Optical nano-imaging of gate-tuneable graphene plasmons

Pablo Alonso-González[1], Jianing Chen[5,1], Michela Badioli[2], Sukosin Thongrattanasiri[3], Florian Huth[1,6], Johann Osmond[2], Marko Spasenović[2], Alba Centeno[7], Amaia Pesquera[7], Philippe Godignon[8], Amaia Zurutuza[7], Nicolas Camara[9], Javier Garcia de Abajo[3], Rainer Hillenbrand[1,4], Frank Koppens[2]

1. CICnanoGUNE, 20018, Donostia–SanSebastián, Spain
2. ICFO-Institut de Ciéncies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain
3. IQFR-CSIC, Serrano119, 28006, Madrid, Spain
4. IKERBASQUE, BasqueFoundationforScience, 48011, Bilbao, Spain
5. Centro de Fisica de Materiales (CSIC-UPV/EHU) and Donostia International Physics Center (DIPC), 20018, Donostia-San Sebastián, Spain
6. NeaspecGmbH, 82152, Martinsried, Munich, Germany
7. Graphenea S.A., 20018, Donostia-SanSebastián, Spain
8. CNM-IMB-CSIC–Campus UAB, 08193, Bellaterra, Barcelona, Spain
9. GREMAN, UMR7347, UniversitédeTours/CNRS, France

p.alonso@nanogune.eu

Abstract

Graphene holds great promise for ultra-compact and electronically controlled plasmonics [1,2]. Recently, resonant coupling of propagating THz waves to plasmons in micro-ribbons has been demonstrated [3], while IR near-field microscopy has been applied to observe the coupling of graphene plasmons to phonons [4]. In our work [5] we use (similar to ref. [6]) scattering-type scanning near-field optical microscopy (s-SNOM) to visualize propagating and localized infrared plasmon modes in graphene nanostructures in real space (**Fig. 1**). By spectroscopic imaging we measure the graphene plasmon wavelength λp as a function of excitation wavelength, which confirms the theoretically predicted plasmon dispersion. We observe that the plasmon wavelength $\lambda_p=\lambda_0/40$ is remarkably reduced compared to the illumination wavelength λ_0, which can directly be attributed to the two-dimensionality and unique conductance properties of graphene. Furthermore, we demonstrate tunability of the plasmon wavelength by gating graphene nanoribbons on a SiO_2 substrate. The possibility to tune plasmons of extreme subwavelength electronically opens up a new paradigm in optical and opto-electronic telecommunications and information processing.

References

[1] A. Vakil, N. Engheta, *Science* **332**, 1291–1294 (2011)
[2] F.H.L. Koppens, D.E. Chang, J. Garcia de Abajo, *Nano lett.* **11**, 3370 (2011)
[3] L. JU, et al., *Nat. Nanotech.* **6**, 630 (2011)
[4] Z. Fei, et al., *Nano Lett.* **11**, 4701 (2011)
[5] J. Chen, et al., *arXiv*:1202.4996
[6] Z. Fei, et al., *arXiv*:1202.4993

Figures

a)

b)

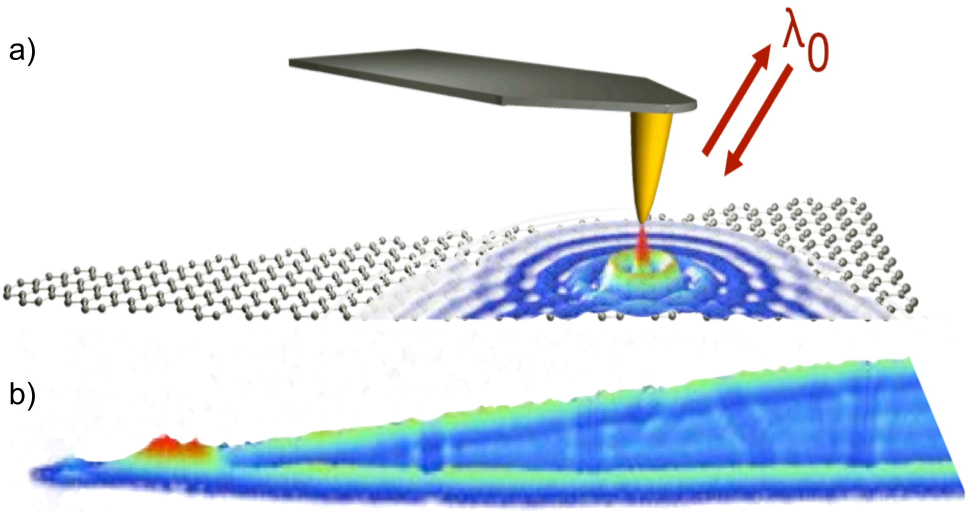

Figure 1: Imaging propagating and localized graphene plasmons by *s*-SNOM. a) Schematic of the experimental configuration used to launch and detect propagating surface waves in graphene. The near fields generated at the apex of an illuminated metal tip launch plasmons on graphene. Back reflection of the plasmons at the graphene edge yields plasmon interference. b) Near-field amplitude image acquired for a tapered graphene ribbon on top of 6H-SiC, revealing interference of graphene plasmons. The imaging wavelength is λ_0=9.7μm. The tapered ribbon is 12 μm long and up to 1 μm wide.