Chemical Sensors based on Quantum Cascade Lasers

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Abstract

Quantum cascade lasers operating in the 3.5 to 24 micron spectral range can be used for trace gas detection in ambient air based on absorption spectroscopy. Recent advances in spectroscopic detection techniques have been employed to achieve minimum detectable absorption coefficients of 10^{-9} cm^{-1} in several real world applications.

Summary

The vast majority of gaseous chemical substances exhibit fundamental vibrational absorption bands in the mid-infrared spectral region from ~500 to 3700 cm^{-1} and the absorption of light by these fundamental bands provides a nearly universal means for their detection. This talk will focus on the development of compact, highly sensitive and selective trace gas sensors based quantum cascade lasers for the detection and quantification of several key trace gas species addressing important analytical instrumentation needs in atmospheric chemistry, environmental monitoring, urban and rural emission measurements, chemical analysis and industrial process control as well as medical and biomedical applications. The use of quantum cascade lasers will permit to target strong fundamental rotational-vibrational transitions in the mid-infrared, which are one to two orders of magnitude more intense than overtone transitions in the near infrared.

Novel pulsed and cw quantum cascade distributed feedback (QC-DFB) lasers fabricated by band structure engineering and grown by molecular beam epitaxy offer an attractive new radiation source for mid-IR and far infrared laser absorption spectroscopy in the 3.5 to 130 μm spectral range. The most technologically developed system to date is based on intersubband transitions (type-I QC) in InGaAs/InAlAs heterostructures [1].More recently, interband cascade (type –II IC) lasers operating in the 3.3 to 4.2 μm spectral region have been demonstrated and applied to the detection of CH_4 at ~ 3.47 μm. [2]

The architecture and performance of several sensitive, selective and real-time gas sensors based on mid-infrared cw and pulsed QC-DFB lasers will be described. To date we have detected 10 gases (CH_4,

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N_2O, CO_2, CO, NO, H_2O, NH_3, C_2H_4, COS and C_2H_5OH as well as isotopic species of some of them at the ppm to the ppt level [3,4]. This requires different sensitivity enhancement schemes such as a multipass gas absorption cell, cavity ring down spectroscopy , off axis integrated cavity output spectroscopy and photo-acoustic absorption spectroscopy which can realize minimum detectable absorbances in the range from 10^{-4} to 10^{-5}.

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