Shot noise in disordered graphene samples

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INTRODUCTION

One of the most promising applications for graphene is in the implementation of sensors, which benefit from the extremely high surface-to-volume ratio of a 2-dimensional material. In order to minimize the variance on the readout of such sensors, we need to reduce all sources of noise as much as possible. A noise contribution particularly relevant for samples with high aspect ratio (ratio of the width to the length) is shot noise, which is expected to have a very peculiar behavior as a function of the chemical potential, as predicted by Tworzidło *et. al* [1] and, therefore, as a function of the voltage applied to a gate electrostatically coupled to the graphene sheet. We developed an approach, based on an envelope function representation, enabling the simulation of samples of realistic size [2], [3].

SIMULATIONS AND COMPARISON WITH EXPERIMENTAL DATA

We consider a graphene sheet, with a width W and a length L, with two contacts (Fig. 1). Contacts are modeled with large potential steps.

In Fig. 2 we report the behavior of the Fano factor as a function of the Fermi energy for an ideal graphene sample 200 nm wide and 40 nm long (and thus with an aspect ratio $W/L = 5$) (red curve) and for the same sample in the presence of disorder due to a 5×10^{11} cm^{-2} concentration of charged impurities placed at a distance of 1 nm from the graphene sheet (green curve). The results for a flake that has the same aspect ratio ($W/L = 5$), but with a width of 1000 nm, is reported in Fig. 3: we notice that, while in the case of ideal graphene there is simply, as expected, a scaling in terms of the energy coordinate, for disordered graphene the behavior is quite different. This can be explained considering that, contrary to the device size, the spatial scale of the disorder is unchanged. In Fig. 4 we report the behavior of the Fano factor for a 200 nm wide sample with $W/L = 1$, again for the ideal case (red curve) and with disorder (green curve).

In Fig. 5 we present a comparison between our simulations of the behavior of the Fano factor as a function of the backgate voltage and the experimental results by Danneau *et al.* [4]: we notice a reasonable agreement with the simulation for a disordered sample with an impurity density of 5×10^{11} cm^{-2} located 2.15 nm away from the graphene sheet. However, it is apparent that the behavior of the Fano factor is not the one due to the effect studied by Tworzydło *et al.*, but, rather, it is a consequence of the prevailing effect of the disorder. Finally, in Fig. 6 we show a comparison between the results obtained by DiCarlo *et al.* [5] and the same simulation as in Fig. 5: in this case the experimental data do not exhibit any significant variation of the Fano factor with the position of the Fermi level: most likely this is the consequence of an even stronger disorder.

ACKNOWLEDGMENT

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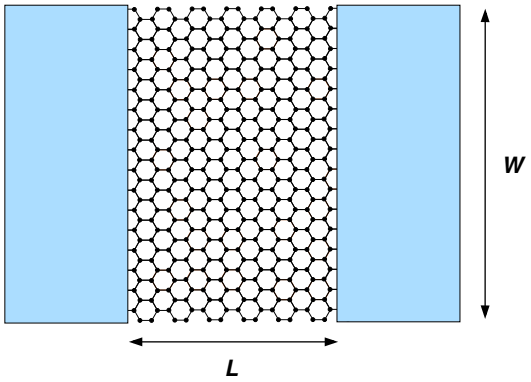

Fig. 1. Graphene sample

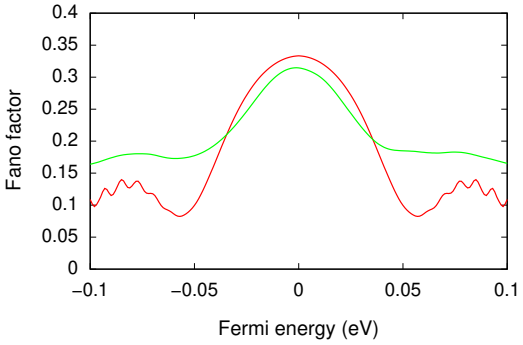

Fig. 2. Fano factor vs. Fermi energy for a graphene sample with $W/L = 5$ and $W = 200$ nm for an ideal sample (red curve) and a disordered sample (green curve)

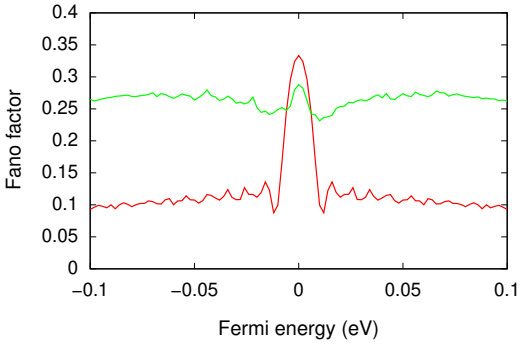

Fig. 3. Fano factor vs. Fermi energy for a graphene sample with $W/L = 5$ and $W = 1000$ nm for an ideal sample (red curve) and a disordered sample (green curve)

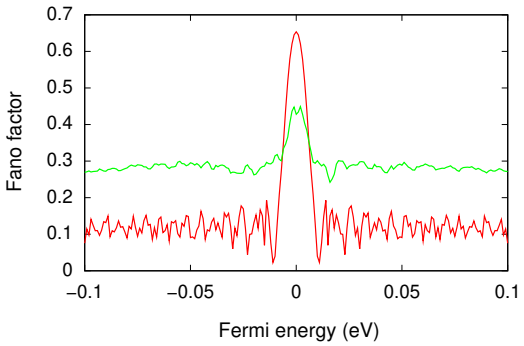

Fig. 4. Fano factor vs. Fermi energy for a graphene sample with $W/L = 1$ and $W = 200$ nm for an ideal sample (red curve) and a disordered sample (green curve)

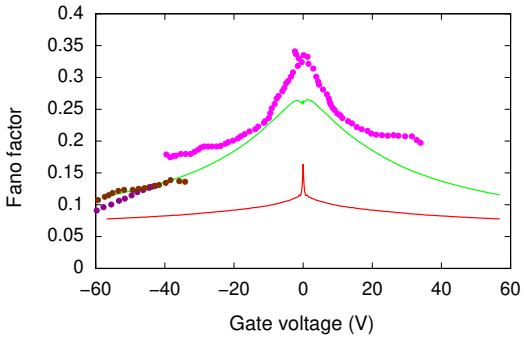

Fig. 5. Comparison between the results of the simulation and the experimental data by Danneau *et al.*

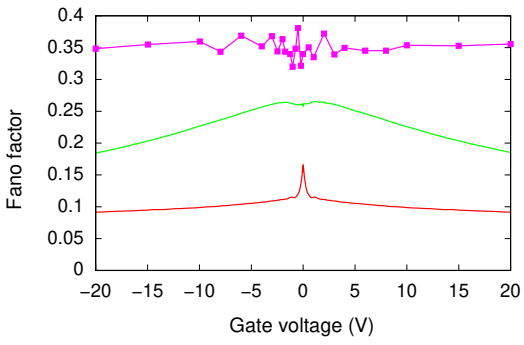

Fig. 6. Comparison between the results of the simulation and the experimental data by DiCarlo *et al.*