Joint Spectrum of Polarization-Entangled Pairs from Parametric Down-Conversion

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Distinguishability in PDC

Production of polarization-entangled photons via the nonlinear process of parametric down-conversion is a well established technique. If the pump used for the PDC process is in the cw regime, the photons emitted in particular emission directions of the cross ring configuration are well described by

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|H\rangle_1|V\rangle_2 - |V\rangle_1|H\rangle_2)$$

That is, two "decay modes" of the pump photons which are indistinguishable apart from their polarization properties.

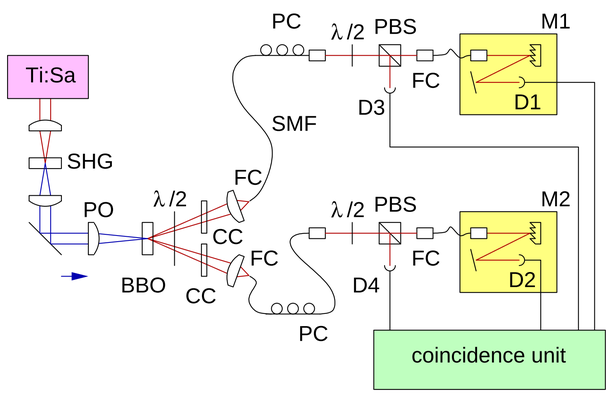

FIGURE 1: Type-II PDC. Each mode is directed to a single mode fiber and into a monochromator.

However, if the pairs of photons should be emitted on a well defined time window or if more than one pair is to be produced, then a pulsed pump is necessary, leading to a much reduced entanglement quality and the need to use interference filters, limiting the degradation but also greatly reducing the available signal.

Joint spectral correlations

The short pulse duration ($\approx$ 150fs) implies a wide distribution of pump frequencies, leading to entanglement of the polarization degree of freedom with the spectral properties of the down-converted photons [1]. A direct observation of these correlations is obtained by feeding each of the down-converted modes into a monochromator and monitoring the coincidence signal (see fig. 1).

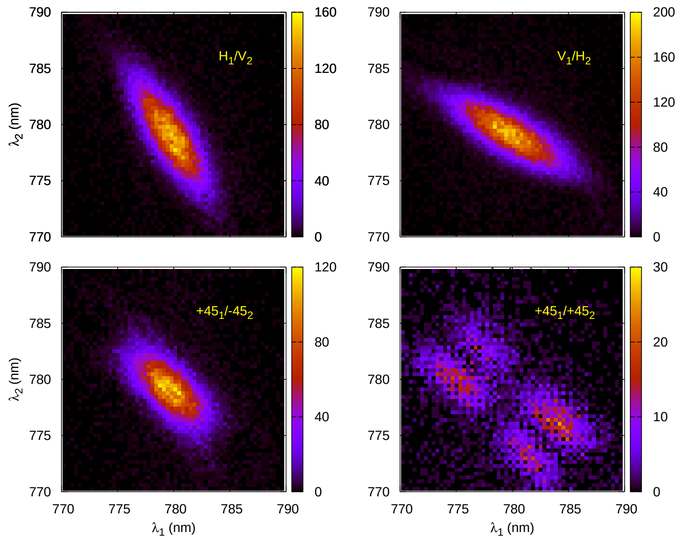

FIGURE 2: Joint spectrum of polarised photons produced by a femtosecond pulsed pump.

The distinguishability of the decay paths can be clearly seen between the HV and VH spectrum. A consequence is the characteristic "lobe" structure in the $+45°/+45°$ spectrum, which shows non-perfect anti-correlations away from the degeneracy lines.

Entanglement

The influence on entanglement quality can be assessed by polarization correlations at each point in the joint spectrum map (see fig. 3).

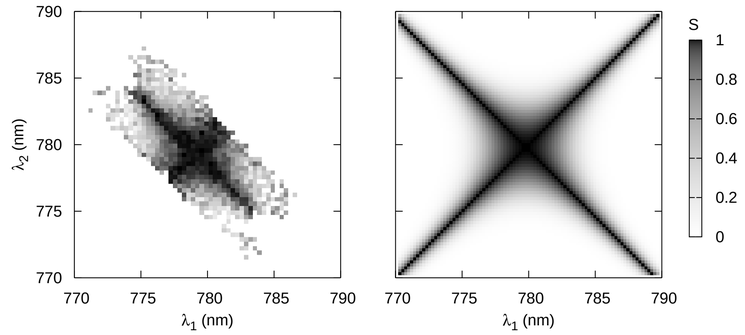

FIGURE 3: Entanglement entropy. On the left, the entanglement entropy extracted from the HV and VH spectrum data. On the right, the calculated entanglement entropy if the state is pure at every point (λ_1, λ_2) with HV and VH contributions given by a fit based on the HV and VH joint spectrum data.

The pairs collected at every point in the spectrum are well described by a pure state with inbalanced contributions from HV and VH. No other degrees of freedom are necessary to account for the degradation in entanglement quality for PDC with a pulsed pump.

$$|\Psi\rangle_{\lambda_1,\lambda_2} = a|H\rangle_1|V\rangle_2 + b|V\rangle_1|H\rangle_2$$

[1] W.P. Grice et al., Phys. Rev. A, **57**, R2289 (1998).

[2] H.S. Poh, et al., http://www.arxiv.org/abs/quant-ph/0608009, (2006).

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