Source of Single-Photons for Quantum Key Distribution in Space

S. Chaabani[1], N. Desnos[2], M. Zajnulina[3], S. Boivinet[3], J.-B. Lecourt[3], A. Kudlinski[4], A. Mussot[4], S. Habraken[1], and Y. Hernandez[3]

[1]Centre spatial de Liège, Université de Liège, Avenue du Pré-Aily, 4031 Angleur, Belgium

[2]PhLAM-IRCICA, Parc scientifique de la Haute Borne, Avenue Halley 50, 59658 Villeneuve d'Ascq, France

[3]Multitel, Rue Pierre Et Marie Curie 2, 7000 Mons, Belgium

[4]Université de Lille, 42 Rue Paul Duez, 59000 Lille, France

Abstract

Quantum Key distribution (QKD) is a cryptographic information transmission method that relies on quantum properties of (entangled) photons to transmit information securely. Two methods are regarded as promising to generate entangled-photon pairs (consisting of a signal and an idler), namely Four-Wave Mixing (FWM), and Spontaneous Parametric Down-Conversion (SPDC). Here, we present a source of entangled photons generated due to degenerate FWM in an experimental Photonic Crystal Fibre (PCF).

Introduction

Security

- In QKD, eavesdropping can be quickly detected as it changes the properties of information carrying photons which is due to fundamental laws of Quantum Mechanics (Fig. 1)

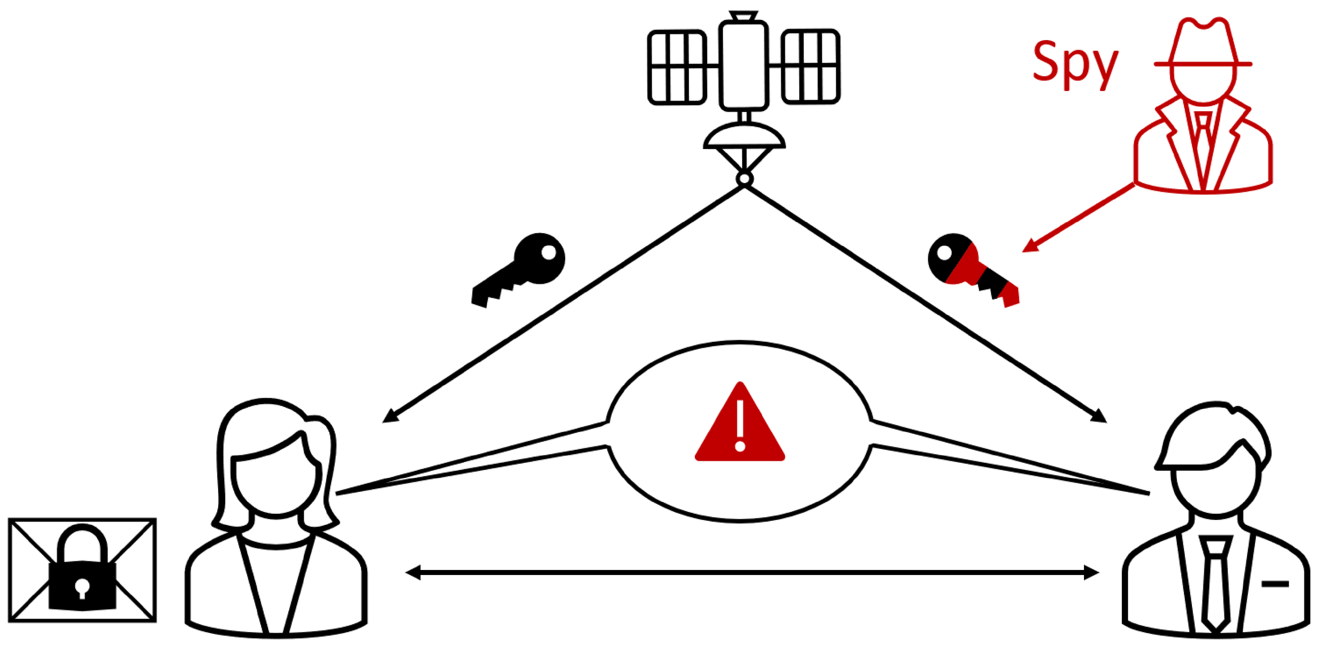

Fig. 1: *Entangled-photon QKD scheme for space*

Addressed problem

- Limited availability of entangled-photon sources suitable for space application is a major obstacle towards a global QKD system

Approach

Generation of entangled photons in atmospheric windows (Fig. 2) with degenerate FWM requires a highly nonlinear optical fibre and large input powers. The use of PCFs and amplifiers allows us to reach such conditions but this approach requires careful optimisation of different stages because:

- PCF dispersion profiles are decisive for phase-matching to drive FWM
- Nonlinearity also drives Raman effect and non-degenerate FWM that are detrimental for performance
- Due to the high peak powers involved, employing some optical components such as filters or gratings is restricted

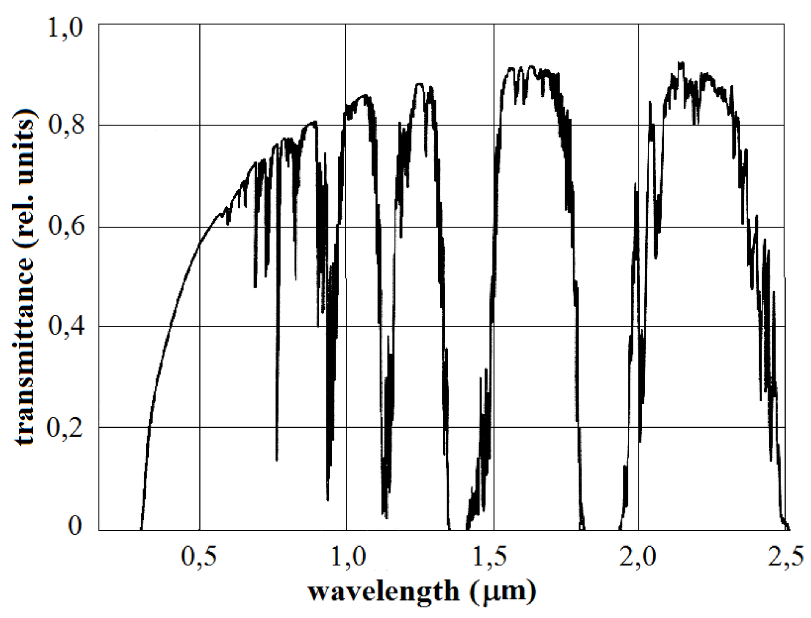

Fig. 2*: Atmospheric spectral transmittance, Belov et al. 2018[1]*

Methods

Set-up (Fig. 3)

- Pulsed laser-diode source at 1064 nm
- Series of optimised Yb fibre amplifiers
- PCFs (experimental "Lille fibre" and commercial NKT Photonics LMA5) with lengths of 40-60 cm
- Comparison of the FWM performance between NKT LMA5 and the "Lille fibre"

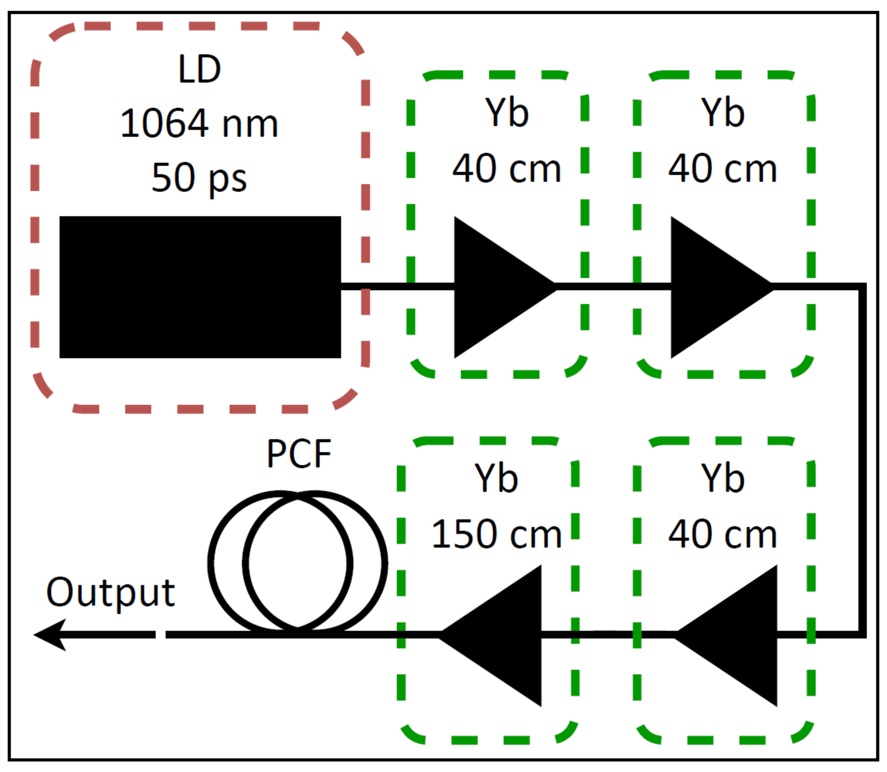

Fig. 3*: Experimental set-up*

Theoretical modelling and simulations (Fig. 4)

- Coupled Generalised Nonlinear Schrödinger equations (GNLS) including dispersion and nonlinearity wavelength-dependent profiles, Raman and Kerr effects
- Two polarisation states (slow and fast axis)
- Integration via 4th-order Runge-Kutta in the interaction Picture Method (RK4IP)

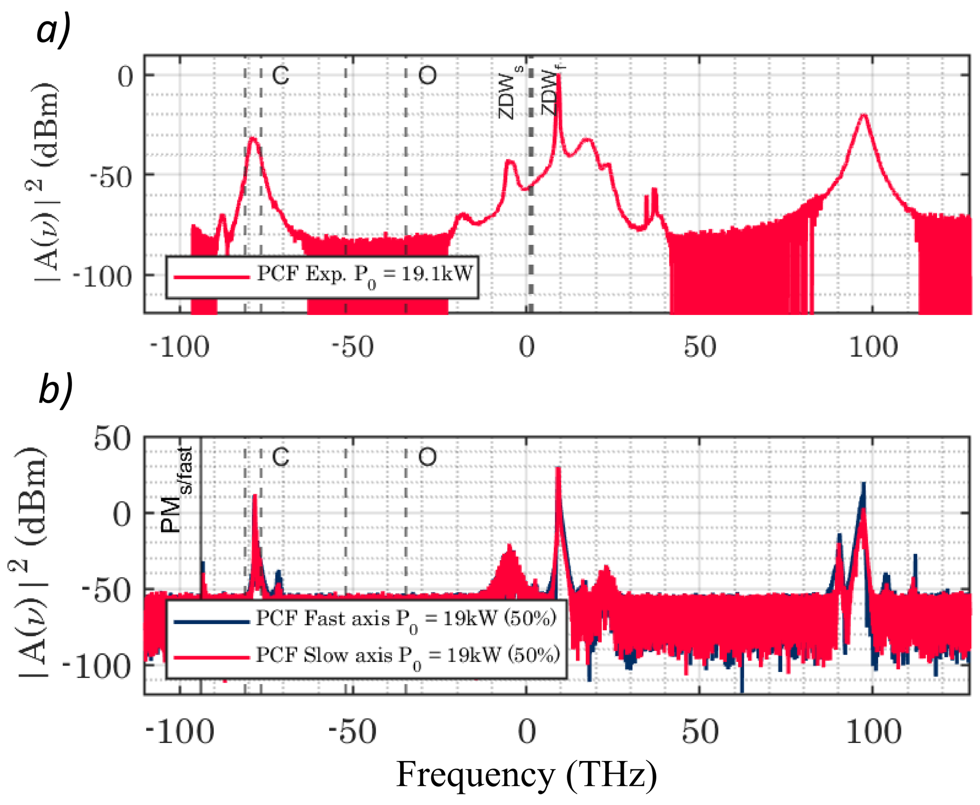

Fig. 4*: Comparison between a) measurements and b) simulations for the Lille fibre*

Results and Conclusion

Generated spectra

- Both measurements and experimental results agree
- Conversion efficiency is 0.17% (signal) and 0.44% (idler) for the fast axis and similar for slow axis
- NKT LMA5 signal in the O band while the Lille fibre one is in the C band

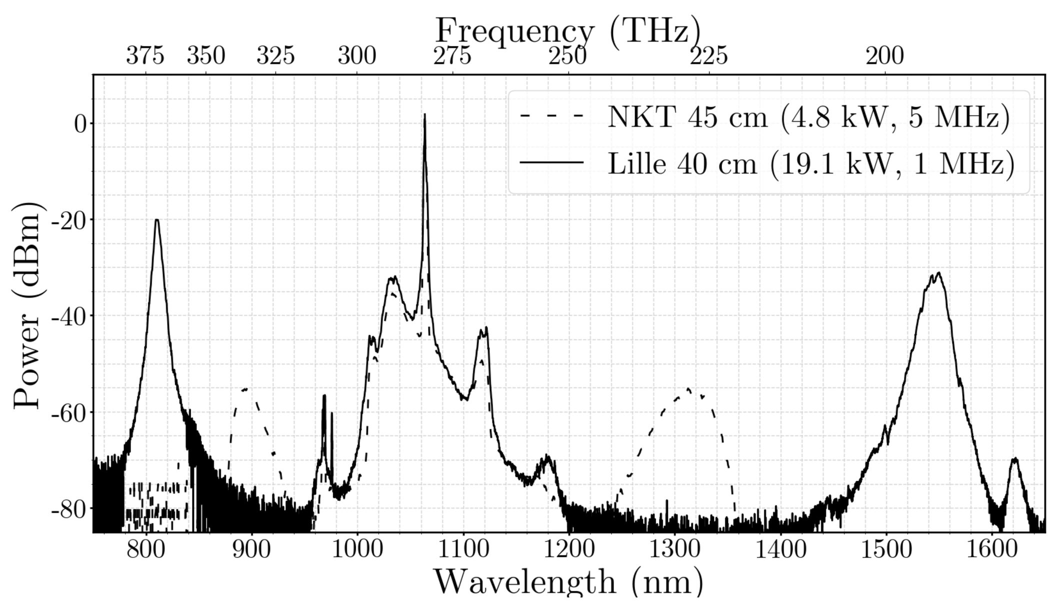

Fig. 5*: Output spectra of the NKT LMA5 and the Lille fibre*

Challenges and Outlook

- Output spectrum of Lille fibre promising because of the presence of two peaks at interesting wavelengths
- The birefringence and rich dynamics of nonlinear fibres have to be understood
- The yield and correlation of signal and idler photons have to be measured
- The pump should be filtered out
- Both signal and outer waves should be attenuated
- The signal and outer waves can be used to conduct an entanglement based QKD protocol thanks to a correlation measurement set-up (Fig. 7)
- Investigation of an SPDC set-up for comparison

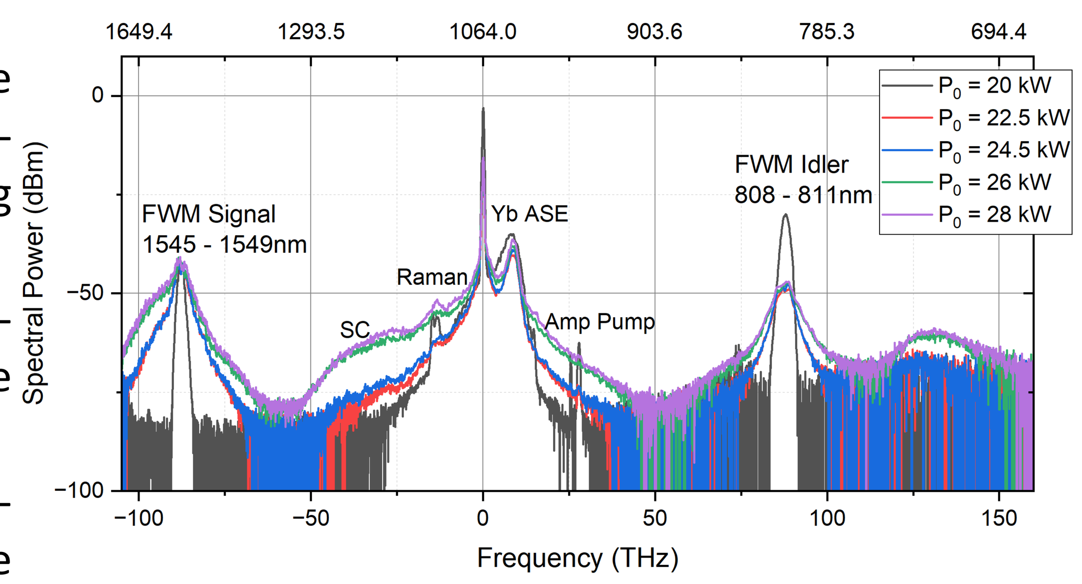

Fig. 6*: Lille fibre spectra for various input peak powers*

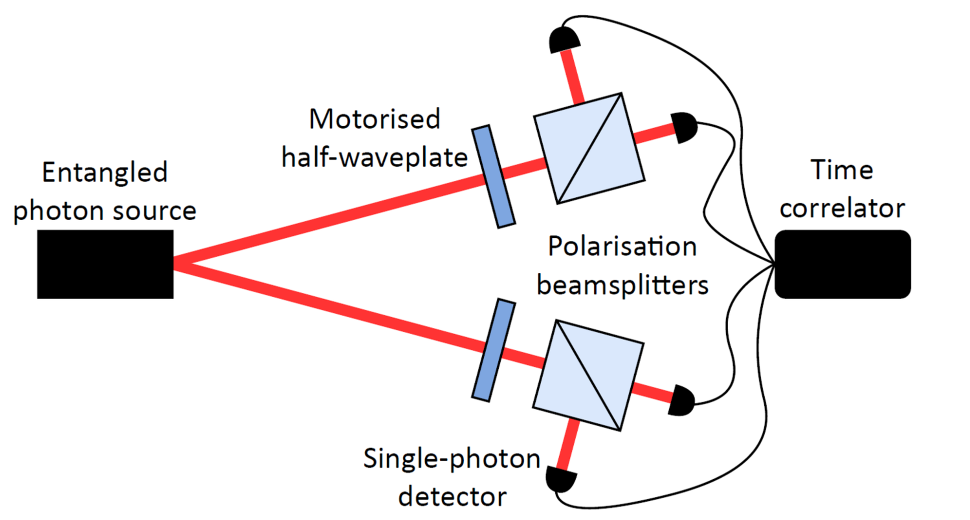

Fig. 7*: Example of a simple correlation measurement set-up*

Related publications

- A. Kudlinski et al., Opt. Express Vol. 21(7), pp. 8437 –8443 (2013)
- R T. Murray et al., Opt. Express Vol. 21(13), pp. 15826 –15833 (2013)

Contacts

selim.chaabani@uliege.be

Acknowledgement

This research is part of the Space4ReLaunch project, which is supported by the SPW Economie Emploi Recherche of the Walloon Region, under grant agreement no. 2210181.

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

[1]Belov, Michael, A Belov, V Gorodnichev, and S Alkov. 'Laser Reflection Method for Vegetation Monitoring at Eye-Safe Sensing Wavelengths in the NIR Spectral Band'. *IOP Conference Series: Materials Science and Engineering* 450 (30 November 2018): 022018. https://doi.org/10.1088/1757-899X/450/2/022018.