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Metallic and Insulating Phases of Interacting Fermions in a 3D Optical Lattice

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Ultracold fermions in optical lattices are a promising tool to simulate solid state physics, since they represent an ideal and highly tunable implementation of the Hubbard Hamiltonian. A proof of principle is to demonstrate a Mott insulating state, where repulsive interactions between the atoms lead to an insulating behavior in a half-filled conduction band. In our experiments we study repulsively and attractively interacting ^{40}K atoms within the combination of a red-detuned dipole trap and a blue detuned lattice. This setup allows us to gradually transform the system from metallic to Mott-insulating and band insulating states. We measure the phase of the system by analyzing the system size and the number of doubly occupied sites and compare our findings to DMFT theory. In addition we investigate the dynamical behavior of interacting fermionic mixtures. We prepare a band insulating system and suddenly release it into a homogenous lattice. We detect a symmetric behavior from a ballistic expansion for non-interacting clouds to a strongly suppressed expansion due to the formation of attractively or repulsively bound pairs. This experiment allows us to study transport properties of the Hubbard model. This work was done together with U.Schneider, S. Will, Th. Best, S. Braun, I. Bloch and with theoretical support from T.A. Costi, R.W. Helmes, D. Rasch, A.Rosch, B. Paredes, M. Moreno-Cardoner, T. Kitagawa, E.Demler.