Super-thermal photon-number statistics in second-harmonic generation

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Second-harmonic generation (SHG) is one of the most widely employed nonlinear processes [1] that finds applications in the technology of laser, to obtain new sources at different wavelengths, because upconverted laser light has the same statistical properties as the fundamental. In particular, the photon number statistics remains Poissonian. Moreover, SHG is exploited to change light wavelength to match the sensitivity of detectors. [2]. Finally, in classical optics SHG is used as an ultrafast correlator, and in quantum optics it has been employed to investigate the temporal correlation properties of twin beam states [3].

In general, it has been demonstrated that not all the properties of the fundamental light are preserved in the SHG process. In particular, light fluctuations are increased by the SHG process, and hence both photon number statistics and correlations of the upconverted light change [4]. The effect has been experimentally observed for single-mode lasers operating below threshold by using photomultpliers in the single-photon-counting regime [5].

Here we present results for the upconversion of pulsed multi-mode thermal fields generated by parametric down-conversion (PDC). We demonstrate that both the SHG field and the residual fundamental become super-thermal, even if the effect is much more evident for the upconverted field than for the residual one, due to the low efficiency of the upconversion process. Our measurements were performed by using two hybrid photodetectors (HPD, mod. R10467U-40, Hamamatsu), which are endowed with partial photon-number resolution and allow both the reconstruction of detected-photon-number statistics and shot-by-shot correlations [6, 7].

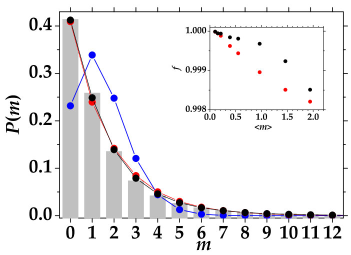

FIG. 1: Experimental statistics (grey columns), Poissonian curve (blue symbols), multi-mode thermal fit (red symbols) and super-thermal fit (black line). Inset: fidelity values.

In Fig. 1 we show a typical detected-photon distribution (grey columns) obtained by upconverting a portion of the PDC light at $\sim$ 700 nm generated by pumping a BBO crystal pumped with a ps-pulsed laser light at 349 nm. Experimental data are compared with a Poissonian distribution with the same mean value (blue symbols), the fit to a multi-mode thermal distribution (red symbols) and the fit to a super-thermal distribution [8] (black symbols) for fixed mean value and the number of modes as the only fitting parameter. The fit to the multi-mode thermal statistics returns an un-physical number of modes (less that one), while that to the multi-mode thermal gives $\sim$ 3 modes. The better superposition of this last fit to data is also testified by the higher values of the fidelity in the inset of the figure.

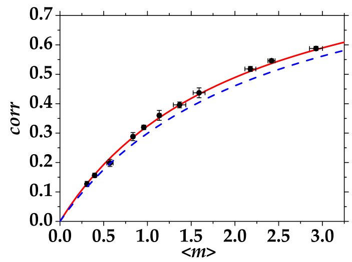

FIG. 2: Detected-photon correlation as a function of the mean number of photons (black dots). Theory for super-thermal (red line) and a multi-mode thermal (blue line) fields.

From the change of the statistics, we also expect enhanced correlations of the SHG light divided at a beam-splitter. In Fig. 2 we show the measured intensity correlation coefficient as a function of the mean number of detected photons (dots). The results agree with the theoretical prediction based on the super-thermal model (red line), while they differ from the theoretical expectation based on a multi-mode thermal description (blue dashed line).

The increased amount of intensity correlations is a resource that can be exploited in new ghost-imaging protocols.

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