Towards a quantum gas of polar YbCs molecules

AtMol
Durham Atomic & Molecular Physics

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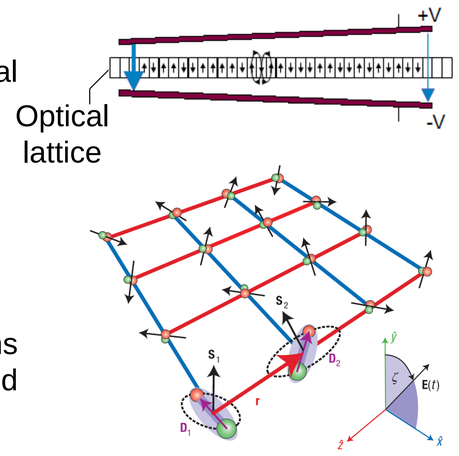
Ultracold polar molecules are an interesting area of atomic and molecular physics, with possible future areas for study including quantum computation and degenerate quantum gases of molecules. This experiment aims to produce ground state YbCs molecules, using techniques such as magneto-association across Feshbach resonances and STIRAP. In order to do this, the first step is to produce and combine ultracold atoms of Ytterbium and Caesium in the same trap.

Why YbCs?

• Ground state polar molecules in a lattice potential could be used for[1,2]:

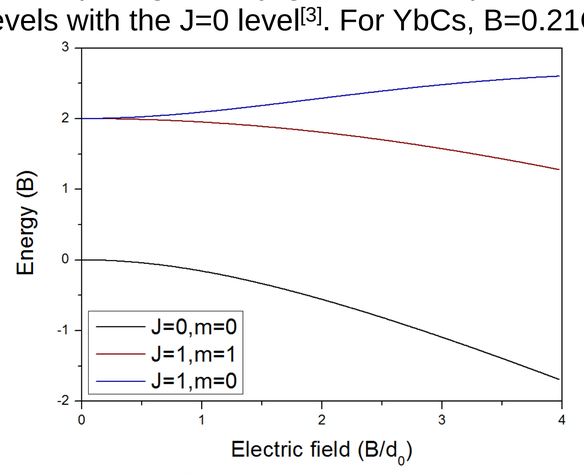
- *Quantum information processing from the entanglement of molecules*
- *Studying crystal-like formations from angle dependent interactions between dipoles*

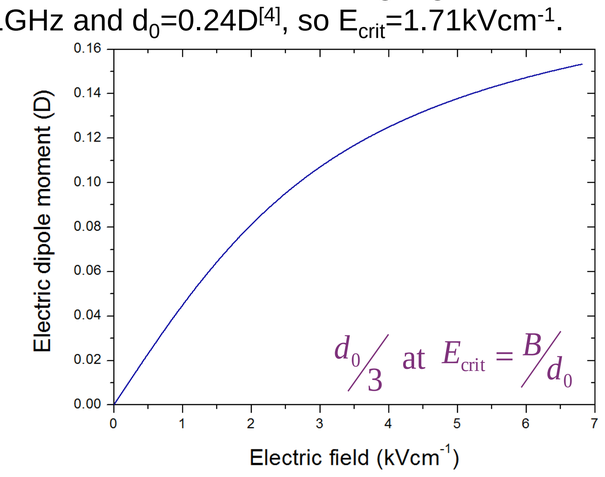


• Ytterbium has two valence electrons, which means that the YbCs molecule will have both electronic and magnetic dipole moments.
• Ytterbium has both fermionic and bosonic isotopes.
• The high number of stable isotopes, along with the heavy mass of caesium gives an increased chance of favourable collision properties.

Electric dipole moment for ground state molecules

Stark splitting for any ground state polar molecule occurs due to mixing higher rotational levels with the J=0 level[3]. For YbCs, B=0.21GHz and d_0=0.24D[4], so E_{crit}=1.71kVcm^{-1}.

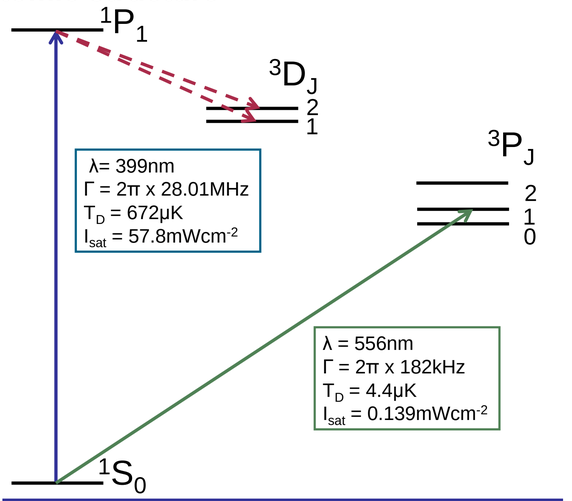




Similar work in YbRb[5] and YbLi[6,7].

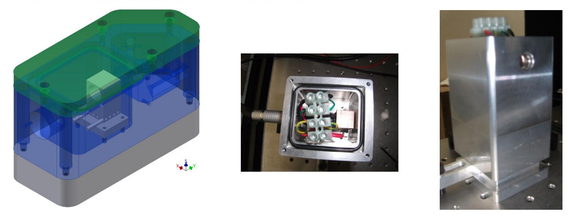
Cooling Ytterbium

Atomic structure

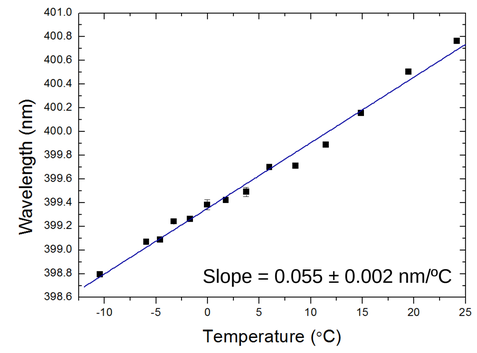


Isotope	Degeneracy?	Relative abundance (%)	Nuclear spin
168	Yes [8]	0.13	0
170	Yes [9]	3.05	0
171	No	14.3	1/2
172	No	21.9	0
173	Yes [10]	16.12	5/2
174	Yes [11]	31.8	0
176	Yes [10]	12.7	0

399nm laser source

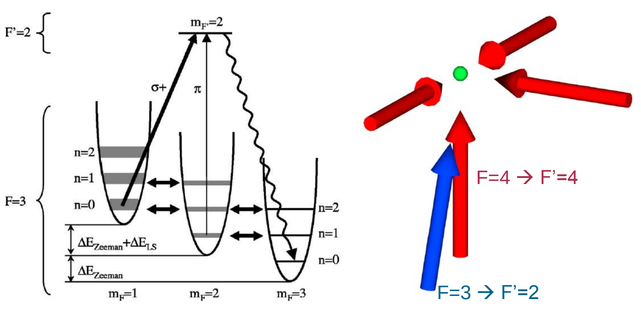


• 399nm light for Zeeman slowing and 556nm for the MOT.
• From the 556nm MOT no further cooling is needed before the Yb is transferred to an optical dipole trap.
• Mitsubishi ML320G2-11 diode.

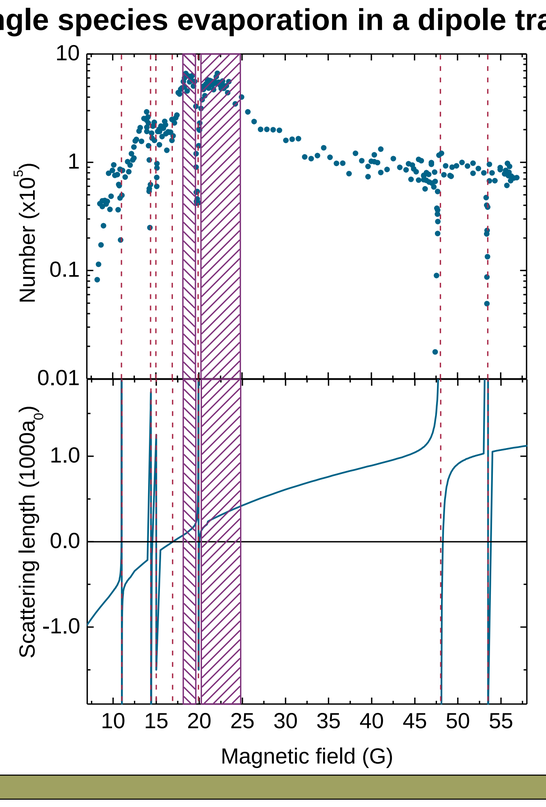


Cooling Caesium

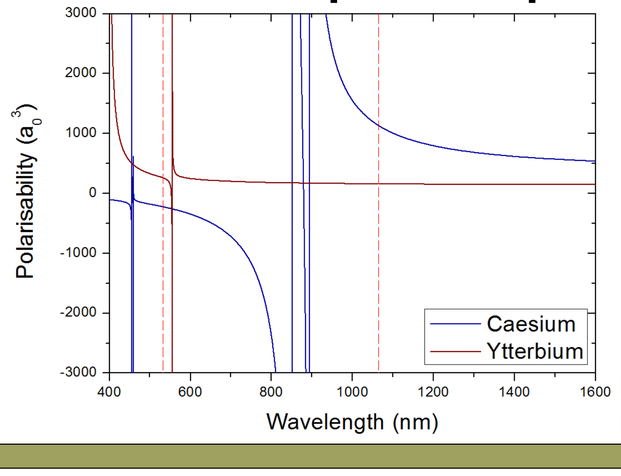
• Need Cs at the same temperature as Yb, so we will use Degenerate Raman Sideband Cooling[12,13] before loading into the optical dipole trap.
•BEC can be made in $|3,+3\rangle$state after normal MOT and molasses stage, pre-cooling with ^{87}Rb before evaporation in an optical dipole trap.



Single species evaporation in a dipole trap



Bichromatic optical trap for Ytterbium and Caesium

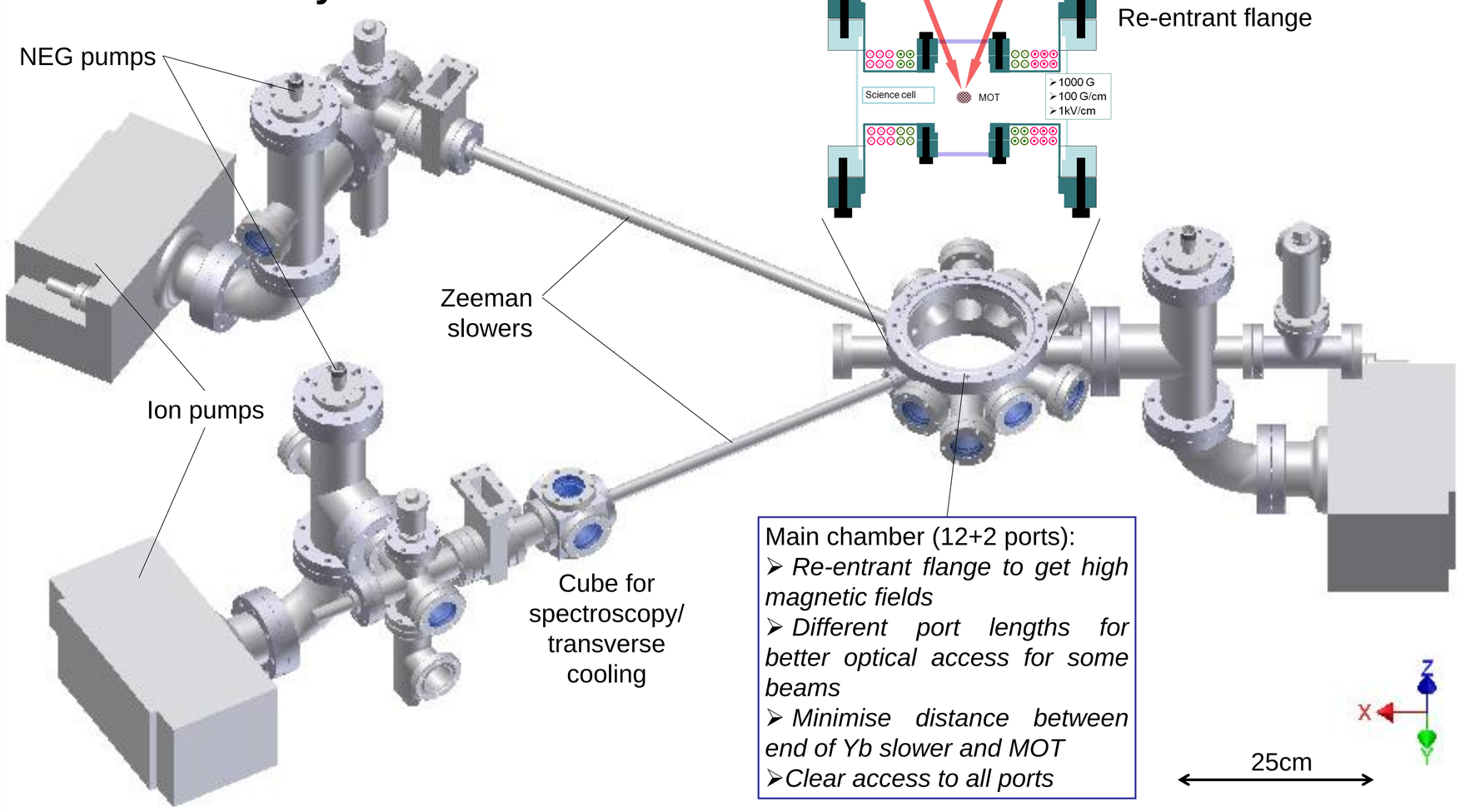


	Polarisability at 532nm (a_0^3)	Polarisability at 1064nm (a_0^3)
Ytterbium	260.6	158.0
Caesium	-223.8	1136.5

$$U_{dip} = -\frac{1}{2\varepsilon_0 c}\mathrm{Re}(\alpha)I$$

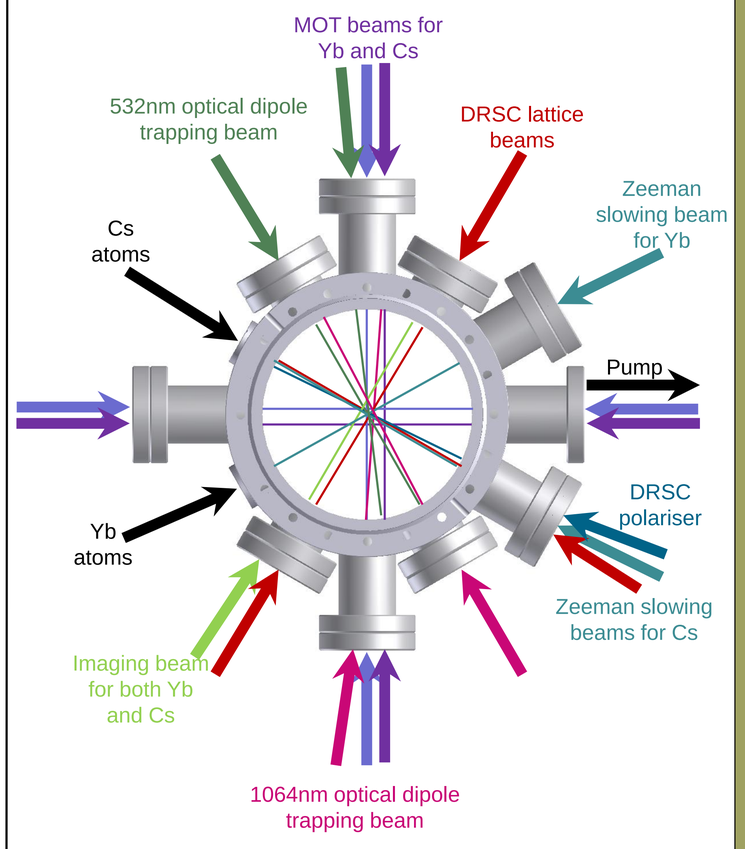
Need to use a bichromatic dipole trap, balancing the trap depths for Yb and Cs using both 532nm and 1064nm light.

Yb-Cs vacuum system



Main chamber

(Possible design)



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References

[1] Micheli A., Pupillo G., Büchler H. P. and Zoller P., *Phys. Rev A*, **76**, 043604, (2007)
[2] Micheli A., Brennen G. K. and Zoller P., *Nature Physics*, **2** (5), 341, (2006)
[3] Avdeenkov A. V., Kajita M. and Bohn J. L., *Phys Rev A.*, **73**, 022707, (2006)
[4] Meyer E. R. and Bohn J. L., *Phys. Rev. A.*, **80**, 042508, (2009)
[5] Tassy S., Nemitz N., Baumer F., Höhl C., Batär A. and Görlitz A., *J. Phys. B.*, **43**, 205309 (2010)
[6] Okano M., Hara H., Muramatsu M., Doi K., Uetake S., Takasu Y. and Takahashi Y., *Appl. Phys. B.*, **98**, 691, (2010)
[7] Ivanov V. V., Khramov A., Hansen A. H., Dowd H., Münchow F., Jamison A. O. and Gupta S., arXiv:1101.5142v1, (2011)
[8] Sugawa S., Yamazaki R., Taie S. and Takahashi Y., arxiv:1107.0107v1, (2011)
[9] Fukuhara T., Sugawa S. and Takahashi Y., *Phys. Rev. A.*, **76**, 051604(R), (2007)
[10] Fukuhara T., Sugawa S., Takasu Y. and Takahashi Y., *Phys. Rev. A.*, **79**, 021601(R), (2009)
[11] Takasu Y., Maki K., Komori K., Takano T., Honda K., Kumakura M., Yabazaki T. and Takahashi Y., *Phys. Rev. Lett.*, **91** (4), 040404, (2003)
[12] Gustavsson M., *Thesis*, University of Innsbruck, (2008)
[13] Kerman A. J., Vuletić V., Chin C. and Chu S., *Phys. Rev. Lett.*, **84** (3), 439, (1999)

Acknowledgements

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