PhD Symposium Synthesized Gauge Fields and Experimental Realizations (SYPS)

organized by
the Working Group "Young DPG" (AGjDPG)

Holger Ahlers
Institut für Quantenoptik
Leibniz Universität Hannover
Welfengarten 1
30167 Hannover

Naceur Gaaloul
Institut für Quantenoptik
Leibniz Universität Hannover
Welfengarten 1
30167 Hannover

Torben Schulze
Institut für Quantenoptik
Leibniz Universität Hannover
Welfengarten 1
30167 Hannover

Quickly after the first realization of Bose-Einstein condensates and degenerate Fermi gases, ultracold matter has been identified as an ideal quantum simulator for condensed matter problems. However, due to their electric charge neutrality, they fail to emulate systems involving the coupling of the orbital degree of freedom to magnetic fields. This limitation motivated the quest for ways to emulate those orbital effects, and interpret them as synthetic fields acting on effective charges. The PhD symposium comprises an interplay between tutorials and up-to-date research talks, focusing on theoretical strategies to synthesize gauge fields as well as novel experimental realizations.

Overview of Invited Talks and Sessions

(Lecture room e415)

Invited Talks

SYPS 1.1	Tue	14:30–15:00	e415	**Artificial magnetism and cold atomic gases** — •Jean Dalibard
SYPS 1.2	Tue	15:00–15:30	e415	**Gauge fields in multi-level atoms: a tutorial** — •Ian B. Spielman
SYPS 1.3	Tue	15:30–16:00	e415	**Controlling and Exploring Topological Bloch Bands Using Ultracold Atoms** — •Immanuel Bloch
SYPS 1.4	Tue	16:00–16:30	e415	**Observing edge states with ultracold neutral fermions in synthetic dimensions** — •Leonardo Fallani

Sessions

SYPS 1.1–1.4	Tue	14:30–16:30	e415	**Synthesized Gauge Fields and Experimental Realizations**

SYPS 1: Synthesized Gauge Fields and Experimental Realizations

Time: Tuesday 14:30–16:30 Location: e415

Invited Talk SYPS 1.1 Tue 14:30 e415

Artificial magnetism and cold atomic gases — •Jean Dalibard — Collège de France and Laboratoire Kastler Brossel, 11 Place Marcelin Berthelot, 75005 Paris, France

The simulation of condensed matter systems is certainly one of the most appealing perspectives opened in the physics of cold atomic gases. Among the large variety of quantum collective phenomena that one hopes to address with atomic vapours, magnetism is one of the richest. However the quest for the simulation of magnetism immediately raises a challenging question: can a system of neutral atoms behave as an assembly of charged particles in a magnetic field?

In this introductory lecture I will explain how atom-light interaction allows one to answer this question positively. I will present some strategies for engineering artificial gauge fields, based for example on the notion of Berry's phase or on time-modulated Hamiltonians. I will also discuss how the notion of topology can emerge in the context of cold quantum matter and explain how it can be characterized by an integer, the so-called Chern number.

Invited Talk SYPS 1.2 Tue 15:00 e415

Gauge fields in multi-level atoms: a tutorial — •Ian B. Spielman — University of Maryland, College Park, MD, USA — National Institute of Standards and Technology, Gaithersburg, MD, USA

We use Raman lasers to induce artificial gauge fields or spin-orbit coupling in the F=1 electronic ground state manifold of rubidium-87, I will describe this physics in the language of the Berry's phase. With this backdrop, I will explain our recent experiments engineering a two-dimensional magnetic lattice in an elongated strip geometry, with effective per-plaquette flux about 4/3 times the flux quanta where the lattice's long direction consisted of the sites of an optical lattice and its narrow direction consisted of the internal atomic spin states: a synthetic dimension.

Invited Talk SYPS 1.3 Tue 15:30 e415

Controlling and Exploring Topological Bloch Bands Using Ultracold Atoms — •Immanuel Bloch — Max-Planck Institut für Quantenoptik, Hans Kopfermann Str. 1, 85748 Garching, Germany — Ludwig-Maximilians Universität, Schellingstr. 4, 80799 München, Germany

In my talk, I will show how recent experiments with cold gases in optical lattices have enabled to realise and probe artificial magnetic fields that lie at the heart of topological energy bands in a solid. Using a novel "Aharonov-Bohm" type interferometer that acts within the momentum space, we are e.g. now able to fully determine experimentally the geometric structure of an energy band. Furthermore, transport measurements in 2d and 1d topological bands have enabled us to realize static and dynamic analogues of the Integer Quantum Hall effect. In 1d, this constitutes the first experimental realization of the celebrated Quantum Pump, proposed more than 30 years ago David Thouless.

Invited Talk SYPS 1.4 Tue 16:00 e415

Observing edge states with ultracold neutral fermions in synthetic dimensions — •Leonardo Fallani — University of Florence, Italy

I will report on recent experiments performed at LENS with ultracold multicomponent 173Yb Fermi gases. We have engineered Raman transitions between different 173Yb nuclear spin states to synthesize an effective lattice dynamics in a finite-sized "extra dimension", which is encoded in the internal degree of freedom of the atoms [1]. By using this innovative approach, we have realized synthetic magnetic fields for effectively-charged fermions in ladder geometries with a variable number of legs. Direct imaging of the individual legs allowed us to demonstrate the emergence of chiral edge currents and to observe edge-cyclotron orbits propagating along the edges of the system, thus providing a direct evidence of a fundamental feature of quantum Hall physics in ultracold fermionic systems.

[1] M. Mancini et al., Observation of chiral edge states with neutral fermions in a synthetic Hall ribbon, Science 349, 1510 (2015).