Generation of non-degenerated polarization entangled photon pairs in periodically poled Ti:$LiNbO_3$ waveguides with interlaced domains

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Entangled photon pair sources are of key importance in the emerging field of quantum information technology. A common method to generate entangled pairs is based on type II phase-matched spontaneous parametric down conversion (SPDC) followed by a spatial separation of the pair using a conventional beam splitter (see e.g. [1], [2]). This scheme can be used to generate entangled pairs at degeneracy with the drawback that half of the generated pairs are "lost" if both photons leave the beam splitter at the same output port. Recently, we have demonstrated a new scheme providing non-degenerated pairs by employing a sophisticated poling pattern [3]. In this contribution we report a source of non-degenerated polarization entangled photon pairs using such a PPLN waveguide together with a polarization maintaining fiber as quantum eraser and a commercially available fiber-based coarse WDM coupler.

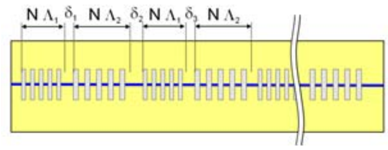

Fig. 1: Schematics of the PPLN waveguide with interlaced domains. The delta-sections guarantee constant phase relations.

The SPDC source is a 50 mm long Ti-indiffused waveguide in PPLN with an interlaced poling pattern consisting of two different periodicities ($\Lambda_1 = 9.30$ µm, $\Lambda_2 = 9.37$ µm) as shown in Fig. 1. Type II phase-matching enables the generation of orthogonally polarized photon pairs via SPDC. At the point of operation for entanglement (pump wavelength λ_p = 780.3 nm and temperature T = 175°C) the emission wavelengths are λ_1 = 1538 nm, where the TM emission of Λ_1 coincides with the TE emission of Λ_2, and λ_2 = 1567 nm, where the TE emission of Λ_1 coincides with the TM emission of Λ_2 (Fig. 2). A Fourier analysis of the domain structure in the spatial domain predicts additional phase matching processes. A domain structure with segments of N=10 domain periods is chosen so that these unwanted phase matching processes occur at wavelengths far off from the primary emission wavelengths λ_1 and λ_2.

The generated photon pairs are coupled from the waveguide into a polarization maintaining fiber (PMF) acting as quantum eraser (Fig. 3). Its length of 5 m is chosen to compensate the difference of the group velocity delays of the generated photons. In this way, a complete temporal indistinguishability of the photons is achieved. This is an advantage compared to the scheme of non-degenerated polarization entangled source proposed by Suhara [4]. Via a fiber-based coarse WDM coupler (spectral width ≈ 20 nm) the photon pairs are spatially separated. The joint state of the two photons at the output ports of the WDM is polarization entangled.

Entanglement is investigated by measuring coincidence counts behind a polarizer and a half wave plate. The observed coincidence count rate shows an interference pattern (visibility ≈ 70%) in two non-trivial bases (Fig. 3). Although the visibility is still far away from optimum, entanglement could be demonstrated. The deterioration of the visibility may be attributed to a non-ideal choice of the operation point and temperature or polarization instabilities during the measurement. Experiments are underway to improve the visibility.

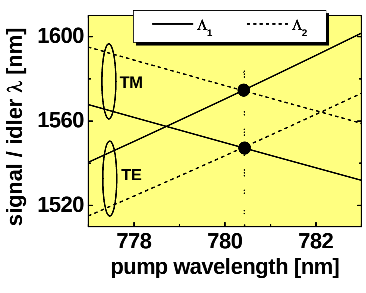

Fig 2: Phase-matching characteristics of the interlaced domain structure.

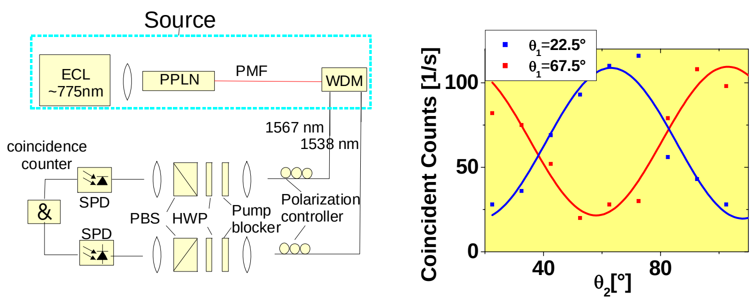

Fig 3: Set up to investigate polarization entanglement (left) and measured coincident counts as function of the orientations of the half wave plates.

References

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