CRDS 用の Yb 添加ファイバーレーザーを用いた 4.5μm 帯中赤外光周波数コム光源の開発

Yb-doped Fiber Laser Based Mid-Infrared Frequency Comb at 4.5 μm for CRDS Application

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In this report, we demonstrated an Yb-doped fiber laser based MIR comb with a wavelength tunability of 3.9-4.7 μm, and a maximum power of 4.2 mW measured at 4.5 μm was observed. The output power had good stability with the fluctuation less than 2 %. Beat note measurement was performed with help of a quantum cascade laser (QCL) [1] [2]. A stable and sharp beat note signal was observed in MIR region with a linewidth of 380 kHz, of which the SNR was larger than 20 dB. The generated MIR comb was overlapped with a QCL, and they were applied for a cavity ring-down spectroscopy (CRDS) cell. The absorption properties of the air was successfully measured with this system.

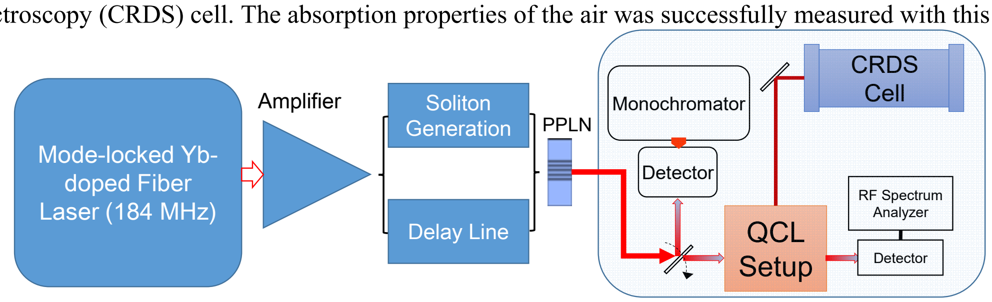

Fig. 1. Experimental diagram of the MIR comb generation using Yb-doped fiber laser system.

In the experiments, we tested a 3-mm-long periodically poled lithium niobate (PPLN) crystal with discrete periods from 25.5 to 28.5 μm with the step of 0.5 μm. The observed peak wavelength could be continuously tuned from 3.9 to 4.7 μm. The average power of the generated MIR comb was larger than 3.0 mW. At the peak wavelength of 4.5 μm, a maximum average output power of 4.2 mW was obtained. The average output power at 4.5 μm was recorded in the time duration more than 150 minutes, and the fluctuation less than 2 % was confirmed. The output beams from the comb was overlapped at a CaF_2 wedged window with a stabilized QCL. The measured RF spectrum from 0 to 200 MHz was shown in Fig. 2(a), where the sharp and stable beat note signals were observed with a signal to noise ratio (SNR) larger than 20dB. The linewidth of the beat signal fitted to a Lorentzian profile was 380 kHz, as illustrated in Fig. 2(b). When the MIR comb was working at a free-running state, the fluctuation of repetition rate measured at 4.5 μm was less than 20 Hz. After the confirmation of the stability and coherence, we measured absorption of the air with the CRDS technique where the MIR comb was overlapped with QCL, and utilized as the frequency reference. The absorption intensity information is shown in Fig. 2(c), where the experimental results fit the HITRAN database very well.

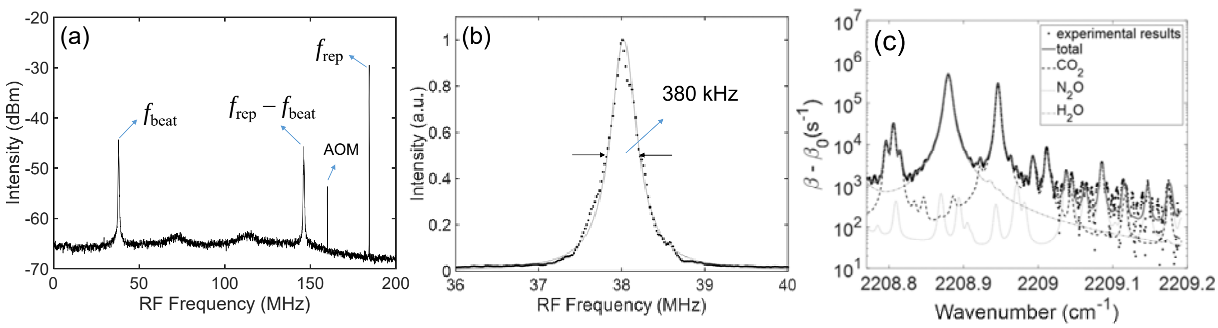

Fig. 2. (a) RF spectra of MIR comb working at 4.5 μm, where the AOM line was from the acousto-optic modulator in the QCL subsystem. (b) Beat signal measured at RBW of 1 kHz. (d) Absorption intensity information.

Ref: [1] L. Jin, et. al, CLEO2017, STu1K.4, ,San Jose, USA, May 14-19, 2017. [2] L. Jin, et. al, IEEE J. Sel. Top. Quantum Electron., 24, 0900907 (2018).