Contribution ID : **139** Type : **Poster**

Robust Quantum Control via the dark state: Adiabatic population engineering in a three-level Λ system

Achieving high-fidelity quantum state population engineering in three-level systems with a Λ configuration presents a significant challenge due to the inherent dissipation of the intermediate state. This work simulates and validates the STIRAP (Stimulated Raman Adiabatic Passage) protocol for high-fidelity population transfer in a three-level (Λ) quantum system. The system is modeled with realistic dissipation in the intermediate state to demonstrate STIRAP's main advantage: using the Dark State for adiabatic population engineering that effectively prevents dissipative losses. Our results confirm that the counter-intuitive pulse sequence achieves near-complete transfer, while the intuitive sequence leads to failure. We then evaluate STIRAP's inherent robustness against common experimental uncertainties, including frequency errors (Detuning) and variable dissipation rates. Finally, we apply a Robust Optimization using GRAPE (Gradient Ascent Pulse Engineering) to design a superior control pulse. This optimized pulse guarantees more stable and predictable performance across these uncertainties, establishing this combined strategy as a highly reliable method for Quantum Control.

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Session Classification : Poster Miscellaneus