

Near-to-far-field evolution of twin beams

Ondřej Haderka,¹ Radek Machulka,¹ Jan Peřina, Jr.,² Alessia Allevi,^{3,*} and Maria Bondani⁴

¹*RCPTM, Joint Laboratory of Optics of PU and Inst. Phys. AS CR,
17. listopadu 12, 77146 Olomouc, Czech Republic*

²*Institute of Physics AS CR, Joint Laboratory of Optics,
17. listopadu 50a, 77146 Olomouc, Czech Republic*

³*Dipartimento di Scienza e Alta Tecnologia, Università degli Studi
dell'Insubria and CNISM UdR Como, Via Valleggio 11, 22100 Como, Italy*

⁴*Istituto di Fotonica e Nanotecnologie, CNR, and CNISM UdR Como, Via Valleggio 11, 22100 Como, Italy*

Parametric down-conversion (PDC) is a well-known nonlinear process extensively investigated for the production of entangled states of light useful for applications ranging from the fundamental tests of quantum mechanics to the implementation of quantum state engineering, quantum information and quantum communication protocols. In the last two decades a lot of attention has been devoted to the study of spatial and spectral correlations. The earliest works were performed by scanning point-like detectors [1], whereas more recent approaches employed single-photon-sensitive intensified CCD (iCCD) [2] or electron-multiplying CCD (EMCCD) cameras [3, 4]. To date, most investigations have been performed in the near-field as well in the far-field configurations [2, 3], even though attention has been devoted also to the transient positions between the two extremes [1, 5, 6], where the entanglement properties are entirely transferred to the phase of the two-photon amplitude [5]. Here we show the transition from the near-field to far-field-like spatial correlations in high-intensity PDC by using a fixed optical system and a movable crystal mount [7]. A 10-times magnified image of a plane that moves from the output face of the nonlinear crystal to a few millimeters behind it is formed on the input slit of an imaging spectrometer, at whose output an iCCD camera is used to register single-shot images. The spectral resolution of the detection system is 0.03 nm/pixel, whereas the spatial resolution is 1.3 μm . The experimental setup allows the simultaneous measurement of spectral (horizontal direction) and spatial (vertical direction) correlations. Indeed, the consistency of the experiment is ensured by monitoring the presence of spectral cross-correlations (see upper panels of Fig. 1) even at positions in which the spatial cross-correlations get lost. A clear transition from position cross-correlations in the near-field configuration to momentum anti-correlations in the far field can be observed by evaluating coordinates, peak value, and full-width at half maximum width of cross-correlation (XC) areas in the spatial domain (see lower panels of Fig. 1). We note that in the transition region the peak value of cross-correlation as well as the spatial Fedorov ratio exhibit a minimum.

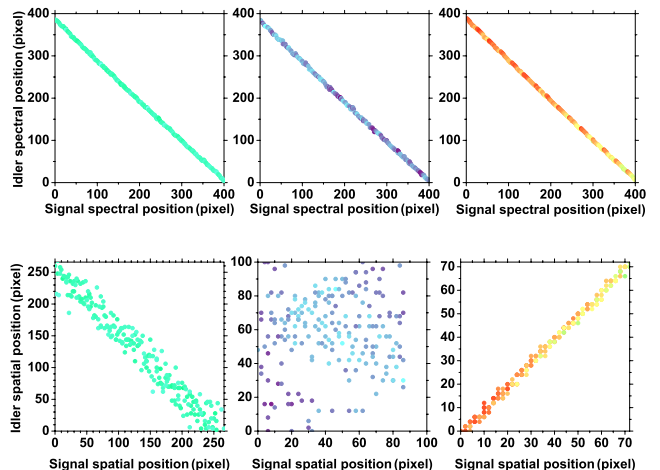


FIG. 1: Spectral (upper panels) and spatial (lower panels) coordinates of the XC peak (idler) as functions of the corresponding coordinates of the AC peak (signal) in three different planes. Left panels: Far-field-like configuration; central panels: Transient region; right panels: Near-field configuration. In the lower panels vertical and horizontal scales differ from distance to distance due to the divergence of the beam.

* Electronic address: alessia.allevi@uninsubria.it

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