Graphene electrically tuneable third harmonic generation

G. Soavi[1]

G. Wang[1], H. Rostami[2], D. Purdie[1], D. De Fazio[1], T. Ma[1], B. Luo[1], J. Wang[1], A. K. Ott[1], D. Yoon[1], S. Bourelle[1], J. E. Muench[1], I. Goykhman[1], S. Dal Conte[3], M. Celebrano[3], A. Tomadin[4], M. Polini[4], G. Cerullo[3], A. C. Ferrari[1]

1 Cambridge Graphene Centre, University of Cambridge, Cambridge CB3 0FA, UK
2 Nordic Institute for Theoretical Physic, Roslagstullsbacken 23, 106 91 Stockholm, Sweden
4 Dipartimento di Fisica, Politecnico di Milano, Piazza L. da Vinci 32, I-20133 Milano, Italy
5 Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, I-16163 Genova, Italy
gs544@cam.ac.uk

Layered materials have a strong nonlinear optical response [1]. Single Layer Graphene (SLG) can provide electrically tuneable nonlinearities over a broad bandwidth thanks to the linear dispersion of Dirac fermions [2]. We show that the THGE in SLG can be modulated by over one order of magnitude by controlling its Fermi Energy (E_F) [3]. We perform gate-dependent measurements on back-gated exfoliated SLG on Si/SiO_2. For the excitation of SLG we use the idler beam of an OPO (Coherent), focused by a 40X reflective objective to avoid chromatic aberrations. The THG signal is collected by the same objective and delivered to a spectrometer (Horiba iHR550) equipped with a nitrogen cooled Si CCD. The idler spot-size is~4.7μm. This corresponds to an excitation fluence~70μJ/cm^2 for the average power (1mW) used in our experiments. The idler pulse duration is~300fs. Fig.1 compares THGE experiments and theory for $\hbar\omega_0$=0.59eV and different T_e over -700meV<E_F<+150meV corresponding to ≈150V<V_G<+150V. As a function of V_G, SLG displays a THG intensity enhancement by over a factor of 20, starting when $\hbar\omega_0<2|E_F|$. The best agreement between theory and experiments is reached when ≈ 1500K<T_e<2000K. The observed gate-dependent enhancement of the THGE can be qualitatively understood as follows. The linear optical response of SLG at T_e=0K has a "resonance" for $\hbar\omega_0 = 2|E_F|$, the onset of intra- and inter-band transitions in SLG. In a similar way, for the SLG third-order nonlinear optical response, resonances occur at T_e=0K for multi-photon transitions such that $m\cdot\hbar\omega=2|E_F|$ with m=1,2,3, which correspond to incident photon energies $\hbar\omega_0=2|E_F|$, $|E_F|$, $2/3|E_F|$ [3]. This result paves the way to novel SLG-based nonlinear photonic devices, in which the gate tunability of THG may be exploited to implement on-chip schemes for optical communications and signal processing, such as ultra-broadband frequency converters.

References

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Figures

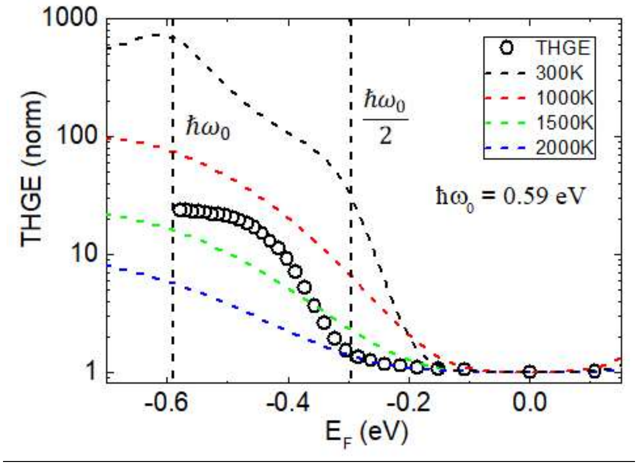

Figure 1: Experiments (circles) and theory (dotted lines) for THGE as a function of E_F and T_e for SLG on Si/SiO_2 at incident photon energies of 0.59eV.