Miniaturized External Cavity Quantum Cascade Lasers for Broad Tunability in the Mid-Infrared

Timothy Day, David Arnone, Salvatore F. Crivello, and Miles J. Weida
Daylight Solutions, Inc., 15029 Daniels St., Foway, CA 92064
Author e-mail address: tday@daylightsolutions.net

Abstract: A room-temperature, grating-tuned external cavity quantum cascade laser is demonstrated. The use of miniaturized components leads to superior performance (8.3 to 9.0 um tuning) and facilitates the development of a robust commercial module.

The mid-infrared (IR) portion of the spectrum from 3 to 12 um offers important opportunities for commercial applications ranging from chemical detection [1] to medical imaging [2]. To date, however, there does not exist a class of commercial lasers that can operate at room temperature and provide broad tunability throughout the mid-IR. It has been recognized [1, 3] for some time now that quantum cascade lasers (QCLs) are a viable semiconductor technology for making tunable mid-IR lasers. Still, QCLs are only just being produced to operate continuous wave (CW) at room temperature, and the only commercial options for tunable QCLs are based on distributed feedback (DFB) technologies that provide limited thermal tuning [3].

The underlying gain medium in QCLs has sufficient gain bandwidth [3, 4] for use in a tunable external cavity laser configuration. Such a configuration has been extremely successful in creating broadly tunable near-IR semiconductor lasers based on diodes as gain media [5]. Several studies[4, 6, 7] have demonstrated that quantum cascade (QC) gain media can be used effectively in an external cavity configuration with grating feedback to provide tunability of 50 to 100 cm⁻¹.

There remain significant technical challenges, however, before grating-tuned external cavity QCLs can be made into commercial products. For example, high quality antireflection (AR) coatings on QC materials are not yet available for the mid-IR. The AR coatings used in the above studies were suboptimal, and were easily damaged by thermal cycling [7]. Furthermore, some of the AR coatings used in these studies, such as Al₂O₃, are not even transmissive for wavelengths longer than 6 um. There are also no commercially available mid-IR optics comparable to the high quality miniature aspheric lenses available in the visible and near-IR. The use of such aspheres makes it possible to create a miniature external cavity with optimal length for optical feedback properties. The above studies all relied on larger, commercially available optics that resulted in suboptimal cavity sizes. Finally, the commercialization of external cavity QCLs will require a rugged opto-mechanical assembly that is immune to the effects of vibration and temperature encountered in field operations. Once again, miniaturization of the cavity and components has proven to result in extremely rugged lasers for field use in the near-IR [8].

In this paper we address each of these aspects in the construction of a miniaturized external cavity QCL. New QC material AR coating techniques are described. The development of miniature mid-IR aspheres is discussed. The incorporation of these elements in a miniature external cavity laser is described. Finally, the performance of the laser is discussed.

References