Topological Spin Transport in Quantum Materials and Entanglement

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Abstract

In this talk, I will present theoretical spin transport features in $MoTe_2$ and WTe_2-based materials which have recently been the subject of great attention within the broad context of Quantum Materials [1]. By focusing on the monolayer limit, using DFT-derived tight-binding models and using both efficient bulk and multi-terminal formalisms and techniques [2,3], I will first discuss the emergence of new forms of intrinsic spin Hall effect (SHE) that produce large and robust in-plane spin polarizations. Quantum transport calculations on realistic device geometries with disorder demonstrate large charge-to-spin interconversion efficiency with gate tunable spin Hall angle as large as $\theta_{xy}\approx 80\%$, and SHE figure of merit $\lambda_s.\theta_{xy}\sim 8\text{-}10$ nm, largely superior to any known SHE material [4]. Besides, I will present our theoretical prediction of an unconventional canted quantum spin Hall phase in the monolayer Td-WTe_2, which exhibits hitherto unknown features in other topological materials [5]. The low-symmetry of the structure induces a canted spin texture in the yz plane, dictating the spin polarization of topologically protected boundary states. Additionally, the spin Hall conductivity gets quantized ($2e^2/h$) with a spin quantization axis parallel to the canting direction. Our theoretical predictions for the canted QSHE findings have just been confirmed experimentally [6]. I will finally briefly mention our recent prediction of giant resistance switch in magnetic topological insulators [7] and discuss the role of entanglement between intraparticle degrees of freedom in spin transport and dynamical patterns of entanglement [8].

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