Strontium Trapping in a Vapor Cell

Alan Gallagher
JILA, NIST and U. of Colorado
Boulder, CO 80309

Strontium is loaded from vapor into a resonance-line (461 nm) MOT, within a sapphire-windowed, poly-crystalline-alumina cell. The cell and magnetic-field coils are within an oven operated at ~300 C, while an external Sr reservoir and ion pump provide ~ $10^9/\mathrm{cm}^3$ Sr density and a much lower background-gas density. Recycling lasers pump from the 5^3P_0 and 5^3P_2 states to 6^3S_1, to prevent “shelved” atom loss that results from the $5^1P_1 \rightarrow 4^1D_2 \rightarrow 5^3P_{2,1}$ branching. The trapped-atom velocity distribution is probed with a frequency-stabilized, intercombination-line (689 nm) laser. An intensity-dependent temperature, that approaches the Doppler limit (T_D) at low intensity, is observed for this structure-free transition that does not undergo polarization-gradient cooling. Trapped-atom lifetimes (τ_t) of 0.1-1s are observed by switched loading. The shape of the loading transient, and the intensity and Sr-density dependence of τ_t, indicate that τ_t is primarily limited by Sr-Sr* collisional loss induced by the trapping beams. Measurements versus these parameters yield a trap-loss rate coefficient, per Sr and Sr*, $k(\nu)$ $6\mathrm{x}10^{-9}$ cm^3/s at –40 MHz detuning, with about 30 % uncertainty due primarily to uncertainty in the trapped-atom density. This loss mechanism, which is roughly proportional to intensity, limits trapped-atom number to ~10^8 and densities to ~$10^{11}/\mathrm{cm}^3$. A calculation based on the semi-classical (Gallagher-Pritchard) model indicates that this loss results from exciting the $^1\Pi_g$ molecular state, which has a high survival probability to small internuclear separation (R) since it does not radiate at close range. Excitation occurs at long range due to retardation of the coupling, so this provides an exceptionally efficient Sr-Sr* loss mechanism. The calculation, which includes this rapidly varying $\Gamma(R)$ and the finite collision temperature, yields a k that is several times larger than the measured value. This model ignores bound states, and it is not clear if this is the cause of the discrepancy.

The magnetic field gradient is rapidly reduced and the blue laser is blocked to transiently load the ~1mK, resonance-line trapped atoms into an intercombination-line trap. About 50% transfer has been achieved with broad-band cooling, using a 789 nm laser that is spectrally-broadened to ~ 2MHz on the red wing of the transition. This produces an 20 μK cloud, which has been further cooled to ~5μK, or 30 T_D, with 20 ms of single-frequency trapping at –50 kHz detuning. In most cases trap temperatures are obtained from the spectral width ($\Delta\nu$) of intercombination-line fluorescence, effectively at zero magnetic field. However, at the lowest temperatures the contrast of Ramsey fringes from temporally separated $\pi/2$ pulses of near-resonant 689 nm light yielded the cloud velocity width, free of several factors that complicate the interpretation of very narrow $\Delta\nu$ fluorescence widths.

The work reported here was carried out by Kurt Vogel and Timothy Dineen; details can be found in Kurt Vogel’s university of Colorado thesis. Jan Hall also made essential contributions, and this work was supported by NSF.