Rb-based Stabilized Laser System as Frequency Reference for CO_2 Monitoring

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A carbon dioxide (CO_2) satellite mission based on the integrated path differential absorption lidar technique has been found potentially suitable to improve the current understanding of the impact of this gas on the climate system and changes. In view of such mission, we report here on the progress realized on a compact frequency reference laser system at 1.57 µm, with desired frequency stability better than 200 kHz at 7 seconds and 20 kHz above 700 seconds.

Rubidium (Rb) has been selected and preferred to CO_2 as absolute frequency reference, as it demonstrates strong and narrow sub-Doppler transition lines (20-30 MHz, FWHM) at 780 nm achievable with low laser power. A centimeter-scale Rb-filled glass cell is sufficient to frequency lock a laser[1] while an optical pathlength of several meters or more is needed for Doppler-broadened CO_2 lines[2] (~400 MHz, FWHM). The Rb frequency stability is transferred to the telecom wavelength range by frequency conversion and an optical frequency comb (OFC) fills the 12-nm gap between the doubled Rb wavelength and the CO_2 absorption line at 1572 nm.

The laser system is illustrated in Figure 1. A fiber-pigtailed DFB laser emitting at 1560 nm is used as a master laser source. Part of its light is launched into a frequency doubling unit built around a PPLN waveguide. The 780-nm generated light inputs an in-house developed frequency reference unit (FRU) where it probes Rb atoms in a saturated absorption scheme. Frequency locking to the Rb transition is achieved by wavelength modulation spectroscopy and feedback to the laser diode current. The optical frequency comb is realized by modulating the other part of the master laser light with a waveguide electro-optical modulator enclosed in a Fabry-Perot cavity. Finally, a slave DFB laser offset-locked to an adequate line of the OFC serves as a frequency reference for monitoring the frequency of the lidar transmitter laser, or to injection-seed it.

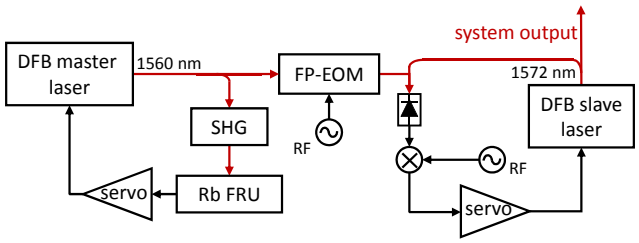

Fig. 1: Diagram of the laser system. FP-EOM: Fabry-Perot electro-optical modulator; SHG: second harmonic generation; Rb FRU: Rubidium frequency reference unit; RF: radio-frequency oscillator.

The frequency stability of the 1.56-µm master laser has been measured by beating against a self-referenced fiber comb stabilized onto an H-maser, showing an Allan deviation of 10 kHz at 1 s, a maximum instability of 20 kHz at 6 s and below 2 kHz between 1'000 and 200'000 s.

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[1] F. Gruet et al., "Compact and frequency stabilized laser heads for Rubidium atomic clocks", Proceedings of the International Conference on Space Optics (ICSO), Ajaccio, Corsica, 9 – 12 October 2012, paper 0048, 2012.

[2] K. Numata et al., "Frequency stabilization of distributed-feedback laser diodes at 1572 nm for lidar measurements of atmospheric carbon dioxide," Appl. Opt., vol. 50, p. 1047-1056, 2011.