Filling-Factor-Dependent Magnetophonon Resonance with Circularly Polarized Phonons in Graphene Revealed by Magneto-Raman Spectroscopy

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Introduction

Central to the problem of understanding properties of condensed matter is the interplay between low energy excitations, such as electron-phonon coupling (EPC). In graphene, the Raman *G* peak is predicted to exhibit anticrossings when the energy of the zone-centre E_{2g} phonon matches the separation of the Landau levels (LLs). This magneto-phonon resonance (MPR) effect can be described as a resonant mixing of electronic and lattice excitations into a combined mode, leading to a splitting proportional to the EPC. A unique feature of MPR in graphene, is the filling-factor dependence of the anticrossing structure of coupled modes, as well as a possibility to resolve the MPR of circularly polarized phonons [1].

Results and Discussion

Here, we report a polarization-resolved Raman spectroscopy study of MPR in graphene [2]. Measurements were performed at 300K for B up to 45T using a high-field magneto-Raman insert, as for Ref.3. By varying the filling factor (ν) through chemical doping, we identified different types of G peak B-field dependencies, providing a comprehensive evidence of MPR on circularly polarized phonons. At high carrier density ($\nu>6$), the G peak does not reveal MPR splitting. For $2<\nu<6$, the G peak exhibits a strong anticrossing reaching ~150cm^{-1} (~20meV) for B=25T. The electron-phonon coupled modes appear only in the σ+ and σ+/ σ- geometry, while the G peak does not split nor shift in σ- and σ-/ σ+ polarizations. For $\nu<2$, the coupled modes appear in both σ+ and σ-polarizations. Moreover, the spectra for the $2<\nu<6$ case show an additional component, indicated in blue in **Figure 1c**. This unexpected increase of Raman intensity in the middle of the anticrossing gap is assigned to mixing and splitting of electron-phonon coupled modes caused by fluctuations of strain-induced pseudo-magnetic fields.

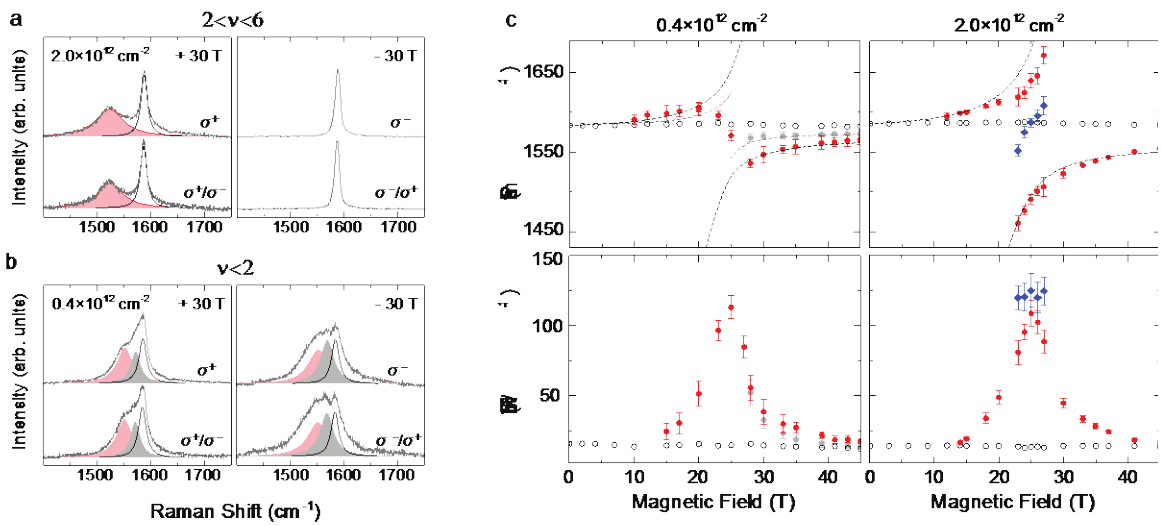

Figure 1. (a,b) Circular-polarized magneto-Raman spectra of graphene measured at 30T. (c) Peak position and FWHM the G peak Lorenzian components as a function of magnetic field.

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[2] Y. Kim *et al.*, arXiv:1211.6094 (submitted to PRL).
[3] Y. Kim *et al.,* Phys. Rev. B **85**, 121403(R) (2012).