Compact Sagnac-type source for entangled photon pairs

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Sources of entangled photon pairs serve as basis for many quantum information experiments, such as quantum computing [1] or quantum key distribution (QKD) [2]. Especially in the field of QKD a popular wavelength combination is 810 & 1550nm, generated by spontaneous parametric down conversion (SPDC) [3]. Previous schemes facilitated two nonlinear crystals behind each other [4], hence limiting the propagation length to a few millimeters. In this work we present a novel implementation of a Sagnac-type photon source designed for operation at three wavelengths, obviating the need for any active stabilization loops. Due to the compact design and excellent stability properties it is a versatile tool for quantum experiments.

Setup

A 30mm long ppKTP crystal is pumped from both sides inside a Sagnac interferometer, generating entangled photon pairs at 810 & 1550nm by means of type-I SPDC (see fig. 1). The pump laser beam at 532nm is prepared externally in terms of spectral purity, focusing conditions and required polarization. It is then passed into the interferometer through a special trichroic mirror which reflects the signal and idler beams and transmits the pump. The two polarization modes are separated and recombined with a broadband polarizer; the necessary polarization flip for one mode is achieved with a periscope. Due to the special geometry no spatial walk-offs are induced, the temporal walk-off caused by the birefringent polarizer is compensated by an additional crystal. Signal and idler are finally separated by a dichroic mirror and coupled into single-mode fibers. The complete interferometer is built out of a monolithic aluminum block taking a footprint of 5x5cm.

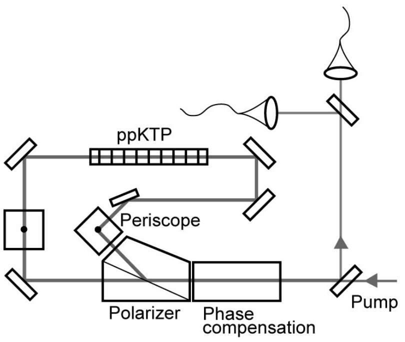

Figure 1: Schematic of the source

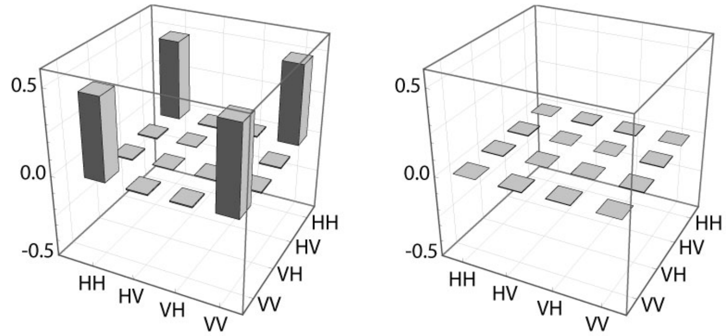

Figure 2: Real and imaginary part of the density matrix

Results

We obtain a coincidence rate of R_c=9300 s^{-1} mW^{-1} for each polarization mode. The generated bandwidth is only 180 GHz without any additional filtering, achieved by the phase-matching conditions of the long crystal. Together with the detector efficiencies (η_{810}=30%, η_{1550}=15%) this results in a brightness B=1.1×10^6 s^{-1} mW^{-1} THz^{-1} of the photons coupled into the single-mode fibers. To evaluate the quality of entanglement of the two-photon state a quantum state tomography measurement was carried out. Figure 2 shows the reconstructed density matrix for a $|\phi^+\rangle$ state, yielding an excellent fidelity of 98.2%.

Conclusion

We demonstrate a compact and stable source of high-brightness entangled photon pairs at 810 & 1550nm. The narrow bandwidth and high degree of entanglement makes it a versatile source for quantum information protocols such as QKD. Especially the wavelength of the idler (1550nm) makes it potentially useful for long distance communication [3] and operation in fiber networks [5]. Moreover, this source is a potential candidate for photonic interfaces to couple flying to stationary qubits needed for quantum repeaters. The further reduction of the bandwidth is achievable by a proper choice of phase-matching and an on-chip resonator.

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