

QC Lasers

The Quantum Cascade Laser (QCL), which is about the size of a pin head, operates on a principle whereby electrons cascade down a series of quantum wells, which result from the growth of very thin layers of semiconductor material.

Whereas a single electron-hole recombination can only ever produce a single photon, the quantum cascade laser electron can cascade down between 20 and 100 quantum wells producing a photon at each step. This electronic waterfall provides a step change in performance in terms of lasing efficiency enabling QC lasers to emit several watts of peak power in pulsed operation and tens of milliwatts CW.

The lasing wavelength for QCL's is determined not by the choice of semiconductor material as with conventional lasers, but by adjusting the physical thickness of the semiconductor layers themselves. This removes the material barriers commonly associated with conventional semiconductor laser technology and opens up the possibility of near-infrared through to THz spectral coverage.

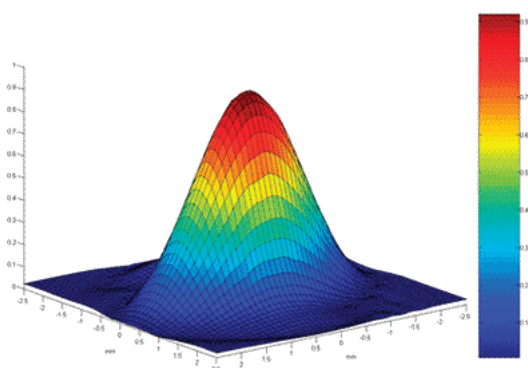


Figure 1. Beam profile for a 10.2 μm Quantum Cascade Laser after processing through Cascade Technologies' ZnSe colimating optics

For the first time an infrared spectroscopic laser source, which has no need for cryogenic cooling, high output powers, large spectral coverage, excellent spectral quality and good tuneability has become a reality.

Technology implementation

The practical implementation of QCL's started in the late 1990's with industry eager to harness the power of a spectroscopic source spanning the full spectrum of the technologically significant mid-IR wavelengths (3 - 25 μm). Researchers at Cascade Technologies have been at the forefront of this development, generating novel patented techniques, enabling the performance of the QC laser to be maximised as a spectroscopic tool for industrial gas sensing.

One such technique, known as Intra pulse spectroscopy, uses the laser in pulsed mode to facilitate its use over the wide range of environmental conditions typically associated with industrial monitoring. Pulsing the laser for up to a microsecond at a time causes

instantaneous localised heating within the device, which results in a large frequency chirp. This chirp is harnessed to provide a near instantaneous frequency sweep through many spectroscopic features of interest.

This rapid sweep combined with high duty cycles provides the technology with many key advantages. These include:

- Up to a million measurements a second
- Sub-parts per Billion Sensitivity
- Room Temperature Operation
- Multiple Gases Simultaneously
- No Consumables

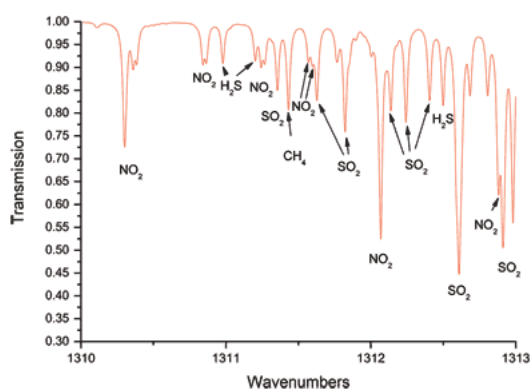


Figure 2. A QCL transmission spectrum, which demonstrates simultaneous measurement of gases including NO₂, SO₂, H₂S and CH₄. (click image to enlarge)

In addition, the ultra fast chirp rate can also be used in conjunction with careful optical design to prevent laser feedback noise and optical fringing, which tends to be the most common noise floor for most practical implementations of optical spectrometers. The removal of this noise floor, without the need of complex fringe removal techniques or expensive optical isolators, enables the laboratory performance of this technology to be easily transferred to real world applications.

These advances in both QC laser technology and spectrometer hardware when combined with novel spectroscopic techniques such as intra pulse spectroscopy offer not simply a small improvement on other methods of gas detection but provide a major step change in sensitivity, speed of operation, fingerprinting capability, size and cost.

Perhaps one of the biggest steps towards achieving significant penetration, however, will come from the recent advances in spectrometer hardware. The development, at Cascade Technologies, of novel QC gas sensors, which exploit recent technological advances including miniaturized integrated electronic systems, plug and play interfaces and micro optics, will progressively replace the unwieldy, fragile and expensive instrumentation of the past.