Quantum Simulation of Open Quantum Systems on IBM-Q Superconducting Quantum Computers

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Quantum computing has promised revolutionary means to solve problems in fields such as quantum chemistry, material design, finance, and industrial managements, yet the high error rate in nowadays near-term noisy intermediate-scale quantum (NISQ) computers has so far rendered these breakthroughs elusive. In this talk, I will show that by detailed understanding of the error characteristics, we can instead use a noise quantum computer to simulate open quantum system dynamics. Specifically, we develop a novel scheme to utilize intrinsic gate errors of IBM-Q devices to enable controllable simulation of energy transfer dynamics of a photosynthetic dimer system without ancillary qubits or explicit bath engineering, thus turning unwanted quantum noises into useful quantum resources. This scheme is enabled by employing tailored decoherence-inducing gates, which simulates quantum dissipative dynamics efficiently across coherent-to-incoherent regimes, and we show that the results are comparable to those of a numerically-exact classical method. Moreover, we demonstrate a calibration routine that enables consistent and predictive simulations of open-quantum system dynamics in the intermediate coupling regime. It is clear that quantum simulation represents the most promising quantum application to demonstrate quantum advantage on, yet available quantum simulation algorithms are prone to errors and thus difficult to be realized. Our work thus provides a new direction for quantum advantage in the NISQ era.

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