Graphene plasmons used to create tunable terahertz laser

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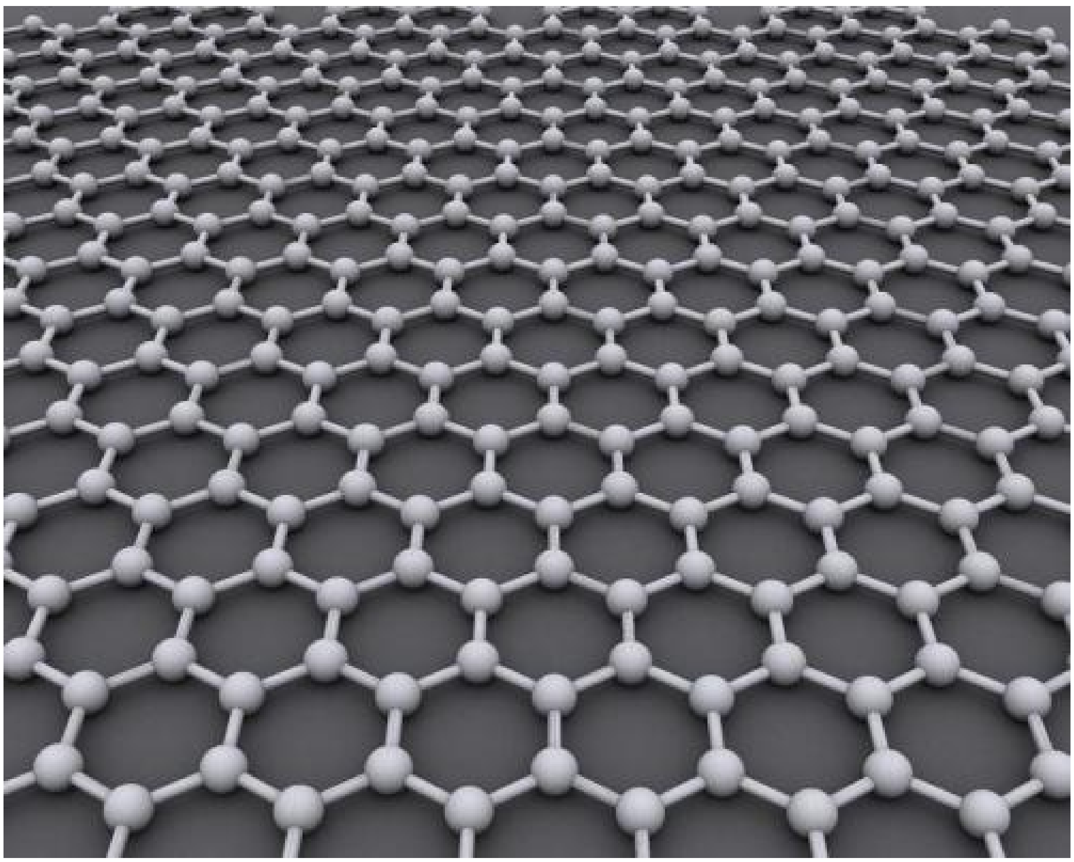

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(Phys.org)—A team of researchers working at the University of Manchester in the U.K has developed a tunable teraherz laser using the unique properties of graphene plasmons. In their paper published in the journal *Science*, the group describes their approach, the four prototypes they produced, how well the lasers worked and the direction they plan to take to fashion the new technology into a usable device. Marco Polini with Istituto Italiano di Tecnologia, gives a Perspective piece on the work done by the team in the same journal issue and offers some comments regarding where the technology may lead.

A laser that works in the terahertz range would be useful in a variety of applications due to the ability of its beam to pass through such things as clothes or coverings on packages. Such lasers have been created, but thus far they have only produced a fixed wavelength, limiting their practicality in real-world use—that may change however, as the team with this new effort has found a way to create a terahertz laser that can be tuned on the fly.

To build the new laser, the team looked to using a sheet of graphene as a replacement for metals in the laser, because its wavelength can be altered by placing it in an electric field. They started by placing a series of quantum aluminum gallium arsenide and gallium arsenide wells of varied thickness onto a substrate, which they subsequently covered with a waveguide made of gold. A layer of graphene was then placed on top of the gold layer into which the researchers had cut several slits to force electrons to tunnel between the wells. They covered the sandwich with a polymer electrolyte and used a cantilever as a means for tuning their laser.

The result is a device capable of producing a terahertz beam, but not in a way that could be useable in everyday applications. After producing four prototypes and testing them under various scenarios, the team believes their device, which they describe as a "proof of concept" can be modified to allow for controlling the voltage that is applied to each slit, which would offer much greater control. There is also an issue, Polini points out, regarding the thickness of the polymer—it prevents the tip on the underside of the cantilever from getting close enough to the sheet of graphene to allow for precise control.

More information: S. Chakraborty et al. Gain modulation by graphene plasmons in aperiodic lattice lasers, *Science* (2016). DOI: 10.1126/science.aad2930

Abstract
Two-dimensional graphene plasmon-based technologies will enable the development of fast, compact, and inexpensive active photonic elements because, unlike plasmons in other materials, graphene plasmons can be tuned via the doping level. Such tuning is harnessed within terahertz quantum cascade lasers to reversibly alter their emission. This is achieved in two key steps: first, by exciting graphene plasmons within an aperiodic lattice laser and, second, by engineering photon lifetimes, linking graphene's Fermi energy with the round-trip gain. Modal gain and hence laser spectra are highly sensitive to the doping of an integrated, electrically controllable, graphene layer. Demonstration of the integrated graphene plasmon laser principle lays the foundation for a new generation of active, programmable plasmonic metamaterials with major implications across photonics, material sciences, and nanotechnology.