Temporal and intensity fluctuation of photon pulses in a high-speed polarization based quantum key distribution system

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Unconditional security of quantum key distribution is guaranteed if and only if Alice can generate quantum states with true randomness. In a polarization-based BB84 quantum key distribution system, Alice utilizes four semiconductor lasers to generate random bits which represent four different polarization states. In detail, Alice drives an electrical pulse into one of four multiple lasers randomly for each time slot to generate a quantum state whose polarization is encoded with passive optical components such as beam splitter, polarization beam splitter, and half-wave plate.

In a semiconductor lasing operation, driving current and initial carrier density are the key factors which determine the output shape of the photon pulses. Even though one injects the same amounts of current into a laser diode, temporal position and output power of the photon pulses can be varied according to the different level of initial carrier density by high speed operation [1]. Since electrical current pulses are injected to one of the laser diodes with 25% probability for each time slot, current injection to each laser diode is unavoidably aperiodic. Aperiodic current injection into a single laser diode causes inconsistency of initial carrier density for each time slot. In other words, optical output pulse can be different even under same current pulse injection due to different initial carrier density of the laser diode.

In this work, we quantitatively report how temporal disparity and intensity fluctuation occurs in a polarization-based quantum key distribution system with multiple semiconductor laser diodes. This side channel effects becomes severe as clock speed of the QKD system increases. We furtherly address the ways to decrease the phenomenon considering the QBER and secure key rates of the QKD system.

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Reference

[1] Ko, H., Choi, B. S., Choe, J. S., Kim, K. J., Kim, J. H., & Youn, C. J. (2017). Critical side channel effects in random bit generation with multiple semiconductor lasers in a polarization-based quantum key distribution system. *arXiv preprint arXiv:1706.08705*.