Fun Phys Master2 internship project 2022

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Subject's title: **Shot-noise in a normal-topological junction**

Subject description:

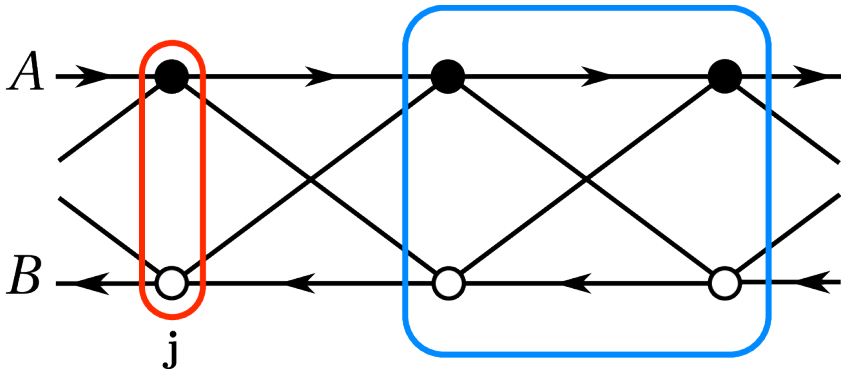
Noise is a fundamentally inescapable ingredient of any electronic device and manifests itself, for instance, in a non-equilibrium situation, when current flows through a conductor, as a consequence of electrons being transmitted or reflected. While at first it may be regarded as a nuisance, it has now been broadly accepted as a key tool to improve our understanding of nanoscale conductors. For instance, in the framework of the fractional Hall effect, studying shot noise allowed experiments to reveal the fractional (anyonic) nature of the excitations at the origin of the transport at the edges, a hallmark of the topological nature of the quantum Hall effect.

Topology in quantum systems corresponds to a hidden (nonlocal) symmetry of the (groundstate) wavefunctions, allowing us to classify them. Unlike standard symmetries (translation, rotation) which are easily broken by defects, the topological ones are usually immune to small perturbations due to a quantized topological invariant, protecting thereby the properties of the system . For instance, within the context of the quantum Hall effect, it explains the position of the transverse conductance at precisely integer (the well-known Chern number) or fractional values of e^2/h and the vanishing longitudinal resistance, i.e. a perfect electronic conduction along the edges. It turns out that, topology is not just found in quantum Hall systems, but, during the past ten years, it has been found to govern many more systems such as Chern insulators, unconventional superconductors, and interacting bosonic and fermionic systems.

In the context of transport in nanowire, it has been recently shown that Majorana bound states at the each of the ends of a topological superconductor lead to unique transport properties, having well defined signatures in the finite frequency noise of a biased junction between a normal metal and such a topological superconductor nanowire. However, in this system, it is still unclear how to quantify the respective impact of the two specific properties, i.e. the Majorana aspect and the edge localization (topology) on the shot noise.

In order to address this question, we propose to study the shot-noise properties in a different system, namely a tight-binding model in the Creutz lattice (see figure). This system has a peculiar band structure: both bands are flat, which means that the eigenstates are localized (the blue plaquette in the figure), contrary to the Bloch states for usual bands which are fully delocalized. Furthermore, the two bands are topological, i.e. exhibiting a non-vanishing winding number (a quantity similar to the Chern number, but for one-dimensional system) In particular, this implies that, for open boundary conditions, the lattice has two edge states localized at each end of the

lattice. Furthermore, playing with the values of the different hopping amplitudes, one can tune the system properties at will: changing the symmetry class of the topological insulator, controlling the localization size of the edge states, the flatness of the bands. This would allow us, in principle, to understand much more clearly how the shot noise properties depend on the different aspect of the system (topology, localization, bandwidth).



In this project, we will want to study the shot noise in the transport properties for a biased junction between a normal metal (a regular ladder geometry) and the Creutz lattice. We will use the non-equilibrium Keldysh formalism to compute the finite frequency emission and absorption noise as functions of the bias voltage and the parameters of the tight-binding model. The project will have both analytical and numerical aspects.

References:

‡1 Noise in mesoscopic physics, Thierry Martin, les Houches Session LXXXI, H. Bouchiat et. al. eds. (Elsevier 2005). arXiv:cond-mat/0501208

‡2 Quantum Transport, Y. Nazarov and Y. Blanter, Cambridge University Press.

‡3 Finite frequency noise in a normal metal - topological superconductor junction,

‡4 D. Bathellier, L. Raymond, T. Jonckheere, J. Rech, A. Zazunov, T. Martin, , Phys. Rev. B 99, 104502 (2019)

‡5 M. Creutz, Phys. Rev. Lett. 83, 2636 (1999).

‡6 Pairing and superconductivity in the flat band: Creutz lattice, Rubem Mondaini, George Batrouni and Benoît Grémaud, Phys. Rev. B 98, 155142 (2018).

Duration: the normal duration of a CPT internship

Any self-financial support? NO this internship would be financed by the CPT.

Specify whether the internship project may naturally lead to a PhD thesis. Not directly.