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Fabrication and characterization of tunable chromatic dispersion compensator based on hollow waveguide

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Abstract

We present the design and fabrication of tunable dispersion compensators consisting of a tapered grating hollow waveguide. The length is increased for increasing the amount of tunable dispersion ranges. A dispersion of -119ps/nm is obtained for 10mm long devices with 0.1nm bandwidth.

1. Introduction

Tunable dispersion compensators such as thin-film multi-cavity etalons [1] and fiber Bragg gratings [2] are becoming important for high speed transmission of 40Gbps or beyond. We have proposed a tunable dispersion compensator based on hollow optical waveguide with a variable air core [3]. However, the tunable dispersion range is limited by the length of hollow waveguides.

In this paper, we present the design and fabrication of long hollow waveguide grating devices so that the dispersion range is increased.

2. Structure of hollow wave guide grating

Figure 1 shows the schematic structure of fabricated tunable chromatic dispersion compensators based on a tapered hollow waveguide. Two multilayer mirrors are used to confine light in the air core of a tapered hollow waveguide. The mirrors composed of 6pair Si/SiO_2, is designed to be a quarter wavelength stuck for oblique incident angles. A first-order circular diffraction grating is formed on the mirror surface as shown in Fig. 1, which gives us reflection and focusing at an input port.

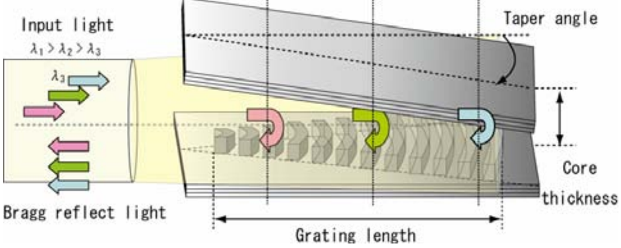

Fig.1 Schematic structure of dispersion compensator based on a tapered hollow waveguide

The Bragg wavelength of the circular grating is dependent on the spatial effective refractive index with the tapered core thickness. Longer wavelengths of input light result in a shorter group delay than shorter wavelengths in the Fig. 1. Variable tapered angles make it possible to realize tunable chromatic dispersion.

First, we calculated the effective refractive index (n_{eff}) of a fundamental mode in a hollow waveguide by using a full-vectorial Mxwell's solver (FIMMWAVE, provided by Photon Design Company), which is based on a film-mode-matching method [4] and Transfer Matrix method. Figure 2 shows the calculated maximum dispersion versus optical bandwidth for different grating lengths of 1, 3, 5 and 10mm.

The result indicates the tradeoff between the maximum dispersion and optical bandwidth, and the dispersion/bandwidth product is determined by the grating length. For a 3mm long device, the tunable dispersion range we obtained is -3.0ps/nm to 2.5ps/nm

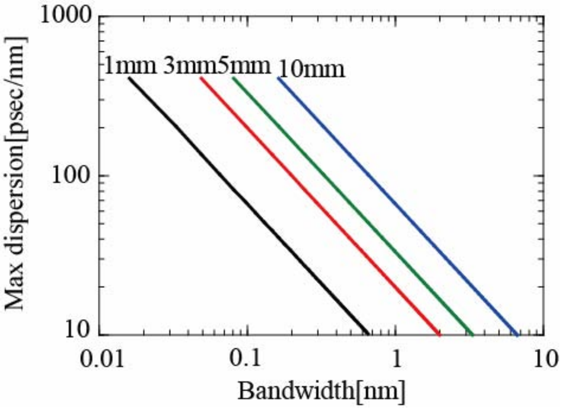

Fig.2 Relationship between bandwidth and maximum dispersion for different grating lengths

[5]. The extension of a grating length to 10 mm gives us a dispersion/bandwidth product of 67psec.

3. Experiment

Figure 3 shows the fabricated 10mm long hollow waveguide device with 6 pair Si/SiO_2 mirrors. The width height and pitch of the SiO_2 grating formed on the mirror are 390nm, 500nm and 780nm, respectively. A movable mirror is placed as shown in Figure 1, and the air core thicknesses of the input and output are precisely controlled by using a rotating stage and PZT actuator.

We used the experimental setup shown in Fig. 4. Figure 5 indicates the measured reflectivity and group delay for different air core thicknesses. The obtained dispersions are -39ps/nm, -29ps/nm and -119ps/nm with 3dB optical bandwidths of 0.6nm, 0.8nm and 0.1nm, respectively.

The dispersion/bandwidth product is in the range of 12-23psec. This number is lower than the value (67psec) we expected in Figure 2 for the 10mm long grating. This would be due to excess losses caused by the low open angle (10 degree) of the fabricated circular grating shown in Fig.3.

4. Conclusion

We present the design and the fabrication of a tunable dispersion compensator based on a hollow waveguide with a variable air core. The numerical calculation shows the increased grating length of the compensator is effective for increasing the maximum dispersion of the compensator. At 10mm grating length, we expect the maximum dispersion/bandwidth product of 67psec.

For the fabricated 10mm long device, we obtained the maximum dispersion of -119psec/nm for a bandwidth of 0.1nm and the product of 12-23 psec. Further increase of grating lengths without excess losses enables us to increase the tunable dispersion range, which would be useful for tunable dispersion compensation in high speed photonic networks.

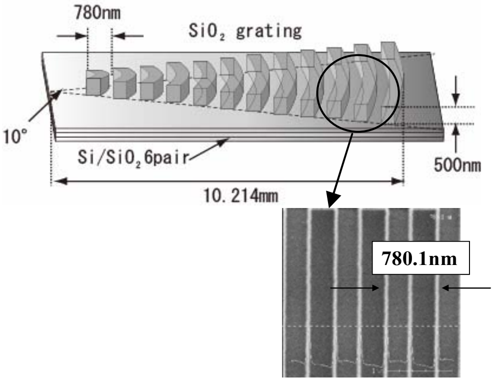

Fig.3 Schematic and top SEM view of fabricated 10mm long circular grating on the mirror.

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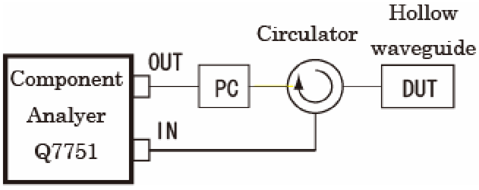

Fig.4 Experimental setup

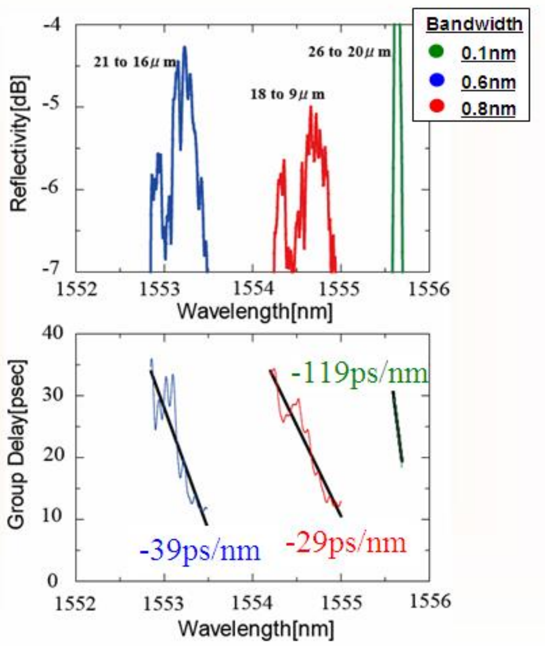

Fig.5 Measurement of reflectivity and group delay for the 10mm long grating device.