Progress towards a Fibre-Based Frequency Reference for Atmospheric CO_2 Measurements

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A laser source stabilised to an absorption line of CO_2 sent into orbit around Earth can be used for differential optical absorption measurements of the CO_2 content of the atmosphere. The accuracy of the measurement hinges strongly upon the frequency stability of the laser used. We present here an ongoing effort to produce a fibre-based frequency reference at 2.05 µm with an accuracy of better than 5 MHz for measurements of CO_2.

Fig. 1 shows an outline of the setup. We use a fibre-coupled DFB laser as light source and a gas-filled hollow-core photonic crystal fibre (HC-PCF) as gas cell for the reference absorption line. Keeping the system fibre-based ensures compactness and low weight well suited for space applications.

The light after the laser is split into an output for the actual atmospheric measurement and an arm for the locking system. The light for the lock is modulated by an electro-optic modulator before passing the gas-filled HC-PCF, where it is partly absorbed by the CO_2 molecules. The light is detected and demodulated to obtain an error signal for the lock, which is passed through a PI circuit for feedback to the current driver for fast control and to the temperature driver to eliminate slow variations.

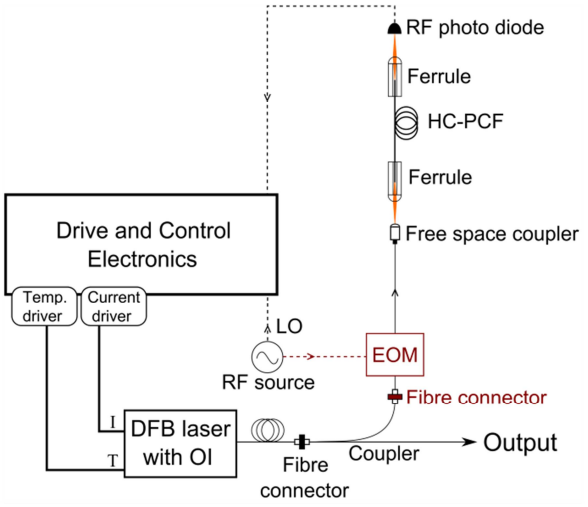

Fig. 1: Experimental setup. A portion of the DFB laser light is tapped off to pass through a gas-filled hollow-core fibre for FM spectroscopy used for locking the laser. OI: Optical Isolator, EOM: Electro-Optic Modulator, LO: Local Oscillator, HC-PCF: Hollow-Core Photonic Crystal Fibre.

Filling a long HC-PCF can be very time consuming and tedious. We have measured the gas filling time for the HC-PCF and compare it to a numerical model with good agreement.

For satisfactory performance, the system needs to be carefully optimised. The optimal length and pressure of the HC-PCF depends on the transition used and the modulation parameters. We have obtained an error signal for the lock for optimised parameters, and present an expected error budget for the final setup keeping a long term accuracy of better than 5 MHz with a tuneability of at least ±200 MHz.

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