FILTERED PHOTON CORRELATIONS OF RESONANCE FLUORESCENCE

J. P. K. Ngaha[1]* and H. J. Carmichael[1]

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

Fluorescence and correlation filtering is a field that has long been studied [1, 2]. In this work we develop a theoretical approach to better filter fluorescence from a resonantly driven atom. We start with a simplest example by looking at a two-level atom driven on resonance coupled as a cascaded system to a multimode cavity ($\hbar = 1$) [3]:

$$H = H_A + H_C + H_{\rm AC} = \frac{\Omega}{2}\Big(\sigma_+ + \sigma_-\Big) + \sum_{j=-N}^{N} \Delta_j a_j^\dagger a_j + \frac{i}{2}\sqrt{\gamma\kappa}\left[A\sigma_+ - \sigma_- A^\dagger\right], \tag{1}$$

where Ω is the driving field Rabi frequency, Δ_j is the frequency of the j^{th} mode of the cavity, γ is the atomic decay rate, κ is the decay rate for each cavity mode, σ_+ (σ_-) is the atomic raising (lowering) operator, and $A = \sum_{j=-N}^{N} a_j$ is the total cavity annihilation operator, where a_j ($a_j^\dagger$) is the photon annihilation (creation) operator for the j^{th} mode; the Hamiltonian is written in a frame rotating at the drive frequency. The Lindblad master equation for this system, illustrated in Figure 1, is

$$\frac{\mathrm{d}\rho}{\mathrm{d}t} = -i[H,\rho] + \frac{1}{2}\left(2C\rho C^\dagger - C^\dagger C\rho - \rho C^\dagger C\right) + \frac{\kappa}{2}\left(2A\rho A^\dagger - A^\dagger A\rho - \rho A^\dagger A\right), \tag{2}$$

with cascaded decay operator $C = \sqrt{\gamma}\sigma_- + \sqrt{\kappa}A$.

For a single cavity mode, the filtering profile is a Lorentzian, which, having long tails, possibly passes non-target frequency photons. By allowing for N evenly spaced cavity modes either side of a central frequency, Δ_0, each with a small bandwidth $\kappa \ll \gamma$, we can realize a better approximation to a bandpass filter. Ultimately, we aim to calculate filtered correlation functions for two-photon resonance fluorescence, as reported in the recent experiment by Gasparinetti et al. [4].

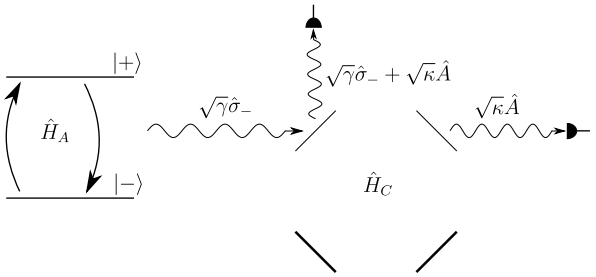

Figure 1: Model of cascaded system filtering of atomic fluorescence.

References

[1] Peng, Z., Yang, G., Wu, Q. & Li, G. "Filtered strong quantum correlation of resoance fluorescence from a two-atom radiating system with interatomic coherence". *Phys. Rev A* 99, 033819 (2019).

[2] Aspect, A., Roger, G., Reynaud, S., Dalibard, J. & Cohen-Tannoudji, C. "Time Correlations between the Two Sidebands of the Resonance Fluorescence Triplet". *Phys. Rev. Lett.* 45, 617620 (1980).

[3] Carmichael, H.J. "Quantum Trajectory Theory for Cascaded Open Systems". *Phys. Rev. Lett.*, 70(15), p.2273, 1993.

[4] S. Gasparinetti, J. C. Besse, M. Pechal, R. Buijs, C. Eichler, H. J. Carmichael, and A. Wallraff, "Two-photon resonance fluorescence of a ladder-type atomic system". Phys. Rev. A 100, 033802-1-8 (2019).

*Contact email: jnga73@aucklanduni.ac.nz