Topological Spin Transport in Quantum Materials and Entanglement

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I will present theoretical spin transport features in $MoTe_2$ and WTe_2-based materials which are particularly interesting 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 $\lambda_s.\theta_{xy}\sim 8$-10 nm, largely superior to any known SHE material [4]. I will show 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. We also predict the control of the canted QSHE by electric field [6]. I will finally discuss the role of entanglement between intraparticle degrees of freedom in spin transport and dynamical patterns of entanglement, as enabling novel platform for generating and manipulating quantum entanglement between internal and interparticle degrees of freedom [7].

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