Versatile frequency reference laser based on modulation sideband locking in an all-fibre configuration

S. Schilt[(1)]*, K. Hey Tow[(2)], M. Petersen[(1)], T. Südmeyer[(1)], L. Thévenaz[(2)]
[(1)] Laboratoire Temps-Fréquence, Université de Neuchâtel, Av. de Bellevaux 51, 2000 Neuchâtel (CH)
[(2)] Group for Fiber Optics, EPFL, SCI-STI-LT Station 11, 1015 Lausanne (CH)
*e-mail: stephane.schilt@unine.ch

The accuracy of a differential absorption lidar (DIAL) instrument depends on the spectral purity, accuracy and frequency-stability of the low-power continuous wave laser that seeds the high power pulsed laser transmitter. A DIAL system usually operates at two different wavelengths, one on-line, placed at or near the centre of an absorption line, and one off-line. Nowadays, space-borne DIAL instruments aiming at monitoring the atmospheric density profile or the integrated column density of a studied gaseous analyte from space to ground are under investigation by space agencies, in particular for the monitoring of CO_2 [1, 2]. The currently considered approach is to position the on-line wavelength not at the centre, but in the wing of the absorption feature, where the gradient of the absorption cross-section is steep and strongly dependent on the width of the absorption profile, thus on the atmospheric pressure and consequently on the altitude. The control of the frequency detuning of the on-line wavelength from the line centre enables fine optimization of the atmospheric optical depth. This requires stabilising the reference seed laser in the wing of the considered molecular absorption feature, with a frequency detuning potentially adjustable from a few hundred MHz up to 3 GHz.

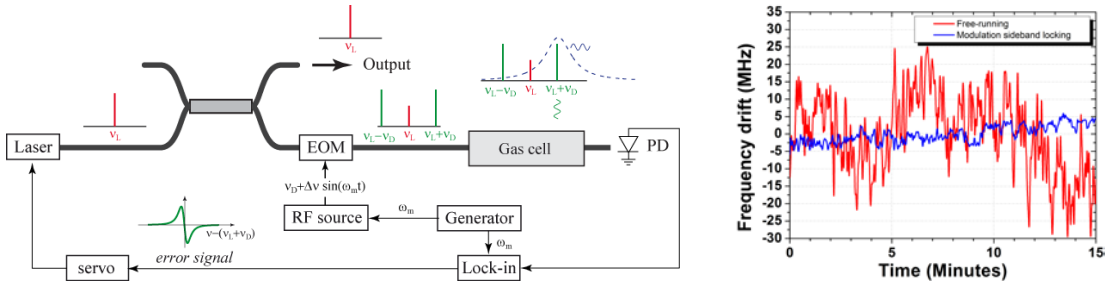

Fig. 1. (a) Experimental setup of the modulation sideband locking. (b) Frequency fluctuations of a DFB laser in free-running mode (red) and locked to an HC-PCF C_2H_2 reference gas cell (blue) using our proposed stabilisation technique.

In this work, we present the first steps towards the developments of a frequency-stabilized laser at 2051 nm in prospect of a future CO_2 LIDAR mission under consideration by the European Space Agency. Since parameters like weight, size, ruggedness and insensitivity to vibrations are of prime importance for space applications, a compact gas cell based on a photonic crystal fibre (PCF) is being used. This is made by filling the PCF with a given low-pressure gas and hermetically sealing it [3]. Detailed spectroscopic investigation has been performed to determine the best parameters (length, filling pressure, etc) of the fibered gas cell for maximum frequency stability of a laser at 2051 nm. For direct frequency-stabilization of a DFB laser to the wing of the R(30) CO_2 transition with an adjustable detuning, we proposed and are implementing a modulation sideband locking technique that is schematized in Fig 1a. This versatile method has the advantage to avoid any direct modulation of the laser that would broaden its spectrum and induce an undesirable intensity modulation. It basically consists in creating a pair of sidebands in the laser spectrum using an electro-optic modulator and in stabilizing one of the sidebands on the centre of the target molecular transition using standard wavelength modulation spectroscopy (WMS).

Preliminary validation experiments of our proposed modulation sideband locking have been performed using the C_2H_2 P(15) absorption line (at around 1533 nm) obtained in a 5-m hollow-core PCF filled at a pressure of 5 mbar. Laser frequency fluctuations were measured over 15 minutes in free-running mode (with a frequency drift larger than 30 MHz and a standard deviation of 12.1 MHz) and for a locked laser. When the feedback loop is activated, the laser is locked with frequency fluctuations reduced to a standard deviation of 2.55 MHz.

[1] http://esamultimedia.esa.int/docs/SP1313-1_ASCOPE.pdf
[2] S.R. Kawa, J. Mao, J.B. Abshire, G.J. Collatz, X. Sun, C.J. Weaver, Tellus **62B**, 759-769 (2010)
[3] F. Benabid, F. Couny, J.C. Knight, T.A. Birks, P. St. J. Russell, Nature **434**, 488-491 (2005)