北京大学量子材料科学中心
International Center for Quantum Materials, PKU

Weekly Seminar

Probing quantum transport in atomically thin semiconducting transition metal dichalcogenides

Ning Wang (王宁）

Department of Physics and Center for Quantum Materials,
the Hong Kong University of Science and Technology, Hong Kong

Time: 4:00Pm, Nov. 28, 2018 (Wednesday)

时间：2018年11月28日 （周三）下午4:00

Venue: Room W563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

Atomically thin semiconducting transition metal dichalcogenides (TMDCs) such as MoS_2, $MoSe_2$, WS_2 and WSe_2 form a family of layered two-dimensional materials exhibiting novel electronic and optical properties. Probing the quantum transport in these TMDCs has been a long-standing challenge due to the low carrier mobility and the large contact resistance in their field-effect devices prepared by the exfoliation method. In this talk, I demonstrate our recent experimental study on quantum transport of few-layer MoS_2 and WSe_2, and their unconventional Landau levels (LLs) with strong interaction effects. We fabricate high-quality n-type MoS_2 and p-type WSe_2 devices by encapsulating these TMDCs in ultra-clean hexagonal boron nitride sheets which effectively eliminate impurity scattering and provide clean interfaces for making high-quality low-temperature ohmic contacts to these semiconducting TMDCs [1]. Few-layer MoS_2 and WSe_2 field-effect devices with mobilities up to 30,000 cm^2/V s have been achieved at cryogenic temperatures. We observe interesting quantum Hall (QH) phenomena involving the Q valley, Γ valley and K valley, such as the Q valley Zeeman effect in all odd-layer MoS_2 devices and the spin Zeeman effect in all even-layer MoS_2 devices [2] and highly density-dependent QH states of Γ valley holes in WSe_2 [3]. The predominant sequences of the QH states of Γ valley holes in few-layer WSe_2 alternate between odd- and even-integers with reducing the density. By tilting the magnetic field to induce Landau level crossings, we show that the strong Coulomb interaction enhances the ratio of Zeeman-to-cyclotron energy, giving rise to the even-odd alternation of the predominant sequences. For n-type MoS_2, we have studied the valley-resolved SdH oscillations relevant to the spin-valley locked massive Dirac electron LLs. With decreasing the carrier density in the conductance band (K valley), we observe LL crossing induced valley ferrimagnet-to-ferromagnet transitions and the enhancement of the valley Zeeman effect by Coulomb interactions. In n-type monolayer and trilayer MoS_2, we first detect the intrinsic valley Hall transport without any extrinsic symmetry breaking through measuring the nonlocal resistance that scales cubically with the local resistance. Such a phenomenon survives at room temperature with a valley diffusion length at the micron scale. We believe that the large intrinsic bandgap in MoS_2 contributes to maintaining a large amplitude of the Berry curvature, allowing to observe the valley Hall effects even at room temperature in monolayer MoS_2.

References:

[1] S.G. Xu, et al., 2D materials **2016**, 3, 021007.
[2] Z.F. Wu, et al., Nat. Comm. **2016**, 7, 12955.
[3] S.G. Xu, et al., Phys. Rev. Lett. **2017**, 118, 067702.

About the speaker

Ning Wang is Chair Professor of Physics, Director of Center for Quantum Materials and Director of Materials Characterization & Preparation Facility at the Hong Kong University of Science and Technology. His research interests include fundamental issues of nano-structure and nano-device technology, quantum transport of two-dimensional structures, and high-resolution transmission electron microscopy.

Professor Wang obtained his BSc (1985) and PhD (1990) degrees in materials physics from the University of Science and Technology, Beijing. In 1989, he received the Alexander von Humboldt Research Fellowship and worked at the Institute for Metal Physics, Goettingen University and the Fritz-Haber-Institute of the Max-Planck Society, Berlin, Germany. In 1993, he joined the Physics Department of the Hong Kong University of Science and Technology. During 1997-2000 he worked in the Department of Applied Physics and Materials Science, the City University of Hong Kong.

Professor Wang has authored/co-authored over 260 peer-reviewed research papers in reputed international journals, 30 conference papers, 2 Book chapters, 5 US Patents. He received Chien-Shiung Wu Physics Award (1990), State Natural Science Award (2005) and Achievement in Asia Award (2006).