Apodized and Un-Apodized Sidewall Grating Filters with Low Coupling Constants in Ultra-Low-Loss Si_3N_4 Planar Waveguides

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Abstract: We demonstrate apodized and un-apodized sidewall grating filters in an ultra-low-loss planar Si_3N_4 integration platform. Record low coupling constants, as low as 0.19 cm^{-1}, and better than 5dB side-lobe suppression with apodization are reported.

OCIS codes: (050.2770) Gratings; (230.7390) Waveguides, planar

1. Introduction

Monolithically integrated gratings with performance characteristics of fiber grating filters are highly desirable for next generation optical communications not only to reduce overall footprint and improve environmental stability, but to also provide the means to integrate filters with active optical elements such as lasers and other photonic integrated circuitry. This is the first time integrated grating filters in an ultra-low loss Si_3N_4 planar waveguide platform have been reported. Among the advantages of this approach are that the gratings are defined in a single lithographic and etch step as part of a simple and highly tolerant fabrication process. Because of this, multiple types of gratings, as well as complex grating functions can be designed along the same waveguide. Also, the ultra-low loss platform allows long gratings to be designed for photonic integrated circuits with a wide range filter functions.

2. Waveguide fabrication

The silicon nitride waveguides are fabricated in a CMOS foundry using 248 nm stepper lithography on 200 mm silicon substrates. Figure 1(a) gives a schematic cross-section representation of the complete waveguide structure. Both the upper and lower thermal oxide claddings are 15 μm thick, while the low-pressure chemical vapor deposition (LPCVD) oxide is 3.1 μm thick. The 2.8 μm wide LPCVD Si_3N_4 waveguide core layer measures 90 nm in thickness. The complete waveguide fabrication process, including bonding steps, follows the work found in [1].

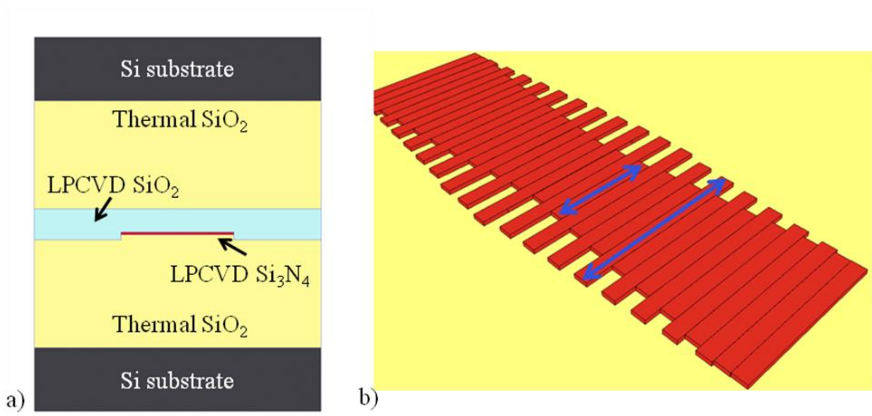

Fig. 1. (a) Waveguide cross section. (b) Three dimensional illustration of a fabricated apodized Si_3N_4 sidewall grating.

Figure 1(b) shows the waveguide geometry with features enhanced (not to scale) for illustrative purposes. The grating coupling constant (κ) is set by designing the width difference between the narrow and wide waveguide sections (highlighted by the blue arrows in Fig. 1(b)). A larger grating width difference, or greater deviation from standard straight waveguide geometry, increases the modal perturbations resulting in an increased coupling constant. The apodized spectral window is achieved through the convolution of the repeating width perturbations with an overarching window function that acts on the maximum and minimum waveguide width along the entire length of the grating.

3. Experimental setup and grating reflectivity spectra

The experimental setup used to measure the reflection spectra of the gratings, consisting of a tunable laser, circulator, power sensor, polarization controller (PC), polarization splitter (PS), and infrared camera, is shown in Fig. 2.

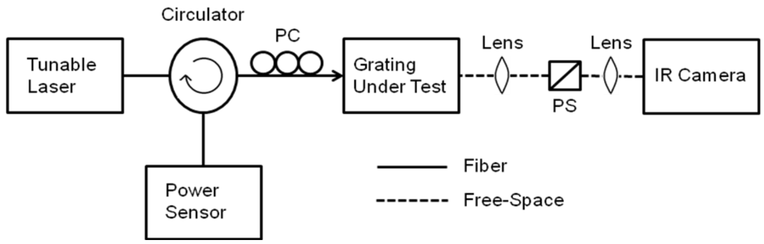

Fig.2. Experimental setup for measuring the reflection spectra of the sidewall gratings.

Measured optical bandwidths, as well as coupling constants (κ) determined through a coupled-mode approach [2], for various gratings designed with different coupling constants are shown in Fig. 3.

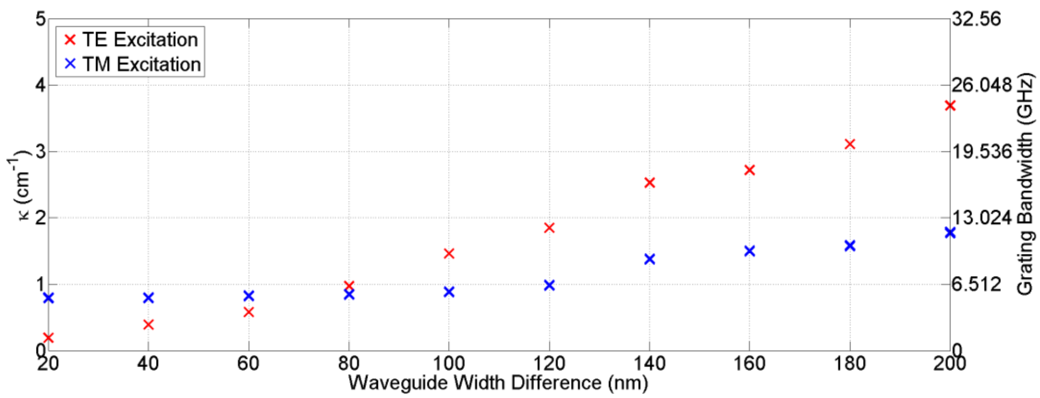

Fig. 3. Measured grating bandwidth for 1 cm long gratings under either TE or TM excitation. The nominal waveguide width is 2.8 µm. The plot also gives fitted coupling constant values (κ) for the same set of gratings.

Apodization of the grating reflectivity spectrum was accomplished through a Blackman window function acting on the waveguide width of the form [3]:

$$w(z) = w_0 + (w_1 - w_0) \times \frac{1 + (1+B)\cos\left(2\pi\left(\frac{x - \frac{1}{2}L}{L}\right)\right) + B\cos\left(4\pi\left(\frac{x - \frac{1}{2}L}{L}\right)\right)}{2 + 2B} \quad (1)$$

where w_0 is the nominal 2.8 µm waveguide width, w_1 is the target value of waveguide width difference, L is the total grating length, and B is the Blackman window parameter (held at 0.18). In Fig. 4 we show the measured return loss spectrum for two different sidewall gratings under TM excitation. As can be seen the apodized grating reduces the effect of the out-of-band reflections by better than 5 dB over the non-apodized grating.

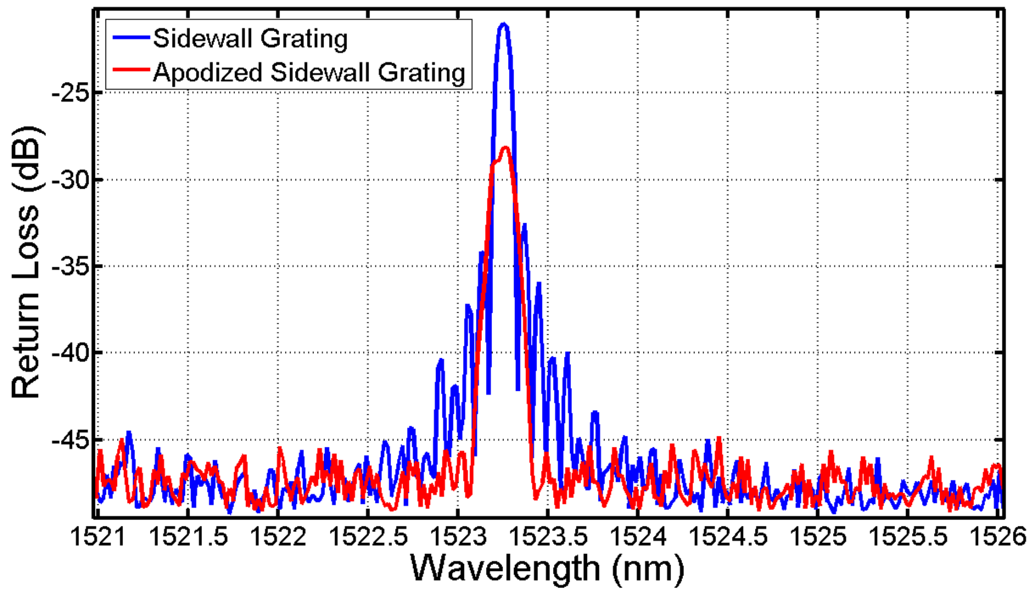

Fig. 4. Measured spectra for two 1 cm long gratings under TM excitation. The Blackmann window apodization has reduced the effect of the grating sidelobes. Here the value of w_1 is equal to 2.85 μm.

4. Summary and conclusions

We have experimentally demonstrated sidewall grating filters with the lowest reported on-chip coupling constants in an ultra-low loss integration platform. These gratings experimentally show improved wavelength selectivity over past approaches. We also demonstrate, for the first time in an ultra-low loss platform, apodized filters with a Blackman window function that show improved rejection of grating side-lobes by better than 5dB.

5. Acknowledgements

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6. References

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