

Optical Quantum Process Tomography in Warm Atomic Vapors

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Quantum Process Tomography (QPT) is one of the fundamental tools for the complete characterization of quantum system dynamics. It enables not only verification of the implementation of a desired quantum operation (e.g., a quantum gate) but also identification of relaxation mechanisms and reconstruction of the Hamiltonian governing the system. In this work, I present the implementation of QPT in a macroscopic cloud of rubidium atoms ($\sim 10^9$ atoms) at room temperature.

The reconstruction method employed is based on Quantum State Tomography (QST), realized via measurements of the linear Faraday effect — tracking the rotation of the polarization plane of a probe light beam propagating through the atomic medium [1–3]. During the presentation, I will demonstrate the full implementation of QPT in a qutrit system formed from the ground states of rubidium-87. I will show how the evolution of selected initial states allows for the estimation of processes occurring in atomic vapor, illustrated through basic quantum gates. Furthermore, I will present a method for reconstructing the generators of the observed dynamics — including time-independent dissipative generators, interaction Hamiltonians with residual fields, and time-dependent control Hamiltonians governing the evolution of the atomic cloud.

[1] M. Kopciuch, M. Smolis, A. Miranowicz, S. Pustelny, *Phys. Rev. A* **109**, 0324029 (2024).

[2] M. Piotrak, M. Kopciuch, A.D. Fard, M. Smolis, S. Pustelny, K. Korzekwa, *Quantum* **8**, 1459 (2024).

[3] M. Kopciuch, S. Pustelny, *Phys. Rev. A* **106**, 022406 (2022).