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Title: Nonclassical effects in photon statistics of parametric interactions

The first section of my thesis will be an introduction to the fundamental goals and methods of theoretical quantum optics. I will demonstrate the way in which a basic knowledge of undergraduate-level quantum mechanics and electrodynamics/optics and the relevant mathematics (which I will assume my readers to possess) can be used to derive and to understand the topics that form the foundation of quantum optics. These topics will include: the quantization of the transverse electromagnetic field; the concept of photons and their representation by Fock states; coherent states and their use in representing the field state with a positive-P function; the derivation of a Focker-Planck/Langevin equation for the positive-P function from the Heisenberg equations of motion; solving Focker-Planck/Langevin equations; the theory of photoelectric detection and photon statistics; and the derivation of photon statistics from a positive-P function.

In the second section, I will apply the methods developed in the first section to derive the positive-P functions for specific quantum optical systems and to produce predictions about their photon statistics. The focus will be on systems involving parametric interactions, including single-atom optical bistability, second harmonic generation, and four-wave mixing. For each of these three systems, I will use the positive-P function to generate various correlation functions that describe the systems' photon statistics. The correlation functions will then be used to demonstrate the interesting non-classical effects displayed by these systems, such as anti-bunching, squeezing, and non-local field correlations.

Finally, the third section will address techniques for the experimental verification of the photon statistics derived in the second section. After briefly reviewing the general methods of experimental quantum optics, I will focus on a specific procedure for detecting squeezing and non-local field correlations. After demonstrating how the currently standard procedure may be extremely susceptible to certain types of experimental error, I will present new modifications to the experiment that may help to eliminate such problems and that also make the experiment applicable to a wider class of optical phenomena.