凝縮系物理学ゼミナール

Condensed Matter Seminar

Date: 13:30-15:00, Wednesday, 19 July 2023

Title: Surface acoustic waves-driven magnon spin Hall effect in atomically thin van der Waals antiferromagnets

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Abstract:

Intrinsic magnetism in two-dimensional (2D) materials had long been believed to hardly survive due to the enhanced thermal fluctuations. However, the recent discovery of exfoliated van der Waals (vdW) magnets has opened up a new avenue for 2D magnetism at finite temperatures [1,2]. Especially, transition metal phosphorus trichalcogenides MPX3 (M = Fe, Ni, Mn; X = S, Se) are a family of easily exfoliatable vdW antiferromagnets [3]. These materials share the same honeycomb lattice structure, but the bulk antiferromagnetic (AFM) phase varies depending on the magnetic elements [4]. Furthermore, compared to ferromagnets, antiferromagnets exhibit ultrafast dynamics in the terahertz regime, null stray field, and robustness against the external magnetic field perturbation. Therefore, the investigation of these materials paves the way towards not only the fundamental understanding of 2D magnetism, but also the possibility of high-speed and compact AFM spintronic devices.

Standard methods such as magnetization measurements and neutron diffraction, which could only access macroscopic magnetic properties, are not suitable for the study of atomically thin magnets. Especially, antiferromagnets do not have net magnetization, direct measurement of AFM ordering using magneto-optical Kerr effect is not available either. Although recent studies have focused on Raman spectroscopy [5,6] and second-harmonic generation [7,8] to detect crystal symmetry lowering associated with the AFM transition, these signals often do not provide clear identification of the AFM order in the monolayer limit. Therefore, a comprehensive method which suits for exploring the magnetic properties of 2D antiferromagnets is highly desired.

Here, we propose a dissipationless magnon spin Hall current driven by the surface-acoustic waves (SAWs) as a novel method to probe the magnetic structures of such 2D vdW antiferromagnets [9]. Owing to extremely large mechanical flexibility of 2D materials, SAWs are ideally suited for fundamental research of them [10]. A spatial modulation of exchange energies due to strain mimics the role of artificial gauge fields for magnons. The strain gauge fields work at two valley points of the Brillouin zone in the opposite direction, leading to the activation of the valley degrees of freedom (DOF). Therefore, the valley DOF with the use of SAWs is a promising concept for mechanical detection and manipulation of the magnetic order in 2D vdW antiferromagnets.

References:

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