Fast Polarization Basis Alignment For Quantum Communications

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Abstract: Many quantum cryptographic schemes use polarization to encode information, although there are implementation problems on optical fiber networks regarding the polarization drift. In this work we assess an algorithm for polarization basis alignment for different channel lengths and polarization linewidth, since both can affect affect the drift behavior.

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1. Introduction

Quantum communication systems use the laws of quantum mechanics to transmit information, offering the possibility of exchanging cryptography keys over an insecure optical link. Quantum information can be encrypted using single-photons with different polarization. Since 1984 when Benett and Bassard proposed the BB84, several experimental schemes to implement quantum protocols using polarization encoding have been proposed and implemented. However, in a real field experiment, qubits sent through an optical fibre are subject to random polarization drifts due birefringence of the fiber, which directly affects the performance of any quantum key distribution protocol. This polarization random drift depends on the field installation conditions such as stress, temperature or external vibrations, and these conditions can be modelled using the polarization linewidth parameter, which determine how fast the polarization drift evolves [1]. Therefore, the reference frames of the transmitter and receiver will be misaligned, which will lead to the increasing the quantum bit error rate (QBER). In this way, an active method for polarization basis alignment (PBA) is required to provide the large deployment of quantum communication systems based on polarization encoding [2]. Mainly two different strategies have been addressed, the interrupted scheme, where the polarization random drift compensation is performed with no data quibts transmission as soon as the QBER rises above a certain threshold [3] [4], and the real-time scheme where methods such as wavelength-division multiplexing or time-division multiplexing are applied [5] [6]. In this work, we will analyze the polarization random drift of a reference state of polarization for different polarization linewidths and we will assess the performance of the QBER based algorithm for PBA proposed in [4], when it is applied on a real quantum communication system.

2. Polarization Random Drift in a Real Quantum Communication System

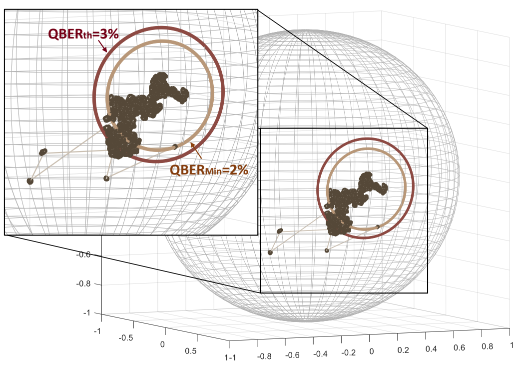

Fig. 1. Random walk of the SOP over the Poincaré sphere for a 900 nHz polarization linewidth. Circle of a sphere defined for both $\mathrm{QBER}_{\mathrm{TH}} = 3\%$ and $\mathrm{QBER}_{\mathrm{MIN}} = 2\%$ for a reference horizontal polarized SOP.

The considered algorithm for PBA is based on the continuous estimation of QBER, which can be represented in a shape of a circle on Poincar sphere. Therefore, each value for QBER can represent a set of possible states of polarization locations. Note that a pre-defined sequence for control qubits during the monitoring mode, where 1 qubit in each 100 is used to estimate the QBER. Furthermore, during the algorithm's actuation mode, all qubits are used and the data transmission is interrupted. In this work, we modelled a system considering 0.1 photons per pulse at transmitter output for data qubits, and an amplitude for data qubits high enough to guarantee a click on the receiver. We also consider an attenuation of 0.2dB/km, single-photon detectors operating at 100 MHz, with a detection efficiency of 25%, a 5×10^{-7} dark count probability, and a gate width of 2.5 ns. Fig. 1 shows the random walk of the SOP over the Poincaré sphere for a polarization linewidth of 900nHz. The SOP walks randomly until achieves a location that corresponds to a QBER above the 2% QBER_{MIN}. This value is defined for a 3% threshold assuring that the estimated value is bellow the threshold. As one can see in the figure, as soon as the QBER rises this boundary limit the algorithm actuates and the SOP can goes outside the boundary. However, during this interval no data qubits are transmitted until the algorithm compensates the drift, i.e. the SOP is lead to a position inside the boundary limit.

3. Polarization linewidth and attenuation impact on algorithm's for PBA performance

Table 1. Algorithm's performance for different values of polarization linewidth and attenuation.

Fiber Length (km)	Polarization Linewidth (nHz)	Actuation Frequency (%)	Overhead (%)	Raw QBER (%)	No-Click (%)
50	900				
80	900				
50	1000				
80	1000				

4. Conclusions

The performance of the PBA algorithm is not affected by attenuation, since for different fiber lengths the assessment measurements remain almost constant. This specification only affects no-click events since the attenuation throughout the quantum channel increases with fiber length. However, for high polarization linewidths both actuation frequency and overhead increase since the speed of polarization random drift increases.

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