MAR07-2006-020315

Abstract for an Invited Paper
for the MAR07 Meeting of
the American Physical Society

Evidence for Superfluidity of Ultracold Fermions in an Optical Lattice[1]

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The study of superfluid fermion pairs in a periodic potential has important ramifications for understanding superconductivity in crystalline materials. By using cold atomic gases, various models of condensed matter can be studied in a highly controllable environment. Weakly repulsive fermions in an optical lattice could undergo d-wave pairing at low temperatures, a possible mechanism for high temperature superconductivity in the copper oxides. The lattice potential could also strongly increase the critical temperature for s-wave superfluidity. Recent experimental advances in bulk atomic gases include the observation of fermion-pair condensates and high-temperature superfluidity. Experiments with fermions and bosonic bound pairs in optical lattices have been reported but have not yet addressed superfluid behavior. Here we report the observation of distinct interference peaks when a condensate of fermionic atom pairs is released from an optical lattice, implying long-range order (a property of a superfluid). Conceptually, this means that s-wave pairing and coherence of fermion pairs have now been established in a lattice potential, in which the transport of atoms occurs by quantum mechanical tunnelling and not by simple propagation. These observations were made for interactions on both sides of a Feshbach resonance. For larger lattice depths, the coherence was lost in a reversible manner, possibly as a result of a transition from superfluid to insulator. Such strongly interacting fermions in an optical lattice can be used to study a new class of hamiltonians with interband and atom-molecule couplings.

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