Symmetrical Clock Synchronization with Time-Correlated Photon Pairs

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We present a distance-independent synchronization protocol based on a symmetric distribution of single-photons between remote clocks [1]. Tight time correlations of the photon pairs generated by spontaneous parametric down-conversion (SPDC) enables precise synchronization. Similar to existing bi-directional protocols [2], the determination of the clock offsets is independent of the signal propagation times for a symmetrical communication channel, and is therefore inherently robust against symmetric-channel-delay attacks. Our protocol, based on existing quantum communication techniques, provides a natural complement to Global Navigation Satellite Systems (GNSS) for quantum key distribution [3,4], and is suited for synchronization between mobile stations where pair rates are typically low and propagation times are constantly changing. The single-photon regime allows, in principle, an additional security layer by distributing polarization entanglement and using a Bell measurement to verify the origin of the photons.

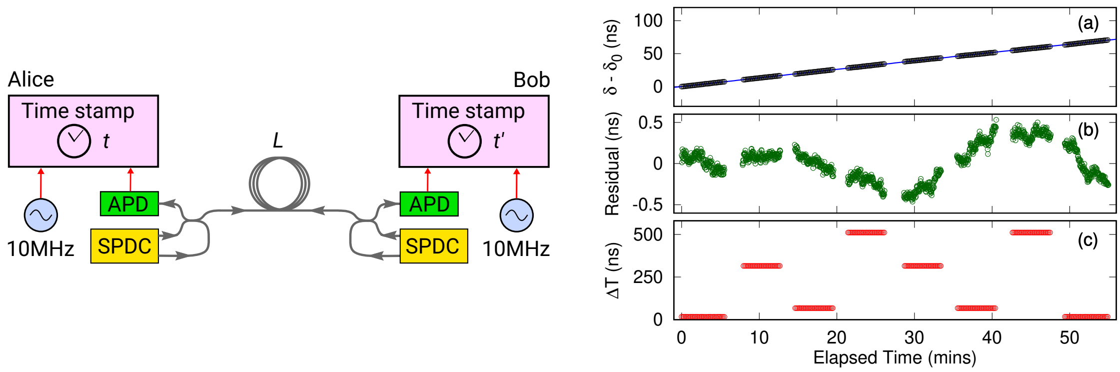

Fig. 1 Left: Clock synchronization setup. Alice and Bob each have a source of time-correlated photon pairs produced from spontaneous parametric down-conversion (SPDC) and an avalanche photodetector (APD). One photon of the pair is detected locally, while the other photon is sent through a single mode fiber of length L to be detected on the remote side. Times of arrival for all detected photons are recorded at each side with respect to the local clock. Right: (a) Measured offset δ between two clocks with independent frequency references, with respect to the initial measured offset δ_0. Each point corresponds to a 2 s acquisition time. Continuous blue line: fit used to extract the relative frequency accuracy ($\approx 4\times10^{-11}$) between the clocks. (b) Residual of the fit fluctuates due to the intrinsic instability of the individual frequency references. (c) The round trip time ΔT was changed using different fiber lengths.

We simulate a symmetric-channel-delay attack by changing the propagation time between Alice and Bob every 5 mins using four fibers of different lengths. The measured offset $\delta(t)$, evaluated from time stamps collected every 2 s, tracks the drift between the two frequency references (Fig. 1 (right, a)). The clock drift is well approximated by a parabolic model that we estimate and subtract from the measured $\delta(t)$. The remaining fluctuation (Fig. 1 (right, b)), does not show any significant correlation with the estimated propagation time (Fig. 1 (right, c)), proving the resilience of the protocol against symmetric-channel-delay attacks. These fluctuations are mainly due to the intrinsic frequency instabilities of the frequency references, resulting in the slightly reduced synchronization precision of 51 ps in 100 s, comparable with the Allan deviation of our clocks ($< 1\times10^{-12}$).

References

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