

Transport Properties of Thermal Shot Noise Through Superconductor-Ferromagnetic /2DEG Junction

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Abstract: We study transport properties of thermal shot noise, thermo power and thermal conductance through superconductor-ferromagnetic /2DEG junction under the effect of Fermi energy, number of open channels and excitation energy. Thermal shot noise, $P_{Thermal}$ is directly related to the conductance through the fluctuation- dissipation theorem; the model consists of a 2DEG region inserted between two identical superconductor electrodes. Ferromagnetic strips are placed onto top of each superconductor/2DEG junction and voltage applied across the model. The results show an oscillatory behavior of the dependence of the thermal shot noise on Fermi energy. These results agree with existing experiments. This research is very important for using a model as a high-frequency shot noise detector.

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1. Introduction

On chip noise detection schemes, where device and detector are coactively coupled within sub millimeter length scales, can benefit from large frequency bandwidths. This results in a good sensitivity and allows one to study the quantum limit of noise, where an asymmetry can occur in the spectrum between positive and negative frequencies [1, 2]. Shot noise measurements allow us to access the dynamical properties of a resonant tunneling device which are not accessible by measuring solely the average current [2]. Shot noise is more interesting, because it contains information on the temporal correlation of the

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electrons which is not contained in the conductance [3-4].

In this paper we study transport properties of thermal shot noise, thermo power and the thermal conductance through superconductor-ferromagnetic /2DEG junction.

2. Method of Calculation

The model consists of a 2DEG region inserted between two identical superconductor electrodes. Ferromagnetic strips are placed onto top of each superconductor/2DEG junction and voltage applied across the model [4]. In order to study electron transport in the model we make use of the Bogolubov-de Gennes equation [5]. Within the Landauer-Buttiker scattering approach, the conductance through the system biased at the across applied voltage V_a can be written as [6]

$$G(\varepsilon) = \left(\frac{e}{h}\right) \int_{-\infty}^{\infty} d\varepsilon \gamma(\varepsilon) \left(-\frac{\partial f(\varepsilon - eV_a)}{\partial \varepsilon}\right) \quad (1)$$

Where $\gamma(\varepsilon)$ is tunneling probability and given by

$$\gamma(\varepsilon) = [N(\varepsilon) - R_0(\varepsilon) + R_A(\varepsilon)] \quad (2a)$$

and

$$\left(-\frac{\partial f(\varepsilon - eV_a)}{\partial \varepsilon}\right) = (4K_B T)^{-1} \text{Cosh} \left(\frac{\varepsilon - \varepsilon_F - eV_a}{2K_B T}\right) \quad (2b)$$

Where $R_0(\varepsilon)$ and $R_A(\varepsilon)$ are normal, Andreev reflection and $N(\varepsilon)$ is the number of open channels in the system, V_a applied voltage, f is the Fermi distribution function, ε is the excitation energy, Δ_0 (Niobium)=0.0015 eV is the superconducting energy gap, critical temperature T_c (Niobium)= 9.3 K, critical magnetic field B_c (Niobium)= 0.1985 Tesla and coherence length ξ_0 (Niobium)=38 nm.

Thermal shot noise, $P_{Thermal}$ is directly related to the conductance through the fluctuation-dissipation theorem [7]

$$P_{Thermal} = (4K_B T) \left(\frac{e}{h}\right) \int_{-\infty}^{\infty} d\varepsilon \gamma(\varepsilon) \left(-\frac{\partial f(\varepsilon - eV_a)}{\partial \varepsilon}\right) \quad (3)$$

Thermal shot noise is more interesting, because it contains information on the temporal correlation of the electrons which is not contained in the conductance. The thermo power S , of the system is given by [8]

$$S = -L/G \quad (4)$$

Where L , is thermo-electric coefficient and G , is the conductance.

The thermal conductance, K , is given by

$$K(\varepsilon) = -\left(\frac{\pi^2 k_B^2}{3e}\right) \left(\frac{T}{h}\right) \int_{-\infty}^{\infty} d\varepsilon \gamma(\varepsilon) \left(-\frac{\partial f(\varepsilon - eV_a)}{\partial \varepsilon}\right) \quad (5)$$

3. Results and Discussions

The thermal shot noise, $P_{Thermal}$, thermo power, S , and the thermal conductance, K , Eqs. 3, 4 and 5 has been computed respectively over Fermi energy, excitation energy, magnetic field and applied voltage. The calculations were performed for the cases: Fig. (1) Show that thermal shot noise as a function of the Fermi energy at different value of the temperature, this results show an oscillatory behavior of the dependence of the thermal shot noise on Fermi energy, the coincidence of peaks in the thermal shot noise with steps in the Fermi energy is clearly visible; these oscillations are due to Coulomb blockade effect [9-11]. Fig. (2) Show that Periodic suppression of thermal conductance as a function of the number of open channels at different applied voltage, the value of thermal conductance it is very high with the increasing the number of open channels. Fig. (3) Show that thermo power as a function of the magnetic field at different temperatures, the value of thermo power decreasing with increasing the magnetic field, the results show an oscillatory behavior of the dependence of the thermo power on magnetic field [11, 12]. Fig. (4) Show that thermo power as a function of the excitation energy, ε , a crossover from the quantization behavior of the thermo power to a δ -function behavior, might be explained as the probability for normal reflections $R_0(\varepsilon)$ be more dominant over the Andreev reflections $R_A(\varepsilon)$ for large numbers of open channels in the system $N(\varepsilon)$ [12-14]. Our results are in good concordant with those in the literature [12-18].

Conclusion

In this paper we study transport properties of thermal shot noise, thermal conductance and thermo power through superconductor-ferromagnetic /2DEG junction under the effect of Fermi energy, number of open channels and excitation energy. These results agree with existing experiments. This research is very important for using a model as a high-frequency shot noise detector.

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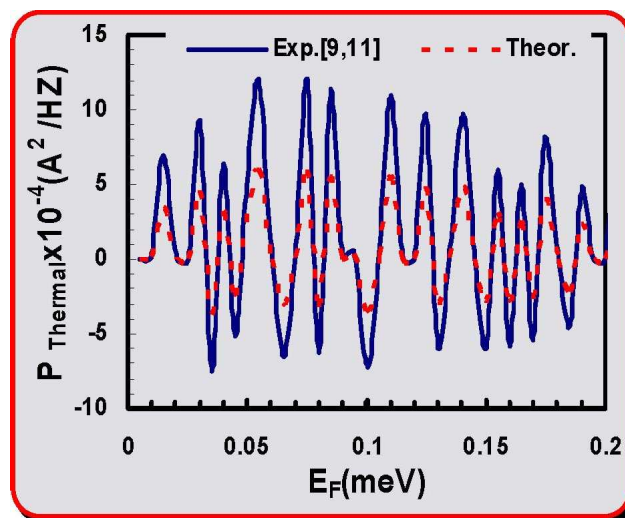


Fig. 1 Thermal shot noise as a function of the Fermi energy.

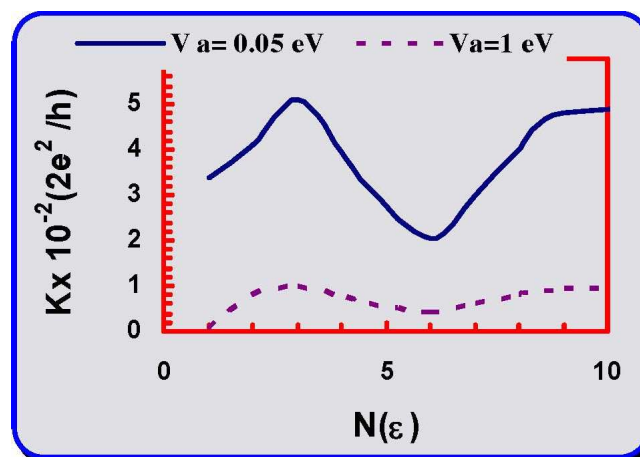


Fig. 2 Thermal conductance as a function of the number of open channels at different applied voltage.

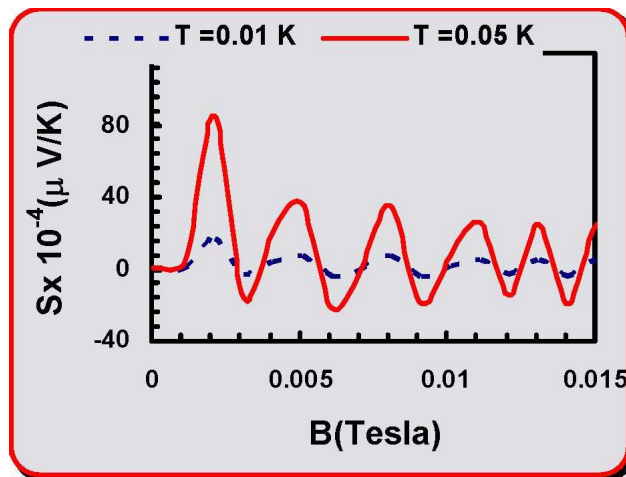


Fig. 3 Thermo power as a function of the magnetic field at different temperatures.

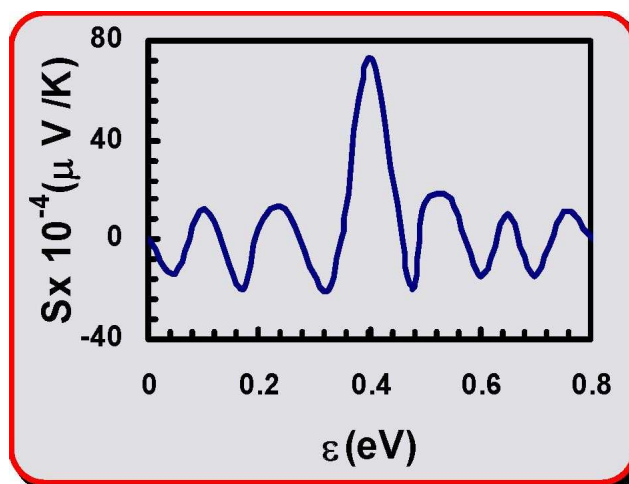


Fig. 4 Thermo power as a function of the excitation energy, ε , a crossover from the quantization behavior of the thermo power to a δ -function behavior.