Controllable Photon-Pair Generation and Quantum Walks in Nonlinear Waveguide Arrays

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We demonstrate experimentally simultaneous photon-pair generation and quantum walks in a lithium niobate waveguide array, where the output photon correlations can be controlled by varying the temperature- and wavelength-dependent phase-matching, switching from classical to quantum statistics.

Introduction

Spontaneous Parametric Down-Conversion (SPDC) – enabling generation of photon pairs for quantum optics

We combine SPDC with quantum walks in waveguide arrays (WAs) enabling simultaneous photon-pair generation and shaping of quantum correlations [2,3].

Dispersion and therefore phase-matching (PM) in WAs is fundamentally different from that in bulk.

Theory

Photon-pair wave-function in WAs with quadratic nonlinearity

\[ \psi(k_{a1}, k_{a2}, \Delta \omega) = \frac{1}{\sqrt{2\pi \Delta \omega}} \exp \left[ -i \mathbf{k} \cdot \mathbf{r} + i \mathbf{\beta} \cdot \mathbf{r} \right] \]

where \( \mathbf{\beta} = \beta_a \mathbf{k}_a + \beta_b \mathbf{k}_b \) and \( \mathbf{k}_a, \mathbf{k}_b \) are the wave vectors of the signal and idler, respectively.

Experiment

Periodic poling helps to archive ee-e SPDC phase-matching using largest component of nonlinear-optical tensor \( d_{33} \), LiNbO\(_3\) birefringence allows to phase-match oo-e SPDC at a higher temperature with lower photo-refraction.

Results

Sample with birefringent phase-matching

both signal and idler are collected from the pumped waveguide 0

Tunable coincidence rate

Experimental

Theoretical

Control of quantum statistics

Correlations control by pump beam reshaping

Summary

• World first experiment on nonlinear quantum walks
• Demonstrates simultaneous bunching and antibunching
• Excellent agreement between our theory and experiment

Outlook

Correlations control by pump beam reshaping

References