Interferometer-Based Background-Free Vibrational Spectroscopy using a Cr: ZnS Mode-Locked Laser

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Vibrational spectroscopy provides promising tools for trace gas sensing, which is highly demanded in the field of environmental monitoring, breath analysis, etc. The traditional absorption spectroscopy commonly faces a challenge of detecting small transmission dips in a strong background, where the limit of detection (LOD) is set by the intensity noise of the light source and the dynamic range of the detector. One can employ an interferometer to eliminate the background to reveal a small change of the electric field as an optical output [1]. Although there have been a few demonstrations [2], none of them achieved ultrasensitivity, probably due to the low optical power and unstable interferometer.

In this study, we demonstrate a highly sensitive background-free vibrational spectroscopy (BFS) using a well-stabilized interferometer and a Cr:ZnS mode-locked femtosecond laser [3], which provides high brightness, broadband spectrum in the mid infrared range with low intensity noise. Figure 1(a) displays the measured background-free spectrum or the free induction decay (FID) signal for methane and carbon monoxide. The FID signals match well the molecular absorption lines provided by the HITRAN database. In order to evaluate LOD, we measure the ro-vibrational transition lines of R-branch for carbon monoxide. As shown in Fig. 1(b), the FID signal is detected up to the transition with a rotational number of J = 34→35, corresponding to a 2×10^{-4} absorbance with a 1 ms integration time. The normalized result 6.32×10^{-6} ($Hz^{-1/2}$) shows a 70-times enhancement compared with a conventional absorption spectroscopy using the similar laser source [4].

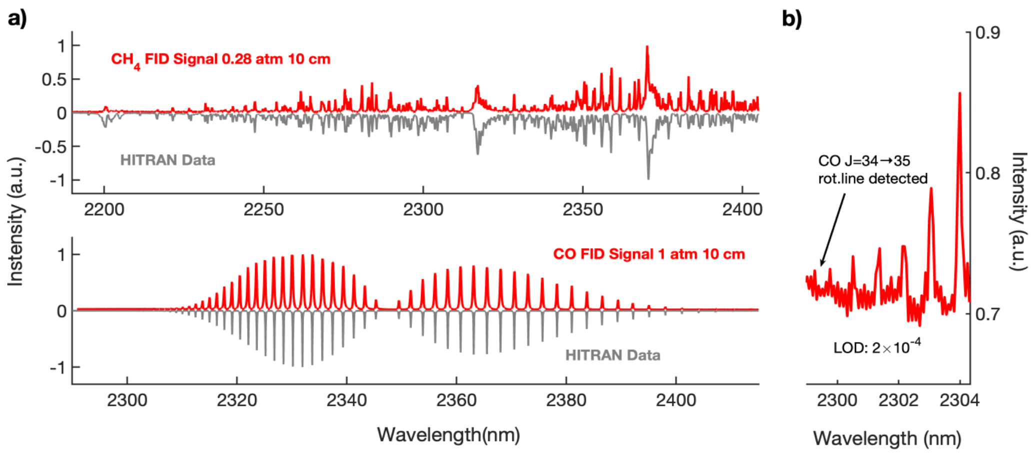

Fig.1(a) The measured FID spectra for methane and carbon monoxide (red) and the HITRAN data (gray). (b) The magnified view at the wavelengths around 2300 nm.

[1] B P Abbott et al., Rep. Prog. Phys. 72 076901(2009). [2] T. Buberl et al., Opt. Express 27, 2432 (2019).
[3] D. Okazaki et al., Opt. Letter 44, 1750 (2019). [4] E. Sorokin et.al., Opt. Express 15, 16540-16545 (2007).