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## Topological Spin Transport in Quantum Materials and Entanglement

### Abstract

In this talk, I will present theoretical spin transport features in  $\text{MoTe}_2$  and  $\text{WTe}_2$ -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  $\lambda_s \cdot \theta_{xy} \sim 8\text{-}10$  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- $\text{WTe}_2$ , 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 discuss the role of entanglement between intraparticle degrees of freedom in spin transport and dynamical patterns of entanglement [7].

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