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Preparation of single-photon states via cavity-assisted spontaneous parametric down-conversion for quantum memory based on $Y^7LiF_4:Nd^{3+}$ crystal

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Abstract. We report on the realization of a tunable single-photon source compatible with quantum memories based on isotopically pure Y^7LiF_4 crystals doped with Nd^{3+} ions. The source is based on spontaneous parametric down-conversion in a PPLN crystal placed in a resonator. The latter is formed by two mirrors which are transparent for the pump (532 nm) and idler (1377 nm) fields but high reflective for the signal field (867 nm). The width of the second-order cross-correlation function between the signal and idler photons is determined to be 1.5 ns for the cavity length of 8 cm, which corresponds to a cavity bandwidth of 100 MHz.

1 Introduction

Single-photon sources are believed to be an important ingredient for long-distance quantum communication and other applications of quantum information science. For getting through the fibre losses and implementing long-distance quantum communication protocols, one can take advantage of quantum repeaters [1, 2], which in turn requires storage of nonclassical light states in a quantum memory device. Among different schemes of quantum memory (see, e.g., recent reviews [3, 4]), off-resonant solid-state Raman schemes might be useful. In this respect, isotopically pure crystal $Y^7LiF_4:Nd^{3+}$ seems to be one of the promising materials [5, 6]. The present work is devoted to developing a heralded single-photon source that is compatible with such a quantum memory device. In doing so, we follow the approach of [7] and make the spectral width of generated single-photon states comparable with the quantum memory bandwidth (10–100 MHz) by using a single-resonant optical parametric oscillator (OPO) operating far below threshold.

2 Basic results

For the parametric interaction in our OPO resonator we use a 20 mm long PPLN crystal (Labfer) that supports quasi-phase matching for type-0 SPDC to convert photons at 532 nm

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to photon pairs, with one photon located at 867 nm (signal field) and the other at 1377 nm (idler field). The former corresponds to the resonant transition of Nd^{3+} ions in the Y^7LiF_4 crystal. Temperature of the nonlinear crystal is controlled to the precision of 0.01°C. The mirrors of the resonator are high reflective only for the signal field (R ≈ 99.8% and 97%), which corresponds to the signal-resonant OPO. The sides of the PPLN are antireflection coated to minimize losses within the cavity. In order to perform cross-correlation measurements between signal and idler photons, each of them is guided to an avalanche photodetectors connected to a coincidence circuit. Filtering of the pump field by several orders of magnitude in each channel is accomplished by a sequence of a diffraction grating, a cut-off dichroic mirror, an interference filter, and also a Bragg fibre filter. An example of the measured second-order cross-correlation function between signal and idler photons is shown in Fig. 1. In this case, the cavity length is equal to 8 cm so that the correlation function broadens from 300 ps, which is observed for SPDC in the free space, to 1.5 ns, which corresponds to the spectral linewidth of 100 MHz. The modulation of the decay curve reflects contribution of adjacent cavity modes and corresponds to the cavity round-trip time of 0.8 ns.

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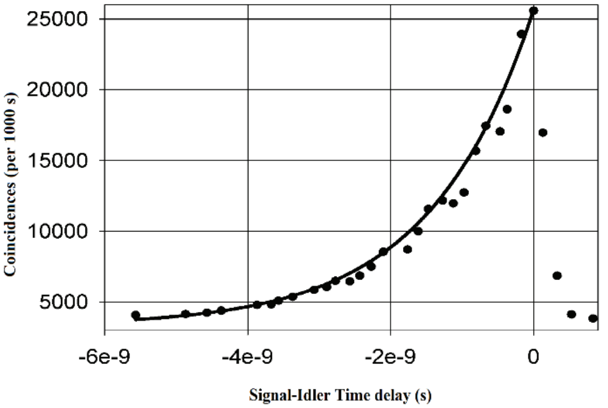

Fig. 1. Second-order cross-correlation function between signal and idler photons.

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