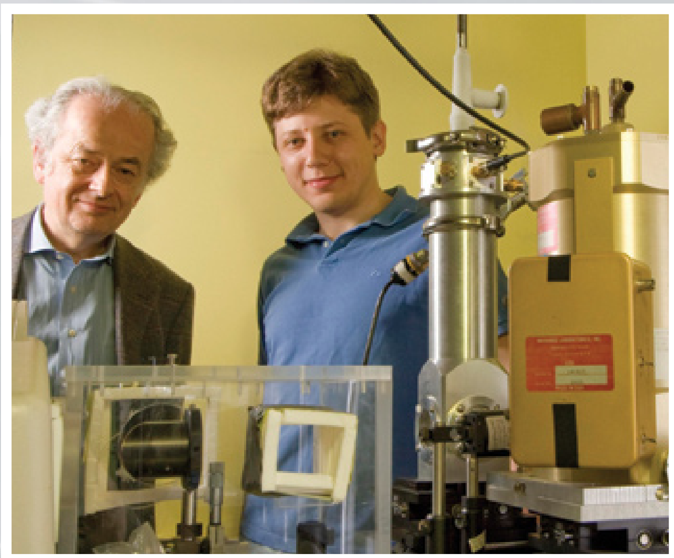
First Electrically Pumped Semiconductor Room-Temperature Terahertz Radiation

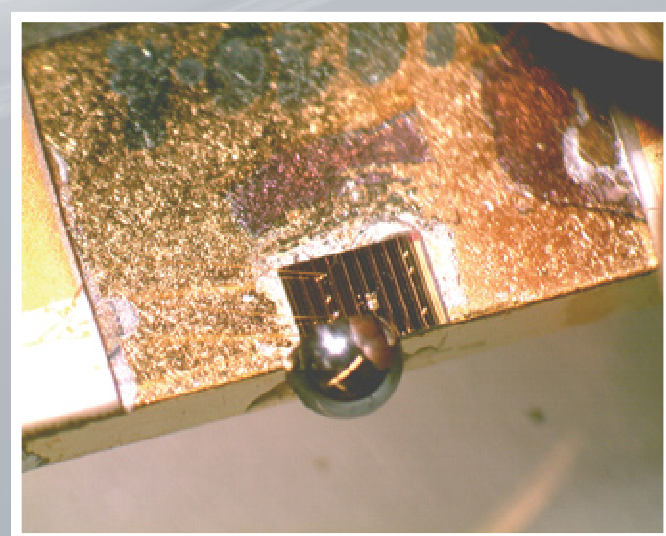
Accomplishment: The first room-temperature electrically pumped semiconductor source of Terahertz radiation was demonstrated using quantum cascade semiconductor lasers. Beams with power levels sufficient for a number of applications were demonstrated.



Impact: Terahertz imaging and sensing is a promising but relatively new technology for imaging of concealed weapons, detecting chemical and biological agents through sealed packages and spotting defects within materials. The devices developed and tested here are an important first step toward requirements for compact, portable and tunable sources of terahertz rays.

Motivation and Approach: The ability of Terahertz rays (T-rays) to penetrate efficiently through paper, clothing, cardboard, plastic and many other materials makes them ideal for imaging of concealed weapons, detecting chemical and biological agents through sealed packages, seeing tumors without harmful side effects, and spotting defects within materials such as cracks in the space shuttle foam. Existing terahertz devices require cryogenic cooling, greatly limiting their applications by increasing system size and complexity and restricting portability. There were previously no compact terahertz devices that could operate at room temperature, or even with simple thermoelectric cooling.

To overcome these serious limitations, a specially-designed room temperature mid-infrared quantum cascade laser was built and tested. Quantum cascade lasers consist of alternating layers of semiconductor materials that are a few nanometers thick. These commercially available lasers are small (a few millimeters in length) and the wavelength of the emitted laser light can be selected over an extremely wide spectral range by choosing the thickness of the semiconductor layers. The laser developed here was designed to generate light at two frequencies simultaneously, which then mix in the active region of the device to emit coherent light at their difference frequency of 5 Terahertz. Beams can be produced with several hundreds of nanowatts of power at room temperature and microwatts of power at temperatures easily achievable with commercially available thermoelectric coolers, which is sufficient for a number of applications.



Team: This research was conducted by Prof. Federico Capasso and Dr. Mikhail Belkin at Harvard University, Prof. Alexey Belyanin and Feng Xie at Texas A&M University and Prof. Jérôme Faist, Milan Fischer and Andreas Wittmann of the Institute of Quantum Electronics, ETH, Zürich, Switzerland. This research was funded in part by the Air Force Office of Scientific Research (Dr. Gernot Pomrenke, Program Manager).