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Microscopic understanding of spin current probed by shot noise[1]

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The spin currents is one of key issue in the spintronics field and the generation and detection of those have been intensively studied by using various materials. The analysis of experiments, however, relies on phenomenological parameters such as spin relaxation length and spin flip time. The microscopic nature of the spin current such as energy distribution and energy relaxation mechanism, has not yet well understood. To establish a better microscopic understanding of spin currents, I focused on the shot noise measurement which is well established technique in the field of mesoscopic physics [Y. M. Blanter and M. B üttiker, Phys. Rep. 336, 1 (2000).]. Although there are many theoretically works about shot noise in the presence of spin currents, for example detection of spin accumulation [J. Meair, P. Stano, and P. Jacquod, Phys. Rev. B 84 (2011).], estimation of spin flip currents, and so on, these predictions have never been experimentally confirmed. In this context, we reported the first experimental detention of shot noise in the presence of the spin accumulation in a (Ga,Mn)As/tunnel barrier/n-GaAs based lateral spin valve device [T. Arakawa et al., Phys. Rev. Lett. 114, 016601 (2015).].

Together with this result, we found however that the effective temperature of the spin current drastically increases due to the spin injection process. This heating of electron system could be a big problem to realize future spin current devices by using quantum coherence, because the effective temperature rise directly related to the destruction of the coherence of the spin current. Therefore, then we focused on the mechanism of this heating and the energy relaxation in a diffusive channel. By measuring current noise and the DC offset voltage in the usual non-local spin valve signal as a function of the spin diffusion channel length, we clarified that the electron-electron interaction length, which is the characteristic length for the relaxation of the electron system, is much longer than the spin relaxation length. In other words, the spin currents in such a semiconducting material can be strongly out of equilibrium.

In this invited talk, I will present a series of experimental work on the spin current in a (Ga,Mn)As/tunnel barrier/n-GaAs based lateral spin valve device, mainly probed by the current noise measurement. Finally I hope I will mention about our future plan to cool down the effective temperature of the spin current by using superconductivity.

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