Reconstructing ultrafast energy-time entangled two-photon pulses

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Abstract

The generation of ultrafast laser pulses and their reconstruction is essential for many applications in modern optics. Quantum optical fields can also be generated on ultrafast time scales, however, the methods available for strong laser pulses are not appropriate for measuring the properties of weak, possibly entangled pulses. Here, we demonstrate a method to reconstruct the joint-spectral amplitude of a two-photon energy-time entangled state from joint measurements in frequency and time. Our reconstruction method is based on a modified Gerchberg-Saxton algorithm. Such techniques are essential to measure and control the shape of ultrafast entangled photon pulses.

Optical pulses can be produced on time scales much shorter than any photodetector response time, and consequently, the only thing fast enough to measure an ultrafast laser pulse is another ultrafast pulse. Techniques such as frequency-resolved optical gating [1] make use of nonlinear optical processes to measure and reconstruct ultrafast pulses. However, adapting them to quantum states of light is challenging due to the low power levels of single photons. In addition, the algorithms developed for laser pulses do not account for the possibility that photons can be entangled. New innovations are therefore needed to reconstruct the joint state of entangled ultrafast photon pulses.

In our work [2], we implement a technique to recover the phase of ultrafast energy-time entangled two-photon pulses based on intensity measurements of the frequency and the arrival time. Inspired by the conventional phase retrieval problem, we develop an algorithm based on a method of alternate projections [3] that iterates between the frequency and time domains imposing the measured intensity constraints at each iteration. Measurements in frequency are performed with single-photon spectrometers and measurements in time are implemented via optical gating with an ultrafast optical laser pulse.

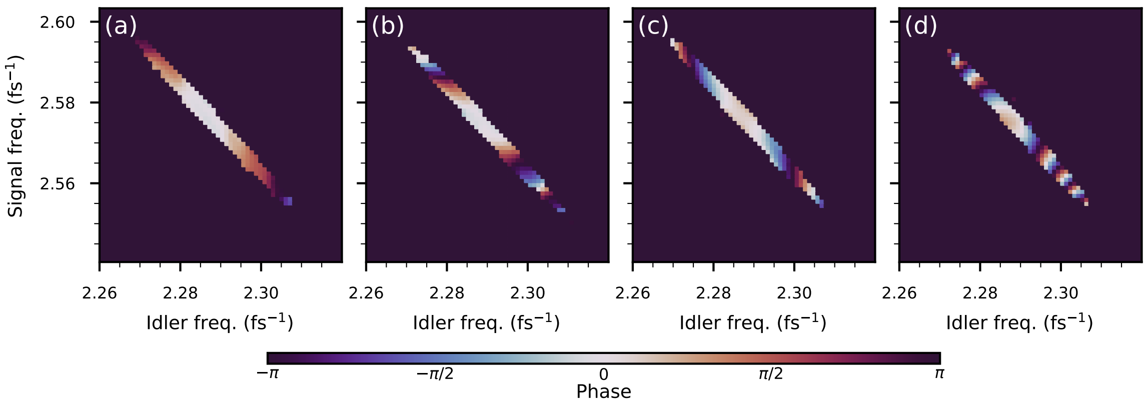

Figure 1: Reconstructed joint spectral phase for energy-time entangled photon pairs with (a) no added dispersion, (b) positive dispersion on the signal, (c) negative dispersion on the idler, (d) negative dispersion on both the signal and idler.

[1] D. J. Kane and R. Trebino, *Single-shot measurement of the intensity and phase of an arbitrary ultrashort pulse by using frequency-resolved optical gating*, Opt. Lett. 18, 823 (1993).

[2] J.-P. W. MacLean, S. Schwarz, and K. J. Resch, *Reconstructing ultrafast energy-time entangled two-photon pulses*, arXiv:1901.11116.

[3] R. W. Gerchberg and W. Saxton, *A practical algorithm for the determination of phase from image and diffraction plane pictures*, Optik 35, 237 (1972).