Implementing Single-Qubit General Quantum Dynamical Maps on Quantum Devices

Mirko Rossini, Miriam Resch, Dennis Herb, Joachim Ankerhold, Brecht I.C. Donvil, and Dominik Maile

Institute for Complex Quantum Systems - Ulm University, Albert-Einstein-Allee 11, Ulm, 89081, Germany

The dynamics of open quantum systems is typically described by completely positive trace-preserving maps, which guarantee physical consistency and direct experimental implementability. However, many transformations of both fundamental and practical interest fall outside this standard framework. Examples include inverse quantum channels, non-Markovian propagators, effective reduced dynamics, and other generalized dynamical maps that are not necessarily completely positive.

We present a general mathematical framework that enables the implementation of such maps for single qubits on quantum devices by decomposing them into experimentally accessible operations combined with classical post-processing. This provides a constructive route to realize transformations that would otherwise be considered nonphysical, while allowing one to characterize the associated experimental overhead.

The method opens several relevant applications. It enables the simulation of generalized open-system dynamics beyond standard Markovian evolution, including reversed dissipative processes for single-qubit systems. It also provides a natural framework for error mitigation through inversion of experimentally reconstructed noise channels, with potential applications in both quantum computing and quantum sensing. In particular, tailored mitigation strategies may significantly improve the performance of noisy single-qubit processors and sensing platforms.

[1] M. Rossini, D. Maile, J. Ankerhold and B. I. C. Donvil, Physical Review Letters 131 (2023) 110603.

[2] M. Resch, D. Herb, M. Rossini, J. Ankerhold and D. Maile, arXiv 2512.11671 (2025).