QCL SPECTROSCOPY AT 9 μM CALIBRATED WITH A HIGH-POWER THULIUM-BASED FREQUENCY COMB

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Optical frequency comb synthesizers (OFCS) comprised of mode-locked femtosecond lasers can be stabilized with Hertz-level accuracy and used in combination with cw lasers for high resolution spectroscopy. As currently established OFCS technologies are confined to the near-IR, mid-IR spectroscopy requires either down-conversion of near-IR combs or up-conversion of the probing laser. Due to the near-IR absorption edge of the nonlinear crystals with extended mid-IR transparency, the conversion efficiency of nonlinear processes increases with the wavelength of the interacting fields. A more straightforward and efficient link between comb and probing laser is thus expected to be obtained by increasing the wavelength of the comb synthesizer. In this work, the use of a novel, powerful Thulium-based OFCS[a] with emission wavelengths near 2 μm is shown to be an excellent candidate to obtain absolute frequency calibration of quantum cascade lasers (QCL) operating at wavelengths as long as 9 μm.

Specifically, by combining the frequencies of a 9 μm QCL with the high power 2 μm comb in a $AgGaSe_2$ crystal, SFG light is created near 1.6 μm. A portion of the 2 μm comb is non-linearly shifted to 1.6 μm. As the carrier envelope offset frequency (f_{ceo}) is the same for the SFG radiation and the shifted comb at 1.6 μm, heterodyning the two signals produces a beat signal independent of f_{ceo}, eliminating the need for an octave spanning comb and f-2f interferometer. We report on the development of this instrument, and the absolute line transitions of NH_3 at 9 μm, enabled by rapid scanning of the repetition rate of the comb enabled to increase the signal-to-noise ratio.[b]

[a] J. Jiang, C. Mohr, J. Bethge, M. Fermann, and I. Hartl, in *CLEO/Europe and EQEC 2011 Conference Digest, OSA Technical Digest (CD)* **PDB_1**, 2001

[b] D. Gatti, A. Gambetta, A. Castrillo, G. Galzerano, P. Laporta, L. Gainfrani and M. Marangoni *Op. Exp.* **19**, 17520 2011