Quantum key distribution with a bright source of telecom single photons based on quantum frequency conversion

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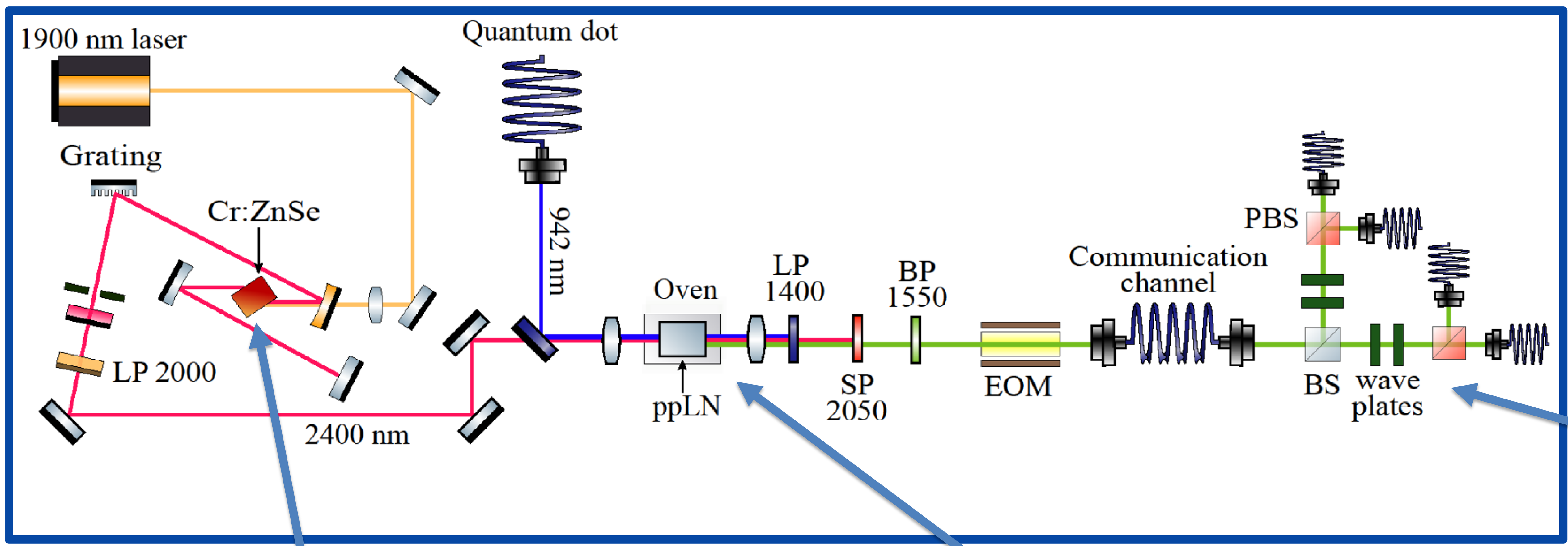
A high performance single photon source in the telecommunication C band is a useful resource for fibre based quantum key distribution. To date near-infrared quantum dots are brighter than their telecom wavelength counterparts.
One route to construct a bright telecom source is to frequency converting a near-infrared quantum dot to telecom wavelengths using difference frequency generation. We have demonstrated a bright frequency converted source in previous work[1] and use it to demonstrate polarisation encoded BB84 over 175 km of fibre.

Source and experimental setup



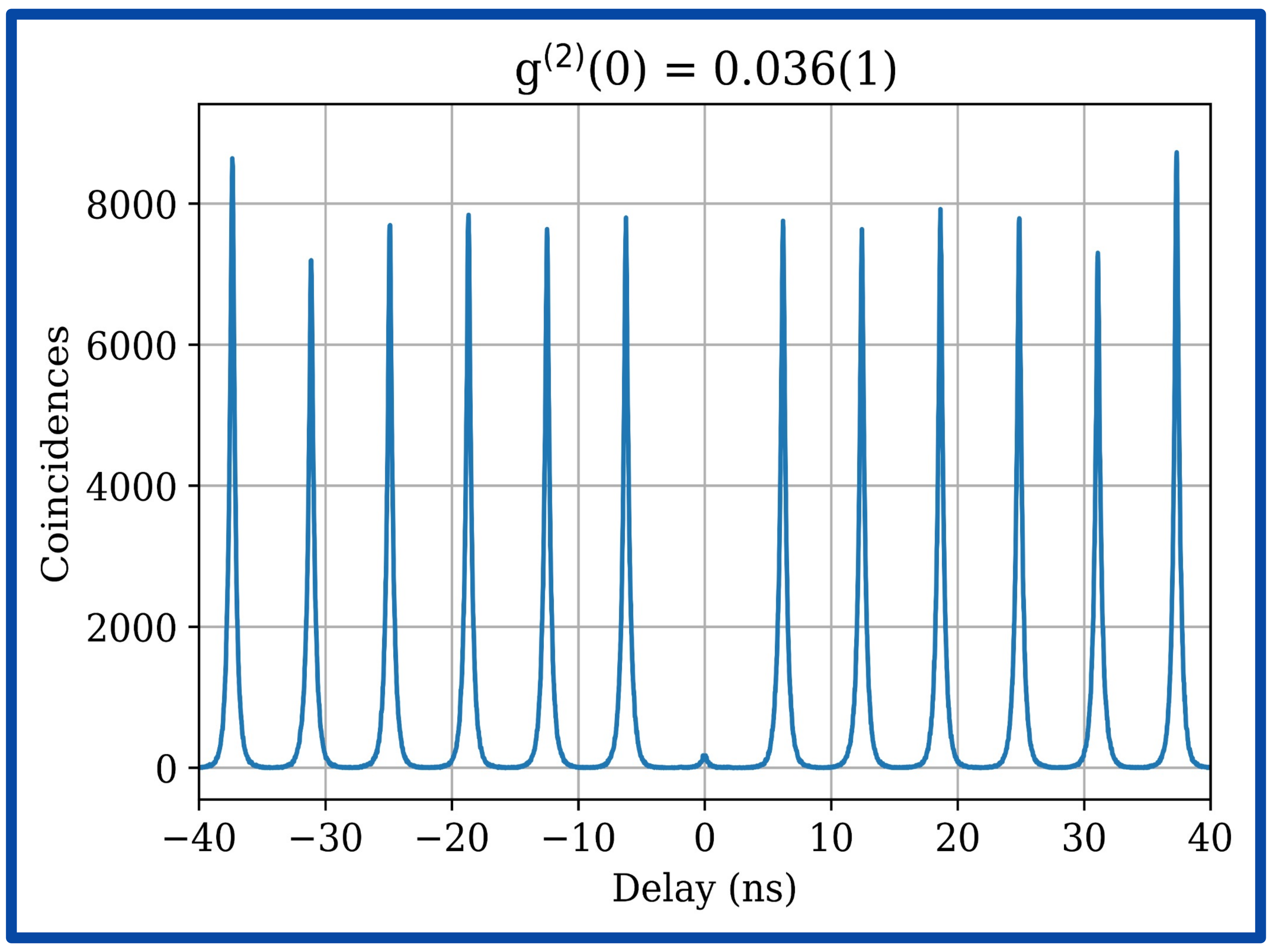
Polarisation states are encoded before being sent over various fibre links and received by Bob. Currently we statically encode states using waveplates, future work will encode on a shot-by-shot basis using an electro-optic modulator.

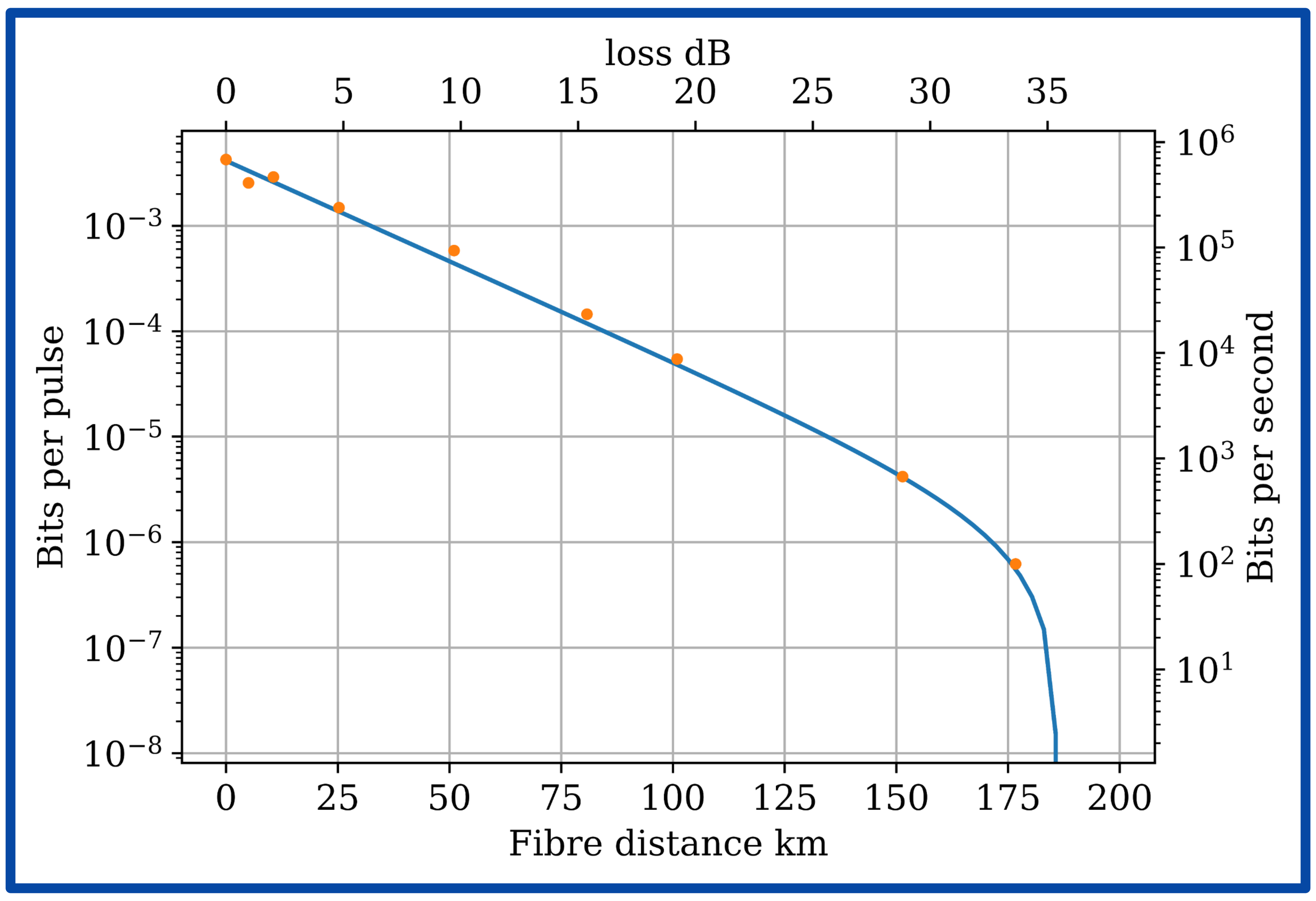
Our conversion process generates photons at 1550 nm by difference frequency generation with a strong pump at 2400 nm.
The 2400 nm light is generated by a homebuilt Cr:ZnSe laser with around 1 W output power over a 400 nm tuning range.

Difference frequency generation takes place in a 48mm periodically poled lithium niobate waveguide, with a type-0 phasematched process.

The source is capable of producing around 2 MHz detected counts at 1550 nm with 160 MHz excitation and $g^{(2)}(0)$~3%.

Second order coherence measurements and measured key rate





Asymptotic Key Rate

$$R = p_{click}\left[\beta\left(1 - H\left(\frac{e_p}{\beta}\right)\right) - f(e_b)H(e_b)\right]$$

- Key rate takes into account multiphoton terms, bounded by finite $g^{(2)}$ and captured by single photon fraction β [2].

Distance (km)	Key rate (bps)
0	685 k
50	94 k
100	9 k
177	105
186	1.2*

*Predicted from theory

Outlook

- Current work is towards implementing shot-by-shot encoding using electro-optic modulation.
- Improving bounds on single photon fraction β to improve key rate and extend maximum distance.
- Implementation of MDI-QKD with multiple sources.

References

1. Morrison et al. A bright source of telecom single photons based on quantum frequency conversion. Appl. Phys. Lett. 118, 174003, 2021.
2. Gottesman et al. Security of quantum key distribution with imperfect devices. Quant. Inf. Comput. 5 (2004) 325-360

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