Designing spin textures and topological transports in insulating antiferromagnets

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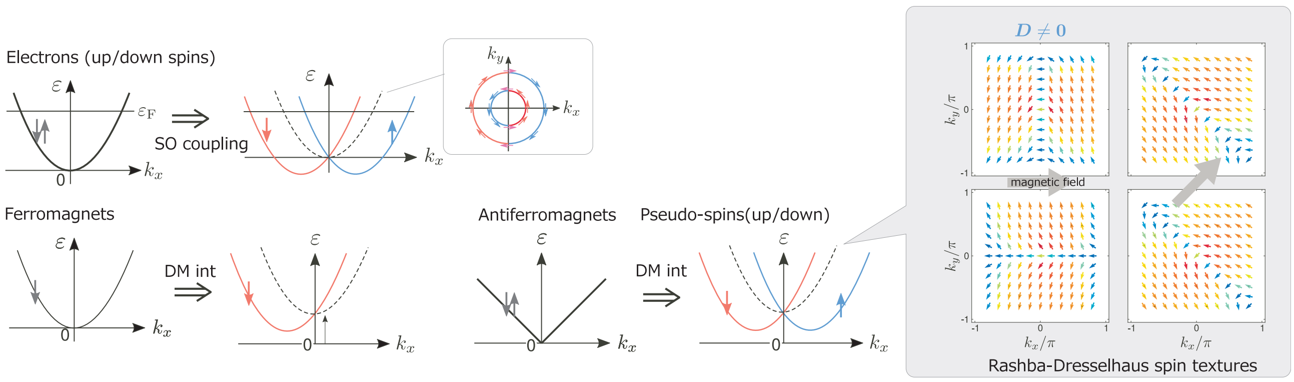
Insulating antiferromagnets are now being recognized as one of the important platforms of spintronic devices[1]. Several advantages over ferromagnets include a relatively high resonance frequency accelerating the writing speed for a memory storage device, and the absence of stray fringing fields important for microfabrication. However, controlling the magnetic structures of antiferromagnets, even detecting the orientation of the ordered moments, is not an easy task. Here, we show that for general antiferromagnets one can theoretically design and control their basic magnetic properties which are tightly bound to magnetotransport effects — an emergent spin texture in reciprocal space[2,3], nonreciprocity of magnon bands[4,5], and topological antiferromagnons that carry heat current[4].

In noncentrosymmetric crystals, the spin-orbit (SO) coupling supported by the broken global inversion symmetry generates Rashba and Dresselhaus types of momentum-dependent electronic spin textures in metals. Although one may expect similar types of phenomena in insulating magnets, the magnons in ferro/ferrimagnets do not have up/down ”spin degrees of freedom” like electrons which can couple to their spatial momentum $\boldsymbol{k}$. In this context, the theoretical highlight of antiferromagnets is the two magnetic sublattices and corresponding two species of magnons, which serve as fictitious up/down ”spin degrees of freedom”. This allows us to design several types of pseudo-SO couplings and related properties; the Dzyaloshinskii-Moriya (DM) interaction that twists the spins work to mix the motion of up/down magnons in a spacially antisymmetric manner, and gives rise to the Rashba and Dresselhaus-types of spin textures of magnon bands. This texture can be easily controlled by a small magnetic field and might hopefully be detected by the microwave measurements. An *anomalous* thermal Hall (ATHE) effect of magnons are also predicted for the two-dimensional square lattice antiferromagnet with easy-axis anisotropy, when a small out-of-plane magnetic field is applied. The origin of this ATHE carried by the SU(2) magnons[4] is qualitatively different from the typical thermal Hall effect (THE) of ferro/ferrimagnets in pyrochlore lattices carried by U(1) magnons[6]. We also show that the pseudo-SO coupling can be generated for other *inversion-symmetry-unbroken cases*, e.g. Kitaev antiferromagnets, where the spatially variant interactions are transformed in a way to mix the kinetic motion of two species of magnons[3]. The basic framework of how to design or predict these phenomena by a sketch of crystal lattices, spin orientations, and the species of interactions, and the magnetic field are shown[2,3,7].



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