Mid-infrared saturated absorption spectroscopy inside the hollow fiber using difference frequency generation source

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Abstract:

Saturation spectroscopy is recognized as a powerful tool to observe the frequency precession far below the Doppler limit [1]. We have performed the mid-infrared Doppler-free spectroscopy inside the hollow fiber using a difference frequency generation (DFG) source. We have established a widely tunable mid-infrared DFG source using a 1 W tapered amplifier boosted external cavity diode laser (ECDL) system and a 10 W YDFA (ytterbium-doped fiber amplifier) boosted Nd:YAG laser system. The two laser beams from ECDL and Nd:YAG laser systems are mixed in a 50 mm long MgO doped periodically poled lithium niobate (MgO:PPLN) crystal to generate the DFG radiation over the tuning range of 3.97 to 4.71 μm. The maximum power of DFG source is about 3 mW. The iodine stabilization scheme is used to stabilize the Nd:YAG laser frequency and saturated absorption spectroscopy is performed on R(60) transition of CO_2 fundamental ($00^01 \leftarrow 00^00$) band at 4.193 μm inside a hollow fiber of diameter 300 μm and length 100 cm while keeping the CO_2 pressure at 100 mTorr. The hollow fiber is manufactured by Opto-Knowledge Systems Inc. having the attenuation of 3dB over 100 cm length. The observed spectrum is fitted with a combination of Gaussian and Lorentzian profile and the full width half maximum (FWHM) of the Lamb dip is reported to 4.56±0.23 MHz. We have also determined the line width (4.40±0.15 MHz) of Lamb dip in well agreement with the measured dip using the dependence of peak amplitude of the third derivative signal with respect to the modulation width [2]. The comparison of width with free space measurements will be discussed [3]. The third derivative locking method is used to lock the ECDL frequency to a hyperfine transition of CO_2. This study may potentially be used in the generation of compact mid-IR frequency standard source.

[1] T. W. Hansch, I. S. Shahin, and A. L. Schawlow, Nature-Phys. Sci. **235**, 63 (1972).

[2] H.-M. Fang, S.-C. Wang and J.-T. Shy, Opt. Commun. **257**, 76 (2006).

[3] C.-C. Liao, K.-Y. Wu, Y.-H. Lien, J.-T. Shy, High precision mid-IR spectroscopy of $^{12}C^{16}O_2$: $00^01 \leftarrow 00^00$ band near 4.3 μm, *Proceedings of the 63rd Ohio State University International Symposium on Molecular Spectroscopy*, Columbus, Ohio, 2008.