Quantum-limited shot noise and quantum interference in graphene based Corbino disk

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Quantum Relativistic Corbino Effect

In the Corbino geometry a disk-shaped sample is surrounded from both interior and exterior sides with metallic leads (Fig. 1). Quite recently, an intriguing interference phenomenon was predicted theoretically for impurity-free Corbino disks both in mono (MLG) and bilayer graphene (BLG) [1, 2, 3]. At the Dirac point as well as on other Landau levels, the conductance exhibits oscillatory dependence on magnetic field due to the discrete spectrum of transmission modes. In general, non-zero conductance at high magnetic fields appears only in close vicinity of the Landau levels. Also, the QGCE was predicted in the linear response regime. Here we extend the analysis beyond the zero voltage limit in order to check how this affects this phenomenon.

\[ G = G_0 + \sum_{n=1}^{\infty} G_{2n} \cos \left( \frac{2\pi n}{L} \right) \]

with \( G_0 = (1-\mu) \frac{2h}{e^2} \frac{2d_0}{L} \) and \( \Phi_0 = \pi \left( R_c^2 - R_i^2 \right) \) is the flux piercing the ring, \( \Phi_0 = \frac{2\pi \hbar}{e} \), \( L = \ln \left( \frac{R_c}{R_i} \right) \), with inner \( R_i \) and outer \( R_c \) radii. The oscillations magnitude increase with radii ratio and exceed 10% of the average conductance for \( R_c / R_i > 5 \). Analogue oscillations are found for higher charge transfer conductances as well.

In BLG oscillations amplitude at the Dirac point, depending on the size of the system, are up to two times larger than in MLG. On the other hand, at other Landau levels the oscillations are of the same magnitude for both materials, provided the valley degeneracy remains (see Fig. 2).

Panel (c) illustrates the scaling of \( \Delta G / \Delta G_{\text{diff}} \) and the source-drain voltage \( V_{\text{sd}} \) for finite source-drain voltage \( V_{\text{sd}} \) and finite magnetic field. Symbols at each panel correspond to \( n_s R_c / \hbar v_F = 25 \) (or 5). Lines depict the linear response values of \( \Delta G / \Delta G_{\text{diff}} \) and \( \Delta G_{\text{diff}} \).

\[ \Delta G / \Delta G_{\text{diff}} = 0.11 \Delta G_{\text{diff}} \]

\[ \Delta G / \Delta G_{\text{diff}} = 0.27 \Delta G_{\text{diff}} \]

\[ \Delta G / \Delta G_{\text{diff}} = 0.14 \Delta G_{\text{diff}} \]

Table 1: Limiting values of period-averaged \( \bar{\Sigma} \), \( \bar{\Delta} \), and oscillation magnitudes \( \Delta \bar{\Sigma} \), \( \Delta \bar{\Delta} \). Numbers in parentheses are standard deviations for the last digit.

\[ \begin{array}{cccc}
R_c / R_i & \bar{\Sigma} & \Delta \bar{\Sigma} & \bar{\Delta} & \Delta \bar{\Delta} \\
2.5 & 0.761(1) & 0.014(1) & 0.552(3) & 0.0064(2) \\
5.0 & 0.763(1) & 0.061(1) & 0.555(2) & 0.017(1) \\
10 & 0.771(1) & 0.191(2) & 0.56(1) & 0.170(2) \\
\end{array} \]

Results

For the purpose of numerical demonstration, we choose \( R_c / R_i = 5 \), and focus on the vicinity of the Dirac point by setting \( \mu = 0 \). The corresponding oscillation magnitudes, in the linear response limit, are

\[ \Delta G / \Delta G_{\text{diff}} = 0.11 \Delta G_{\text{diff}} \]

\[ \Delta G / \Delta G_{\text{diff}} = 0.27 \Delta G_{\text{diff}} \]

\[ \Delta G / \Delta G_{\text{diff}} = 0.14 \Delta G_{\text{diff}} \]

A striking feature is the total lack of effects of both the radii ratio \( R_c / R_i \) and the source-drain voltage \( V_{\text{sd}} \) on limiting values of \( \bar{\Sigma} \), \( \Delta \bar{\Sigma} \), \( \Delta \bar{\Delta} \), and \( \Delta \bar{\Delta} \), strongly depends on \( R_c / R_i \). Figures 3 and 4. The limiting values are expected to appear generically in graphene-based nanosystems at high magnetic fields and for finite source-drain voltages, similarly as pseudodiffusive shot noise (\( \Delta \bar{\Sigma} = 1/3 \) and \( \Delta \bar{\Delta} = 1/15 \)).

References


The work was realised in the Project TEAM awarded to our group by the Foundation for Polish Science (FNP) for the years 2011-2014.