TT 1: Focussed Session: The Mott Transition in Model Systems

Time: Monday 10:15–13:00 Location: HSZ 03

Invited Talk TT 1.1 Mon 10:15 HSZ 03
Strongly Correlated Fermionic Quantum Gases in Optical Lattices — •Immanuel Bloch — Institut für Physik, Johannes Gutenberg-Universität, Germany

Mixtures of ultracold quantum gases in optical lattices can act as novel fundamental model system, with which the physics of the Hubbard model can be experimentally tested in a versatile and highly tunable experimental setting. We present experiments on the static and dynamic properties of such strongly interacting fermions in optical lattices and compare these to state of the art calculations using e.g. Dynamical Mean Field Theory (DMFT) in three dimensions. For repulsive interacting degenerate quantum gas mixtures, we find that by increasing the interactions between the particles, the system can be tuned from a metal over a Mott insulator into a band insulator for increasing compression of the quantum gas. We have implemented a novel detection method that can directly measure the resulting compressibility of these interacting fermionic many-body systems. For increasingly attractive interactions, we find that beyond a critical interaction strength between the particles the gas expands rather than contracts. Such an anomalous spatial expansion is intimately linked to the formation of attractively bound fermion pairs in the system. Finally, novel experiments on the dynamical expansion of interacting fermions are presented. Such diffusion measurements should allow us to shed new light on the complex interplay of interacting fermions in disordered potentials in the future.

Topical Talk TT 1.2 Mon 10:45 HSZ 03
Mott transition and metastable superconductivity of repulsive Fermions in optical lattices — •Achim Rosch — Institute of Theoretical Physics, University of Cologne, 50937 Cologne

Cold atoms in optical lattices can be used to realize and control strongly correlated states of matter with unprecedented flexibility and precision. One can, for example, study the physics of the fermionic Mott transition by measuring [1] to what extent an atomic cloud in the Mott regime can be compressed. The experiments are well described by the dynamical mean field theory [1].

With cold atoms one can also realize novel non-equilbrium states. We show theoretically [2] that one can prepare an s-wave superfluid state when a dense clould of atoms described by the strongly repulsive Hubbard model is slowly expanded. Here we use that doubly occupied sites have an exponential large lifetime in the limit of strong repulsion. These pairs condense at a finite momentum which allows for a reliable detection of this exotic state of matter.

[1] U. Schneider, L. Hackermuller, S. Will, Th. Best, I. Bloch, T. A. Costi, R. W. Helmes, D. Rasch, A. Rosch, preprint arXiv:0809.1464, accepted for publication in Science

[2] A. Rosch, D. Rasch, B. Binz, M. Vojta, preprint arXiv:0809.0505, accepted for publication in PRL

Topical Talk TT 1.3 Mon 11:15 HSZ 03
Carrier dynamics of two-dimensional organic charge-transfer salts close to the Mott transition — •Martin Dressel[1], Natalia Drichko[1], Michael Dumm[1], and Jaime Merino[2] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Departamento de Física Teórica de la Materia, Universidad Autónoma de Madrid, Spain

In recent years, it became clear that electronic interactions have a severe influence on the physics of two-dimensional electron systems [1-3]. Strong Coulomb repulsion drives a transition to a Mott-insulator in a half-filled meta, while in the case of a quarter-filled conduction band charge order is observed. Optical spectroscopy is the superior method to investigate the electronic properties. Our findings on organic crystals are compared with theoretical predictions.

Organic conductors serve as model systems to study physics in two-dimensions. The Mott transition can be tuned by decreasing the temperature or by increasing the effective electronic correlations. Physical and chemical pressure are proper tools to tune the bandwidth; doping or change of the stoichiometry allow for a variation of the carrier concentration. Close to the Mott transition but still on the metallic side, quasi-particles are observed in the 1/2-filled system κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]X only at temperatures well below 100 K, with a considerable growth of the Drude-like contribution. The itinerant carriers exhibit strong renormalization effects as the metal-insulator transition is approached.

[1] M. Dressel et al., Chem. Rev. **104** 5689 (2004).

[2] D. Faltermeier, et al., PRB **76**, 165113 (2007).

[3] J. Merino, et al., PRL **100**, 086404 (2008).

15 min. break

Topical Talk TT 1.4 Mon 12:00 HSZ 03
Mott Transition in Frustrated Lattice Systems — •Hirokazu Tsunetsugu — Institute for Solid State Physics, University of Tokyo, Kashiwa, Japan

I will review in my talk our recent theoretical works on strongly correlated itinerant electrons on two typical frustrated lattices; Kagome and anisotropic triangular lattices. The main issues are how geometrical frustration modifies the Mott metal-insulator transition, one of the most interesting phenomena driven by strong correlation, and how magnetic correlations under frustration effects are related to coherence of electron dynamics, and also the possibility of new type of spin correlations near the transition point. To investigate these points, we have investigated a half-filled Hubbard model on these frustrated lattices by a cluster extension of dynamical mean field theory. In addition to the general trend of suppression of Mott transition, we found one-dimensional like spin correlations in the Kagome case and a reentrant insulator-metal-insulator crossover/transition in the anisotropic triangular lattice. The latter behavior is consistent with the phase diagram of κ-type ET salts experimentally determined by Kanoda group. Our results indicate that the interplay between large entropy inherent to spin frustration and short range antiferromagnetic correlation is responsible for this interesting reentrant behavior.

[1] T. Ohashi, N. Kawakami, and H. Tsunetsugu, Phys. Rev. Lett. **97**, 066401 (2006).

[2] T. Ohashi, T. Momoi, H. Tsunetsugu, and N. Kawakami, Phys. Rev. Lett. **100**, 076402 (2008).

Topical Talk TT 1.5 Mon 12:30 HSZ 03
Lattice Effects in Strongly Correlated π-electron Systems Close to the Mott Transition — •M. de Souza[1], A. Bruehl[1], C. Strack[1], B. Wolf[1], R.S. Manna[1], J.A. Schlueter[2], D. Schweitzer[3], and M. Lang[1] — [1]Physikalisches Institut, Goethe-Universität Frankfurt, Max-von-Laue Str. 1, SFB/TRR49, D-60438 Frankfurt (M), Germany — [2]Chem. and Mat. Science Divisions, Argonne NL, Argonne, IL 60439, USA — [3]Physikalisches Inst., Universität Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany

Organic charge-transfer salts have been recognized as model systems for studying the interplay of strong electronic correlations and low dimensionality. Depending on the chemical composition and/or hydrostatic pressure, the materials show a rich variety of electronic phases including Mott insulating, spin- and charge-ordered, anomalous metallic, spin-liquid-like as well as superconducting states. By using ultrahigh-resolution thermal expansion measurements, we have explored the role of the lattice degrees of freedom for some of the above-mentioned phases. We will discuss the Mott transition in κ-(D8-BEDT-TTF)$_2$Cu[N(CN)$_2$]Br [1], the mysterious charge-order transition coinciding with ferroelectric order in (TMTTF)$_2$X [2] as well as the spin-liquid-like properties observed for κ-(BEDT-TTF)$_2$Cu$_2$(CN)$_3$ [3]. Our results highlight the intricate role of the lattice degrees of freedom for stabilizing the various ground states in these materials.

[1] M. de Souza *et al.*, Phys. Rev. Lett. **99**, 037003 (2007).

[2] M. de Souza *et al.*, Phys. Rev. Lett. **101**, 216403 (2008).

[3] S. Yamashita *et al.*, Nature Phys. **4**, 459 (2008).