

Trap losses due to near-resonant Rydberg dressing of cold atomic gases

B. J. DeSalvo*, J. A. Aman*¹, F. B. Dunning*, T. C. Killian*, S. Yoshida[†], and J. Burgdörfer[†]

* Department of Physics & Astronomy MS61, Rice University, Houston, Texas, USA

[†] Institute for Theoretical Physics, Vienna University of Technology, Vienna, Austria, EU

Synopsis Studies of near-resonant dressing of cold strontium gases and BECs held in an optical dipole trap (ODT) with the 30^3S_1 Rydberg state reveal that, even when well detuned from resonance, such dressing can lead to a rapid decrease in the ground state atom population in the trap. This decrease is attributed to Rydberg atom excitation, which can trigger direct escape from the trap and population of long-lived metastable states.

Rydberg states can be used to tune the interaction between “ground state” atoms by introducing a small admixture of Rydberg character into their wavefunctions through dressing with optical radiation tuned near resonance with the transition to a Rydberg state. Here we examine the effects of introducing long-range interactions between strontium atoms contained in a dense cold thermal gas or BEC by Rydberg dressing.

Samples of cold ^{84}Sr atoms are prepared in an optical dipole trap (ODT) and dressed with the 30^3S_1 Rydberg state, which introduces nearly-isotropic repulsive interactions, utilizing the $^3\text{P}_1$ intermediate state and radiation at 689 and 319 nm. The ground state atom population in the trap is measured by releasing them from the trap. As it falls the atom cloud expands and is imaged by absorption of 461 nm light tuned to the $^1\text{S}_0 \rightarrow ^1\text{P}_1$ transition. The kinetic energy acquired by a ground state atom upon excitation to a Rydberg state is such that many of them escape the ODT. In addition, even if remaining trapped, many decay to long-lived $^3\text{P}_0$ and $^3\text{P}_2$ states which also represents a loss of ground state atoms from the ODT.

Figure 1 shows trap losses observed using a cold thermal gas containing $\sim 5 \times 10^5$ atoms at a density of $\sim 4 \times 10^{11} \text{ cm}^{-3}$ as a function of overall two-photon detuning, Δ . Data are included for two-photon Rabi frequencies $\Omega_{\text{eff}}/2\pi$ in the range ~ 15 -200 kHz and dressing times, t_D , ~ 80 -800 μs . The product $\Omega_{\text{eff}} \times t_D$ is maintained approximately constant resulting in similar atom losses on resonance. As Ω_{eff} is increased the loss features broaden and sizeable trap losses are seen even when well detuned from resonance, an effect that is even more pronounced for (higher-density) BECs. The large trap losses can be attributed to a multistep process invoked previously [1,2] in which initial (off-

resonant) excitation of Rydberg atoms enables the excitation of neighboring atoms facilitating the growth of localized groups of Rydberg atoms even when well detuned from resonance. Time-dependent studies of trap loss provided further support for this mechanism. While this mechanism will limit both the strength and duration of the dressing that can be applied to dense cold atom samples, it should be less important for atoms contained in an optical lattice whose separations can be better controlled.

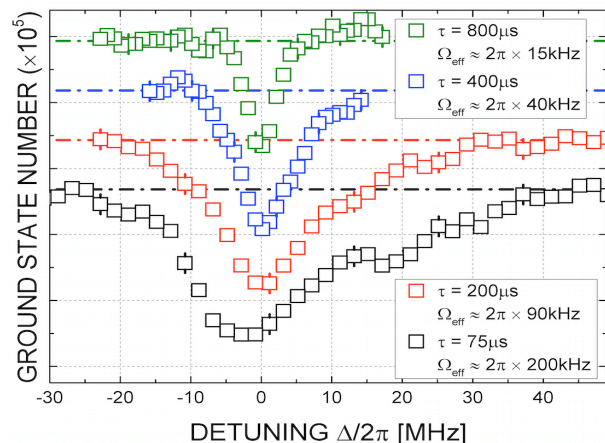


Figure 1. Measured decrease in the ground state population present in a cold thermal ^{84}Sr gas as a function of detuning Δ . Estimated Rabi frequencies, Ω_{eff} , and dressing times, t_D , chosen to keep the product $\Omega_{\text{eff}} \times t_D$ approximately constant, are as indicated

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References

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¹E-mail: jim.aman@rice.edu

