Direct Photoassociation of Halo Molecules in ^{86}Sr

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Synopsis We report the creation of $^1S_0+^1S_0$ Halo molecules in ^{86}Sr through direct photoassociation in an optical dipole trap using two-color photoassociation. This provides detailed information on the interactions between ground-state ^{86}Sr atoms, which is of particular interest because low-energy collisions are resonant in this isotope.

Halo molecules represent a unique class of quantum states where the molecular bond length far exceeds the classical turning point determined from the underlying van Der Waals potential [1, 2]. Such states have enabled exploration of the strongly interacting regime near universality, where collisional behavior of the system is governed solely by the scattering length and is independent of the microscopic details of the atomic interaction. Traditionally halo molecules are created using magnetic feshbach resonances, however, creation with magnetic fields can preclude investigation of short-time dynamics, and many atoms lack magnetic Feshbach resonances.

In ^{86}Sr, the least bound dimer of the $X\ ^1\Sigma_g^+$ ground state potential is bound by $E_B \approx h \times 85$ kHz, which gives rise to the large s-wave scattering length for this isotope, $a = 798a_0$, where a_0 is the Bohr radius. In this work, we populate this halo state using two-color photoassociation near resonance with intermediate molecular states of the excited $^1S_0+^3P_1$ potential (See Fig. 1.).

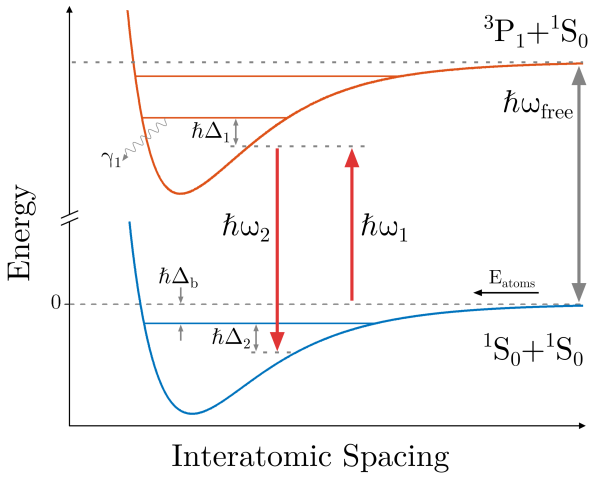

Figure 1. Excitation scheme for producing ground state halo dimers. Two near resonant lasers with frequencies ω_1 and ω_2 are detuned from an intermediate molecular state by Δ_1. The two-photon detuning from the halo state, Δ_2, is varied to obtain the photo-excitation spectrum.

We observe large AC Stark shifts of the halo molecule binding energy and creation of halo molecules through higher order Raman processes (Fig. 2). This evidence points to strong coupling between excited and ground state molecular dimers. This suggests that STIRAP should be effective for improving molecular conversion efficiency, providing a route to controlled creation and manipulation of molecular states. Characterization of this halo state is a first step towards using fast-switching optical fields to tune two-body ground state properties near unitarity to explore the regime of strongly interacting many body dynamics [3, 4].

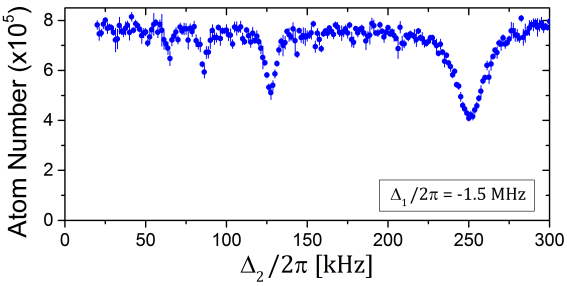

Figure 2. Spectrum of the halo dimer production at high laser intensity. Both Raman lasers are equal intensity, $I_1 = I_2 \approx 1.1$ W/cm^2. Data is averaged over four experimental scans and error bars represent the standard error.

References

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[2] T. Köhler *et al.* 2006 *Rev. Mod. Phys* **78** 1311

[3] M. Yan *et al.* 2013 *Phys. Rev. Lett.* **110** 123201

[4] M. Yan *et al.* 2013 *Phys. Rev. Lett.* **111** 150402