On photonic spectral entanglement improving quantum communication

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Abstract

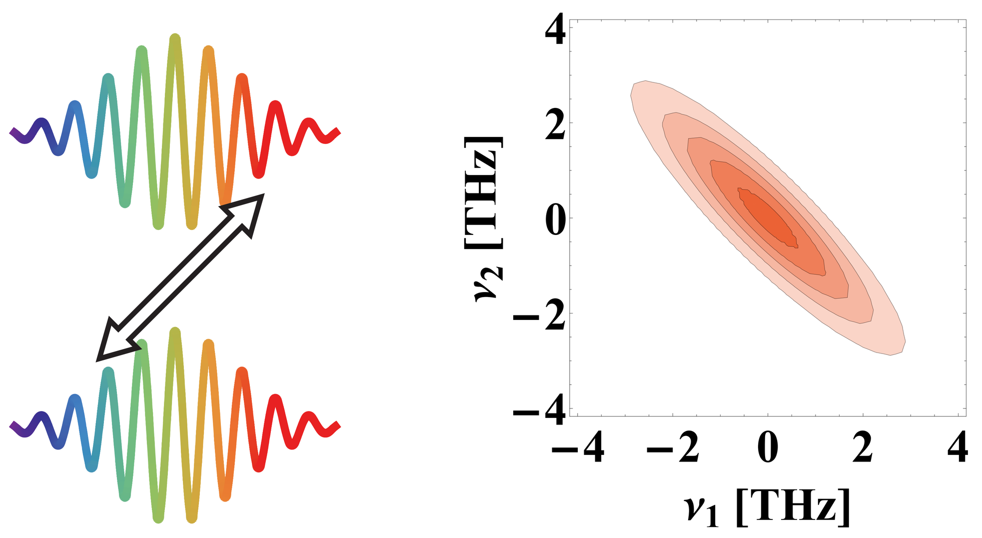
The main aim of quantum communication (QC) is sending secure message over long distance. However, necessary realistic setup elements for quantum communication implementation suffer from various imperfections. Due to this fact the distance in quantum communication is limited and sending message may be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

We have recently shown the way to improve a detection system by using spectrally entangled photons [1,2]. The analysis showed that the stronger the spectral correlation, the narrower the wave packet (less noise). Also, we apply our results to increase the maximal security distance in QC protocol by using spectrally correlated photon pairs.

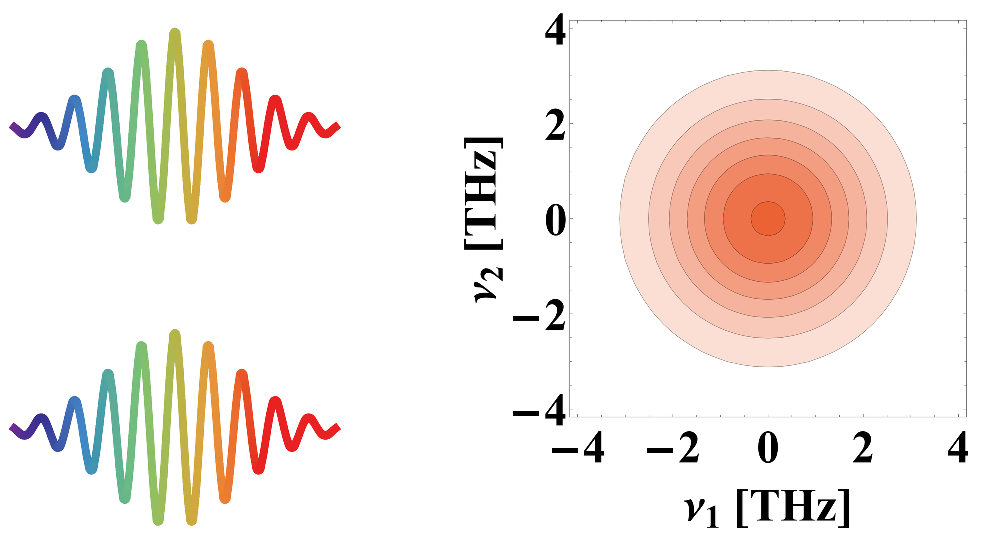
Spectral entanglement

A pair of photons produced in the process of parametric down-conversion can be entangled in all degrees of freedom: polarization, spectral and spatial. Here we utilized polarization entanglement to provide security and spectral entanglement to extend the transmission distance. The strength and the kind of spectral correlation has a strong effect on the method of alleviating deteriorating effects of the detector imperfections. The types of spectral correlations:

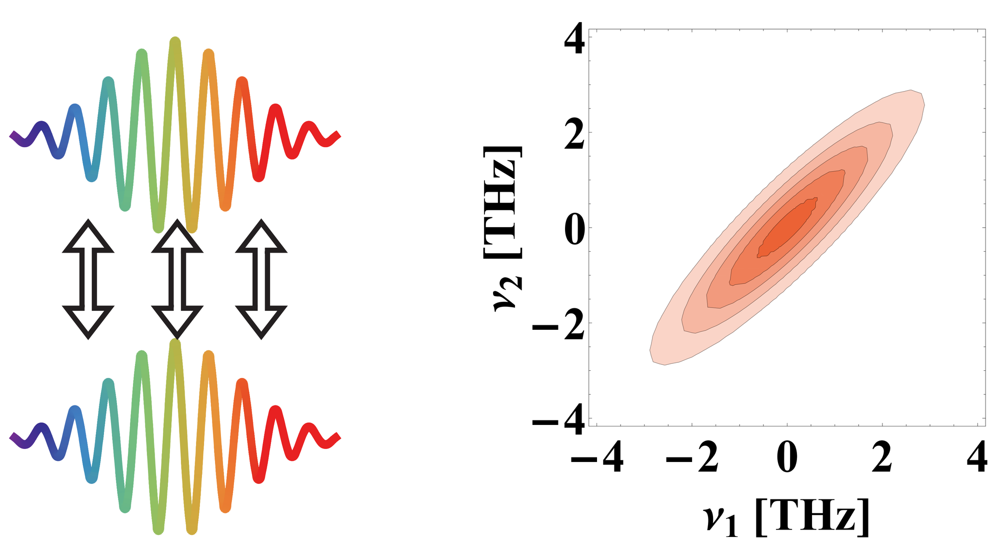
- negative



- no correlation



- **positive**[3, 4]



Implementation

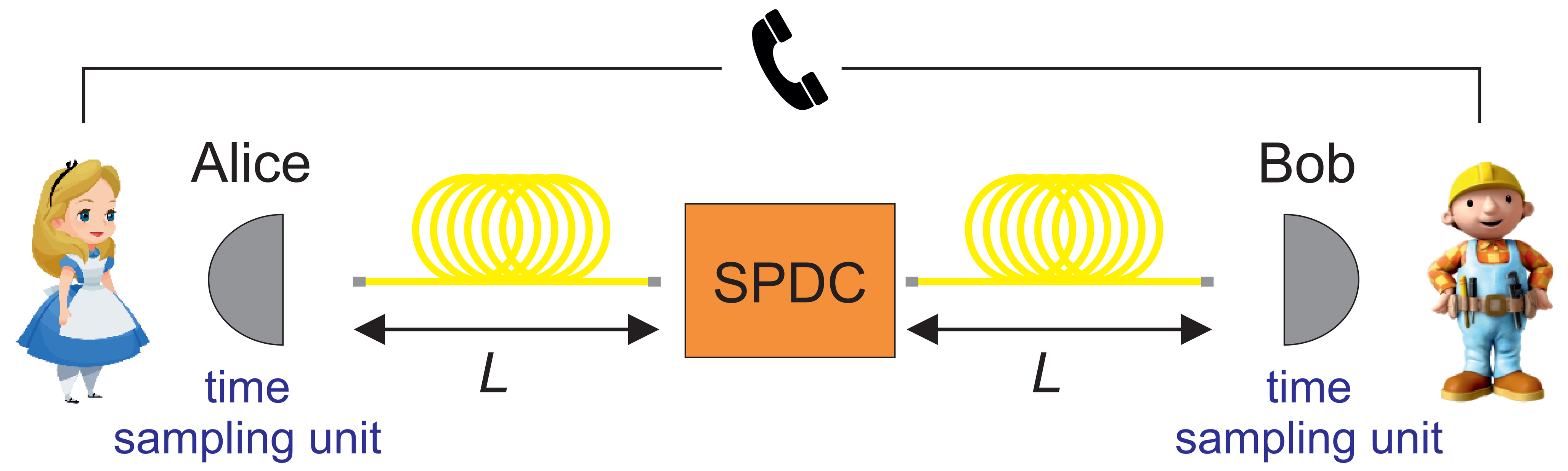
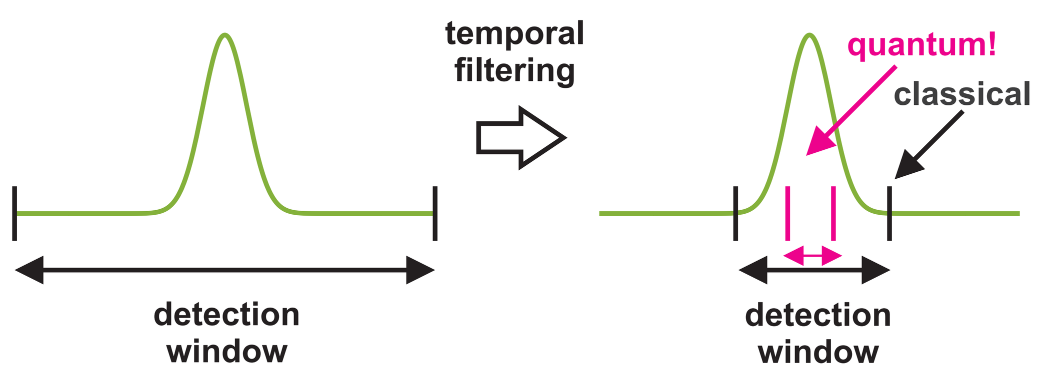


Figure 1: Detection scheme with the source of photons located in the middle between Alice and Bob.

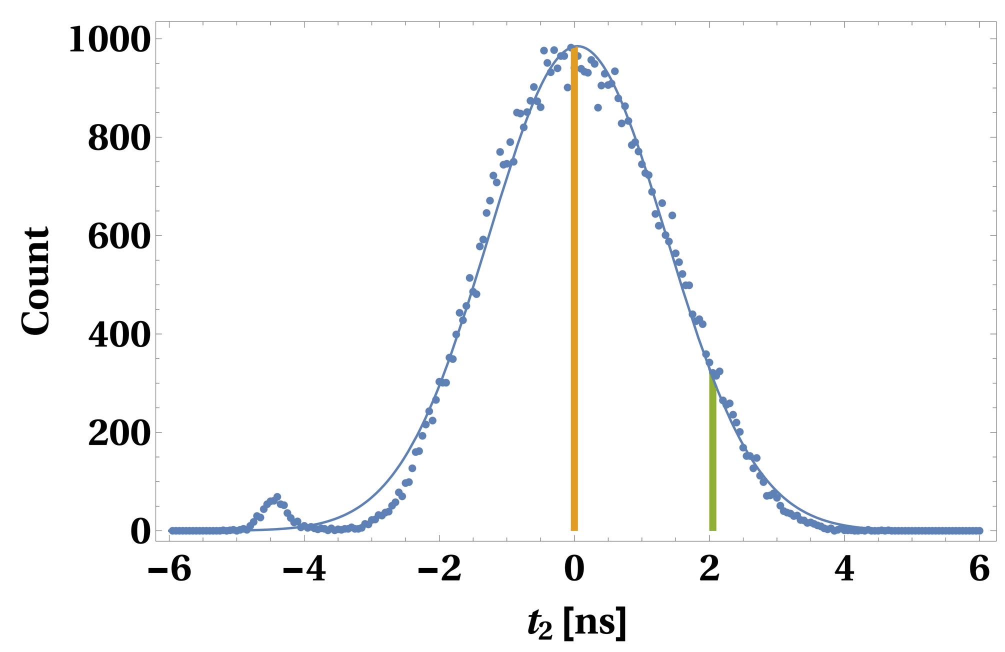
Temporal filtering

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

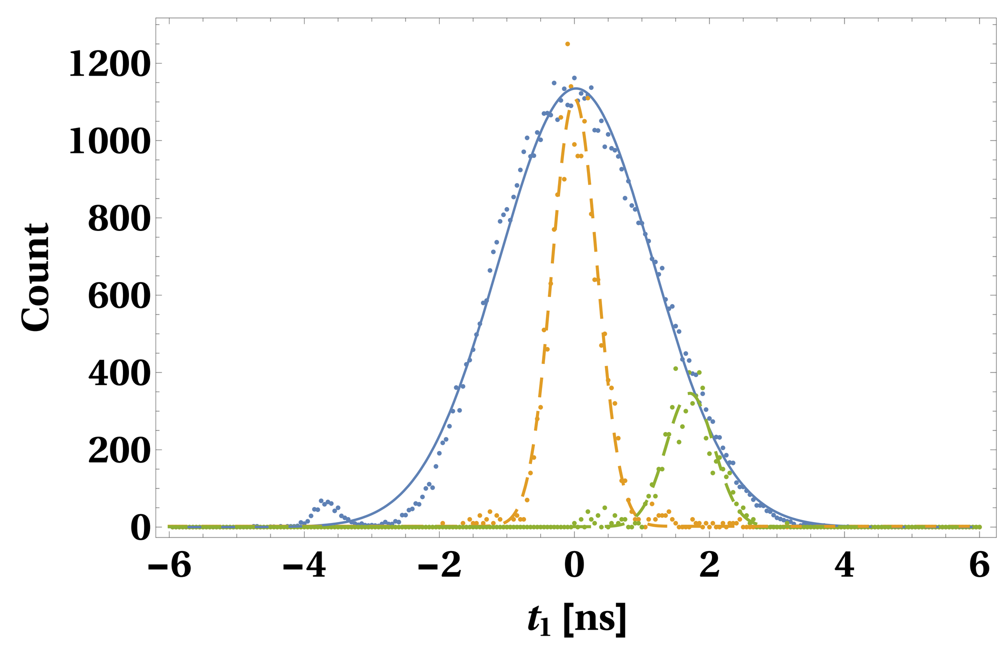


However the use of spectrally correlated photons allows to narrower wave packet, in the case the information about another photon detection time is known.

The (non)-heralded distribution of arrival times 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 arrival times



(b) (Non)-heralded distribution of arrival times

Figure 2: The distribution of arrival time of the photons (blue dots) obtained in the experiments. In panel (a), two exemplary sets of detections in a rage 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).

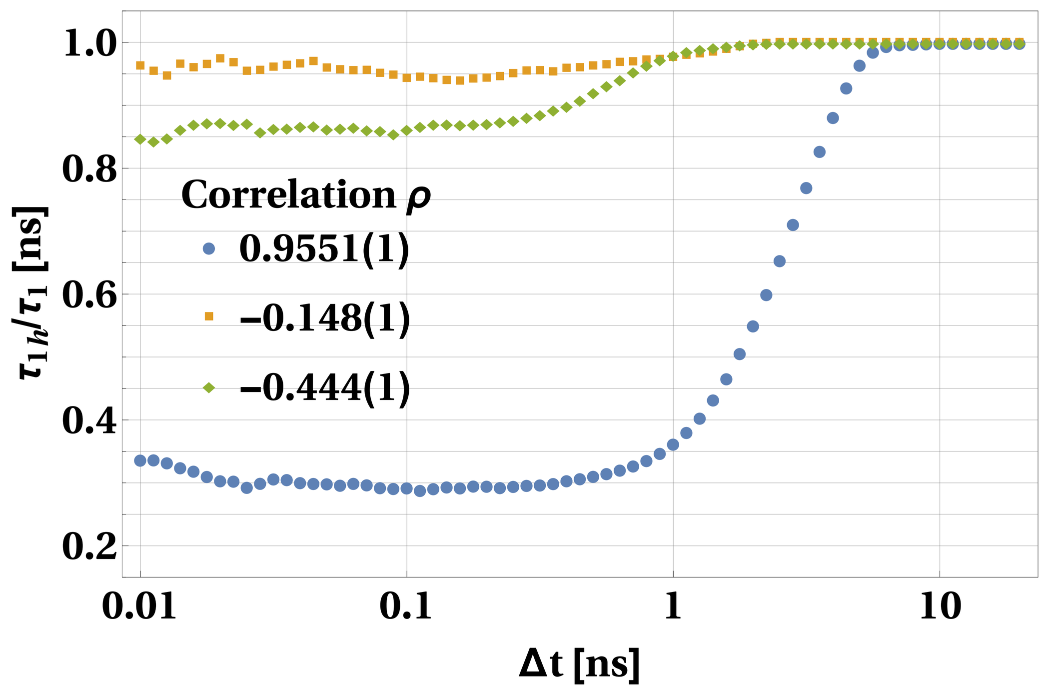


Figure 3: The ratio of the heralded to the non-heralded widths as a function of the time window of the heralding photon for different value of correlation.

The experimental results can be applied for security analysis of the quantum key distribution scheme in order to increase maximal security distance by utilizing photon pairs featuring spectral correlation.

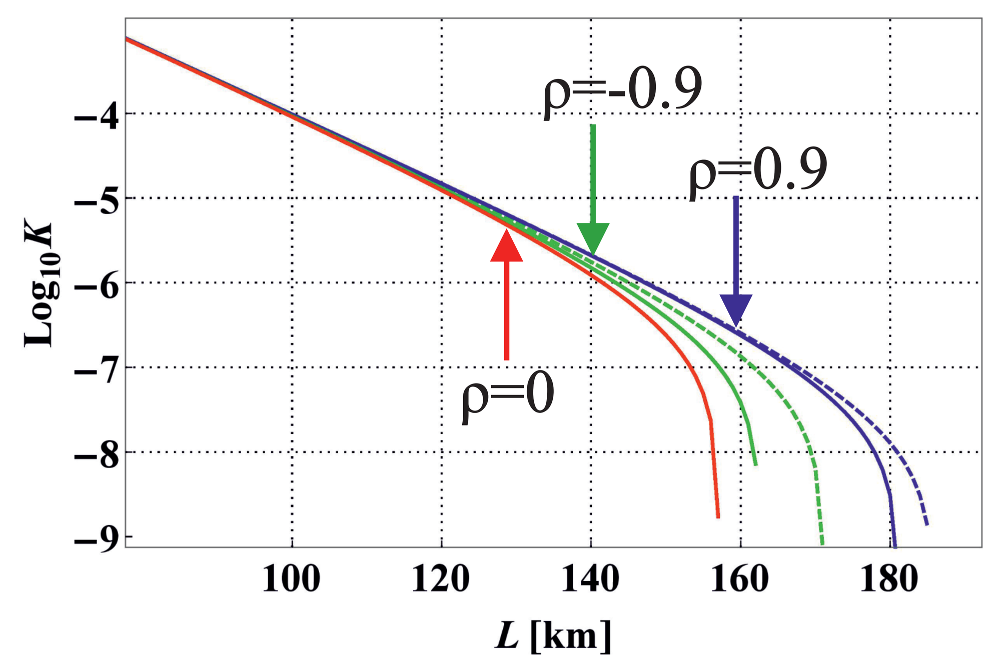


Figure 4: The secure key generation rate as a function of the fiber link length for different spectral correlations, ρ. The dashed (solid) lines correspond to the case where the global time reference is (is not) available [1].

References

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