Generating Ultra-Broadband Biphotons via Chirped QPM Down-conversion

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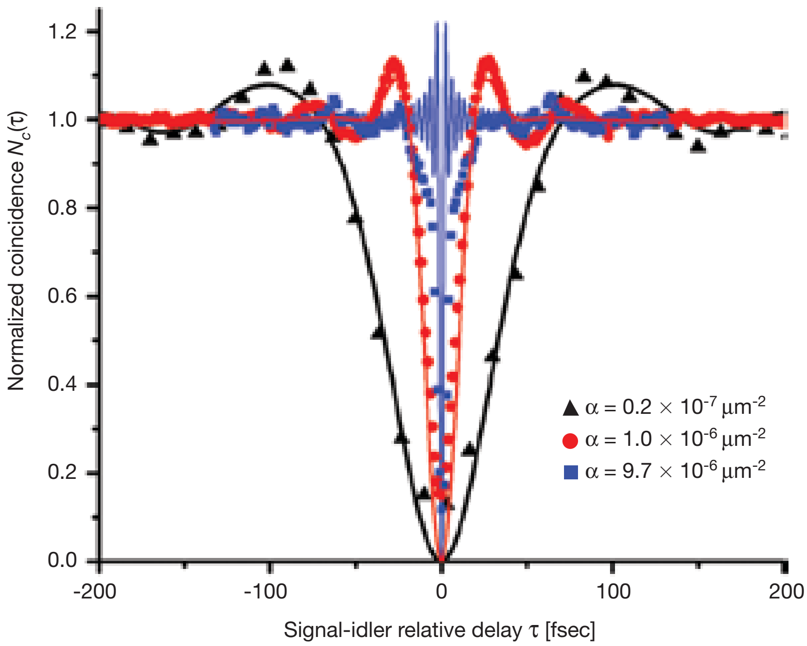
An important research goal in quantum optics is the design and implementation of new sources of quantum light, such as entangled photons (biphotons) with tunable spectral properties that match the specific application under consideration. The optimum biphoton bandwidth can stretch from ultra-narrow (on the order of MHz) for certain atom-photon interactions to ultra-broad for applications such as high-axial-resolution quantum optical coherence tomography (QOCT).[1]

The most widely used method for generating biphotons is through spontaneous parametric down-conversion (SPDC), in which two lower-frequency photons are generated when a strong pump field interacts in a nonlinear crystal. One way of generating ultra-broadband biphotons is to make use of a quasi-phase matched (QPM) nonlinear grating with a nonuniform poling period.[2] The poling pattern $\Lambda(z)$, where z is the spatial coordinate along the direction of pump propagation, provides a collection of phase-matching conditions over the length of the grating, which leads to broadband biphoton generation; at the same time, the poling pattern can be chosen to engender a special phase relation among the various spectral components, thereby allowing the biphoton wavepacket to be compressed using the techniques of ultrafast optics.

An international collaboration, comprising groups at the Quantum Imaging Lab at Boston University, the Institute of Photonic Sciences in Barcelona and the Ginzton Lab at Stanford University, used a continuous-wave laser pump, together with an appropriately designed linearly chirped periodically poled stoichiometric lithium tantalate grating, to generate biphotons with the largest bandwidth ever observed, about 300 nm.[3] It is fitting that, on the 20th anniversary of the development of the Hong-Ou-Mandel (HOM) interferometer,[4] these biphotons were used to observe the narrowest HOM dip measured to date, with a FWHM of 7.1 fs, (see figure) corresponding to an axial resolution of 1.1 μm in QOCT.

The generation of such ultra-broadband nonclassical light opens the door to the production of a high flux of nonoverlapping biphotons with optical powers of the order of μW—which is essential for implementing applications such as entangled-photon microscopy,[5] spectroscopy[6] and photoemission.[7]



Normalized HOM coincidence interferograms (dips) for various degrees of linear chirp, indicated by the chirp parameter α. Symbols represent measured data points, whereas solid curves are numerical simulations.

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