Light with orbital angular momentum for quantum information schemes

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The use of light with orbital angular momentum (OAM) for quantum technology applications is considered. We briefly review the principles of encoding information in quantum systems. We discuss the encoding of qubits using OAM of light and the possibility of expanding the Hilbert space – encoding of qudits. The problems of quantum communication using OAM on the example of a cryptographic protocol for quantum key distribution is discussed. The original results of generation of multimode quantum signals will be presented. We will show the possibilities of storing and conversion of quantum states of light with OAM. The features of performing quantum computations on photonic systems with OAM will be considered.

The application of high-dimensional quantum systems (qudits) in quantum computing and communications seems to be a promising avenue due to the possibility of increasing the amount of information encoded in one physical carrier. The OAM is an exciting resource for constructing a qudit since the OAM can take any integer values, which allows us to work in the Hilbert space of high dimension [1]. Since Laguerre-Gaussian modes with OAM are well localized in the spatial domain, several well-proven experimental techniques for generating [2, 3], separating and detecting such multimode radiation [4–6] exist. Many methods of OAM manipulation based on phase holograms [7], q-plates [8], and a system of cylindrical lenses [9] have also been proposed. However, performing efficient mode conversions with different OAMs applying such optical elements requires a mode-specific change of the system parameters, which cannot satisfy quantum computing needs.

We will consider new approaches for quantum light with OAM manipulating [10–14].

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[1] Allen L, Beijersbergen M W, Spreeuw R J C and Woerdman J P 1992 *Phys. Rev.* A **45** 8185
[2] Slussarenko S, Karimi E, Piccirillo B, Marrucci L and Santamato E 2011 *J. Opt. Soc. Am.* A **28** 61
[3] Xiao Q, Klitis C, Li S, Chen Y, Cai X, Sorel M and Yu S 2016 *Opt. Express* **24** 3168
[4] Mirhosseini M, Malik M, Shi Z and Boyd R W 2013 *Nat. Commun.* **4** 1
[5] Leach J, Padgett M J, Barnett S M, Franke-Arnold S and Courtial J 2002 *Phys. Rev. Lett.* **88** 257901
[6] Dai K, Gao C, Zhong L, Na Q and Wang Q 2015 *Opt. Lett.* **40** 562
[7] Heckenberg N R, McDuff R, Smith C P and White A G 1992 *Opt. Lett.* **17** 221

[8] Karimi E, Piccirillo B, Nagali E, Marrucci L and Santamato E 2009 *Appl. Phys. Lett.* **94** 231124
[9] Beijersbergen M, Allen L, van der Veen H and Woerdman J 1993 *Opt. Commun.* **96** 123
[10] Vashukevich E A, Losev A S, Golubeva T Yu, and Golubev Yu M 2019 Phys. Rev. A **99**, 023805
[11] Vashukevich E A, Golubeva T Y and Golubev Y M 2020 *Phys. Rev.* A **101** 033830
[12] Vashukevich E, Bashmakova E, Golubeva T Yu and Golubev Yu M 2022 Laser Phys. Lett. **19** 025202
[13] Bashmakova E N, Vashukevich E A, Golubeva T Yu , Golubev Yu M 2022 Opt. Spectrosc. **130** (14), 2120
[14] Bashmakova E N, Vashukevich E A, Golubeva T Yu, Parallel multi-two-qubit SWAP gate via QND interaction of OAM light and atomic ensemble. 2023 (https://arxiv.org/abs/2306.16565)