EPJ Web of Conferences 103, 10010 (2015)
DOI: 10.1051/epjconf/201510310010

The Source of Time-Correlated Photons at 1.064 μm and its Applications

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Abstract. The source of time-correlated photon-pairs at 1064 nm is described. The source consists of the spontaneous parametric down-conversion (SPDC) generator, pumped by cw laser operating at 532 nm, and the measuring and control appliances. One of the main parts of the electronic systems is the "time-to-digital converter" which is designed and built by our group. The system allows to create and detect correlation of photon pairs with resolution better than 1 ns. We adduce the results of a quantum key distribution through open air. The key length was about 5000 bits and the accuracy ~0.1%.

Keywords: quantum optics, spontaneous parametric down-conversion

The SPDC sources of correlated and entangled photons have taken its rightful place in modern quantum optical technologies [1,2]. In present work we report the time-correlated source of photons at 1064 nm and its applications on quantum key distribution via a novel time-algorithm with low error rate. The usage of this wavelength is motivated by potential possibility of applications of such sources as cryptographic sources implemented in existing fiber-based Internet connections with the future YAG:Nd^{3+} point-to-point re-transmitters. For the same goal we use the quantum key distribution algorithm based on time-correlations. It should be noted that sources at 1064 nm previously were not widely used due to low quantum efficiency of existing avalanche-photodiodes. But now appropriate detectors for this spectral region have been invented and we may change our mind about this spectral region. Our source is based on the single-crystal SPDC scheme using a BBO crystal. The pump (0-300 mW) was the second harmonic of cw YAG:Nd^{3+} diode-pumped laser. It has coherence length of ~ 3 mm. The SPDC crystal is the 3-mm length type-I cut (e-oo) BBO crystal. We use ID Quantique id400 SERIES avalanche photodiode having high quantum efficiency at 1064 nm, the multichannel time-to-digital converter IDQ's id800-TDC and the self-designed, developed as a part of the import substitution programm, time-to-digital converter "TDC-6" having the characteristics shown below:

Number of Channels	Data Transfer Rate	Timing resolution	RMS	Input levels	Minimum Pulse Width	Dimensions
3	3 Msa/s	81 ps	80 ps	LVTTL (5V tolerant)	4 ns	200x50x200

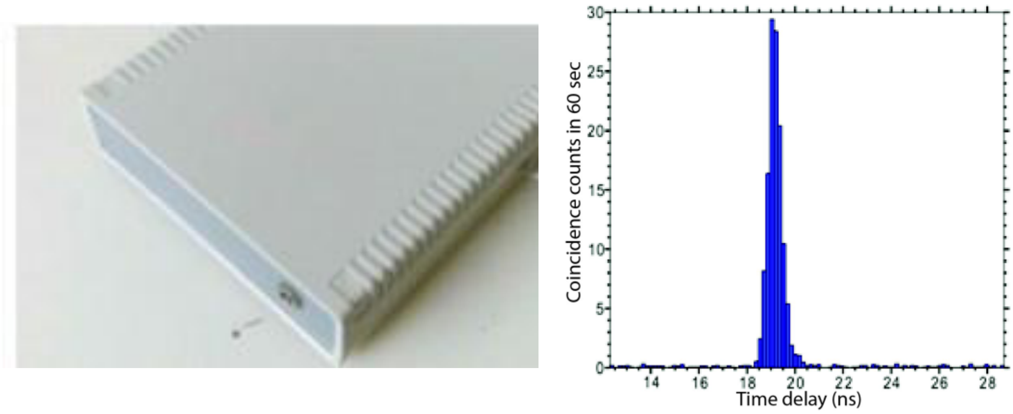

Figure 1. Left: outward appearance of the time-to-digital converter "TDC-6". Right: Typical correlation function in the presence of delay Δt=t1-t2 between channels

The outward appearance of the device is shown in Fig. 1 (left).

Quantum key distribution is demonstrated in a system having one of the photons propagating through a few meter length delay line. Also we have developed an algorithm for histogram construction which allows adequately process data regardless the sign of the delay between channels.

A typical histogram (with delay line of 5 m) is shown in Fig. 1(right). The method of histogram construction underlies our proprietary time-correlation based method of quantum key distribution. In the scheme the correlated photon rate can be varied from 0 to 10 million per second by changing the pump power. The photo detectors (ID Quantique id400 SERIES avalanche photo diodes) has a dead time of 10 μs. In order to have the better signal-noise ratio we used the regime with 20-40 thousand photons per second. Thus the quantum key forming rate was about 1,000 bit/sec. The number of counted photons in each channel was about 100,000 pcs, 5000 of them were coincided in two channels. This provided an opportunity to form a key length of about 5,000 bits. The data clearly demonstrate that the key distribution does not exhibit any periodicity and regularity, i.e. as expected, they are the good quality random sequences. The quantity of errors in the raw key was less than 0.1%. Experiments have shown that the number of errors during the formation of the key does not depend on the length of the delay line. It is important that the number of errors is in sub-percent level, which is more than sufficient for commercial implementation of the algorithm, because such error rate can easily be fixed at the level of an open communication channel with the help of common error-correcting codes.

The developed algorithm uses random registration time. Therefore, its basic principle based on time-correlated events may be used not only for single photons, but also for multi-photonlight pulses.

We thank OOO "LOEP" for financial support, as well as professor A. Chirkin for fruitful discussions.

References

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