Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **3522** Type: **Oral (Non-Student) / Orale (non-étudiant(e))**

Suppression of Raman Interaction due to destructive interference in Alkali Atoms

Wednesday, 8 June 2022 14:15 (15 minutes)

Raman interactions are a powerful tool for performing arbitrary rotations between two Zeeman levels of an individual ion or a neutral atom. Universality of the technique places it on central roles in many quantum technologies: single qubit gates in atomic quantum processors, mediating interactions in quantum simulators, and mapping quantum information into long-lived states in optical quantum memories, to name a few.

The conventional three-level effective theory manifests that the fidelity of the Raman operation grows inversely proportional to the single photon detuning. In our work we show that this approximation does not always hold for all alkali atoms due to their multi-level structure. The destructive interference of the hyperfine sub-levels could fully suppress the Raman interaction at large detunings leaving us with some finite optimal fidelity in comparison to asymptotically ideal theoretical case. We use a formalism based on Clebsch-Gordan coefficients and rotational symmetries of atoms, which allows us to generalize our results to all alkali atoms. We experimentally show the effect on Rb-87 and discuss how to circumvent the problem.

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Session Classification: W2-10 DAMOPC I (DAMOPC) | DPAMPC I (DPAMPC)

Track Classification: Technical Sessions / Sessions techniques: Atomic, Molecular and Optical Physics, Canada / Physique atomique, moléculaire et photonique, Canada (DAMOPC-DPAMPC)