Abstract Submitted
for the DAMOP18 Meeting of
The American Physical Society

Heisenberg Picture Nonlinear Optics and Vacuum Modes in $\chi^{(2)}$ Processes[1] JUSTIN T. SCHULTZ, SULTAN A. WADOOD, A. NICK VAMIVAKAS, CARLOS R. STROUD, JR., University of Rochester — Many quantum mechanical phenomena such as Casimir forces, spontaneous emission, and the Lamb shift have been attributed to the quantum electromagnetic vacuum. Vacuum fluctuations have even been used to model the quantum efficiency of a detector and explain shot noise in homodyne detection. Several recent experimental results involving nonlinear optical interactions have also been interpreted using vacuum fields. The theory describing these processes relies on an effective Hamiltonian that reduces the effect of the nonlinear medium to one single component of the second-order nonlinear susceptibility. The Hamiltonian leads to the interpretation that the vacuum modes "seed" the nonlinear process and are therefore responsible for the observed effects. However, the quantum mechanical nature of the nonlinear medium is not considered. To improve our understanding of these processes, we develop a Heisenberg-picture model of nonlinear optics and show that the interaction of a dipole with its own source field can describe these results without a seeding vacuum field. Our work complements earlier results showing, for example, that spontaneous emission can be explained as resulting from either vacuum fluctuations or radiation-reaction fields based on the choice of operator ordering.

[1]Army Research Office Grant No. W911NF1610162

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Date submitted: 26 Jan 2018 Electronic form version 1.4