Ultracold collisions and molecule formation in optical tweezers

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Optical tweezers are shallow potential wells formed at the waist of a tightly focussed laser beam, which confine particles through their polarizability. It is now becoming possible to load pairs of atoms and molecules into a single tweezer and study their interactions and collisions under highly controlled conditions. Simon Cornish's experimental group in Durham has loaded single Rb and Cs atoms into the same tweezer, and we have studied hyperfine-changing collisions [1] using interaction potentials that we previously fitted to the positions of Feshbach resonances and near-threshold bound states. Kang-Kuen Ni's group at Harvard has loaded single Na and Cs atoms into the same tweezer, and measured resonance positions and spectroscopic properties in the tweezer; we have collaborated to achieve NaCs molecule formation both by magnetoassociation (tuning across a Feshbach resonance) [2] and coherent Raman photoassociation [3].

Optical tweezers offer a rich platform for highly selective studies of atomic and molecular collisions and reactions. Configurable tweezer arrays also offer further possibilities for quantum science, ranging from fundamental studies of few-body dipolar physics to quantum simulation and quantum computing [4]. They nevertheless present many challenges for theory at both the single-particle and few-particle levels.

[1] R. V. Brooks et al., "Preparation of one ^{87}Rb and one ^{133}Cs atom in a single optical tweezer", https://arxiv.org/abs/2104.05760

[2] J. T. Zhang et al., "Forming a single molecule by magnetoassociation in an optical tweezer", Phys. Rev. Lett. 124, 253401 (2020).

[3] Y. Yu et al., "Coherent optical creation of a single molecule", https://arxiv.org/abs/2012.09043

[4] M. Hughes et al., "A robust entangling gate for polar molecules using magnetic and microwave fields", Phys. Rev. A 101, 062308 (2020).