Going to 2.1 µm for Space Quantum Key Distribution

S. Chaabani[1,2*], A. Groulard[1*], M. Zajnulina[2], J.-B. Lecourt[2], S. Habraken[1], and Y. Hernandez[2]

[1] *Centre Spatial de Liège, Université de Liège, Angleur, 4031, Belgium*
[2] *Multitel Innovation Centre, Mons, 7000, Belgium*
[*] *Both authors contributed equally to this work.*

Quantum key distribution (QKD) is a secure communication method that relies on the laws of quantum mechanics. Despite the success of the Micius satellite in 2016 [1], and Europe's will to develop the IRIS^2 QKD satellite network [2], the operating wavelength is not yet determined.

We developed a comprehensive model to simulate a link between a ground station and a satellite at an arbitrary location on its orbit. This broadband model incorporates effects such as beam divergence, atmospheric absorption, solar noise, and more, to find the optimal wavelength regarding the signal-to-noise ratio (SNR) at the receiver telescope for given losses (Fig. 1(a)). For both uplink and downlink scenarios, we found the ∼2 to ∼2.5 µm atmospheric window to be by far the most promising, with the lowest atmospheric losses near 2.1 µm.

To validate our model, we present a tunable heralded single-photon source (Fig. 1(b)). An amplified mode-locked pulsed fibre laser (1064 nm, 32.45 MHz, 7.9 ps) is frequency doubled in a periodically poled lithium niobate (PPLN) crystal C1. Subsequently, the output of C1 is exploited for Type-0 spontaneous parametric down-conversion (SPDC) in the seven-grating PPLN crystal C2. When light is launched into the first and fifth gratings, idler photons are centred at 713 and 804 nm, with signal photons at 2.1 µm and 1570 nm respectively (Fig. 1(c)).

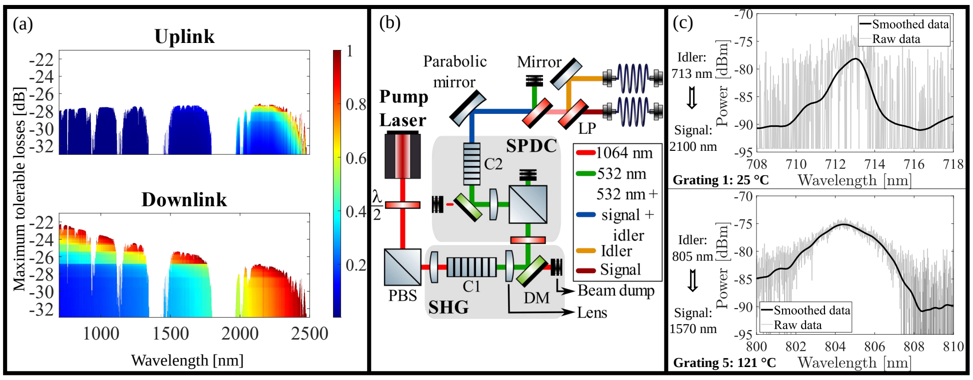

Figure 1: (a): Normalized SNR for each wavelength assuming any tolerable losses for a satellite at zenith at 500 km, (b): Schematic representation of the experimental set-up. PBS: polarisation beamsplitter, SHG: second-harmonic generation, C1: PPLN crystal, DM: dichroic mirror, C2: multi-grating PPLN crystal, SPDC: spontaneous parametric down-conversion, LP: longpass filter. (c): output spectra of idler photons in two different positions of the crystal C2.

As a next step, we will refine the model by incorporating a computation of the Quantum Bit Error Rate (QBER) to assess the interest of longer wavelengths in a quantum communication context. In parallel, our source will allow to study the propagation of the correlated photon pairs with signal photons from 1064 to 2300 nm in free-space. We will first characterise and optimise our source in the range accessible by the detectors available in the lab (< 1700 nm) and expand to further wavelengths later.

[1] J. Yin *et al* 2017 *Science* **356**, 1140-1144.

[2] O. Johnson, A. Kürsteiner 2023 *International Telecommunications Society (ITS)*, 277981.