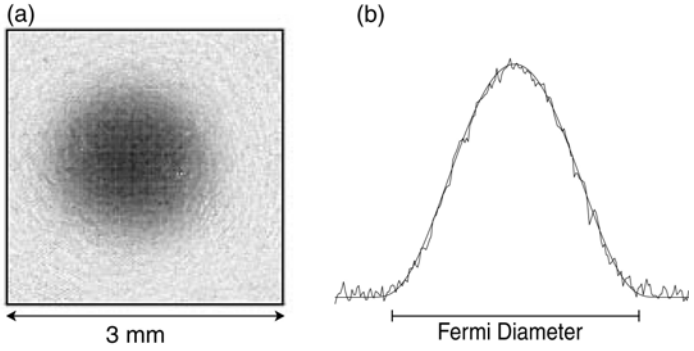
Fifty-fold improvement in the number of quantum degenerate fermionic atoms

For a long time, the cooling of Fermi gases was lagging behind the studies of atomic Bose-Einstein condensates (BECs) due to the complexity of cooling methods. The Pauli exclusion principle prohibits elastic collisions between identical fermions at ultra-low temperatures, and makes evaporative cooling of spin-polarized fermionic samples impossible. For this reason, cooling of fermions must rely on some form of mutual or sympathetic cooling between two types of distinguishable particles. A key element in fermion cooling is the design of better "refrigerators" for sympathetic cooling.

We have realized evaporative cooling of sodium in the upper hyperfine state (F=2) and achieved Bose-Einstein condensates in this state by direct evaporation. Sympathetic cooling of lithium with that cloud decreased losses due to inelastic collisions encountered in earlier experiment with sodium in the lower (F=1) state.

This resulted in the production of degenerate Fermi samples comparable in size with the largest alkali BECs [1]. We successfully cooled up to 7×10^7 magnetically trapped ^{6}Li atoms to below half the Fermi temperature (T_F), an improvement in atom number by a factor of 50 over the largest previously reported Fermi sea. Further, in samples containing up to 3×10^7 atoms, we observed temperatures as low as 0.05 T_F, the lowest ever achieved. At these temperatures, the fractional occupation of the lowest energy state differs from unity by less than 10^{-8}.



Large and ultra-degenerate Fermi sea. (a) Absorption image of 3×10^7 ^{6}Li atoms released from the trap and imaged after 12 ms of free expansion. (b) Axial (vertical) line density profile of the cloud in (a). A semiclassical fit (thin line) yields a temperature T = 93 nK= 0.05 T_F . At this temperature, the high-energy wings of the cloud do not extend visibly beyond the Fermi energy, indicated in the figure by the momentum-space Fermi diameter.

1. Z. Hadzibabic, S. Gupta, C.A. Stan, C.H. Schunck, M.W. Zwierlein, K. Dieckmann, and W. Ketterle, *Fifty-fold improvement in the number of quantum degenerate fermionic atoms*, Phys. Rev. Lett. **91**, 160401 (2003).