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Unveiling the Landau Levels Structure of Graphene Nanoribbons

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Abstract:

Carbon-based nano-electronics is, in the actuality, one of the most promising subjects of nanotechnology. The lateral confinement in graphene leads to a series of 1-D electronic sub-bands with a confinement gap. In presence of a large enough magnetic field, the band structure evolves to magneto-electric sub-bands and graphene-like Landau levels are expected to develop. Up to now, Hall quantization in graphene nanoribbons (GNRs) remains puzzling since no experimental evidence has been found for widths smaller than 200 nm [1]. Lithographically patterned GNRs of 100 and 70 nm widths are made using oxygen plasma etching and a PMMA etching mask. These GNRs present a weakly diffusive transport regime. Magneto-resistance (MR) measurement show the first experimental evidence of Hall quantization in GNRs for filling factors ν= 2 and 6. On the other hand, anomalies in the magneto-transport measurements are evidenced: (i) The maxima of MR for all the ribbons, fingerprint of the Landau levels depopulation [2], present an up-shift of several Tesla compared to the theoretical value [3], (ii) the narrower ribbons exhibit the expected $6G_0$ conductance maxima for a two-terminal measurement [2] but the $2G_0$ plateau is absent and the depopulation of the N=2 Landau level goes along with an unusual double peak of the resistance.
To unveil the origin of the singular Landau spectrum we performed numerical simulations of the GNR band structure as a function of the perpendicular magnetic field. We directly compared the oscillatory behaviour of the magneto-resistance and the onset of the magneto-electric sub-bands. The simulations give evidence of magneto-oscillations of the Fermi energy which consistently explains the broadening of the magneto-resistance peaks and their up-shift lo larger magnetic field [4]. The presence of a second peak in the MR spectrum also finds a natural explanation: this is the clear signature of the orbital degeneracy lifting enhanced by the magnetic field and the pinning of the Fermi energy.

References

[1] J. M. Poumirol, et al. PRB, 82 (2010) 041413.
[2] J. R. Williams et al. PRB, 80 (2009) 045408.
[3] N. M. R. Peres et al. PRB, 73 (2006) 241403
[4] R. L. Ribeiro et al. (submitted to PRL).