Cold Molecule Formation in Bose-Einstein Condensates and Optical Lattices

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The high atomic densities in Bose-Einstein Condensates and optical lattices with two atoms per cell offer the prospects for the coherent formation of translationally cold diatomic molecules in the electronic ground state. This can be done using a stimulated Raman process to specific target vibrational-rotational levels. We earlier proposed that cold ground state molecules can be made via spontaneous decay of an excited state [1], but this is a relatively uncontrolled process. We have recently proposed that two-color photoassociation offers a controlled way to make molecules in a Bose-Einstein condensate [2]. In fact, it should be possible to convert a significant fraction of condensed atoms to molecules in a time short compared to the trap period. The same two-color photoassociation process should be applicable to pairs of atoms trapped in the Lamb-Dicke limit in a single cell of an optical lattice.

Atom pairs in a condensate or lattice will possess a discrete photoassociation spectrum when light is detuned far to the red of atomic resonance. If the detuning is sufficiently large, the discrete lines are well-isolated from each other. The ratio of pair to atomic light scattering is linear in atomic density, and for densities of 10^{14} atoms/cm^3 or more, the pair light scattering rate at photoassociation resonance frequencies can exceed that for the free atoms by orders of magnitude [3]. In two-color Raman photoassociation, the effect of excited state spontaneous decay can be strongly suppressed [2,4], and efficient coherent molecule formation is possible. We present specific calculations for the Na_2 dimer. In addition to molecule formation, two-color photoassociation spectroscopy in condensates or lattices could be a sensitive probe of the last few bound state in the ground state potentials, and could help provide important data for refining theoretical models of elastic and inelastic threshold scattering in cold and ultracold atomic gases.

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