Michael LOHSE

Group of Prof. Dr. Immanuel Bloch,
Fakultät für Physik, Ludwig-Maximilians-Universität München

1. Short CV

1987: Born in Heidelberg, Germany
2007-2013: Student, Department of Physics, University of Karlsruhe
2009/2010: Visiting Student, Edward L. Ginzton Laboratory, Stanford University (group of Prof. Yoshihisa Yamamoto)
2013: Diploma Thesis "*Large-Spacing Optical Lattices for Many-Body Physics with Degenerate Quantum Gases*", group of Prof. Immanuel Bloch, Max-Planck-Institut für Quantenoptik
Since April 2013: PhD student, group of Prof. Immanuel Bloch, Ludwig-Maximilians Universität München
Since July 2014: PhD student in the ExQM PhD Programme

Awards & Prizes

2006	Scholarship of the Max Weber Programme (declined)
2007-2013	Scholarship of the Studienstiftung des deutschen Volkes

External collaborations:
B. Paredes - CSIC/UAM (Madrid, Spain)
S. Nascimbène – Collège de France/Laboratoire Kastler Brossel (Paris, France)
N.R. Cooper – University of Cambridge (Cambridge, United Kingdom)
N. Goldman – Université Libre de Bruxelles (Brussels, Belgium)
O. Zilberberg – ETH Zürich (Zurich, Switzerland)
R. Citro - Università degli Studi di Salerno (Salerno, Italy)
H. Price – Università di Trento (Trento, Italy)

2. PhD Project: "Ultracold Bosonic Atoms in Optical Superlattices"

Ultracold atoms in optical lattices are a promising model system for studying quantum many-body systems. The charge neutrality of atoms, however, prevents a direct simulation of the effects of magnetic fields on charged particles like for example the quantum Hall effect.
In the first part of my PhD, we have been working on the experimental implementation of a technique that allows for the generation of large homogeneous and tunable artificial magnetic fields in optical lattices, i.e. makes the neutral atoms behave as if they were charged particles in an external magnetic field. It is based on laser-assisted tunneling which can be used to engineer position-dependent complex tunneling amplitudes such that atoms moving in the lattice accumulate a phase shift equivalent to the Aharonov-Bohm phase for charged particles in magnetic fields.
Using this technique and in collaboration with B. Paredes (Madrid), we could observe cyclotron orbits of individual atoms [1] as well as an analogon of the Meissner effect for atoms in quasi-1D ladder systems [2]. Moreover, together with S. Nascimbène (Paris), N. Cooper (Cambridge) and N. Goldman (Brussels), we could demonstrate the non-trivial

topological properties of the band structure in the presence of an artificial magnetic field by measuring the Chern number of lowest band in the Hofstadter model [3].
In the past year, we have been studying so-called topological charge pumps that enable the transport of charge through an adiabatic cyclic evolution of the Hamiltonian even in insulating systems. For filled bands, this motion is quantized and extremely robust against perturbations as the transported charge is related to a topological invariant. It can therefore be regarded as a dynamical version of the integer quantum Hall effect. In a joint project with O. Zilberberg (Zurich), we could realize such a pump with bosonic atoms in a dynamically controlled optical superlattice and observe the quantized deflection for the first time [4].

Outlook:
Currently we are working on extending the idea of topological pumping to spin systems which would allow to generate pure spin currents in the absence of charge transport. For this, we are developing a technique to directly measure spin currents in optical lattices. In the future, we would like to study charge pumping in 2D systems were effects related to the 4D quantum Hall effect are predicted. In this project, we are collaborating with O. Zilberberg (Zurich) and H. Price (Trento). This collaboration would be greatly facilitated by an extended stay in either Trento or Zurich, funded by ExQM.

Publications and preprints:
[1] M. Aidelsburger, M. Atala, M. Lohse, J.T. Barreiro, B. Paredes, and I. Bloch, "Realization of the Hofstadter Hamiltonian with Ultracold Atoms in Optical Lattices", *Phys. Rev. Lett.* **111**, 185301 (2013)
[2] M. Atala, M. Aidelsburger, M. Lohse, J.T. Barreiro, B. Paredes and I. Bloch, "Observation of chiral currents with ultracold atoms in bosonic ladders", *Nature Physics* **10**, 588 (2014)
[3] M. Aidelsburger, M. Lohse, C. Schweizer, M. Atala, J.T. Barreiro, S. Nascimbène, N.R. Cooper, I. Bloch and N. Goldman, "Measuring the Chern number of Hofstadter bands with ultracold bosonic atoms", *Nature Physics* **11**, 162 (2015)
[4] M. Lohse, C. Schweizer, O. Zilberberg, M. Aidelsburger and I. Bloch, "A Thouless quantum pump with ultracold bosonic atoms in an optical superlattice", *Nature Physics* **12**, 350 (2016)

Presentations at conferences:
2014:
- DPG Frühjahrstagung (Berlin), "Realization of the Hofstadter Hamiltonian with Ultracold Atoms in Optical Lattices"

2015:
- DPG Frühjahrstagung (Heidelberg), "Measuring the Chern number of Hofstadter bands with ultracold bosonic atoms"
- Physics of bulk-edge correspondence & its universality – Workshop (Tokyo, Japan), "Measuring the Chern number of Hofstadter bands with ultracold bosonic atoms"
- MPQ-Kavli Workshop (Delft, Netherlands), "A Thouless quantum pump with ultracold bosonic atoms in an optical superlattice"