Graphene plasmons – From electrical detection to full phase control

Achim Woessner[1]
Y. Gao,[2] M.B. Lundeberg,[1] P. Alonso-Gonzalez,[3] I. Torre,[4] C. Tan,[2] R. Hillenbrand,[3] J. Hone,[2] M. Polini,[4] F.H.L. Koppens[1]
1 ICFO-Institut de Ciencies Fotoniques, 08860 Castelldefels (Barcelona), Spain
2 Columbia University, New York, NY 10027, USA
3 CIC nanoGUNE, Donostia-San Sebastián, Spain
4 IIT, Graphene labs, Via Morego 16163 Genova, Italy

achim.woessner@icfo.eu

Controlling, detecting and generating plasmons by all-electrical means are crucial for on-chip nano-optical circuits. Graphene can carry long-lived plasmons that are highly confined and controllable *in situ*.[1] However, electrical detection and full phase control of the of graphene plasmons has thus far been elusive.

We show first how high-resolution near-field photo-current nanoscopy[2] can directly detect and image propagating graphene plasmons. Instead of achieving detection via added optoelectronic materials, as is typically done in other plasmonic systems, our device directly harvests the natural plasmon decay product – hot carriers – and converts them into a voltage through the thermo-electric effect.

We use high quality graphene encapsulated between two layers of hexagonal boron nitride and employ two local metal gates to fully tune the thermo-electric and plasmonic behavior. We investigate the plasmon propagation, frequency dispersion, and thermo-electric generation.[3,4]

We then show a novel graphene plasmonic phase modulator which is capable of tuning the phase of light between 0 and 2π *in situ*.[5]

With a footprint of only 350 nm it is more than 30 times smaller than the 10.6 µm light free space wavelength. The phase modulation is achieved by spatially controlling the graphene plasmon phase velocity in a device where the spatial carrier density profile is tunable by electrostatic gating.

We measure graphene plasmons propagating through an *in situ* controlled carrier density landscape for the first time. We show how in simple terms the result can be explained by the optical path length but in order to fully understand the phase shift we provide a complete scattering theory following a Lippmann-Schwinger random phase approximation approach. We find an amazing agreement between the full theory without fitting parameters and the experiment.

These works constitute essential steps towards on-chip two-dimensional trans-formation optics for ultra-compact phase modulators and biosensing applications.

Figures

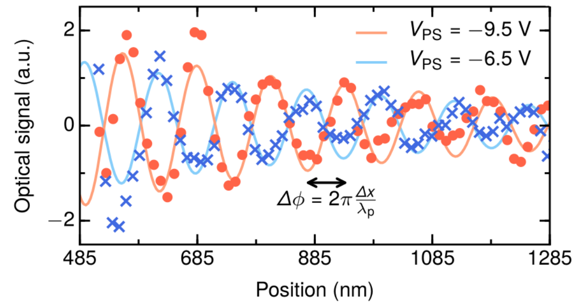

Figure 1: Measured phase shift of π.

References

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