Photon Correlations In Strongly Non-Degenerate Parametric Down Conversion

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Abstract

Parametric down conversion with output THz and optical beams is investigated. Methods to manage spatial properties and photon correlations of emitted squeezed quantum light are developed. Solutions for collection of THz radiation with wide angular spectrum are provided.

Squeezed states of light are very attractive for the investigation both theoretically and experimentally. Such non-classical states of light can be generated by parametric down conversion or 4-wave mixing. The important feature of generated light is strong photon entanglement both in the frequency and space domain. If the pump intensity is high the generated non-linear signal contains huge number of photons and is referred to as bright squeezed state of light [1]. Such states can be considered as macroscopic non-classical states of light and very promising and perspective for numerous important applications. In this work we consider the case for strongly non-degenerate parametric down conversion (PDC) when the energies of generated photons can differ for several orders of magnitude such as the signal photon corresponds to the optical frequency while the idler belongs to the terahertz (THz) frequency range. Generation of THz radiation with non-classical features opens new perspectives in numerous practical applications. To control the mode content and properties of such non-classical squeezed light both in the spectral and spatial domain is a very important problem. For this purpose it is very important to develop new theoretical approaches able to describe the spatial properties of the generated squeezed THz field especially in the regime of rather high parametric amplification. In this work we developed a theoretical approach to describe the spatial properties and photon correlations of squeezed electromagnetic fields generated in strongly non-degenerate PDC process. The approach is based on the concept of independent Schmidt modes and is valid for the cases of both weak and strong nonlinear interaction [2]. The Hamiltonian is diagonalized by passing from plane waves to a new set of collective angular modes such as the “broadband modes” introduced in [3] for the frequency domain.

Firstly, we consider a system of just one nonlinear crystal. The shapes and weights of different Schmidt modes are analyzed and the THz radiation is found to be characterized by rather broad angular distribution. The obtained theoretical results are compared with the experimental data [4]. To manage spatial properties and photon correlations of emitted squeezed quantum light the nonlinear interferometer based on two consequent nonlinear crystals is used. Due to the interference effect such scheme allows one to enhance the generated squeezed radiation at some polar angles and frequencies and at the same time to suppress it at the others. Being very sensitive to the refraction index of the intermediate layer such interferometer can be used for precise measurements of dispersion properties of different materials, especially in the THz frequency region. Moreover, it is possible to amplify a non-linear signal in a certain Schmidt mode with a rather narrow polar angular distribution which allows to collect the THz signal without the loss of its nonclassical properties. One more important thing is that simultaneously with the PDC the THz radiation is involved in the process of sum frequency generation (SFG) so as both Stocks and anti-Stocks components are generated with the participation of the THz photons. For this reason we generalized our theory and investigate both the PDC and SFG processes simultaneously. The idea of detection of the THz radiation by measuring the correlations between generated Stocks and anti-Stocks components is suggested.

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