Optical excitation and stabilization of ultracold field-linked tetratomic molecules

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In recent years, shielding of ultracold molecules [1, 2] from close collisions inside an optical dipole trap has brought remarkable achievements in cooling molecules to quantum degeneracy [3, 4]. Shielding can be achieved by an external static electric field or a near-resonant microwave. This external field also allows the creation of weakly bound tetratomic molecules (“tetramers") from a pair of ultracold diatomic molecules. Such tetramers have been realized recently for shielded NaK molecules using an external microwave field [5]. These tetramers are termed field-linked (FL) molecules as an external field is necessary to create them.

The FL tetramers that have been realized are very shallow with binding energies of the order of 100 kHz. The motivation of this work is to develop a methodology to create deeper bound tetramers starting from the loosely bound FL tetramers. Our methodology draws the ideas of photoassociation of ultracold atoms to diatoms followed by stabilization to ground state, and stimulated Raman adiabatic passage (STIRAP) transfer of weakly bound diatoms to deeply bound ground vibronic molecules. We envisage similar routes of creating deeply bound tetramers starting from the weakly bound states or a pair of colliding diatoms. We consider static-electric-field shielded alkali diatomic molecules initially in their ground vibronic $|X^1\Sigma^+, v = 0\rangle + |X^1\Sigma^+, v = 0\rangle$ (hereafter X+X) pair state. We identify the excited vibronic manifold $|X^1\Sigma^+, v = 0\rangle + |b^3\Pi_0, v' = 0\rangle$ (hereafter X+b) for photoassociation and an intermediate state for STIRAP transfer to deeply bound states in the X+X manifold. For this, we develop shielding methods for X+b and predict Frank-Condon factors (FCFs) between FL states of X+b and X+X. We also predict photoassociation spectra for shielded molecules to form FL tetramers in X+b manifold. We obtain highly tunable FCFs between ground and excited tetramer states and promising photoassociation spectra. Our theoretical results should guide future experiments for stabilizing weakly bound ultracold tetramers.

References

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