The Protocol of Quantum Key Distribution on Beams with Space Structured Polariztion

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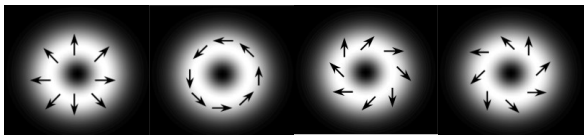
The work proposes a protocol for quantum key distribution using Laguerre-Gaussian beams with space structured polarization invariant to rotation of the radial coordinate in a plane normal to the beam propagation axis. It is shown that axial polarization symmetry makes such beams insensitive to rotations relative to the optical axis, which makes it possible to use them to transmit information in cryptographic protocols in space communication systems. ***Keywords: quantum key distribution; satellite-to-ground communications; vector beams with structured polarization; cube corner reflectors.***

I. Introduction

The development of quantum key distribution (QKD) systems is due to the increased requirements for the protection of information in communication networks. The BB84 QKD protocol, which is basic for quantum cryptography, uses two bases of single-photon quantum states with linear polarization. It is important to note that the application of the BB84 protocol with linear polarized bases for the QKD tasks of low-orbit spacecraft is significantly difficult due to the need for fixation the position of the light polarization plane at each moment of time by both transmitting and receiving systems on Earth and in space.

This problem can be eliminated if beams with space structured polarization are used [1]. It is proposed to use the polarization degree of freedom of such beams as an information carrier in QKD systems. Fig. 1 shows the intensity profile of such beams, the arrow shows the direction of polarization at each point in transverse plane of beam



a) b) c) d)

Fig. 1. Beams with axial symmetry intensity distribution: a) radial-polarized beam; b) axial-polarized beam; c) right-twisted polarized beam; d) left-twisted polarized beam

II. Quantum Key Distribution Protocol Scheme

Obtaining beams with a given axial polarization structure and their detection are two individual tasks. It was shown in [2] that second-order beams are formed when a linearly polarized beam is reflected from a cube corner reflector (CCR). The problem of beam detection in a classical cryptographic channel can be solved using a device acting as a radial polarizer.

However, for quantum channels, the use of absorbing elements – radial polarizers, is unacceptable. Based on this constraint, we consider the procedure for detecting polarization degrees of freedom in the configuration of the Mach-Zander interferometer, the elements of which are CCRs. In this work we propose a scheme for the rapid generation of beams with

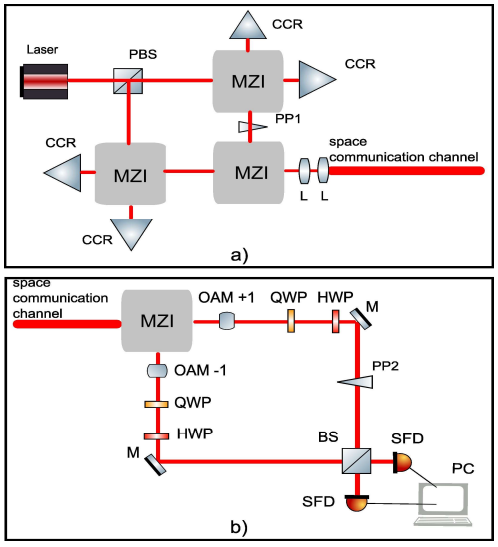


Fig.2. The optical scheme of a) transmitting device and b) receiving device. In the diagram: PBS, BS – polarization and regular beam splitters, HWP, QWP – half- and quarter-wave plates, OAM ±1 – phase hologram changing the value of the topological charge of the beam, L – collecting lens, M – mirror, SFD – single-photons detector, PP – controlled phase plate, MZI – Mach-Zehnder interferometer with PBS, PC – computer.

given axial polarisation structure, as well as the encoding and decoding of quantum information within the framework of the QKD protocol (Fig.2).

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References

[1] Д. Д. Решетников, А. Л. Соколов, Е. А. Вашукевич, В. М. Петров, Т. Ю. Голубева, «Протокол квантового распределения ключа на аксиально-симметричных поляризационных пучках в атмосферном канале», Известия вузов. Радиофизика, Т.67, №.1, 2024.

[2] A. L. Sokolov, "Optical vortices with axisymmetric polarization structure", J. Opt. Soc. Am. A., 30, vol. 7, 2013