Integrated Photon Pair Source
Based on SOI Micro-Ring Resonators

B. Schrenk*[1], F. Laudenbach[1], P. Müllner[1], D. Fowler[2], R. Hainberger[1], and H. Hübel[1]

(1) AIT Austrian Institute of Technology GmbH, Donau-City-Strasse 1, A-1220 Vienna, Austria

(2) CEA-LETI, MINATEC Campus, 17 Rue des Martyrs, Grenoble 38054, France

Corresponding author: bernhard.schrenk@ait.ac.at

1. Introduction

The generation of single photons or photon pairs is key technology for most quantum information experiments and applications. Most photon pair sources are based on $\chi^{(2)}$ processes in nonlinear crystals making use of the very clean conversion to achieve the highest visibilities. In order to scale up quantum systems in terms of multi-source implementation or more complex systems such as photon pair sources linked with optical signal conditioning circuits photonic integration is required. However the aforementioned sources are not suitable for chip integration and even if waveguide technology is used these sources still have a too large footprint [1]. The silicon-on-Insulator (SOI) platform offers high conversion efficiencies with a very small foot print [2]. In addition, the $\chi^{(3)}$ processes is clean with no appreciable contamination due to scattering effects. On top of this, SOI technology is compatible with well established CMOS technology as used in microelectronics. In this work we present such a photon pair source at telecom wavelengths around 1550 nm based on a silicon micro-ring resonator. We further show the potential of such a source to facilitate broadband pair emission over multiple DWDM channels.

2. SOI Micro-Ring Resonator as Photon Pair Source

The key component used for photon pair generation is a silicon micro-ring resonator (MRR) with a FWHM bandwidth of 12.5 GHz and a free spectral range of 125 GHz. The MRR was fabricated on SOI technology using a 220×500 nm^2 waveguide cross-section. Figure 1(b) shows the fabricated chip. The waveguide-to-ring coupling was optimised with respect to propagation losses of 1 dB/cm for TE polarisation. The footprint of the MRR structure is 250 × 250 μm^2, which is orders-of-magnitude smaller than traditional crystal-based implementations. With this a high integration density can be facilitated. Connection to off-chip circuitry is made through grating couplers. The single-mode fibre pigtails used for fibre-to-waveguide coupling can be seen in Fig. 1(b). Figure 1(c, orange curve) plots the measured transmission function at the drop port of the MRR. An extinction higher than 20 dB is yielded. The tilt in the envelope of the transmission function results from the set angle for fibre-to-waveguide coupling.

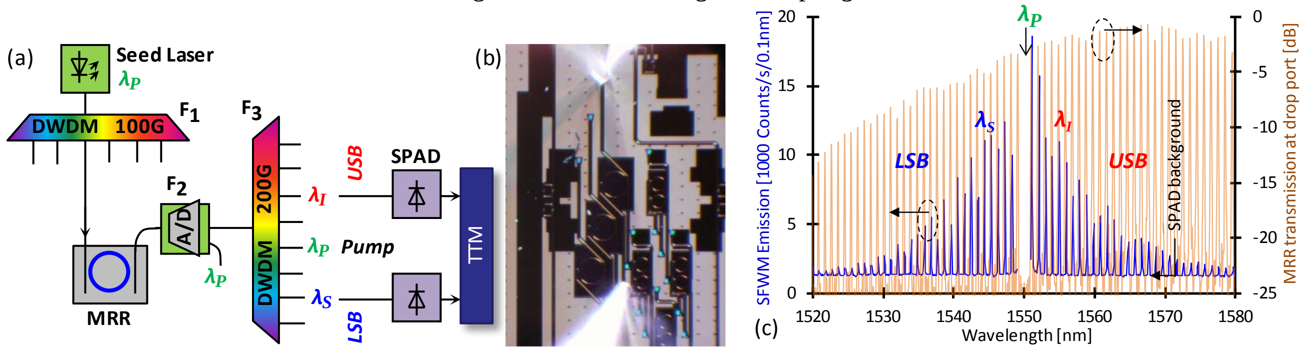

Fig. 1. Generation of photon-pairs with photonic integrated silicon micro-ring resonator.
(a) Experimental setup, (b) fabricated device, (c) MRR transmission and emission spectra.

3. Experimental results

In order to evaluate photon pair generation through spontaneous four-wave mixing (SFWM) in the MRR, the device was embedded in the setup shown in Fig. 1(a). We used a continuous-wave pump at λ_P to excite the ring resonances. The pump light was spectrally cleaned using a DWDM filter (F_1) and the polarisation was aligned to achieve maximal coupling to the waveguide structure. The generated photon pairs were collected at the drop port of the MRR and coupled to an optical filtering circuit consisting of an add-drop DWDM filter (F_2) to reject the remaining pump light and a DWDM demultiplexer (F_3) to separate signal and idler photons of a pair. Due to energy conservation the signal (λ_S) and idler (λ_I) pairs are located symmetrically around the pump channel C37 within the lower (LSB) and upper sideband (USB). Figure 1(c, blue curve) shows the SFWM emission spectrum at the drop port of the MRR, acquired through a single-photon spectrum analyser. Emission in the LSB and USB resonances adjacent to the pump wavelength λ_P = 1550.1 nm can be clearly observed. The broadband emission of the photon pair source can be exploited to facilitate pair generation over multiple DWDM channels.

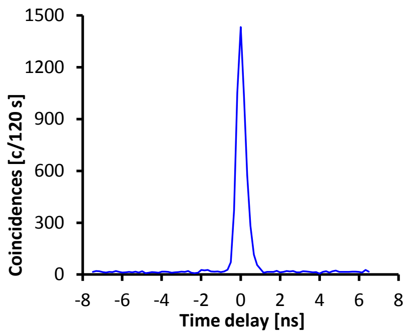

Fig. 2. Coincidence measurements between signal and idler photon in channels C33 and C41.

In order to measure coincidences, particular MRR resonances were selected in view of available DWDM filters in the C-band. For this reason we used a pump at λ_P = 1547.6 nm (ITU channel C37). Coincidences were observed pairing channels C35/C39 and C33/C41. Signal and idler photons were detected in free running InGaAs SPADs (10% quantum efficiency) and correlations were analysed using a time-to-digital converter. The combination of channel C33 with channel C41 proved particularly well matched with measured pair rates of up to 40 coincidences/s and a visibility of 95% (Fig. 2). The other combination (C35/C39) had a reduced coincidence rate of 20 c/s which resulted in a lower visibility of 73%. We believe that the reduction is caused by a mismatch of the ring resonances and the fixed DWDM grid. In future this mismatch can be eliminated by heating the resonators and hence altering its spectral properties. Moreover the coincidence rate, which depends quadratic on coupling efficiencies, can be further improved by optimising the chip-to-fibre coupling.

Acknowledgement: This work was supported by the Austrian Research Promotion Agency FFG through the PHELICITI project under grant agreement n^o 838835.

References

[1] I. Herbauts, B. Blauensteiner, A. Poppe, T. Jennewein, and H. Hübel, *Opt. Exress* **21**, 29013 (2013)

[2] D. Grassani, S. Azzini, M. Liscidini, M. Galli, M.J. Strain, M. Sorel, J.E. Sipe and D. Bajoni, *Optica* **2,** 88 (2015)