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Multi-Wavelength and Nonlinear Quantum Cascade Lasers

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Quantum Cascade (QC) lasers are a rapidly evolving mid-infrared technology well suited for chemical sensing applications. For sensing of trace gas mixtures, large molecules, or liquids, probing at a single wavelength is often not sufficient, but the analyte must be sampled at various wavelengths. Here, we will discuss various means of providing multi-wavelength emission from QC lasers. Four different routes are currently being investigated. First, the active waveguide core of a QC laser can be subdivided into substacks of different active regions, hence allowing for multi-wavelength emission. We will discuss the design optimization procedures employed to develop a multi-wavelength laser module with several wavelengths covering the $7-13$ μm wavelength range. Second, QC lasers can be designed to emit different wavelength light when operated at different (positive or negative) bias settings. We have recently developed such a QC laser capable of emitting at ~ 8 and ~ 11 μm. Third, nonlinear QC lasers that in addition to QC laser active regions also include nonlinear mixing regions emit light not only at the fundamental frequency, but also at nonlinear frequencies. Second harmonic generation with up to 2 mW of nonlinear light has recently been demonstrated. Finally, QC lasers with very broad gain spectra can in principle be used to tune over significant wavelength ranges using an external cavity. A key component for such tunability is a low reflectance laser facet to suppress laser action based on feedback from the laser facets. We will show approaches to facet reflection reduction through sub-wavelength facet patterning. This work is supported through collaboration with Pacific Northwest National Labs / Battelle by DARPA L-PAS, the DOE, and the NSF ECS-0400615. This work is being conducted in collaboration with A. Dirisu, S.S. Howard, Z. Liu, O. Malis, G. Shu, D.L. Sivco, and F. Toor.