Squeezed state measurement using multipixel homodyne detection

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Abstract

Multimode non-classical states of light in the ultrafast regime represent promising candidates for practical quantum information protocols due to their high dimensionality and scalability. Such applications require controllable state preparation and measurement techniques. We generate such states using a nonlinear optical cavity pumped synchronously with an ultrafast pulse train, and control the modal properties of these states with highly tunable spectral-temporal manipulation of the pump pulse train. The multimode state at the output of the cavity is then fully reconstructed by simultaneous homodyne measurements of eight spectral modes.

Entanglement among multiple modes is a necessary resource in the field of quantum information technology. In this context, frequency comb sources of femtosecond pulsed light represent a useful resource, with approximately 10^5 individual frequency modes across the pulse bandwidth. It has been recently shown[1] that a synchronously pumped optical parametric oscillator (SPOPO) can generate highly multimode nonclassical states of light (Fig. 1a). Frequency-doubled pulses from a Ti:Sapph laser are propagated in a nonlinear crystal (BiBO) with round-trip time matched to the pump pulse train cycle time. Correlations appear among the many spectral modes of the frequency comb of the down converted light, giving rise to a squeezed vacuum state at 795 nm centre wavelength with a highly multimode structure. The SPOPO is thus a promising candidate as a broadband nonclassicality resource.

The quantum state of the output of the SPOPO is determined by the phase matching conditions, cavity resonance mode, and the mode properties of the pump [2]. A high degree of control over the mode structure of the output can thus be achieved by shaping the spectral mode of the pump beam using a pulse shaper ,The nonclassical output states can then used as a resource for diverse applications such as non-Gaussian state preparation via photon substraction and measurement-based quantum computation (MBQC) protocols [3].

To verify the effectiveness of the pump shaping, we measure the SPOPO output state using spectrally resolved homodyne detection. To this end, we have developed a multipixel homodyne detection scheme which allows us to simultaneously monitor quadrature variance in eight spectral modes. This allows the reconstruction of the complete covariance matrix and hence, assuming Gaussianity, provides full information about the quantum state. We performed full Gaussian state reconstruction on the cavity output for several pump pulse profiles and compare with earlier theoretical results.

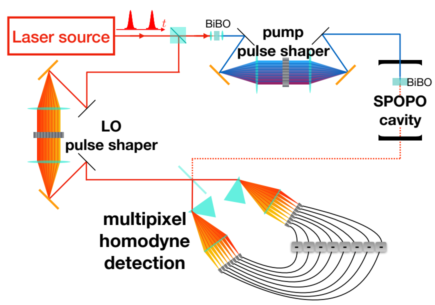

Figure 1: scheme of the experiment

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[2] F. Arzani, C. Fabre, and N. Treps *Versatile engineering of multimode squeezed states by optimizing the pump spectral profile in spontaneous parametric down-conversion*, Phys. Rev. A **97**, 033808 (2018).

[3] Y.-S. Ra, C. Jacquard, A. Dufour, C. Fabre, and N. Treps, *Tomography of a Mode-Tunable Coherent Single-Photon Subtractor*, Phys. Rev. X **7**, 031012 (2017).