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Population dynamics in a sodium spinor condensate[1]

PAUL LETT[2], Joint Quantum Institute

Spinor condensates provide an accessible way to study the dynamics of a quantum system. A number of interesting studies have been published of spin population dynamics and domain formation in ferromagnetic Rb BECs, and we have begun to examine the antiferromagnetic case of Na. Na atoms are condensed in the F=1 state in a tight optical trap which holds the different spin projections equally well. For Na the spatial wavefunction of the BEC can be treated as "single mode," and there is no phase separation of the spin projections. This allows a description with a single spatial wavefunction and an independent "spinor" wavefunction containing the spin variables. The interesting collisions are ones that couple two m=0 atoms to one m=+1 and one m=-1 atom. The linear Zeeman shift cancels and the interesting interactions are simply the quadratic Zeeman shift and the difference between the scattering lengths for the different spin states. Na is antiferromagnetic inasmuch as the m=+1/m=-1 collision has a lower energy state than the collision of two atoms in the same spin state. If the populations are initialized to a non-equilibrium state a collisional exchange takes place, leading to oscillations in the spin populations. The collisional interaction tends to cancel the quadratic Zeeman interaction in an antiferromagnetic system, leading to a divergence in the oscillation period near a critical magnetic field. We observe population oscillations and see signs of this divergence. We measure a phase diagram for the equilibrium populations as a function of magnetic field and magnetization (the difference in population between spin +1 and spin -1) that shows signs of a zero-temperature quantum phase transition. We have begun a series of experiments to observe the population dynamics through Faraday rotation spectroscopy. This is a less-destructive means of observing the system and should allow us to both observe and control the dynamics of the system.

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[2]NIST, Gaithersburg and University of Maryland