One-way Differential QPSK Quantum Key Distribution with Channel Impairments Compensation

Q. Xu¹, M. B. Costa e Silva¹, P. Gallion¹, F. J. Mendieta²

¹ : Ecole Nationale Supérieure des Télécommunications, CNRS, LTCI UMR 5141, 75013 Paris, France.
² : on leave from CICESE, km.107 Carr. Tijuana, Ensenada, Baja California 22800, México

Reliable continuous operation, high key generation rates and long exchange distance are essential for a practical Quantum Key Distribution (QKD) system. We report an experimental demonstration of a BB84 QKD one-way system using fainted pulses and a QPSK key format including a time-multiplexed unmodulated carrier reference at Alice’s end, and a differential reception at Bob’s end [1], in which phase drift and polarization mismatch are two critical impairments to overcome.

We use a four-phase state BB84 protocol in which keys are encoded on the relative phase difference between two pulses $\Phi_A (\pm \pi/4, \pm 3\pi/4)$ and $\Phi_B (\pm \pi/4)$ as depicted in Fig. 1(a) [2]. Polarization and phase fluctuations in the common channel (long fiber link) are compensated thanks to this differential scheme, and the problem reduces to the interferometer drift compensation.

We perform coherent detection for the QPSK signals that consists of delaying and mixing the two pulses at Bob’s end. We construct two prototype detection schemes at telecom wavelength: a) “Photon counting” using equal intensity pulses and cooled Geiger-mode APDs that provide the built-in decision; b) “Super homodyne” using strong reference pulses (the lower arm at Alice’s end) and balanced P.I.N photodetectors at room temperature that provides a high mixing gain, and in this case the mean square photocurrent fluctuation is close to the shot noise limit.

A practical continuously operating one-way QKD system requires overcoming some critical impairments that decrease the visibility of interferometer and increases the QBER considerably: 1) the instability and mismatch of polarization states; 2) the phase drift $\Delta \Phi$ due to different temperature, pressure and mechanical stress conditions.

In our experimental setup based on the photon counting approach, the pulses have mutually orthogonal polarizations in Alice’s interferometer which constitutes the QPSK key at the long fiber input. We also use a QBER-based feedback to compensate for the phase drift $\Delta \Phi$ with an all-fiber phase shifter (PS in Fig. 1(a)). The phase tracking and compensation algorithm is realized with a portion of training frames to correct the phase error $\Delta \Phi$. A numerical result of real time phase compensation with 10% training frames is shown in Fig. 1(b) for the photon counting scheme. Base on these results, presently we develop a feedback configuration adapted for the super homodyne approach.

References