

# O-band Silicon Photonic Bragg-Grating Multiplexers using UV Lithography

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**Abstract:** We demonstrate 4 channel Bragg-grating based WDM fabricated using 193 nm lithography on the silicon on insulator platform with small features under 140 nm for use in the O-band.

## 1. Introduction

Integrated optical filters are a key component of next generation communications which are needed to enable cloud services, video streaming and other data-heavy applications. Using wavelength division multiplexing (WDM) in data centers allows fibers to transport more information, but requires high performance and low cost filters that work in the O-band near infrared band, where the chromatic dispersion in conventional fibers is minimal.

Integrated WDM is currently achieved using lattice filters [1] or arrayed waveguides [2], though these methods use a large footprint and have a limited free-spectral range. Others possible approaches include Bragg gratings [3] and micro-ring filter [4].

Contra-directional couplers [5] are devices similar to Bragg gratings that can offer large bandwidth, compact footprint and high sidelobes suppression, but the small feature size needed for gratings limits the performance when fabricated with conventional deep-ultraviolet lithography [6] [7]. This issue is compounded when designing a device for the O-band as the small wavelength size requires a proportionally smaller grating step.

In this presentation, we propose a novel contra-directional coupler (contra-DC) geometry using a slab to increase mode coupling, and fabricate it using 193 nm lithography with a phase-shifted mask. We present results for a 4 channel mu/demultiplexer in the O-band with high sidelobes suppression.

## 2. Device

### 2.1. Design

The contra-directional coupler consists of two waveguides in close proximity, with a periodic change to the gap in-between them. This causes a wavelength selective contra-directional coupling at  $\lambda_c = \Lambda(n_1 + n_2)$ , where  $\Lambda$  is the grating pitch, and  $n_1$  and  $n_2$  are the effective refractive indices of the first-order and second-order eigenmodes in the coupler. The waveguides are highly asymmetric to suppress the co-directional coupling that would occur with two identical waveguides.

Figure 1 shows the proposed cross-section of the waveguides in the coupling region. We observe that the modes are only weakly confined to the waveguides due their small widths (220 nm and 360 nm) and the slab; and that there is a strong overlap with the sidewalls of the grating. This bigger overlap allows us to design contra-DCs with a stronger coupling which reduces the loss and enables larger bandwidth.

The contra-DCs are apodized to reduce side-lobes, with the coupling following a gaussian profile with  $a = 10$  as described in [5].

### 2.2. Fabrication process

The fabrication process is a CMOS compatible deep UV (193 nm) lithography, offered by IME, in Singapore. It uses a phase shifted mask as described in [CITE PHASE SHIFTED] which allows greater precision to resolve small features such as grating corrugations.



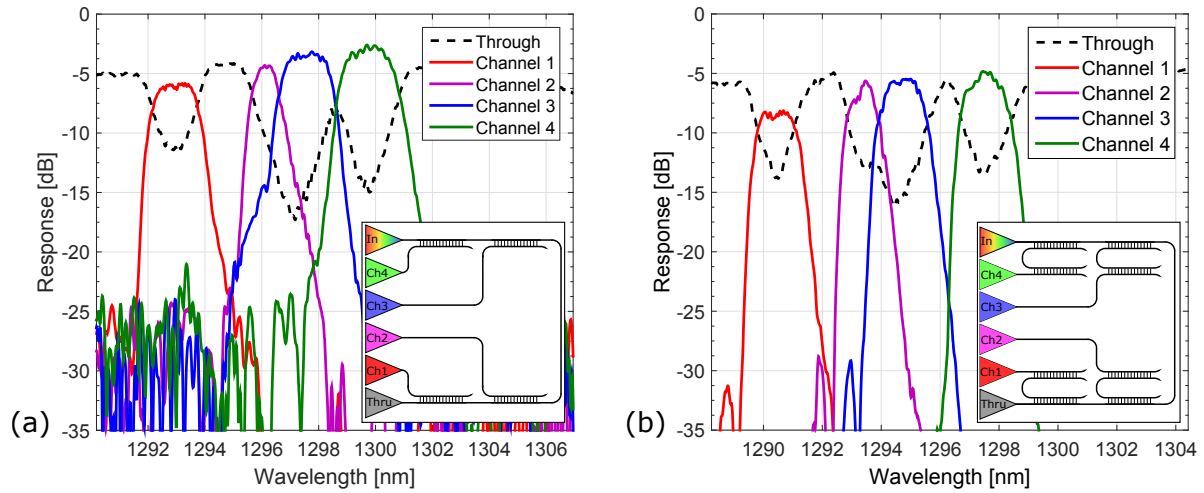


Figure 3. a) Single stage WDM. b) Double staged WDM

dropped in reverse order such that channel 3 has precedence over channel 2. This also explains why smaller channel numbers experience an higher loss, they have a longer optical path through more devices.

One obvious defect is that the second channel is smaller and offset. This is a systematic glitch in all the devices we measured, caused by the fact that channel 2 has an even grating pitch of 260 nm and that the grid resolution of the fabrication is 1 nm, causing it to snap differently to the grid then the other devices. This causes its central wavelength to be slightly higher.

### 3. Conclusion

The demonstrated device shows it is possible to fabricate apodized Bragg-based contra-directional couplers using UV lithography which are suitable for WDM operation in the O-band.

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### References

1. F. Horst, W. M. Green, S. Assefa, S. M. Shank, Y. A. Vlasov, and B. J. Offrein, "Cascaded mach-zehnder wavelength filters in silicon photonics for low loss and flat pass-band wdm (de-) multiplexing," *Optics express* **21**, 11652–11658 (2013).
2. K. Okamoto and K. Ishida, "Fabrication of silicon reflection-type arrayed-waveguide gratings with distributed bragg reflectors," *Optics letters* **38**, 3530–3533 (2013).
3. A. D. Simard, N. Belhadj, Y. Painchaud, and S. LaRochelle, "Apodized silicon-on-insulator bragg gratings," *Photonics Technology Letters, IEEE* **24**, 1033–1035 (2012).
4. Q. Xu, B. Schmidt, J. Shakya, and M. Lipson, "Cascaded silicon micro-ring modulators for wdm optical interconnection," *Optics express* **14**, 9431–9435 (2006).
5. W. Shi, Wang, C. Lin, H. Yun, Y. Liu, T. Baehr-Jones, M. Hochberg, N. A. Jaeger, and L. Chrostowski, "Silicon photonic grating-assisted, contra-directional couplers," *Optics express* **21**, 3633–3650 (2013).
6. W. Shi, H. Yun, C. Lin, M. Greenberg, X. Wang, Y. Wang, S. T. Fard, J. Flueckiger, N. A. Jaeger, and L. Chrostowski, "Ultra-compact, flat-top demultiplexer using anti-reflection contra-directional couplers for cwm networks on silicon," *Optics express* **21**, 6733–6738 (2013).

7. W. Shi, H. Yun, C. Lin, J. Flueckiger, N. A. Jaeger, and L. Chrostowski, “Coupler-apodized bragg-grating add-drop filter,” *Optics letters* **38**, 3068–3070 (2013).