[Acoustic terahertz graphene plasmons revealed by photocurrent nanoscopy]

Terahertz (THz) fields are widely used for sensing, communication and quality control. In future applications, they could be efficiently confined, enhanced and manipulated well below the classical diffraction limit through the excitation of graphene plasmons (GPs).

These possibilities emerge from the strongly reduced GP wavelength, λp, compared with the photon wavelength, λ0, which can be controlled by modulating the carrier density of graphene via electrical gating. Recently, GPs in a graphene/insulator/metal configuration have been predicted to exhibit a linear dispersion (thus called acoustic plasmons) and a further reduced wavelength, implying an improved field confinement, analogous to plasmons in two dimensional electron gases (2DEGs) near conductive substrates. Although infrared GPs have been visualized by scattering-type scanning near-field optical microscopy (s-SNOM), the realspace imaging of strongly confined THz plasmons in graphene and 2DEGs has been elusive so far—only GPs with nearly freespace wavelengths have been observed. Alonso-González et al., demonstrate real-space imaging of acoustic THz plasmons in a graphene photodetector with split-gate architecture. To that end, they introduce nanoscale-resolved THz photocurrent near-field microscopy, where near-field excited GPs are detected thermoelectrically rather than optically. This on-chip detection simplifies GP imaging as sophisticated s-SNOM detection schemes can be avoided. The photocurrent images reveal strongly reduced GP wavelengths (λp ≈ λ0/66), a linear dispersion resulting from the coupling of GPs with the metal gate below the graphene, and that plasmon damping at positive carrier densities is dominated by Coulomb impurity scattering.

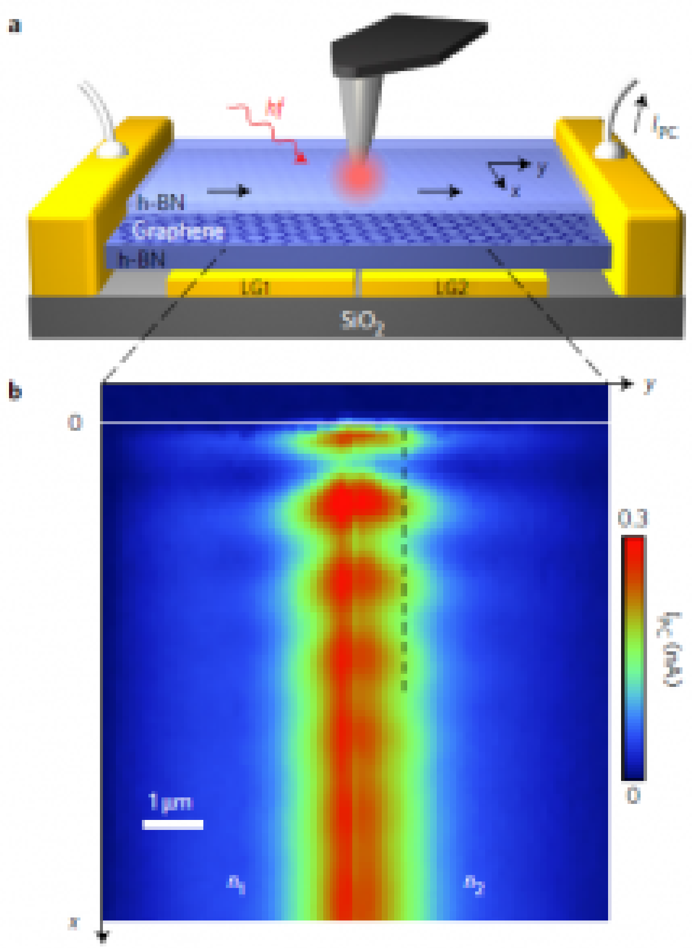


Figure 1 | THz photocurrent nanoscopy of graphene plasmons in a split-gate photodetector. a, Schematics of the experimental set-up. The laser-illuminated metal tip of an atomic force microscope (AFM) serves as a nanoscale near-field light source. The near-field induced photocurrent in the graphene (encapsulated by h-BN layers) is measured through the two metal contacts to the left and right. LG1 and LG2 represent the split gate (gold) used to control the carrier concentration in the graphene to the left and the right of the gap between them. b, Image of the experimental near-field photocurrent, IPC, recorded at f=2.52 THz. The carrier densities were chosen to be n1 = 0.77 × 1012 cm−2 and n2 = −0.71 × 1012 cm−2. The horizontal white solid line marks the edge of the graphene sheet.

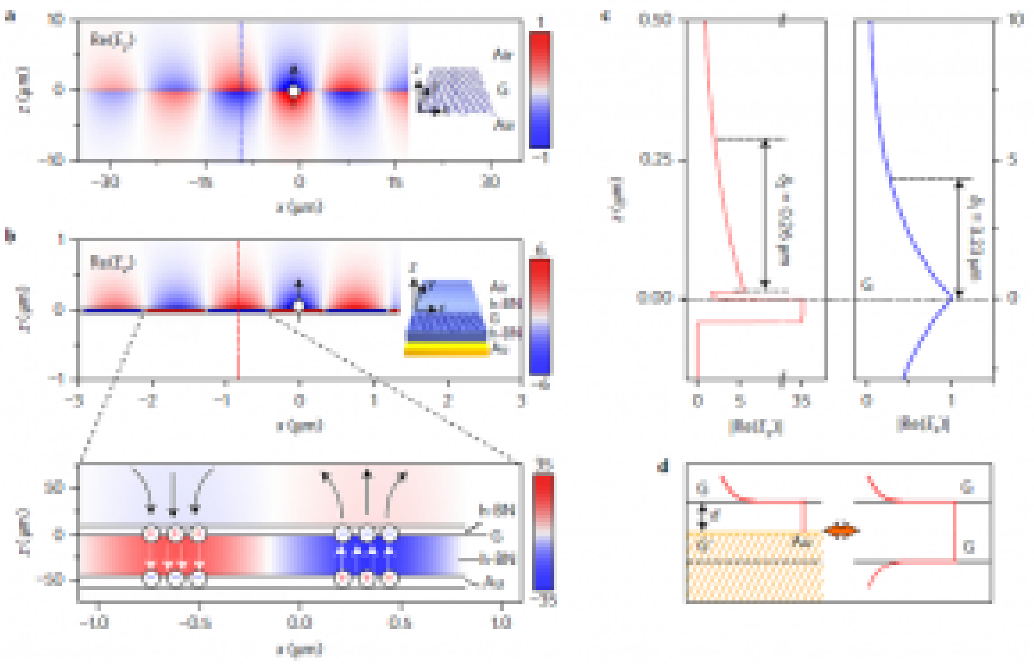
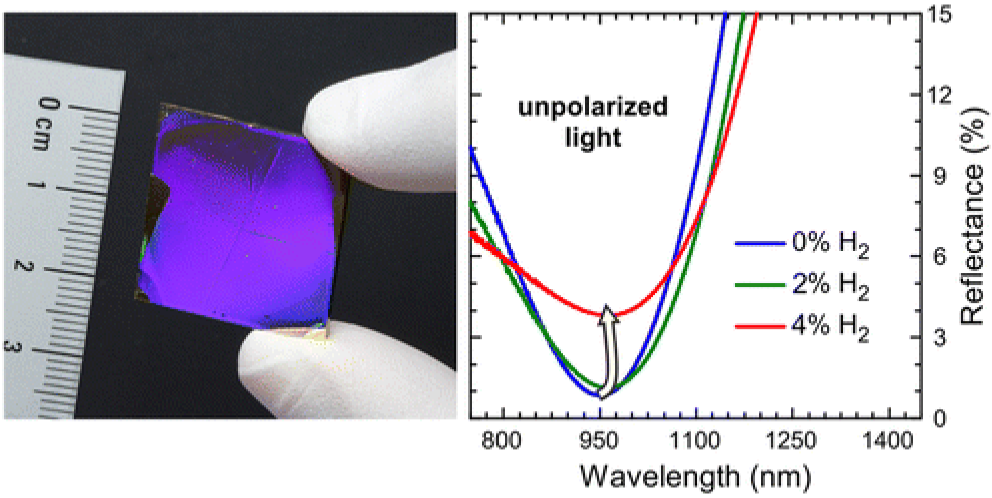


Figure 2 | Near-field distribution of THz graphene plasmons. a,b, Numerical simulations of the near-field distribution of THz graphene plasmons excited by a point dipole source located above a free-standing graphene sheet (air/G/air) (a) and an air/BN/G/BN/AuPd/SiO2 heterostructure (b) assuming the experimental layer thicknesses. The real part of the vertical field component, Re(Ez(x,z)), at a frequency of 2.52 THz is shown for both cases. The + and – symbols in the zoomed-in image in b sketch the charge distribution in graphene and AuPd. c, Near-field profiles |Re(Ez)| perpendicular to the grapheme surface. Left, profile along the dashed red line in b. Right, profile along the dashed blue line in a. Both profiles were normalized to the maximum of |Re(Ez)| on top of a free-standing graphene sheet. d, Schematics of the plasmonic near-field profile for a graphene sheet above a gold surface (left) and for two parallel graphene sheets (right). The distance between the two graphene sheets is twice the distance between the graphene and the gold surface.

Paper reference: http://www.nature.com/nnano/journal/vaop/ncurrent/full/nnano.2016.185.html

News is sent to us by Ms Hosseini.

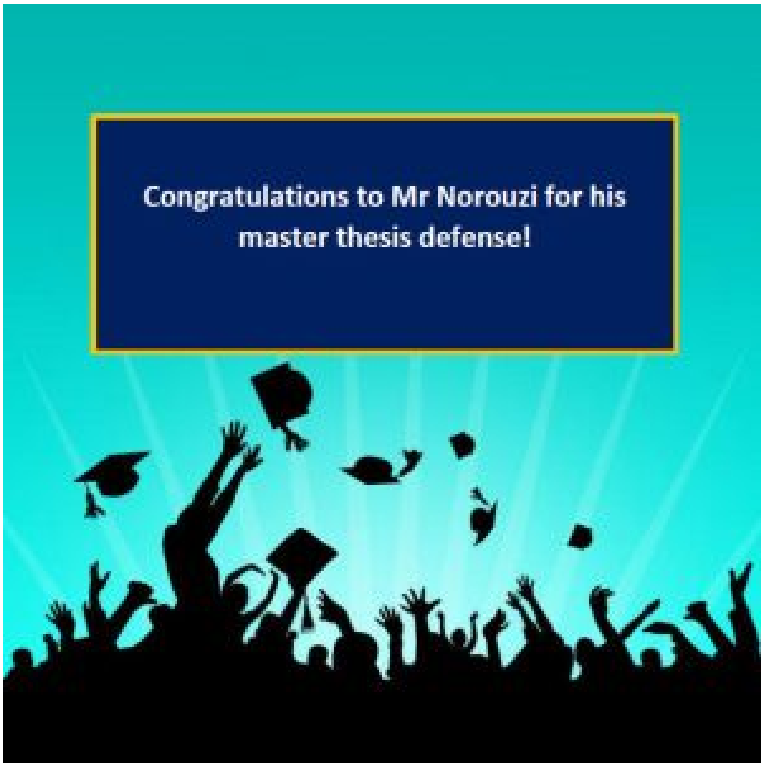
[Large-Area Low-Cost Plasmonic Perfect Absorber Chemical Sensor Fabricated by Laser Interference Lithography]



Bagheri et al. (2016) employ laser interference lithography as a reliable and low-cost fabrication method to create nanowire and nanosquare arrays in photopolymers for manufacturing plasmonic perfect absorber sensors over homogeneous areas as large as 5.7 cm^2. Subsequently, they transfer the fabricated patterns into a palladium layer by using argon ion beam etching. Geometry and periodicity of their large-area metallic nanostructures are precisely controlled by adjusting the interference conditions during single- and double-exposure processes, resulting in active nanostructures over large areas with spectrally selective perfect absorption of light from the visible to the near-infrared wavelength range. In addition, they demonstrate the method's applicability for hydrogen detection schemes by measuring the hydrogen sensing performance of our polarization independent palladium-based perfect absorbers. Since palladium changes its optical and structural properties reversibly upon hydrogenation, exposure of the sample to hydrogen causes distinct and reversible changes within seconds in the absorption of light, which are easily measured by standard microscopic tools. The fabricated large-area perfect absorber sensors provide nearly perfect absorption of light at 730 and 950 nm, respectively, and absolute reflectance changes from below 1% to above 4% in the presence of hydrogen. This translates to a relative signal change of almost 400%. The large-area and fast manufacturing process makes our approach highly attractive for simple and low-cost sensor fabrication, and therefore, suitable for industrial production of plasmonic devices in the near future.

Source: http://pubs.acs.org/doi/abs/10.1021/acssensors.6b00444

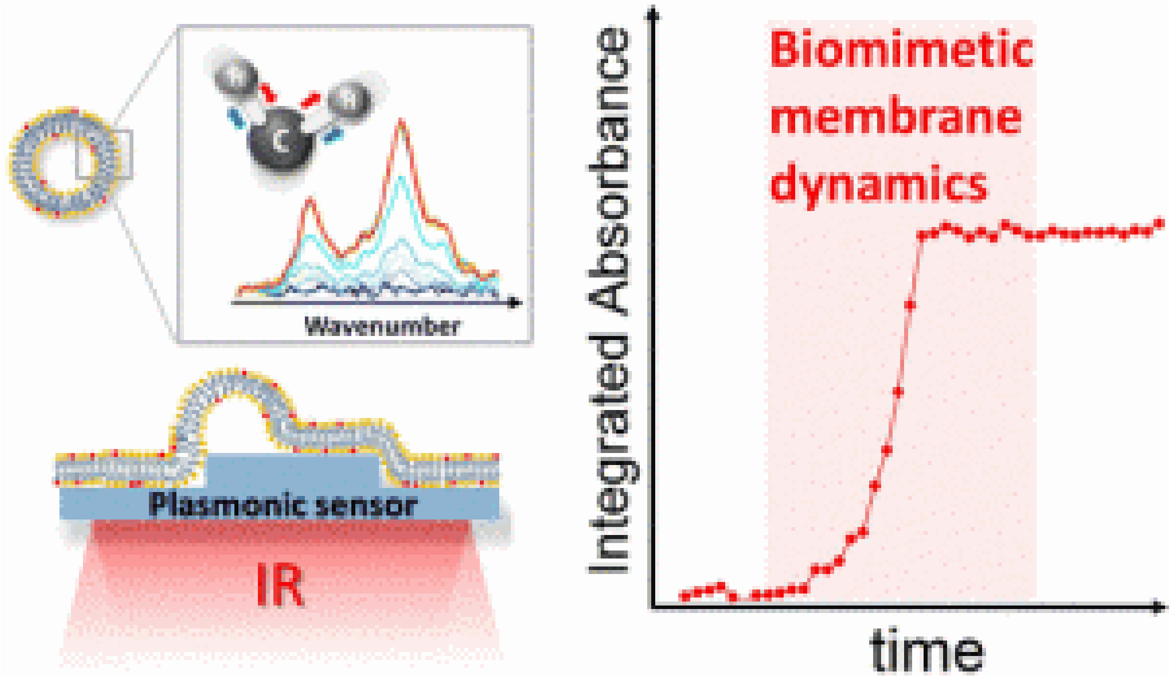
Thesis Defense



Congratulations to Mr Norouzi for his master thesis defense!

- Logo is taken from http://www.hippoquotes.com/graduation-quotes-for-high-school-friends.

[Infrared Plasmonic Biosensor for Real-Time and Label-Free Monitoring of Lipid Membranes]



Odeta Limaj et al., report infrared plasmonic biosensor for real-time and lable-free monitoring of lipid membranes.

In this work, they present an infrared plasmonic biosensor for chemical-specific detection and monitoring of biomimetic lipid membranes in a label-free and real-time fashion. Lipid membranes constitute the primary biological interface mediating cell signaling and interaction with drugs and pathogens. By exploiting the plasmonic field enhancement in the vicinity of engineered and surface-modified nanoantennas, the proposed biosensor is able to capture the vibrational fingerprints of lipid molecules and monitor in real time the formation kinetics of planar biomimetic membranes in aqueous environments. Furthermore, they show that this plasmonic biosensor features high-field enhancement extending over tens of nanometers away from the surface, matching the size of typical bioassays while preserving high sensitivity.

Reference:

Odeta Limaj, Dordaneh Etezadi, Nathan J. Wittenberg, Daniel Rodrigo, Daehan Yoo, Sang-Hyun Oh, and Hatice Altug– Nano

Lett., 2016, *16* (2), pp 1502–1508

DOI: 10.1021/acs.nanolett.5b05316

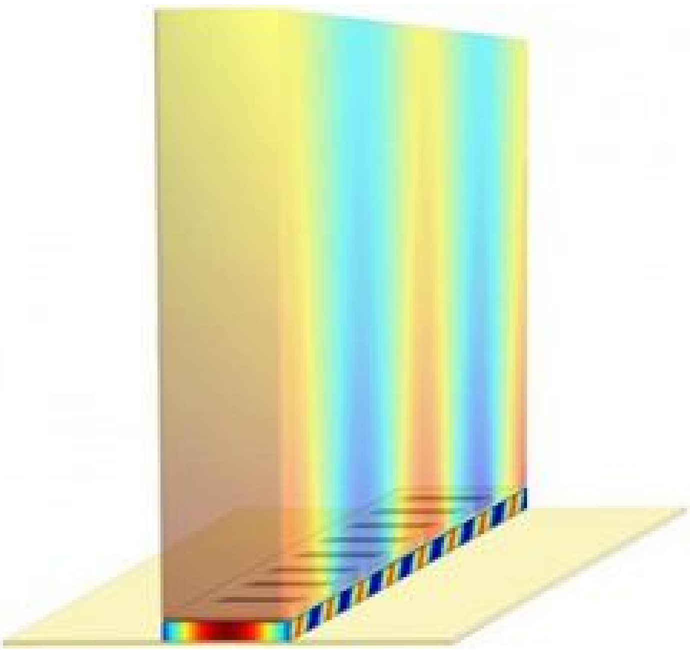
Link address: http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.5b05316

[Plasmonic Lasers Get a Sharper Focus]

RESEARCH NEWS

Plasmonic Lasers Get a Sharper Focus

Stewart Wills



In the Lehigh team's "antenna feedback" approach, the plasmonic-laser cavity is enclosed between two metal films, with periodic slits on the top film. One SPP wave is confined inside the 10-micron-thick cavity; the other, with a larger spatial extent, is located on top of the cavity and coupled both to it and the far field, allowing a strong, narrow-beam emission. [Image: Sushil Kumar]

Lasers based on coherent surface plasmon polaritons (SPPs)—subwavelength oscillations of electrons that are excited when incident light hits a metal-dielectric interface—hold promise for ultraminiaturized, chip-scale optics, and also as a possible platform for terahertz quantum cascade lasers (QCLs). But there's a catch: SPP lasers, precisely because of their subwavelength apertures, tend to have divergent radiation patterns, making it tough to produce a sharp, directional beam.

Now, a research team led by Sushil Kumar of Lehigh University, Penn., USA, has devised an "antenna feedback" scheme that reportedly can provide single-mode operation and strong, highly directional far-field coupling in such SPP lasers, bringing them "closer to practical applications" (Optica, doi:[10.1364/OPTICA.3.000734](https://doi.org/10.1364/OPTICA.3.000734)). The team's work includes a proof-of-concept terahertz QCL based on the scheme that, according to the study, achieved the narrowest beam yet reported for such a QCL.

The pros and cons of "spasers"

SPP lasers—also called plasmonic lasers or "spasers"—operate by confining light energy as coherent SPP oscillations in subwavelength cavities (commonly parallel-plate Fabry-Perot-type cavities in with a length greater than the subwavelength cavity width). Their subwavelength dimensions make these lasers intriguing for certain applications in integrated photonics and nanophotonics. Parallel-plate cavities with SPP modes are also used for terahertz QCLs (which have some interesting potential applications in biosensing and standoff detection of dangerous materials), as they can show low-threshold, high-temperature performance at those frequencies.

It turns out, however, that it’s difficult to extract light from the plasmonic energy trapped in the spaser cavity. And when light can be made to leak out, it tends to be low in power and highly divergent, which limits its usefulness in actual applications.

A plasmonic phased array?

Kumar’s team found a potential solution through a distributed-feedback approach that the team has dubbed “antenna feedback,” and that Kumar compares to the action of phased-array antennas in microwave communication systems. The team demonstrated by numerical modeling that a grating of slits on one side of the subwavelength Fabry-Perot resonator, spaced at a specific value, would allow a single SPP mode within the cavity to diffract outside of the cavity in the surrounding medium, through Bragg diffraction. The energy outside of the cavity builds up with positive feedback (again the result of the selection of the grating period).

As a result, a second intense SPP wave develops in the medium outside of the cavity that remains coupled to the cavity’s metal cladding but also can form a highly directional beam outside of it. “The narrow-beam emission,” the team writes, “is due in part to the cavity acting like an end-fire phased-array antenna at microwave frequencies.”

In a proof of concept, the team implemented the antenna-feedback scheme in a terahertz QCL, using a box-shaped cavity consisting of two 100-µm by 1400-µm metallic plates, separated by a distance of 10 µm. The researchers report that the resulting laser showed a beam divergence as small as 4 degrees by 4 degrees—“the narrowest beam reported for any terahertz

QCL to date," according to the study.

Applications in security and elsewhere

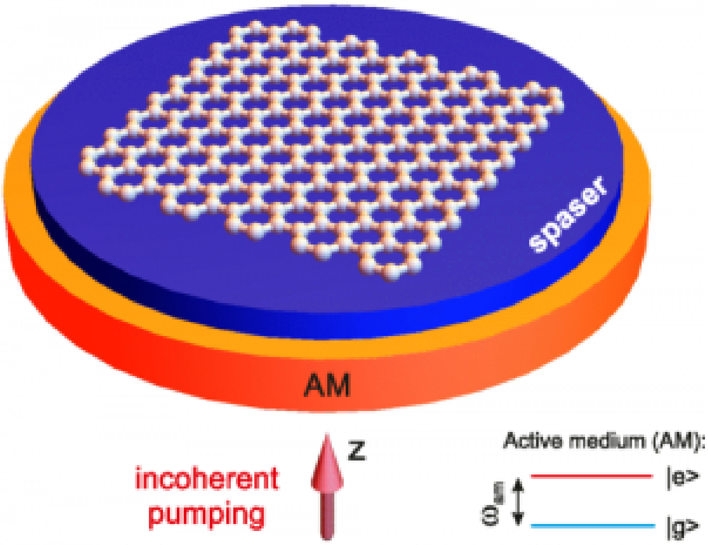
The researchers note that terahertz QCLs in particular have some interesting applications in security and standoff detection. At a recent innovation conference, they pointed out that "approximately 80 to 95 percent of explosives, and all commonly used ones, have unique and identifiable terahertz signatures."

But, while their experiments focused particularly on terahertz QCLs, they stress that the antenna-feedback scheme should be applicable to plasmonic lasers of any operating wavelength that operate with Fabry-Perot cavities. That, in turn, could aid help make other applications of plasmonic lasers, in areas such as nanophotonics, more feasible, according to the scientists.

Publish Date: 14 July 2016

News source: http://www.osa-opn.org/home/newsroom/2016/july/plasmonic_lasers_get_a_sharper_focus/

[Self-consistent description of graphene quantum amplifier]()



The development of active and passive plasmonic devices is challenging due to the high level of dissipation in *normal* metals. One possible solution to this problem is using *alternative* materials. Graphene is a good candidate for plasmonics in the near-infrared region. In this paper, we develop a quantum theory of a graphene plasmon generator. Lozovic et al. account for quantum correlations and dissipation effects, thus they are able to describe such regimes of a quantum plasmonic amplifier as a surface plasmon emitting diode and a surface plasmon amplifier using stimulated radiation emission. Switching between these generation types is possible *in situ* with a variance of the graphene Fermi level. They provide explicit expressions for dissipation and interaction constants through material parameters, and they identify the generation spectrum and the second-order correlation function, which predicts the laser statistics.

DOI:https://doi.org/10.1103/PhysRevB.94.035406

New source: http://journals.aps.org/prb/abstract/10.1103/PhysRevB.94.035406