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# Packaged Integrated SPDC Photon Pair Source with Polarisation Splitter

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Spontaneous parametric down-conversion (SPDC) in nonlinear crystals is the most commonly used means to generate single photon pairs for quantum key distribution systems [1]. By using waveguides instead of bulk crystals, highly efficient devices can be obtained. Both, type-I and type-II phase-matched integrated devices have been demonstrated in periodically poled lithium niobate (PPLN) [2-4]. Although the type-II process is less efficient, it has two favourable properties: the spectrum of down-converted photons is narrower compared to type-I and orthogonally polarised photons are emitted.

In this contribution we present a fully packaged integrated optical circuit comprising a waveguide type II SPDC source, an integrated polarisation splitter and a pump rejector as shown in Fig. 1. It represents a first example of an integrated circuit in $LiNbO_3$ for quantum information processing and quantum cryptography. A polarisation maintaining single mode fibre is used to couple the pump radiation at ~780 nm into the waveguide. The end-faces of the waveguide were angle-polished to avoid back reflections into the fibre. The waveguide was fabricated by an in-diffusion of photo-lithographically defined 7 µm wide, 80 nm thick titanium stripes for 9 h at 1060 °C. A 66 mm long section of the waveguide was poled with a 9.1 µm period in order to enable quasi-phase-matching for SPDC generated by 780 nm pump radiation at a temperature of 50 °C. A specially designed zero gap coupler acting as a polarisation splitter separates the orthogonally polarised signal and idler photons (at 1560 nm). The coupler provides a splitting ratio of about 20 dB for both polarisations. With a dielectric mirror deposited on the waveguide end-face the residual pump radiation is rejected. A suppression of the pump by ≈ -17 dB with only small excess losses (≈-0.2 dB) for the down-converted photons is achieved. The overall device was packaged in an Al-housing with provision for stabilising the substrate temperature (Fig. 2).

The packaged source was first characterised operating the device in the reverse direction, i.e. we coupled tunable orthogonally polarized 1.5 µm radiation into both output fibres and studied second harmonic generation. The measured fibre-to-fibre SHG efficiency was about 2 %/W with a phase matching bandwidth of 100 pm.

Photon pair generation was investigated by performing coincidence experiments. Using single photon detectors and a time-to-digital converter, the arrival time difference of photons emitted from the two fibre outputs was measured. In Fig. 3 a typical result is shown, which clearly reveals the pair generation. The pump power was 330 µW. From these measurements we can conclude that the rate of photon pairs emitted from the two output fibres was about $10^6$ pairs/s. The spectral emission bandwidth is less than 1 nm. Therefore, we estimate the normalized brightness of our device to be about $10^4$ pairs/(s GHz mW).

There is still a large potential to improve the source: in particular, coupling losses can be substantially reduced resulting in a higher efficiency. A polarisation splitter of higher splitting ratio would suppress most of the photons of unwanted polarisation. Also the pump suppression at both outputs can be further improved e.g. by inserting fibre optical band-pass filters.

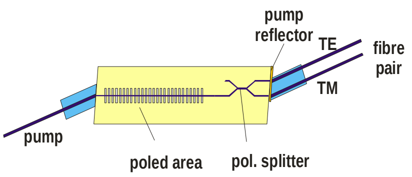


**Fig. 1:** Scheme of the integrated photon pair source with fibre pigtails.

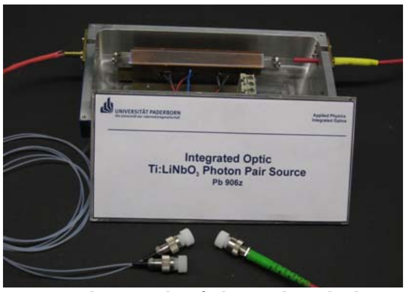


**Fig. 2:** Photograph of the packaged photon pair source.

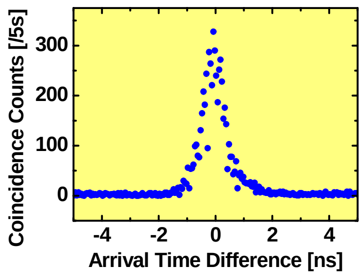


**Fig. 3**: Coincidence counts versus the arrival time difference. Detection efficiency was 15 % and gate width was 100 ns.

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