Noisy squeezing in continuous-variable quantum communication

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We address the role of anti-squeezing excess noise in continuous-variable (CV) quantum communication using Gaussian quadrature modulation and homodyne detection, motivated by advantages offered by the use of squeezing in continuous-variable quantum key distribution (QKD) [1]. Anti-squeezing noise unavoidably appears in the process of generation of squeezed states due to intrinsic losses in an optical parametric oscillator, which reduce squeezing and lead to higher anti-squeezing variance than that of a pure state. We study the role of such phase-sensitive anti-squeezing noise in CV QKD, assuming trusted and untrusted preparation scenarios.

In the case of trusted anti-squeezing noise being a part of the trusted preparation, which is the typical assumption in CV QKD, and a channel with fixed transmittance (typical for fiber links), the noise is even slightly helpful for the trusted parties and allows analytical derivation of the Holevo bound, upper bounding the information leakage, in the limit of infinitely strong anti-squeezing noise. If the channels are fluctuating, however (which is typical for the atmospheric channels where turbulence effects lead to transmittance fluctuations also referred to as fading), presence of even trusted anti-squeezing noise leads to appearance of untrusted channel noise, concerned with fading [2], and limits applicability of squeezed-state CV QKD, requiring squeezed states with high purity or even reduced squeezing [3].

In the stricter assumption of untrusted anti-squeezing (meaning that an eavesdropper controls the squeezer), the presence of such noise significantly limits the achievable key rates, secure distances and robustness to channel noise, the latter shown in Fig. 1. Therefore, for a squeezing source to be untrusted, high level of purity of squeezed states is required.

We also consider finite-size effects concerned with the estimation of parameters in CV QKD [4] and show that the parameter estimation is undermined by the presence of anti-squeezing noise even if it is trusted, hence limiting the efficiency of the protocols.

Our results set the bounds on anti-squeezing noise for practical squeezed-state CV QKD and represent a challenging task of high squeezed-state purity requirement for practical implementation of the protocols.

References

[1] R García-Patron, N.J. Cerf, Phys. Rev. Lett., 102 (2009) 130501; L.S. Madsen, V.C. Usenko, M. Lassen, R. Filip, U.L. Andersen, Nature Communications, 3 (2012) 1083; V.C. Usenko, R Filip, New Journal of Physics, 13 (2011) 113007

[2] V.C. Usenko, B. Heim, C. Peuntinger, C. Wittmann, C. Marquardt, G. Leuchs, R. Filip, New J. Phys. 14 (2012) 093048Authors, Journal, Issue (Year) page

[3] I. Derkach, V.C. Usenko, R. Filip, New J. Phys. 22 (2020) 053006

[4] L. Ruppert, V.C. Usenko, R. Filip, Phys. Rev. A 90 (2014) 062310

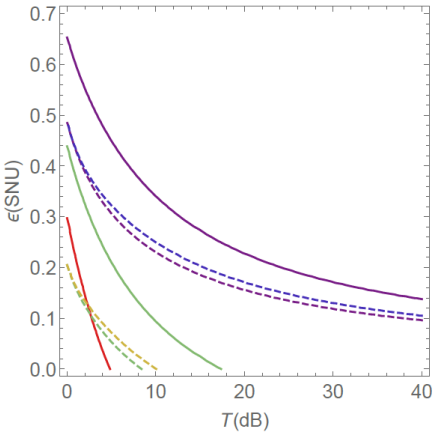

Figure 1: Maximum tolerable channel noise for strong (-10 dB, solid) and weak (-3 dB, dashed) pure squeezing (purple) and with untrusted anti-squeezing noise of 0.5 shot-noise units (SNU, green) and 1 SNU (red). Blue line: 10 SNU trusted anti-squeezing noise.