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Six-Mode Entangled States of Continuous Variables

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Abstract. A quantum theory of six-mode light state, generated in three waveguides in each of which a parametric process takes place, is developed. Coupling between modes of waveguides is evanescent. Density matrix of the six-mode state is determined and nonclassical properties of the state are studied.

Keywords: entangled quantum state, quadrature components.

Multimode entangled quantum states of light attract considerable attention in quantum information and quantum computation as they expand their capabilities. To date, a number of methods of generating multimode entangled states of light has been developed: coupled parametric interactions taking place inside and outside of the optical resonator, optical parametric interactions in the spatially modulated pumpe and interactions in nonlinear waveguide structures. The latter are of particular interest because they allow to create compact sources of multimode entangled states.

We present the results of the development of a quantum theory of coupled parametric processes in the nonlinear waveguide structures. The theory is elaborated for the case of three non-degenerate parametric processes, coupling between them is carried out by evanescent modes.

In the fixed-field approximation, the process under consideration is described by the following interaction Hamiltonian

$$\mathrm{H}_{\mathrm{int}} = i\hbar[\sum_{j=1}^{3}\beta(a_1^{(j)+}a_2^{(j)+} - h.c.) + \gamma((a_1^{(2)+}(a_1^{(1)} + a_1^{(3)}) + a_2^{(2+)}(a_2^{(1)} + a_2^{(3)}) - \mathrm{h.c.}).$$

The superscript (j) represents the channel number, the subscript refers to the frequency. Same parametric processes occur in the channels (coefficient). Evanescent coupling takes place between the modes (coefficient).

The expression for the canonical transformation matrix connecting bose-operators at input and output of waveguides is obtained. The theory developed by us in [1] is used to find the state vector of the multimode field generated and the density matrix, which allows us to calculate the entropy characteristics. We study the correlation between the modes of the quadrature components of different channels.

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Reference

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