# Subwavelength grating Bragg grating filters in silicon-on-insulator

J. Wang, I. Glesk, and L. R. Chen

Narrowband filters based on Bragg gratings (BGs) in subwavelength grating (SWG) waveguides in silicon-on-insulator are reported. The SWG BGs are fabricated using electron beam lithography with a single etch. For SWG BGs 1.12 mm in length, the measured 3 dB bandwidths are ~ 0.5 nm and have a peak reflectivity as high as 94.4% in the C-band.

*Introduction:* There is an increasing need for integrated solutions in optical communications and interconnections applications [1]. In the past few years, a variety of active and passive devices as well as integrated subsystems in CMOS-compatible silicon photonics platforms have been realized [2]. Subwavelength grating (SWG) waveguides have attracted interest due to their potential for low loss and flexibility in tailoring the effective index [3,4]. Indeed, a number of SWG-based devices/building blocks in silicon-on-insulator (SOI) have been developed, including waveguide crossings [5], bends [6], couplers [6-8], and ring resonators [9]. Bragg gratings (BGs) have important applications as optical filters and for implementation in more complex wavelength selective devices. A number of BGs and BG-based devices in SOI have been reported [10-13]. Recently, we proposed BG filters in SWG waveguides by interleaving two SWG waveguides with different duty cycles [9]. In this paper, we provide experimental verification of such SWG BG filters. The fabricated devices have high reflection (> 90%), narrow 3 dB bandwidth (0.5 nm), and occupy a relatively small footprint.

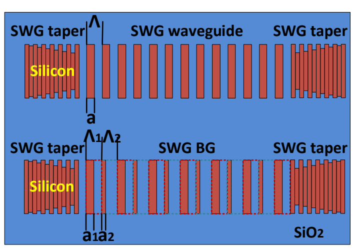


**Fig. 1** Top view of an SWG waveguide and an SWG BG.

*Device design and fabrication:* Fig. 1 compares the schematic of an SWG waveguide and an SWG BG in SOI. The effective index of the SWG waveguide depends on the duty cycle $f = a/\Lambda$, where $a$ is the is the width of the high index medium (here Si) and $\Lambda$ is the period. An SWG BG can then be realized by interleaving two SWG waveguides with different duty cycles $f_1 = a_1/\Lambda_1$ and $f_2 = a_2/\Lambda_2$; the SWG BG has a period of $\Lambda_1 + \Lambda_2$. By varying $f_1$ and $f_2$, we create a periodic variation in the effective index and can thus obtain Bragg reflection [9].

The cross-section of the SWG waveguides used in our experiments is shown in Fig. 2*a*. The width and height of the silicon layer are 500 nm and 220 nm, respectively; it sits on top of a 3 μm thick buried oxide (BOX) layer and has an index-matched top oxide cladding. We consider SWG waveguides with $\Lambda$ = 280 nm (to obtain a transmission window spanning the C-band) and 1,000 periods. Two SWG tapers are used to convert light into (and from) a Bloch mode before (and after) propagating through the SWG waveguide, see [5,9] for details. A Y-branch is used to extract the reflection response of the SWG BGs. For the SWG BGs, we use $\Lambda_1 = \Lambda_2$ = 280 nm and vary $f_1$ and $f_2$ by changing $a_1$ and $a_2$. The length of the grating is 1.12 mm (each of the interleaved SWG waveguides comprises 1,000 periods). Vertical grating couplers (VGCs) [14] optimized for TE transmission are used to couple light in and out of the device. A full layout of the device is shown in Fig. 2*b*; it occupies a footprint of 1.18 mm × 254 μm. The devices were fabricated at the University of Washington Nanofabrication Facility using electron beam lithography with a single full etch. An SEM image of an SWG BG (before deposition of the top oxide cladding) is shown in Fig. 2*c*.

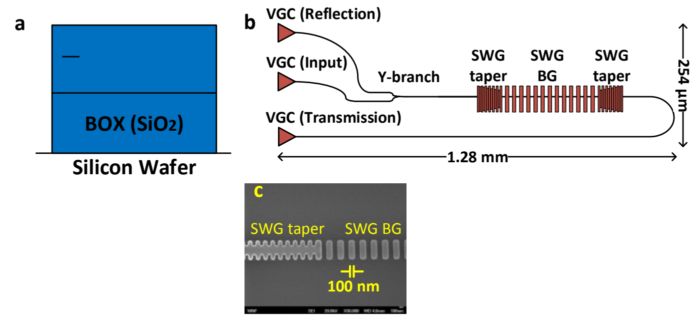


**Fig. 2** SWG BGs
*a Schematic of device cross-section*
*b Device layout*
*c SEM of the fabricated SWG BG prior to oxide cladding deposition*

*Experimental results and discussion:* A tunable laser scanned in steps of 10 pm and an optical power meter are used to measure the spectral responses of the devices. The total fiber-to-fiber loss is typically 15 dB. Fig. 3*a* shows the measured transmission response of the SWG waveguide without and with a BG based on $f_1$ = 50% and $f_2$ = 48%. When there is no modulation of the effective index, no spectral features appear within the waveguide transmission band (the general variation in amplitude is due in part to the spectral response of the VGCs). On the other hand, the SWG BG exhibits a clear rejection peak at a resonant wavelength of 1546.8 nm. Fig. 3*b* shows a zoom of the measured transmission and reflection responses about 1546.8 nm: the transmission loss is -12 dB corresponding to a peak reflectivity of 90.4%; the 3 dB bandwidth is 0.5 nm.

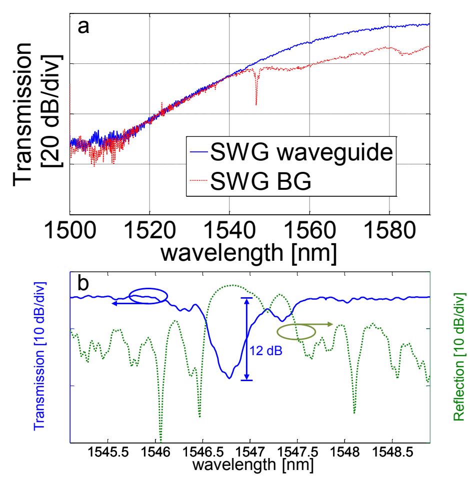


**Fig. 3** Measured response of SWG waveguide and SWG BG ($f_1$ = 50% and $f_2$ = 48%).
*a Transmission spectrum of the SWG waveguide and the SWG BG*
*b Zoom of transmission and reflection responses about the resonant peak at 1546.8 nm*

By varying $f_2$, we can tune the Bragg wavelength. In particular, we can shift the reflection peak to shorter wavelengths by reducing $f_2$ (i.e., decreasing the effective index) [9]. Fig. 4 compares the reflection response of the above SWG BG to one with $f_1$ = *50%* and $f_2$ = 44%; the center wavelength of the reflection peak has shifted from 1546.8 nm down to 1533.2 nm. The peak reflectivity of the second grating is 94.4% and also exhibits the same 3 dB bandwidth of 0.5 nm.

*Summary:* We have demonstrated and experimentally verified SWG BG filters in SOI. The SWG BGs exhibit high reflectivity (> 90%) and a relatively narrow reflection bandwidth (0.5 nm) while occupying a compact footprint (1.18 mm × 254 μm). The Bragg wavelength can be tuned by changing the duty cycle of the interleaved SWG waveguides. The filters are compatible with other SWG building blocks and can be used to develop more complex devices with enhanced functionality for applications in communications and sensing.

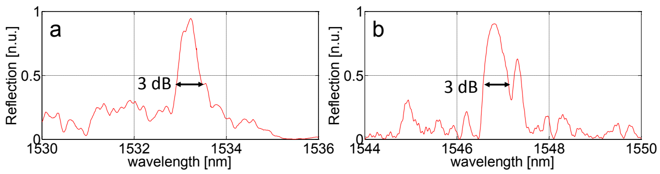


**Fig. 4** *Reflection response of SWG BGs*
*a* $f_1 = 50\%$ *and* $f_2 = 44\%$
*b* $f_1 = 50\%$ *and* $f_2 = 48\%$

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