Observation of quantum correlated twin beams in cascaded nonlinear interactions

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We report on the observation of squeezing in the intensity difference of twin beams generated in intracavity cascaded nonlinear processes: a primary process of second harmonic generation of the pump laser triggers an optical parametric oscillation (OPO) giving rise to two parametric modes around the pump frequency. Although this system can exhibit multimode emission, here it 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.

In our experiment, a cw Nd:YAG laser at 1064.45 nm is used to pump a periodically poled Lithium Niobate crystal, placed inside a cavity resonating for the fundamental and its second harmonic. To limit the subharmonic modes to a single pair of signal and idler waves, the cavity's zero-order resonance is locked at a finite detuning from the pump laser frequency. Out of the cavity, the downconverted modes are spatially separated from the fundamental and second harmonic beams and sent to a pair of balanced detectors. The two photocurrents are finally subtracted, and the noise in the difference is spectrally analyzed. Fluctuations in intensity difference are below the shot noise in the frequency bandwidth up to 14 MHz. The maximum squeezing level of -2.3 ± 0.3 dB is reached around 900 kHz, which, corrected for detection losses, results in -5.0 ± 1.3 dB at the exit of the resonator.

Demonstration of twin-beam correlations in our cascaded system opens the way to extensive investigations of its exclusive nonclassical properties. In fact, the complex interactions between the two nonlinear processes produce a variety of nonclassical effects that are not accessible to each single nonlinear process, such as multipartite entanglement, of paramount importance for the development of advanced quantum protocols.