A ps-pulse laser for ultrafast entanglement generation at 42.66 GHz repetition rate

Sophie Zeiger[1], Fabian Laudenbach[1,*], Bernhard Schrenk[1], Michael Hentschel[1], and Hannes Hübel[1]

[1] Security & Communication Technologies, Center for Digital Safety & Security, **AIT Austrian Institute of Technology GmbH**, Giefinggasse 4, 1210 Vienna, Austria

*Contact: fabian.laudenbach@ait.ac.at

Abstract

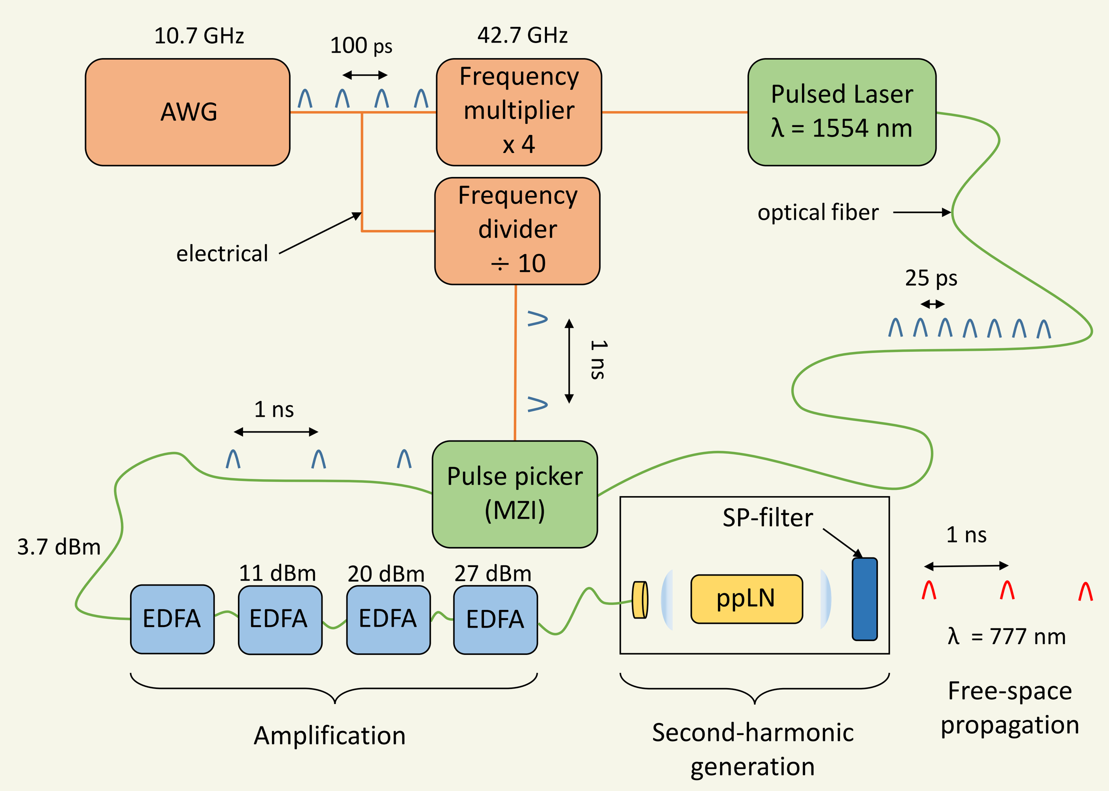
We present a high-speed source for polarisation-entangled photon pairs at telecom wavelength [1]. With a tunable clock rate of up to 42.7 GHz it is, to the best of our knowledge, the fastest entangled-photon source ever demonstrated and therefore highly relevant for photonic quantum computation.

Introduction

Entangled-photon sources are a key element for almost any kind of quantum-information application. In particular, photonic quantum-processing algorithms such as one-way quantum computing [2] and blind quantum computing [3] require photons with not only high entanglement visibility but also high spectral indistinguishability and purity. Moreover, scalability of these applications can only be achieved under high clock rates. Our entangled photon source can be operated at a generation rate of up to 42.7 GHz and is therefore basically only limited by the jitter of the detectors. We achieve a high spectral purity without narrow bandpass-filtering by mutually matching the length of the downconversion crystal and the pump laser's pulse duration [3], yielding polarisation-entangled photon pairs with minimal spectral correlation.

Pump preparation

High-rate picosecond laser at 777 nm



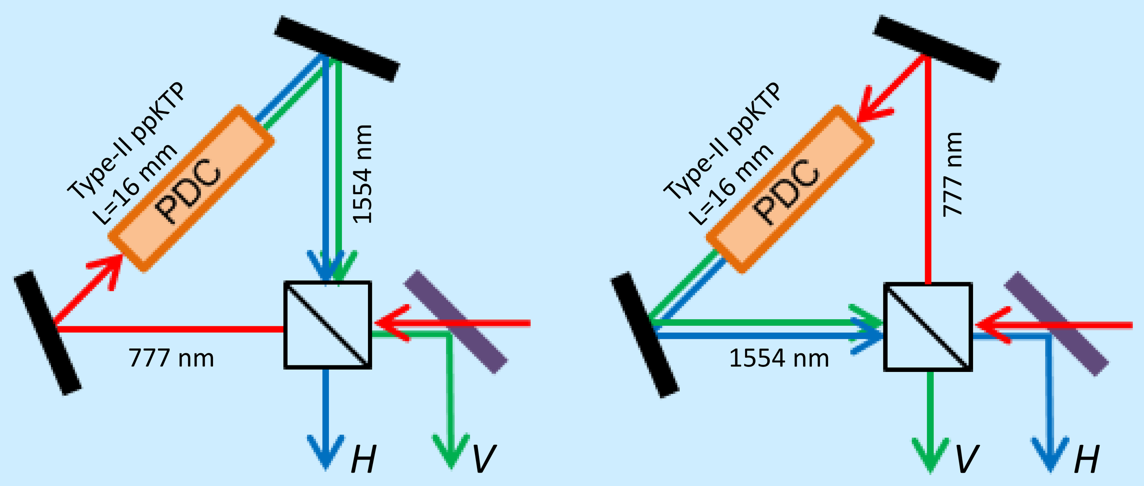
- Tunable pulse rate of up to **42.7 GHz**
- Tunable centre wavelength: **775–780 nm**
- Pulse duration: ~ **2 ps**
- Amplified power at 1554 nm: ~ **0.5 W**
- SHG power at 777 nm: ~ **100 mW**

Three ingredients for high interference visibility

- *Polarisation: maximally entangled*
$$|\psi^-\rangle = \frac{1}{\sqrt{2}}(|H\rangle_s|V\rangle_i - |V\rangle_s|H\rangle_i)$$
- *Frequency: separable*
$$f(\omega_s,\omega_i) = \mu_p(\omega_s+\omega_i)\cdot\phi(\omega_s,\omega_i) \approx f_s(\omega_s)\cdot f_i(\omega_i)$$
- *Spectral distribution: identical*
$$\mu_s \approx \mu_i$$

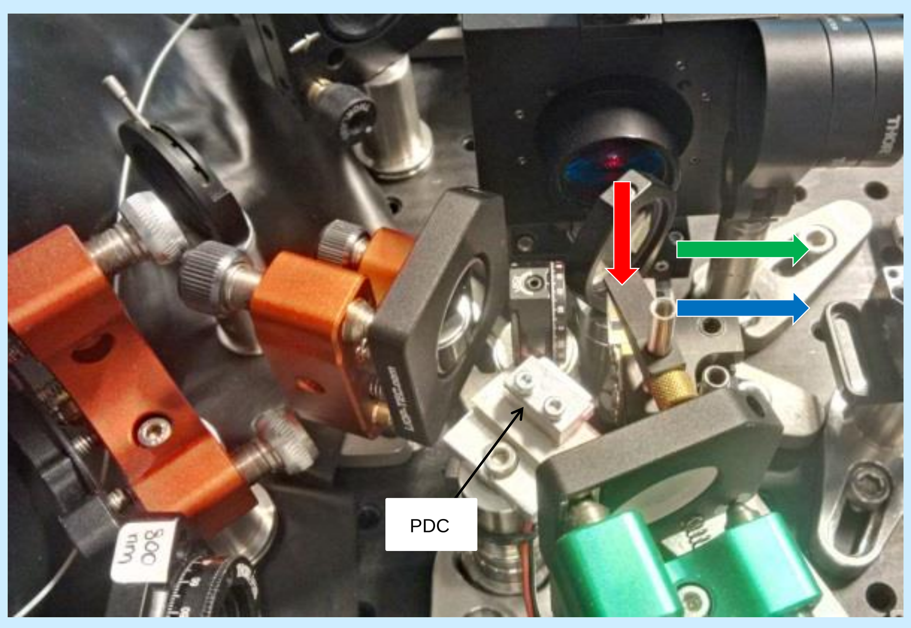
Entangled-photon source

The Sagnac interferometer: polarisation entanglement by lost which-way information

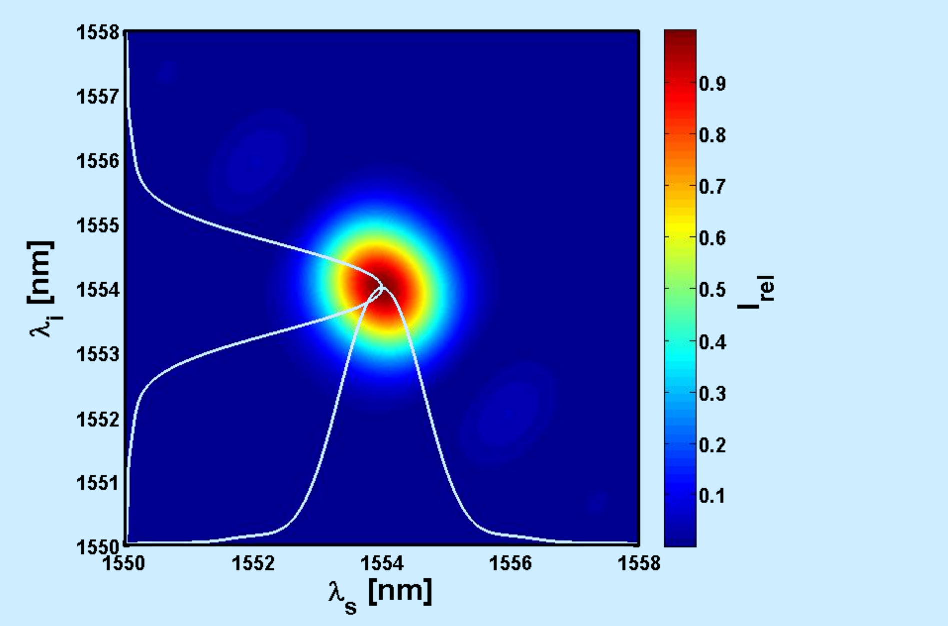


Clockwise pump direction

Counter-clockwise pump direction



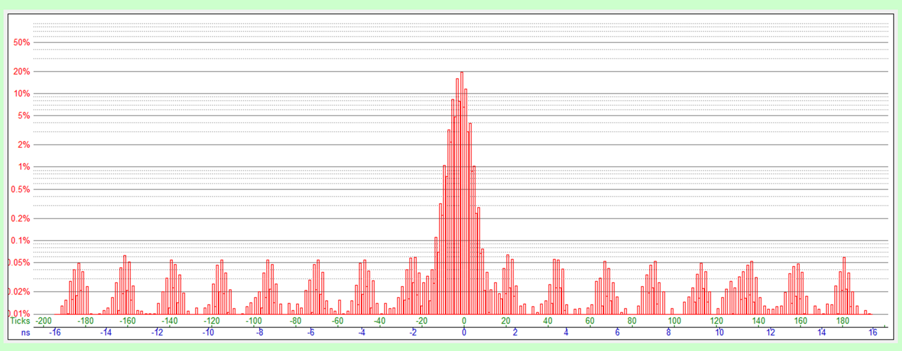
High purity due to minimised spectral correlation



Mutual matching of crystal length (16 mm) and pulse duration (~ 2 ps) allows to achieve low spectral correlation between signal and idler [4].

Detection InGaAs SPADs

High entanglement visibility

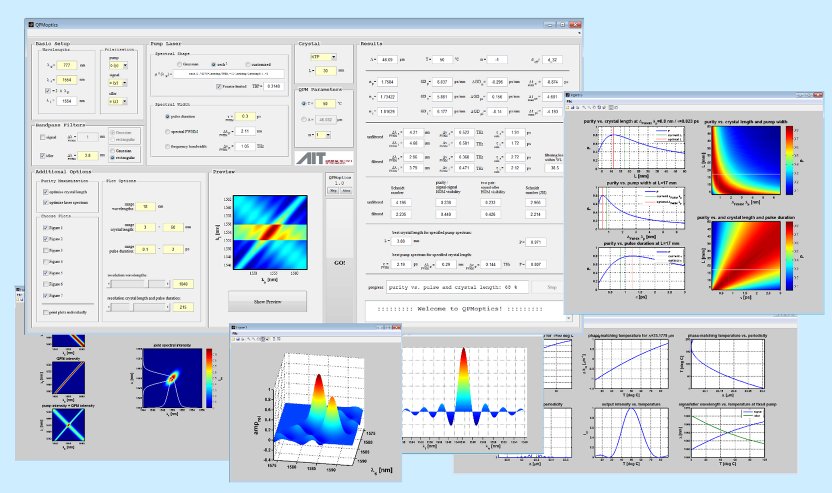


Temporal correlation between signal and idler events when operated at 500 MHz.

- Visibility: **0.97** $\pm$ **0.05** = $1/\sqrt{2} + 5\sigma$
  (corresponding to CHSH parameter ~ **2.685**)
- Coincidence counts: ~ **170/s** at 30 mW pump power

Detection was performed using two free-running InGaAs detectors (IDQ 210). Detection efficiency was set to 10 %. Counts from both detectors were recorded at a time-tagging unit (TTM-8000). The time tags were further processed to compute delay histograms and coincidence rates. Observed coincidence rates were in the region of **170 coincidences/second**. Hence, taking into account the detection efficiencies, the source produces ~ **17,000 fibre-coupled photon pairs per second** at 30 mW pump power.

Software-based optimisation



Numerical simulations using our tool `QPMoptics` [5] helped to optimise the photon source ahead of the experiment. → http://www.roithner-laser.com/scientific.html

References

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