Conductance fluctuations in graphene

Bobo Liu, Richard Akis, and David K. Ferry
School of Electrical, Computer, and Energy Engineering, Arizona State University, Tempe, AZ 85287
email: ferry@asu.edu

ABSTRACT

Conductance fluctuations in graphene which arise from a long-range disorder potential induced by random impurities are investigated with an atomic tight-binding lattice. The screened impurities lead to a slow variation of the background potential and this varies the overall potential landscape as the Fermi energy or an applied magnetic field is varied. We find qualitative agreement with recent experiments, and it appears that the reduction of the fluctuations in a magnetic field arises from a field induced smoothing of the conductance landscape.

INTRODUCTION

Conductance fluctuations of a semiconductor at low temperature have been studied for many years [1]. In such systems, the conductance will exhibit such fluctuations as the Fermi energy, or an applied magnetic field, is varied. It is presumed that this arises from the variations in the local potential landscape and changes in the electron wave interference as these variations are introduced. Recently, these fluctuations have been observed in monolayer and bilayer sheets of graphene, and it was recently observed that these fluctuations are small in a magnetic field and at higher densities [2].

We use an atomic-basis, tight-binding model to study the transport. The atoms are treated in slices, which contain two atomic rows in order to preserve the slice symmetry [3]. Disorder is introduced through the appearance of an on-site potential at each atom. In this work, a number of donor and acceptor impurities are randomly sited on a plane spaced a small distance from the graphene sheet itself.

RESULTS

We find a significant magnetic field-induced reduction in the magnitude of the fluctuations computed for Fermi energy sweep. This is not due to any symmetry breaking process (such as that due to the breaking of time reversal symmetry or the lifting of spin or valley degeneracy), since such mechanisms are not included in our calculations. Indeed, spin degeneracy should be lifted also when the magnetic field is applied in the plane of the graphene, but no such evidence of such symmetry breaking was found in the study of ref. 2. In particular, an in-plane magnetic field shows no effect of the magnetic field on the amplitude of the fluctuations. So, there must be another explanation for the magnetic-field induced reduction in the amplitude of the conductance fluctuations. Reflection from impurities is reduced as edge states form in the magnetic field. The result is to suppress the amplitude of the fluctuations in the conductance. A similar reduction in the amplitude of the fluctuations with density has been seen for both gate voltage sweeps and magnetic field sweeps.

CONCLUSION

The idea conductance fluctuations in disordered material is described as both ergodic and universal in nature is not applicable. We suggest that a new understanding of universality should be adopted, one based upon the Anderson theory, and which we call *Anderson universality*. We will demonstrate how this brings the graphene data into line with similar observations in GaAs and other materials.

REFERENCES

[1] D. K. Ferry, S. M. Goodnick, and J. P. Bird, *Transport in Nanostructures*, 2nd Ed. (Cambridge Univ. Press, Cambridge, 2009).
[2] G. Bohra *et al.*, *Nonergodicity and microscopic symmetry breaking of the conductance fluctuations in disordered mesoscopic graphene*, Phys. Rev. B **86**, 161405 (2012).
[3] B. Liu, R. Akis, and D. K. Ferry, *Conductance fluctuations in graphene nanoribbons,* J. Comp. Electron. **13**, 950 (2014).

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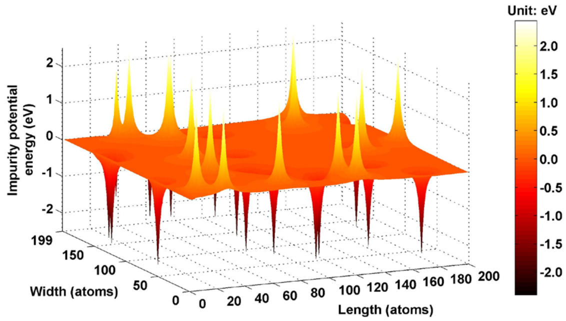

Fig. **1**. Potential that arises from the random set of impurities. A different ensemble is used for each simulation run.

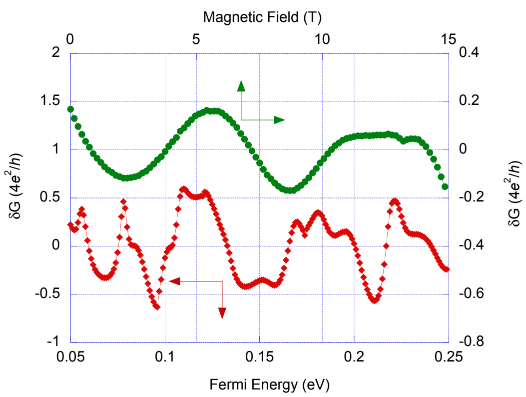

Fig. 2. Typical traces of the fluctuating part of the conductance (a background fit has been subtracted) for magnetic field and Fermi energy sweeps.

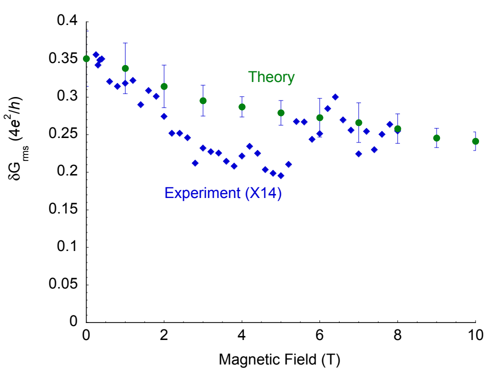

Fig. 3. Comparison of the magnetic field dependence of the fluctuations observed for Fermi energy sweeps with the data of Ref. 2.

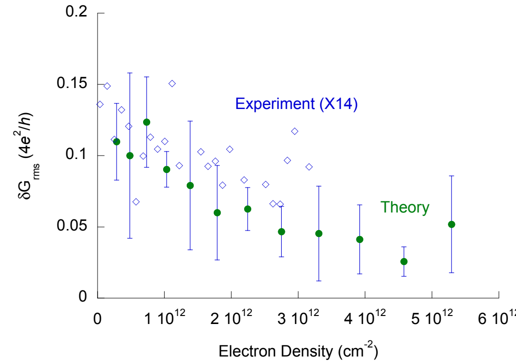

Fig. 4. Variation of the amplitude of the fluctuations for magnetic field sweeps with density. The data from Ref. 2 is also plotted for comparison.

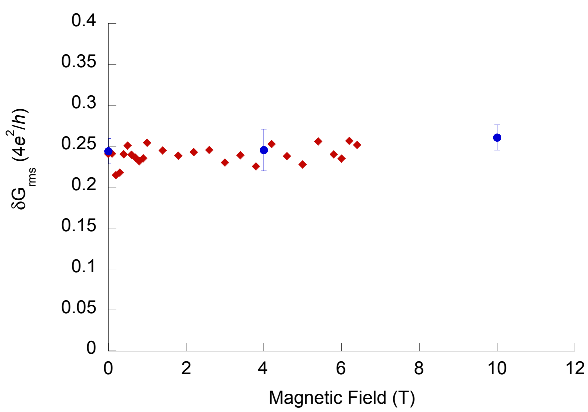

Fig. 5. Amplitude of fluctuations for a Fermi energy sweep when a short range potential is used (blue circles). The red diamonds are data from Ref. 2 for an *in-plane* magnetic field.