Dynamics of quantum resources in photonic quantum memristors

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Abstract: We present a study on photonic quantum memristors (PQMs), showing memristive behavior in the dynamics of coherence and entanglement. We perform a digital simulation of PQMs on IBM-Q, demonstrating non-linear quantum computing and non-Markovian dynamics.

The memristor is a two-terminal electrical component linking magnetic flux linkage to charge through a non-linear relationship, with a time-dependent internal state variable [1]. Memristors exhibit memory through dynamics depending on past system states, allowing them to show non-Markovian evolution. Recently, quantum memristors have been studied in various platforms, and an experimental photonic quantum memristor (PQM) has been proven [1]. In this contribution, we discuss our results about quantum features in PQMs, demonstrating memristive dynamics on entanglement and coherence, and present a quantum circuit conversion for simulating PQMs on a real quantum computer [3].

We first go through the dynamics of a single PQM, showing that it manifests hysteresis loops in quantum coherence. This indicates that the PQM retains quantum information about past states.

We then discuss our findings about the dynamics of a network of two independent PQMs. Using entangled photons as input, we show that memory effects impact both the entanglement and coherence dynamics of the output photons, without any interaction between the PQMs (Fig. 1 (Bottom left)). These results highlight that this system can maintain quantum correlations between different subsystems without direct interaction between them. We adopt a form factor metric to quantify memory effects and demonstrate that the dynamics of PQMs can be fine-tuned to optimize memory retention (Fig. 1 (Bottom right)). Finally, we present a Qiskit-based circuit model of a PQM (Fig. 1 (Top left)), implemented on IBM's quantum computers. The digital quantum simulation successfully reproduces the memristive behavior of a physical PQM in a non-Markovian regime (Fig. 1 (Top right)).

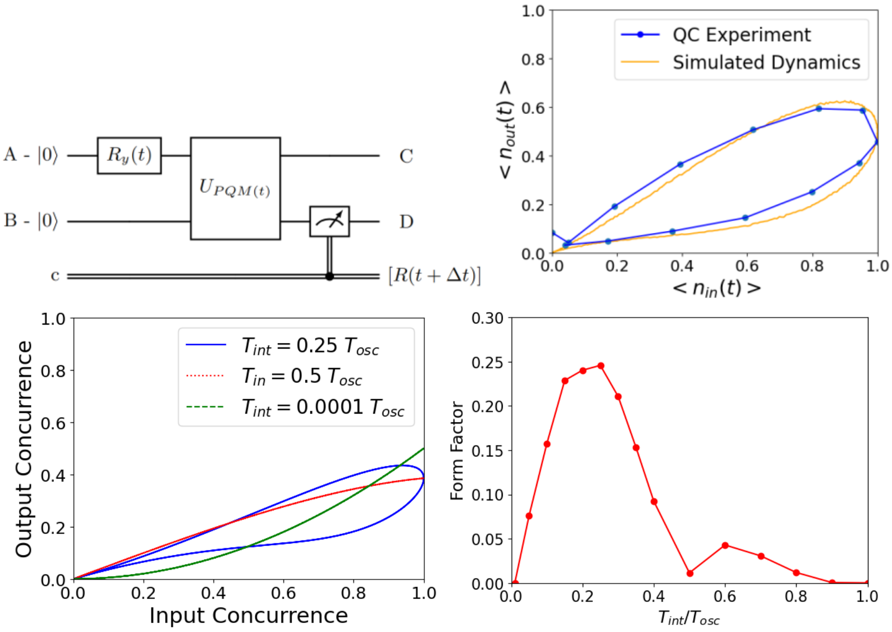

Fig. 1. Top left: Quantum circuit representing one time step of the digital quantum simulation of a single PQM. **Top right:** Comparison between theoretical results and experiment on a quantum computer. **Bottom left:** Hysteresis cycle in the concurrence dynamics in a two PQMs assembly. **Bottom right:** Form factor of the concurrence cycle at different values of the internal properties of the PQM.

References

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