Stevens Institute of Technology

Nanotechnology Graduate Program

Quantum Cascade Lasers

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Professor Claire Gmachl

Department of Electrical Engineering and MIRTHE, Princeton University

Quantum Cascade (QC) lasers are a rapidly evolving new type of semiconductor laser that emits in the mid-infrared to terahertz range of the spectrum. The active material of the lasers consists of many hundreds of alternating, only few atomic layers thick semiconductor layers. By choice of the layer thicknesses, the laser properties – foremost the emission wavelength – can be tailored essentially at will. Therefore, one can use mature semiconductor materials that have been developed over many decades of telecommunications R&D, and create new laser sources at wavelengths between 3 and 300 μm. Aside from their considerable wavelength tailorability, the lasers' key strengths include high optical power, high operating temperature, inherent compactness and reliability, and a fascinating design potential.

We will first provide an easy and illustrative introduction into QC lasers, followed by specific laser aspects for select applications. The latter include foremost chemical trace gas sensing, as well as infrared counter measures and free-space optical communication.

In the second part of the presentation, we will discuss an example of how the lasers continue to hold surprises, and how these are harnessed to design better and more functional lasers. In so-called "cascaded" QC lasers, laser action can be induced in portions of the laser bandstructure that is generally not accessible to all conventional semiconductor lasers.

Claire Gmachl received the Ph.D. degree (sub auspicies praesidentis) in electrical engineering from the Technical University of Vienna, Austria, in 1995. In 1996, she joined Bell Laboratories, Lucent Technologies, Murray Hill, NJ, as Post-Doctoral Member of Technical to work on Quantum Cascade laser devices and microcavity lasers. In March 1998 she became a Member of Technical Staff in the Semiconductor Physics Research Department and a Distinguished Member of Staff in 2002. In September 2003, Gmachl joined Princeton University as an Associate Professor in the Department of Electrical Engineering and adjunct faculty to PRISM; since July 2007 she is Full Professor at Princeton University. Her group's research is centered around mid-infrared photonics, especially high performance and innovative Quantum Cascade lasers, semiconductor band-structure engineering, and novel materials for the mid-infrared Gmachl is the Director of MIRTHE, the NSF Engineering Research Center on Mid-InfraRed Technologies for Health and the Environment. This six-university research center develops mid-infrared trace-gas sensors for applications in the environment, health, and security through a cross-disciplinary approach that spans from applications and policy, and systems engineering, to material science. Gmachl has co-authored more than 170 publications, has given more than 100 presentations at conferences and seminars, and holds 26 patents. She is an Associate Editor for Optics Express and a member of the IEEE/LEOS Board of Governors. Gmachl is a 2005 MacArthur Fellow.

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