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Tunable Interactions in Quantum Degenerate Lithium[1]

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Quantum degenerate gases provide an ideal environment for studying fundamental physics. In these systems, a Feshbach resonance can be utilized to tune the interactions between certain colliding pairs of atoms, yielding control over both the magnitude and sign of the interactions. This has opened the doorway to a new area in which the underlying physics of non-linear optical phenomena and many solid-state effects can be explored in the ideal environment of a quantum degenerate gas. We will first discuss the experimental realization of a quantum degenerate Bose-Fermi mixture via sympathetic cooling [truscott01]. By confining this quantum degenerate gas in an all optical potential, the atom-atom interactions of the bosons can be manipulated to produce bright matter-wave solitons [strecker02] which are individual Bose-Einstein condensates (BEC) that we have observed to propagate for over 3 seconds without dispersion. Further, a highly interacting Fermi gas can be produced near a Feshbach resonance, and through manipulation of the external magnetic field, long lived ultra-cold bosonic molecules can be formed from the Fermi gas [strecker03]. The unexpected long lifetime of these vibrationally excited ($v' = 38$) molecules enables them to be evaporatively cooled to a molecular BEC. We use a pure molecular condensate as a probe of the BEC/BCS crossover region within the broad Feshbach resonance. Using an interrogation laser tuned to a bound-bound molecular resonance, the deeply bound molecular component of the gas is measured as a function of magnetic field, probing the fundamental many-body physics of a strongly interacting Fermi gas.

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