

Anisotropic magnon transports in van der Waals altermagnetic and ferromagnetic insulators

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Magnons, as the quanta of spin waves, are powerful carriers for spin-information transport at the nanoscale, facilitating the development of wave-based computing technologies with low energy consumption. Emergent van der Waals (vdW) magnets that host long-range spin order at atomic thickness provide intriguing opportunities for miniaturized magnonics. Importantly, the spin Seebeck effect (SSE) and spin Nernst effect (SNE) arising from magnon transport offer effective approaches to generate longitudinal and transverse spin currents in magnetic insulators. However, the SSE in antiferromagnets normally requires a large magnetic field to produce magnon imbalance, while the SNE exploits the spin Berry curvature, which is typically proportional to the strength of spin-orbit coupling in both antiferromagnets and ferromagnets.

Here, based on state-of-the-art first-principles calculations and model analyses [1,2], we report the SSE and SNE in vdW altermagnetic and ferromagnetic insulators, which are entirely independent of magnetic fields and spin-orbit coupling [3]. In altermagnetic monolayers $\text{Cr}_2\text{Te}_2\text{O}$ and $\text{Cr}_2\text{Se}_2\text{O}$, breaking the combined symmetries of space inversion P , time reversal T , and translation τ , while preserving the combined symmetry of mirror M_ϕ and τ , leads to an anisotropic spin-momentum locking of magnons. This phenomenon is mediated by anisotropic exchange coupling favored by the Goodenough-Kanamori-Anderson rules. Interestingly, this spin-momentum locking gives rise to the SSE and SNE, enabling efficient generation of longitudinal and transverse spin currents when the thermal gradient is aligned with, and deviates from, the principal crystal axes, respectively.

Moreover, anisotropic magnon dispersions can also be realized in synthesized ferromagnetic monolayers CrPS_4 and CrSBr , arising from C_4 symmetry breaking-induced anisotropic exchange couplings [4]. Consequently, an anisotropic SSE and a magnon Hall effect accompanied by the SNE are achieved when the thermal gradient is aligned with, and deviates from, the principal crystal axes, respectively. These nontrivial magnonic transports can be further manipulated by temperature and gate current. Our findings thus pave an avenue toward efficient heat-to-spin conversion based on vdW magnetic insulators, free from limitations such as Joule heating, external magnetic fields, and spin-orbit coupling.

References:

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