C-Band Apodized Chirped Gratings in Aluminum Oxide Strip Waveguides

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We report on apodized chirped Bragg gratings in aluminum oxide strip waveguides. Applications for this device include nonlinear photonics, specifically dispersion compensation in mode-locked lasers operating in the telecom C-band.

Keywords: *Apodized chirped Bragg gratings, aluminum oxide strip waveguides*

INTRODUCTION

Apodized chirped Bragg gratings (ACGs) are widely used in ultrafast laser systems to compensate for the dispersive effects that can cause degradation of the laser pulse. The advancements in ultrafast lasers on a silicon chip in recent years [1-3], have attracted the increasing interest of researchers in dispersion control using ACGs for ultrashort pulse generation [4]. ACGs are being studied in silicon-on-insulator [5-7] and more recently, in silicon nitride-on-insulator [8, 9] platforms. In this work, we report the design, fabrication, and characterization of ACGs in aluminum oxide strip waveguides at telecom wavelengths.

Aluminum oxide (Al_2O_3) waveguides are an ideal gain host material for ultrafast lasers on a silicon chip as it offers several advantages, such as broadband low-loss operation from ultraviolet to mid-infrared, multi-layer integration with CMOS platforms, and high rare earth ion solubility [10]. A moderate refractive index in aluminum oxide (1.72 at 1550 nm) makes ACGs manufactured in Al_2O_3-on-insulator less sensitive to fabrication variations than ACGs in silicon and silicon nitride-on-insulator platforms.

RESULTS

We designed the Al_2O_3-in-SiO_2 ACG to have a flat group delay dispersion around 1560 nm in TE polarization. We used uniform-period Bragg gratings (Λ = 516 nm) with corrugated side waveguide walls and applied squared-cosine apodization. The linear chirp of the Bragg wavelength (λ_B) is achieved by increasing the effective mode index (n_{eff}) along the grating using relation $\lambda_B(z) = 2\, n_{eff}(z)\, \Lambda$ (see *Figure 1* a). The average waveguide widths are w_{in} = 578 nm at the input, w = 1100 nm in the middle, and w_{out} = 2422 nm at the output of the 516 µm long grating. The corrugation depth Δw in the middle of the ACG is 500 nm. ACGs were fabricated in several steps. The 550 nm thick aluminum oxide layer has been deposited by reactive sputtering on the top of a thermally oxidized silicon wafer. The ACGs were patterned using electron beam lithography and etched by reactive ion etching. The resulting alumina oxide strip waveguides with a sidewall angle of around 80 degrees were protected with PECVD silica cladding. *Figure 1* (b) shows the cross-section of the fabricated waveguide.

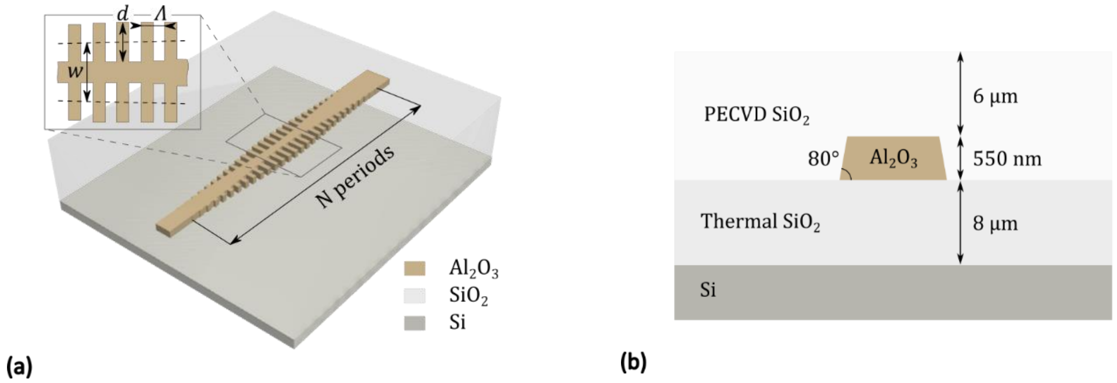

Figure 1 (a) schematics of aluminum oxide apodized chirped grating buried in silica cladding. The inset of the figure shows the parameters of the ACG and the tapered average width profile with dashed lines, (b) Cross-section of the 550 nm thick aluminum oxide strip waveguide

We performed transmission measurements by coupling supercontinuum light in TE polarization into the waveguide and measuring the transmitted power spectrum using an optical spectrum analyzer. *Figure 2* (a) shows the measured power spectrum of the transmitted light through the waveguide with the ACG (black curve) and a straight 1.6 µm wide reference waveguide (red curve). Dispersion measurements are performed with a home-built white-light interferometry setup [11]. We obtained information about the dispersion of the gratings from the Fourier transform of the measured interferogram.

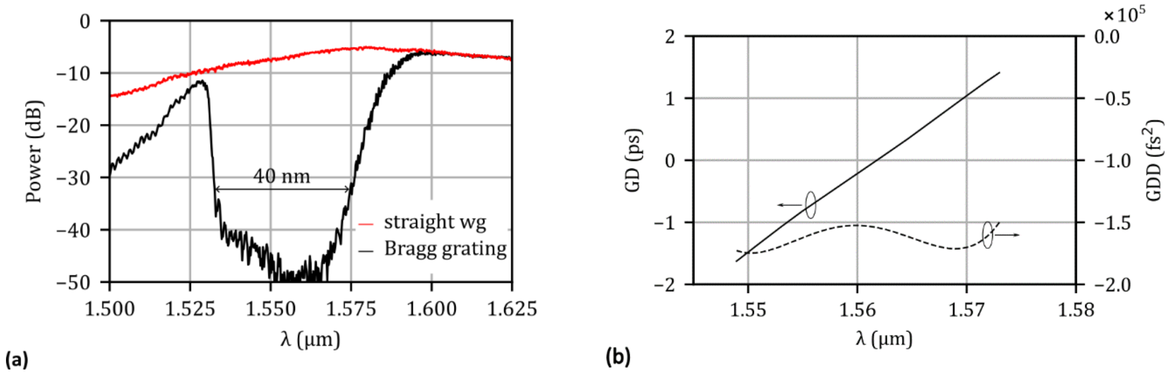

Figure 2 (a) the measured transmitted power spectrum from the ACG and reference straight waveguide. (b) The extracted group delay (GD) is on the left axis and group delay dispersion (GDD) is on the right axis.

The measured transmission spectrum from the ACG shows a strong drop in the transmission to less than 1% (-20 dB) around over a 40 nm bandwidth in comparison to the transmitted signal through the reference waveguide (see *Figure 2* (a). In a wavelength range between 1550 nm and 1573 nm, we measured the phase of the interfering reflected signals from the ACG and reference mirror with a standard deviation of σ = 0.013 π rad from the fitted curve. A group delay (GD) and group delay dispersion (GDD) were extracted from the measured phase as the first and second derivatives of the 9th-order polynomial fit (see *Figure 2* b). This results in flat dispersion of -163270 fs^2 (0.1280 ps/nm) and a deviation of 7520 fs^2 from 1550 nm to 1573 nm with a corresponding GD of 3.03 ps. Flat and smooth GDD over 23 nm bandwidth can enable dispersion compensation for 150 fs pulses in on-chip mode-locked lasers.

CONCLUSION

What reported the design, manufacturing, and characterization of the Al_2O_3-in-SiO_2 ACG working around 1560 nm wavelength. The ACG provides a strong reflection over around a 40 nm bandwidth and smooth and flat dispersion over a 23 nm bandwidth. Our ACG can be readily applied for intracavity dispersion compensation of 150 fs pulses in the C-band for applications such as in integrated femtosecond lasers.

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