Tommaso Corti

Department of Science and High Technology, University of Insubria
Via Valleggio 11 - 22100 Como, Italy
corti.tommaso@gmail.com

Dimensionality of the spatio-temporal entanglement of PDC photon pairs

A. Gatti, T. Corti, E. Brambilla, D.B. Horoshko

The process of parametric down-conversion (PDC) occurring in a nonlinear crystal is a widely employed source of entangled photons. One of the appealing feature of this process is the possibility of generating high-dimensional entanglement , both because various degrees of freedom of the photon pair are entangled (polarization, time-energy, position-momentum), and because spatial and temporal entanglement is realized in a high-dimensional Hilbert space, due to the naturally ultra-broad bandwidths of PDC.

In this context, an obvious question concerns the effective dimensionality of the entanglement of the state (or alternatively the number of entangled modes generated by the process), quantified by the so-called Schmidt number. At difference with traditional approaches, which typically concentrate on a single degree of freedom at a time, in this work the degree of entanglement of the two-photon state is investigated in the framework of a fully spatio-temporal model for PDC. A comparison with the results obtained in either a purely spatial or a purely temporal model shows that the degree of entanglement of the PDC state cannot be trivially reduced to the product of the Schmidt numbers obtained in models with lower dimensionality, unless the detected bandwidth is very narrow [1].

Our result is a non-trivial consequence of the non-factorability of the state in the spatial and temporal degrees of freedoms of twin photons, recently evidenced both in theory and experiments in the framework of the so called X-entanglement [2-4]

In the limit of a broad pump beam, we introduce a useful geometric interpretation of our results, which shows that the Schmidt number quantifying entanglement is basically the ratio between the volume of the region where phase matching efficiently occurs and a correlation volume, thus being proportional to the number of spatio-temporal correlated modes.

[1] A. Gatti, E. Brambilla, T. Corti and D. M. Horoshko, Phys. Rev.. A 86, 053803 (2012). arXiv:1207.6932v1

[2] A. Gatti, E. Brambilla, L. Caspani, O. Jedrkiewicz, and L.A. Lugiato, , Phys. Rev. Lett. 102, 223601 (2009); arXiv:0812.3533v1

[3] L. Caspani, E. Brambilla and A. Gatti, , Phys. Rev A, 81, 033808 (2010).

[4] O. Jedrkiewicz, J.-L. Blanchet, E. Brambilla, P. Di Trapani, A. Gatti, , Phys. Rev. Lett. 108, 253904 (2012) , arXiv:1203.3661 ; O. Jedrkiewicz, A. Gatti, E. Brambilla, P. Di Trapani , Phys. Rev. Lett., 109, 243901 (2012), arXiv:1208.4504.