Tools for the Performance Optimization of Single-Photon Quantum Key Distribution

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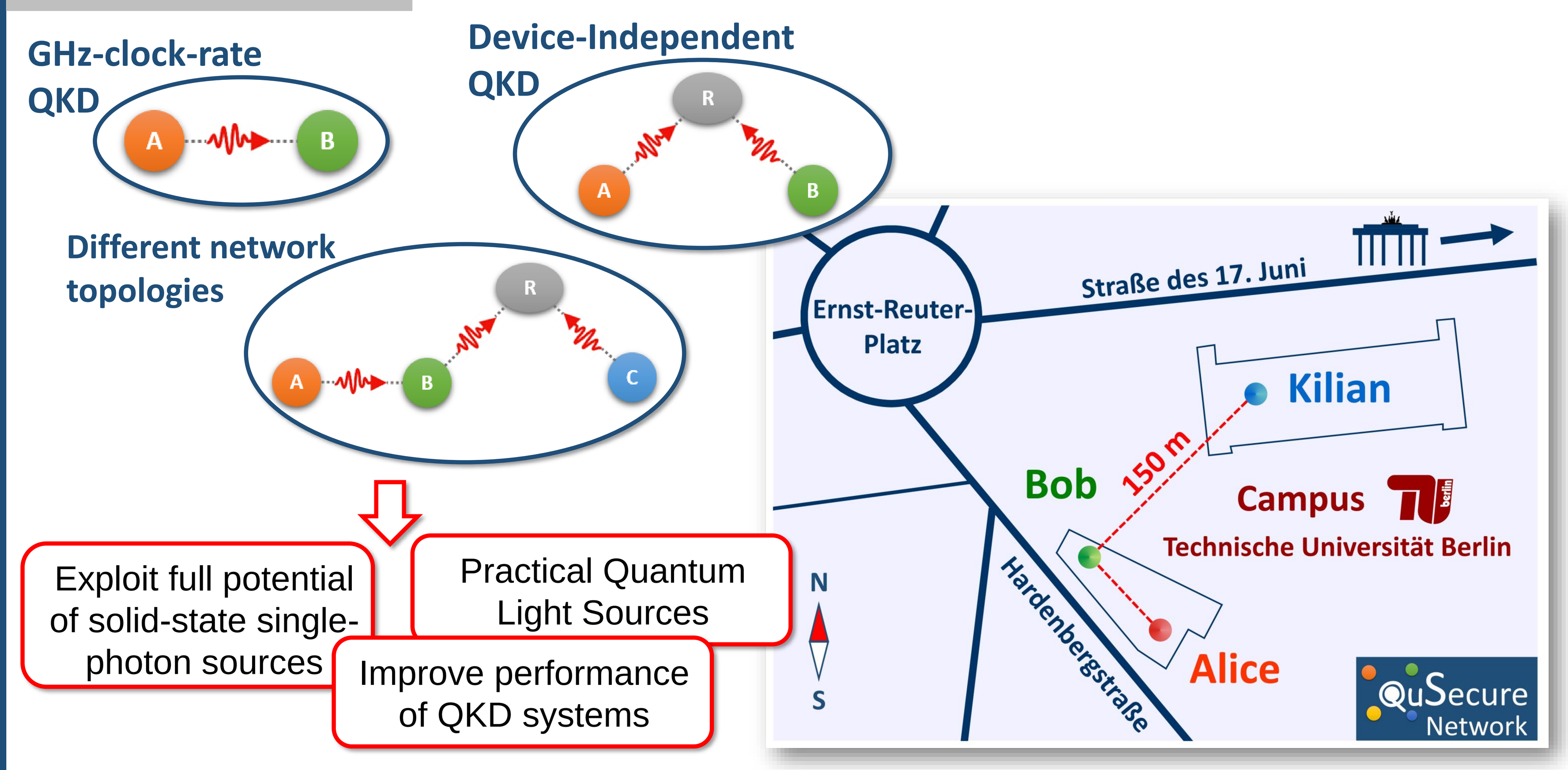
Group Website

Motivation — Quantum-secured Networks

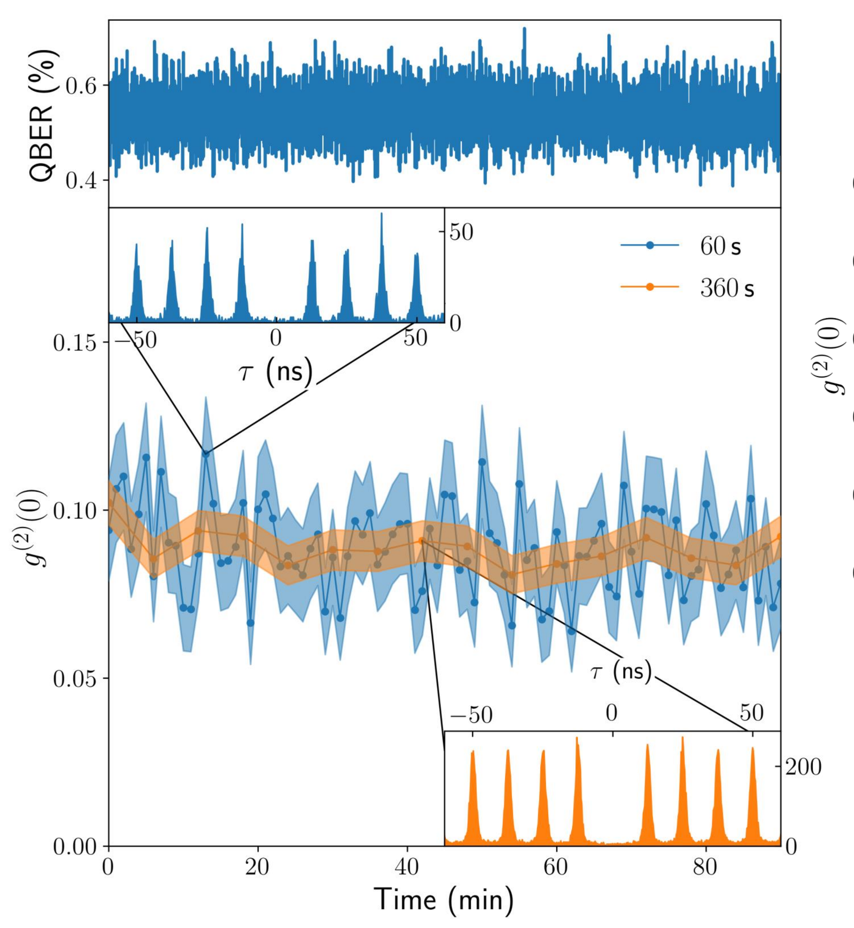


Background — Single-Photon QKD Performance

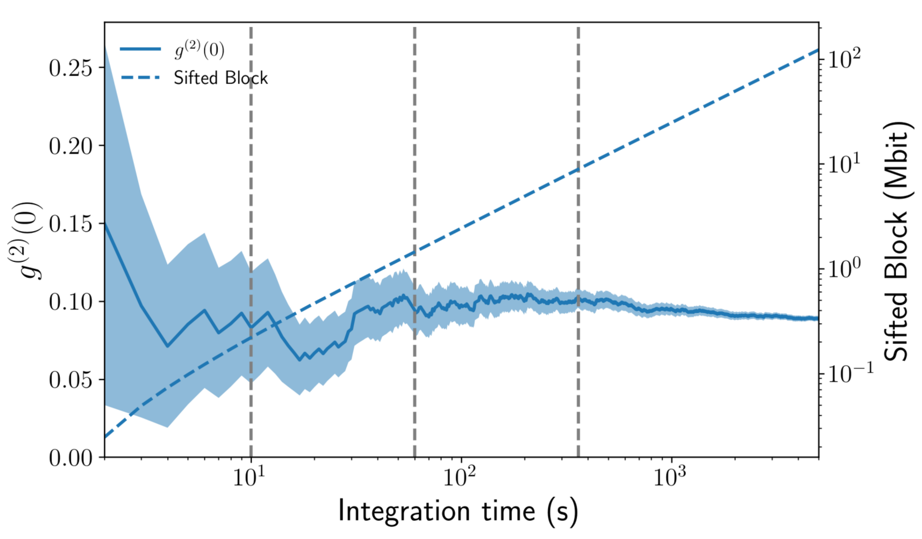
Secret Key Rate (asymptotic) [1]	$S = \frac{p_{\text{click}}}{2}\left(\beta\tau(e) - f(e)h(e)\right)$	Quantum Bit Error Ratio	$\text{QBER} = \text{QBER}_{\text{prep}} + \text{QBER}_{\text{Ch}} + \text{QBER}_{\text{Bob}}$
Sifted Key Rate	$p_{\text{sifted}} = \frac{p_{\text{click}}}{2}$	Multi Photon Probability	$p_{\text{m}} \leq \frac{\mu^2 g^{(2)}(0)}{2}$

[1] E. Waks et al., Phys. Rev. A 66, 042315 (2002)

Real-Time Security Monitoring



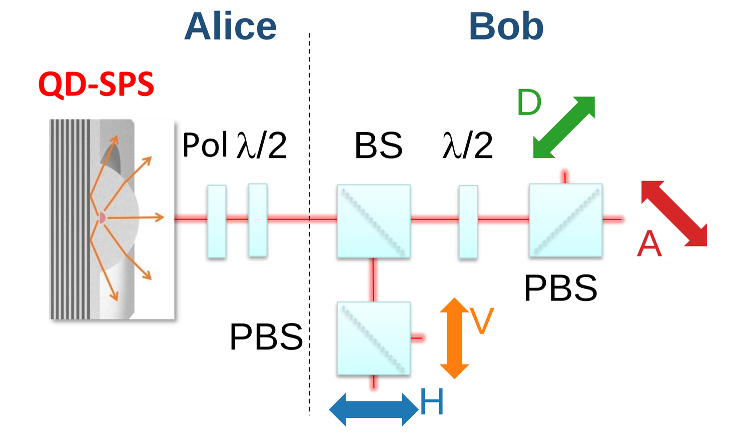
Proof-of-concept Real-Time Photon Statistics



- Real-time: Autocorrelation calculated from timestamps used for actual key distribution
- Extract $g^{(2)}(0)$ for secret key estimation Observation of channel disturbance (e.g. Eve using coherent light source)

QKD Testbed

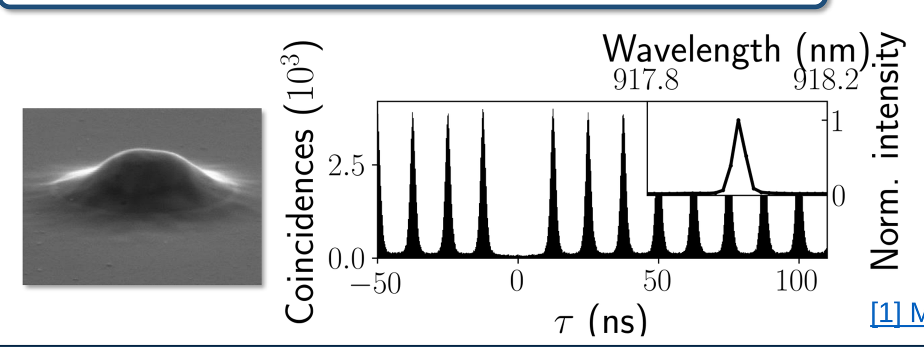
Measurement setup



Receiver Module "Bob"

- Deterministically fabricated singe-photon source [1]
- Static polarization preparation at "Alice"
- 4-state polarization analyzer for BB84 QKD: Standard optical components + Si-APDs + quTag (TDC electronics)

QD-Microlense Single-Photon Source

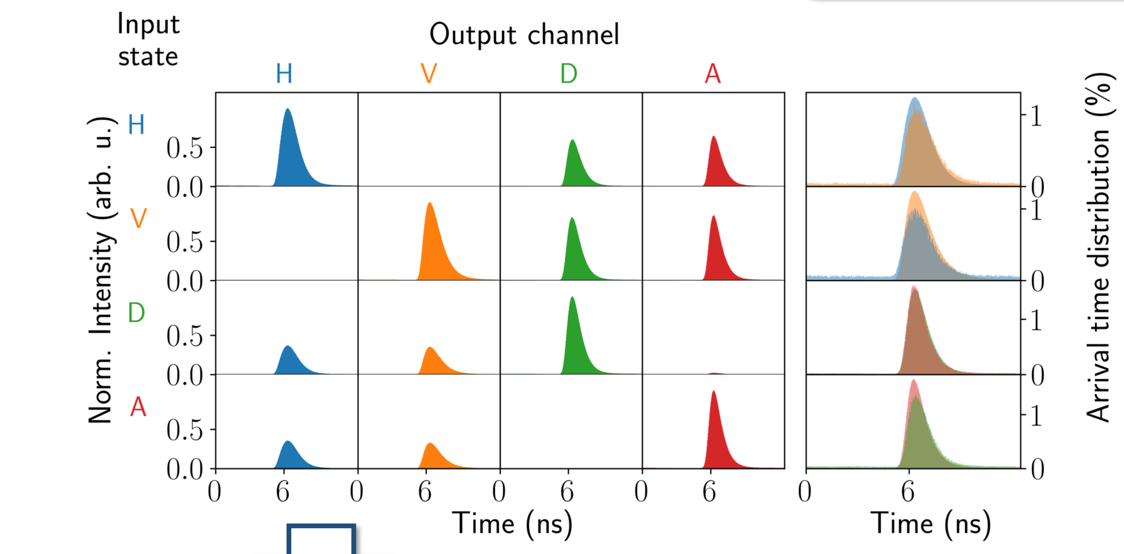


[1] M. Gschrey et al., Nature Commun. 6, 7662 (2015)

Kupko et al., npj Quantum Inf. 6, 29 (2020)

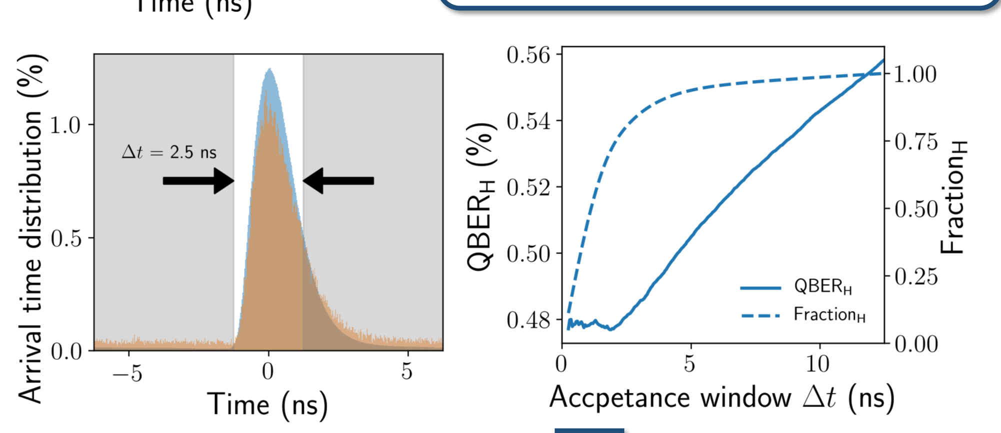
Temporal Filtering

Measured photon arrival distributions

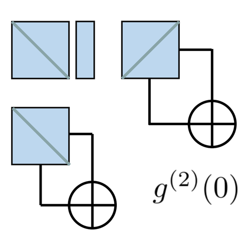


$$\text{QBER}_{\text{Bob}} = \underbrace{\frac{q p_{\text{signal}}}{p_{\text{click}}}}_{\text{optical}} + \underbrace{\frac{p_{\text{dc}}/2}{p_{\text{click}}}}_{\text{Noise}}$$

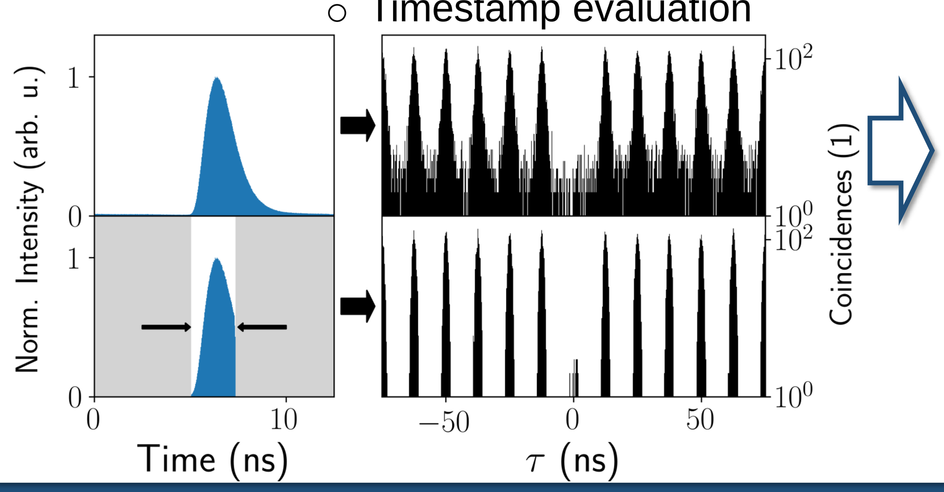
Trade-off between sifted key and QBER



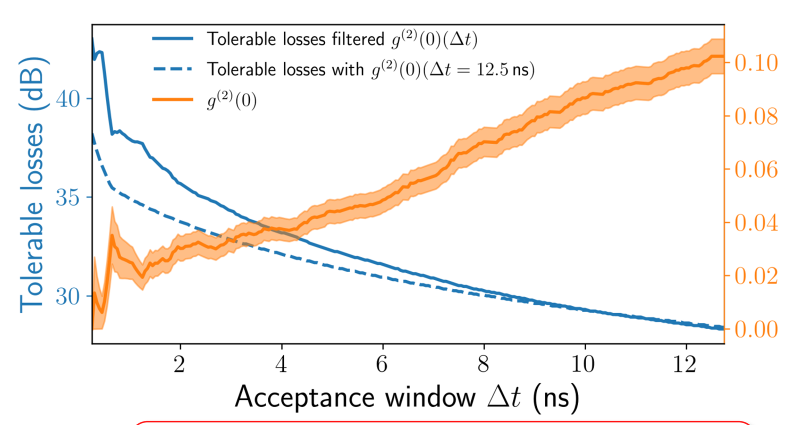
Photon statistics



- $g^{(2)}(0)$ via HBT-measurement
- Channels of each bases combined
- Timestamp evaluation



Secret Key Rate

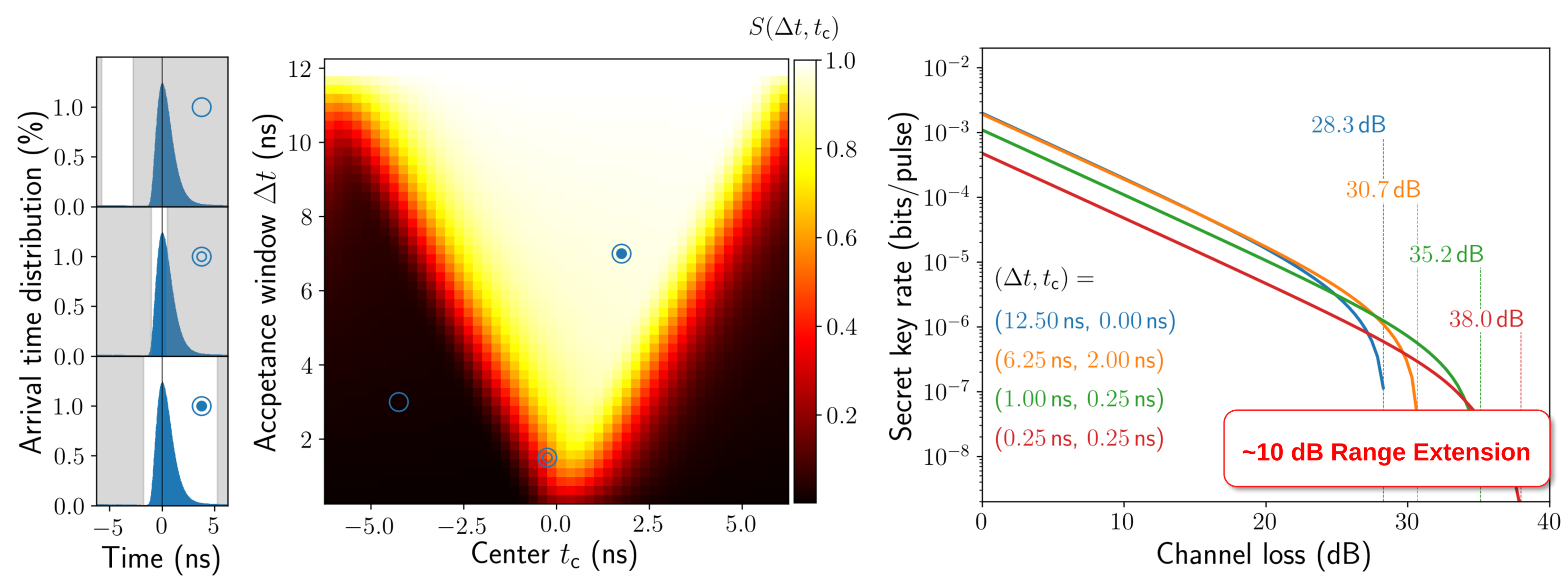


Tight filtering for enhanced transmission distance

2D Temporal Filtering

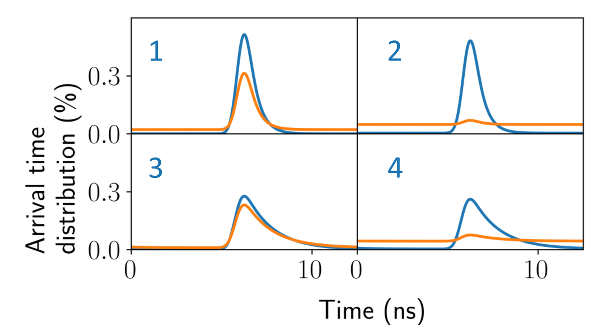
Experimental data

Acceptance window: Width Δt and Center t_c

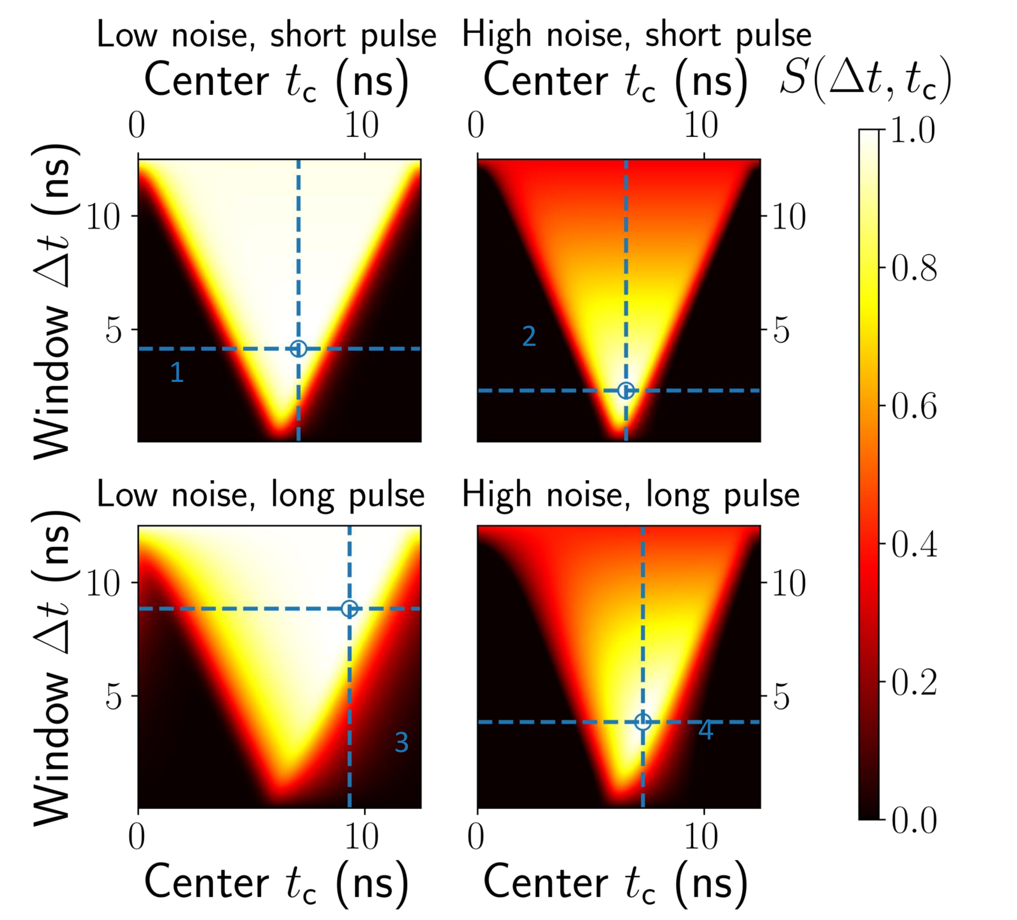


Simulations

- Secret key rates $S(\Delta t, t_c)$
- Assuming $g^{(2)}(0) = 0$
- Short vs. long pulsewidth + High vs. low noise:



Up to 184 % gain in key capacity under noisy conditions



Outlook — BQN – The Berlin Quantum Network

Next Steps

Single Photon Source
- **Telecom O-band CBG SPSs**
- Full implementation of Plug-and-Play SPS
- Source with electrically triggered SPS

QKD Implementation
- Modulation of Signal with fast EOM
- Investigation of sender side Alice
- Full implementation in laboratory and in field

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