Title : Modelling Controlled-NOT Gate Based on Rubidium-87 Atom Quantum Bits

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ABSTRACT

The quantum computer with the atom qubit platform harnesses atomic phenomena, such as the electronic state of atoms, atom-electromagnetic field interaction and atom-atom interaction. According to these phenomena, controllability over atomic states using laser fields is crucial in achieving quantum information processing, such as quantum gate operation. The objective is to study Rabi oscillation and Rydberg interaction, then utilize these knowledges to model the Controlled-NOT gate. The study starts by understanding the Rabi oscillation of the rubidium-87 atom modelled by quantum electrodynamics treatment. Then, Quantum Toolbox in Python (QuTiP), utilizing the Lindblad master equation, is used to help with the simulation. Next, the Rydberg interaction between two atoms is included, and then all these theoretical considerations are used to construct a simulation of the Controlled-NOT gate sequence. In this project, 0, 1 and Rydberg state are assigned for the $5S_{1/2}$ F=1, 2 and $97D_{5/2}$. There are four laser fields in this

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system. Two of them are coupling between 0 and 1 state, and the other two coupling between qubit state and Rydberg state. Results from the simulation show the probability of atoms in each qubit state at the end of sequences and fidelity matrices. The minimum fidelity from the simulation are over 99% for both A-S CNOT and H-C_z CNOT gate sequences depending on the chosen Rydberg states. In conclusion, this study just builds a simulation for modeling the CNOT gate sequence, and the result will be used as a guideline for real experiments in the future.