Spatial Properties of Bright Squeezed Vacuum in Near and Far Field Regions

R V Zakharov[1,2] and O V Tikhonova[1,2]

[1] *Faculty of Physics, M V Lomonosov Moscow State University, 119991 , Moscow, Russia. Contact Phone: +74959391682*
[2] *Skobeltsyn Institute of Nuclear Physics, 119991, Moscow, Russia. Contact Phone: +74959391818*
Contact Email: roma1997z@mail.ru

Non-classical states of light are of great interest for many practical applications in metrology, quantum imaging, optomechanics. Squeezed states of light can be generated by parametric down conversion or 4-wave mixing. 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 are characterized by strong correlations between many photons. It is interesting that such states can be described by independent spatial modes that carry orbital angular momentum [2]. The orbital angular momentum inherent for twisted light is important for its interaction with atomic quantum systems. For this reason to control both spatial and frequency properties of such light is very necessary but remains still an unsolved problem.

In this work we investigate theoretically the spatial features of non-classical squeezed light generated in a system of two separated nonlinear crystals which is in fact a nonlinear interferometer. Such scheme is convenient for practical purposes as it allows one to control effectively the properties of generated light. The image of output light can be obtained both in the near and far field region by focusing it in the image or focal plane respectively. The analysis of mode content and spatial properties of bright squeezed vacuum is based on the theoretical approach developed in [3] and is performed using the Schmidt decomposition. To find all required characteristics in the near field region we calculate the Fourier transformation of two photon amplitude and Schmidt modes in the far field region.

The obtained results demonstrate a great difference between the spatial properties of squeezed light in near and far field regions. While in the far field region signal and idler photons are found to be strongly correlated for opposite transverse wave vectors, in the near filed the photons are likely to be emitted from the same point. In the far field region azimuthal and "radial" degrees of freedom are found to be almost independent on each other and modes with different orbital momenta can be found at the same polar angle of ejection. In contrast, in the near field modes with different orbital momenta have different spatial distributions that allows to separate them easily. These features have strong influence on the spatial distributions of the auto and cross-covariance that manifest the correlations of signal and idler photons in detail. The phases of contributing Schmidt modes are found to be of great importance for the mutual signal-idler correlations in the near field region, while they can be neglected in the far field. The influence of the pump parameters and the separation between the crystals on the obtained distributions is analyzed. The possibility to use different properties of the bright squeezed vacuum in the near and far field regions to obtain selectively the required azimuthal or radial modes is demonstrated.

References

[1] K Yu Spasibko, T Sh Iskhakov and M V Chekhova, Opt. Express **20**, 7507 (2012)

[2] A Mair, A Vaziri, G Weihs and A Zeilinger, Nature **412**, 313 (2001)

[3] P Sharapova, A M Perez, O V Tikhonova and M V Chekhova, Phys Rev A **91**, 043816 (2015)