

Overcoming the atmospheric turbulence effects in free-space continuous-variable quantum key distribution

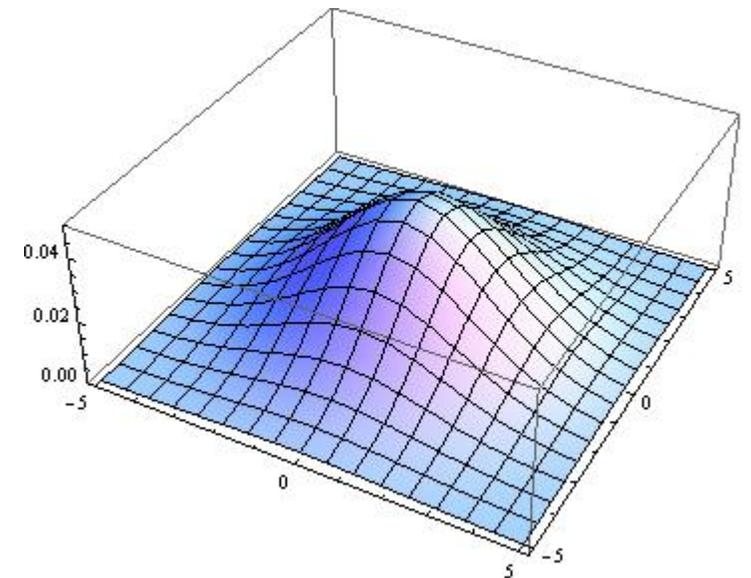
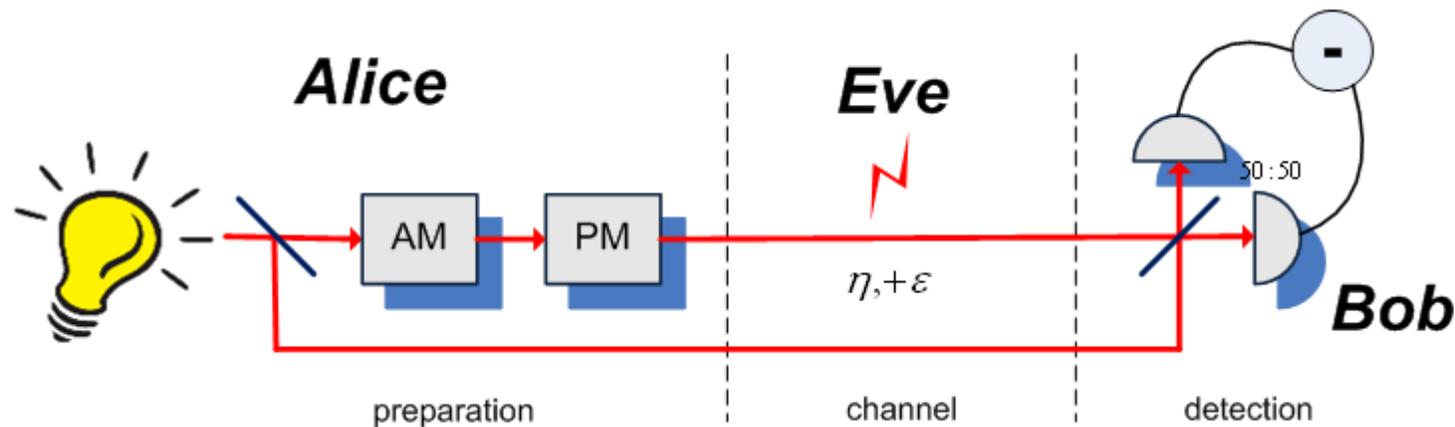
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Continuous-variable quantum key distribution (CV QKD)

- Coherent / squeezed light, homodyne detection
- Amplitude / phase quadrature modulation (Gaussian distributions)

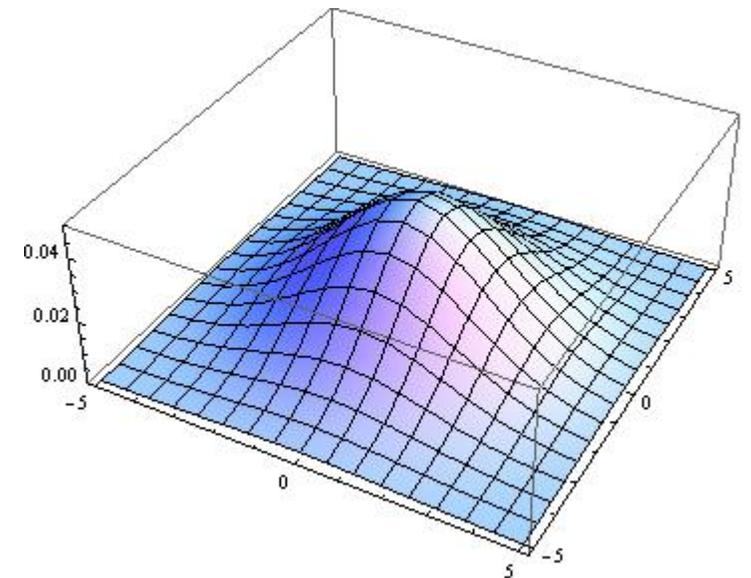
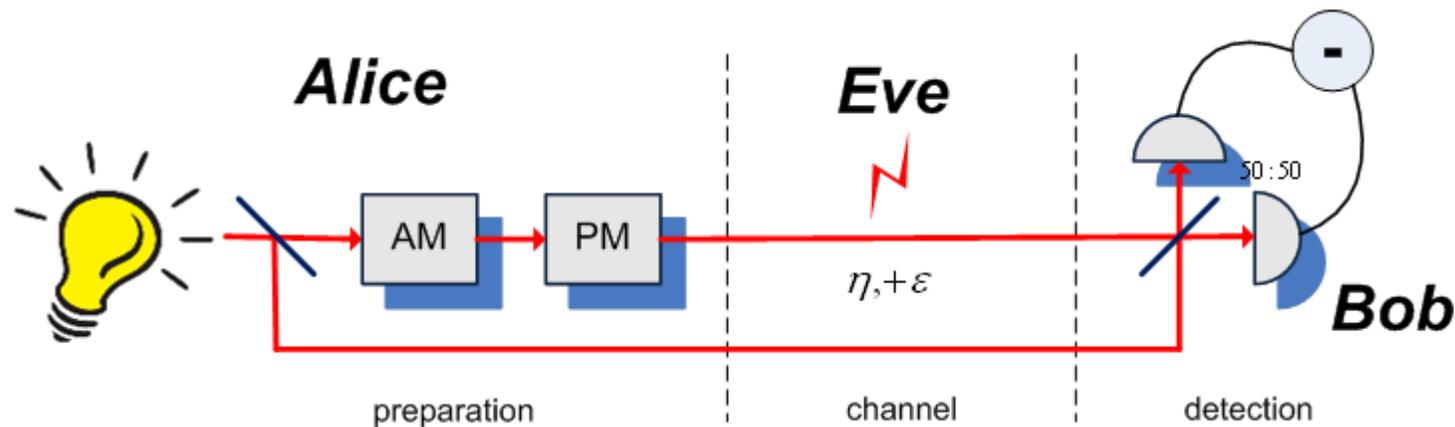


[E. Diamanti, A. Leverrier, Entropy **17**, 6072 (2015)]

[VU, R. Filip, Entropy **18**, 20 (2016)]

Continuous-variable quantum key distribution (CV QKD)

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80 km [Nat. Photonics 7, 378–381 (2013)]
100 km [Sci. Rep. 6, 19201 (2016)] in fiber

CV QKD: towards space application

Main alternative: **Discrete-variable QKD**

[DV-CV QKD comparison: M. Lasota, R. Filip, VU, PRA 95, 062312 (2017)]

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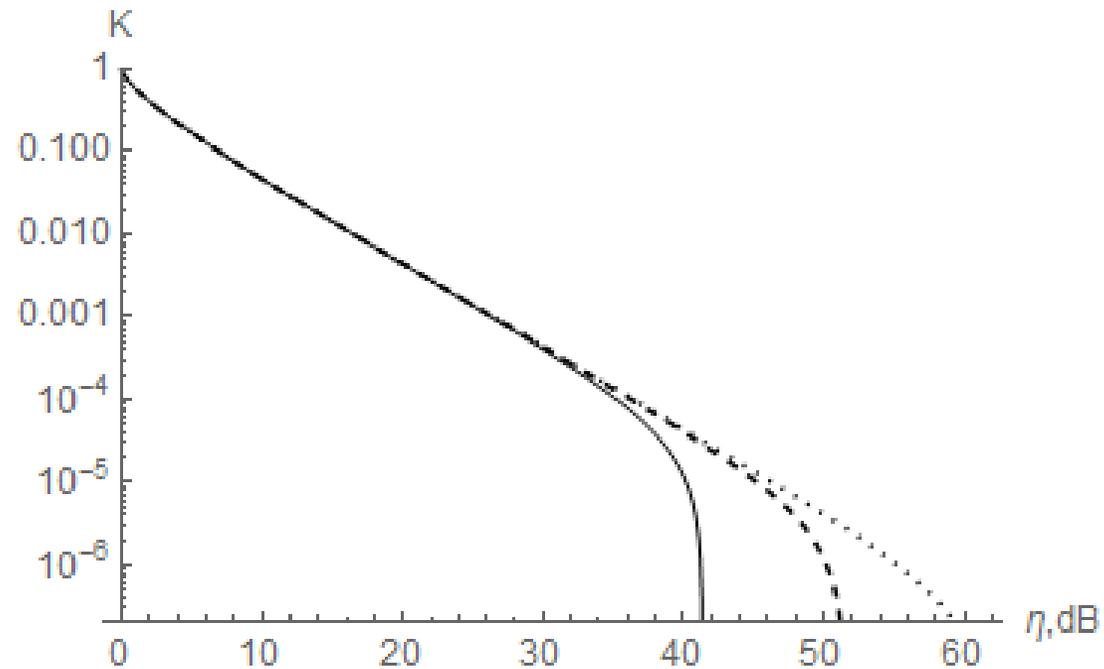
Advantages of CV QKD:

- Homodyne detection filters out background radiation
- Bright pulses can simplify targeting
- Large encoding alphabet - potentially higher key rates
- Homodyne detection is more feasible

CV QKD: towards space application

Issues for CV QKD	Possible solutions
Necessity of phase locking	“Local” local oscillator
Gaussian modulation - demanding post-processing algorithms	Non-Gaussian modulation, development of efficient codes
Finite-size effects and channel estimation	Optimization of estimation, double modulation
Strong loss and channel fluctuations	Technical improvements, use of Gaussian post-selection, channel binning, squeezed states

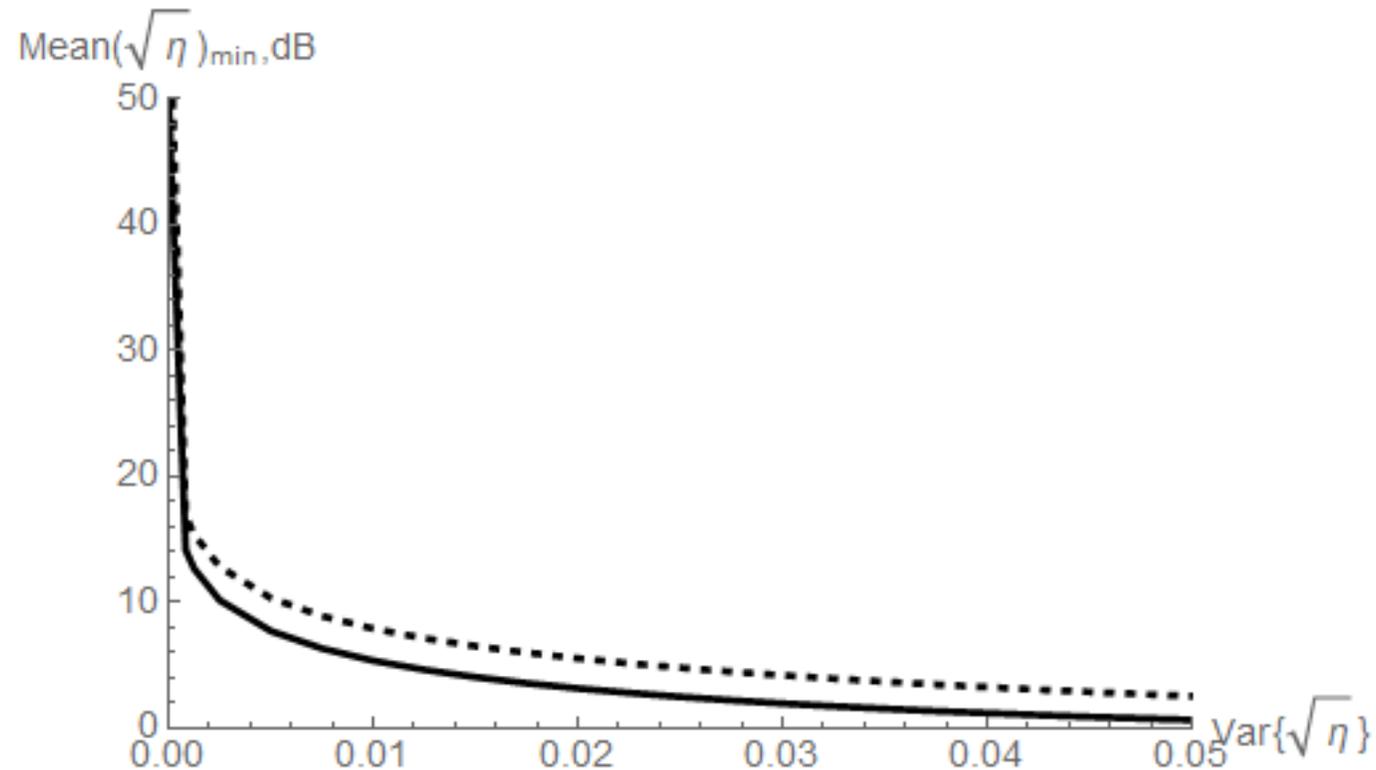
CV QKD: strong loss and finite-size effects



Key rate as a function of channel loss for different data sizes: $10^{\{12,14,16\}}$
(from left to right) for coherent-state protocol

CV QKD: channel fluctuations

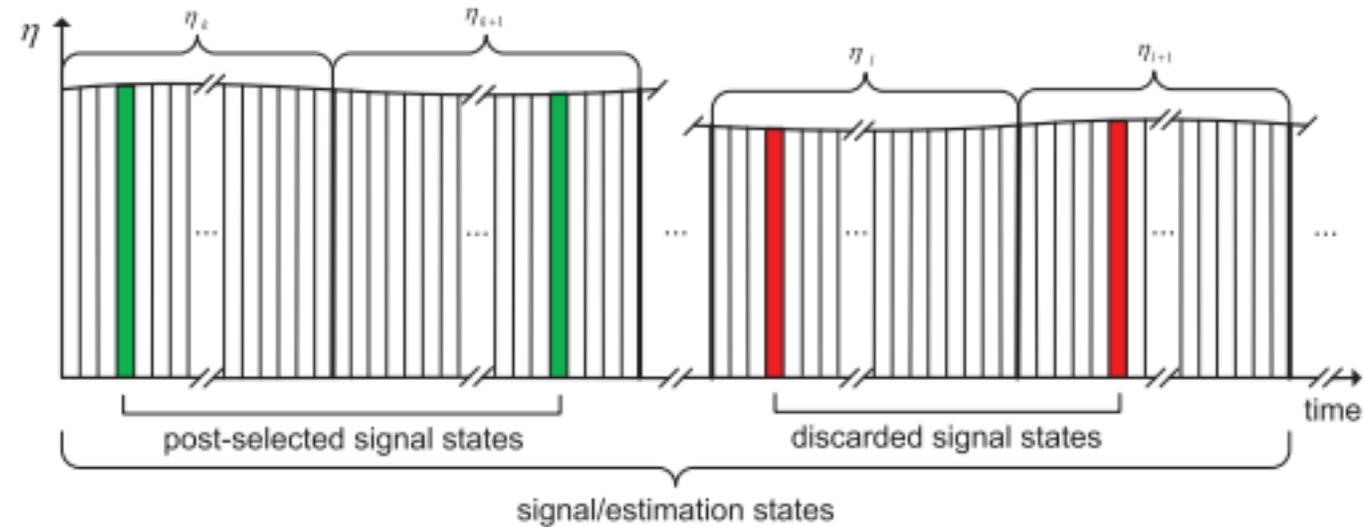
Atmospheric turbulence causes transmittance fluctuations, which can be harmful for CV QKD [VU et al., NJP 14, 093048 (2012)].



Impact of the channel fading on CV QKD with coherent (solid) and squeezed (dashed) states

CV QKD: channel fluctuations

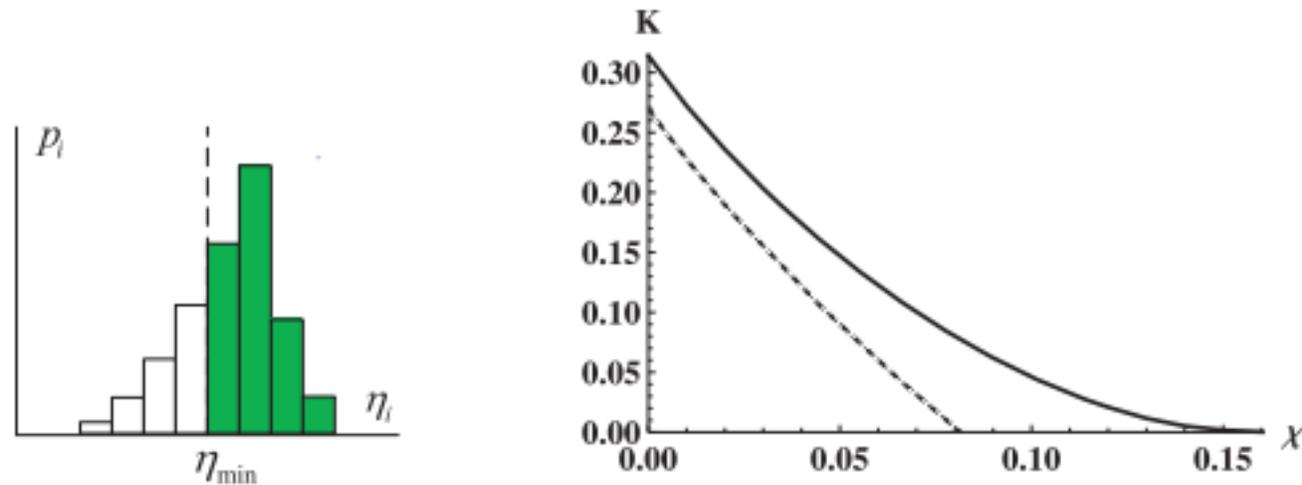
Negative effect of fading in CV QKD be compensated by sub-channel post-selection



Sub-channel post-selection

CV QKD: channel fluctuations

Negative effect of fading in CV QKD be compensated by sub-channel post-selection

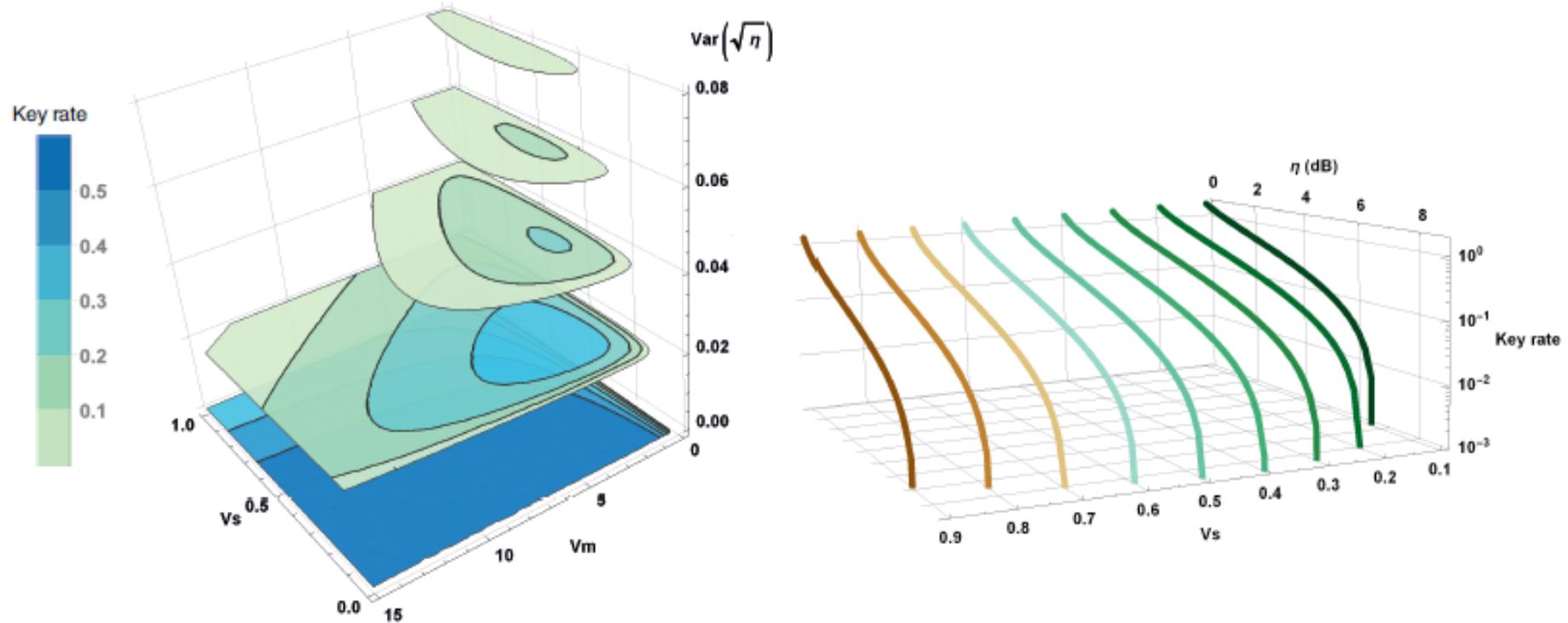


Post-selection of a transmittance interval (left) and optimized key rate versus channel noise (right)

[VU et al., New J. Phys. 14, 093048 (2012)]

CV QKD: channel fluctuations

Negative effect of fading in CV QKD be compensated by signal state squeezing

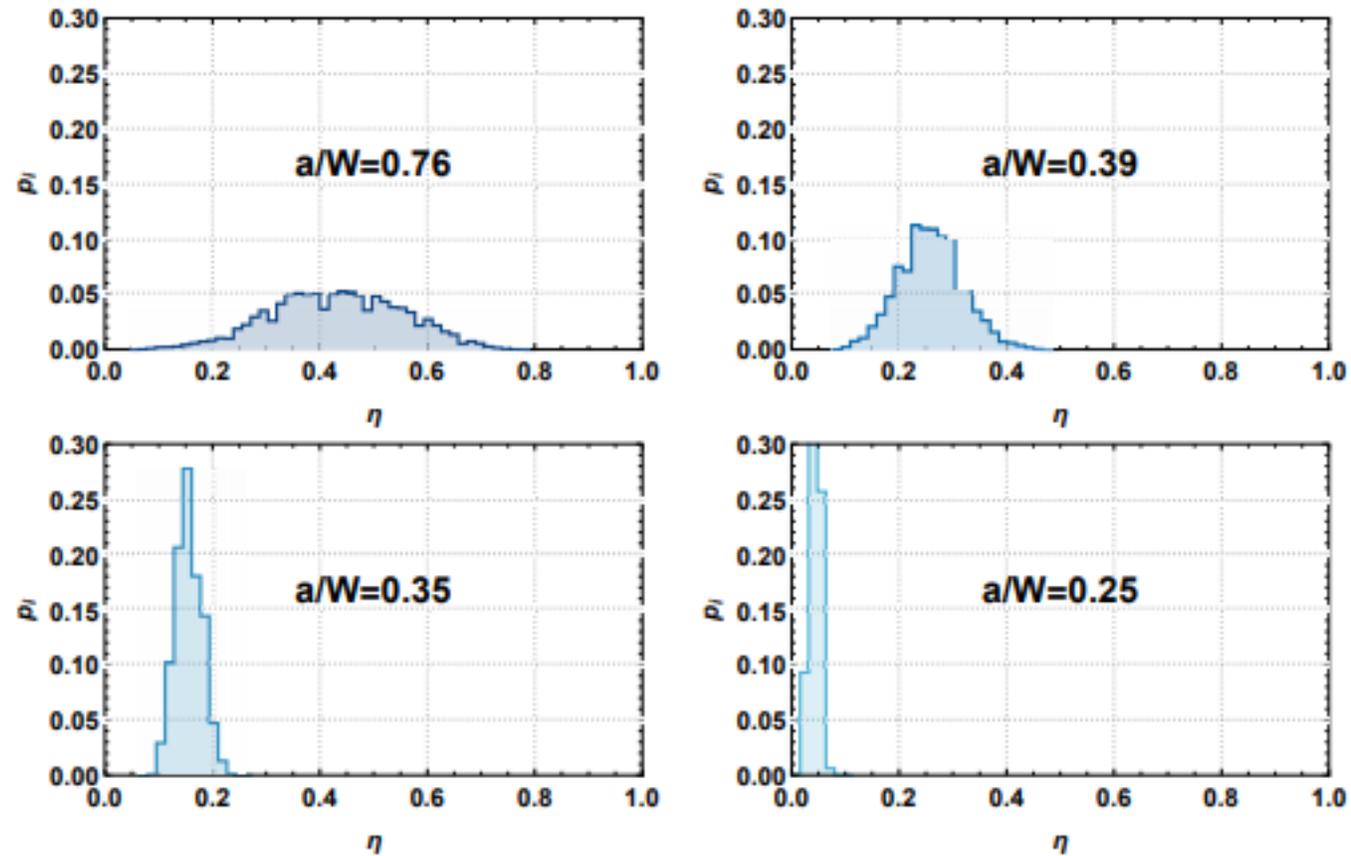


Key rate versus signal squeezing and modulation (left);
versus signal squeezing and average loss (right)

[Derkach, VU, Filip, arXiv:1809.10167]

CV QKD: channel fluctuations

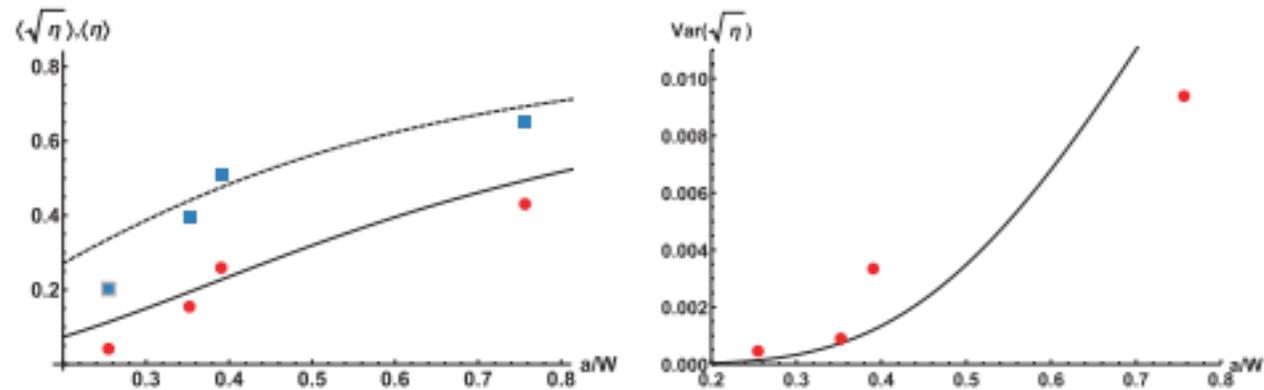
Negative effect of fading in CV QKD be compensated by beam expansion



Transmittance distribution profiles for different aperture-to-beam size ratios

CV QKD: channel fluctuations

Negative effect of fading in CV QKD be compensated by beam expansion



Channel stabilization with beam expansion (at lower a/W)

[VU et al., Opt. Exp. 26, 31106 (2018)]

Outlook

- CV QKD in space is promising
- However it will face several issues
- Channel fading (transmittance fluctuations) is one of the major
- Solutions may include post-selection, use of squeezed states and set-up adaptations
- Channel estimation becomes critical

Thank you for attention!

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