Engineering multi-photon coherent formation of ultracold rubidium molecules with femtosecond laser pulses

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Abstract

We investigate the possibility of coherently forming deeply bound ultracold Rb_2 molecules using multi-photon transitions driven by shaped femtosecond laser pulses. In multi-photon processes a broadband laser can drive a narrow transition due to optical interference. Furthermore modified selection rules apply to multiphoton transitions compared to single-photon ones allowing for novel pathways of molecule formation.

We determined the required electronic structure of the rubidium molecule using state-of-the-art *ab initio* techniques, calculating potential energy curves, electric transition dipole moments, nonadiabatic radial and angular coupling matrix elements, and spin-orbit coupling matrix elements for all singlet and triplet states below 26000 $\mathrm{cm}^{-}1$.

We employ the electronic structure data to investigate the nuclear dynamics of multi-photon transitions with laser pulses shaped using coherent and optimal control. Starting from an atom pair colliding in the $a^3\Sigma_u^+$ lowest triplet state, we propose three-photon photoassociation with pulses shaped such as to suppress purely atomic transitions. Photoassociating into states with partial ion-pair character is expected to enhance the total efficiency of proposed process. Subsequent stabilization using a two-photon transition driven by optimally shaped pulses should allow for the efficient production of rubidium molecules in the $X^1\Sigma_g^+$ ground electronic state. Photoassociation represents a basic example for coherent control of a binary reaction.

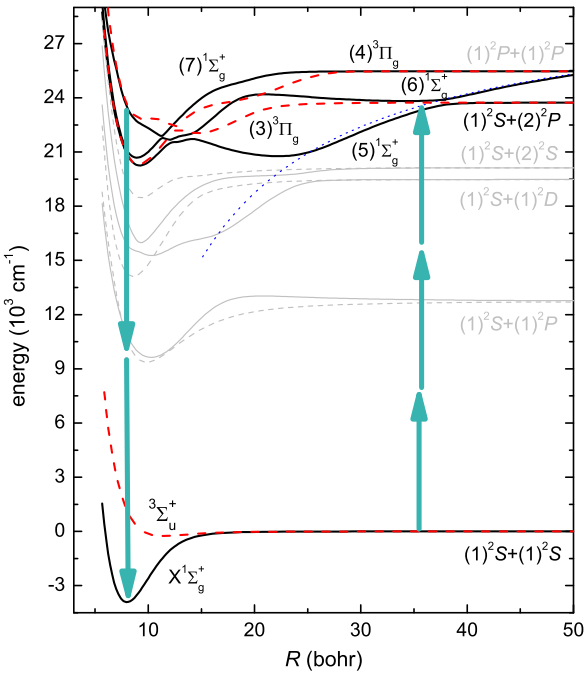

Figure 1: Proposed scheme for the multi-photon formation of ultracold Rb_2 molecules.