Coherence and dimensionality of intense spatio-spectral twin beams

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Spatio-spectral model of intense twin beams has been developed in parametric and paraxial approximations using the decomposition into paired spatial and spectral Schmidt modes [1]. Intensity auto- and cross-correlation functions have been determined and compared in the spectral and temporal domains as well as the transverse wave-vector plane and the crystal output plane. The model has been applied to non-collinear type-I interaction in an 8-mm long BBO crystal pumped by a ps-pump pulse [2, 3]. Around 80 spectral modes and 80 thousand spatial modes participated in the interaction. It has been shown that the spectral, temporal and transverse wave-vector coherence quantified by intensity auto- and cross-correlation functions increases with the increasing pump intensity. The corresponding auto- and cross-correlation functions have been shown to approach each other for larger pump intensities. This contrasts with the behavior of coherence in the crystal output plane that is practically independent on the pump intensity. This is a consequence of the special mode structure in which the zeroes in intensity mode profiles occur at the same positions for all radial modes.

Entanglement dimensionality of a twin beam [4] has been determined comparing several approaches: based upon photon-pair operators, using photon-number statistics in the signal field, and defining the ratio of the width of intensity profile and the width of appropriate auto-correlation function. All the approaches give comparable results, as the curves in Fig. 1 obtained in the wave-vector transverse plane and the crystal output plane document. Entanglement dimensionality decreases with the increasing pump intensity. This is a consequence of the exponential increase in the population of the central modes that dominate for more intense pump fields over the remaining modes. This also causes the increase of coherence observed in the spectral and temporal domains and also in the wave-vector transverse plane.

The developed model also allows for its extension to the case of depleted pump fields.

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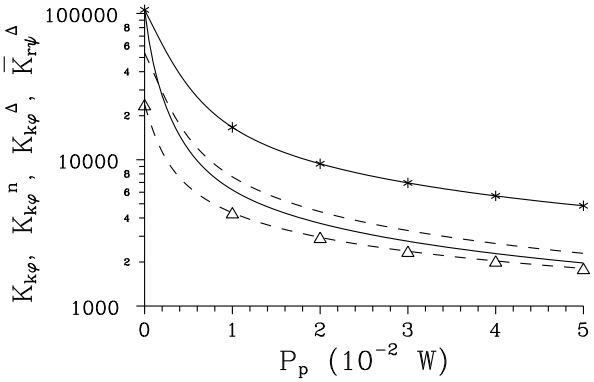

FIG. 1. Entanglement dimensionality $K_{k\varphi}$ (plain solid curve), number $K^n_{k\varphi}$ of signal-field modes determined from photon-number statistics (solid curve with $*$) and number $K^\Delta_{s,k\varphi}$ [$\tilde{K}^\Delta_{s,r\psi}$] of signal-field modes in the transverse wave-vector [crystal output] plane given by the ratio of signal beam width and width of the appropriate auto-correlation function (plain dashed curve [dashed curve with $\triangle$]) as they depend on pump power P_p; 1 mm wide pump beam with 0.1 nm spectral width is assumed.

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