Mid-infrared trace gas detection enhanced by tuning fork, optical cavity and hollow-core fiber

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Mid-infrared trace gas detection plays a significant role in many sectors such as energy systems, transportation, environmental monitoring, agriculture, safety, and security. With quantum cascade laser (QCL) and interband cascade laser (ICL) used as the light source, it is promising to develop high-resolution mid-infrared laser-based spectrometers with a portable size and low power consumption. Photoacoustic spectroscopy (PAS) and photothermal spectroscopy (PTS) are two highly sensitive methods for chemical analysis by detecting the absorption-induced acoustic wave and refractive index change, respectively. However, there is still room for improvement compared to the most sensitive spectroscopic techniques such as cavity ring-down spectroscopy (CRDS) or noise-immune cavity-enhanced optical-heterodyne molecular spectroscopy (NICE-OHMS).

In this talk I will discuss recent advances in the development of ultra-sensitive PAS enhanced by tuning fork and optical cavity, as well as PTS enhanced by hollow-core fiber and phase-sensitive interferometry. PAS signal is proportional to the overall incident laser power (W). The most recent innovation of PAS with a double opto-acoustic resonance enables ultra-sensitive and wide-dynamic-range gas detection [1]. The merging of a high-Q-factor acoustic resonator (i.e., quartz tuning fork) with a high-finesse optical resonator leverages on a double standing wave effect. By using a mW-level QCL, the doubly resonant QEPAS sensor demonstrates ppt-level CO detection in the mid-infrared. In comparison, PTS signal is proportional to the light power density (W/m^2), which can be readily achieved in a hollow-core fiber [2]. By taking advantage of mid-infrared fiber technology, I will present our recent innovation of mid-infrared-pump near-infrared-probe PTS for trace gas sensing [3-5]. The variation of refractive index caused by the pump-laser can be sensitively detected by agile interferometric methods such as the Mach-Zehnder interferometer, heterodyne interferometer, Fabry-Pérot interferometer, and fiber mode interferometer.

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