Voltage pulse unveils a far away perturbation

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Abstract

Here we present the unveilling of dynamical interferences in a Fermi liquid by a voltage pulse propagating through a quantum wire. Time-dependent simulations were performed with the open-source Python package Kwant and its extension Tkwant.

INTRODUCTION

MODEL

We consider a N sites one dimensional wire connected to two semi-infinite leads. We model the system by the following tight-binding Hamiltonian:

$$\mathbf{H} = -\gamma \sum_i c_i^\dagger c_{i+1} + \sum_i w(t)\theta(-i) c_i^\dagger c_i + \sum_i V_{QPC}(i) c_i^\dagger c_i \tag{1}$$

The scattering region will be indexed by $i \in [\![1, N]\!]$, whereas left (right) lead sites are indexed with $i \leq 0$ ($i \geq N+1$). The hopping The voltage pulse is modeled by the second term, with $\theta(x)$ being the Heaviside function and $w(t)$:

$$w(t) = V_P e^{-2(\frac{t-t_0}{\tau})^2} \tag{2}$$

V_P being the amplitude, τ the width and t_0 the starting time of the perturbation. We introduced a Quantum Point Contact (QPC) which consists in a filtering potential barrier:

$$V_{QPC}(i) = V_0 e^{-(\frac{i-i_0}{\xi})^2} \tag{3}$$

V_0 being the amplitude, ξ the width and x_0 the position of the QPC. The time-dependent peturbation can be absorbed by the gauge transforming leading to a redefinition of the hopping parameter the left lead where the pulse is applied and the scattering region:

$$\gamma \to \gamma e^{-i\phi(t)} \tag{4}$$

with:

$$\phi(t) = \frac{e}{\hbar} \int_{-\infty}^{t} w(u) du \tag{5}$$

SIMULATION

Tkwant allows to evolve the states in time. The density is obtained by integrating over the energy of all onebody states:

$$n(i,t) = \int \frac{dE}{2\pi} f(E) |\psi(i,E)|^2 \tag{6}$$

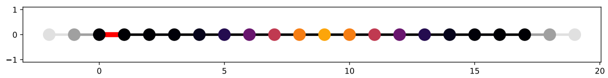

FIG. 1: A schematic of the system. The wire is connected to two semi-infinte leads. The site color reflects the QPC's voltage amplitude. The time-dependent hopping parameter is displayed in red.

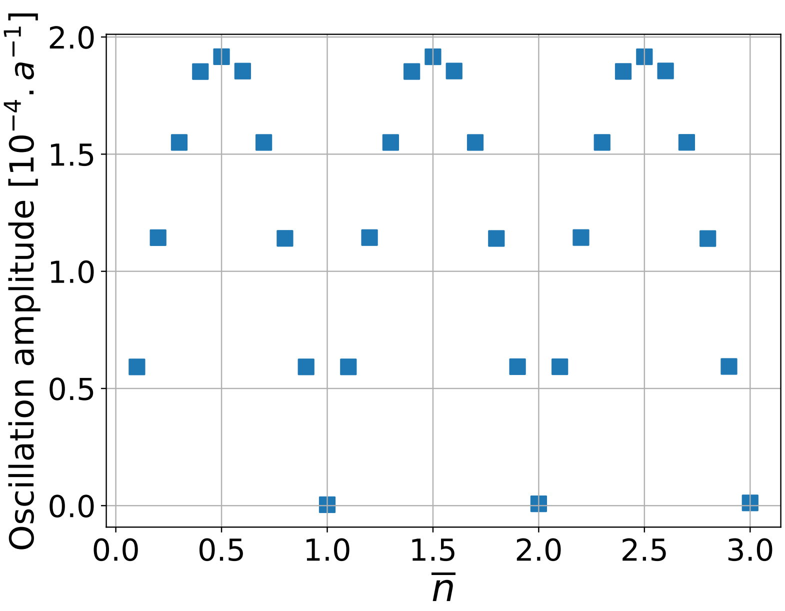

FIG. 2