A Portable and Miniaturized, Frequency Comb-Calibrated, Laser Heterodyne Radiometer for Atmospheric CO2 monitoring

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Abstract: An LHR approach, combining a remarkably high level of portability and frequency comb calibration, is evaluated for the first time in urban areas for ground-based monitoring of atmospheric CO_2 (easily adaptable for other greenhouse gases).

1. Introduction

Annual global emissions of carbon dioxide (CO_2) have been steadily increasing, with atmospheric CO_2 concentrations rising from 365 ppm in 2002 to over 400 ppm today [1] and could reach 600 – 1000 ppm by 2100 [2]. Such an alarming trend, with a major influence on climate change, has attracted a global effort focused on monitoring and reducing CO_2 emissions. Laser Heterodyne Radiometry (LHR), introduced in the 1970s [3], has become a well-suited technique for passive monitoring of greenhouse gases (GHGs) [4], allowing accurate determination of atmospheric column constituents such as CO_2.

In this work, a LHR system for the study of atmospheric CO_2 is preliminary evaluated in a large city. The LHR system, previously characterized in laboratory using the synthetic spectrum generated by a 1550 nm super luminescent diode and a CO_2 reference gas cell [5], allows the spectral characterization of atmospheric CO_2 at three different absorption lines (1570.28 nm, 1570.54 nm and 1570.82 nm) both using the traditional LHR operation mode and using a wavelength modulated local oscillator in LHR (WM-LHR) [6]. It should be mentioned that, as its main feature, the instruments has an embedded frequency comb-based calibration system which ensures exquisite accuracy in the determination of the spectral linewidth. The preliminary results show the great potential of the implemented LHR system for atmospheric CO_2, easily adaptable to detect other desired analytes, whose applicability is supported by its miniaturized (portable) and autonomous (battery-powered) design.

2. LHR system design

A block diagram of the LHR system is shown in Fig. 1. The incoming signal is combined with the local oscillator laser via a 2 x 2 fiber coupler feeding an amplified balanced detector for optical signal mixing. The amplified and band-pass filtered heterodyne signal is then detected with a USB power sensor that provides a digitized reading of the averaged signal power. Operation mode (traditional or WM-LHR) is configured electronically, either by modulating the intensity of the incoming signal (using the electro-optical modulator) or by modulating the laser current, both controlled by the data acquisition system. Finally, frequency calibration is achieved by using a single-stage electro-optic frequency comb generator. The whole system, including the three modules illustrated in Fig. 1, is battery-operated.

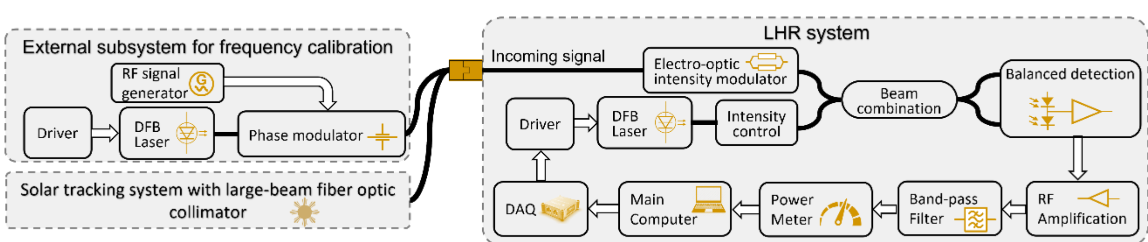

Fig.1. Block diagram of the LHR system, including the external subsystem for frequency calibration and the solar tracking module for sunlight collection.

3. Results and discussion

The LHR system was first pre-tested in the field by performing measurements in urban centers on the outskirts of Madrid, Spain. In Fig. 2 is shown a characterized spectral absorption line of CO_2 at 1570.54 nm recovered from the

LHR system in both operation modes (traditional and wavelength modulated). The data shown is the result of the averaging of 5 consecutive spectra, each with 150 measurement points and an integration time of 20 ms per point. No baseline correction has been performed to the measurement. The frequency axis was calibrated using a frequency comb spectrum acquired during field measurements by connecting the external subsystem for frequency calibration to the incoming signal port of the LHR system, with the zero reference arbitrarily fixed. As it can be seen, the measured absorption line is clearly visible, supporting the LHR system applicability for atmospheric CO_2 monitoring. Let us also observe that the WM-LHR measurement roughly describes the first derivative of the absorption line measured in the traditional LHR mode, which contains additional information that is currently being evaluated for integration into the modeling stage in order to enhance its performance.

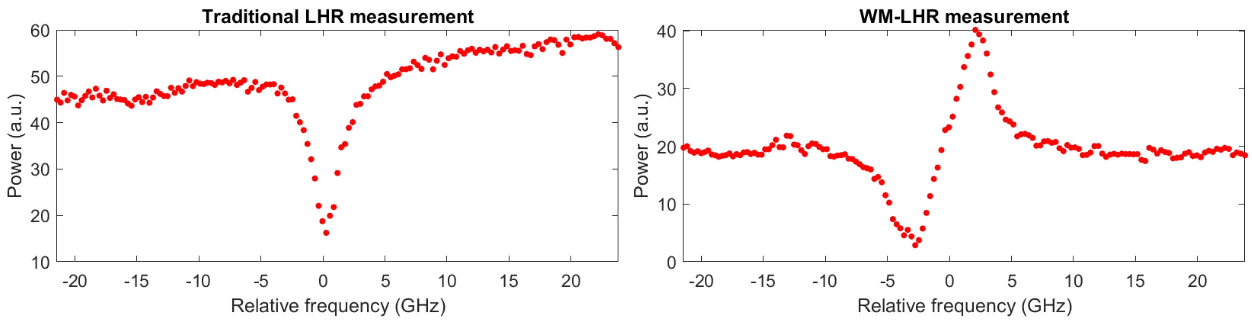

Fig. 2. Measured CO_2 absorption line at 1570.54 nm under traditional and WM-LHR operation modes. Frequency axis has been calibrated by using the comb reference signal.

4. Conclusions

In this work, a portable, miniaturized, frequency comb calibrated LHR system for atmospheric CO2 monitoring is presented and preliminarily evaluated. The in-field measurements taken in urban areas (and considering the adaptability of the system for targeting many other GHGs), shows the potential of the proposed LHR system for accurate characterization and analysis of the atmospheric constituents. Several experimental tests are being performed to evaluate the stability in the frequency calibration process and the performance of the LHR system.

5. References

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6. Acknowledgment

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