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

(*Department of Chemistry, School of Science, The University of Tokyo*)
〇Takanori Nishi, Erik Lötstedt, Kaoru Yamanouchi
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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 imperfectness of 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]. Due to the noise of the quantum computer, we found that the VQS could not reproduce the correct behavior of the temporal evolution of the populations even during the first few time steps. To reduce the effect of noise, we employ a quantum mitigation method called the Clifford data regression (CDR) [4]. As shown in Fig. 1, the populations in the three vibrational ground levels of the X, A, and B states (dashed lines) are qualitatively reproduced by using the VQS combined with the CDR (solid lines).

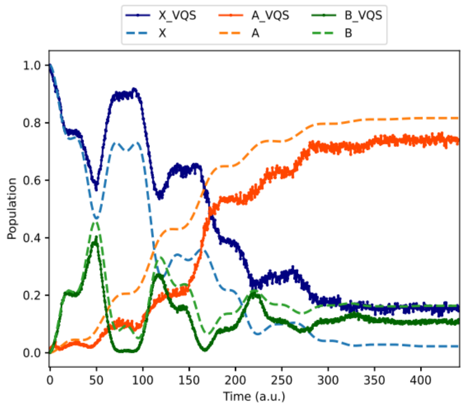

Figure 1 The temporal evolutions of the populations in the vibrational ground levels of the X, A, and B states of N_2^+ obtained by the VQS with the error mitigation using the CDR.

References:

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