



Weekly Seminar

Function follows form:

When shape dictates the physics of quantum materials

Philip J.W. Moll

Max-Planck Institute for the Structure and Dynamics of Matter, Germany



Time: 3:00 pm, Oct.21, 2026 (Wednesday)

时间: 2026年10月21日 (周三) 下午3:00

Venue: Room w563, Physics building, Peking University

地点: 北京大学物理楼, 西563会议室

Abstract

Symmetry is a core guiding theme in condensed matter research, informing the search for novel materials with unusual response functions. It enforces certain response functions to vanish if they are incompatible with the symmetry of the crystal lattice. For example, centro-symmetry and electronic directionality, such as diode-like behavior, is fundamentally incompatible. While this is rigorously true for bulk response functions, mesoscopic shapes may change the effective symmetry group of the problem, and unlock functionality forbidden by symmetry in the bulk. With recent advances in 3D mesoscopic control of single crystal structures via focused ion beam machining, shape control emerges as a powerful design principle towards electronic functionality in quantum materials.

A few recent examples of novel electronic behavior demonstrate this principle. In the Kagome superconductor CsV_3Sb_5 , mesoscopic confinement within the Kagome planes uncovers chiral transport[1] associated with a thus-far enigmatic coherent many-body state[2]. Further in Bi [3], strongly quantizing magnetic fields push electric transport currents to the surface – replacing completely the electronic symmetry of its hexagonal unit cell by the designed shape. Shape control uncovers a 3D version of the quantum Hall effect, in which geometric edge currents encircle the device in the quantum limit. In the iron-based superconductor FeSe [4], an inversion symmetric material, strong superconducting diode effects can be designed, tuned and even inverted by shape control over the formation of nematic domains on the mesoscale. These cases serve as an example for the emergent paradigm of 3D shape control over electronically active quantum materials.

[1] C. Guo et al., Nature 611, 461–466 (2022) ; [2] C. Guo et al., Nature 647, 68–73 (2025)

[3] J. Seo et al., Nat. Phys. 22, 232 (2026); [4] R.D.H. Hinlopen et al., arXiv:2604.26631

About the speaker

Philip Moll is a director at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) in Hamburg, Germany, where he leads the Microstructured Quantum Matter department, and a professor at the University of Hamburg. Since 2026 he also holds a Distinguished Professorship at Tohoku University in Japan.

His research explores how the size and shape of a crystal change the physics inside it. His group pioneered the use of focused ion beam machining to sculpt single crystals of quantum materials into three-dimensional structures on the micrometer scale, turning sample geometry from a nuisance into an experimental tool. With these bespoke devices, the group studies electronic transport in strongly correlated and topological materials. Highlights include the first direct evidence of hydrodynamic electron flow in ultra-clean delafossite metals, field-induced nematicity and strain-engineered superconductivity in heavy-fermion compounds, Weyl-orbit and quasi-symmetry-protected transport in topological semimetals, and, most recently, magnetically switchable electronic chirality in the kagome metal CsV_3Sb_5 .

Philip studied physics at ETH Zurich and received his PhD there in 2012 in the group of Bertram Batlogg, where he first used focused ion beam fabrication to study iron-based superconductors in high magnetic fields. After postdoctoral work at ETH and at UC Berkeley with James Analytis on topological semimetals, he was awarded an independent Max Planck Research Group at the MPI for Chemical Physics of Solids in Dresden in 2015. In 2018 he joined EPFL in Lausanne as a tenure-track assistant professor at the Institute of Materials, before taking up his current position in Hamburg in 2022. His work has been recognized with the ETH Medal (2013), the ABB Award of the Swiss Physical Society (2014) and the Nicholas Kurti Science Prize (2018), and he was named a World Economic Forum Young Scientist in 2020. In 2025 he was elected a Fellow of the American Physical Society. He has received two ERC grants (Starting Grant 2017, Consolidator Grant 2023) and a Swiss National Science Foundation Professorship, and serves on the steering committee of the European FIB Network and the scientific advisory committee of HFML-FELIX.