High-precision phase compensation for continuous-variable quantum key distribution with feedback optimization technique

Yingming Zhou,[1] Weiqi Liu,[2] Tao Wang,[1] Peng Huang,[1,*] and Guihua Zeng[1,2,†]

[1] *State Key Laboratory of Advanced Optical Communication Systems and Networks, and Center of Quantum Sensing and Information Processing (QSIP), Shanghai Jiao Tong University, Shanghai 200240, China*

[2] *College of Information Science and Technology, Northwest University, Xi'an 710127, Shaanxi, China*

Phase compensation is a necessary procedure in practical continuous-variable quantum key distribution(CVQKD) due to the phase drift of quantum signal over quantum channel. However, the inaccuracy of phase compensation algorithm at low signal-to-noise-ratio(SNR) would lead to extra excess noise. Such behavior inevitably degrade the performance of the CVQKD system. Here, we present a novel approach to control the extra excess noise, which can be implemented with more efficient software algorithm in the post-processing procedure based on the noise raw key data. Subsequently, with assistance of such approach, the phase drift can be quietly restricted and the performance of the practical CVQKD system can be improved.

Currently, a few phase compensation schemes in the CVQKD system[1] employed either hardware algorithm[2] by means of adjusting of light path or software algorithm[3] utilizing the noise raw key data. In particular, instantaneity and accuracy of such algorithms have influences on both performance and security of the practical CVQKD system. The overdue phase compensation would affect the generation of secure secret key and decrease the secret key rate, while the inaccuracy $\Delta\phi$ of such algorithm would induce phase noise to the involved CVQKD system.

A previous compensation scheme employs the cross-correlation algorithm[3] to calculate the phase drift angle ϕ. In detail, as shown in Fig.1, the cross-correlation values between the known phase drift training data and the received data on Bob's side are computed. In this case, the phase drift will be derived to compensate for the angle on Alice's side. However, the accuracy of such approaches are limited by the imprecise calculation of the cross-correlation.

Here, we propose a novel high-precision algorithm called as feedback optimization technique, which is based on the same data flow just like previous schemes but different from the cross-correlation approach. The schematic of the proposed feedback optimization technique is demonstrated in Fig.2, In this scheme, Bob first preestablishes a drift angle ϕ to compensate for training data in a frame. And then we use the received data on Bob's side to subtract the compensated training data. In this way, a deviation signal could be obtained. Following this, the Least Mean Square Error is availably calculated to feedback a more closer drift angle on the training data. Thus, this high-precision phase will be obtained to transmit to Alice's side and used to compensate for the Alice's data.

Based on the proposed scheme, the real-time performance and the compensational precision are investigated, and then the phase noise can be accurately derived. In our implementation, each phase drift angle ϕ is computed with over 4000 pulses. The phase error can be suppressed to 0.01° per frame under a normal SNR of approximately 0.01. In this way, the phase noise would decrease to a more lower level about 10^{-8}. Hence, much less excess noise will be achieved in practices, while the secret key rate can be improved and the secure transmission distance can be prolonged. In addition, the practical security of the involved CVQKD system can be also guaranteed[4].

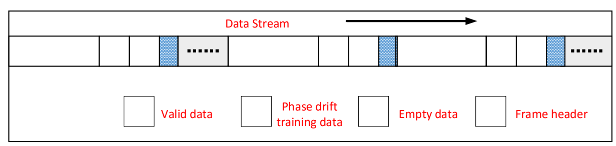

FIG. 1. Sample data flow of the CVQKD system

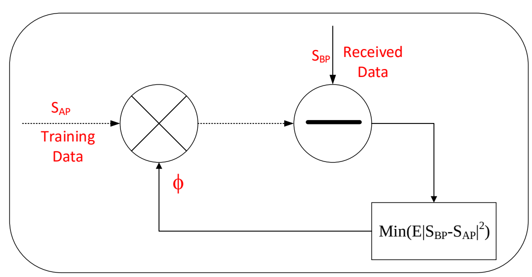

FIG. 2. Schematic of the high precision phase compensation

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* huang.peng@sjtu.edu.cn
† ghzeng@sjtu.edu.cn