

Population transfer in a laser-driven three-level system by a noisy quantum computer

UTokyo, °Takanori Nishi, Erik Lötstedt, Kaoru Yamanouchi

E-mail: nishi@chem.s.u-tokyo.ac.jp

Simulating the temporal evolution of quantum systems is an important practical application of quantum computers, which can be realized if we can map the problem of interest to qubits and implement the time-propagator by the quantum gates. However, with the near-term noisy intermediate-scale quantum (NISQ) computers, such an algorithm accumulates errors as the simulation time increases due to the imperfect quantum gates and the decoherence of the qubits. In order to keep the length of the quantum circuit short even for the long time-propagation, we employ the variational quantum simulator (VQS) method [1], with which the parametrized wave-packet is prepared using the fixed-depth quantum circuit and the time evolution of the parameters is calculated on the classical computer.

We apply the VQS to the simulation of a laser-driven three-level system, which has been adopted to describe the phenomenon called “air-lasing,” in which the coherent and unidirectional emission at 391 nm from N_2^+ is created by the strong-field ionization of N_2^+ in air [2]. The calculation was performed on the IBM Quantum computer *ibm_kawasaki* [3]. As shown in Fig. 1, the populations in the three vibrational ground levels of the three levels X, A, and B states (dashed lines) of N_2^+ are not reproduced by the VQS (solid lines) because of the noise in the quantum computation. To reduce the effect of noise, we employ a quantum mitigation method called the Clifford data regression (CDR) [4]. As shown in Fig. 2, the populations in the three vibrational ground levels (dashed lines) are qualitatively reproduced by using the VQS combined with the CDR (solid lines).

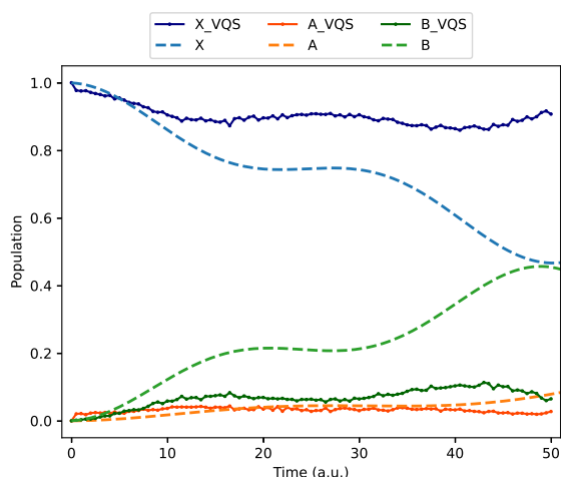


Figure 1 The temporal evolution of the populations in the three vibrational ground levels of the X, A, and B states of N_2^+ obtained by the VQS.

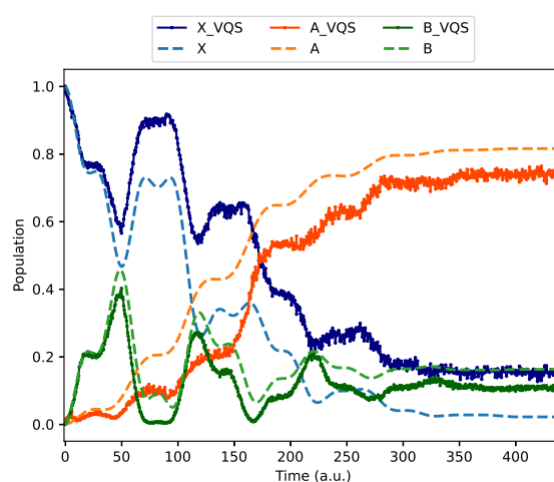


Figure 2 The temporal evolution of the populations in the three vibrational ground levels of the X, A, and B states of N_2^+ obtained by the VQS with the error mitigation using the CDR.

References

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