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UV-written planar chirped Bragg gratings for use in dispersion management

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Abstract—**We demonstrate for the first time experimental results of chirped and chirp-apodized Bragg gratings written into planar substrates. The gratings are written using Direct Grating Writing, allowing both buried channels and gratings to be defined simultaneously. The experimental results are then compared to theory and agree well with predicted spectra.**

Keywords- Bragg gratings; planar waveguides; chirped gratings; dispersion compensation

I. INTRODUCTION

Optical filters incorporating Bragg gratings have become a powerful tool in applications such as high-speed optical telecommunications [1]. Planar Bragg grating structures have been demonstrated [2] and have the potential to address several telecoms channels simultaneously. These integrated planar optical devices have been extended to include chirped and chirped-apodized Bragg gratings.

Chirped gratings have particular interest in dispersion compensating and residual dispersion compensating devices [3]. The group delay arising from linearly chirped Bragg gratings is a linear function of wavelength. Therefore such devices can be used to recompress broadened pulses. Also, non-linearly chirped gratings can be used to correct residual dispersion due to improper dispersion slope matching from dispersion compensating fiber.

Planar chirped Bragg gratings utilize a writing technique known as Direct Grating Writing (DGW) [4]. This avoids the use of phase masks and allows buried channel waveguides and grating structures to be written simultaneously. DGW also avoids the problem of additive-only refractive index change.

In this paper we provide experimental results of planar chirped and chirped-apodized Bragg grating structures written via our DGW method. Reflection spectra for various chirp parameters are given along with their group delay curves.

II. THEORY

Linearly chirped Bragg gratings have a period of refractive index modulation that varies along the length of the grating. The consequence of this is the reflection bandwidth increases, but the peak power reflected diminishes. However, the group delay becomes a linear function of wavelength, and this can be exploited in dispersion management systems.

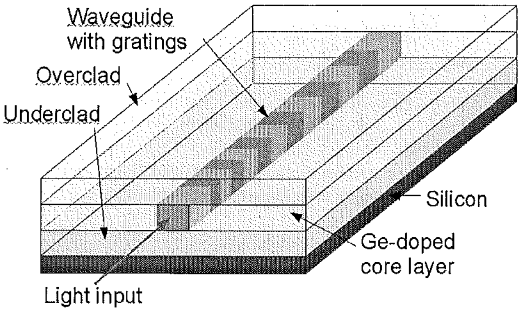

Figure 1. A DGW buried channel waveguide with integral chirped Bragg grating

Planar geometry substrates have the benefit of being able to write multiple devices on the same substrate. Therefore they provide the ability to simultaneously process multiple optical sources. Planar devices are also robust and have easily accessible gratings to allow for modification of the grating properties, such as tuning the grating period.

Fig. 1 shows a typical chirped grating written into the Ge-doped core of a 3-layer silica-on-silicon substrate. The interference pattern created by crossing two 244nm beams is periodically printed in the core, forming a grating. The grating is written by simultaneously modulating the 5μm diameter beams with an AOM whilst translating the sample under the beams using a computer-controlled air-bearing stage system.

III. RESULTS AND DISCUSSION

Shown in Fig. 2 are the reflection spectra of chirped (red) and chirp-apodized (blue) planar gratings written via DGW. The modeled data is shown in black. The chirped grating is 5mm long with a chirp rate of 5nm/cm and the apodized chirped grating uses a Gaussian apodization profile. Experimental data shows good agreement with the modeled data.

The chirped grating has a bandwidth of 2.3nm whereas the apodized grating has a bandwidth of only 0.8nm. However, this apodized grating avoids the group delay ripple as shown in the red curve, providing a more linear group delay response with a slope of -10ps/nm as shown in Fig. 3.

Further devices were fabricated to test the range of chirp available using the DGW method in the planar geometry. Fig. 4 demonstrates the range of chirp fabricated thus far using our

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method. Fig. 5 displays the group delay spectra for these gratings. All gratings are 9mm in length. The chirp ranges from 2.8nm/cm (left, blue) up to 14.4nm/cm (right, red), however this is not the physical limit. The peak reflected power has only dropped by 3dB despite the large increase in chirp.

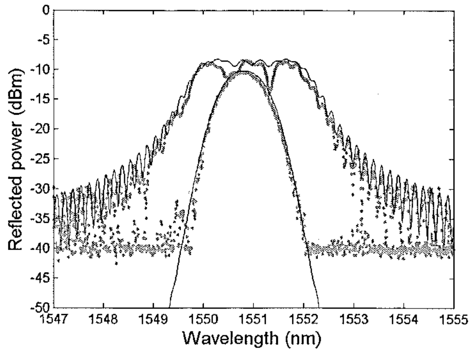

Figure 2. Reflection spectra of chirped (red) and chirp-apodized (blue) gratings with theoretical fit (black)

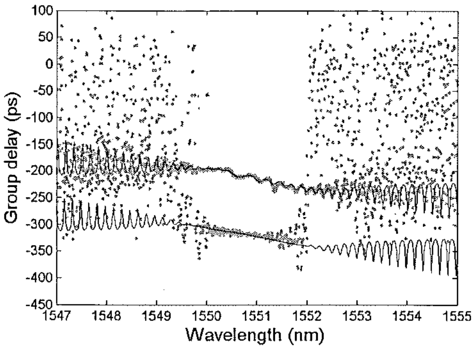

Figure 3. Group delay of chirped (red) and chirp-apodized (blue) gratings with theoretical fit (black)

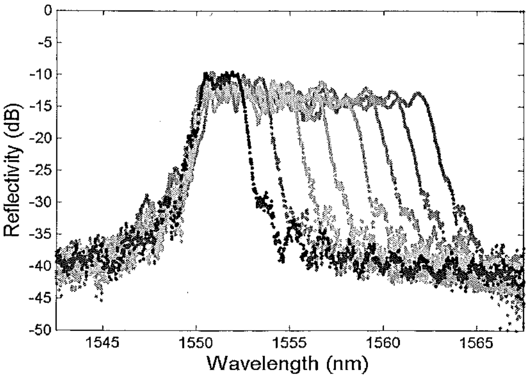

Figure 4. Reflection spectra of linearly chirped Bragg gratings with chirp rates of 2.8 - 14.4 nm/cm

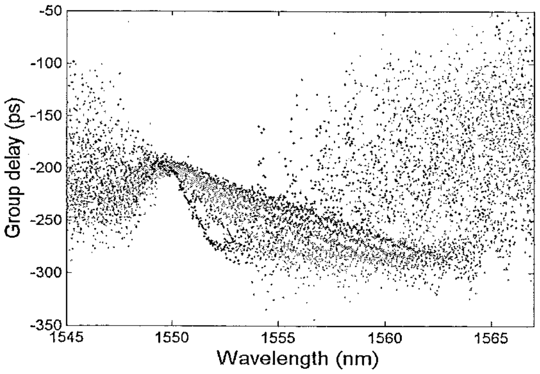

Figure 5. Group delay of linearly chirped Bragg gratings with chirp rates of 2.8 - 14.4 nm/cm

These results demonstrate that the simplified writing process can produce zero d.c. refractive index gratings. They also demonstrate that the uniformity of our planar Flame Hydrolysis Deposited (FHD) substrates and the stability of our DGW system are sufficiently high to allow fabrication of high quality gratings.

IV. CONCLUSIONS

We have demonstrated chirped and chirp-apodized planar Bragg grating devices using our Direct Grating Writing method. This produces highly configurable gratings with various chirp parameters and apodization profiles while simultaneously writing buried channel waveguides mode-matched to standard single-mode fiber. These planar devices provide a robust geometry allowing external modification of grating parameters. Chirp parameters can be controlled by thermal tuning, stress tuning, and if using an exposed channel waveguide, liquid crystal and optofluid tuning. This provides a means for producing adaptive, residual dispersion compensating devices from our planar chirped gratings.

We will present results on the use of integrated heated electrode elements to provide localized chirp correction.

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