Quantum non-Gaussianity (QNG) corresponds to an essential resource in many prospective applications of quantum technologies. QNG states of light have been demonstrated in a broad range of experimental platforms with various complementary advantages [1]. However, in order to allow for their direct and efficient utilization for interaction with the target quantum system, their degrees of freedom have to be well-defined and controllable. This imposes a requirement on the generation of QNG light in a single optical mode. While the intrinsic single-photon sources including trapped ions, atoms, or molecules, naturally offer a close-to a single mode emission, their technologically more accessible counterparts including majority of the solid-state emitters and sources based on heralded generation of nonclassical states in various parametric nonlinear processes typically provide a multimode output. Although several demonstrations of a single-mode operation of nonclassical light sources based on these platforms have been recently demonstrated, an unambiguous observation of a single-mode QNG light has never been presented.

We present the generation of a single-mode QNG light from the process of a spontaneous four-wave mixing (SFWM) in a warm atomic vapor [2]. The source utilizes a laser excitation of $^{87}$Rb atoms in a double-$\Lambda$ scheme with a counter-propagating single-laser geometry. The unique combination of the laser interaction area with atoms in the proximity of the vapor cell viewport, auxiliary optical pumping, paraffin coating, and particular mode selection allows for the observation of a single-mode QNG light. The QNG character is proven by the evaluation of QNG criteria based on the photon statistics [3]. While the bare nonclassical properties of the generated heralded Stokes or anti-Stokes light are observable in a broad range of excitation parameter regimes and with tunable output spectral and temporal profiles, the crucial parameter for the achievement of the QNG regime critically depends on the optimization of the absorption losses of the near-resonant anti-Stokes field versus its directionality in the large-bandwidth SFWM regime. The robustness of the measured single-mode QNG to losses and to excess noise is demonstrated by introducing a thermal noise generated by an independent atomic source and artificial losses in the Stokes channel and shown on Fig 1 (b). The single-mode regime has been proven by comparison of the measured photon wavepackets in the triggered intensity correlation functions with their phase coherence. Demonstrated close-to single-mode operation can provide the missing fundamental ingredient for efficient nonlinear interactions with QNG light in atomic ensembles [4].

![Fig. 1](image-url)

**Fig. 1 (a)** The single-mode QNG source is based on spontaneous four-wave mixing in hot atomic ensemble, where pump $P$ and retroreflected coupling beams $C$ produce Stokes and anti-Stokes photons in a double-$\Lambda$ electronic energy level scheme. **(b)** Evaluation of the statistical properties of the Stokes field by comparing the ratio of the single photon probability $P_1$ corresponding to the two-photon efficiency to the multiphoton probability $P_2$. Orange line and data represent nontrivial dependence on the interaction area position, solid green line and datapoints show the effect of the thermal noise added to heralded Stokes signal, with the NSR = 0.018 ± 0.001 of unheralded noise to heralded signal being the threshold for QNG witness observability. QNG property remains detectable with up to 43% losses introduced to the Stokes channel, as depicted by the simulation shown as the dashed green curve.

**References**

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