Congratulations to new ICFO PhD Graduate

Dr. Tobias Grass graduated with a thesis on quantum gases in synthetic gauge fields.

April 23, 2013

Dr. Grass received his Diplom in Physics at the Freie Universitat Berlin before joining ICFO?s Quantum Optics research group led by ICREA Professor at ICFO, Maciej Lewenstein. His research has centered on many-body phenomena which emerge from the interplay of ultracold atoms with a synthetic gauge field. Dr. Grass presented a thesis entitled ?Ultracold Atoms in Artificial Gauge Fields? that was jointly supervised by Prof. Maciej Lewenstein and Dr. Bruno Julia Diaz.

ABSTRACT:

The present thesis studies a variety of cold atomic systems in artificial gauge fields. In the first part we focus on fractional quantum Hall effects, asking whether interesting topological states can be realized with cold atoms. We start by making a close connection to solid-state systems and first consider fermionic atoms with dipolar interactions. Assuming the system to be in the Laughlin state, we evaluate the energy gap in the thermodynamic limit as a measure for the robustness of the state. We show that it can be increased by additionally applying a non-Abelian gauge field squeezing the Landau levels. We then switch to bosonic systems with repulsive contact interactions. Artificial magnetic fields for cold bosons have extensively been discussed before in the context of rotating Bose gases. We follow a different approach where the gauge field is due to an atom-laser coupling. Thus, transitions between different dressed states have to be included. They are shown to break the cylindrical symmetry of the system. Modifying the Laughlin state and the Moore-Read state accordingly, we determine the parameter regimes where they are good representations for the ground state of the system obtained via exact diagonalization. One of the most interesting features of fractional quantum Hall states is the anyonic behavior of their excitations. We therefore also study quasiholes in the Laughlin state and the modified Laughlin state. They are shown to possess anyonic properties, which become manifest even in small systems. Moreover, the dynamics of a single quasihole causes visible traces in the density of the system which allow to clearly distinguish the Laughlin regime from less correlated phases. In the latter, a sequence of collapses and revivals of the quasihole can be observed, which is absent in the Laughlin regime. Extending our study to bosonic systems with a pesudospin-1/2 degree of freedom, we discuss the formation of strongly correlated spin singlets. Strikingly, at filling ?=4/3, the system is described by a state with non-Abelian excitations, which is constructed as the zero-energy ground state of repulsive three-body contact interactions. Systems with internal degrees of freedom also allow for implementing artificial spin-orbit coupling. It is shown to give rise to a variety of incompressible states. In the second part of the thesis, we concentrate on condensed system. Bose-Einstein condensates with spin-orbit coupling are shown to have a degeneracy on the mean-field level, which is lifted by quantum and thermal fluctuations. The system becomes experimentally feasible in three dimensions, where the condensate depletion remains finite, and thus allow for an experimental observation of this order-by-disorder mechanism. Finally, we study the influence of Abelian and non-Abelian gauge fields on the quantum phase transitions of bosons in a square optical lattice. Re-entrant superfluid phases and superfluids at finite momenta are interesting properties featured by such systems.

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Thesis comittee