Generation of Narrowband Polarization-Entangled Photon-Pairs Using a Type-II Periodically Poled Lithium Niobate Waveguide

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Abstract

We report on the generation of narrowband polarization-entangled photon-pairs at a telecommunication wavelength using the Type-II periodically poled lithium niobate waveguide. The two photon interference fringe was obserbed with 82% visibility without correcting accidental coincidence counts, under use of single-photon detectors based on the sinusoidally gated avalanche photodiodes.

Introduction

Entangled photon pairs at telecommunication wavelengths offers the possibility to realize quantum key distribution (QKD) over long distance[1. To date, the many entangled photon-pair sources have been reported, for example, the use of the spontaneous parametric down conversion (SPDC) process [2,3 and four-wave-mixing process [4. In particular, the SPDC process in periodically poled lithium niobate (PPLN) waveguide (Type-0 phase matching) has been widely used for the generation of entangled photon-pairs at a telecommunication wavelength, since it is very efficient [2,3. However, since the bandwidth of the photon pairs generated by the Type-0 PPLN waveguide is much broad, the narrowband filtering is required to apply the photon-pair source to long-distance fiber communications. The generation ratio of the photon pairs is significantly decreased in such narrowband condition. We have demonstrated that the Type-II PPLN waveguide had high brightness, and its photon-pair generation ratio in the narrowband condition was higher than that of Type-0 one [5. Then the Type-II PPLN waveguide can generate the cross-polarized photon pairs, which indicate that the waveguide has the possibility to directry generate the polarization-entangled photon pair with a simple single-pass setup.

Here we present preliminary results of the generation of the narrowband polarization-entangled photon pairs at a communication wavelength using the type-II PPLN waveguide.

Experimental setup

Our experimental setup is depicted in Fig. 1. We used the 30-mm-long adhered-ridge PPLN waveguide that utilized the nonlinear tensor element d_{24} for Type-II quasi phase matching[5. The ridge waveguide allows a strong confinement of the pump energy and an efficient transmission

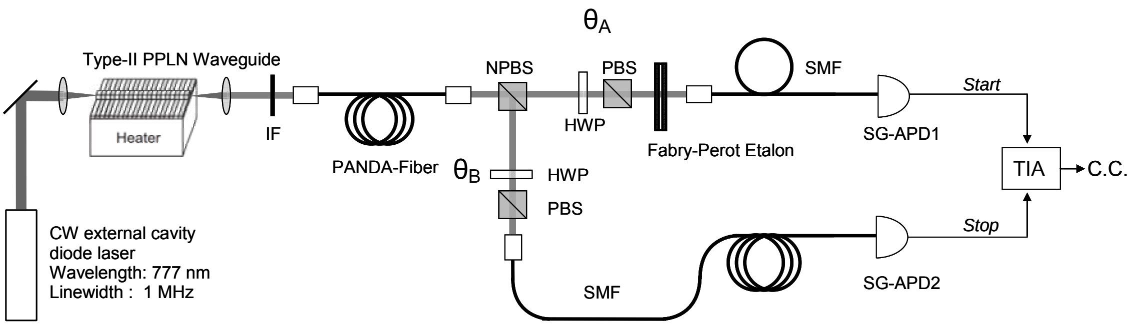

FIG.1. Experimental setup. IF: interference filter, NPBS: non-polarizing beamspliter, SMF: single-mode fiber, SG-APD1,2: 500-MHz sinusoidally gated InGaAs/InP avaalanche photodiodes, TIA: Time interval analyzer, C.C.: coincidence counts

of ligth in both of the TE and TM mode. The CW external cavity diode laser at 777 nm with a linewidth of 1 MHz was used for the pump. The signal (in TM mode) and idler (in TE mode) photons generated via the SPDC process in the waveguide were orthogonally polarized each other. In order to measure only the down-converted photon pairs, the emerging light from the waveguide passed through an interference filter (IF) centered at 1550 nm (width of 30 nm). The signal and idler photons were separated by the non-polarizing beamsplitter (NPBS), and two outputs from the NPBS are subsequently coupled into each single-mode fiber (SMF) connected with the single-photon detectors based on the sinusoidally gated InGaAs/InP avalanche photodiodes (SG-APD) operated with a gating repetition frequency of 500 MHz [(6].

The signal and idler photons emarged from the waveguide can be temporally distinguished, resulting from the polarization dependent group velocity dispersion in the long PPLN waveguide. the dispersion was compensated by transmission through the polarization-maintaing PANDA fiber (used as a birefringent medium) and narrowband wavelengh filter. The photon pairs had an intrinsic bandwidth of approximately 120 GHz, which was filtered to 20 GHz by use of the air-gap Fabry-Perot etalon (whose free spectral range was 250 GHz).

The polarization correlation was measured using the polarization analyzers composed of a rotatable half-wave plate (HWP) and a polarizing beam splitter (PBS). rotating the polarization angle θ_B while fixing the polarization angle θ_A on 0° or 45°, we measured the coincidence counts. The coincidence counts normalized by the single-counts were plotted as a function of porarization rotation angle in Fig. 2. when the θ_A was fixed on 0°, the coincidence fringe with a visibility of grater than 84% was observed without correcting the accidental conincedence counts. Then, as regareds θ_A=45°, the uncorrected visivility was 82 %.

In this experiment, although the average number of photon pair was set to 0.02 per gate width, the two photon interference visibility could not be beyond 90 %. The degradation of the visibility was caused by the somewhat high dark count probability (>10^{-5}) of the single-photon detector we used. If the dark count probability was reduced to

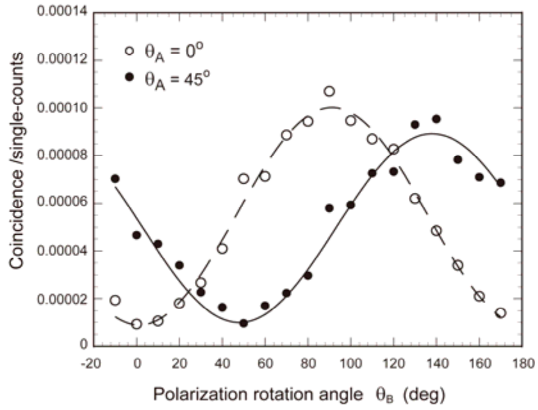

FIG.2. Experimental results

~10^{-6}, the un-corrected visibility would exceed 90%.

Conclusions

We demonstrated generation of polarization-entangled photon pair using the type-II PPLN waveguide. The entangled photon pair source is based on the simple single-pass setup. Then the photon pairs have bandwidth of only 20 GHz, which inplies that the polarization and chromatic dispersions in the fiber can be ignored even if the communication fiber length is much longer than 100 km. These features is advantageous to apply the source to practical long-distance QKD systems.

Acknowledgments

This work was partly supported by the National Institute of Information and Communications Technology (NICT).

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