Sub-Wavelength engineered waveguide Bragg filter for optical pump-rejection

Diego PEREZ-GALACHO[1*], Carlos ALONSO-RAMOS[1], Florent MAZEAS[2], Xavier Le ROUX[1], Dorian OSER[1], Weiwei ZHANG[1], Delphine MARRIS-MORINI[1], Laurent LABONTE[2], Sébastien TANZILLI[2], Eric CASSAN[1], Laurent VIVIEN[1]

[1]Centre for Nanoscience and Nanotechnology, CNRS, Univ. Paris-Sud, 91405 Orsay, France

[2]Université Nice Sophia Antipolis, Laboratoire de Physique de la Matière Condensée, CNRS UMR 7336, Parc Valrose, 06108 Nice cedex 2, France

[*] diego.perez-galacho@u-psud.fr

Silicon photonics has become a major technology in the recent years. Its development has been driven mainly by datacom and sensing applications. However it can also be used for generating and manipulating entangled photon pairs [1]. This paves the way to the envisioned monolithic integration of quantum-processing circuits. On-chip photon pairs generation has been already demonstrated using spontaneous four wave mixing in Si microresonators [1]. Due to huge difference in terms of power between the pump signal and the photon pair signal, on-chip pump-rejection filters are required in order to use this kind of nonlinear sources. The requirements for these filters comprise not only high rejection but also narrow bandwidth (typically around 1nm). Implementing on-chip filters with those characteristics is nowadays a real challenge. Architectures based on contradirectional couplers [2] and rings and reflectors [3] have been reported with sub-nanometer bandwidth, however they lack the appropriate rejection levels. Ultra high rejection can be obtained with Mach-Zehnder interferometer based filters [4], but they need active tuning and often exhibit broader bandwidth. Bragg filters can be used just properly designing the modulation of the waveguide width, but in order to meet the bandwidth demands corrugations width below 10nm can be required [5], complicating its fabrication. In this work, we present a Bragg filter based on Sub-Wavelength Grating (SWG) waveguides overcoming these fabrication constraints. Its schematic representation is shown in Fig. 1 (a), it is based on dividing the Bragg period (Λ_B) into two SWG periods (Λ_1, Λ_2). The widest part of each SWG period are slightly different (ΔW), implementing an effective Bragg grating width corrugation. Using this approach the minimum width corrugation is no longer limited by the minimum feature size (as in conventional Bragg filters), but its limitation arises from the resolution of the lithography process. This resolution is normally in the order of just a few nanometers, therefore our approach enables the use of very small modulation widths leading to very narrow filters.

In order to evaluate experimentally the proposed filtering structure, the SWG based Bragg filters were fabricated. We used a 220 nm thick SOI platform with 2µm thick BOX. Since the resolution of our electron-beam lithography process is 5nm, we used that value as modulating width (ΔW=5nm). SEM pictures of the fabricated filter are shown in Fig (b) and (d).

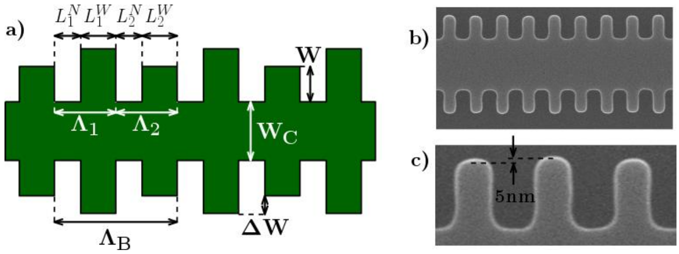

Fig. 1. SWG based Bragg filter: schematic view (a) and SEM pictures (b) and (c).

In order to characterize the device, TE-polarized light was injected and extracted of the chip by means of grating couplers. In Fig. 2 the experimental results of the SWG based Bragg filter are shown for three different lengths, alongside with the results of a straight waveguide. As expected, the longer the filter the higher the rejection. It can be seen that the transmission outside the rejection band is comparable to the reference waveguide in the three cases and it is within the alignment precision of our setup. From Fig. 2, we see that the 1000µm long filter exhibits an outstanding performance with a bandwidth as narrow as 1.1nm and a rejection exceeding 40dB. This represents an improvement close to 30dB in rejection compared to previously reported Si Bragg filters based on SWG engineering [6]. These results are an important step towards the realization of Si pump-rejection filters for on-chip photon-pair sources and quantum processing applications.

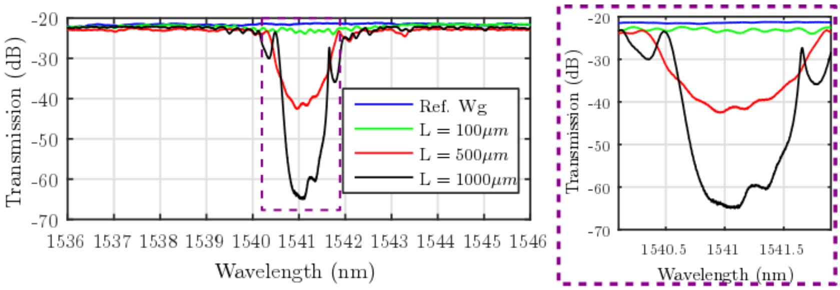

Fig. 2. Experimental results of the fabricated filter for three different lengths.

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