New directions in quantum cascade laser applications: from optofluidic lasers to plasmonic laser antennas

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Quantum cascade lasers are rapidly becoming a mature technology in terms of device design and performance levels. However, there are still major opportunities in adding new functionalities that can significantly increase their range of applications.

In this talk, I will describe the new directions in QCL research in F. Capasso’s group: optofluidic lasers, based on intracavity microfluidic delivery, for a new lab-on-a-chip (chemical sensing of fluids and of analytes carried by the latter), plasmonic laser antennas, i.e., a new generation of mid-infrared light sources capable of creating high intensity subwavelength (~λ/20) size spots in the near field for spatially resolved absorption spectroscopy and chemical analysis, and our recent research efforts in Terahertz spectral range.

**Optofluidic lasers.** The demonstration of the first electrically pumped photonic crystal laser has opened the door to a new generation of “holey” lasers. We have designed and fabricated two classes of structures. In the first one, row holes are drilled using focused ion beam below and above the active region. Simulations show that this strongly coupled distributed feedback lasers can produce substantial wavelength tuning as different fluids are circulated through the structure. In the second type, a 2D photonic crystal defect cavity is defined on the facet of QC laser chip. The high Q will enhance the sensitivity of the laser. Note that in the above structures the laser itself acts simultaneously as the light source, the analysis chamber and the detector (by detecting changes in the laser characteristics). Simpler optofluidic DFB QCLs encapsulated in a polymeric enclosure for microfluidic injection and their tuning with fluids will also be discussed.

**Plasmonic laser antennas.** I will review our recent work on a new surface plasmon device that consists of a resonant optical antenna integrated onto the facet of a commercial diode laser, termed a plasmonic laser antenna. This device allows intense and spatially confined optical fields to be generated in the near-field zone. Spot sizes of 30 nm have been measured at a wavelength ~0.8 µm using aperture-less NSOM (E. Cubukcu, et al., Appl. Phys. Lett., in press). This device can be implemented in a wide variety of semiconductor lasers emitting in spectral regions ranging from the visible and the near infrared to the mid- and far-infrared. I will describe ongoing work on the development of optical antennas defined on the facet of high quality QCLs grown by MOVPE.

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