Macroscopic Quantum Tunneling of a Topological Ferromagnet

Kajetan M. Fijalkowski, Nan Liu, Pankaj Mandal, Steffen Schreyeck, Karl Brunner, Charles Gould, and Laurens W. Molenkamp

Faculty for Physics and Astronomy (EP3), Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany

Institute for Topological Insulators (ITI), Am Hubland, D-97074, Würzburg, Germany

Since the early days of quantum mechanics, physicists have been trying to understand how the laws governing the microscopic world merge into those describing the classical mechanics at macroscopic size scales. A trademark quantum mechanical phenomenon that has no direct analog in classical physics is quantum tunnelling between different eigenstates of the system. This posed an intriguing question regarding the possibility of existence of quantum tunnelling in systems that can be regarded as macroscopic.

Only in the recent couple of decades the experimental techniques have reached a level of advancement that allowed to directly address that question experimentally. This was done in the context of macroscopic quantum tunnelling between different states in the Josephson junctions [1], as well as quantum tunnelling of magnetic domain walls [2], and magnetization [3] in magnetic systems.

Here, we investigate the electronic transport in a $(V,Bi,Sb)_2Te_3$ ferromagnetic topological insulator nanostructure in the quantum anomalous Hall regime. This provides access to the dynamics of an individual ferromagnetic domain. Telegraph noise resulting from the magnetization fluctuations of this domain is observed in the Hall signal. Careful analysis of the domain switching statistics provides evidence for macroscopic quantum tunneling of magnetization [4]. This ferromagnetic macrospin is not only the largest magnetic object in which quantum tunneling has been observed, but also the first observation of the effect in a topological state of matter.

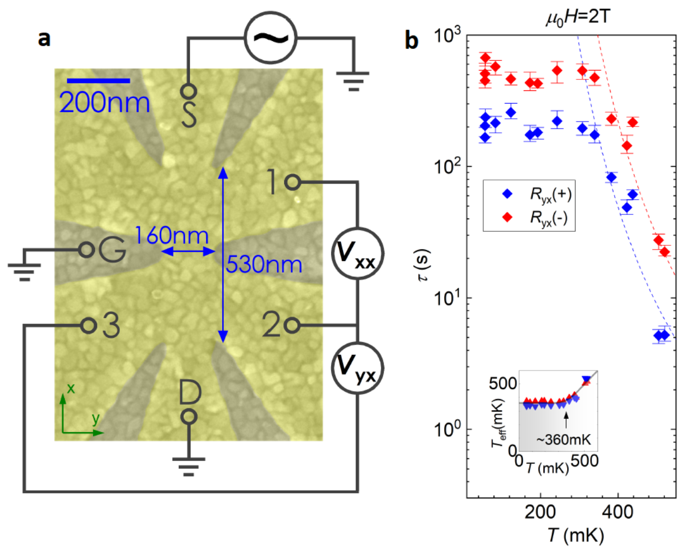

Figure 1: (a) High magnification false color SEM image of the device together with a circuit diagram schematic. (b) Evolution of lifetime τ for each state with temperature, demonstrating a low temperature saturation caused by macroscopic quantum tunneling of magnetization [4].

[1] R. F. Voss et al., *Phys. Rev. Lett.* **47**, 265 (1981)
[2] J. Brooke et al., *Nature* **413**, 610 (2001)
[3] L. Thomas et al., *Nature* **383**, 145 (1996)
[4] K. M. Fijalkowski et al., *ArXiv*:2206.03972 (2022)