Absorption spectroscopy with quantum cascade lasers

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Abstract

Recently developed quantum-cascade distributed feedback (QC-DFB) lasers [1] have been shown to be useful tunable single-frequency light sources for laser-based absorption spectroscopy in the important mid-IR region [2-5]. The application of cw and pulsed single frequency QC-DFB lasers to the sensitive detection of CH_4, N_2O, NO, C_2H_5OH (ethanol) and different isotopic species of H_2O in ambient air will be reported. In order to determine the ethanol concentration from its dense infrared spectrum, a new approach based on a linear correlation technique was applied.

A commercial multipass cell aligned for a 100 m optical path was used. The pressure in the cell was set to 20-40 Torr. A "zero-air" background subtraction technique [6] was also used to enhance the detection sensitivity to the ppb concentration level. Spectra of ambient air and a pollutant-free "zero air" were alternatively taken with the sequential subtraction of the zero-air signal from the ambient air signal. In some measurements, pure air with an addition of 5% CO_2 was used as a zero gas. The laser radiation was detected with a liquid nitrogen cooled photovoltaic MCT detector. The QC laser frequency was rapidly tuned with current at a 100 to 1000 Hz repetition rate with a variable duty cycle. In experiments with a near-room temperature pulsed QC laser, 7 to 10 ns current pulses were applied to the laser. Fast frequency tuning was obtained using a sub-threshold ramped current, as in Ref. 5. A pulsed QC laser shows a line broadening caused by frequency chirping due to the pulsed drive current. The narrowest laser linewidth obtained had a FWHM of 0.016 cm^{-1} (480 MHz).Frequency scans were typically over a 2 cm^{-1} range for cw and 0.25 cm^{-1} for pulsed operation. In a pulsed mode, longer continuous frequency scans were also achieved with the QC laser temperature tuning in -15˚C to +15˚C range (~0.09 cm^{-1}/˚C).

Absorption spectra of ambient air obtained with cw and pulsed QC-based gas sensors will be reported. The best estimated sensitivity is 2.5 ppb for CH_4, 1.0 ppb for N_2O, 2 ppb for NO, 63 ppt for H_2O and 125 ppb for C_2H_5OH.

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