Integrated photon pair source for SOI-based quantum optics

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Photon pair sources are an important building block for optics based Quantum Information Processing (QIP) such as Quantum Key Distribution (QKD) and Linear Optics Quantum Computing (LOQC) [1]. Beyond the demand for reliable and cheap photon pair sources for QKD, LOQC also requires interferometers that are mechanically stable and loss-free for which integrated photonics is particularly attractive [2]. In this context, photon pair generation (PPG) has been demonstrated via the third order nonlinear interaction between a silicon straight waveguide (Si-w) and a pulsed beam [3]. Such a source cannot be directly followed by other integrated components as photon pairs would be generated throughout the silicon chip. The solution we propose to suppress the pump beam consists of a Sagnac Loop Interferometer (SLI) in which photon pairs are generated and pump beam destructively interferes with itself, thereby allowing photon pairs to be generated in a localised part of the silicon chip. Furthermore, our study has been performed in a continuous instead of a pulsed regime, thereby avoiding any synchronization between detectors and laser and allowing for much cheaper laser sources. Our experimental setup is presented in Fig. 1. The experiment is performed at different pump power both in the a Si-w and the SLI. Results are presented in Fig. 2. The flux of generated pairs and the Signal-to-noise ratio are limited by the outcoupling loss and detector inefficiency. The photon flux is less than expected because the emitted spectrum is around 8nm (FWHM) broad instead of the expected 70nm. The performance of the SLI is not yet perfect: the pump suppression efficiency decreases with the pump power (from -22dB to -15dB) due to unexpected nonlinear behaviour in the directional coupler that changes the coupling ratio; and the Signal-to-Noise ratio is lower than in the Si-w which might be due to PPG in the broad (800nm) waveguide before the SLI.

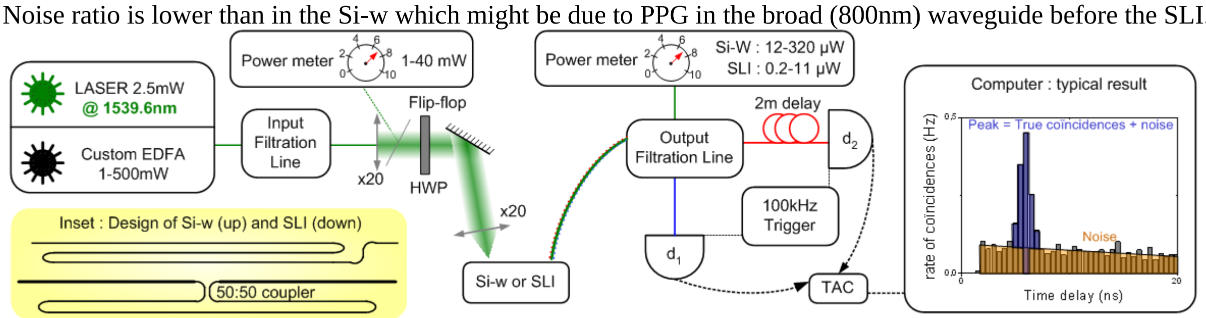

Fig. 1 : The Input Filtration Line plays the role of a passband filter that suppress 150dB on frequencies outside of the band [1538.9-1540.6]. The Half-Wave-Plate (HWP) aligns the polarization on the TE-like mode of the 500x200nm² silicon waveguide (made by IMEC). Coupling in/out the Si-w is ensured by gratings couplers (in free-space at the input to avoid nonlinear scattering noise from a fiber). The Output Filtration is a notch filter which suppresses 150dB on the pump band and separates Stokes [1542-1558] nm from anti-Stokes [1523-1538] nm photons. d1 and d2 are Avalanche Photodiodes (APD); d2 is trigged with a 5ns delay with respect to d1. They are operated in Geiger mode with gate duration of 50ns. The typical result is a peak that corresponds to true coincidences (purple) and noise in other time-bins (brown). The noise is due to destroyed photon pairs and darkcount of APDs. Inset : The Si-W is 11.3 mm long and the loop in the SLI is 10 mm long.

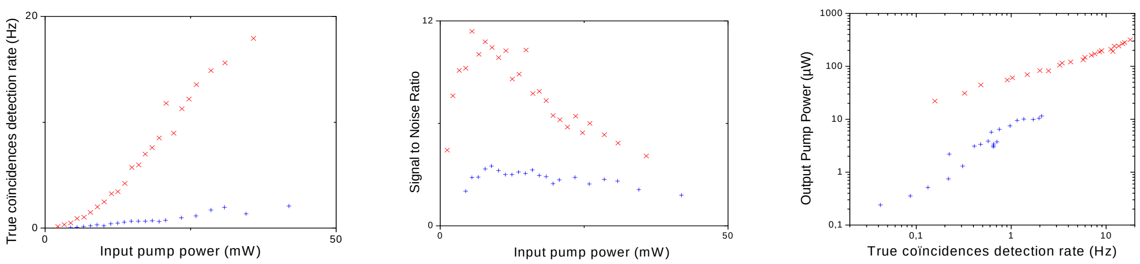

Fig. 2. x correspond to Si-W and + to SLI. *Left* : The evolution of the number of true coincidences (flux) vs the input pump power P is 4 times lower in the SLI than in the Si-W because P is divided by 2 and the flux increases as P². Note that the flux saturates at higher power because of nonlinear loss. *Center*: The evolution of the Signal-to-Noise Ratio (SNR) vs P is lower in the SLI indicating some pairs are split. *Right*: The output pump power for a given flux is almost 10dB lower in the SLI even thought the conversion efficiency is 4 times lower which proves the suppression of the pump beam in the SLI.

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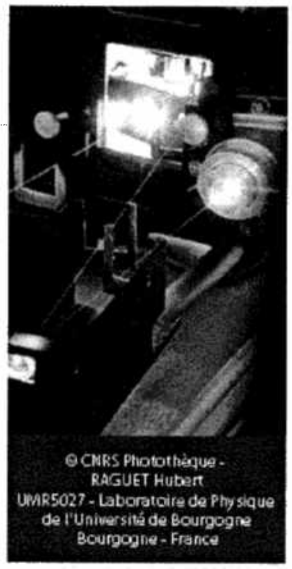

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