Double-Chirped Bragg Gratings in a Silicon Nitride Waveguide

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Abstract: Double-chirped Bragg gratings for use in dispersion compensation are demonstrated using silicon nitride waveguides, on a silicon photonics platform that allows for 3-D integration of photonic devices with CMOS electronics.

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1. Introduction

Chirped Bragg gratings have long been used for dispersion compensation in fiber communications links [1]. In femtosecond pulse compression applications, such as intracavity dispersion compensation in mode-locked lasers, a smooth dispersion profile is required. This led to the development of double-chirped mirrors, which enabled generation of few-femtosecond pulses in Ti-sapphire lasers [2]. With the advent of silicon photonics, there is increasing interest in fabricating mode-locked laser systems on-chip [3−5]. An integrated photonic implementation of double-chirped mirrors is therefore highly desirable. Apodized chirped gratings for pulse compression have been demonstrated in silicon waveguides, by modulating the waveguide sidewalls [6]. In this paper, we present a novel approach to a double-chirped grating using silicon nitride waveguides, which is fabricated in a CMOS-compatible silicon photonics platform.

2. Device Design and Fabrication

The grating is formed by periodically introducing small blocks of nitride at the edges of the central waveguide, to introduce a perturbation to the effective index of the waveguide mode. This approach allows the strength of the perturbation to be widely tuned, by varying the spacing of the blocks with respect to the central waveguide. Chirping of the center wavelength of the grating is implemented by tapering up the width of the central waveguide, such that the effective index of the waveguide mode is increased as a function of length along the device. A top-view schematic of the device and a cross-section of the waveguide are shown in Figure 1. The devices were fabricated in a 300-mm CMOS foundry, using PECVD to grow the nitride layer and optical immersion lithography to pattern the waveguides. The nitride layer thickness was 200nm, with 4µm of SiO_2 above and below the waveguides.

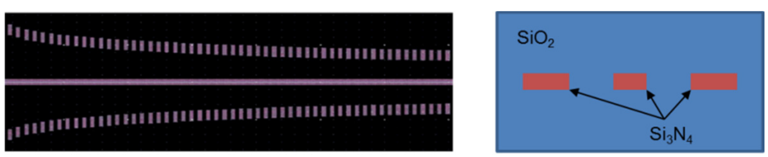

Fig. 1. (Left) Top-view schematic of double-chirped grating, with nitride waveguides represented in pink. (Right) Cross-section of grating.

3. Experimental Results

To measure the performance of the chirped grating devices, we used a LUNA OVA-5000 optical vector analyzer. The tunable laser output from the LUNA was passed through a polarization controller and coupled into the gratings using a cleaved SMF-28 fiber. Index-matching fluid was used at the chip facet to minimize spurious reflections. The coupling loss at the facet could not be measured directly, but is estimated to be on the order of ~2-3 dB per facet, for a total of ~4-6 dB coupling loss on and off the chip. Figure 2(a) shows the insertion loss (including coupling losses) of one of the gratings centered at 1560nm, in both reflection and transmission. The grating was measured to have a TE insertion loss of 4.95±0.1 dB in reflection mode across a 12-nm bandwidth, and an insertion loss in transmission mode of greater than 25 dB across that same band. Most of the insertion loss measured in reflection is therefore likely due to coupling losses. If we assume total coupling losses of 4-5 dB for this measurement, then the transmission loss is at least 20-21dB between 1554 nm and 1566 nm, which corresponds to a reflectivity of at least

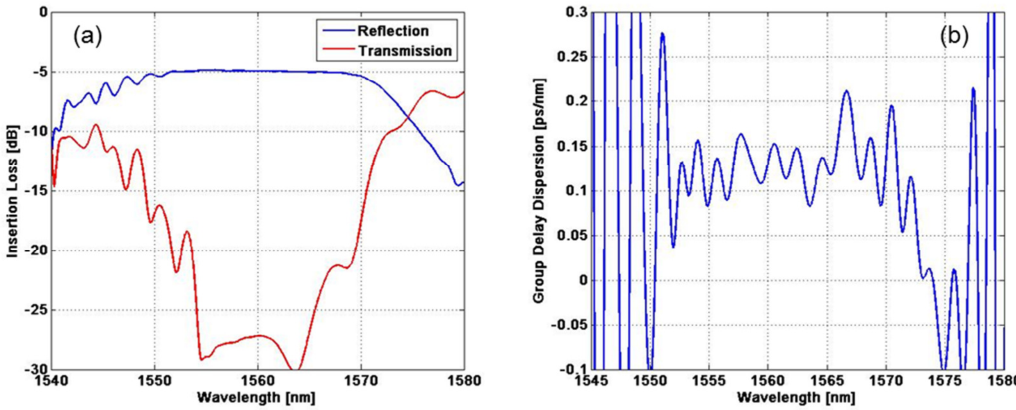

Fig. 2. (a) Grating insertion loss for TE-polarized input in reflection mode (blue) and transmission mode(red). (b) GDD of the same grating.

99% across the band of interest. Figure 2(b) shows the group-delay dispersion of the same grating, as measured by the LUNA. The device was measured to have a mean GDD of 0.125 ps/nm between 1554 nm and 1566 nm, with a standard deviation of 0.02 ps/nm across that wavelength range. Importantly, the double-chirped design does not suffer from significant group-delay oscillations within the wavelength range of interest, as can be seen from the plot. Figure 3 shows the TE insertion loss, phase response, and GDD in reflection for gratings of different lengths. As the length of the grating is decreased, the GDD decreases as expected, although the reflection bandwidth also decreases.

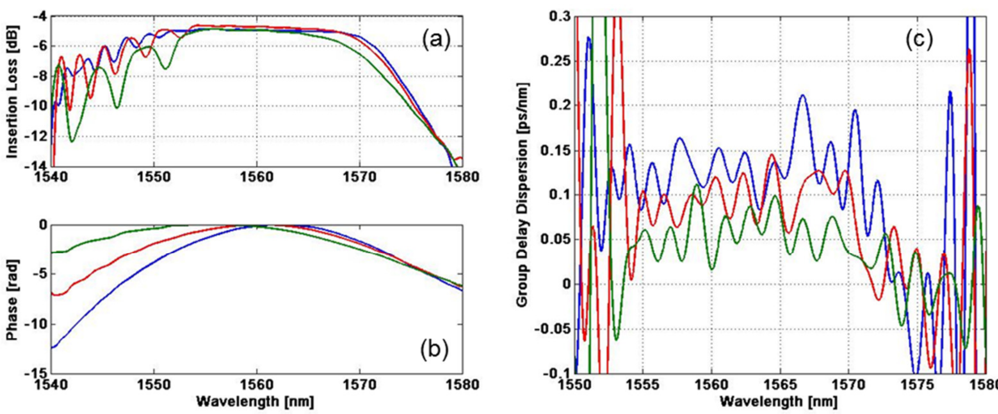

Fig. 3. (a) Insertion loss, (b) phase response, and (c) GDD in reflection mode for gratings with lengths of 480μm (blue), 360μm (red) and 240μm(green).

4. Conclusion

We have designed, fabricated and characterized double-chirped Bragg gratings in a silicon nitride waveguide structure. The gratings have a reflectivity of at least 99% over a broad bandwidth, while maintaining a relatively flat GDD profile across the reflection band. We expect these devices to be very useful for integrated mode-locked laser systems.

Acknowledgements

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