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Comment on 'Noiseless amplification in cavity-based optical systems with an internal two-photon process. II. Self-frequency-doubling laser and second-harmonic generation, self-down-converting laser'

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Pregnolato *et al.* [1] considered the noise properties of a cavity that contains both an active medium and a two-photon process (frequency doubling or down conversion). In an elegant extension of previous analyses [2–5] they considered the prospects for noiseless amplification. The active medium is modelled as a two-level laser operating in the radiative limit (i.e. non-radiative dephasing is not considered). For the self-frequency-doubling laser it is found that large squeezing is available in either cavity mode (low or high frequency) as long as the decay rate of that mode is greater than both the decay rate of its partner mode and the population inversion decay rate. It is also found that near-'noiseless amplification' of a small monochromatic signal injected on the lower-frequency mode is possible. The motivation given for modelling the system is that it is spatially compact and may allow for the realization of monolithic experimental devices.

We wish to emphasize strongly the key role of dephasing in these systems. Not only does it affect the dynamics, such as the resonant relaxation oscillation but also it has a marked effect on noise reduction in realizable systems [6]. This point has only been briefly emphasized previously [7, 8]. The model given in [1] does not correspond to a probable experiment, as it considers only radiative dephasing. As [6] demonstrates, non-radiative dephasing introduces additional noise that will obscure the squeezing, to the extent that the experiment is not viable with current laser systems.

Dephasing is the decay rate of the lasing coherence and contains radiative and non-radiative contributions. In practical lasers the non-radiative contribution tends to be much larger than the radiative contribution, leading to a large overall dephasing rate. (Non-radiative dephasing is collisionally induced in gas lasers and phonon induced in solid-state or monolithic lasers.) If the value of the total dephasing is larger than both the laser cavity decay rate and the population inversion decay rate, then considerable noise is added to the phase quadrature of the laser. This is typically the case. (For example, consider a commercial miniature Nd-doped yttrium aluminium garnet nonplanar ring laser dephasing rate $\gamma_{\mathrm{p}} = 1\times 10^{12}\,\mathrm{s}^{-1}$; total cavity decay rate $\gamma_{\mathrm{cav}} = 8\times 10^{8}\,\mathrm{s}^{-1}$; population inversion decay rate $\gamma_{\mathrm{tot}} = 3\times 10^{7}\,\mathrm{s}^{-1}$).

The effect of the dephasing on the squeezing may be summarized as follows:

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dephasing adds considerable noise to the phase quadrature of the lasing (fundamental) mode, which is consequently transmitted to the second-harmonic mode. Amplitude quadrature squeezing of the second harmonic survives at very low detection frequencies. At higher frequencies the cavity mixes in the internal phase noise. Thus, the greater the dephasing rate, the narrower is the bandwidth of the squeezing, as the phase noise at a given frequency becomes stronger. In practice the dephasing rate is so large that squeezing of the second harmonic survives only at such low frequencies that technical and pump noise will tend to obscure the squeezing. In addition, the phase noise on the second harmonic generates further amplitude noise on the fundamental via parametric generation; consequently, no fundamental squeezing is predicted.

In summary, a self-frequency-doubling laser is not a promising source of squeezed light. This is due to the large dephasing rates that are endemic to current laser sources.

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