Recent advances of widely tunable quantum cascade laser technology for chemical sensing applications

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This talk will focus on the recent development of compact, novel trace gas sensor technology based on the use of widely tunable, single frequency, continuous-wave (cw), thermoelectrically cooled (TEC) quantum cascade lasers (QCLs). This technology now permits the detection and quantification of both small and large molecular gas species with resolved and unresolved spectroscopic features respectively 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, which include: 1) a bound-to-continuum QC laser design reported in Ref. [2] and further developed for wide single mode frequency tuning spectroscopic applications [3] and 2) a heterogeneous QC structure reported in Ref. [4]. Bound-to-continuum QC lasers have an intrinsically broader gain profile because the lower state of the laser transition is a broad continuum. A luminescence spectrum of 297 cm^{-1} FWHM (full width at half maximum) at room temperature was observed for $\lambda \approx 10$ µm QCL devices [3]. Even broader gain profiles with FWHM of ~ 350 cm^{-1} were achieved by combining both concepts in a heterogeneous quantum cascade active region structure based on two bound-to-continuum designs emitting at 8.4 and 9.6 µm [5]. To take advantage of the broadband gain of such QCLs, an external cavity (EC) configuration is used to obtain single mode operation at any wavelength within the laser gain profile. A widely tunable QC laser source based on a novel external cavity (EC) QCL architecture [6] was recently demonstrated with two cw TEC Fabry-Perot QCL gain chips operating at ~ 5.2 and 8.6 µm, respectively. The EC QCL configuration employs a piezo-activated cavity mode tracking system for truly 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 QCL gain media at 5.2 µm a coarse laser frequency tuning range of ~ 55 cm^{-1} as well as a high resolution continuous mode-hop free tuning within a range of 1.2 cm^{-1} with a maximum available optical power of ~ 1mW 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 to be reported 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 Fabry-Perot QCL gain medium operating at 8.6 µm [7] resulted in single mode laser frequency tuning of 135 cm^{-1} with a maximum optical cw power of ~50 mW. An application of a broadly tunable EC-QCL for quartz enhanced photoacoustic spectroscopic (QEPAS) multispecies detection at ppb-levels will be reported for a mixture of two broadband absorbers (acetone and Freon 125) with overlapping absorption spectra at 1208.62 cm^{-1}.

References

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