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WITHDRAWN Observing the effects of Time Ordering in Single Photon Frequency Conversion

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Frequency conversion (FC) is one of the most common nonlinear processes used in quantum optics.
This process has the property that the Hamiltonian that governs it does not commute with itself at different times, and hence time ordering becomes an important aspect in the description of its dynamics.
Recently, it has been shown that the Magnus expansion provides an appropriate description of the effects of time ordering in several nonlinear quantum optical processes[1-2].
One of the most important results derived from the use of the Magnus expansion in nonlinear optics is that the joint conversion amplitude (JCA) that governs the conversion processes in FC becomes a nonlinear function of the classical pump electric field because of time ordering effects.
In the low pump intensity regime, and assuming that the joint conversion amplitude can only upconvert one Schmidt frequency mode, one can show that the probability of upconversion is $\sin^2 \varepsilon$ where ε is linearly related to the peak electric field of the pump. As the intensity is increased time ordering corrections create more Schmidt frequency modes, with a dependence on the electric field of the pump is nonlinear.
With these observations in mind, we predict that efficiencies of maximum 80% can be achieved by using intensities that make $\sin^2 \varepsilon \approx 1$. The inability to achieve 100% conversion is due to two effects:

1. None of the Schmidt functions of the full JCA, including time ordering, will perfectly match the profile of the initial photon that is matched to the low pump intensity JCA.
2. The parameter ε that determines the "rotation angle" of the single photon is, because of ordering effects, a nonlinear function of the electric field.

We also find that these nonlinearities can also help achieve unit efficiencies by harnessing more than one of Schmidt mode of the high pump intensity JCA.
With this observations in mind we propose an experiment where these nonlinear effects can be observed and used to achieve near unit efficiency FC.

[1] N. Quesada and J.E. Sipe, Phys. Rev. A **90**, 063840 (2014).
[2] N. Quesada and J.E. Sipe, to appear in Phys. Rev. Lett. (2015) (arXiv:1410.0012).

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