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Photo-induced anomalous Nernst effects in transition metal dichalcogenides

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1. Introduction

Monolayer transition metal dichalcogenides (TMDCs) such as MoS2, MoSe2, WS2 and WSe2 are quasi-two-dimensional semiconducting alternatives to graphene that have recently attracted much attention due to their remarkable electronic and optoelectronic properties [1–4]. The lack of inversion symmetry in TMDCs, in contrast to graphene, gives rise to nontrivial quantum phenomena [5,6] rooted in the topological nature of the Bloch electrons. In addition, valley-spin coupled physics [5] emerges in TMDCs from broken inversion symmetry and strong spin-orbit interaction, making TMDCs intriguing candidates for spintronic and valleytronic applications.

Thermoelectric effects ubiquitously appear in materials under a thermal gradient. These can provide microscopic insight into the electronic structure and the dynamics of electronic transport and optical excitations. Indeed, spontaneous photocurrent generation in MoS2 under laser illumination was reported most recently and was interpreted in terms of a photo-thermoelectric effect with an unusually large Seebeck coefficient [7].

In this presentation, we theoretically investigate the basic thermoelectric response of TMDCs under light illumination. We establish that their photo-thermoelectric response is nontrivial and experimentally measurable due to the interplay of strong spin-orbit interaction, spin relaxation asymmetry (between election and hole bands) and the topological properties of Bloch wave functions, manifested in a finite Berry curvature [8].

2. Results

In our setup, a TMDC is sandwiched between hot and cold heat reservoirs and is subjected to circular polarized light. Irradiation by circular polarized light excites electron-hole pairs selectively at either the K or K' valley of the TMDC band structure.

Our findings show that monolayer TMDCs subjected to circular polarized light exhibit intriguing thermoelectric properties due to strong spin-orbit interaction, which breaks electron-hole symmetry, and broken inversion symmetry, which induces a finite Berry curvature. The Nernst effect describes the transverse voltage response to a longitudinal thermal gradient in the presence of an external magnetic field. Surprisingly, TMDCs display a large anomalous Nernst signal of the order of sub-microvolts per Kelvin, despite the absence of an external magnetic field and magnetic moments, as shown in Fig.1. Here, this anomalous Nernst effect requires the broken inversion symmetry, which induces a finite Berry curvature, in addition to spin-orbit coupling, electron- hole asymmetry and valley degeneracy breaking (through photoexcitations). Hence, the valley Nernst effect is absent in graphene.

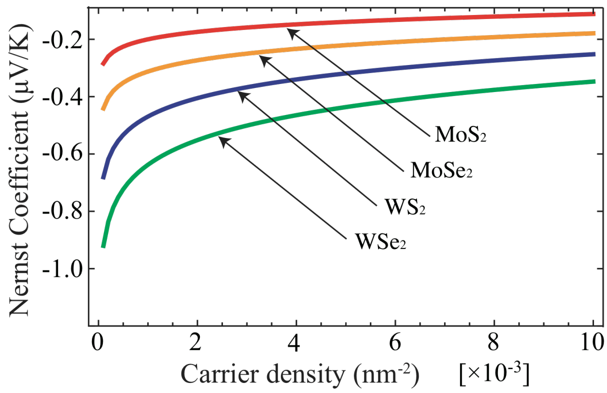

Fig.1. Carrier density dependence of the Nernst coefficient for photo-generated electron-hole carriers in TMDCs.

3. Conclusions

We have theoretically investigated the photo-thermoelectric properties of monolayer TMDCs using semiclassical transport theory. We have found that monolayer TMDCs subjected to circular polarized light exhibit anomalous thermoelectric properties. These features are characteristic to TMDCs and not expected to appear in two-dimensional relatives like graphene.

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