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Disclosing the X-shaped geometry of PDC correlation through frequency up-conversion

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Ultra-broadband parametric down-conversion (PDC) is characterized by a spatio-temporal twin-photon correlation that displays a peculiar X-shaped geometry non-factorable in the space-time domain which has been investigated in [1.2]. This geometry of the twin-photon correlation, which we call X-entanglement, expresses a strong coupling between the temporal delay and the transverse spatial separation of the twin photons measured at the crystal output face. This interdependence of the correlated variables (known as multi-parameter entanglement) has since long been recognized as a resource for engineering entanglement in quantum interferometric experiments.

In this work, we demonstrate how X-entanglement can be disclosed by using the inverse PDC process, i.e. sum frequency generation (SFG), taking place in a second crystal in which the PDC source is imaged. By imposing independently a temporal delay □t and a transverse spatial shift □x between two twin components of the PDC light, the measurement of the up-converted SFG intensity allows to reconstruct the twin-photon correlation function in the full spatio-temporal domain. The revealed correlation is skewed in space-time in accordance with the X-structure predicted by the theory. Its strong localization both along the spatial and the temporal dimensions, in the picosecond and in the micrometer range respectively, is determined by the broad spatial-temporal PDC bandwidths intercepted in the experiment [3,4]. We also investigate how the phase-matching process in the second crystal (used as a correlator) affects the measurement of the PDC correlation functions.

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