Time-delayed feedback dynamics of qubits

Alex Chapple[1,*], Scott Parkins[1], Howard Carmichael[1]

[1] The Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand

[*] Corresponding author: acha809@aucklanduni.ac.nz

The use of feedback is a powerful means of manipulating open quantum systems and has been employed in various quantum technologies in both theoretical and experimental work [1, 2]. In this work we study the photon statistics and time-delayed feedback dynamics of a driven qubit in a half-open waveguide terminated by a mirror on one end, as well as two qubits placed at some distance apart in a waveguide. To this end we use Quantum Trajectory theory and the space-discretised waveguide model, a recently developed numerical model that specialises in simulating open quantum systems in the non-Markovian regime [3]. I will also briefly describe the advantages and disadvantages of our numerical model compared to other commonly used methods, and discuss the information that can only be accessed using Quantum Trajectory theory.

With such non-Markovian setups, we investigate phenomena such as trapped photon states, photon pair emissions, and a relatively new phenomenon known as super-super radiance. Furthermore, we show that by adjusting the phase and/or time delay, we can dynamically transition from super-Poissonian light to sub-Poissonian light or even a system that outputs super-Poissonian light to the left and sub-Poissonian light to the right. Finally, we discuss the potential applications of our system to various quantum technologies as well as the model's applications to other fields of study, such as chiral QED.

[1] J. Geremia, J. K. Stockton, and H. Mabuchi, "Real-time quantum feedback control of atomic spin-squeezing," *Science*, vol. 304, no. 5668, pp. 270–273, 2004.

[2] A. L. Grimsmo, "Time-delayed quantum feedback control," *Phys. Rev. Lett.*, vol. 115, p. 060402, Aug 2015.

[3] S. Arranz Regidor, G. Crowder, H. Carmichael, and S. Hughes, "Modeling quantum light-matter interactions in waveguide qed with retardation, nonlinear interactions, and a time-delayed feedback: Matrix product states versus a space-discretized waveguide model," *Phys. Rev. Research*, vol. 3, p. 023030, Apr 2021.