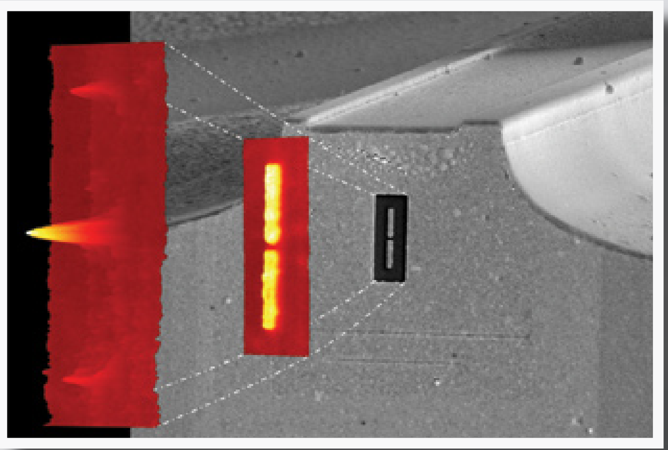
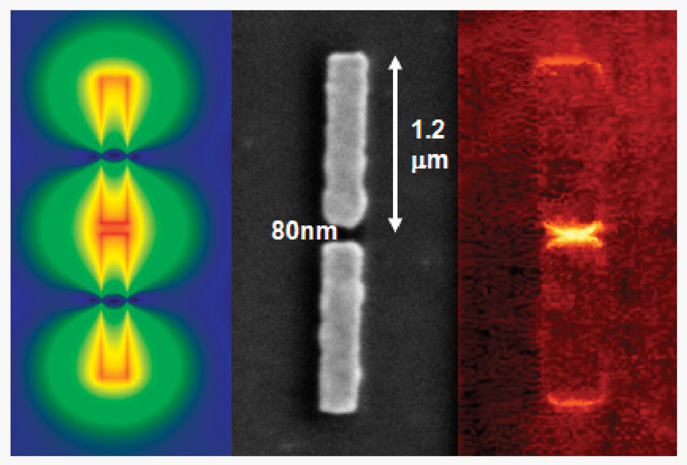
Quantum Cascade Laser Nano-Antenna for Future Identification of Biological Threats

Accomplishment: A simple, compact approach to concentrate infrared laser light to a spot size of roughly 100 nanometers was conceived and demonstrated. This may enable chemical mapping with a spatial resolution that is 50-100 times better than conventional infrared microscopes.



Impact: Among the long term applications suggested by the high spatial resolution of this device is the identification of biological threats such as spores, bacteria and cells. This device also suggests the possibility of broadband spectral coverage, which might be useful to identify complex, heavy molecules such as those in toxic chemicals, explosives, and drugs.



Motivation and Approach: Biological materials have specific absorption profiles in infrared light, and so they can be uniquely identified with a chemical composition map obtained by scanning a spot of infrared light and measuring the transmitted light. A spatial resolution of one micron or less is needed to resolve spores and bacteria and to identify separate features of cells, but the spatial resolution of infrared microscopes is limited by the physics of optics to no less than the wavelength of the infrared light used, about 4 to 10 microns. Additionally, accurate chemical determination requires more than one wavelength of infrared light, but current infrared microscopes, especially those with the best spatial resolution, cannot provide the needed wavelength coverage.

The present innovation deposits a nano-antenna on the face of a quantum cascade laser to overcome a major obstacle of infrared microscopes for chemical mapping with high spatial resolution. Quantum cascade lasers consist of alternating layers of semiconductor materials that are typically a few nanometers thick. These lasers are small (a few millimeters in length), can be designed to produce light over the full infrared spectrum, and are commercially available. The nano-antenna consists of two aligned gold rectangles, each having a length about half the wavelength of the infrared light, separated by a gap of roughly 100 nanometers. The gold nano-rods concentrate the laser light in the antenna gap to produce an intense, localized light source that is 50-100 times smaller than the typical spot size in conventional infrared microscopes. Submicron resolution of biological samples may now be possible with this quantum cascade laser/ nano-antenna assembly.

Team: This research was led by Prof. Federico Capasso, with contributions from Prof. Kenneth Crozier, Dr. Mikhail Belkin and Dr. Laurent Diehl (all at Harvard University), and from Dr. David Bour, Dr. Scott Corzine, and Dr. Gloria Höfler, formerly with Agilent Technologies. This research was funded in part by the Air Force Office of Scientific Research (Dr. Gernot Pomrenke, Program Manager).