On photonic spectral entanglement improving quantum communication

Karolina Sedziak, Mikołaj Lasota, Piotr Kolenderski

Faculty of Physics, Astronomy and Informatics, Institute of Physics,
Nicolaus Copernicus University
Grudziadzka 5, 87-100 Toruń, Poland

NICOLAUS COPERNICUS UNIVERSITY

NATIONAL LABORATORY OF ATOMIC, MOLECULAR AND OPTICAL PHYSICS

Abstract

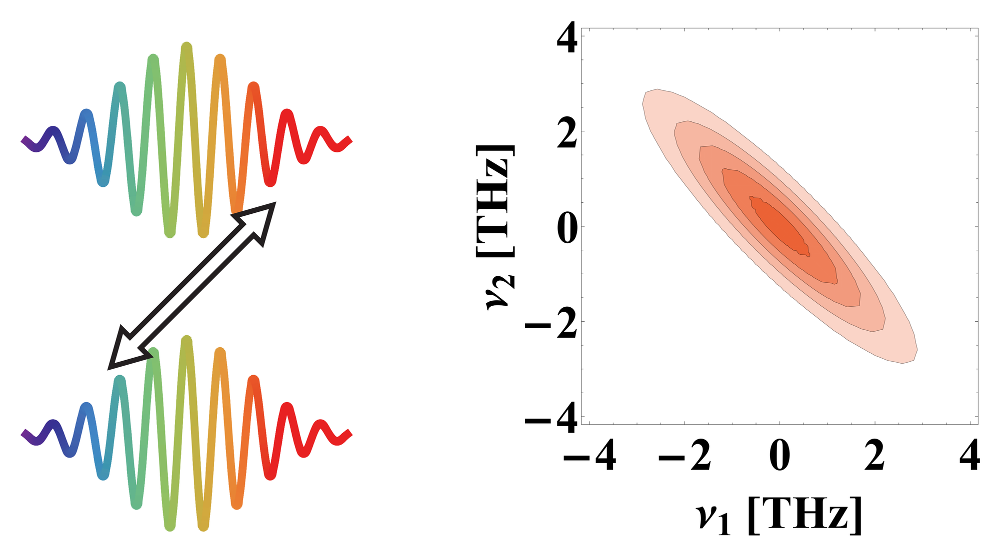
The main goal of quantum communication (QC) is sending secure messages over long distances. However, necessary realistic setup elements for quantum communication implementation suffer from various imperfections. Due to this fact, the distance in quantum communication is limited and sending messages may no longer be secure.

We have recently shown the way to improve the performance of photon detection system by modifying spectrally entangled photons [1,2]. The analysis showed that the stronger the spectral correlation, the narrower the wavepacket (less noise). We applied our results to increase the maximal security distance in a QC protocol.

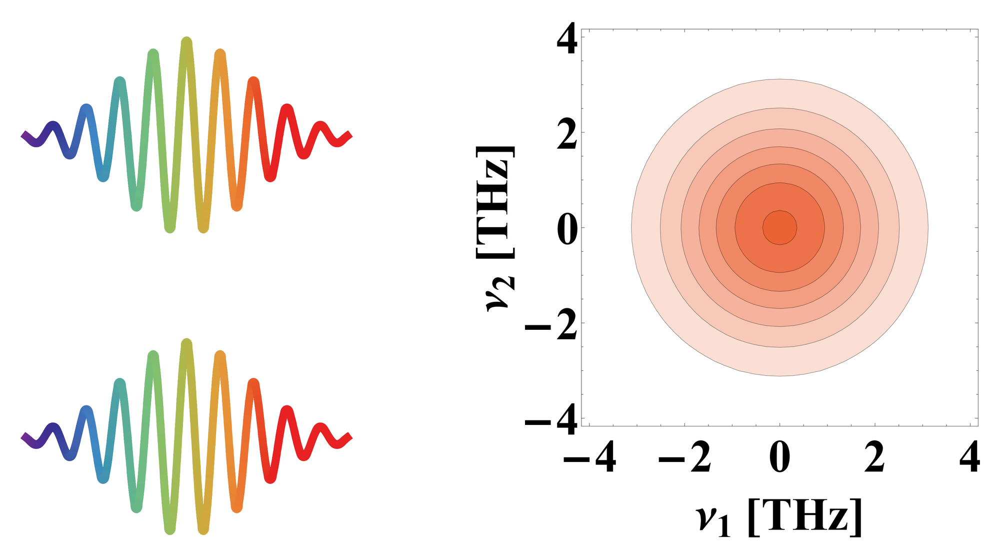
Spectral entanglement

A pair of photons produced in the process of parametric down-conversion can be entangled in several degrees of freedom: polarization, spectral and spatial. The types of spectral entanglemnt:

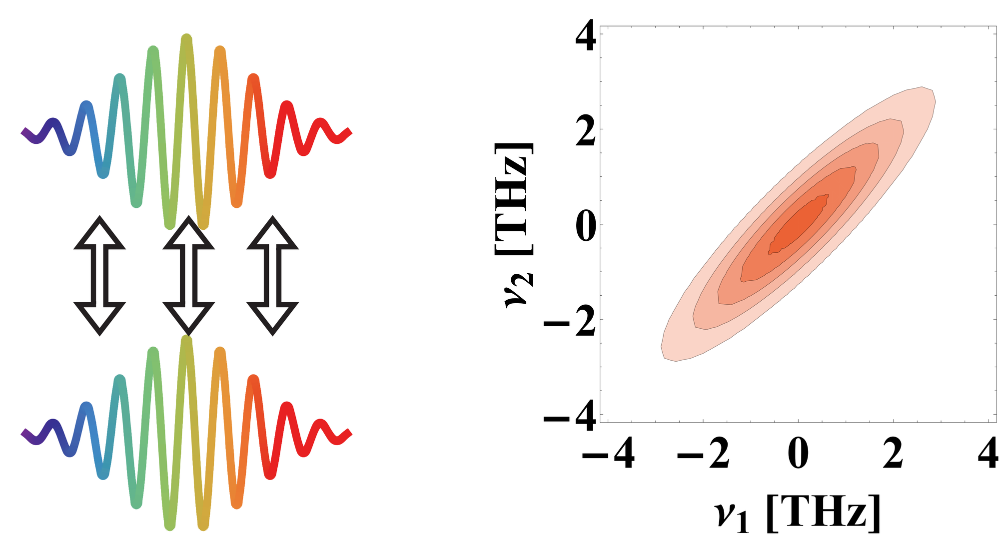
- negative



- no correlation



- positive [3, 4]



Here we utilized polarization entanglement to provide security and spectral entanglement to extend the maximal distance of security. The strength and the types of spectral entanglement have a strong effect on a temporal filtering method.

Implementation

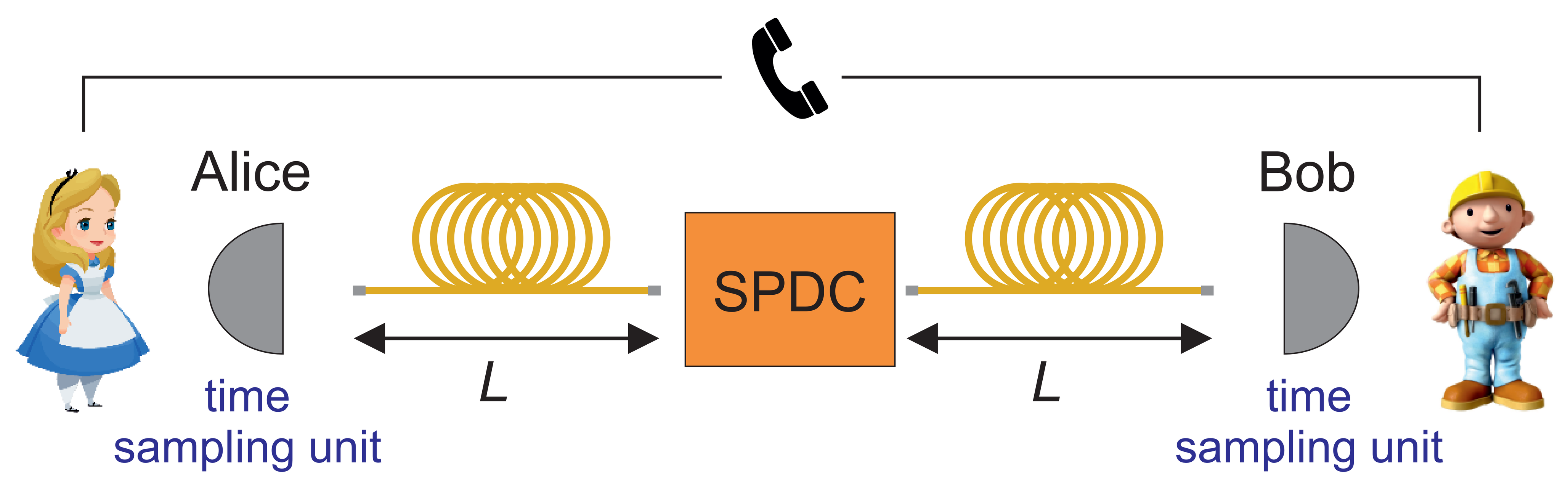
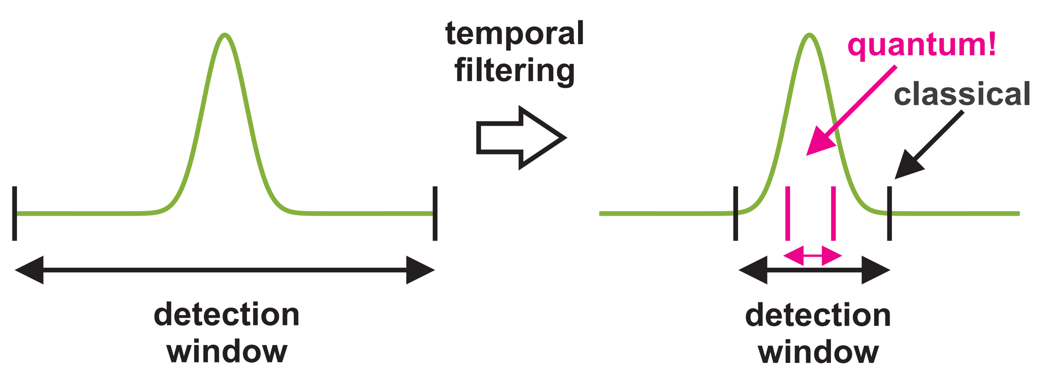


Figure 1: Detection scheme with the source of photons located in the middle between Alice and Bob.

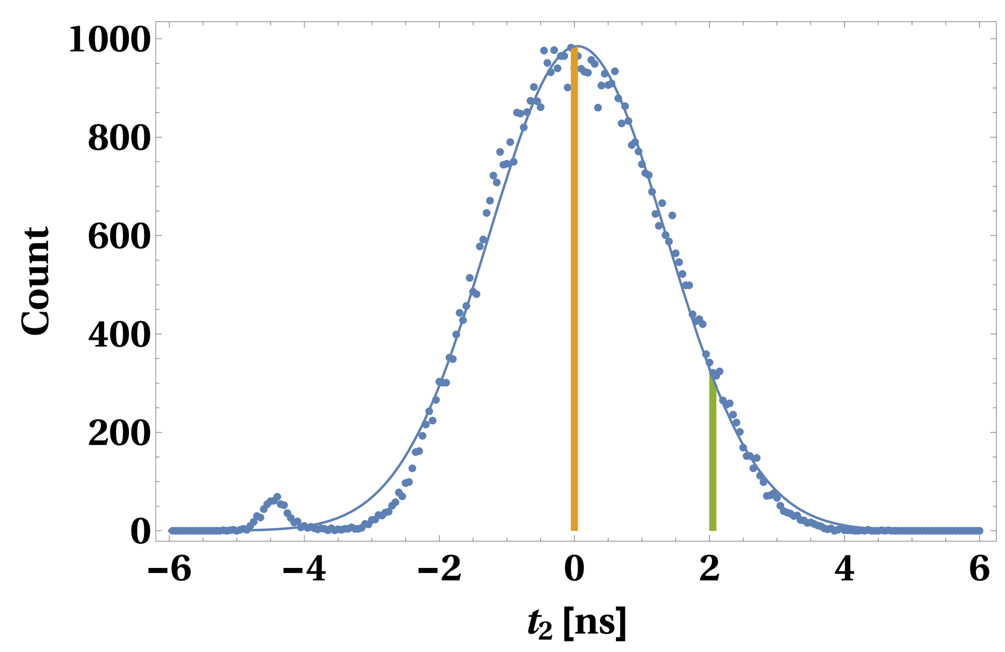
Temporal filtering

A popular method to decrease errors independent from the real classical signals is temporal filtering [5].

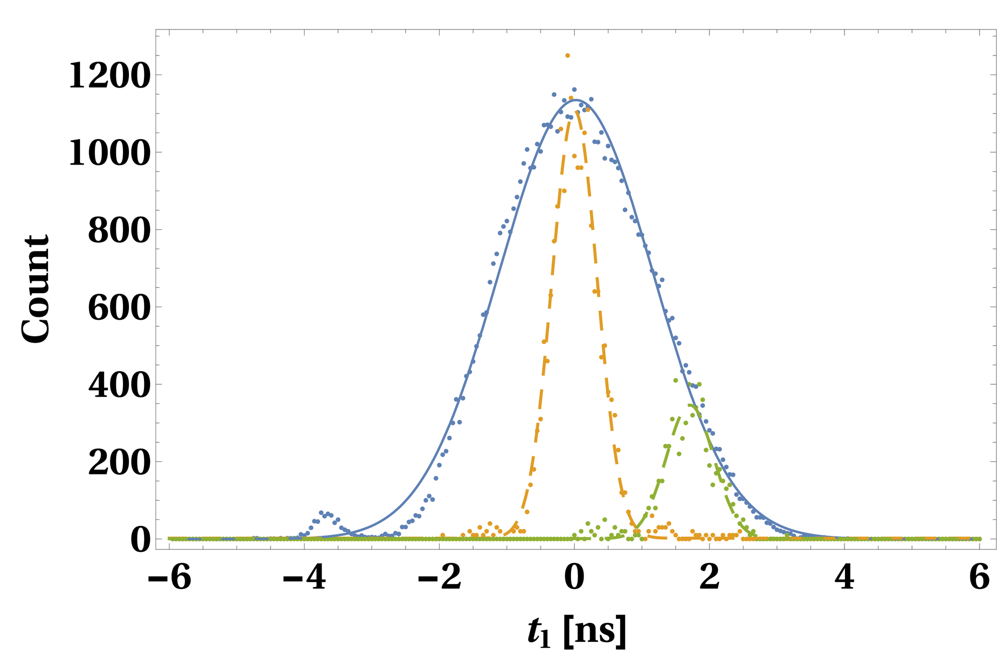


Furthermore, the use of spectrally correlated photons allows one to narrow the wave packet. In this case the information about another photon detection time is known.

The (non)-heralded distribution of photon's arrival time is depicted in Fig. 2 using (solid) dashed lines. We observe that the temporal width of the heralded photon is narrower compared to the non-heralded one [6].



(a) Heralding distribution of photon's arrival time



(b) (Non)-heralded distribution of photon's arrival time

Figure 2: The distribution of arrival time of the photon (blue dots) obtained in the experiments. In panel (a), two sets of detection times in a range of 100 ps centered around a chosen time t_2, marked by orange and green areas, correspond to distribution of arrival time of the heralded photons (green and orange dots) depicted in panel (b).

Results

The study of the ratio of the heralded to the non-heralded widths is presented in Fig.3. There is a lower limit of the heralded photon width, given by a relation $\tau_{1h}/\tau_1 \approx \sqrt{1-\rho^2}$. In our case the limit is around 300 ps which is far above the detection system jitter, which is around 45 ps (RMS).

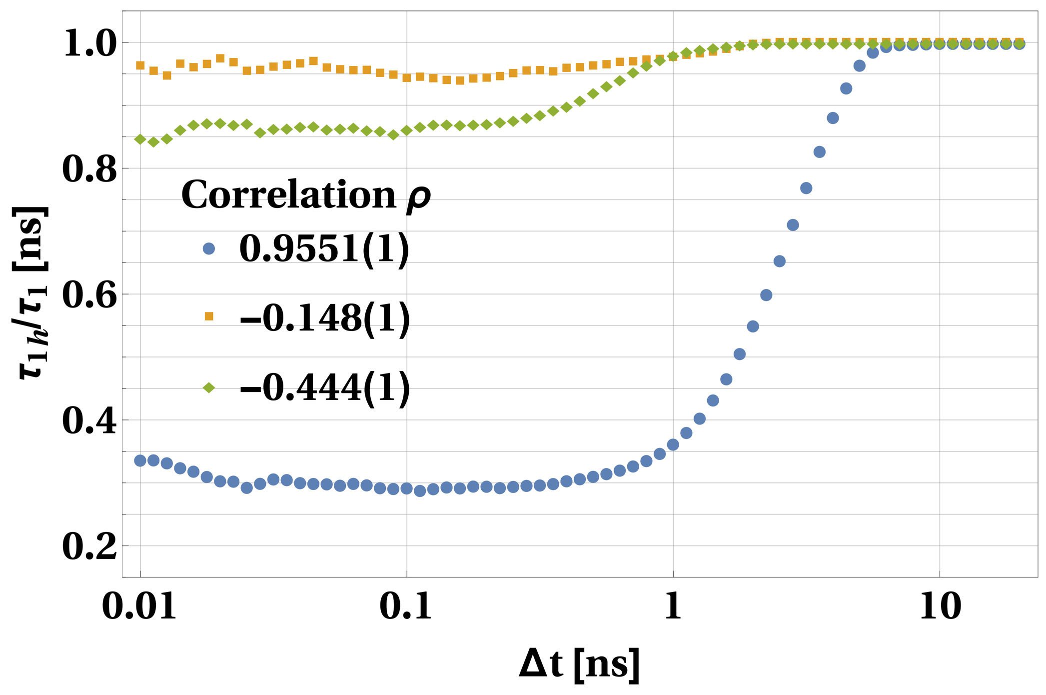


Figure 3: The ratio of the heralded to the non-heralded widths as a function of the time window of the heralding photon for different values of correlation.

Our method for narrowing the wavepacket can be applied to increase maximal security distance in typical symmetric QC scheme [1].

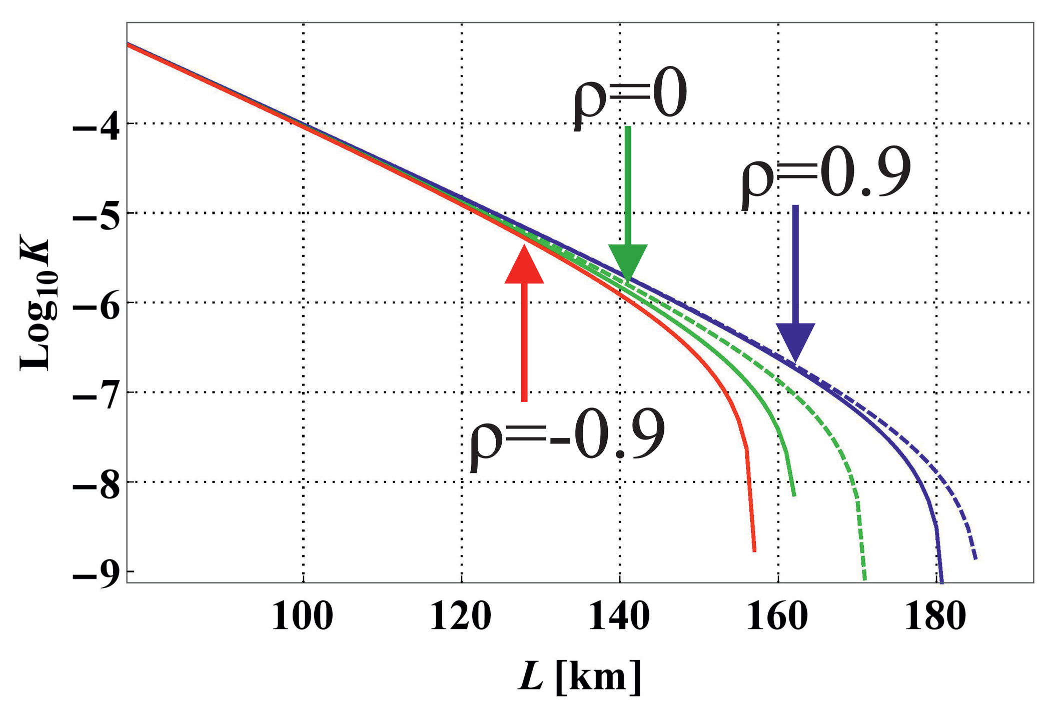


Figure 4: The secure key generation rate as a function of the fiber link length for values of spectral correlation coefficient, ρ. The dashed (solid) lines correspond to the case where the global time reference is (is not) available.

References

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