

Giant enhancement of third-harmonic generation in graphene–metal heterostructures

**I. Alonso Calafell¹, L. A. Rozema¹, D. Alcaraz Iranzo², A. Trenti¹,
P. K. Jenke*², J. D. Cox^{3,4}, A. Kumar², H. Bieliaiev¹, S. Nanot^{2,5}, C. Peng⁶,
D. K. Efetov², J.-Y. Hong⁶, J. Kong⁶, D. R. Englund⁶, F. Javier García de
Abajo^{2,7}, F. H. L. Koppens^{2,7}, P. Walther¹**

1. *Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Vienna, Austria.*
2. *ICFO-Institut de Ciències Fotoniques, The Barcelona Institute of Science and Technology, Castelldefels, Spain.*
3. *Center for Nano Optics, University of Southern Denmark, Odense, Denmark.*
4. *Danish Institute for Advanced Study, University of Southern Denmark, Odense, Denmark.*
5. *Laboratoire Charles Coulomb (L2C), Université de Montpellier, CNRS, Montpellier, France.*
6. *Quantum Photonics Group, RLE, Massachusetts Institute of Technology, Cambridge, MA, USA.*
7. *ICREA-Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain.*

Nano-optical plasmonic structures have the potential to amplify nonlinear processes by efficiently focusing far-field light into small sub-wavelength volumes. Two dimensional materials such as graphene are promising candidates for nonlinear optoelectronic applications due to their strong intrinsic and electrically tunable optical nonlinear response, while supporting plasmonic excitations. Here, we enhance the third-order optical nonlinear response of graphene–insulator–metal heterostructures by three orders of magnitude with respect to bare graphene. We achieve this using metallic nanoribbons to simultaneously launch acoustic graphene plasmons and enhance the far field pump light in the graphene layer. Furthermore, by manipulating the electrical environment we can modulate the nonlinear optical signal. This work shows the potential of nonlinear processes driven by graphene plasmons in graphene–insulator–metal heterostructures for optically controlled and electrically tunable nano-optoelectronic components, compatible with established nanofabrication techniques [1].

References

[1] I. Alonso Calafell, L. A. Rozema, D. Alcaraz Iranzo, A. Trenti, P. K. Jenke, J. D. Cox, A. Kumar, H. Bieliaiev, S. Nanot, C. Peng, D. K. Efetov, J.-Y. Hong, J. Kong, D. R. Englund, F. Javier García de Abajo, F. H. L. Koppens, P. Walther. Giant enhancement of third-harmonic generation in graphene–metal heterostructures. *Nat. Nanotechnol.* **16**, 318–324 (2021).

*Corresponding author: philipp.jenke@univie.ac.at