Squeezing beats turbulence in free-space continuous-variable quantum cryptography

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Continuous-variable quantum key distribution (CV QKD)

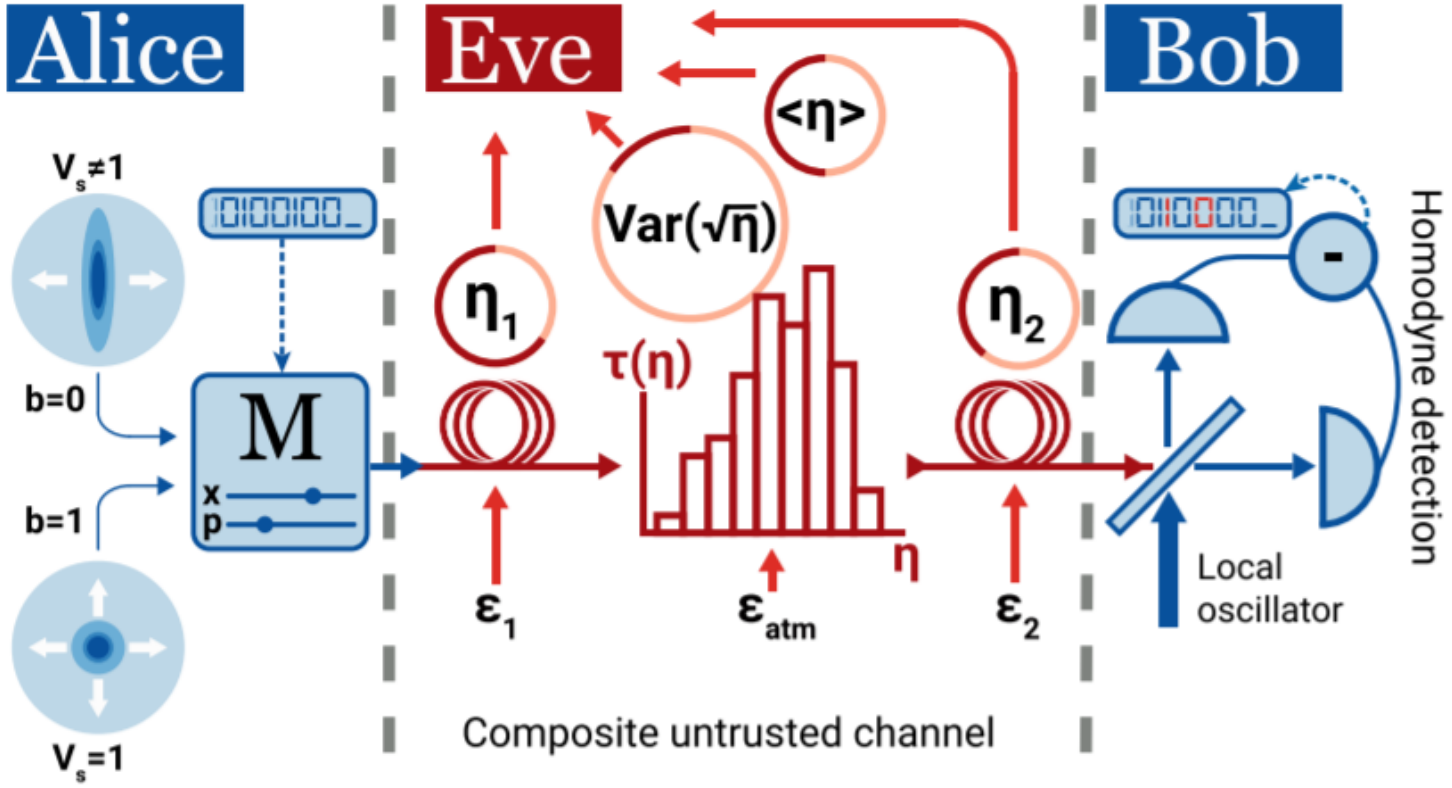
- Feasible and efficient alternative to discrete-variable QKD
- Gaussian quadrature modulation + homodyne detection
- Coherent or squeezed signal states

Applicability over free-space atmospheric channels

- Atmospheric turbulence causes fluctuations of transmittance (mainly due to beam wander)
- Transmittance fluctuations (a.k.a. fading) result in quadrature excess noise
- Fading limits rate/secure distance of CV QKD in free-space channels [NJP 14 093048 2012]

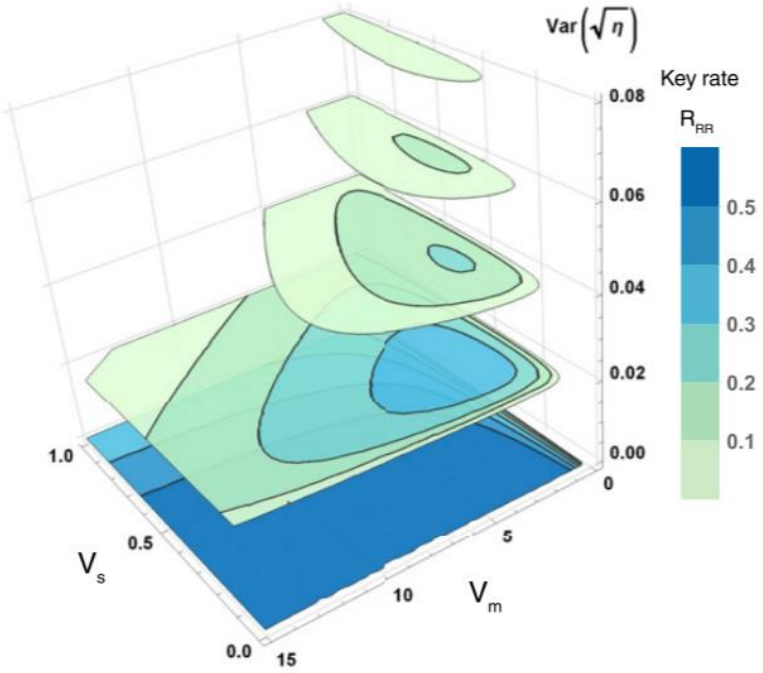
Role of squeezing in continuous-variable QKD

- Squeezing can make the protocols more robust to losses/noise [Nat. Comm. 3 1083 2012, NJP 13 113007 2011]
- **Can squeezing be helpful in free-space CV QKD?**

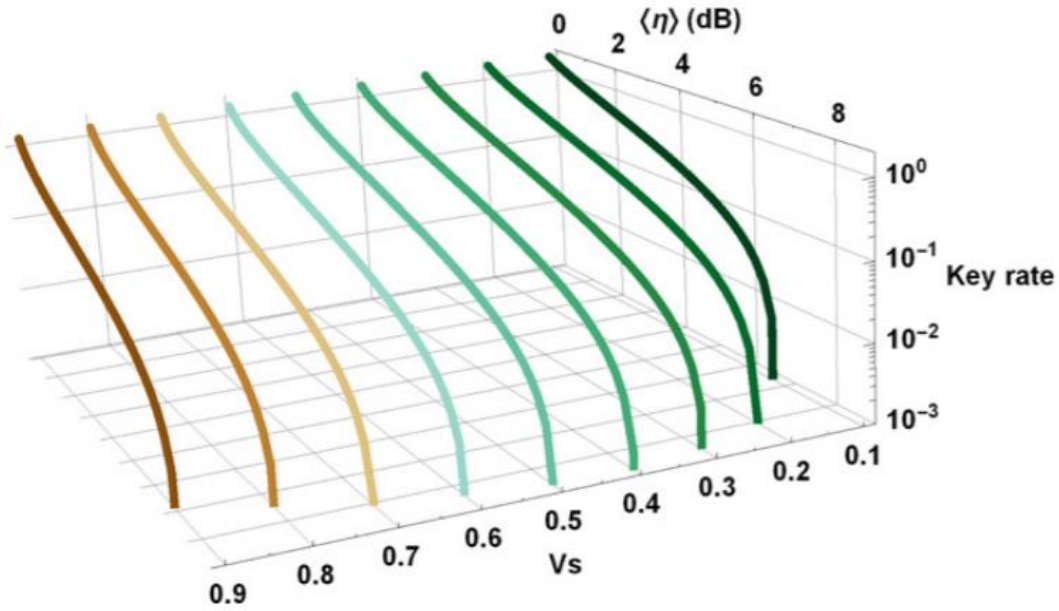


Free-space CV QKD scheme based on squeezed or coherent states, composite untrusted channels (fading+fixed), and homodyne detection.

We study the security of the scheme against Gaussian collective attacks using purification-based security analysis (see e.g. Entropy 18 20 2016)

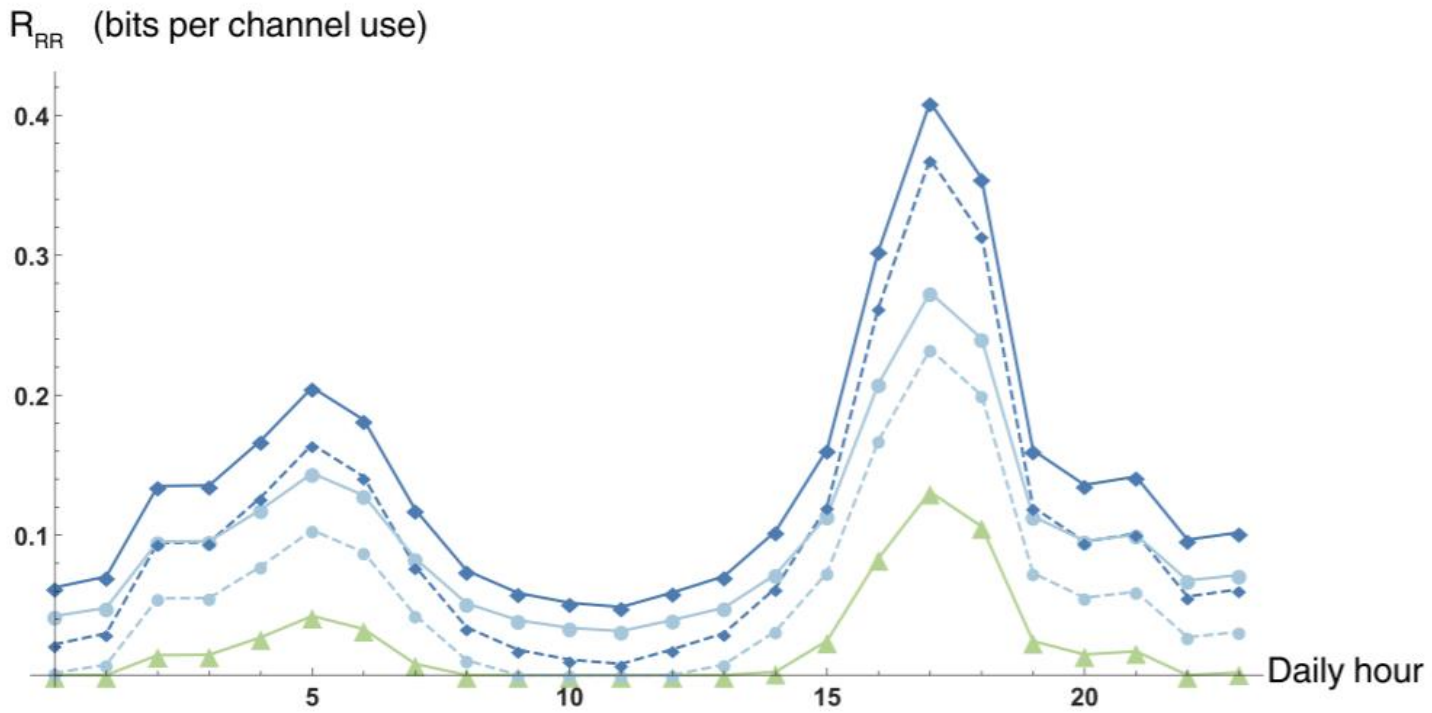


Secure key rate versus signal squeezing V_s, modulation variance V_m, and transmittance variance $Var(\sqrt{\eta})$

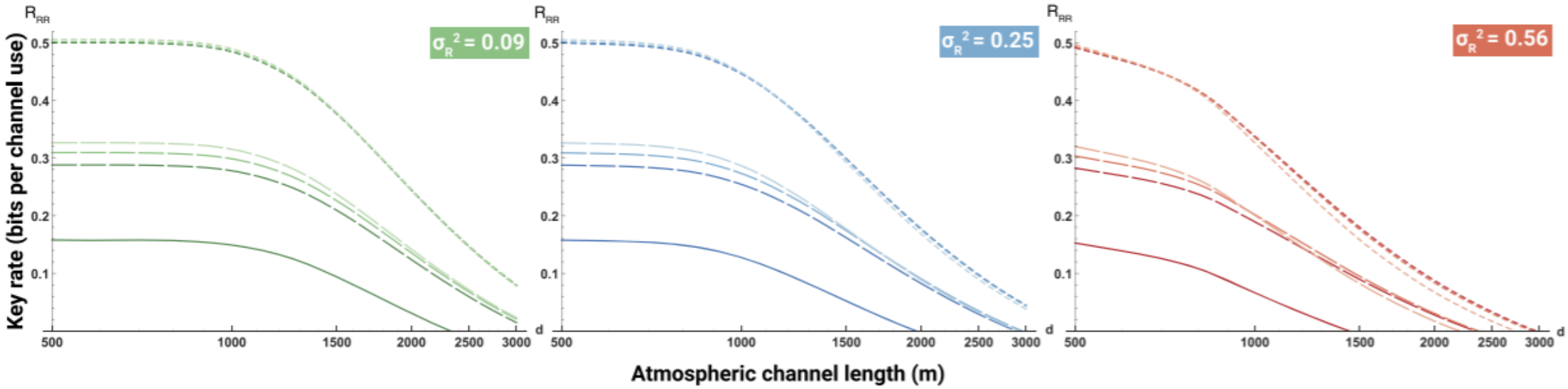


Secure key rate versus mean losses $\langle\eta\rangle$ at different levels of squeezing, modulation variance is optimized

"Squeezing beats turbulence in free-space CV QKD" by I. Derkach, V.C. Usenko, and R. Filip



Key rate simulated for real free-space channel data [Radioengineering 21 455–8 2012] for optimized squeezed-state (blue lines) and coherent-state (green line) protocols in asymptotic (solid lines) and finite-size (dashed lines) regimes.



Key rate versus channel distance at different values of Rytov parameter σ_R^2(which defines the strength of beam wander) for optimized squeezed-state (dashed and dotted lines with squeezing limited to -3 and -10 dB respectively) and coherent-state (solid lines) protocols

Summary

Squeezing can improve robustness of continuous-variable quantum key distribution to channel losses and noise in conditions of fluctuating channels, but amount of squeezing should be optimized.

Results are confirmed for the real free-space channels.

Details of models and calculations can be found in I. Derkach et al, New J. Phys. 22 053006 (2020).