Quantum Correlated Twin Beams in Cascaded Quadratic Processes

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Abstract: Twin beams are observed in an optical resonator where cascaded second harmonic generation and optical parametric oscillation occur. We measure a squeezing level up to -5 dB in their intensity difference.

Squeezed states of light are a key resource to implement quantum communication and computation protocols with continuous variables, as well as to improve the precision of measurements beyond the shot noise limit [1,2]. As first observed by Heidmann et al. [3], twin beams generated by parametric down-conversion exhibit strong intensity correlation, resulting in squeezing of the measured intensity difference.

Here we report on the first observation of quantum correlation in twin beams generated in intracavity second harmonic generation (SHG) through a cascade of nonlinear processes: a primary process of SHG of the pump laser at 1064.45 nm is followed by an internally pumped optical parametric oscillation (OPO) giving rise to two parametric modes around the pump frequency. Although this scheme can exhibit multimode emission in the form of optical frequency combs [4], here the system is operated so that only a pair of parametric modes occurs, which were predicted to display reduced fluctuations in the intensity difference, as for twin beams in a conventional OPO [5]. In our experiment, sketched in the left panel of Fig. 1, a final reduction of noise up to −5 dB is achieved with respect to the standard quantum limit [6] (right panel of Fig. 1). This demonstration opens the way to extensive investigations of the exclusive nonclassical properties of the cascaded scheme: in fact, the complex interactions between SHG and OPO lead to a variety of nonclassical effects that are not accessible via each single nonlinear process, such as multipartite entanglement. Also, the results of our investigations could help in establishing more compact and stable schemes, such as nonlinear quadratic microresonators, as efficient and viable sources of nonclassical light.

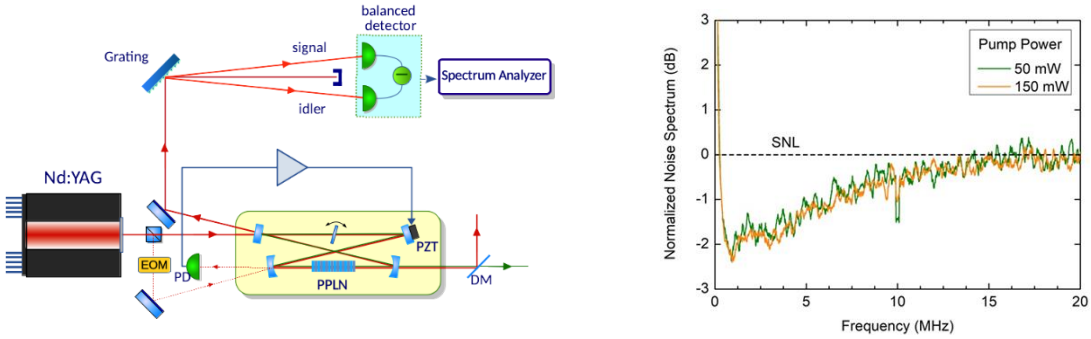

Fig. 1. Left panel: Scheme of the four-mirror, traveling-wave cavity for twin beams generation. PPLN, periodically poled lithium niobate crystal; PD, photodiode; EOM, electro-optic modulator; DM, dichroic mirror; PZT, piezoelectric actuator. Right panel: Normalized noise spectra of the photocurrents difference for quantum correlated twin beams, for two different pump powers. The dashed line SNL indicates the shot noise limit.

References

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