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 ($\text{Al}_2\text{O}_3$) 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 $\text{Al}_2\text{O}_3$-on-insulator less sensitive to fabrication variations than ACGs in silicon and silicon nitride-on-insulator platforms.

RESULTS

We designed the $\text{Al}_2\text{O}_3$-in-$\text{SiO}_2$ ACG to have a flat group delay dispersion around 1560 nm in TE polarization. We used uniform-period Bragg gratings ($\Lambda = 516$ nm) with corrugated side waveguide walls and applied squared-cosine apodization. The linear chirp of the Bragg wavelength ($\lambda_B$) is achieved by increasing the effective mode index ($n_{\text{eff}}$) along the grating using relation $\lambda_B(z) = 2 n_{\text{eff}}(z) \Lambda$ (see Figure 1 a). The average waveguide widths are $w_{\text{in}} = 578$ nm at the input, $w = 1100$ nm in the middle, and $w_{\text{out}} = 2422$ nm at the output of the 516 $\mu$m long grating. The corrugation depth $\Delta w$ 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](image)

**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 fs² (0.1280 ps/nm) and a deviation of 7520 fs² 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 Al₂O₃-in-SiO₂ 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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**References**