Application of virtual photon subtraction in two-way continuous-variable quantum cryptography

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Continuous-variables quantum key distribution(CV-QKD) [1] based on Gaussian modulated coherent state has been rapidly developed in the past few years due to its natural advantages on combination with commercial telecom systems. But general tolerable excess noise at long distance such as 100km is less than 0.005 not high enough to achieve a robust commercial CV-QKD system. Thus the improvement method of tolerable excess noise is always attractive in practical CV-QKD research. Two-way CV-QKD [2] is proposed to tolerate higher excess noise by a non-trivial superadditive of quantum channel. There is a more feasible two-way CV-QKD [3] protocol which is easier to implement by repalcing the displacement operation with a beam splitter. Although two-way CV-QKD can enhance tolerable excess noise compared to one-way protocol, the tolerable noise still decreases rapidly below 0.005 with increase of distance.

Here, we present an application of virtual photon subtraction in two-way CV-QKD to improve the tolerable noise at long distance. Photon subtraction can enhance the entanglement of two-mode squeezed vacuum state which is always used as source of entanglement-based CV-QKD. However, practical photon subtraction cannot approach the expected performance because of the imperfect efficiency of photon number resolving detector. Fortunately, the virtual photon subtraction [4] implemented by non-Gaussian post-selection can simplify the physical scheme and promote the efficiency to 100%. Virtual photon subtraction can be applied on two sources of two-way CV-QKD independently. Since the secret key is modulated only by Alice, the performance can only be improved by Alice using photon subtraction. Numerical simulations show that the transmission distance can be enhanced to 300km by using virtual photon subtraction with appropriate parameters. Moreover, the tolerable noise can maintain a mostly constant value at 0.02 in the range of 100 km to 300 km so that the robustness of system can be improved significantly especially at long transmission distance.

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