

Quantum information processing with hybrid photon states

Isaac Nape¹, Eileen Otte², Jun Lui³, Adam Vallés¹, Carmelo Rosales-Guzmán¹, Filippo Cardano⁴, Jian Wang³, Cornelia Denz², Andrew Forbes¹

¹ School of Physics, University of the Witwatersrand, Private Bag 3, Wits 2050, South Africa.

² Institute of Applied Physics, University of Muenster, Corrensstr. 2/4, D-48149 Muenster, Germany.

³ Wuhan National Laboratory for Optoelectronics, School of Optical and Electronic Information, Huazhong University of Science and Technology, Wuhan 430074, Hubei, China.

⁴ Dipartimento di Fisica "Ettore Pancini", Università di Napoli Federico II, Complesso Universitario di Monte Sant'Angelo, Via Cinthia, 80126 Napoli, Italy.

Author e-mail address: isaacnape@gmail.com

Abstract: Quantum information processing with spatial modes of light is highly topical. Here, we realize high dimensional encoding with self-healing spin-orbit coupled states and employ them for applications in quantum key distribution. Furthermore, we exploit spin-orbit entanglement (non-locally) to realize a hybrid quantum channel, through a 250 m fiber and free-space, and demonstrate quantum erasers, a Bell violation and perform quantum state reconstruction to characterize the channel. We also present a security analysis of quantum channel.

1. Introduction

Significant limitations are imposed on quantum channels when traditional qubit encoding is used. Recently, vector vortex fields with coupled polarization (spin) and orbital angular momentum (OAM) are topical, promising applications for quantum information processing [1]. Here we present the advantage of combining polarization and OAM to realize high-dimensional quantum key distribution possessing self-healing [2,3]. Further, we also establish a free-space and fiber (250 m) hybrid link with non-local spin-orbit correlations to establish a secure hybrid channel, showing Bell inequality violations, quantum state tomography and quantum erasure tests [4] to confirm correlations over the channel.

2. Results

In Fig. 1 (a) we measured the overlap probabilities between high dimensional vector vortex states and their mutually unbiased basis states of scalar modes. In Fig. 1 (b) we performed a security analysis of the channel in free-space (FS) and disturbed by physical obstructions of sizes 600 μm and 800 μm , for a Bessel-Gaussian (BG) radial profile and Laguerre-Gauss (LG) profile. In addition, we prepared a hybrid quantum channel where the photons transmit through free-space (OAM) and a 250 m fiber (polarization). We present the reconstructed density matrix in Fig. 1 (c).

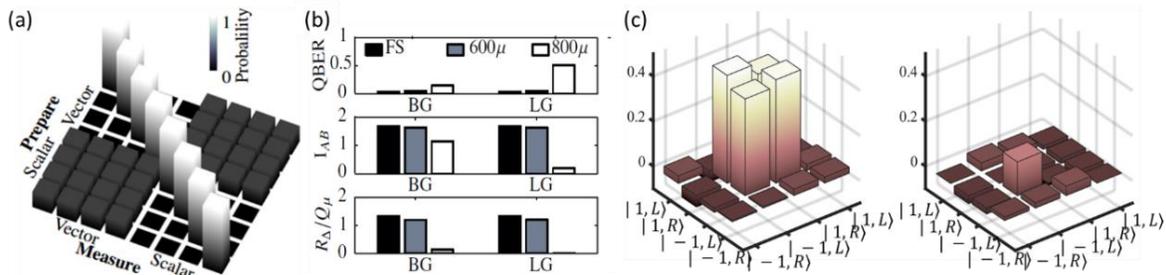


Fig. 1(a) Prepare and measure overlap probabilities between the high-dimensional vector basis and its mutual unbiased scalar basis. (b) Security analysis of the high-dimensional channel. (c) Reconstructed density matrix of the hybrid link where the polarized photon is transmitted through a 250m fiber and the OAM photon is transmitted through free-space.

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