A better method for calculating filtered photon correlations

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Abstract: *Fluorescence from a resonantly driven two-level system is coupled into an array of single-mode cavities whose outputs are combined to calculate frequency filtered photon-correlations. Coupled operator moment equations form the basis of the calculations, providing a natural and efficient way to calculate second-order correlation functions.*

Fluorescence and correlation filtering is a field with a rich history and, with the advent of quantum dots, continues to be studied [1-3]. In this work we develop an efficient theoretical approach to better filter fluorescence from a driven system. To demonstrate this, we model a resonantly driven two-level system coupled as a cascaded system into an array of tunable single-mode filter cavities. This allows us to derive a set of moment equations for the two-level system and cavity mode operators, building upon the uncoupled Maxwell-Bloch equations:

$$\frac{\mathrm{d}}{\mathrm{d}t}\langle\hat{\boldsymbol{\sigma}}\rangle = \boldsymbol{M}\langle\hat{\boldsymbol{\sigma}}\rangle + \boldsymbol{b}, \tag{1}$$

where $\langle\hat{\boldsymbol{\sigma}}\rangle$ is the set of Pauli operator expectation values, $\langle\hat{\sigma}_{\pm}\rangle$ and $\langle\hat{\sigma}_z\rangle$, $\boldsymbol{M}$ is a matrix governing the evolution of the operator moments, and $\boldsymbol{b}$ is the non-homogeneous vector establishing a non-trivial steady state. The Pauli operator moments act as the progenitor source terms for all of the system's dynamics, and feed in to the higher order moments, as depicted in Fig. 1, where $\hat{a}_j$ and $\hat{a}_j^{\dagger}$ are the photon annihilation and creation operators for the j^{th} filter mode.

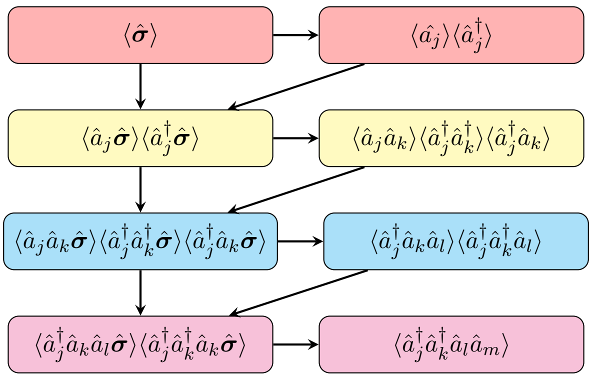

Figure 1: The operator moments have couple in a cascaded scheme, where lower-order moments can be solved independently from the higher-order moments.

In this work we will discuss how the structure of these coupled equations gives us a natural path to computing frequency filtered second-order photon-photon auto-correlations and cross-correlations. When solving the Lindblad master equation, computations could take up to 30 hours. With the moment equations, however, we cut the computation time down to less than a second. This allows us to perform much larger calculations, such as scanning for regions of anti-bunching with two multi-mode filters, as shown in Fig. 2.

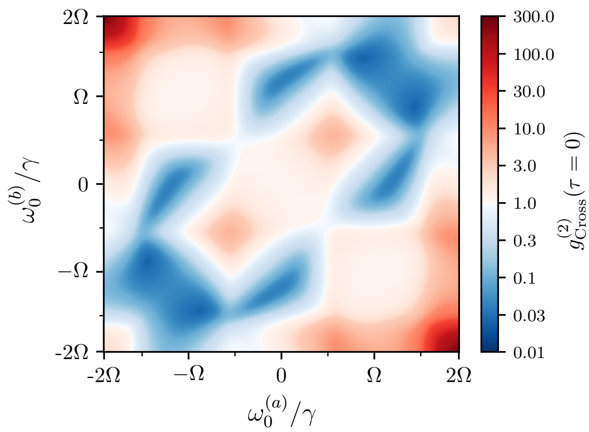

Figure 2: Initial photon correlation value for two tunable multi-mode array filters centered at the frequencies $\omega_0^{(a)}/\gamma$ and $\omega_0^{(b)}/\gamma$, where γ is the emitter linewidth.

References

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