

Loss-resistant verification of quantum non-Gaussian photon statistics

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Quantum non-Gaussian states of light have fundamental properties that are essential for a multitude of applications in quantum technology. However, many of these features are difficult to detect using standard criteria due to optical losses and detector inefficiency. As the statistics of light are unknown, the loss correction on the data is unreliable, despite the fact that the losses can be precisely measured. To address this issue, we employ a loss-mitigated verification technique utilizing quantum non-Gaussian witnesses, which incorporate the known optical losses and detector inefficiency into their derivation. This approach allows us to address the considerable challenge of experimentally demonstrating unheralded quantum non-Gaussian states of single photons and photon pairs.

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I. INTRODUCTION

The development of quantum technology is contingent upon the utilization of quantum non-Gaussian states [1–3], which are indispensable for sensing [4,5] and hybrid systems comprising quantum bits [6–8]. The advancement of quantum systems for photonic sources in atomic [9–12], solid-state [13,14], and nonlinear optics [15,16] platforms is hindered by the difficulty in detecting quantum non-Gaussian aspects of photons. A significant challenge for many new sources and their initial tests is the loss of light during transfer from the source to the measurement and the inefficiency of the detection process. Such loss, exceeding 3 dB, limits the direct observation of a witness of quantum non-Gaussian light using a negative Wigner function [17,18].

A significant advance was made by quantum non-Gaussianity witnesses, enabling the 3-dB limit to be surpassed and quantum non-Gaussianity to be identified directly [19–24]. Subsequently, this methodology has been successfully deployed in nonlinear optics [25,26], atomic physics [9,27], and solid-state sources [13,14]. The optical loss and detection inefficiency can be accurately quantified and characterized, which is advantageous. Nevertheless, the direct correction of the unknown quantum statistics of light for this loss is typically unreliable, due to stochastic nature of losses. Therefore, we incorporate the precisely characterized inefficiency

into the construction of the quantum non-Gaussianity criteria. This allows conclusive proof of unheralded quantum non-Gaussian single-photon states and their coincidences generated from quantum emitters, using only directly measurable probabilities.

The efficiency of optical transmission, light collection, and detection is limited for many photonic measurements widely used in quantum physics. Failure to achieve unity efficiency can be modeled as the presence of a lossy channel with transmission η [28]. We derive a criterion for certifying quantum non-Gaussianity that incorporates this model of nonideal efficiency and experimentally verify it. Quantum non-Gaussianity can be observed in a variety of states including single photons and pairs of photons [20,27]. To address single photons, we consider a measurement that employs a beam splitter and two nonideal detectors, D_1 and D_2 . We define the probability $P_{1,\eta}$ of a click on detector D_1 and the probability $P_{2,\eta}$ of a coincidence click on both detectors D_1 and D_2 per generated state. Both probabilities $P_{1,\eta}$ and $P_{2,\eta}$ depend on the transmission of the lossy channel η . While there are criteria [20,29] for quantum non-Gaussianity that include all mixtures of Gaussian states, the states studied experimentally may not meet this criterion due to high optical losses, which result in low overall detection efficiency. In a regime of photonic states with $P_{2,\eta} \ll P_{1,\eta}$, we can approximate the criterion derived in Ref. [20] with $P_{1,\eta}^3 \gtrsim P_{2,\eta}/4$ [14].

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II. THEORETICAL FRAMEWORK

Here, we present an approach that takes into account measurement losses. To this end, we have derived the threshold by maximizing the linear combination $F_{\alpha,\eta} \equiv P_{1,\eta} + \alpha P_{2,\eta}$ over mixtures of pure Gaussian states, where we consider that the

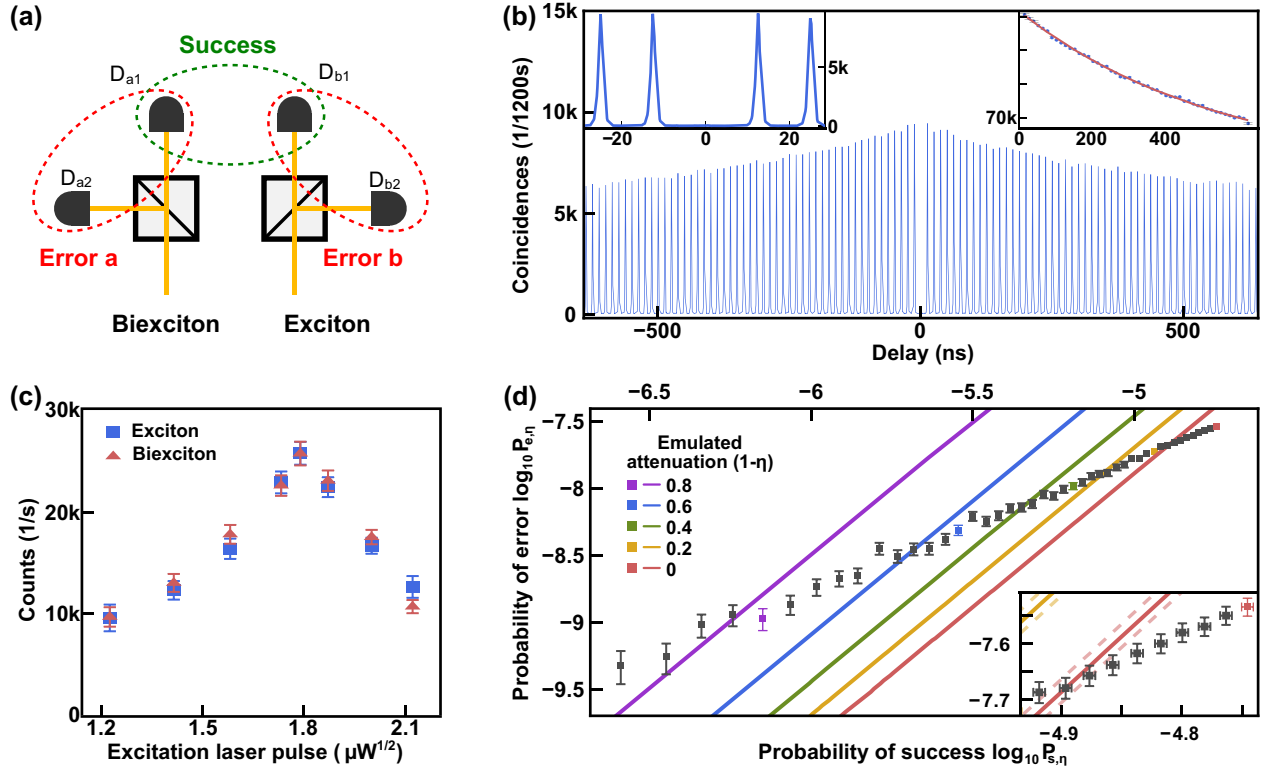


FIG. 1. (a) Schematic of the measurement setup. Coincidences between D_{a1} and D_{b1} (indicated by the green circle) are considered to be successful outcomes, while coincidences between either D_{a1} and D_{a2} or D_{b1} and D_{b2} (indicated by the red circles) are considered to be error events. (b) Autocorrelation function measured using exciton photons. The inset in the top left-hand corner of the figure shows the autocorrelation function near zero delay. The measurement gives the value of $g^{(2)}(0) = 0.0154(4)$. The inset on the top right shows the summed area under each peak. These values were fitted with an exponential function to derive the blinking rate. (c) Result of the Ramsey interference measurement. We determined the excitation laser power corresponding to a $\pi/2$ pulse by estimating where the Ramsey fringes reach their maximum amplitude. (d) Comparison between our data and the non-Gaussian coincidence criterion. Each line represents a threshold of the criterion. The color coding of the lines indicates the attenuation introduced. The point with the highest probability of success (also shown in the inset) has the coordinates corresponding to the experimentally determined $P_{e,\eta}$ and $P_{s,\eta}$. We find this point to be 11.52 standard deviations from the criterion threshold. The remaining points were derived by emulating the attenuation of the optical signal (loss) by undersampling. The attenuation was varied in the same range as for the criterion thresholds and in steps of 0.02. The color of the points and lines (thresholds) changes when the introduced attenuation exceeds 0.2. The points positioned to the right of the corresponding threshold indicate the respective quantum state is non-Gaussian. Inset: Area of the plot with the lowest attenuation in greater detail. The dashed lines represent the uncertainty associated with threshold, which arises from the measurement error of the setup transmission and the imbalance of the beam splitters.

probabilities $P_{1,\eta}$ and $P_{2,\eta}$ were detected employing a lossy channel (detector) with a given efficiency η .

Additional information on the numerical derivation of the threshold can be found in the Supplemental Material [30]. In a regime of states with low probability $P_{2,\eta}$, the criterion takes on the approximate form $P_{1,\eta}^3 \gtrsim \eta/[4(2-\eta)]P_{2,\eta}$. This inequality indicates that the criterion is more lenient than the one given in Ref. [14].

To certify the non-Gaussianity of photon pairs [29], we consider that each photon in the pair occupies a different mode and assume that both of them propagate through the same lossy channel. To perform the measurement, each mode is sent to a beam splitter followed by two detectors D_{m1} and D_{m2} , where $m \in \{a, b\}$ represents the mode index, as shown in Fig. 1(a). For a given transmission η of the lossy channel, we introduce the probability $P_{s,\eta}$ of a coincidence between detectors D_{a1} and D_{b1} . Similarly, we define the probability $P_{e,m,\eta}$ of a coincidence between detectors D_{m1} and D_{m2} pertaining to the same mode m . Based on the probabilities $P_{s,\eta}$

and $P_{e,\eta} \equiv [P_{e,a,\eta} + P_{e,b,\eta}]/2$, we can, in principle, derive a criterion capable of rejecting a generic multimode Gaussian state. In practice, however, the derivation of such a Gaussian state is computationally demanding, even in the case of ideal detection [29]. This is due to necessity of maximizing over the large number of parameters required to identify a generic multimode Gaussian state.

As this is a pervasive issue in quantum state benchmarking, we put forth a viable solution: the derivation of more specific, pertinent, and indispensable models for the source under examination. Therefore, we reduce our study to the subset of multimode states $\rho_N = \prod_{i=1}^N \otimes \rho_i(\lambda_i)$ with two-mode Gaussian state $\rho_i(\lambda_i)$ defined as

$$\rho_i(\lambda_i) = \frac{1}{1 + \lambda_i^2} \sum_{n=0}^{\infty} \lambda_i^n |n\rangle_{a_i} \langle n| \otimes |n\rangle_{b_i} \langle n|, \quad (1)$$

where λ_i determines the distribution of photons correlated in the a_i th mode and the b_i th mode. The state ρ_N represents

a model state of light emitted from spontaneous parametric down-conversion process [29,31]. After considering the potential impact of a lossy channel on the state ρ_N , we express the measured probabilities $P_{s,\eta}$ and $P_{e,\eta}$ as a function of the parameters λ_i in the state $\rho_N = \prod_{i=1}^N \rho_i(\lambda_i)$. In order to establish a criterion for N modes, we need to identify for each N a threshold in terms of $P_{s,\eta}$ and $P_{e,\eta}$ that covers all states ρ_N . Because deriving such thresholds for any state ρ_N becomes challenging, we focus on an experimentally relevant regime of small $P_{e,\eta}$ where we can assume $\lambda_i \ll 1$ in Eq. (1) and derive the thresholds analytically, as summarized in the Supplemental Material [30]. In this limit, the criterion follows approximately as

$$P_{s,\eta} > \eta \frac{N}{2\sqrt{N(N+1)}} \sqrt{P_{e,\eta}}. \quad (2)$$

In order to encompass all possible scenarios, we consider the asymptotic multimode limit of $N \gg 1$, where the left side attains its maximum over N . This provides the most rigorous version of the criterion. This enables us to reject the multimode two-mode squeezed Gaussian states $\rho_N = \prod_{i=1}^N \rho_i(\lambda_i)$ with generally different λ_i , which, however, obey the limit $\lambda_i \ll 1$ for each i .

III. EXPERIMENT

Our photon-pair source consists of a quantum dot embedded in a micropillar cavity with a diameter of 2.74 μm [32]. During the measurements, the quantum dot was kept in a closed-cycle cryostat at a temperature of 4.856(8) K. We excited the quantum dot resonantly using a pulsed Ti:sapphire laser. To ensure the generation of pairs of photons, the quantum dot was driven using two-photon resonant excitation of the biexciton [33]. The level scheme of the quantum dot is shown in the Supplemental Material [30]. The excess laser scattering was eliminated by employing a combination of spectral and polarization filtering. The emitted biexciton-exciton photon pairs were spectrally separated using a diffraction grating and coupled in respective single-mode fibers. The biexciton and exciton photons were detected using avalanche photodiode (APD) detectors.

The measurement scheme used to assess our source against the non-Gaussian coincidences criterion is depicted in Fig. 1(a). The fiber-coupled biexciton (exciton) photons were transmitted through a fiber beam splitter and subsequently detected by an APD detector. We employed a total of four APD detectors, two for each fiber beam splitter we used. The coincidences recorded by detectors D_{a1} and D_{a2} (D_{b1} and D_{b2}) are designated as error events, as they indicate a simultaneous emission of two biexciton (exciton) photons. Conversely, the coincidences recorded between the detectors D_{a1} and D_{b1} are considered to be successful events. The probability of success is defined as $P_{s,\eta} = C_s/C_0$. Here, C_0 is the photon pair generation rate, while C_s is the rate of coincidences recorded between D_{a1} and D_{b1} . The probability of an error event $P_{e,\eta}$ is defined as $(C_{e,a} + C_{e,b})/2C_0$. Here, $C_{e,a}$ ($C_{e,b}$) is the rate of coincidences recorded by detectors D_{a1} and D_{a2} (D_{b1} and D_{b2}).

To ascertain the values of $P_{s,\eta}$ and $P_{e,\eta}$, we require to accurately determine C_0 . The photon pair generation rate for a resonantly excited single quantum dot emitter is dependent

on the emission probability and the blinking rate. The blinking rate is commonly estimated using an autocorrelation measurement [shown in Fig. 1(b)], where it induces an exponential decay of the height of the peaks [34]. By fitting the exponential decay, we estimated that the effect of blinking reduces the rate at which photon pairs are generated to 56.6(6)% of the laser repetition rate. The emission probability is a function of the pulse area of the excitation laser and is commonly determined by Rabi oscillations measurements. However, the accurate fitting of the Rabi oscillation demands coherence to be preserved even for very high pulse area. We resorted to a simpler approach where we employed Ramsey interference. Namely, the amplitude of the Ramsey interference fringes increases with the pulse area, reaching maximum at $\pi/2$ pulse, to gradually fall to zero at π pulse [shown in Fig. 1(c)]. Consequently, Ramsey interference can be used to determine the laser power that equals the excitation pulse area of $\pi/2$.

We performed the measurement using an excitation laser with repetition rate of 80 MHz and a pulse area of $\pi/2$. These two parameters combined with the above-determined blinking yield a photon pair generation rate of 22.64(25) MHz. However, due to suppression of the laser excess scattering by means of polarization only the photon pairs with vertical polarization will take part in the measurement. Therefore, we can consider that during the measurements we performed, the photon pair generation rate was $C_0 = 11.32(12)$ MHz.

The coincidence counts were sampled within a 1408-ps coincidence window, selected to facilitate the efficient detection of both biexciton and exciton photons with lifetimes of 249.8(7) and 397.2(9) ps, respectively. The detector D_{a1} and D_{b1} count rates were 50.6(2) and 75.3(3) kcounts/s, respectively. Our measurements yielded 244 113(494) coincidence counts recorded between D_{a1} and D_{b1} in a measurement time of 1200 s. During the same time span, we recorded 430(21) coincidence counts between D_{a1} and D_{a2} and 365(18) between D_{b1} and D_{b2} . These number yield $P_{s,\eta} = 1.797 \pm 0.020 \times 10^{-5}$ and $P_{e,\eta} = 2.93 \pm 0.11 \times 10^{-8}$.

The criterion for non-Gaussian coincidences accounts for losses of the setup and the detection. The overall losses of the optical elements were quantified by utilizing a laser with a wavelength corresponding to that of the emitted photons. The measurement yielded an optical transmission of 0.534(16). The fiber coupling efficiency was determined to be 0.692(2). Due to the fiber mating losses, only 0.7948(4) of the light coupled into the single-mode fibers was fed into fiber beam splitters. The fiber coupling and mating losses were averaged over biexciton and exciton. It is assumed that the APD quantum efficiency is 0.5 and is the same for all the APD detectors used in the measurement. This value is significantly higher than the actual quantum efficiency, as stated in the specifications. It can thus be estimated that the total losses of the apparatus, including the detectors, are at least 0.8533(34), indicating an η of at most 0.1467(34).

The experimentally determined probabilities of success and error [illustrated in Fig. 1(d) as the point with the highest success probability] substantiate the assertion that our source emits non-Gaussian coincidences. The obtained result is 11.52 standard deviations away from the criterion threshold. Moreover, the effect of optical losses in the range from 0 to 0.8 was emulated by means of undersampling of the data. Figure 1(d)

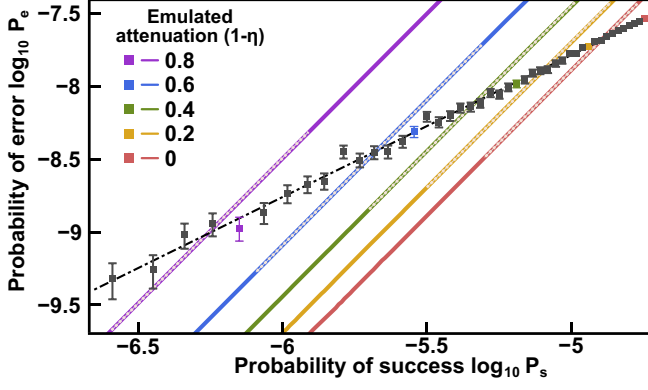


FIG. 2. Calculation of the non-Gaussian depth by data fitting. The different criterion thresholds, represented by solid colored lines, are second-order expansions of the criterion in the vicinity of the data points. A linear fit is performed on each of the criterion thresholds and on the complete dataset. Subsequently, the non-Gaussian depth of the states was obtained from the intersection between the criterion threshold and the data fit. The results are given below in Table I.

illustrates the impact of attenuation on the probabilities of error and success. This approach allows for the emulation of optical losses in the channel up to the level of the detector dark counts. This is so, as coincidences between dark counts are removed by undersampling, whereas they would remain unaltered by the introduction of losses in the optical path. However, we estimated that such events would contribute less than 0.031 coincidences on average over the course of the entire measurement. It can thus be concluded with a high degree of confidence that the results presented accurately reflect the process of experimentally introducing optical losses.

To test the robustness of the criterion in the presence of losses, we proceeded to estimate the non-Gaussian depth [14] of our state. Non-Gaussian depth is the maximum optical attenuation that can be applied to a specific quantum state while still exhibiting quantum non-Gaussianity. In order to achieve this, we derived an approximate analytical form for the criterion. The complete range of data points was also fitted, as illustrated in Fig. 2. Subsequently, the point of intersection between the each threshold and the fit was calculated. The respective non-Gaussianity depths are shown in Table I.

In addition to the results shown so far, we have also used the same source to certify quantum non-Gaussianity for unheralded single-photon states. To achieve this, we deliberately excluded the biexciton data from our analysis and focused only on the exciton photon emission from our device. The

TABLE I. The non-Gaussian depth of the state determined for different levels of attenuation.

Attenuation ($1 - \eta$)	Non-Gaussian depth (dB)
0	0.764 ± 0.039
0.2	0.740 ± 0.035
0.4	0.710 ± 0.033
0.6	0.667 ± 0.035
0.8	0.595 ± 0.049

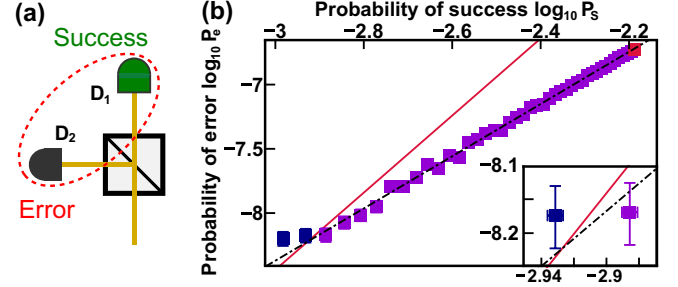


FIG. 3. (a) Experimental scheme to certify quantum non-Gaussianity of unheralded single-photon states. Coincidences between detectors on D_1 and D_2 are denoted as error events, while a click on detector D_1 is considered to be the success event. (b) Comparison between our data and the criterion for quantum non-Gaussianity of single-photon states [30]. The solid red line indicates the criterion. It marks the transition between Gaussian states (blue squares) and non-Gaussian states (purple squares). For the criterion threshold plotted here, the losses of our measurement apparatus were not taken into account; nevertheless, our data show that the detected state is quantum non-Gaussian and positioned 183 standard deviations from the criterion threshold. Analogous to the data in Fig. 1(d), we have undersampled to emulate optical losses in steps of 0.02. The obtained data have been fitted (dashed black line) to determine the non-Gaussian depth (7.41 ± 0.11 dB). The inset shows the states that cross the threshold.

experimental implementation in this case involves a stream of exciton single photons and a beam splitter, as shown in Fig. 3(a).

The results are shown in Fig. 3(b). We have used single-photon non-Gaussianity criterion [30], which defines the probability of error P_e using the probability of success P_s and the transmission of a beam splitter T_{bs} [0.5166(3)] in front of the two detectors D_1 and D_2 :

$$P_e < 2 \cdot P_s^3 \times \frac{1 - T_{bs}}{T_{bs}^2}. \quad (3)$$

The measured state is 183 standard deviations from the criterion threshold. We determined a non-Gaussian depth of 7.41 ± 0.11 dB via a fit to the data points, which corresponds to an η of 18.17(21)%.

IV. CONCLUSION

In conclusion, we have developed two criteria for the quantum non-Gaussianity of single photon and photon pair states. Both of our criteria can handle known optical losses, making them a very powerful tool for studying states of light in lossy and long-distance channels. To our knowledge, no other study incorporates loss directly into the criterion, enabling observation of the non-Gaussianity of single-photon pairs despite significant optical and detection losses. We have tested these criteria in practice using a quantum dot-based source of photon pairs.

The proposed methodology can be further extended to the detection of multiphoton quantum non-Gaussianity [35] and also to the loss-resistant form of a hierarchy of quantum non-Gaussian states [25], allowing the identification of increasing quantum non-Gaussian aspects when the stellar

hierarchy [36,37] or even more general approaches [25] remain challenging in the experiment.

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DATA AVAILABILITY

The codes and experimental data are available on [38].

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- [1] M. Walschaers, Non-Gaussian quantum states and where to find them, *PRX Quantum* **2**, 030204 (2021).
 - [2] L. Lachman and R. Filip, Quantum non-Gaussianity of light and atoms, *Prog. Quantum Electron.* **83**, 100395 (2022).
 - [3] A. A. Rakhubovsky, D. W. Moore, and R. Filip, Quantum non-Gaussian optomechanics and electromechanics, *Prog. Quantum Electron.* **93**, 100495 (2024).
 - [4] F. Wolf, C. Shi, J. C. Heip, M. Gessner, L. Pezzè, A. Smerzi, M. Schulte, K. Hammerer, and P. O. Schmidt, Motional Fock states for quantum-enhanced amplitude and phase measurements with trapped ions, *Nat. Commun.* **10**, 2929 (2019).
 - [5] K. C. McCormick, J. Keller, S. C. Burd, D. J. Wineland, A. C. Wilson, and D. Leibfried, Quantum-enhanced sensing of a single-ion mechanical oscillator, *Nature (London)* **572**, 86 (2019).
 - [6] N. Ofek, A. Petrenko, R. Heeres, P. Reinhold, Z. Leghtas, B. Vlastakis, Y. Liu, L. Frunzio, S. M. Girvin, L. Jiang, M. Mirrahimi, M. H. Devoret, and R. J. Schoelkopf, Extending the lifetime of a quantum bit with error correction in superconducting circuits, *Nature (London)* **536**, 441 (2016).
 - [7] Z. Ni, S. Li, X. Deng, Y. Cai, L. Zhang, W. Wang, Z.-B. Yang, H. Yu, F. Yan, S. Liu, C.-L. Zou, L. Sun, S.-B. Zheng, Y. Xu and D. Yu, Beating the break-even point with a discrete-variable-encoded logical qubit, *Nature (London)* **616**, 56 (2023).
 - [8] V. V. Sivak, A. Eickbusch, B. Royer, S. Singh, I. Tsioutsios, S. Ganjam, A. Miano, B. L. Brock, A. Z. Ding, L. Frunzio, S. M. Girvin, R. J. Schoelkopf, and M. H. Devoret, Real-time quantum error correction beyond break-even, *Nature (London)* **616**, 50 (2023).
 - [9] D. B. Higinbottom, L. Slodička, G. Araneda, L. Lachman, R. Filip, M. Hennrich, and R. Blatt, Pure single photons from a trapped atom source, *New J. Phys.* **18**, 093038 (2016).
 - [10] S. Daiss, S. Welte, B. Hacker, L. Li, and G. Rempe, Single-photon distillation via a photonic parity measurement using cavity QED, *Phys. Rev. Lett.* **122**, 133603 (2019).
 - [11] B. Hacker, S. Welte, S. Daiss, A. Shaukat, S. Ritter, L. Li, and G. Rempe, Deterministic creation of entangled atom-light Schrödinger-cat states, *Nat. Photon.* **13**, 110 (2019).
 - [12] V. Magro, J. Vaneecloo, S. Garcia, and A. Ourjoumtsev, Deterministic freely propagating photonic qubits with negative Wigner functions, *Nat. Photon.* **17**, 688 (2023).
 - [13] A. Predojević, M. Ježek, T. Huber, H. Jayakumar, T. Kauten, G. S. Solomon, R. Filip, and G. Weihs, Efficiency vs multi-photon contribution test for quantum dots, *Opt. Express* **22**, 4789 (2014).
 - [14] I. Straka, A. Predojević, T. Huber, L. Lachman, L. Butschek, M. Miková, M. Mičuda, G. S. Solomon, G. Weihs, M. Ježek, and R. Filip, Quantum non-Gaussian depth of single-photon states, *Phys. Rev. Lett.* **113**, 223603 (2014).
 - [15] A. Ourjoumtsev, R. Tualle-Brouri, J. Laurat, and P. Grangier, Generating optical Schrödinger kittens for quantum information processing, *Science* **312**, 83 (2006).
 - [16] S. Neergaard-Nielsen, B. Melholt Nielsen, C. Hettich, K. Mølmer, and E. S. Polzik, Generation of a superposition of odd photon number states for quantum information networks, *Phys. Rev. Lett.* **97**, 083604 (2006).
 - [17] C. T. Lee, Measure of the nonclassicality of nonclassical states, *Phys. Rev. A* **44**, R2775(R) (1991).
 - [18] C. T. Lee, Moments of P functions and nonclassical depths of quantum states, *Phys. Rev. A* **45**, 6586 (1992).
 - [19] R. Filip and L. Mišta Jr., Detecting quantum states with a positive Wigner function beyond mixtures of Gaussian states, *Phys. Rev. Lett.* **106**, 200401 (2011).
 - [20] M. Ježek, I. Straka, M. Mičuda, M. Dušek, J. Fiurášek, and R. Filip, Experimental test of the quantum non-Gaussian character of a heralded single-photon state, *Phys. Rev. Lett.* **107**, 213602 (2011).
 - [21] M. G. Genoni, M. L. Palma, T. Tufarelli, S. Olivares, M. S. Kim, and M. G. A. Paris, Detecting quantum non-Gaussianity via the Wigner function, *Phys. Rev. A* **87**, 062104 (2013).
 - [22] C. Hughes, M. G. Genoni, T. Tufarelli, M. G. A. Paris, and M. S. Kim, Quantum non-Gaussianity witnesses in phase space, *Phys. Rev. A* **90**, 013810 (2014).
 - [23] J. Park, Y. Lu, J. Lee, Y. Shen, K. Zhang, S. Zhang, M. S. Zubairy, K. Kim, and H. Nha, Revealing nonclassicality beyond Gaussian states via a single marginal distribution, *Proc. Natl. Acad. Sci. USA* **114**, 891 (2017).
 - [24] L. Happ, M. A. Efremov, H. Nha, and W. P. Schleich, Sufficient condition for a quantum state to be genuinely quantum non-Gaussian, *New J. Phys.* **20**, 023046 (2018).
 - [25] L. Lachman, I. Straka, J. Hloušek, M. Ježek, and R. Filip, Faithful hierarchy of genuine n -photon quantum non-Gaussian light, *Phys. Rev. Lett.* **123**, 043601 (2019).
 - [26] C. Baune, A. Schönbeck, A. Samblowski, J. Fiurášek, and R. Schnabel, Quantum non-Gaussianity of frequency up-converted single photons, *Opt. Express* **22**, 22808 (2014).

- [27] J. Mika, L. Lachman, T. Lamich, R. Filip, and L. Slodička, Losses resistant verification of quantum non-Gaussian photon statistics, *npj Quantum Inf.* **8**, 123 (2022)
- [28] L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics* (Cambridge University Press, Cambridge, 1995).
- [29] L. Lachman and R. Filip, Quantum non-Gaussian photon coincidences, *Phys. Rev. Lett.* **126**, 213604 (2021).
- [30] See Supplemental Material at <http://link.aps.org/supplemental/10.1103/nbkg-8jz9> for additional details on the derivation of the non-Gaussianity criteria, the quantum dot emission process, and the loss emulation technique.
- [31] R. Pollmann, F. Roeder, V. Quiring, R. Ricken, C. Eigner, B. Brecht, and C. Silberhorn, Integrated, bright broadband, two-colour parametric down-conversion source, *Opt. Express* **32**, 23945 (2024)
- [32] L. Ginés, M. Moczał a-Dusanowska, D. Dlaka, R. Hošák, J. R. Gonzales-Ureta, J. Lee, M. Ježek, E. Harbord, R. Oulton, S. Höfling, A. B. Young, C. Schneider, and A. Predojević, High extraction efficiency source of photon pairs based on a quantum dot embedded in a broadband micropillar cavity, *Phys. Rev. Lett.* **129**, 033601 (2022).
- [33] H. Jayakumar, A. Predojević, T. Huber, T. Kauten, G. S. Solomon, and G. Weihs, Deterministic photon pairs and coherent optical control of a single quantum dot, *Phys. Rev. Lett.* **110**, 135505 (2013).
- [34] T. Huber, A. Predojević, G. S. Solomon, and G. Weihs, Effects of photo-neutralization on the emission properties of quantum dots, *Opt. Express* **24**, 21794 (2016).
- [35] I. Straka, L. Lachman, J. Hloušek, M. Miková, M. Mičuda, M. Ježek, and R. Filip, Quantum non-Gaussian multiphoton light, *npj Quantum Inf.* **4**, 4 (2018).
- [36] U. Chabaud, D. Markham, and F. Grosshans, Stellar representation of non-Gaussian quantum states, *Phys. Rev. Lett.* **124**, 063605 (2020).
- [37] U. Chabaud, G. Roeland, M. Walschaers, F. C. Grosshans, V. Parigi, D. Markham, and N. Treps, Certification of non-Gaussian states with operational measurements, *PRX Quantum* **2**, 020333 (2021).
- [38] R. Checchinato, J.-H. Littmann, L. Lachman, J. Lee, S. Hofling, C. Schneider, R. Filip, and A. Predojevic, Data for “Losses resistant verification of quantum non-Gaussian photon statistics” (version v1), Zenodo (2025), <https://zenodo.org/records/17292685>.