A novel canted spin Hall effect and spin-orbit torques in the 2D topological materials MoTe2 and WTe2

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ABSTRACT

The field of spintronics has evolved tremendously beyond its founding concepts of giant and tunnel magnetorresistances that dominated research in the 1990's and early 2000's. The discovery, understanding and manipulation of new effects such as the spin Hall effect (SHE), the quantum SHE and spin-orbit torques, remarkably widened the toolbox of microscopic mechanisms and material platforms available to manipulate and optimize spin transport towards more effective, low-power information processing and storage technologies. I will present the most recent new direction brought about by combining two-dimensional topological materials, reduced symmetries and strong spin-orbit coupling: the canted (quantum) spin Hall effect. I will overview recent experimental and theoretical work [1-3] where we establish that a family of transition-metal dichalcogenides — which includes WTe2 and MoTe2 — displays the first realization of a canted SHE, and is accompanied by a set of other unique — and highly desirable — spintronic characteristics: extremely long spin diffusion lengths, persistent spin textures, and gate-tunable SHE. The underlying physics will be discussed based on a microscopic model that has been developed from first-principles and validated through extensive numerical simulations of spin transport and the SHE in these materials. I will also show theoretical and experimental work that, in addition, demonstrates the promising potential of these systems for nonlinear magnetotransport [4] and, in particular, to generate large and gate-tunable spin torques [5], thereby enabling all-electrical magnetization switching using atomically-thin semiconductor materials; in a proof-of-principle experiment, we demonstrate their effectiveness in reducing critical switching currents.

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