2.5 GHz clocked quantum key distribution over 379 421 **km**

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QCrypt2018 | 29 august 2018 | ArXiv 1807.03222

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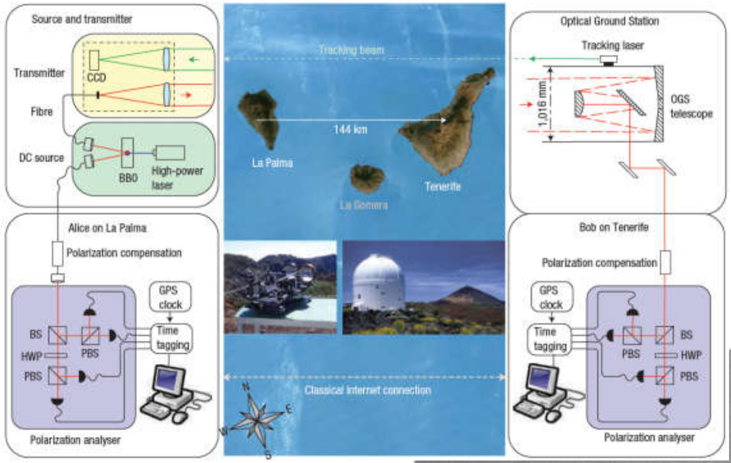
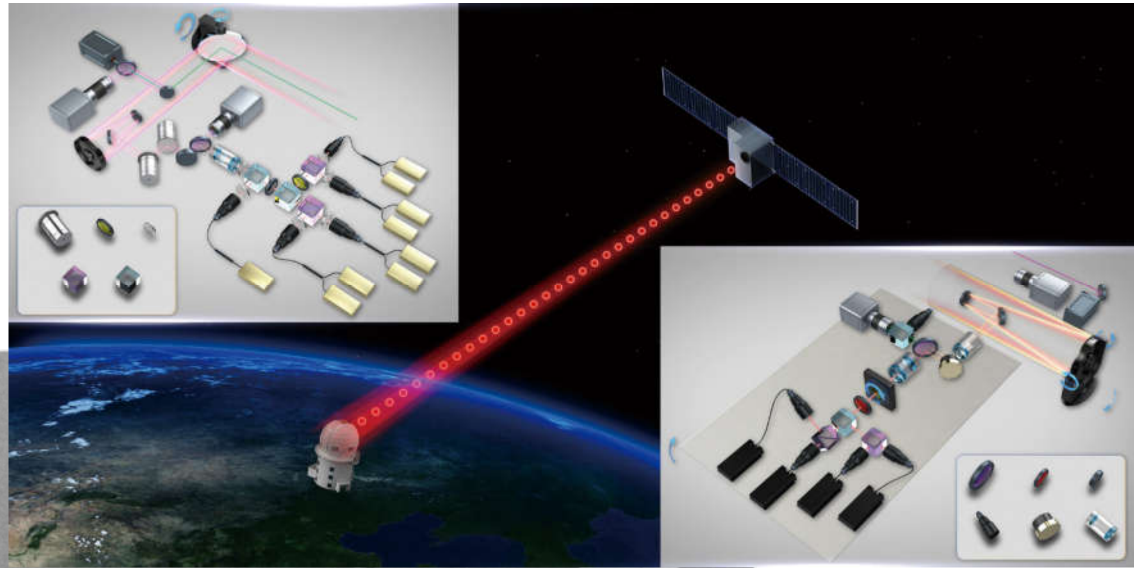
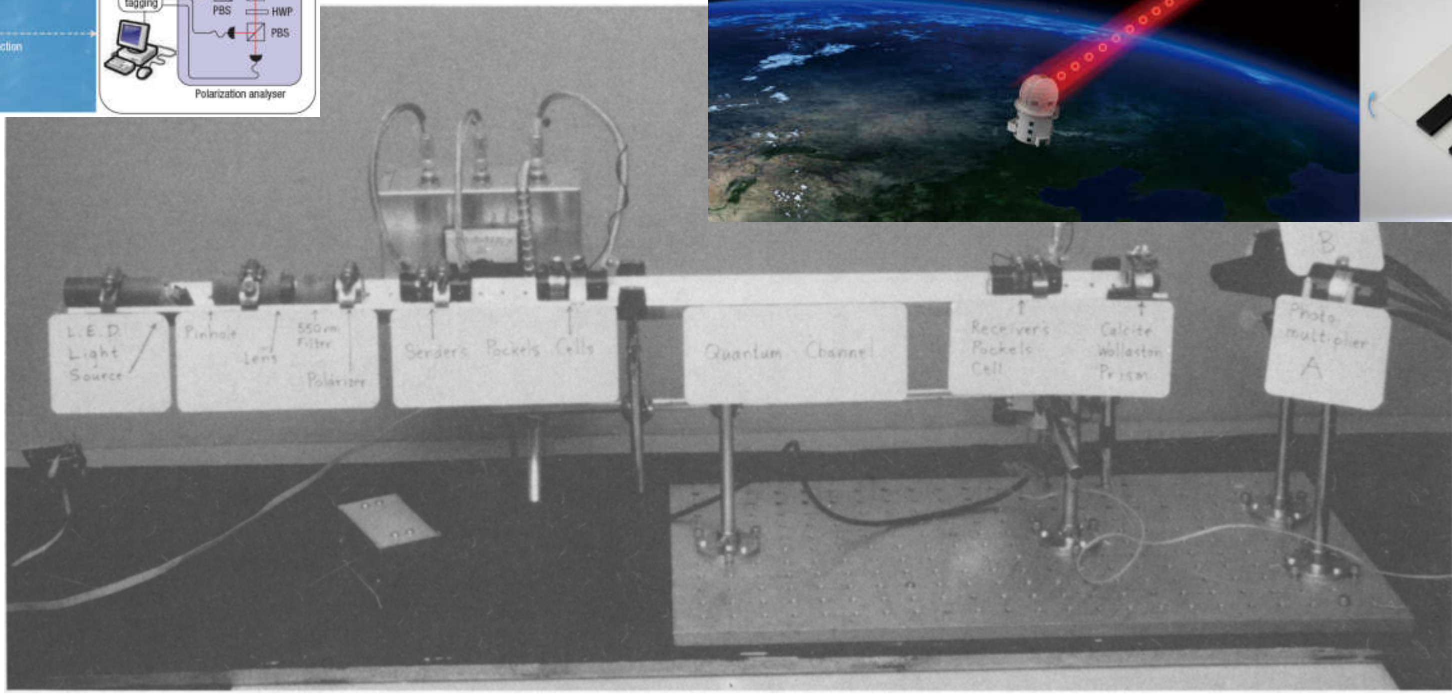


PRL 98,
010504 (2007)



Nature, 549,
43–47 (2017)



Journal of cryptology 5, 3 (1992)

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What does ultimately limit the transmission distance in QKD ?

the acquisition time

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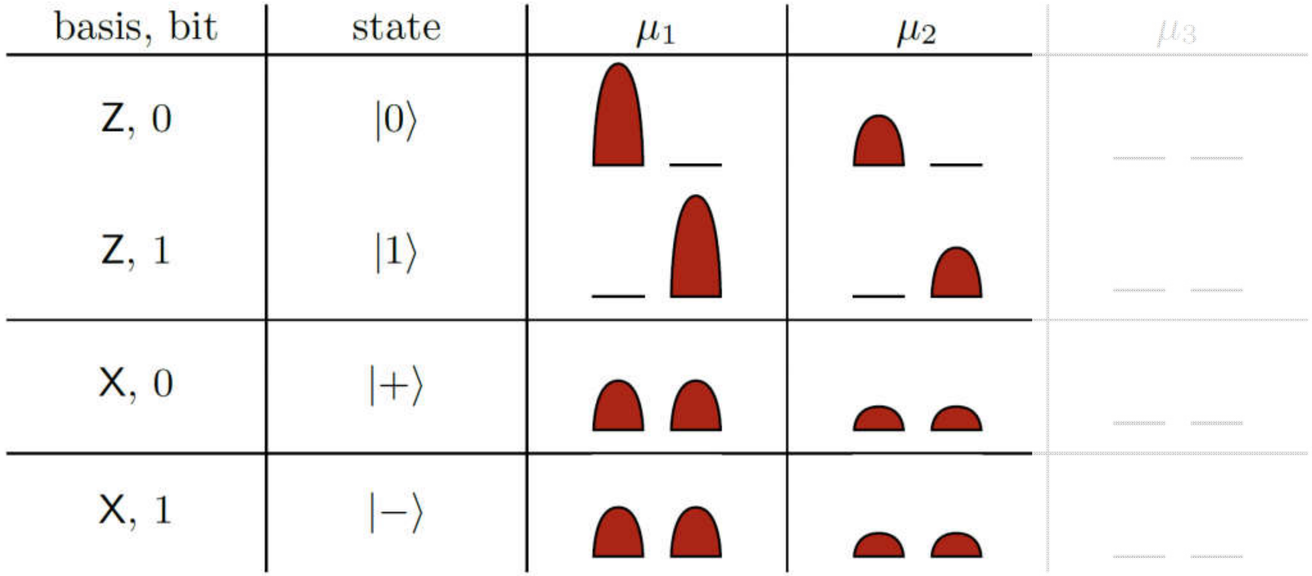
Protocol

- Time-bin encoding
- Decoy-state method



Phys. Rev. A72, 012326 (2005)

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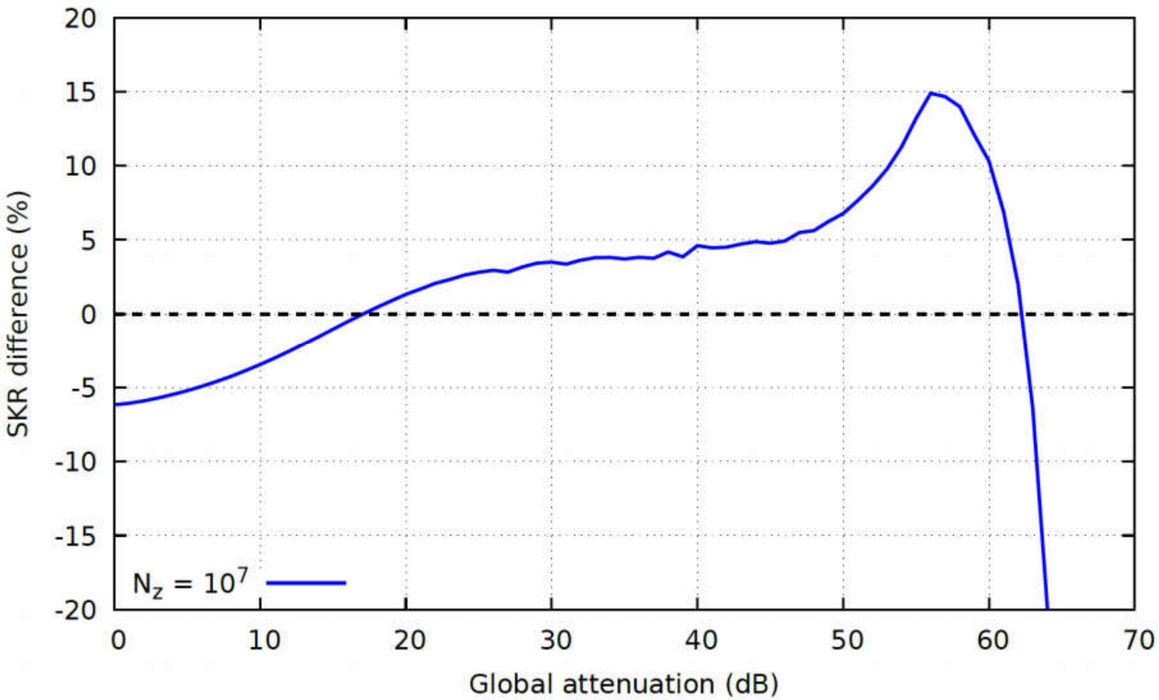
1-decoy versus 2-decoy

1-decoy (i.e. two levels in total) is more efficient for most experimental settings !



Poster: D. Rusca et al. *The 1-decoy state protocol: the best choice for practical QKD*
Paper: Appl. Phys. Lett. 112, 171104 (2018)

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Protocol

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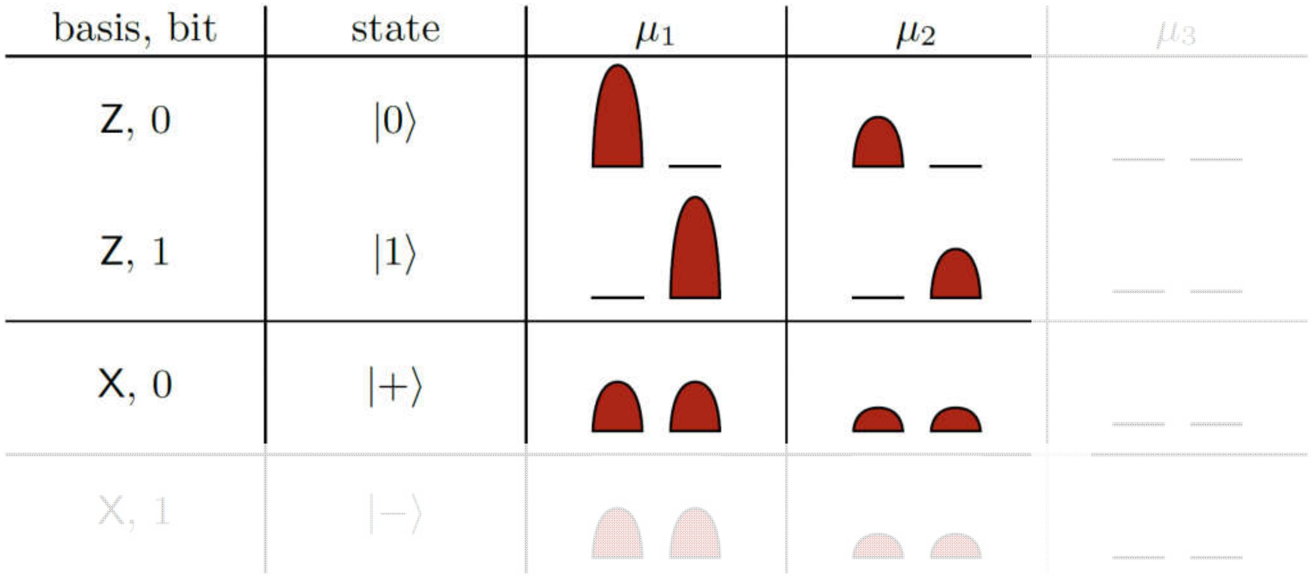
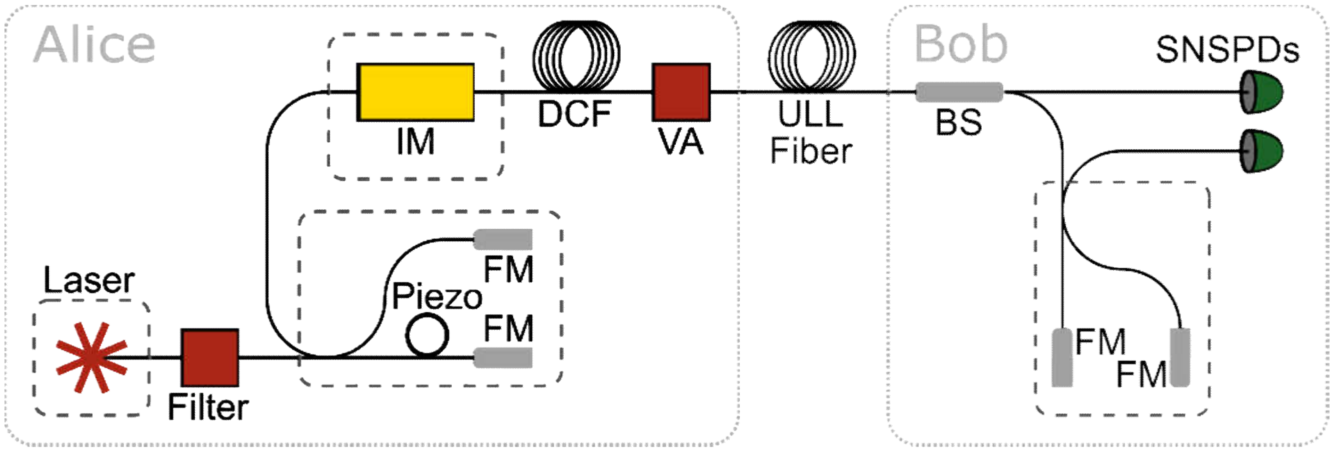


Phys. Rev. A 74, 042342 (2006)



4 states, 4 outcomes

↓

3 states, 3 outcomes

Security proof available on the ArXiv | 1808.08259

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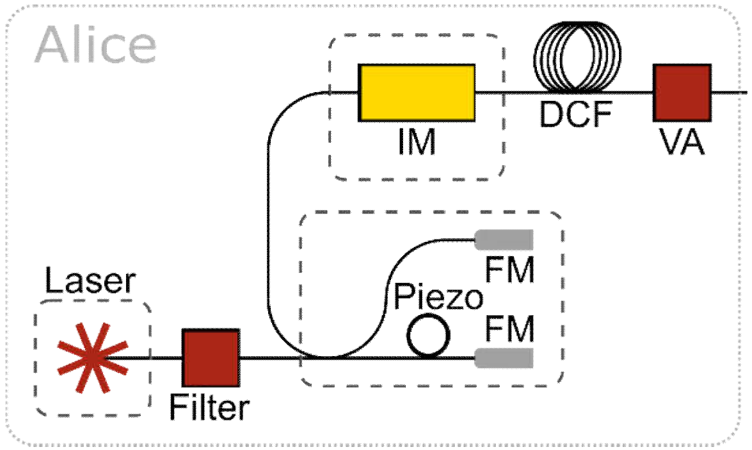
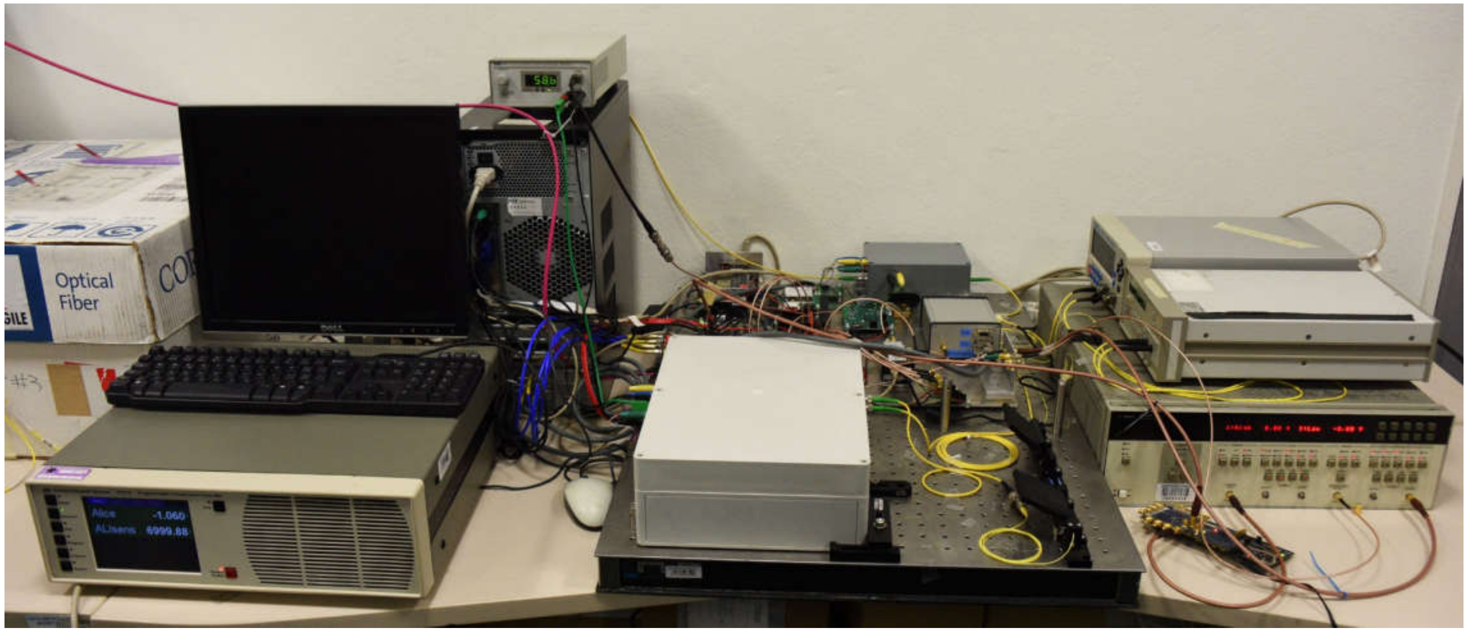
1. all fibred high repetition rate source

- Phase-randomized DFB laser:
    - Repetition rate: 2.5 GHz
    - Pulse duration: 30 ps
- High speed integrated intensity modulator: 5 GHz





→ requires dispersion compensation fibre: -140 ps/nm/km

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2. quantum channel: ultra low-loss fibres

Corning ULL-28® ultra low loss fibre: 0.16 dB/km

Attenuation including connectors and splices: 0.17 dB/km

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3. detectors

Superconducting nanowire single-photon detectors

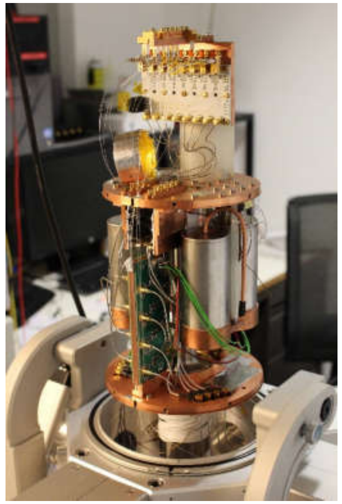
Amorphous molybdenum silicide

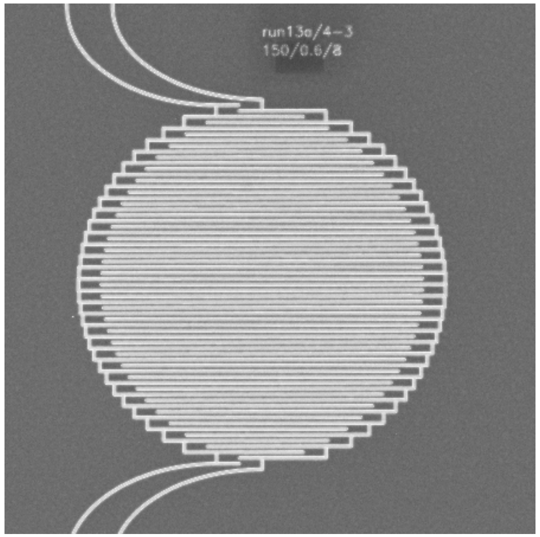
Temperature: 0.8 K

Dark counts: < 0.3 count/s

Efficiency: 50% (at low dark counts rates)

Timing jitter: 30 ps





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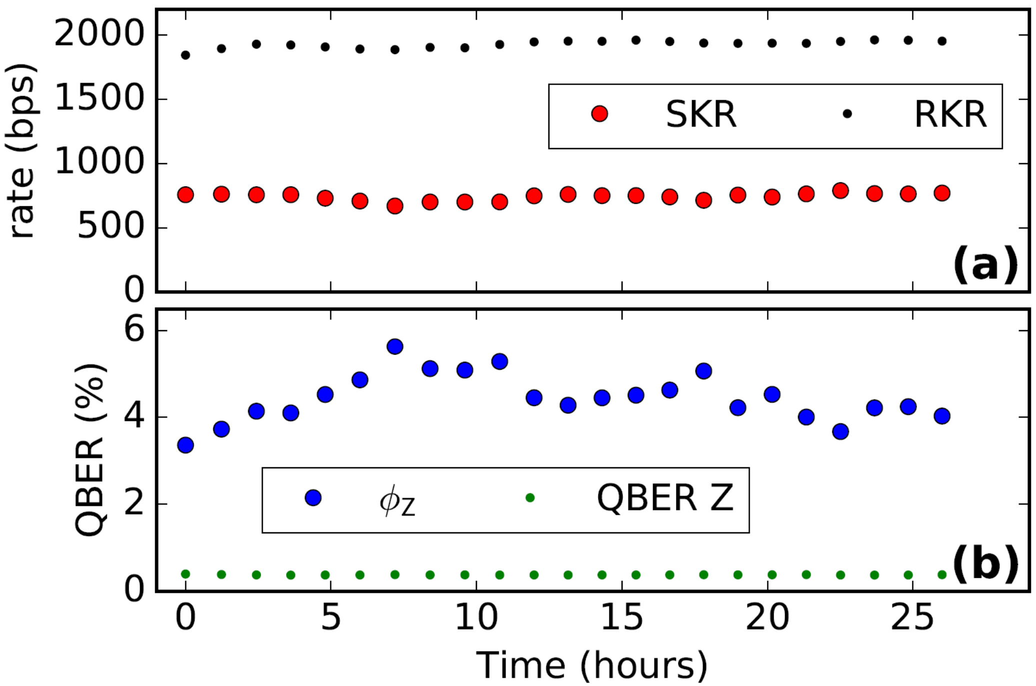
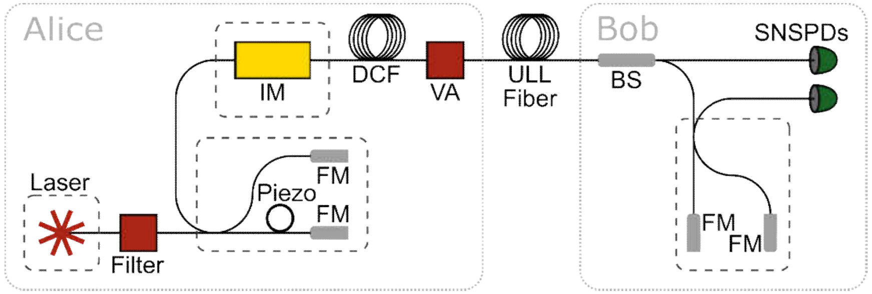
QBER and stability over time

Channel length fluctuations

Interferometers phase fluctuations





Distance: 300 km

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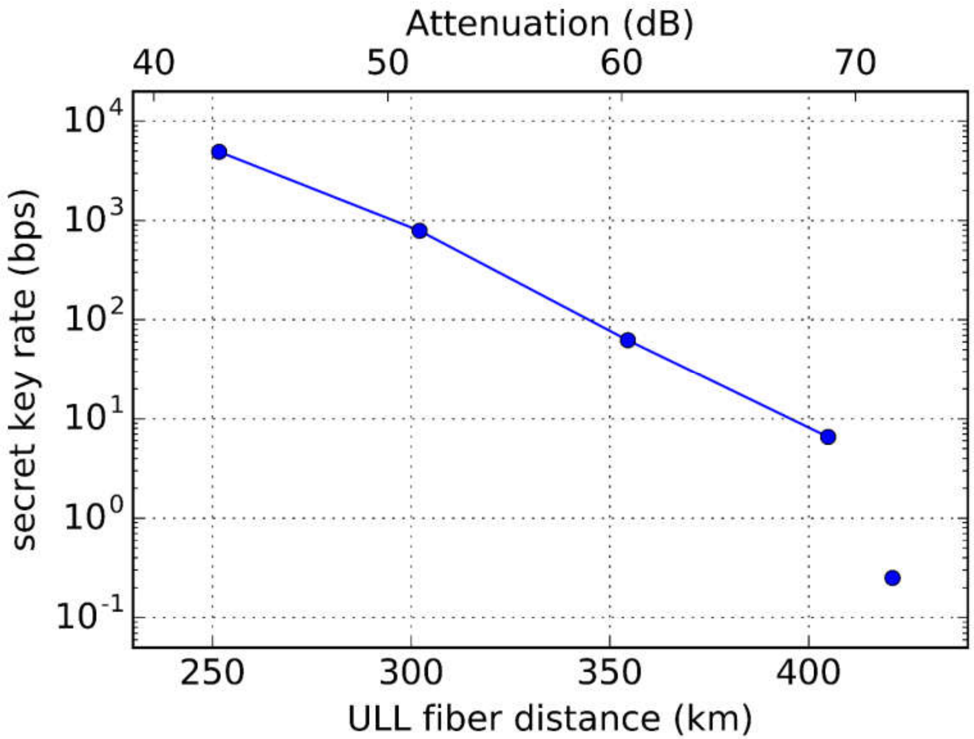
Secret key rate vs distance



421 km | 71.9 dB

24.2 h overall acquisition time

12.7 h of data used

length (km)	attn (dB)	μ_1	μ_2	block size	block time (h)	QBER Z (%)	ϕ_Z (%)	RKR (bps)	SKR (bps)
251.7	42.7	0.49	0.18	$8.2 \cdot 10^6$	0.20	0.5	2.2	$12 \cdot 10^3$	$4.9 \cdot 10^3$
302.1	51.3	0.48	0.18	$8.2 \cdot 10^6$	1.17	0.4	3.7	$1.9 \cdot 10^3$	$0.79 \cdot 10^3$
354.5	60.6	0.35	0.15	$6.2 \cdot 10^6$	14.8	0.7	1.8	117	62
404.9	69.3	0.35	0.15	$4.1 \cdot 10^5$	6.67	1.0	4.3	17	6.5
421.1	71.9	0.30	0.13	$2.0 \cdot 10^5$	24.2 (12.7*)	2.1	12.8	2.3 (4.5*)	0.25 (0.49*)

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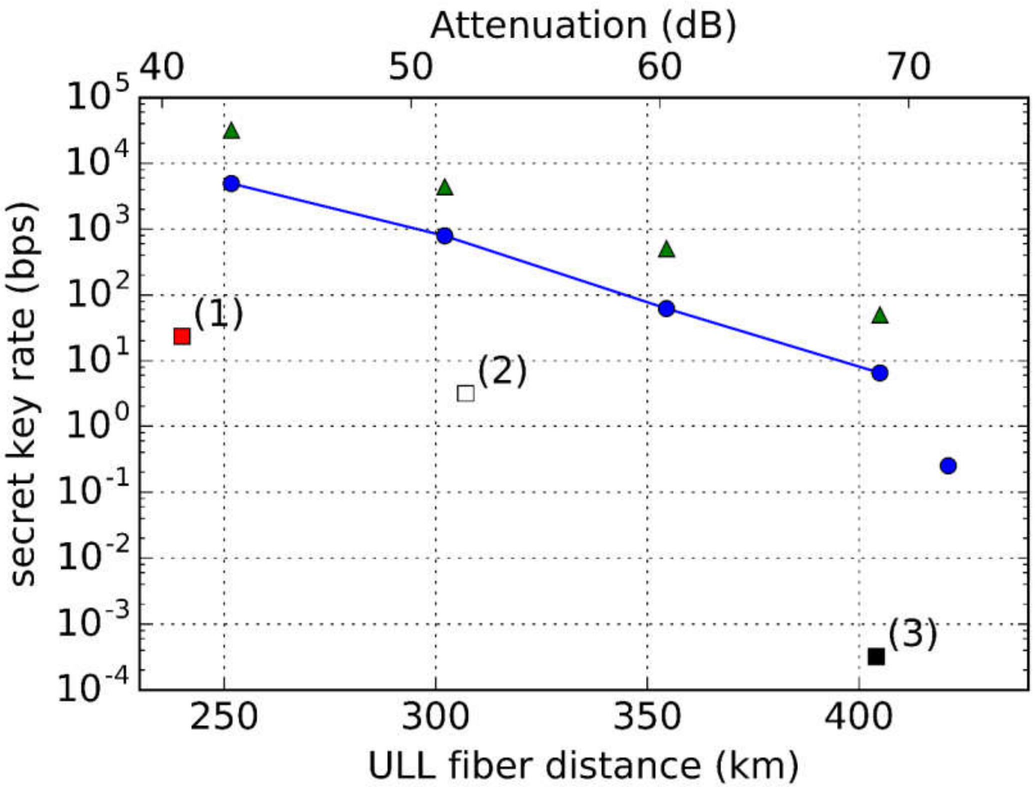
How close are we from an ideal system ?



Ideal system

- BB84 with decoy state
- 2.5 GHz repetition rate
- No detector noise
- 100% detection efficiency
- Same block size than exp. points

(1) **BB84**, Fröhlich et al., Optica **4**, 163 (2017)

(2) **COW**, Korzh et al., Nat. Phot. **9**, 163 (2015)

(3) **MDI**, Yin et al. Phys. Rev. Lett. **117**, 190501 (2016)

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Increasing the repetition rate ?

- Limits of the modulation capability

Classical communications
Max 40 GHz repetition rate
Only 3 dB modulation required

QKD
Need for phase-randomized pulses
High extinction

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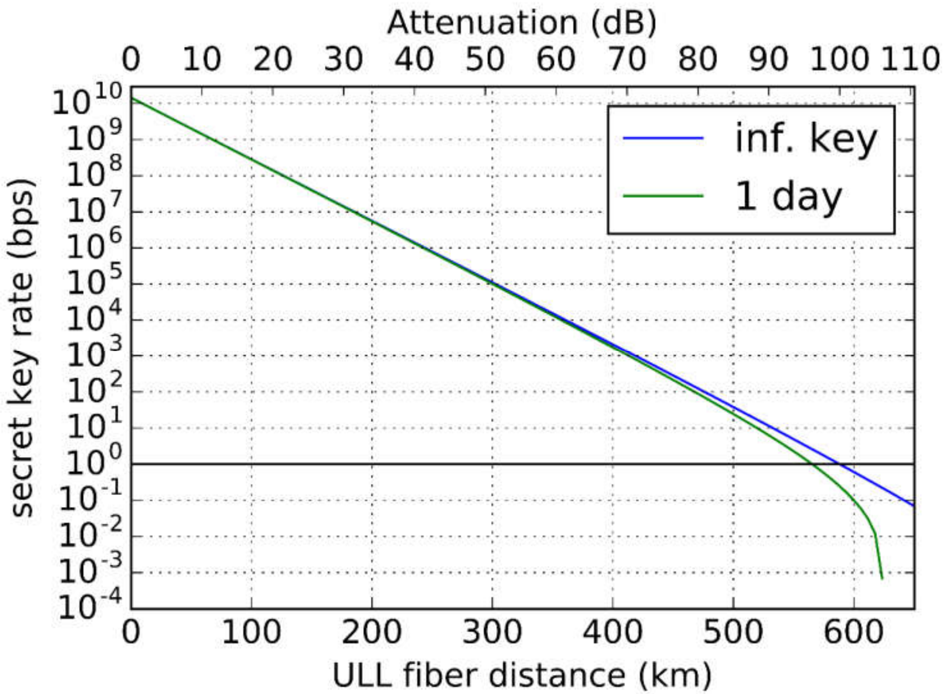
Ultimate limit

- BB84 with decoy state
- 40 GHz repetition rate
- 0 Hz dark counts
- 100% detection efficiency
- 1 day acquisition time



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Conclusion

A system mainly based on of-the-shelf components

- A QKD transmitter based on commercially available components combined with some in-house-made electronics
- Commercially available ultra low-loss fibres
- In-house-made SNSPDs (but almost commercially available)

Transmission of secret keys over 421 km of optical fibre

Thank you for you attention !

Quantum technologies group | leader: Hugo Zbinden

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