A novel long-distance continuous-variable quantum key distribution scheme with state-discrimination receiver and non-Gaussian operation

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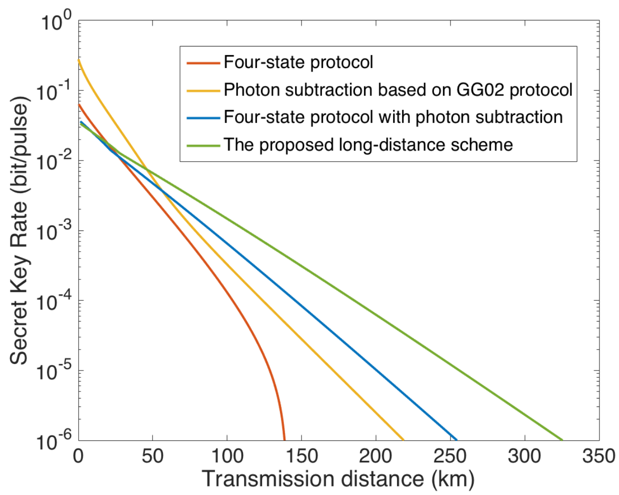

FIG. 1. Secret key rates as a function of transmission distance for every optimal modulation variance. Red line shows the original four-state CVQKD protocol, yellow line denotes the optimal one-photon subtraction scheme for Gaussian modulated coherent state, blue line represents the scheme of four-state protocol with one-photon subtraction, and the green line denotes the proposed long-distance scheme with state-discrimination receiver and non-Gaussian operation.

Continuous-variable quantum key distribution (CVQKD) could potentially achieve higher secret key rate, but seems unfortunately limited to much shorter transmission distance than its discrete-variable counterpart [1]. The transmission distance of CVQKD is mainly limited by the reconciliation efficiency and detection efficiency at very low signal-to-noise ratio (SNR).

To solve these problems, we propose a long-distance continuous-variable quantum key distribution (CVQKD) scheme in point-to-point quantum communication. In stead of traditional Gaussian modulation which continuously encodes information into both quadrature $\hat{x}$ and quadrature $\hat{p}$, we adopt four-state discrete modulation to encode information. This modulation can well tolerate lower signal-to-noise rate (SNR) hence it is more suitable for the long-distance transmission [2]. Meanwhile, an improved state-discrimination receiver is applied at Bob's side to lengthen the maximal transmission distance, since the receiver can be deemed optimized quantum measurement for the received nonorthogonal coherent states that allows the state-discrimination beating the standard quantum limit [3, 4]. In addition, a non-Gaussian operation, in particular, the photon subtraction operation is used to split the incoming signal at Alice's side. This non-Gaussian operation has been proven to be beneficial for improving performance of CVQKD [5, 6]. We consequently integrate these techniques into a novel long-distance CVQKD scheme by adopting multiplexing technique.

The proposed scheme can greatly increase the secure transmission distance and thus meet the requirement of long-distance transmission. Fig. (1) shows that the transmission distance of the proposed long-distance CVQKD scheme surpasses over 300 km and outperforms other existing CVQKD schemes in terms of the maximum transmission distance.

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