Polarization-multiplexed continuous-variable quantum key distribution

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1 Introduction

Quantum key distribution (QKD) promises an implementation of establishing secret keys between two remote parties based on the uncertainty principles of quantum physics [1]. Continuous-variable quantum key distribution (CV-QKD) taking advantage of commercial-accessible components loosens the requirements for extreme operating environment and expensive devices [2,3]. The establishment of the protocol security with discrete-modulation [4-6] makes it a prospective approach to widespread application. In this paper, we propose a polarization-multiplexed CV-QKD protocol with four-state modulation capable of full use of two orthogonal polarization channels and experimentally investigate it. The experiment results show the polarization and phase compensation scheme solves the difficulties of estimating the overall phase rotation for dual-polarization signals, which makes the dual-polarization modulation scheme a superior alternative for its double secret key rate.

2 Experimental setup

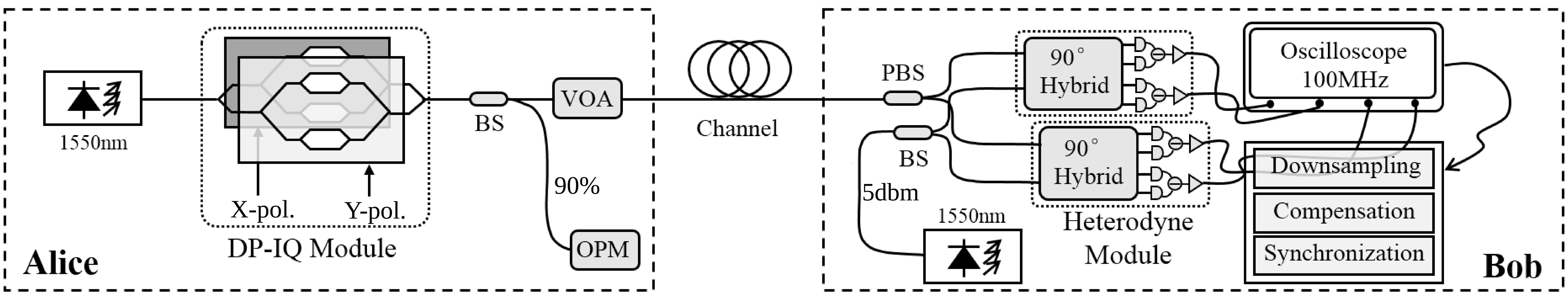

Figure 1 Experimental setup of proposed polarization-multiplexed CV-QKD scheme.

- 5MHz repletion rate, 1550nm narrow linewidth laser, random key data sequence of 2^{10}, mean photon number of 0.1 per symbol
- First and second reference data sequences of 50, signal data sequences of 1024 per calculation period
- Sampling rate of 100MHz, oversampling factor of 20

3 Phase compensation scheme

- Introduce a pair of reference $(X_1, X_2, Y_1, Y_2)^T$ and $(X_3, X_4, Y_3, Y_4)^T$, where

First group				Second group			
X		Y		X		Y	
x	p	x	p	x	p	x	p
X_1	X_2	Y_1	Y_2	X_3	X_4	Y_3	Y_4

- Matrix A_R consisting of reference data should be full-rank, where

$$A_R = \begin{pmatrix} X_1 & X_2 & Y_1 & Y_2 \\ X_2 & -X_1 & Y_2 & -Y_1 \\ X_3 & X_4 & Y_3 & Y_4 \\ X_4 & -X_3 & Y_4 & -Y_3 \end{pmatrix}.$$

- Use reference data A_R and detected reference data M_R to calculate a overall rotation matrix S through $M_R = SA_R$.
- Compensate polarization mixing and relative phase by rotating Bob's received data using S.

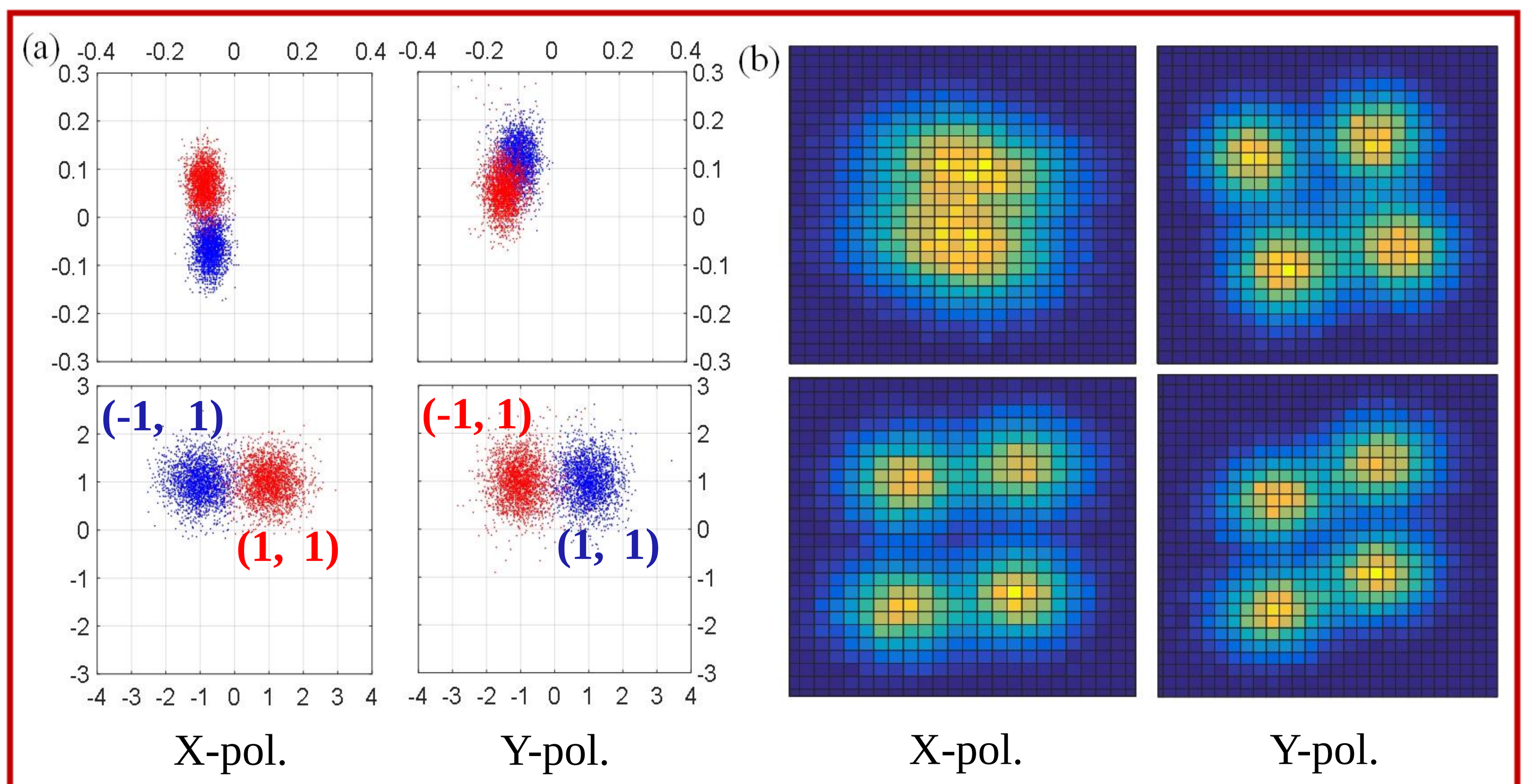

Figure 2 Bob's received (a) reference data and (b) key data without (top) and with (bottom) phase and polarization compensation of X and Y polarization. Blue/red points: the first/second group of reference data.

4 Results

- After Bob's detection, 10^6 sampling points of x/p quadrature on dual polarization are divided into 43 groups each including reference and key part.
- Bob's received reference data (top) is recovered (bottom) as Alice encodes $(-1,1)$ and $(1,1)$ on X polarization, and $(1,1)$ and $(-1,1)$ on Y polarization's first and second reference signals as shown in **Fig. 2(a)**.
- Method in [2, 3] is adopted to calculate the secret key rate of four-state protocol $K_{DP} = 2K_{SP}$, $K_{SP} = \beta I\ (M_A\!:H_B) - \sup S_{BE}^{G}(\kappa_{AB})$.
- Phase distortion and polarization mixing of received signals are simultaneously compensated before normalization by shot-noise variance as shown in **Fig. 2**.

5 Conclusion

We experimentally demonstrate a dual-polarization modulated CV-QKD system for the first time. The results show that combined with our efficient polarization and phase compensation scheme, this low-complexity scheme can further improve the secret key rate and prompt CV-QKD to be network-compatible [7] and on-chip integrated [8].

Reference

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