Sensors for chemical analysis of trace gases based on widely tunable Quantum Cascade Lasers

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The recent development of trace gas sensor technology based on the use of widely tunable, single frequency, continuous-wave (cw), thermoelectrically cooled (TEC) quantum cascade lasers (QCLs) will be reported. This technology now permits the detection and quantification of molecular gas species with both resolved and unresolved absorption bands in the mid-infrared as well as the monitoring of multiple gas species for applications in such diverse fields as in environmental monitoring, industrial process control, medical diagnostics and homeland security [1].

Several specific QCL designs have addressed this issue [2-5]. An external cavity (EC) configuration is used to obtain single mode operation at any wavelength within the active medium gain profile. A widely tunable QCL source based on a novel EC-QCL architecture [6] was recently demonstrated with cw TEC QC gain chips operating at 5.2 and 8.6 μm. The EC QCL configuration employs a piezo-activated cavity mode tracking system for mode-hop free wavelength scanning. The mode-tracking system provides independent control of the EC length, diffraction grating angle and laser current. To-date using a 5.2 μm QCL gain medium a coarse laser frequency tuning range of ~ 155 cm^{-1} as well as continuous mode-hop free tuning range of up to 2 cm^{-1} with a maximum available optical power of ~ 11mW was demonstrated. Wide wavelength tunability and a narrow laser linewidth of < 30 MHz, which allowed resolving spectral features separated by less than 0.006cm^{-1} makes this EC-QCL based light source ideally suitable for high resolution spectroscopic applications and multi-species trace-gas detection. The recent availability of a MOCVD grown buried heterostrusture QC gain medium operating at 8.6 μm [7] resulted in single mode laser frequency tuning range of 135 cm^{-1} with a maximum cw output power of ~50 mW. An application of a broadly tunable EC-QCL for single and multi-species quartz enhanced photoacoustic spectroscopic (QEPAS) detection at the ppb-level will be reported for two molecules with unresolved rotational structure and overlapping broadband absorption features at 1208.62 cm^{-1}: Freon 125 (C_2HF_5), a convenient safe simulant for toxic chemical and biological agents, and acetone (CH_3COCH_3), a recognized biomarker for diabetes.

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