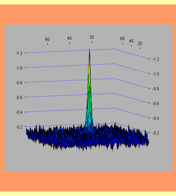

All Optical Bose-Einstein condensation of chromium

Q. Beaufils, T. Zanon, B. Laburthe-Tolra, E. Maréchal, **L. Vernac**, J. C. Keller, O. Gorceix

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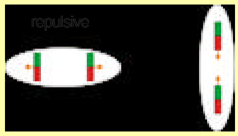
Why is chromium interesting ?

- large magnetic moment 6μ_B
- large dipole - dipole interactions
- physics of Spinor condensates (multi component BEC)

- Cr has a fermionic (^{53}Cr) and a bosonic (^{52}Cr) isotope with a large abundance (resp. 10% and 84 %)
- Possibility to reach a Fermi sea by sympathetic cooling
- Possibility to study a degenerate mixture BEC - Fermi sea

Study of the dipole - dipole interactions in quantum gazes

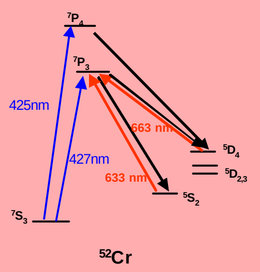


The dipole - dipole interactions are '**long range**' (1/r^3) and **anisotropic**

Chromium specificities for trapping

- difficult to obtain an atomic beam : high melting point (1700°)
- chromium MOTs are small and have a relatively small number of atoms (large light assisted inelastic losses)
- presence of metastable states: adds difficulties but solutions as well !
- large inelastic collisions in the ground state (spin exchange/dipolar) makes the condensation in Magnetic Traps impossible

Chromium atomic levels



^{53}Cr

I = 3/2

Hyperfine structures with Relatively small splitting

All trapping frequencies achievable from one laser with AOMs

Laser Sources

- Cooling transition (425 nm) : Ti:Sa laser doubled
- Metastable states repumping: commercial laser diodes
- Optical pumping (427 nm) : commercial diode doubled

Description of our experiment

- Commercial high temp oven (1500 °C and more)
- One meter long Zeeman Slower
- Experimental chamber with P=5.10^{-11} mBarr

Our first results (2005) : a double MOT ^{52}Cr/^{53}Cr

Atom numbers ^{53}**Cr**: 4.10^5 ^{52}**Cr**: 4.10^6 Temperature: 110 µK

Accumulation is possible in the D states in a MT…
…but we chose to try to load directly an optical trap

R. Chicireanu et al., Phys. Rev. A **73**, 053406 (2006)

Loading efficiently a 1D chromium optical trap

Two major improvements

We accumulated atoms in the D states inside a 1D optical trap **directly** from the MOT

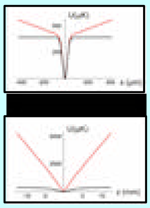
RF sweeps can average out magnetic forces

Using accumulation towards another metastable state via depumping

1 D Optical trap characteristics:

- we use of a 50 Watt multimode fiber laser (1075 nm)
- horizontal trap made by a 35 Watt retro reflected beam
- laser focused on the atoms with a 40 µm waist
- trap depth = 500 µK

Total potential :
a mixed trap



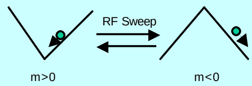
Optical forces dominate transversally

Magnetic forces dominate longitudinally

Results:
About one million atoms in low field seeking states are trapped in 200 ms

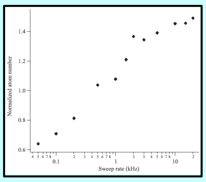
R. Chicireanu et al., Euro Phys J D **45**, 189 (2007)

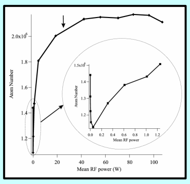
Nice but insufficient to reach degeneracy by evaporative cooling !
→ the initial number of atoms has to be increased



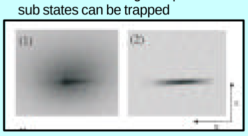
RF frequency sweeps must be :

- **Large** enough (freq. ramps from 0.5 to 10 MHz)
- **Fast** enough
- **Powerful** enough



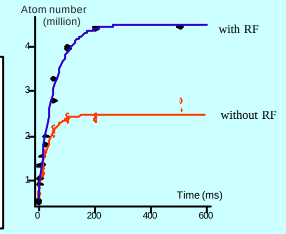


We thus obtain a larger trap and **all** the m_J sub states can be trapped



Q. Beaufils et al, arXiv:0711.0663 (2007)

- A weak 427 nm beam is depumping atoms towards $^5S_2$ (and the D states)
- A « dark spot » 633 nm repumper cancels the depumping beam in the MOT trapping region but doesn't excite atoms in the OT

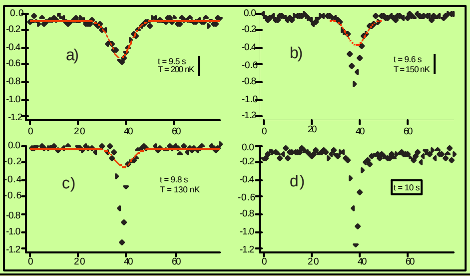


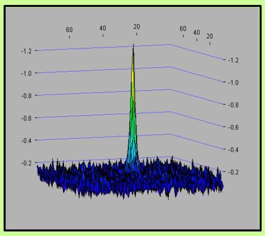
At the end of the loading :
- we switch off the MOT gradient
- we repump the atoms towards the ground state
- we optically pump them to the high field seeking m_J = -3 absolute ground state

- 5 million atoms at T=80 K and a density ~ 3.10^{11} at/cm^3
- main limiting process: inelastic collisions

Our first BEC

- After the 1D OT loading we form a **crossed optical trap** (use of a λ/2 + pbs)
- We lower the IR laser power from 35 W to 500 mW in 10 s





(17 novembre 2007)

BEC specs :

We obtain on a regular basis 20 000 atoms in an almost pure BEC

Density : 6.1013 at.cm-3

Chemical potential : 800 Hz

Trap frequencies :

90, 110 and 150Hz

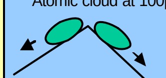
Ongoing experiments

- Use of large RF fields to modify the Landé g_J factor

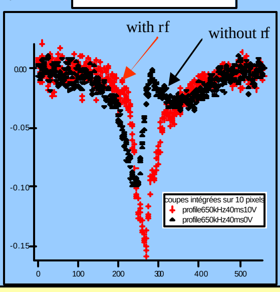
when the RF frequency [illegible] is larger than the Larmor frequency [illegible]$_0$:

$$g_J(\Omega) = g_J J_0\left(\frac{\Omega}{\omega}\right)$$

Atomic cloud at 100µK

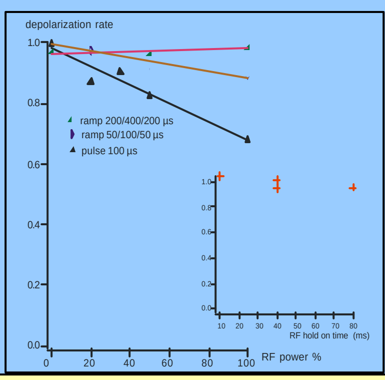


Longitudinal potential for mJ=-3 substates around B=0



- Use of large RF fields to change coherently the internal state

In presence of strong RF field the eigenstates are RF dressed states



- Study of the collective modes of excitations

The dynamical eigenfrequencies of the BEC are changed due to the dipolar interactions
→ small effect (5% range)

Next

- Formation of molecules in the BEC
- Loading of the BEC in an optical lattice
- Study of the thermalization of fermionic polarized gazes

Long term goal

Obtaining a degenerate Fermi gas By sympathetic cooling and studying a degenerate boson-fermion mix in an **optical lattice**

(*) Work supported by : Conseil Régional Ile-de-France (Sesame contract), Ministère de l'Education Nationale et de la Recherche (CPER 2001-2006), European Union (Fonds Européen de Développement Régional) and IFRAF.