Practical quantum key distribution (QKD) systems inevitably have imperfections, one of which is the imperfection of single-photon source. Regular light source applied in QKD always have large vacuum component and significant multiphoton probabilities, resulting in a relatively limited secure transmission distance and final key generation rate. The single-photon-added coherent state (SPACS) , which has no vacuum component and may contain surprisingly large single-photon probability, seems to be a good choice for QKD, and it has been prepared in many experiments.

SPACS can be written as

$$|\alpha, 1\rangle = \frac{e^{-|\alpha|^2/2}}{\sqrt{1+|\alpha|^2}} \sum_{n=0}^{\infty} \frac{\alpha^n}{\sqrt{n!}} \sqrt{n+1}\,|n+1\rangle. \tag{1}$$

where the absence of vacuum term contribution is evident. The probability of finding n photons in the state is given by

$$P_n(\mu) = \frac{n e^{-\frac{1}{2}(\sqrt{\mu^2-2\mu+5}+\mu-3)}(\sqrt{\mu^2-2\mu+5}+\mu-3)^{n-1}}{2^{n-2}(n-1)!(\sqrt{\mu^2-2\mu+5}+\mu-1)}, \tag{2}$$

for all $n \geqslant 1$, where μ is the intensity of SPACS. In this paper, with the combination of decoy-state method, we implement SPACS into both the standard BB84 QKD protocol and the new proposed measurement-device-independent quantum key distribution (MDI-QKD), comparing its performance with the cases of using other sources. The following figures are the simulation results of the key generation rates by using different sources (SPACS, WCS, HSPS and SPS). And finally, we take into account of the statistical fluctuation.

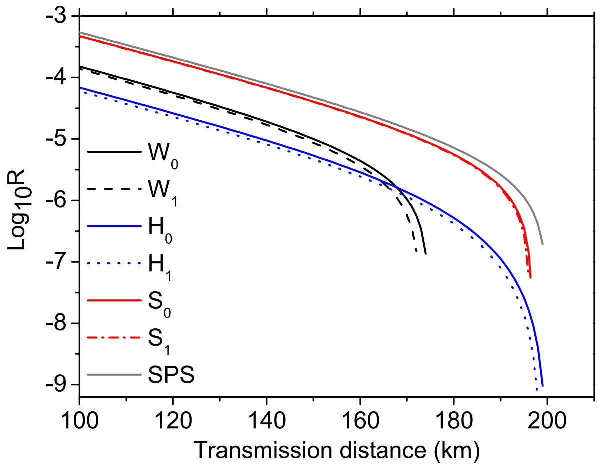

FIG. 1: Comparison of the key generation rates by using different sources (SPACS, WCS, HSPS and SPS) in the standard BB84 protocol.

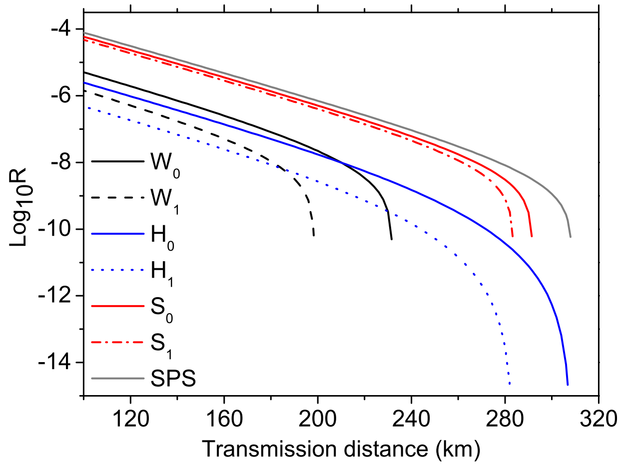

FIG. 2: Comparison of the key generation rates of the MDI-QKD by using SPACS, WCS, HSPS, and SPS.

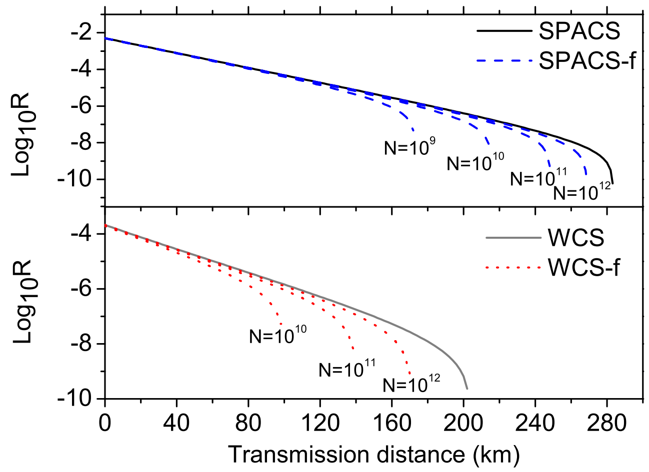

FIG. 3: Key generation rates of MDI-QKD using SPACS with statistical fluctuation, compared with the finite data case of using WCS.

In summery, we have investigated the performance of SPACSs in either the standard BB84 protocol or the MDI-QKD, comparing it with other existing sources, e.g. WCS and HSPS. Our simulations demonstrate that by implementing SPACSs, it can irresistibly defeat all other existing sources, and show excellent behavior in both the transmission distance and the final key generation rate. Moreover, this source can be generated with current technology. Therefore, it has a promising prospect in the field of quantum communications in the near future.