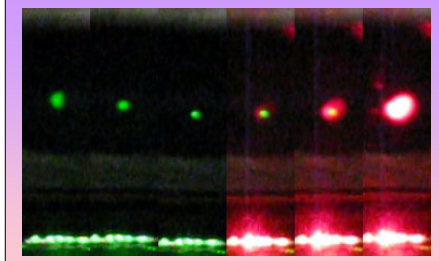
Ultracold Mixtures of Lithium and Ytterbium Atoms

V. Ivanov, A. Hansen, A. Khramov, W. Dowd, and S. Gupta

Department of Physics, University of Washington, Seattle, WA 98195

DAMOP Conference – Houston TX – May 2010

Introduction

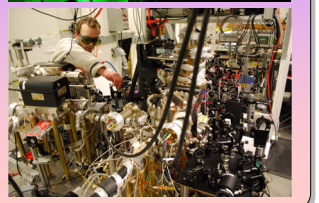


Compression of trapped Ytterbium followed by loading of Lithium. The fully loaded Yb MOT is subjected to a 500ms quadrupole field ramp, which also optimizes conditions for loading of Li. After ~1s of loading, the MOT beams are simultaneously shut off, and ~10^6 atoms of either species are transferred to the optical dipole trap.

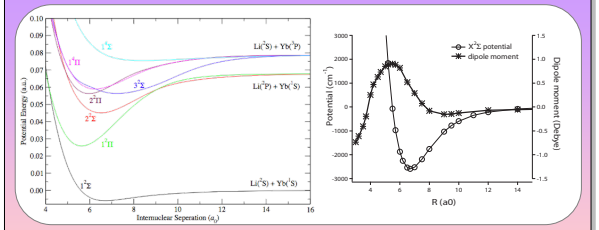
We have trapped ultracold atoms of lithium and ytterbium in a far-detuned optical trap. We will study interspecies interactions, and also prepare diatomic polar Li-Yb molecules.

The Li-Yb system is promising for several reasons:

- Both Li and Yb can be cooled to quantum degeneracy in single-species experiments.
- Stable bosonic and fermionic isotopes are available for both species, allowing for various combinations of fermi and bose gases.
- Species-selective trapping techniques with external magnetic fields are realizable.
- The differences in electronic structure and size of the constituents makes ultracold Li-Yb an ideal candidate for a sensitive electron EDM search.

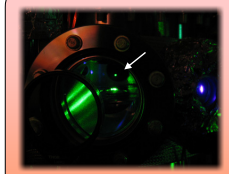


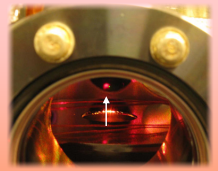
Theoretical Potential Curves

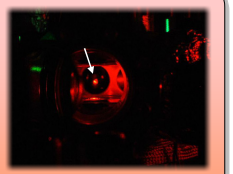


Yb-Li ground and excited potentials. Preliminary ab-initio calculations by Peng Zhang, ITAMP, Harvard

Preliminary ab-initio calculations of the $X^2\Sigma$ ground state potential and the electric dipole moment by S. Kotochigova, Temple Univ/NIST.







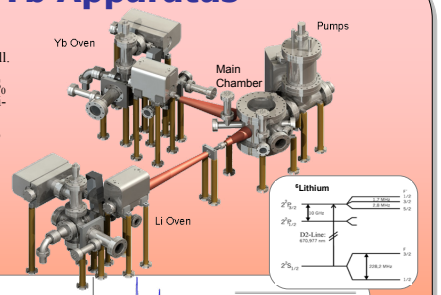
Magneto-optical trapping of **ytterbium** (green), **lithium** (red), and **combined** MOT. In the dual species setup neither species is optimized for number or temperature due to their different magnetic sensitivities. For transfer to two-species ODT, a sequential MOT loading scheme is employed.

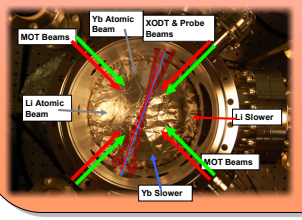
Dual Species Li-Yb Apparatus

For the Li MOT we use a tapered amplifier (TOptica Photonics), which produces up to 400 mW at 671nm. We stabilize on the ^{6}Li D2 crossover using a heat pipe vapor cell.

For slowing of Yb we utilize the strong 400nm transition $^1S_0 \rightarrow {}^1P_1$. We use a 532 nm (Coherent Verdi V-18) pumped Ti-Sa laser (Coherent 899) at 800nm, which is then frequency-doubled in an external bowtie cavity using a LBO crystal to produce up to 100mW of blue light.

For the Yb MOT beams we use the weak 556nm transition $^1S_0 \rightarrow {}^3P_1$. We frequency-double the output of a fiber laser (Koheras Boostik, 1W) with a PPLN waveguide (HC Photonics), generating about 20mW of green light.





Planned Experiments

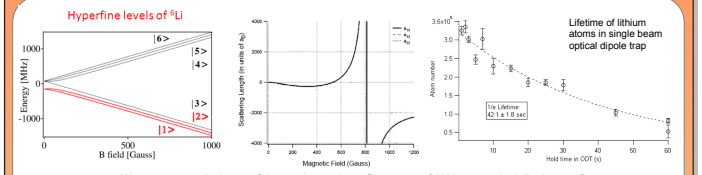
Studies in the Li-Yb Mixture

- Thermalization studies between the Li-Yb atoms in an ODT
- Photoassociation and Optical Feshbach Resonances in the Li-Yb
- Yb as an impurity probe of the BEC-BCS crossover in Li
- Strongly interacting Li-Yb mass-mismatched Fermi mixtures

Studies with the LiYb Molecule

- Create ultracold/quantum degenerate polar molecular gas using photoassociation followed by Raman processes.
- Explore resulting highly anisotropic interactions both in a homogeneous system and in an optical lattice.
- Measure the electron EDM in this paramagnetic molecule with a high Z-nucleus.
- Candidate for lattice-confined quantum bits interacting via dipole-dipole interactions and as a quantum simulator for lattice spin models.

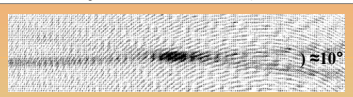
Fermi Degeneracy in Lithium

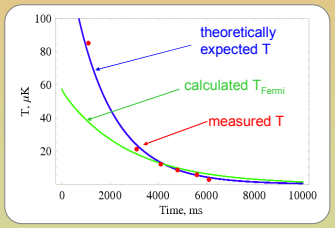


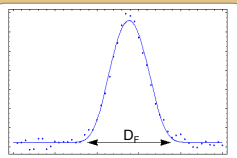
We trap an equal mixture of the two lowest hyperfine states of 6Li in our optical dipole trap. By increasing the magnetic field to 330G, we achieve a high collision rate with $a_{12} \sim -300a_0$.

Crossed-Beam ODT

Initial: $U_0 = 4$ mK, $v_{mean} = 10.8$ kHz
$N_1 \sim N_2 > 10^6$, T ~ 200μK
Reach $T<T_F$ with $N_1 \sim N_2 > 10^5$ after ~ 5 secs evaporative cooling.

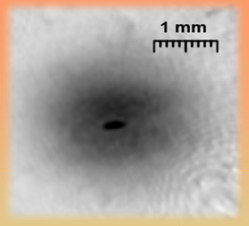






Thomas-Fermi fits to absorption profiles indicate T/T_F values as low as 0.2. Representative profile and fit with T_F=11μK and 1.5ms time-of-flight expansion is shown. D_F is the zero-temperature Fermi diameter in real space.

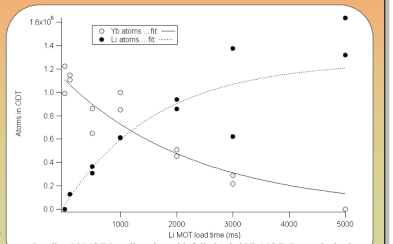
Dual Species Optical Dipole Trap



Normalized absorption image of 10^6 optically trapped Li atoms, surrounded by the expanding remnants of its MOT, 1.3ms after transfer to ODT.

For the ODT we use a 100W 1064nm fiber laser (IPG YLR-100-LP). The trap depth is controlled by a single-pass AOM. The trapping beam is focused to a 30μm waist, and our calculated trapping frequencies are 13kHz (1.1kHz) radially and 85Hz (7.3Hz) axially for Li (Yb).

The Li MOT is loaded for only a short time (~1s) in the presence of a fully loaded Yb MOT. The two species are then transferred to the ODT. Depending on the Li loading time we can control the relative populations of Li and Yb. After loading into the ODT the initial temperature of either species is ~200μK.



Loading Li MOT in collocation with fully loaded Yb MOT. Due to inelastic inter-species collisions Yb population rapidly decays in presence of Li.

Acknowledgements: E.N. Fortson and B. Blinov groups at UW
J. K. Smith, W. Willcockson, R. Weh, W. English, J. Pi, N. Maloney, C. Teale, R. Saxe, J. Grad, E. Lee-Wong

Funding: University of Washington Royalty Research Fund
National Science Foundation
Alfred P. Sloan Foundation
NSERC

Group website: http://phys.washington.edu/users/deepg

Come to our talk: Session W5 , Saturday 9am, Arboretum I-III