FM 10: Topology: Artificial Systems

Time: Monday 14:00–15:45 Location: 1199

Invited Talk FM 10.1 Mon 14:00 1199

Engineered electronic states in atomic lattices and hybrid 2D systems — •Peter Liljeroth — Department of Applied Physics, Aalto University School of Science, PO Box 15100, 00076 Aalto, Finland

Constructing designer materials with engineered electronic properties is one of the emerging topics in condensed matter physics. I will discuss this approach using examples based on atomic manipulation by the tip of a scanning tunneling microscope (STM), molecular self-assembly, and direct growth of hybrid 2D materials to reach the desired structures.

Using atomic manipulation, it is possible to construct lattices where every atom is in a well-defined, predetermined position. This opens possibilities for creating artificial materials and I will illustrate this concept by showing how chlorine vacancies on Cu(100) [1] can be used to implement various one-dimensional artificial lattices with topological domain wall states and engineered band structures with flat bands.[2,3]

In the second part of the talk, I will focus on the kind of engineered electronic states that can be realized in hybrid structures consisting of magnetic and superconducting transition metal dichalcogenides. Direct molecular-beam epitaxy growth allows the construction of vertical heterostructures with clean and high-quality interfaces,[4] which is of importance for the realization of the possible edge modes.

[1] F.E. Kalff et al. Nat. Nanotech. 11, 926 (2016). [2] R. Drost et al. Nat. Phys. 13, 668 (2017). [3] Md N. Huda et al. in preparation. [4] S. Kezilebieke et al. in preparation.

FM 10.2 Mon 14:30 1199

Topologically Protected Giant End Spins in Carbon Nanotubes — •Gergely Zarand[1], Pascu Moca[1,2], Wataru Izumida[3], Balazs Dora[4], and Örs Legeza[5] — [1]BME-MTA Exotic Quantum Phases Research Group, Institute of Physics, Budapest University of Technology and Economics, Hungary — [2]Department of Physics, University of Oradea, Romania — [3]Department of Physics, Tohoku University, Sendai, Japan — [4]Department of Theoretical Physics and MTA-BME Lendulet Topology and Correlation Research Group, Budapest University of Technology and Economics, Hungary — [5]Strongly Correlated Systems Lendület Research group, Wigner Research Centre for Physics, Budapest, Hungary

Carbon nanotubes can be classified according to topological classes. For most chiralities, semiconducting nanotubes display topologically protected end states of multiple degeneracies. We study these end states in the presence of Coulomb interactions by means of DMRG-based quantum chemistry tools and demonstrate the formation of giant end spins, the close analogues of ferromagnetic states emerging at graphene nanoribbon edges. The interaction between the two ends is sensitive to the length of the nanotube, its dielectric constant, as well as the size of the end spins: for $S=1/2$ end spins their interaction is antiferromagnetic, while for $S>1/2$ it changes from antiferromagnetic to ferromagnetic with increasing nanotube length. The interaction between end spins can be designed by controlling the dielectric constant of the environment, thereby providing a possible platform for two-spin quantum manipulations.

FM 10.3 Mon 14:45 1199

The Creutz-Hubbard ladder: a multi-purpose setup — •Matteo Rizzi — Institute for Theoretical Physics, Universität zu Köln, Germany — Institute for Quantum Control (PGI-8), Forschungszentrum Jülich, Germany

We briefly review recent contribution of ours about the Creutz Hubbard ladder, which allows to explore topological flat bands and undoubled Dirac cones, (symmetry-protected) fractional interacting phases as well as exotic transport properties, all in a single tunable setup. We provide experimental recipes for cold atomic gases. We employ analytical mappings onto effective models and numerical tensor networks calculations, thereby computing static and dynamical observables and entanglement properties, too.

References: J. Jünemann, A. Piga, S.-J. Ran, M. Lewenstein, M. Rizzi, A. Bermudez, PRX 7, 031057 (2017) M. Bischoff, J. Jünemann, M. Polini, M. Rizzi, PRB 96, 241112(R) (2017); A. Bermudez, E. Tirrito, M. Rizzi, M. Lewenstein, S. Hands, Ann. Phys. 339, 149 (2018); E. Tirrito, MR, G. Sierra, M. Lewenstein, and A. Bermudez, PRB 99, 125106 (2019); S. Barbarino, D. Rossini, M. Rizzi, R. Fazio, G.E. Santoro, and M. Dalmonte, NJP 21, 043048 (2019).

FM 10.4 Mon 15:00 1199

Identifying Quantum Phase Transitions using Artificial Neural Networks on Experimental Data — Benno Rem[1,2], •Niklas Käming[1], Matthias Tarnowski[1,2], Luca Asteria[1], Nick Fläschner[1], Christoph Becker[1,3], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]ILP Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]ZOQ Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Machine learning techniques such as artificial neural networks are currently revolutionizing many technological areas and have also proven successful in quantum physics applications. Here we employ an artificial neural network and deep learning techniques to identify quantum phase transitions from single-shot experimental momentum-space density images of ultracold quantum gases and obtain results, which were not feasible with conventional methods. We map out the complete two-dimensional topological phase diagram of the Haldane model and provide an accurate characterization of the superfluid-to-Mott-insulator transition in an inhomogeneous Bose-Hubbard system. Our work points the way to unravel complex phase diagrams of general experimental systems, where the Hamiltonian and the order parameters might not be known.

FM 10.5 Mon 15:15 1199

Creating anomalous Floquet Chern insulators with magnetic quantum walks — M. Sajid[1], J. K. Asbóth[2], D. Meschede[1], R. F. Werner[3], and •A. Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Germany — [2]Wigner Research Centre for Physics, Budapest, Hungary — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

We propose a realistic scheme to construct anomalous Floquet Chern topological insulators using spin-1/2 particles carrying out a discrete-time quantum walk in a two-dimensional lattice [1]. By Floquet engineering the quantum-walk protocol, an Aharonov-Bohm geometric phase is imprinted onto closed-loop paths in the lattice, thus realizing an Abelian gauge field, the analog of a magnetic flux threading a two-dimensional electron gas. We find that because of the nonperturbative nature of the periodic driving, a second topological number in addition to Chern number is necessary to fully characterize the anomalous Floquet topological phases of magnetic quantum walks and to compute the number of topologically protected edge modes expected at the boundaries between different phases. We discuss an implementation of this scheme using neutral atoms in two-dimensional spin-dependent optical lattices, which enables the generation of arbitrary magnetic-field landscapes, including those with sharp boundaries. Magnetic quantum walks may open a new route to studying topological properties of charged particles in strong magnetic fields.

[1] M. Sajid *et al.*, Phys. Rev. B (in press, 2019)

FM 10.6 Mon 15:30 1199

Topological bands and Anomalous Floquet-Anderson Insulators in two-dimensional quantum walks — •Janos Asboth[1] and Tibor Rakovszky[2] — [1]Wigner Research Centre for Physics of the H.A.S., and Budapest University of Technology and Economics — [2]Technical University of Munich

We study the interplay of topology and Anderson localization in two-dimensional periodically driven systems, specifically, quantum walks. In previous work, we have found that when disorder is introduced by onsite potential "kicks" to the simplest two-dimensional quantum walks (two Floquet bands, vanishing Chern number), they undergo Anderson localization, but their edge states survive, realizing a so-called Anomalous Floquet-Anderson Insulator (AFAI). Choosing more complicated walk protocols, we tune the topological invariants of the Floquet bands, and investigate what happens to Floquet-Chern insulators under the effect of disorder. We find Anderson localization via the "levitation and annihilation" of the bands, and ask whether this mechanism can also lead to an Anomalous Floquet-Anderson Insulator.