Going to 2.1 µm for Space Quantum Key Distribution

A. Groulard[1*], S. Chaabani[1*], M. Zajnulina[2], J.-B. Lecourt[2], Y. Hernandez[2] and S. Habraken[1]
[1]Centre Spatial de Liège, Université de Liège, Avenue du Pré-Aily 19, 4031 Angleur, Belgium
[2]Multitel, Rue Pierre Et Marie Curie 2, 7000 Mons, Belgium
*Both authors contributed equally to this work. Email: agroulard@uliege.be , selim.chaabani@uliege.be,

Introduction

Quantum Key Distribution (QKD) is a secure cryptographic information transmission method that relies on quantum properties of photons. Space QKD imposes a huge challenge: efficiently crossing the atmosphere. Motivated by a comprehensive model to simulate a satellite-to-ground link, we address this problem with a tuneable heralded single-photon source with signal photons ranging from 1064 to 2300 nm in free-space. The photons are produced via spontaneous parametric down-conversion (SPDC) in a seven-grating periodically poled lithium niobate (PPLN) crystal.

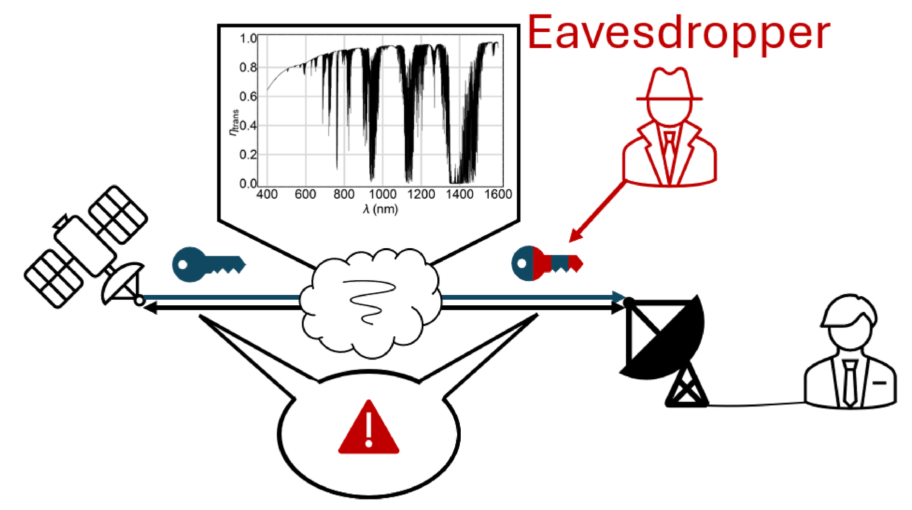

Fig. 1: A QKD scheme for space with the atmospheric transmittance over the wavelength. Adapted from [1].

Broadband atmospheric model

Including multiple effects, the model predicts the best wavelength in terms of signal-to-noise ratio (SNR) for a given affordable loss (Fig. 2).

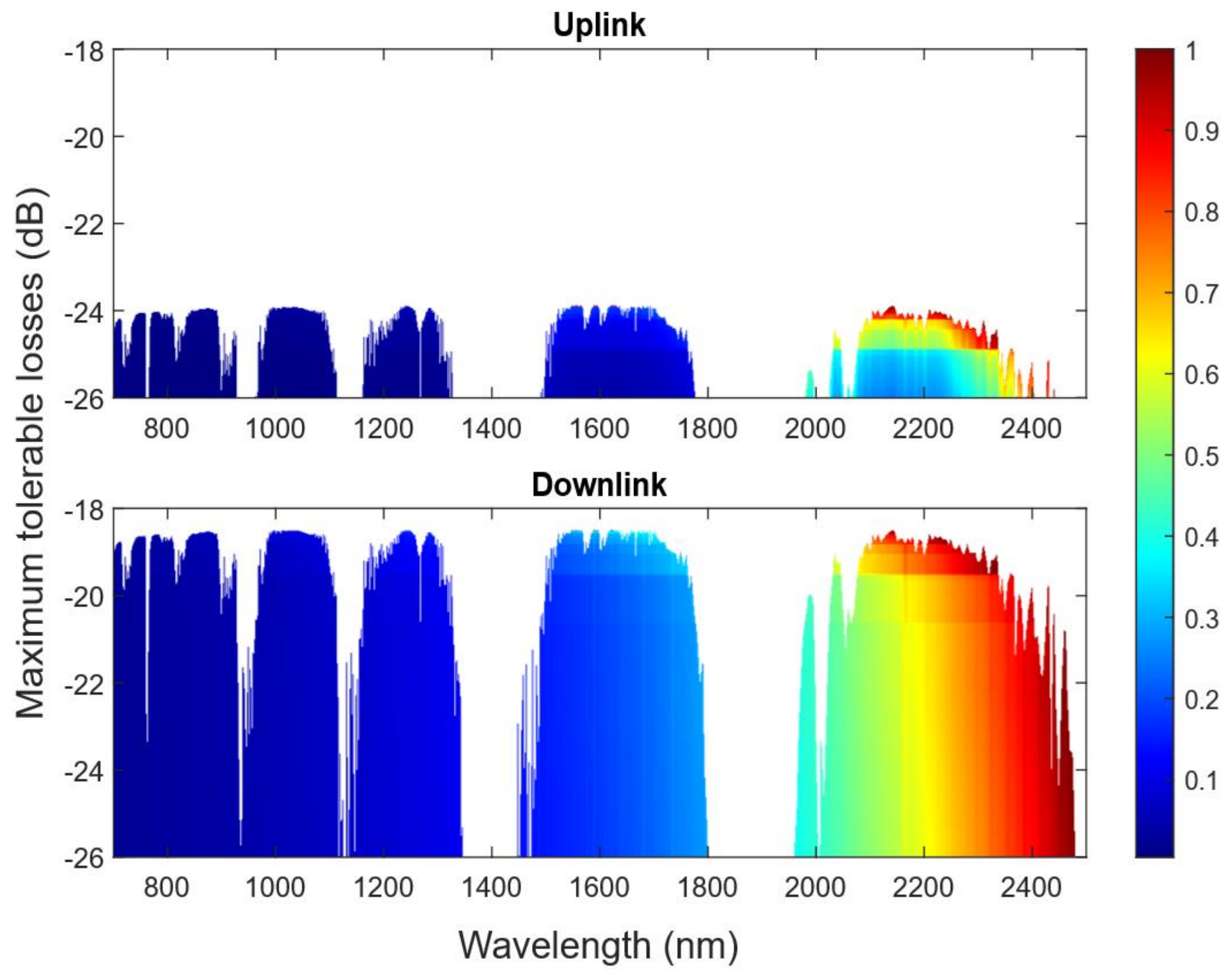

Fig. 2: The outline of the curves is the intrinsic atmospheric loss specific to each wavelength. The colour map indicates the most interesting wavelength provided a given level of loss in the optical link.

Best atmospheric window: over 2 µm

Heralded photon source

With our heralded photon source, we can study many signal wavelengths thanks to the idler photons [2].

Pump laser: mode-locked, 1064 nm, 7,9 ps pulses, 32.45 MHz, 300 pm linewidth

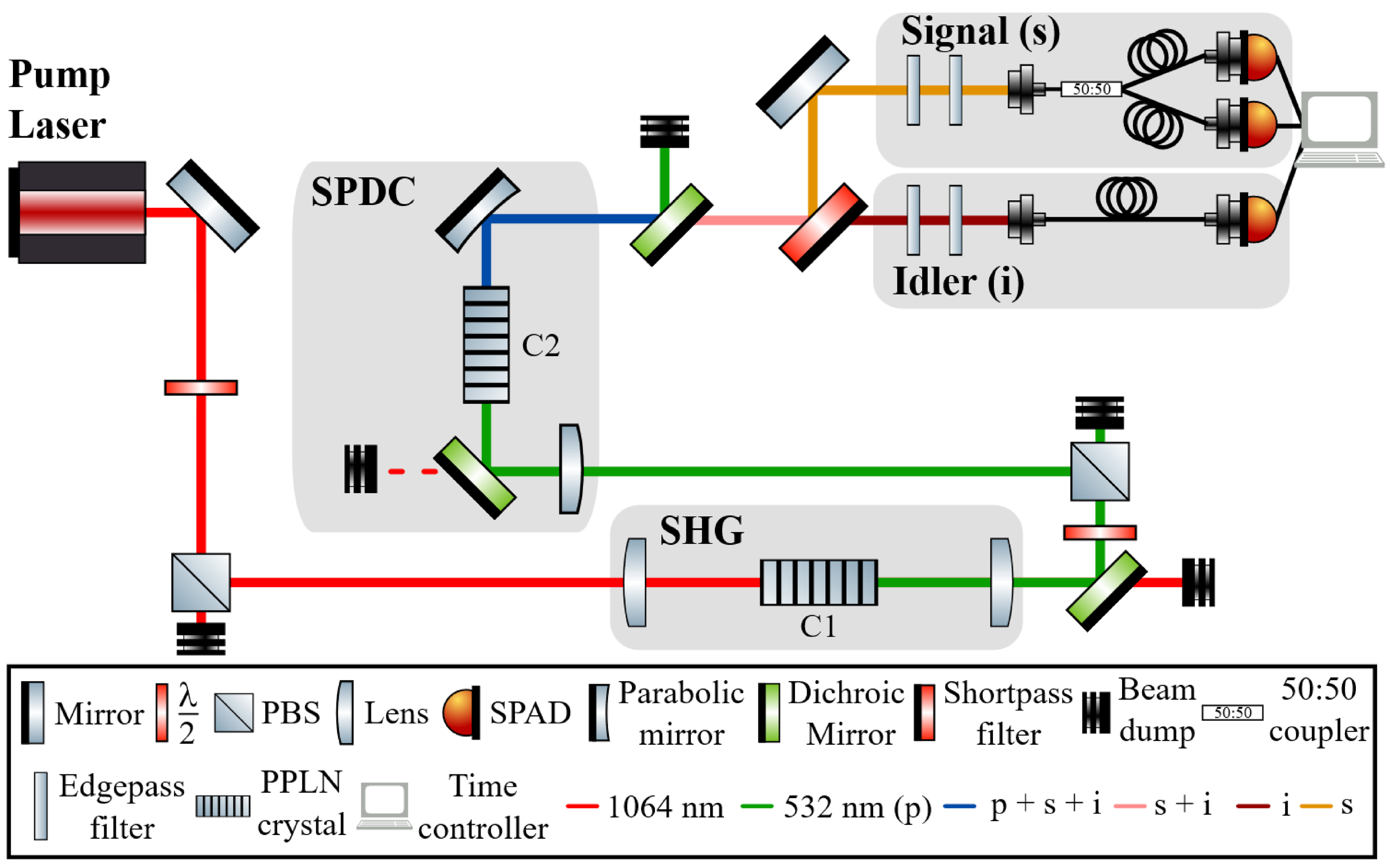

Fig. 3: Optical set-up. PBS: polarisation beamsplitter, SHG: second harmonic generation, C2: multi-grating PPLN crystal, SPDC: (type-0) spontaneous parametric down-conversion.

Spectral output

$$\frac{1}{\lambda_p} = \frac{1}{\lambda_i} + \frac{1}{\lambda_s}$$

$$\text{e.g. } \frac{1}{532} = \frac{1}{805} + \frac{1}{1565}$$

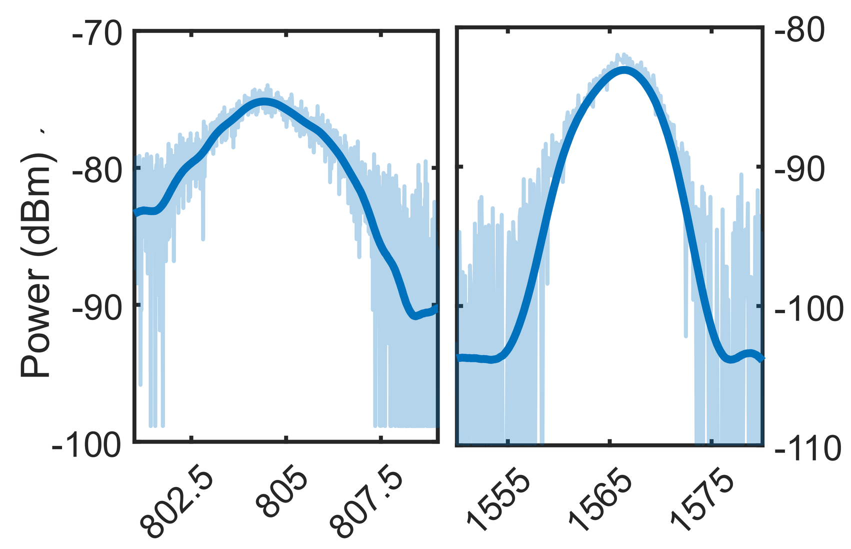

Fig. 4: Complementary idler and signal peaks.

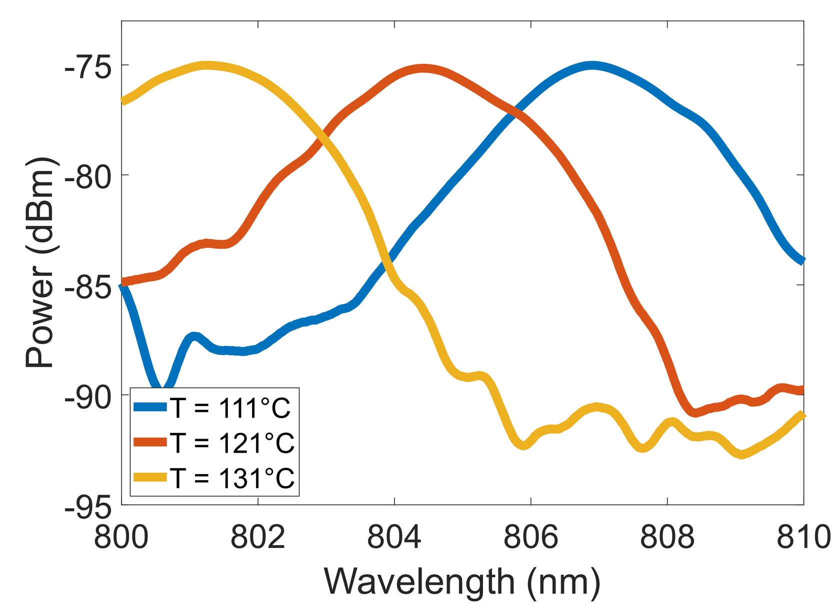

Fig. 5: Spectrum of the idler photon out of the fourth grating of C2 at different temperatures.

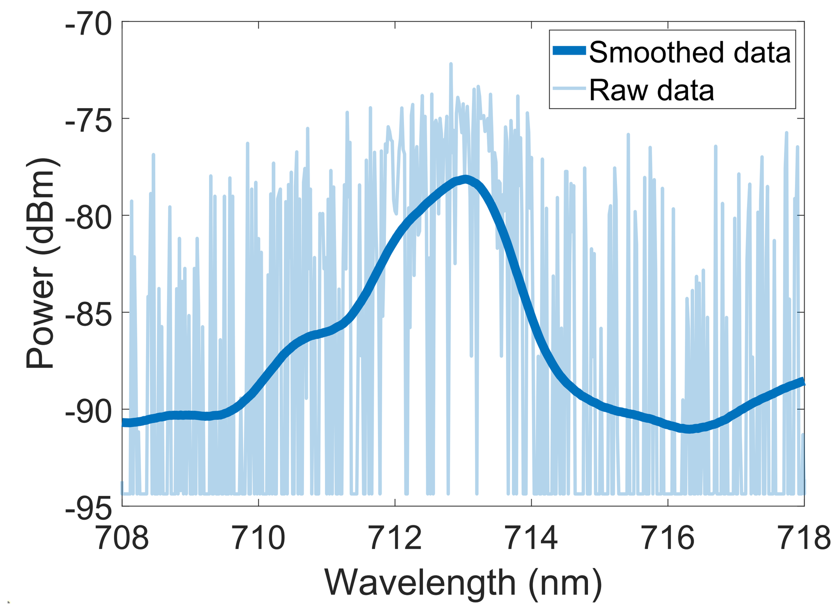

Fig. 6: Spectrum of the idler photon out of the seventh grating of C2 at ambient temperature.

$$\Delta T + \#grating \longrightarrow \lambda_s \in [1064 : 2300\ nm]$$

However, no access to the whole range with our current detectors

Temporal output

Heralding of signal photons by idler

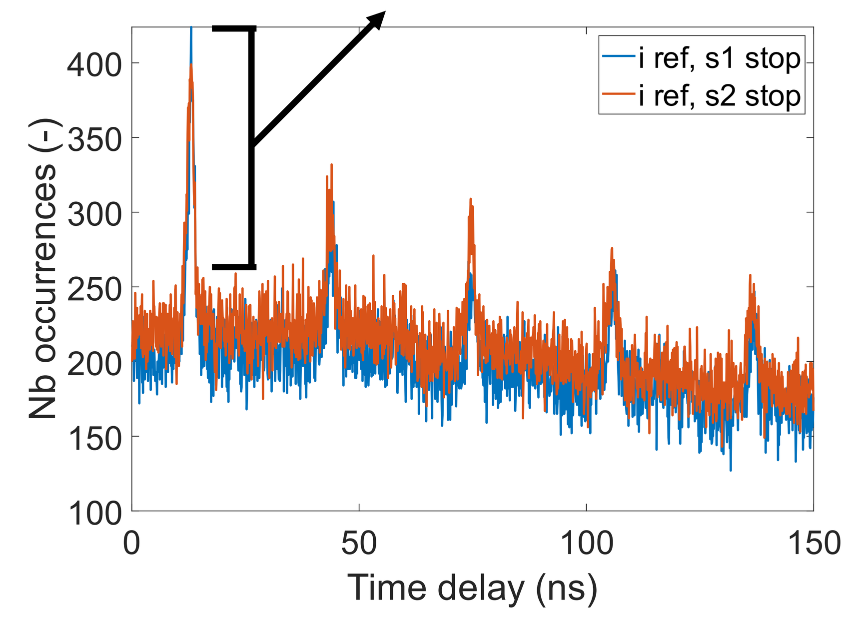

Fig. 7: Time delay between consecutive detections in the idler detector and signal detectors.

No triple coincidences → single photons

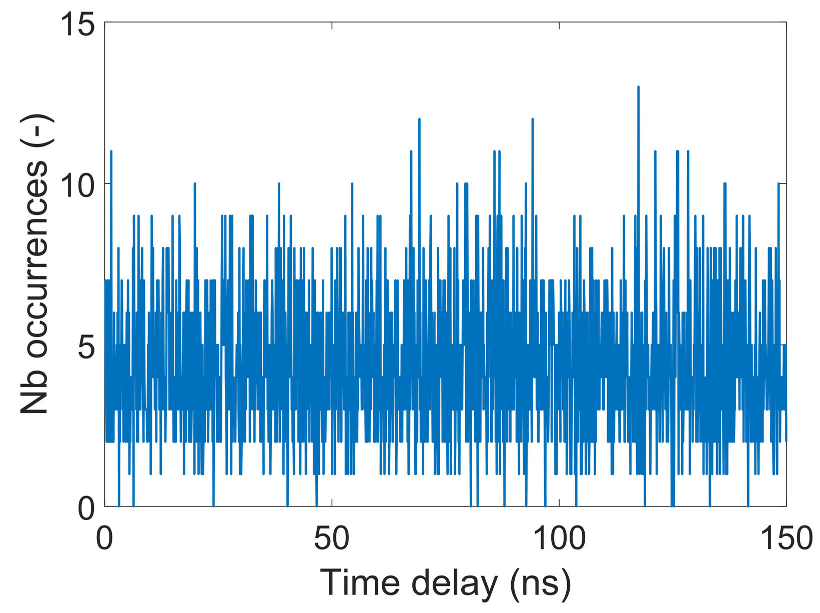

Fig. 8: Time delay between consecutive detections in the signal detectors.

Conclusions

2 µm atmospheric window is advantageous

Can reach it with our source

Perspectives

Include detectors in the model

Optimisation of heralding and single photon rate

Study further wavelengths and focus on 2.1 µm

References

[1] R. N. Lanning et al., Phys. Rev. Applied 16, 044027 (2021), doi: 10.1103/PhysRevApplied.16.044027
[2] S. A. Castelletto and R. E. Scholten, Eur. Phys. J. Appl. Phys. 41, 181-194 (2008), doi: 10.1051/epjap:2008029.

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More information is available at: *https://www.space4relaunch.be.*

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