, 011106 (2018).
[2] Li S., Dong L., Wu H., Sampaolo A., Patimisco P., Spagnolo V., Tittel F. K., Anal. Chem. 91, 5834-5840 (2019).
[3] Sampaolo A., Csutak S., Patimisco P., Giglio M., Menduni G., Passaro V., Tittel F. K., Deffenbaugh M., Spagnolo V., Sens. Act. B Chem. 282, 952-960 (2019).