Laser cooling Rydberg molecules - He_2

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The helium dimer in its metastable triplet state is a promising candidate to become the first homonuclear molecule ever laser-cooled. Nearly diagonal Franck-Condon factors are obtained, because the electron employed for optical cycling occupies a Rydberg orbital that does not take part in the chemical bond.

Laser cooling and trapping of the helium dimer would result in a controllable, simple 4-electron system at record low temperature, allowing quantum sensing and precision measurements to test quantum electrodynamics and the quantum nature of collisions with unprecedented accuracy - while being accessible to highly accurate ab initio computational methods.

The prospects for laser cooling He_2 are discussed, and the rovibronic level structure and transition moments in He_2 are analyzed to identify the most suitable electronic transitions for laser cooling. By evaluating the number of scattered photons and the scattering force under different vibrational repumping schemes, we determine the optimal optical cycling strategies (see Fig. 1). Loss mechanisms such as spin-forbidden transitions, predissociation, and ionization processes are studied and found to not introduce significant challenges for cooling.

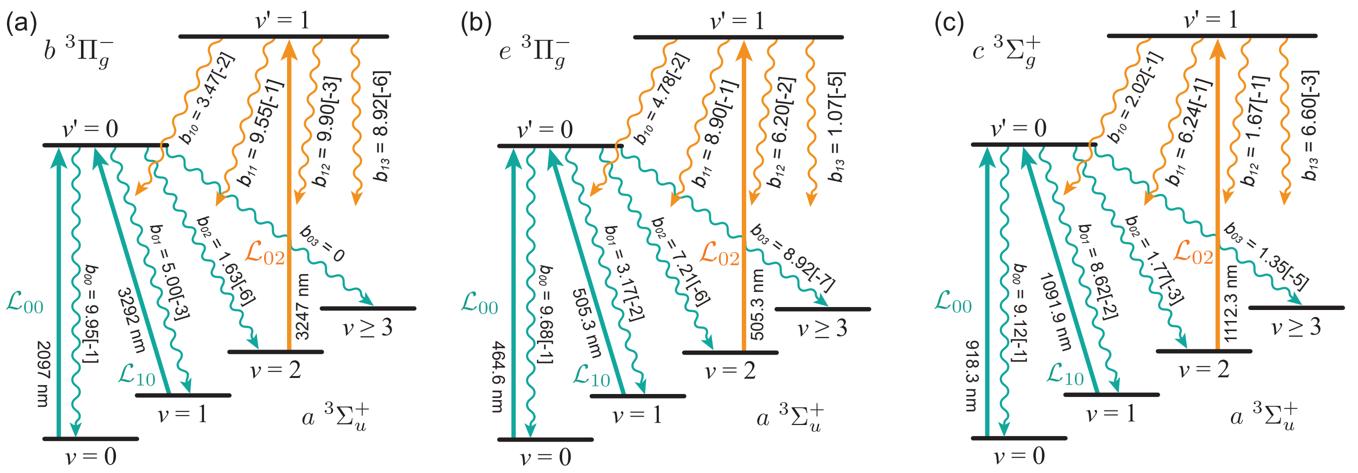

Figure 1: Vibrational branching ratios for (a) $a - b$, (b) $a - e$ and (c) $a - c$ laser cooling transitions.

References

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