Deterministic preparation of ultracold RbCs molecules in magic-wavelength optical tweezers

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Ultracold polar molecules are an exciting new platform for quantum science and technology. The combination of rich internal structure of vibration and rotation, controllable long-range dipole-dipole interactions and strong coupling to applied electric and microwave fields has inspired many applications. These include quantum simulation of strongly interacting many-body systems, the study of quantum magnetism, quantum metrology and molecular clocks, quantum computation, precision tests of fundamental physics and the exploration of ultracold chemistry. Many of these applications require full quantum control of both the internal and motional degrees of freedom at the level of single molecules.

Here we report the assembly of individual ultracold ground-state RbCs molecules in optical tweezers. Starting from individual Rb and Cs atoms [1] cooled to the motional ground state of separate tweezers [2], we combine the atoms into a single tweezer [3] and then use a combination of magnetoassociation and stimulated Raman adiabatic passage (STIRAP) to create a molecule [4]. The conversion efficiency from atom pairs to ground state molecules is around 50 %. However, we demonstrate a protocol to rearrange the molecules based upon high-field detection of the Rb atom in cases where the association is unsuccessful. We will discuss on-going experiments to transfer the molecules into magic-wavelength [5] tweezers, where for bulk gases we have demonstrated rotational coherence times exceeding a second [6]. This will enable the observation of spin-exchange interactions between molecules, leading to the prospect of entangling pairs of molecules and performing small-scale quantum simulations. Finally, we report a new hybrid platform that combines single ultracold molecules with single Rydberg atoms [4], opening a myriad of possibilities.

References

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