Shot Noise Enhancement at Spin-dependent Hopping

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Coulomb repulsion induces correlations between electrons and makes charge transport at hopping in one-dimensional chains more "continuous" [1] by preventing two electrons from occupying the same site and maintaining a certain average distance between the carriers in the chain. The Fano factor $F = S(\omega = 0)/(2eI)$ defined as the ratio of the spectral current density fluctuations at low frequency $S(\omega = 0)$ to the stationary current I (times 2 the electron charge e) is a useful measure characterizing the smoothness of the transport process: The smaller the Fano factor, the more regular the charge transport. For a single-trap assisted hopping between two normal metal electrodes the Fano factor is reduced from 1 and takes the minimum value of ½ at equal tunneling rates to/from the trap.

The Pauli exclusion principle results in spin-driven correlations [2] as it forbids two electrons with the same spin projection to occupy the same trap state. At trap-assisted hopping from a normal metal source electrode ($\mathbf{p}_S$=0) to a ferromagnetic (FM) drain electrode, Fig.1, the finite spin on a trap leads to large magnetoresistance [3], [4] (Fig.2). We analyze the shot noise/Fano factor.

Fig.3 shows that, in contrast to spin-independent hopping, the shot noise is significantly enhanced to F=3, where the current is small. It implies that the electrons are transferred in bunches of three electrons in average separated by longer waiting times. At spin-dependent tunneling between two FM electrodes (Fig.1) the shot noise can be enhanced (Fig.4) at the current maximum as well (Fig.5). Although the correlations between the current and the noise are opposite to the case of tunneling from a normal metal to a FM electrode, in both cases the noise enhancement is due to spin correlations. Strong spin dephasing reduces the shot noise at some angles between the magnetic field and the drain FM below unity, however, dephasing does not reduce the Fano factor at the maximum (Fig.6).

[1] A.N. Korotkov and K.K. Likharev, Phys. Rev. B **61**, 15975 (2000)
[2] Y. Wang et al., Phys. Rev. X, **6**, 011011 (2016)
[3] Y. Song and H. Dery, Phys. Rev. Lett. **113**, 047205 (2014)
[4] V. Sverdlov et al., WINDS 2017; Solid-State Electron., submitted (2018)

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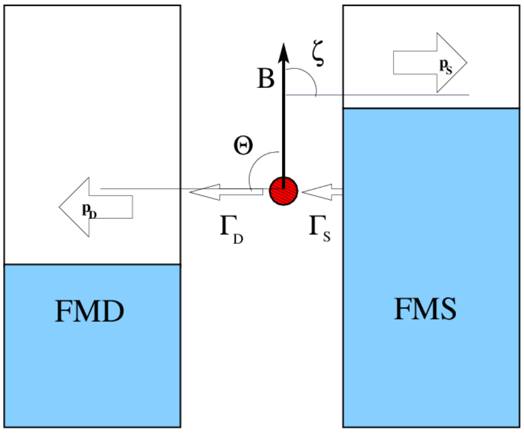

Fig.1: The ferromagnetic source (FMS)/drain(FMD) polarizations $\mathbf{p}_{S,D}$ form angles Θ and ζ, φ with respect to the magnetic field **B**. The trap is coupled by the rates $\Gamma_{S(D)}$ to FMS (FMD).

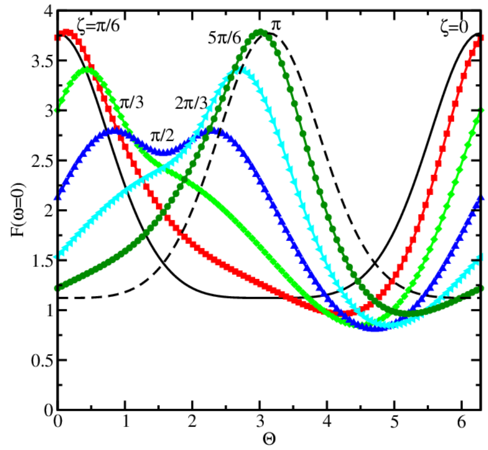

Fig.4: Shot noise at hopping between the source and drain ferromagnetic electrode as a function of Θ for several ζ. Γ_S=5Γ_D, ω_L=$\Gamma_D/2$, p_S=p_D=0.8. There is no spin relaxation nor dephasing.

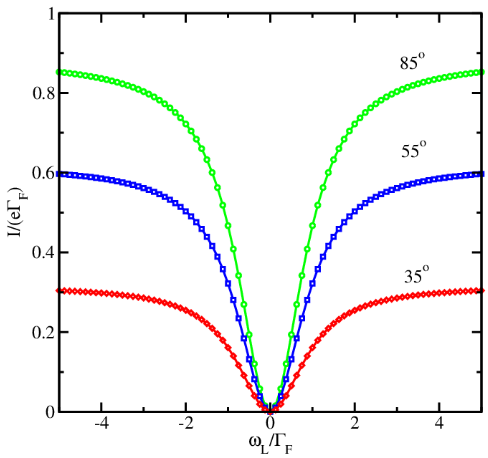

Fig.2: Trap-assisted tunneling magnetoresistance at tunneling from a normal metal to a ferromagnetic electrode, for several angles between the field **B** and $\mathbf{p}_D$, for $\mathbf{p}_S$=0. $\Gamma_F = \omega_L$, |**p**|=1, .$\Gamma_N = 8\Gamma_F$.

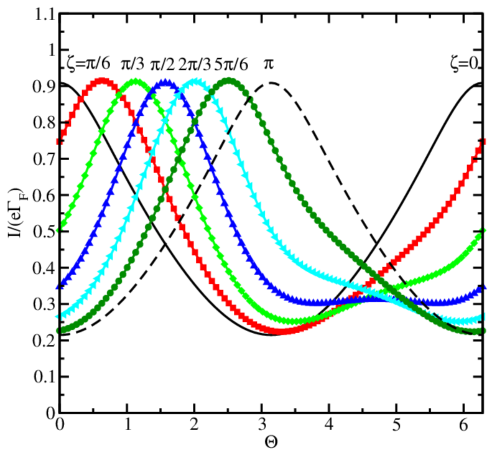

Fig.5 Trap-assisted tunneling current between the source and drain ferromagnetic electrode as a function of Θ for several ζ. Γ_S=5Γ_D, ω_L=$\Gamma_D/2$, p_S=p_D=0.8. There is no spin relaxation nor dephasing.

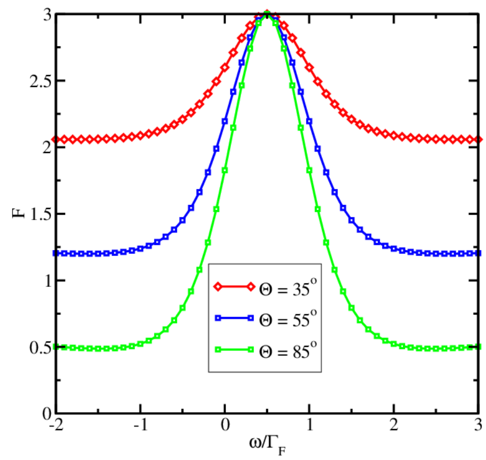

Fig.3: Fano factor at spin-dependent hopping as a function of the Larmor frequency, for several angles between the magnetization and the magnetic field.

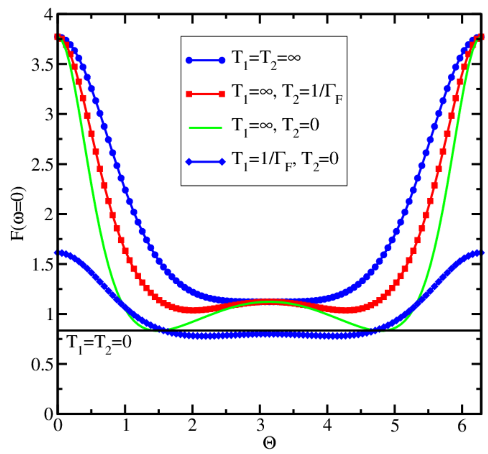

Fig.6: Effect of spin relaxation and dephasing on shot noise as a function of Θ for $\zeta, \varphi = 0$. The parameters are: Γ_S=5Γ_D, ω_L=Γ_D/ 2, p_S=p_D=0.8.

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