

Towards direct imaging of ultracold RbCs molecules

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Imaging ultracold molecules with minimal perturbation is crucial for the advancement of precision measurements and quantum simulation. Dispersive imaging, which relies on phase shifts induced by off-resonant light due to intrinsic anisotropy of excited molecular rotational states to generate optical birefringence, has been proposed as a minimally destructive alternative to absorption imaging. We present numerical simulations of dispersive imaging for ultracold RbCs molecules, following the theoretical framework of ref. [1]. Using experimentally relevant parameters and considering the transition from $X^1\Sigma^+$, $\nu = 0$, $J = 1$ to the $J = 0$ rovibrational state of $A^1\Sigma^+ - b^3\Pi$ (Fig. 1 (a)), which has the smallest ratio of the partial transition linewidth to the excited-state linewidth, we model the image formation on a CCD camera (Fig. 1 (b)) and analyse the feasibility of this technique for detecting molecular clouds. We simulate the signal and the number of photons incident on the cloud as a function of laser detuning. Our simulations incorporate key effects such as optical phase shifts, laser detuning, probe intensity, and pulse duration. We evaluate the optimal imaging conditions to achieve high detection fidelity while minimising loss due to photon scattering. These results provide insight into the applicability of dispersive imaging for real-time, non-destructive observation of RbCs molecules in optical traps. Finally, we report progress towards the experimental implementation of this technique, including precision spectroscopy of the transitions from the rovibrational ground state of the molecules to the coupled $A^1\Sigma^+ - b^3\Pi$ potential around 935 nm.

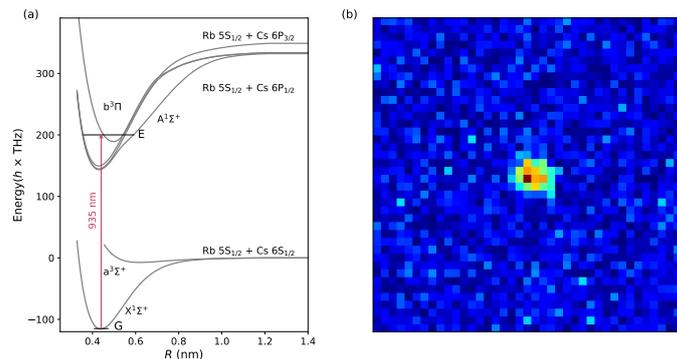


Figure 1: (a) Ground and relevant excited adiabatic potentials of the $^{87}\text{Rb}^{133}\text{Cs}$ molecule as functions of atom-atom separation R . The vertical arrow indicates transition from the $\nu = 0$, $J = 1$ imaging state (G) in the $X^1\Sigma^+$ state to the $J = 0$ rovibrational state (E) of the coupled $A^1\Sigma^+ - b^3\Pi$ complex. (b) Dispersive imaging of ~ 4500 RbCs molecules with density $1 \times 10^{11} \text{ cm}^{-3}$ for a magnification of $4 \mu\text{m}.\text{pixel}^{-1}$ corresponding to $\sim 1^0$ rotation.

References

- [1] Q. Guan, M. Highman, E. J. Meier, G. R. Williams, V. Scarola, B. DeMarco, S. Kotochigova and B. Gadway, *Phys. Chem. Chem. Phys.* **22**, 20531-20544 (2020).