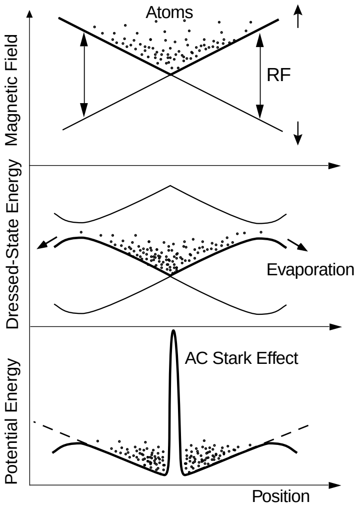
Progress in year 1995

1. *Optically plugged magnetic quadrupole trap*

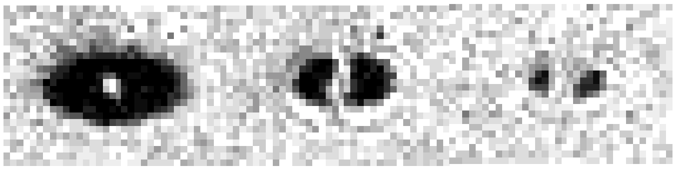
In 1995, we have demonstrated a novel atom trap which consists of a combination of magnetic fields and far-off-resonant light. This trap offers a superior combination of large trapping volume and tight confinement. It allowed us to attain samples of ultracold atoms at unprecedented densities ($>10^{14}$ cm^{-3}) and to evaporatively cool atoms to Bose-Einstein condensation [1].

The trap used a magnetic spherical quadrupole field which provided a tightly confining linear trapping potential. This potential suffered from trap loss due to non-adiabatic spin-flips in the center of the trap, which was suppressed by overlapping a focused argon ion laser beam. This light (514 nm) was blue-detuned with respect to the sodium resonance at 589 nm and created a repulsive potential due to the ac Stark effect (see figure).



The trapping potential of the optically plugged magnetic trap has three components: The linear magnetic potential is due to the magnetic field gradient. Radio-frequency radiation is used to evaporate atoms - in an effective potential picture, it creates a potential with a finite depth. Finally, the light shift (ac Stark shift) of a focused laser beam repels the atoms from the zero of the magnetic field. The total potential consists of magnetic Zeeman shifts, level shifts due to rf radiation and light shifts.

During evaporative cooling, the cloud shrunk and finally split up into two parts held in the double-minimum trapping potential (see figure).

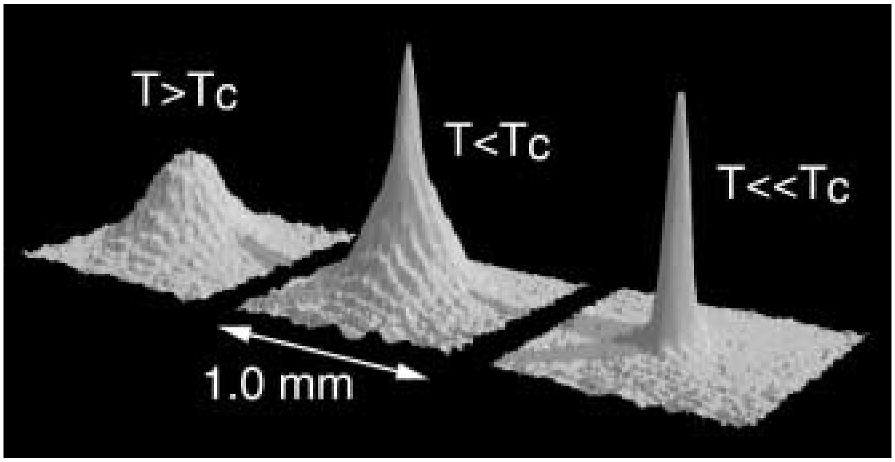


(a) (b) (c)

Absorption images of atom clouds trapped in the optically plugged trap. Cloud (a) is already colder than was attainable without the “plug” (Ar ion laser beam). Cloud (b) shows the break-up of the cloud into two “pockets” in the two minima of the potential. The size of cloud (c) reaches the optical resolution of the imaging system (< 10 µm) still absorbing 90 % of the probe light. This sets an upper bound on temperature (< 10 µK) and a lower bound on density ($5\ 10^{12}$ cm^{-3}).

2. A. Bose-Einstein condensation in a weakly interacting gas

In 1995 we observed Bose-Einstein condensation in a novel atom trap which consisted of a combination of magnetic fields and far-off-resonant light. This trap offered a superior combination of large trapping volume and tight confinement. It allowed us to obtain samples of ultracold atoms at unprecedented densities (10^{14} cm^{-3}) and to evaporatively cool atoms to Bose-Einstein condensation in seven seconds [1]. Condensates contained up to 5×10^5 atoms at densities exceeding 10^{14} cm^{-3}. The striking signature of Bose condensation was the sudden appearance of a bimodal velocity distribution when the sample was cooled below the critical temperature of ~2 μK (see figure) . The distribution consisted of an isotropic thermal distribution and an elliptical core attributed to the expansion of a dense condensate.



Bose-Einstein condensation in sodium. Shown are absorption images of ballistically expanding clouds above, slightly and well below the phase transition temperature.

1. K.B. Davis, M.-O. Mewes, M.R. Andrews, N.J. van Druten, D.S. Durfee, D.M. Kurn, and W. Ketterle, Phys. Rev. Lett. **75**, 3969 (1995).