Single-photon Heralded Generation of Non-gaussian Resources

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Physique quantique et applications

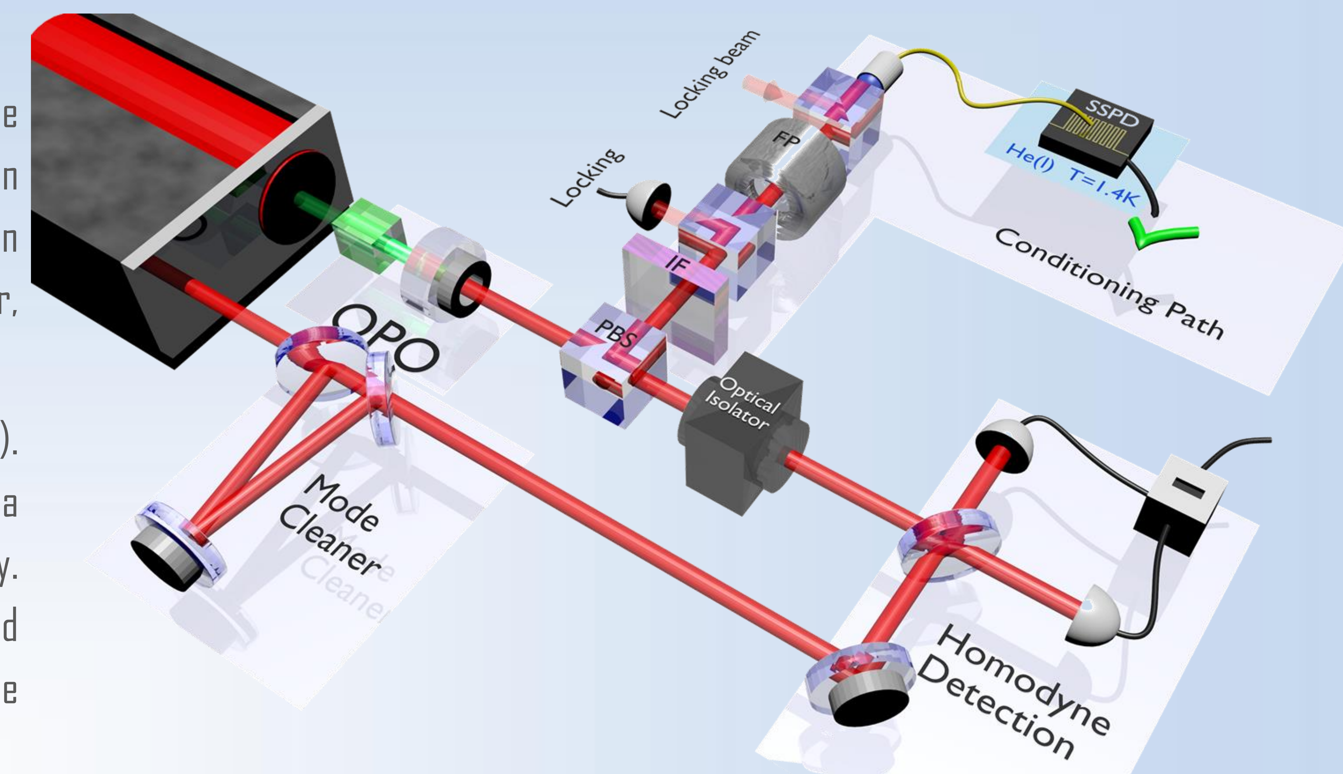
High fidelity non-Gaussian resources generated via conditional preparation

A driving component for the development of diverse quantum information applications is the ability to efficiently engineer non-classical states of light. We present the conditional preparation of high-purity single-photon Fock state [1] based on a continuous-wave type-II optical parametric oscillator (OPO) [2] and coherent state superposition (CSS) based on a type I OPO.

Using a continuous-wave type-II OPO far below threshold, we demonstrate a novel source of heralded single-photons with high-fidelity [1]. The generated state is characterized by homodyne detection and exhibits a 79% fidelity with a single-photon Fock state (91% after correction of detection loss). The low admixture of vacuum and the perfect spatiotemporal mode are critical requirements for their subsequent use in quantum information processing. Thanks to the OPO cavity, the spatial mode enables to reach high interference visibilities without the need of additional filtering. Moreover, the frequency-degenerate interaction makes the operation much simpler than previous realizations.

As shown in the experimental setup, the orthogonally-polarized signal and idler modes (1064nm) are separated by a polarizing beam-splitter (PBS). The idler mode is spectrally filtered (Conditioning Path), in order to eliminate the non-degenerate modes from the OPO, and then detected by a superconducting single-photon detector (SSPD). Given a detection event, the heralded single-photon is characterized by quantum state tomography. The signal from the homodyne detection is processed to obtain the quadrature measurements in the temporal mode of the OPO [3]. Accumulated measurements give the marginal distribution of the state. The data are then processed using a maximum likelihood algorithm (MaxLik) to estimate the density matrix.

By a similar scheme, involving a type-I OPO and tapping a small part of the output with a beam splitter, we also demonstrated the generation of a state closed to a coherent state superposition.

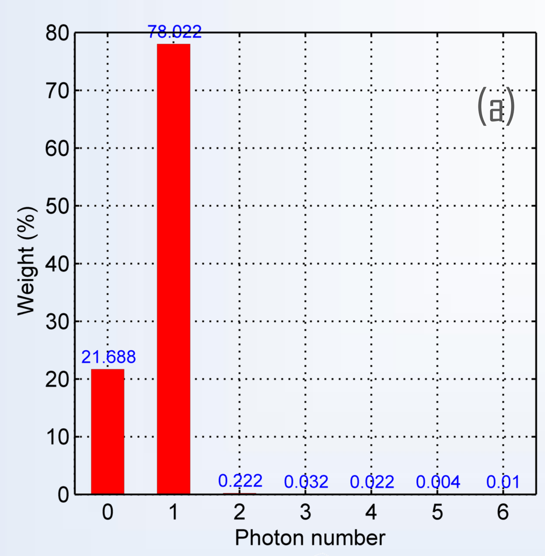


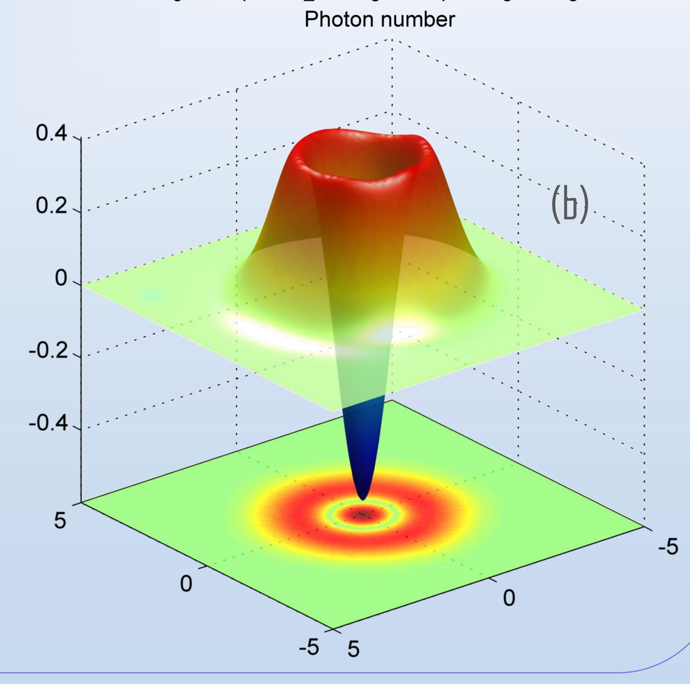
Experimental setup

Single-photon with a type II OPO

Single photons are attractive carriers of quantum Information and they are the main constituents of various quantum communication protocols [4,5]. Single photon state can be prepared by conditional detection of one photon from photon number correlated beams, i.e. twin beams.

$$\sum_{m=0}^{\infty} \lambda_m |m\rangle\,|m\rangle \xrightarrow{|1\rangle\langle 1|} |1\rangle$$



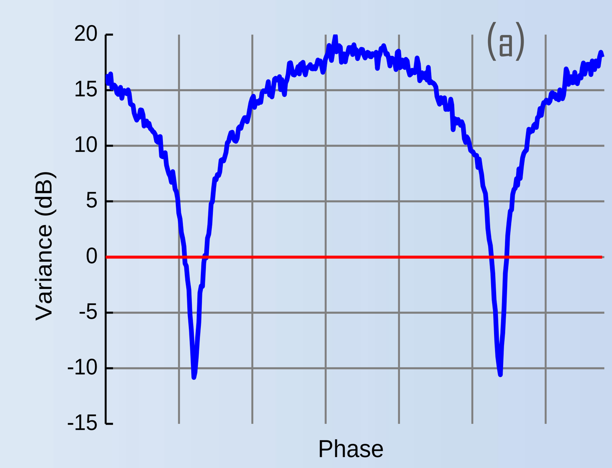


(a) Diagonal elements of the density matrix of the generated state without correction from detection losses.

(b) Corresponding Wigner function without correction from detection losses.

"Schrödinger's kitten" with a type I OPO

CSS state has potential applications in high precision metrology and plays an important role in many quantum information processing tasks including quantum computation and quantum teleportation. An ideal squeezed vacuum is a superposition of even photon-number states, thus one-photon subtracted state is a superposition of odd photon-number states which is similar to the superposition of coherent states with small amplitude.

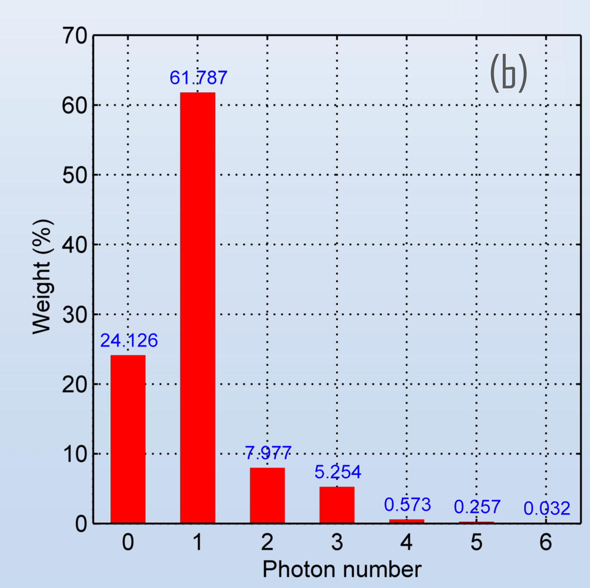


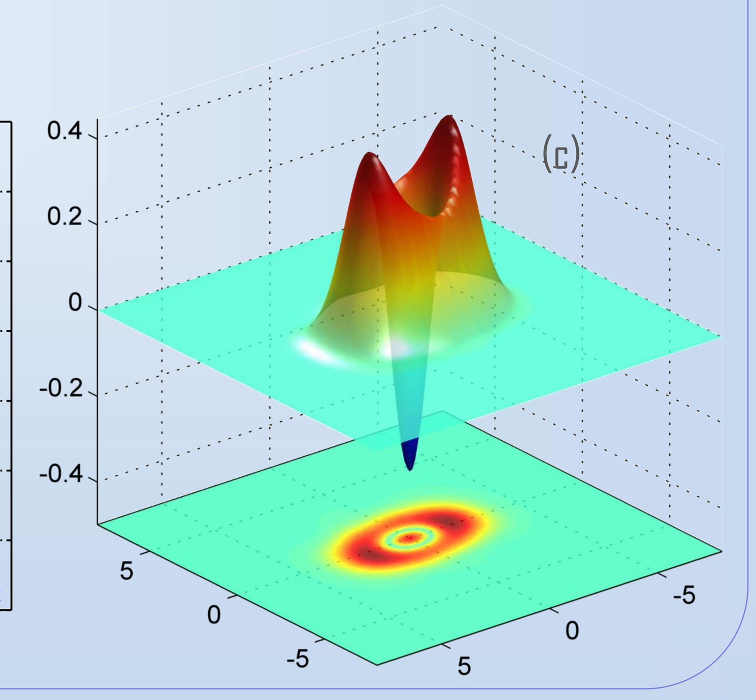
$$\hat{S}|0\rangle = \sum_{m=0}^{\infty} \lambda_m\, |2m\rangle \xrightarrow{\hat{a}} \sum_{m=0}^{\infty} \beta_m\, |2m+1\rangle \rightarrow |\alpha\rangle - |-\alpha\rangle$$

(a) Squeezing obtained with a pump power close to threshold

(b) Photon number distribution for the generated coherent state superposition

(c) Corresponding Wigner function without correction from detection losses.





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References

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