QUANTUM SECURITY
at all distance scales

Photon 2022

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Quantum key distribution with a bright telecom wavelength quantum dot single-photon source

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Quantum Dot Fabrication

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Direct emission at 1550 nm

Quantum key distribution over 120 km using ultrahigh purity single-photon source and superconducting single-photon detectors

Kazuya Takemoto, Yoshihiro Nambu, Toshiyuki Miyazawa, Yoshiki Sakuma, Tsuyoshi Yamamoto, Shinichi Yorozu & Yasuhiko Arakawa

ARTICLE OPEN

Quantum teleportation using highly coherent emission from telecom C-band quantum dots

M. Anderson[1,2], T. Müller[1*], J. Huwer[1], J. Skiba-Szymanska[1], A. B. Krysa[3], R. M. Stevenson[1], J. Heffernan[4], D. A. Ritchie[2] and A. J. Shields[1]

High emission rate from a Purcell-enhanced, triggered source of pure single photons in the telecom C-band

Cornelius Nawrath,[1,*] Raphael Joos,[1,†] Sascha Kolatschek,[1] Stephanie Bauer,[1] Pascal Pruy,[1] Florian Hornung,[1] Julius Fischer,[1,2] Jiasheng Huang,[1] Ponraj Vijayan,[1] Robert Sittig,[1] Michael Jetter,[1] Simone Luca Portalupi,[1] and Peter Michler[1]

Bright, low-noise, OR coherent at 1550 nm

Frequency conversion to 1550 nm

Quantum interference between independent solid-state single-photon sources separated by 300 km fiber

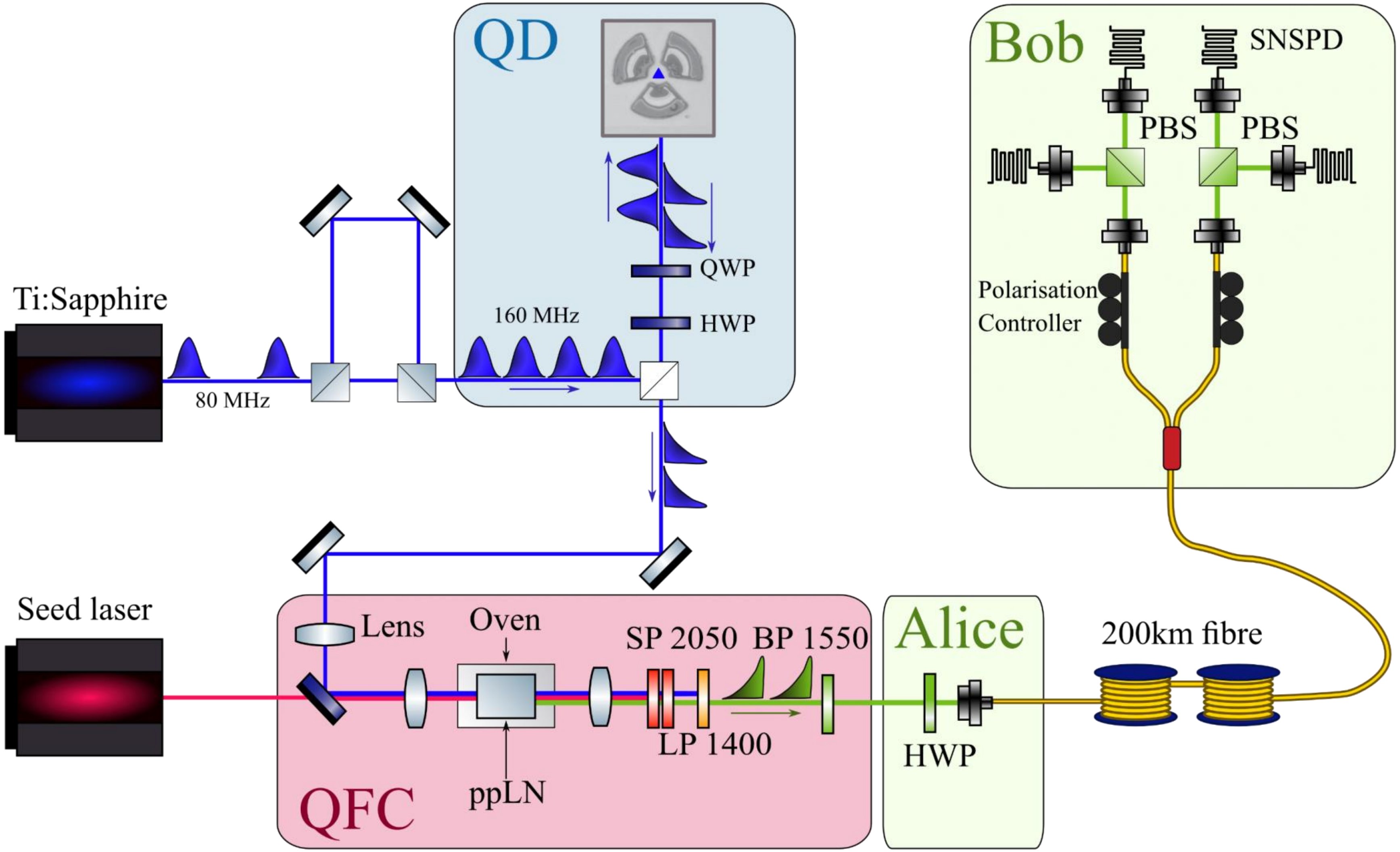
Xiang You[1,2,*], Ming-Yang Zheng[3,*], Si Chen[1,2,*], Run-Ze Liu[1,2,*], Jian Qin[1,2], M.-C. Xu[1,2], Z.-X. Ge[1,2], T.-H. Chung[1,2], Y.-K. Qiao[1,2], Y.-F. Jiang[3], H.-S. Zhong[1,2], M.-C. Chen[1,2], H. Wang[1,2], Y.-M. He[1,2], X.-P. Xie[3], H. Li[4], L.-X. You[4], C. Schneider[5,6], J. Yin[1,2], T.-Y. Chen[1,2], M. Benyoucef[7], Yong-Heng Huo[1,2], S. Höfling[5], Qiang Zhang[1,2,3], Chao-Yang Lu[1,2], Jian-Wei Pan[1,2]

A bright and fast source of coherent single photons

Natasha Tomm, Alisa Javadi, Nadia Olympia Antoniadis, Daniel Najer, Matthias Christian Löbl, Alexander Rolf Korsch, Rüdiger Schott, Sascha René Valentin, Andreas Dirk Wieck, Arne Ludwig & Richard John Warburton

Nature Nanotechnology **16**, 399–403 (2021) | Cite this article

Bright, low-noise, AND coherent at 900 nm



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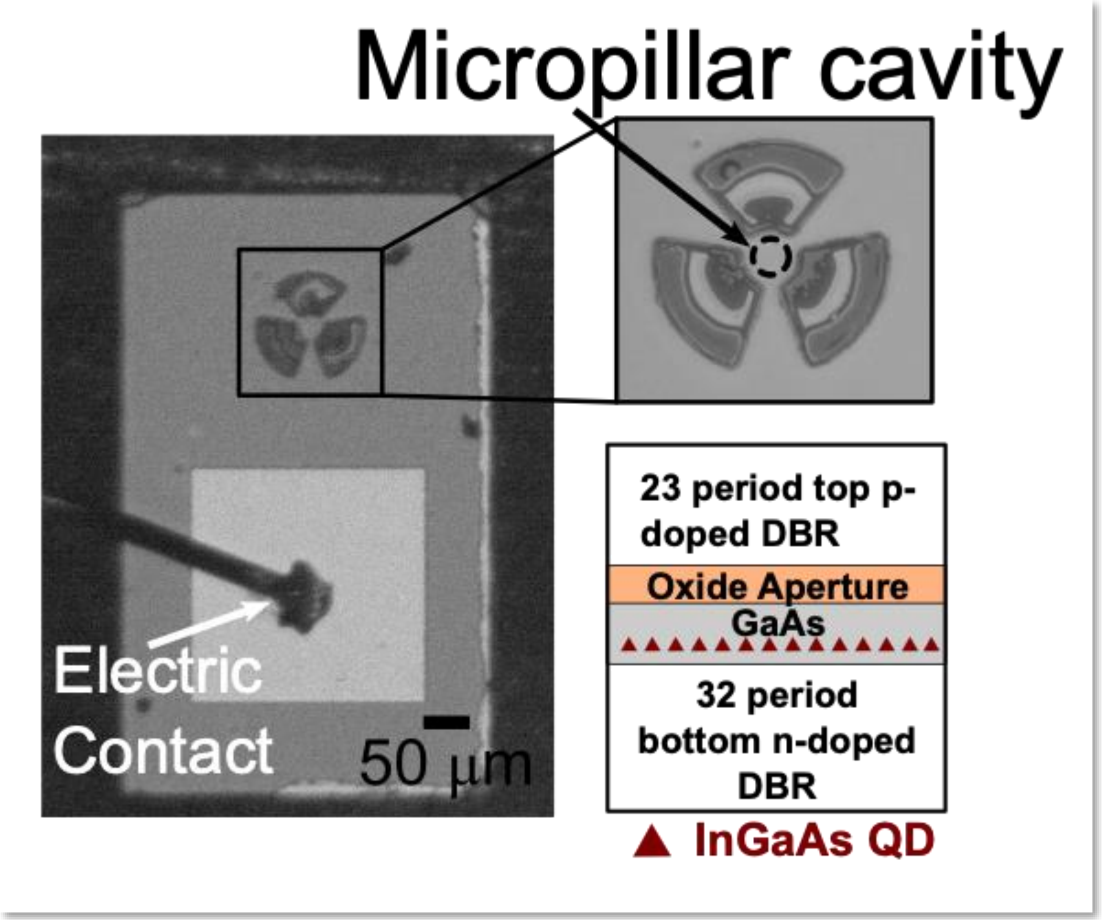
Quantum Dot

Device

- InGaAs/GaAs self-assembled QD
- $Q = 4.4 \times 10^4$
- Purcell factor ≈ 4

Performance

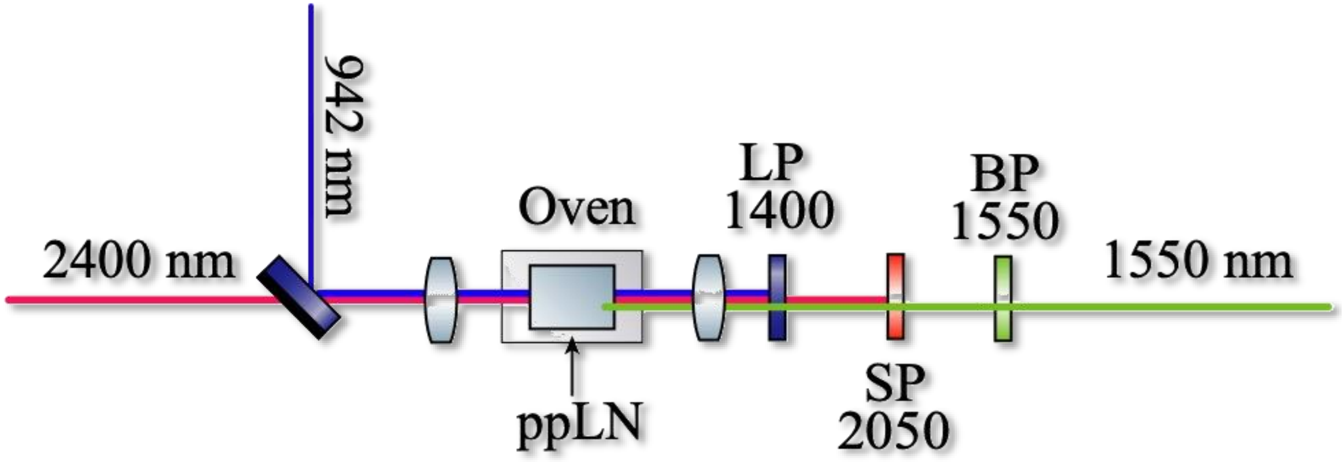
- Quasi-resonant excitation
- 5 MHz counts at 160 MHz excitation rate
- 940 nm
- $g^2(0) = 2.0\%$
- $V_{HOM} = 88\%$

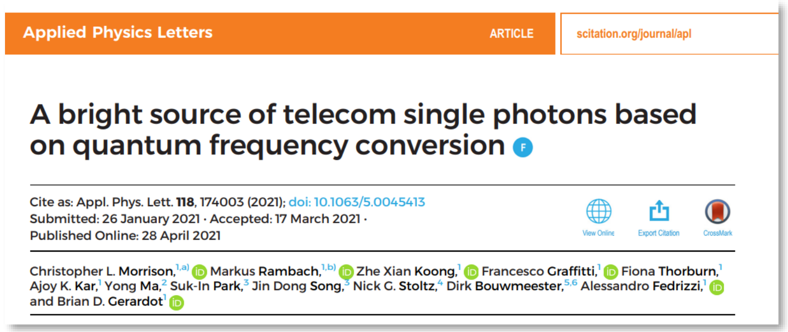


Quantum Frequency Conversion

Type 0 DFG

- 942 nm to 1550 nm
- 57% internal efficiency
- 40% end to end efficiency
- Coherence maintaining





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A bright source of telecom single photons based on quantum frequency conversion

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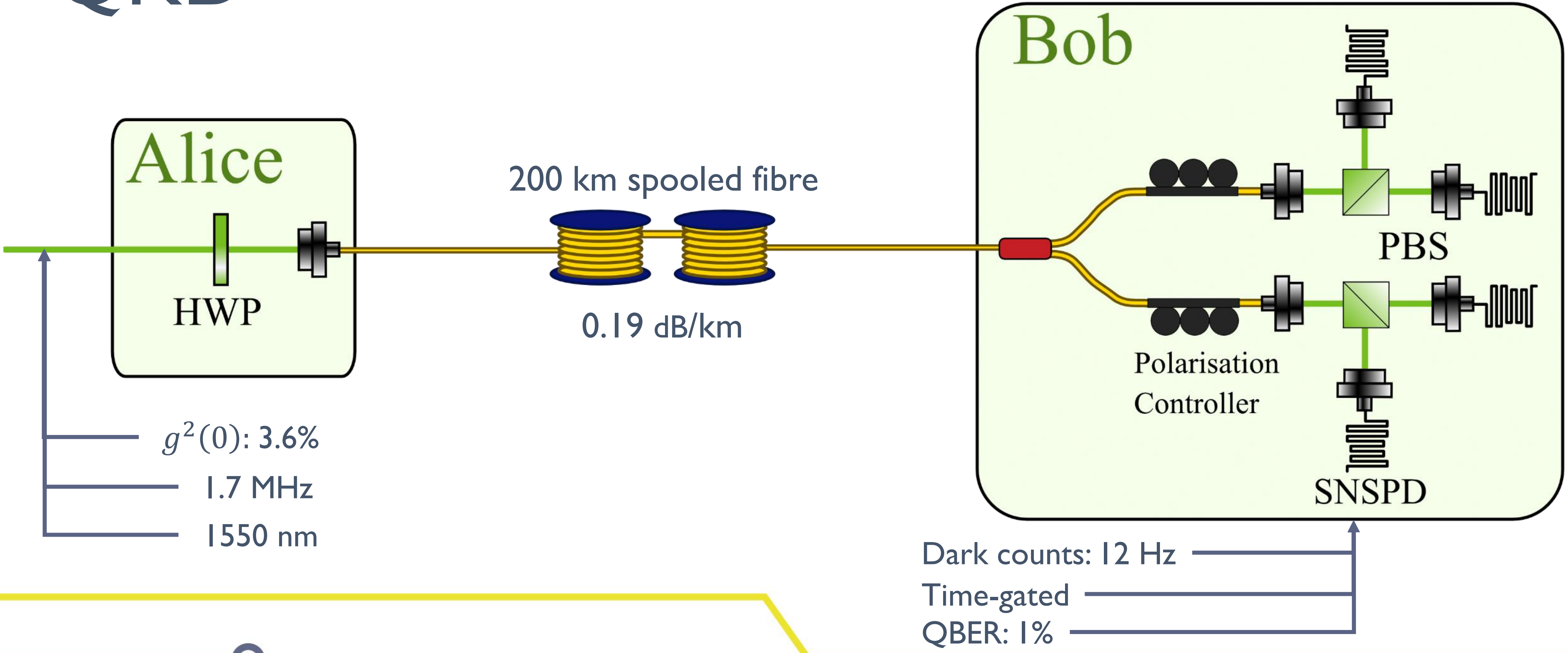
QKD



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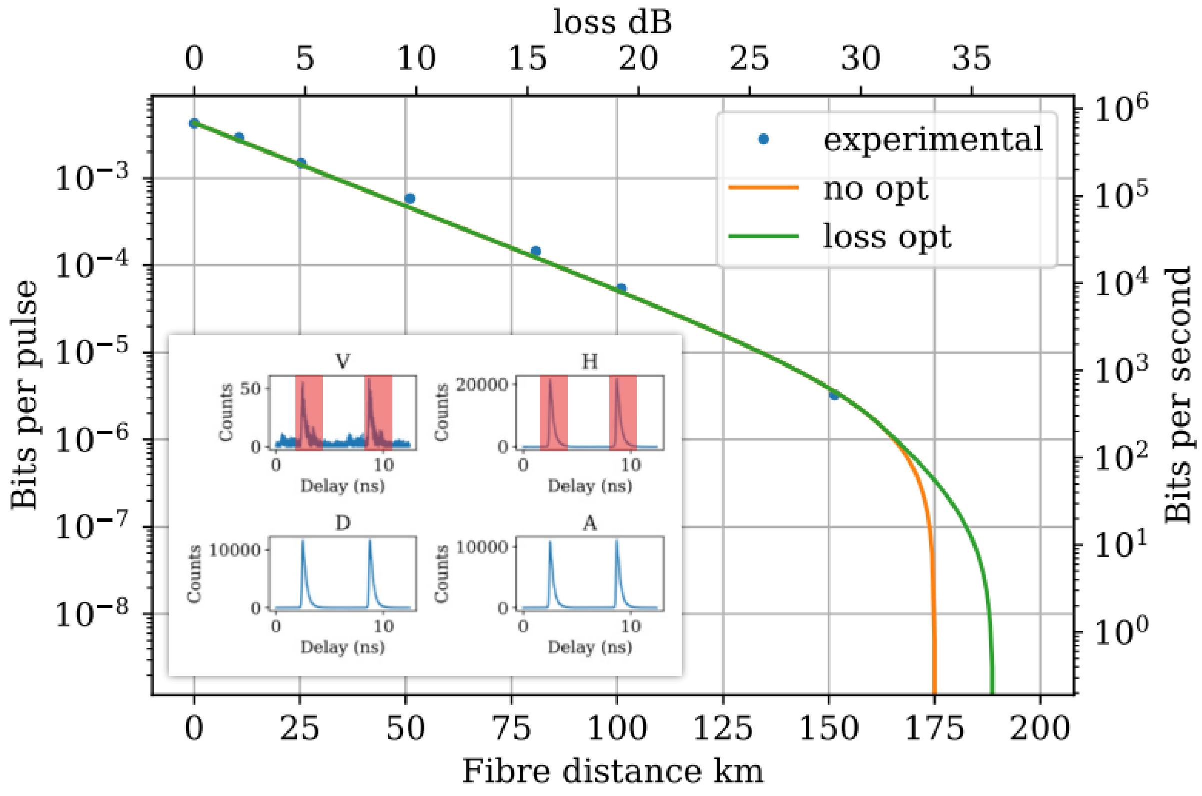
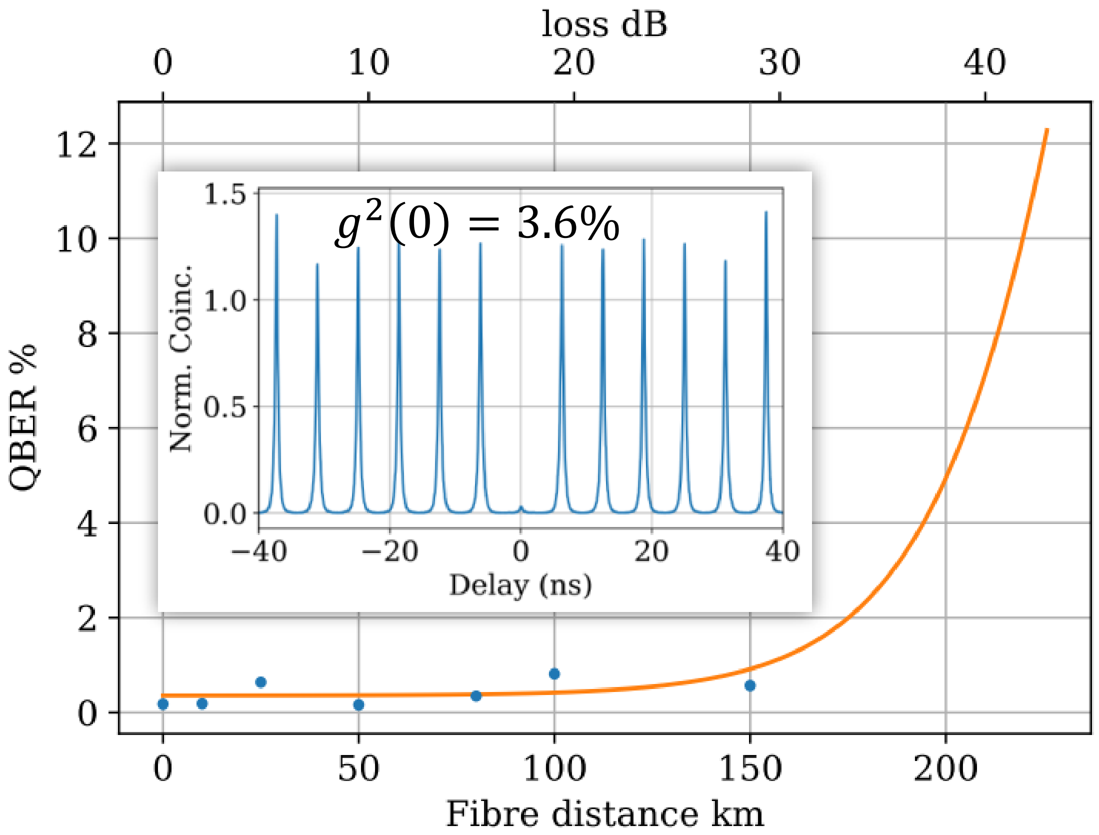
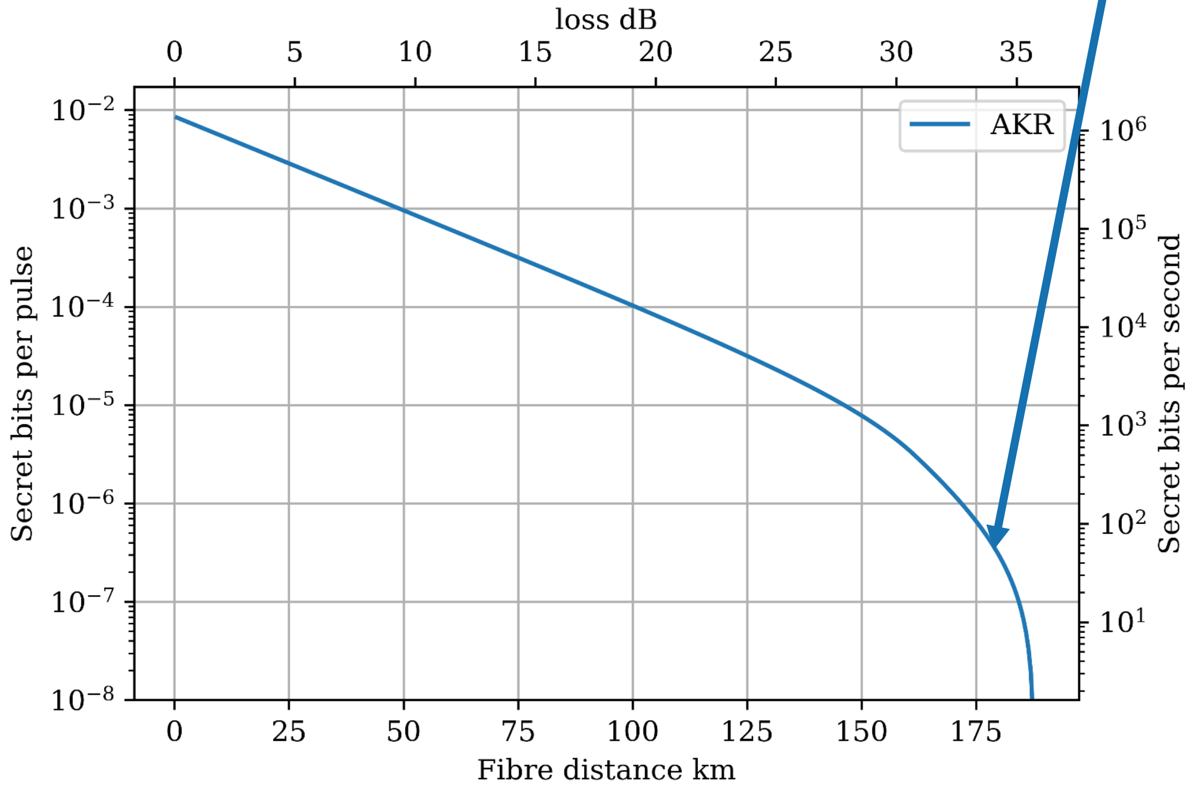
Asymptotic Key Rates





Finite Key Rates

GLLP
[Quant. Inf. Comput. 5, 325 (2004)]

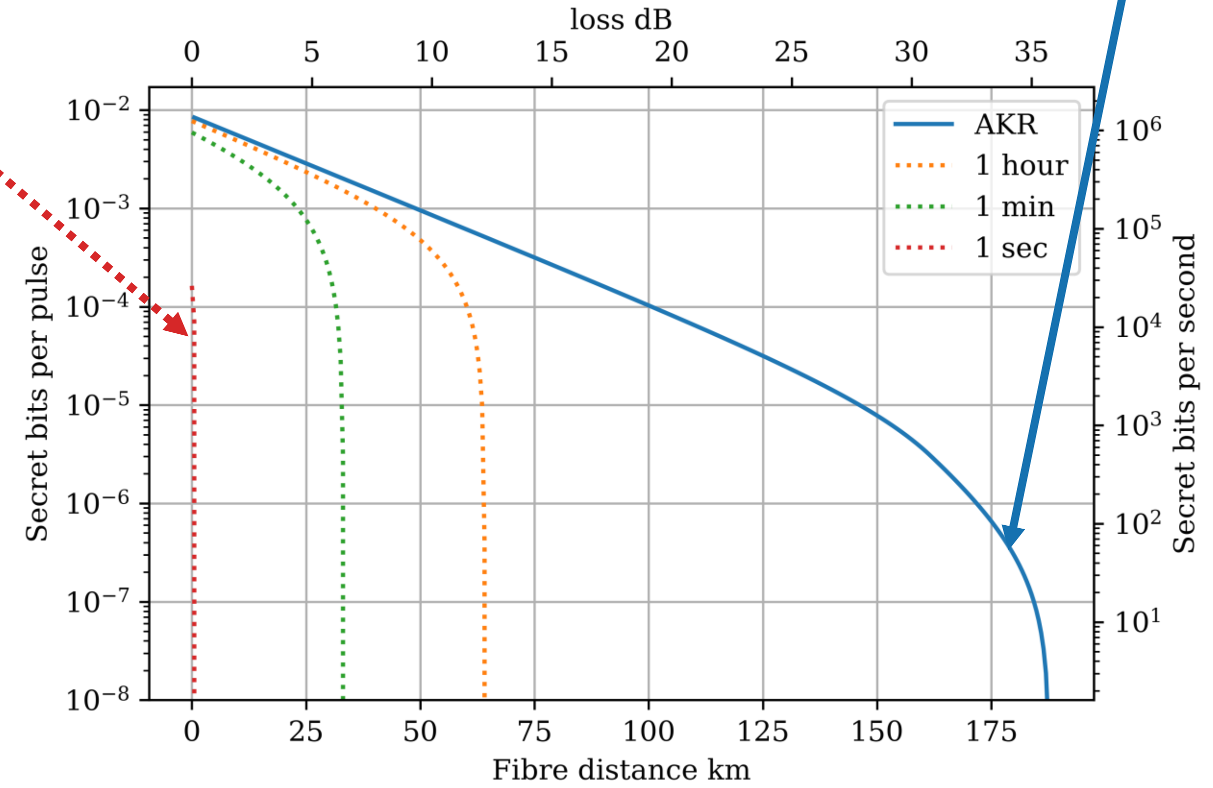


$$\mathrm{AKR} = p_{\mathrm{click}}\left[A\left(1 - H\left(\frac{e_X}{A}\right)\right) - f_{\mathrm{EC}}(e_Z)H(e_Z)\right]$$

Finite Key Rates

GLLP
[Quant. Inf. Comput. 5, 325 (2004)]

Cai and Scarani
[NJP, 11, 045024 (2009)]



$$\mathrm{AKR} = p_{\mathrm{click}}\left[A\left(1 - H\left(\frac{e_X}{A}\right)\right) - f_{\mathrm{EC}}(e_Z)H(e_Z)\right]$$

Finite Key Rates

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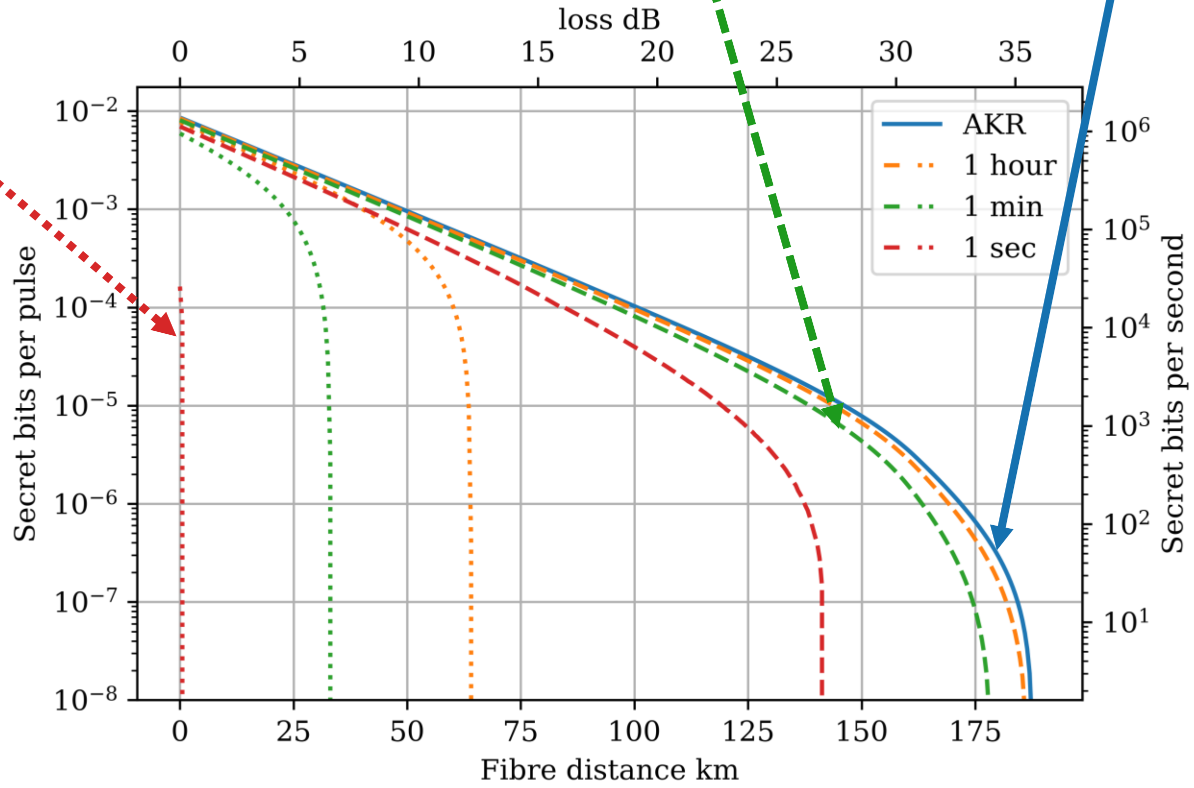
New analysis

GLLP
[Quant. Inf. Comput. 5, 325 (2004)]



$$\mathrm{AKR} = p_{\mathrm{click}}\left[A\left(1 - H\left(\frac{e_X}{A}\right)\right) - f_{\mathrm{EC}}(e_Z)H(e_Z)\right]$$

$$\mathrm{FKR} = \frac{1}{N_S}\left[\boxed{\underline{\mathrm{N}}_{R,nmp}^{X}}\left(1 - \boxed{H\left(\bar{\phi}^{X}\right)}\right) - \lambda_{EC} - 2\log_2\frac{1}{2\varepsilon_{PA}} - \log_2\frac{2}{\varepsilon_{cor}}\right]$$

Yin et al.
[Scientific Reports 10, 1 (2020)]

Finite Key Rates

Cai and Scarani
[NJP, 11, 045024 (2009)]

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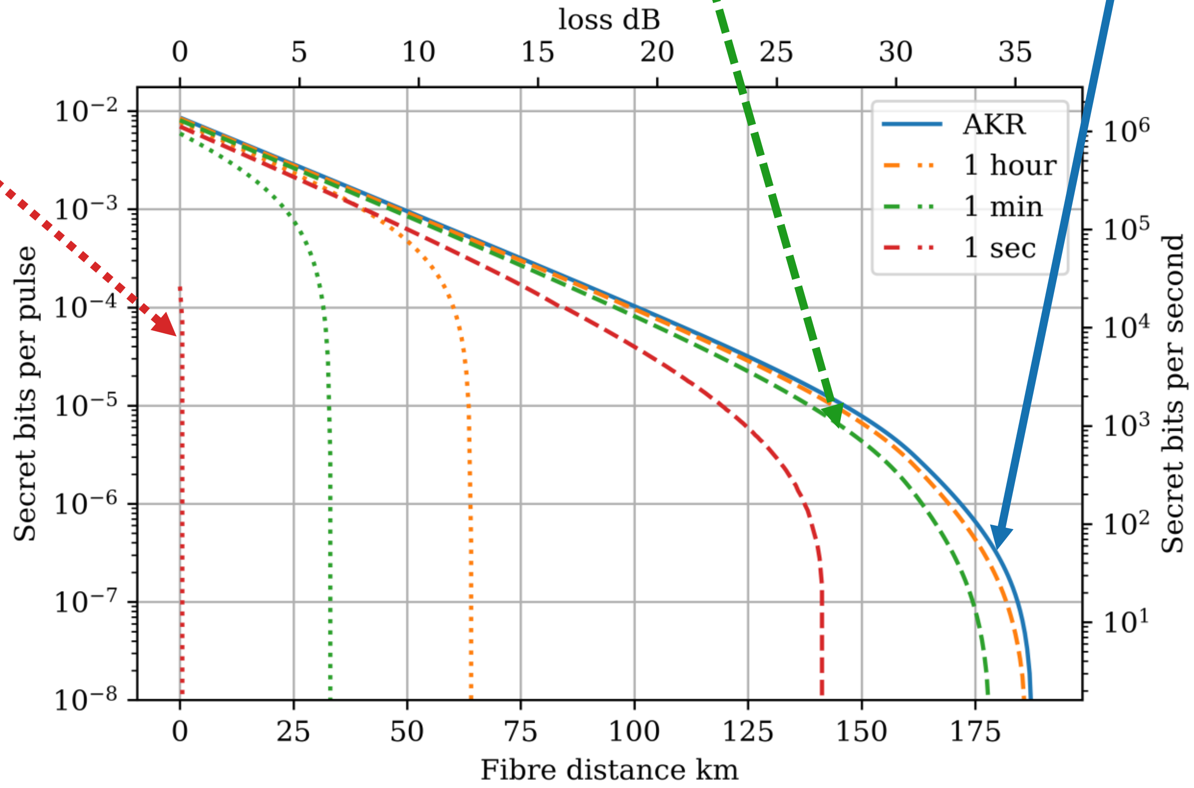

Want a 1kbit key in 1 second?
1 km → 125 km

Want 100 kbit/s over 50km?
1 hour → 1 second

Time required to reach 90% AKR at 125 km?
10,000 years → 1 hour

$$\mathrm{AKR} = p_{\mathrm{click}}\left[A\left(1 - H\left(\frac{e_X}{A}\right)\right) - f_{\mathrm{EC}}(e_Z)H(e_Z)\right]$$

$$\mathrm{FKR} = \frac{1}{N_S}\left[\boxed{\mathrm{N}^X_{R,nmp}}\left(1 - \boxed{H\left(\bar{\phi}^X\right)}\right) - \lambda_{EC} - 2\log_2\frac{1}{2\varepsilon_{PA}} - \log_2\frac{2}{\varepsilon_{cor}}\right]$$

Yin et al.
[Scientific Reports 10, 1 (2020)]

Summary

- QD + DFG as a source for telecom quantum networks
- Importance of finite key analysis
- Significantly enhanced performance of single photon QKD

Outlook

- The future is bright (quantum dots)
- Practical QKD with single photons

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Thank you

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