Interfacing Type-II Weyl Semi-Metals with 2D Magnets

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The modern challenge in computing lies in Moore's law approaching its physical limits, hindering the continued exponential growth in computational power. In the search for energy-efficient and scalable alternatives, spin-based transport phenomena—including magnonics and spin caloritronics have gained significant attention. Magnonics utilizes the spin of electrons to propagate information via collective spin excitations (magnons), while spin caloritronics exploits the interplay between thermal gradients and spin currents to enable thermally driven spin transport.

Two-dimensional (2D) van der Waals (vdW) materials, with their atomically flat interfaces and weak interlayer coupling, offer a highly tunable platform to study these effects. Their versatility enables the construction of versatile heterostructures with potential for enhanced control over spin injection, propagation, and detection. However, electrical transport studies of magnons and spin caloritronic phenomena have traditionally relied on heavy metals like platinum, which complicates investigations in air-sensitive vdW magnets such as CrI_3—a candidate topological magnon insulator *[1]*. This limitation motivates the search for alternative spin injectors and detectors compatible with a wider range of 2D magnets.

To this end we study two-dimensional Weyl semimetals that offer a rich platform for spintronic and caloritronic applications owing to their strong spin orbit coupling, topologically protected edge states and their spin hall responses *[2]*. In this talk, I will present our recent transport measurements from two different systems, namely WTe_2 and $TaIrTe_4$ interfaced with an A-type layered antiferromagnet, $CrPS_4$ **. In the WTe_2 – based devices, in a non-local geometry, we observe magnon spin injection and detection by WTe_2 owing to both conventional and "unconventional" spin Hall effect. In the $TaIrTe_4$-based devices, owing to the rich caloritronic response of the material *[3]*, we are able to directly probe the thermal conductivity of $CrPS_4$ and thus how the thermal conductivity changes through the spin-flop/spin-flip transition of the 2D magnet. Furthermore, we observe signatures of conventional spin-Nernst magnetoresistance indicating that $TaIrTe_4$ acts as a caloritronic spin source in the group of van der Waals materials.

References:

[1] Phys. Rev. X 8, 041028 (2018)
[2] arXiV:2504.01300 (2025)
[3] arXiV:2207.13687 (2022)
** The results are based on manuscripts under preparation.