

Tunable quantum cascade laser based sensor for ethylene monitoring

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Abstract: Ethylene monitoring is important in atmospheric chemistry, medical diagnostics, biology and agronomy. A tunable quantum cascade laser spectrometer has been developed to measure ethylene concentrations in the 10 μm region. The laser is thermoelectrically cooled and operates in a pulsed mode. A sensitivity of 5ppm with a 1 meter path length has been demonstrated.

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The monitoring of ethylene concentrations at the ppm and sub ppm (parts per million) levels is important in a number of gas sensing applications. For example, ethylene is a polluting volatile organic compound involved in atmospheric chemical processes that impact anthropogenic climate changes [1, 2]. Ethylene detection is also effective in non-invasive medical diagnostics. It is present in both exhaled air and releases by the skin and its concentration level can serve as a potential disease indicator [3]. Furthermore, ethylene acts as a plant hormone and is involved in fruit ripening. Hence, ethylene monitoring is of particular interest in biology and agronomy [4].

In the work to be reported in this presentation a tunable Quantum Cascade Laser (QCL) spectrometer has been used to record high-resolution absorption spectra of ethylene in the 8-12 μm atmospheric window, which is relatively interference free of water vapor lines. Specifically, a doublet of lines at 993.367380 and 993.368441 cm^{-1} in the ν_7 ro-vibrational transition band of ethylene was selected [5]. The laser operates in a pulsed mode at quasi-room temperature. It offers good selectivity (line width of ~ 200 MHz), a high peak power, and a high repetition rate (optimum 300kHz) for fast data acquisition. The laser frequency is tuned over the ethylene lines by the addition of a linearly increasing sub-threshold current to the train of nanosecond pump pulses. This current produces temperature variation of the active laser region [6].

The ethylene sensor consists of the QC laser source, a sampling gas cell, and a mid-infrared MCT detector with a 1 mm^2 sensitive area, followed by a gated integrator. The cell is 21 inches length (0.53m) and outfitted with ZnSe Brewster windows. An operating pressure in the 40-70 torr range was selected in order to obtain an absorption line width that is comparable to the QC laser linewidth. Pulse generation, laser tuning and signal acquisition are controlled by a laptop via a PCMCIA multifunction card (National Instruments) and a LabView based software.

With this sensor configuration we achieved to-date a 10 ppm detection limit of ethylene diluted in pure nitrogen. As long as the self-broadening remains insignificant, the absorbance, at a given pressure and temperature, depends only on the product of the concentration and the path length. For example, the minimum C_2H_4 detection level can be extrapolated to 50 ppb for a 100 meters optical multi-pass cell.

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