Mixtures of Degenerate Atomic Gases : Bosonic ^7Li and Fermionic ^6Li

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We designed a system in which two lithium isotopes, the boson ^7Li and the fermion ^6Li can be trapped in a Magneto-Optical Trap and cooled etin a magnetic Ioffe-Pritchard trap [1]. This provides a physical system with several interesting situations ranging from mixture of interacting degenerate quantum gases with different statistics, Bose-Einstein condensate with attractive or repulsive interactions at will, and possibly to pairing of strongly interacting fermions [2] as for the Bardeen-Cooper-Schriefer (BCS) transition in supraconductors.

Since there are no s-wave collisions between identical fermions at zero temperature due to the Pauli exclusion principle we developped a sympathetic cooling scheme in which the bosons are cooled down using the classical evaporative cooling technique and the fermions thermalize by elastic collisions with the bosons. Using ^7Li atoms in a hyperfine state where the scattering length is positive (repulsive interactions) we were able to reach the degeneracy regime with both isotopes [3]. The equilibrium temperature of the mixture is $0.28\mu K \simeq 0.2(1)T_C = 0.2(1)T_F$ where T_C is the BEC transition temperature and T_F the Fermi temperature. The signature of the BEC phase transition is straightforward in the momentum distribution of the bosons whereas precise study of the fermions distribution is needed to observe the effect of Fermi pressure. This mixture offers interesting prospects for the study of phase separation effects [4, 5].

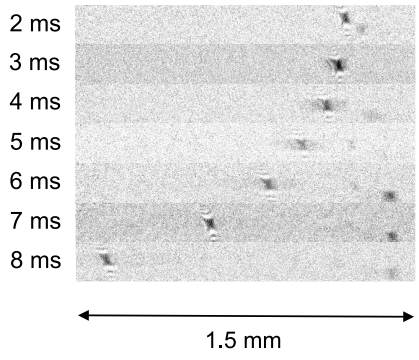

Figure 1: Absorption images of a soliton travelling in the horizontal 1D optical waveguide.

The scattering length can also be tuned by means of a bias magnetic field when a *Feshbach resonance* [6] occurs between two hyperfine states of one or two isotopes. Using such a resonance we could reach Bose-Einstein Condensation with ^7Li in an optical trap with a positive scattering length ($a = 2.1$ nm at 665 G) and then tune the scattering length to a negative value ($a = -0.21$ nm at 425 G) [8]. In a one-dimensional configuration, this attractive condensate exhibits a so-called solitonic behaviour. The non-linearity arising from the attractive interaction term compensates the dispersion due to the kinetic energy term resulting in a propagation without spreading [7]. After releasing our attractive condensate in a 1-D optical dipole trap we observed a propagation without spread over a macroscopic distance of 1.1 mm.

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