北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Seminar

A Pathway to the Four-Dimensional Quantum Hall Effect

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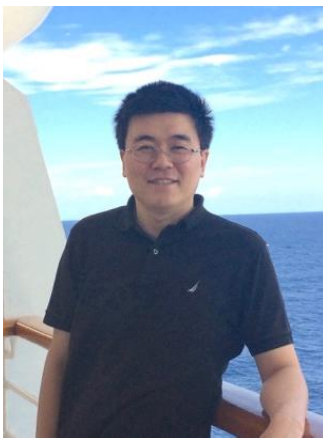
清华大学



Time: 10:00 am, April 28, 2026 (Tuesday)

时间：2026年4月28日（周二）上午10:00

Venue: Room w563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

The four-dimensional quantum Hall effect (4D QHE) was first theoretically proposed by S.C. Zhang *et al.* in 2001 [1] and is closely related to the SU(2) Yang monopole in five-dimensional space. For a long time, this theory lacked suitable material systems for experimental verification. In 2008 and 2009, the groups of S.C. Zhang [2] and D. Vanderbilt [3] independently demonstrated that, by treating three-dimensional space together with time as a four-dimensional parameter space, the 4D QHE can manifest as the topological magnetoelectric effect (TME) in three-dimensional topological insulators. Analogous to the two-dimensional quantum Hall effect characterized by the first Chern number, the 4D QHE is characterized by the second Chern number. Currently, three-dimensional topological insulators serve as the primary material platform for 4D QHE research, but the expected TME signal is extremely weak, necessitating ultra-high-sensitivity measurement techniques.

In this talk, I will present our recent breakthroughs in addressing this long-standing experimental challenge. First, using the quantum anomalous Hall (QAH) system as a validation platform, we developed an ultra-sensitive out-of-plane charge accumulation measurement technique with a resolution of <0.1 fC/Gs, achieving the first observation of quantized charge accumulation in the multi-domain 4D QHE regime [4]. Second, we pioneered an active capacitive compensation method that introduces an effective negative capacitance in the gate line, equivalently enhancing the gate capacitance. This approach successfully recovered over 95% of the severely attenuated signal in QAH samples, removing a key technological barrier for single-domain 4D QHE detection [5].

With these core technologies established, we are now positioned to pursue the final experimental observation of the 4D QHE through both transport and optical measurement approaches. This talk will provide a comprehensive overview of the scientific concepts, technical innovations, and future directions of our research, highlighting our systematic progress toward unveiling this fundamental topological phenomenon. If time permits, other directions [6,7] of ongoing research in my lab will also be presented.

References

1. S.C. Zhang *et al.*, *Science* **294**, 823–828 (2001)
2. S.C. Zhang *et al.*, *Phys. Rev. B* **78**, 195424 (2008)
3. D. Vanderbilt *et al.*, *Phys. Rev. Lett.* **102**, 146805 (2009)
4. Y. Li *et al.*, *arXiv*:2509.08701
5. Y. Li *et al.*, *arXiv*:2603.05025
6. Y. Li *et al.*, *arXiv*:2603.05341
7. J. Chen *et al.*, *arXiv*:2510.12361

About the speaker

梁田，清华大学物理系副教授。2009年、2011年分别本科、硕士毕业于日本东京大学物理系，2016年于美国普林斯顿大学物理系获博士学位。2016年至2018年、2018年至2021年分别担任美国斯坦福大学博士后、日本理化学研究所特别研究员。2021年加入清华大学物理系，主要研究方向为拓扑量子材料的输运与光学测量。至今已发表近40篇论文，其中包括Nature及子刊8篇、 Science及子刊2篇、PNAS与PRL 7篇、以及其他论文20余篇。总引用数8000余次。现任科技部重点研发计划（青年项目）首席科学家。