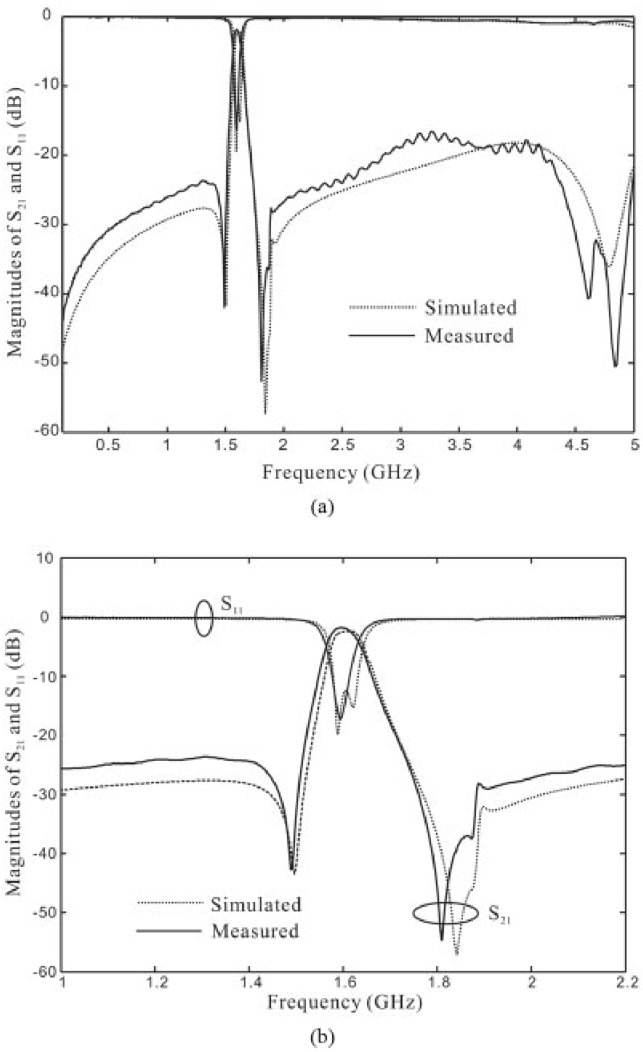

Figure 4 Comparison of simulated and measured *S*-parameters for the proposed dual-mode bandpass filter. (a) Over a wide frequency range (0.1–5.0 GHz); (b) over a narrow frequency range (1.0–2.2 GHz)

patch filter can achieve a size reduction by 60%. Furthermore, Figure 4(a) allows us to observe that the spurious passband in the 4.5–5.0 GHz range is fully suppressed, resulting in a widened upper stopband. Figure 4(b) shows that the filter achieves the good passband behavior, with the insertion loss less than 2.2 dB and fractional bandwidth of 4.5%. In addition, the S_{21}-magnitude in the whole low range (DC to the dominant passband) is kept below -20 dB, showing a good DC-blocking performance.

4. CONCLUSION

In this article, a stopband-improved compact dual-mode bandpass filter is presented by employing the side-slit patch resonator. Our studies at first confirm that the first resonant frequency is largely lowered while its second counterpart frequency keeps unchanged as the slits on four sides of a patch are introduced. As the stub-loaded feed lines are inserted into side slits, it is shown that the first spurious passband can be effectively suppressed. After the proposed resonator circuit is investigated, a dual-mode filter using this resonator is designed and fabricated. The filter is exhibited in simulation and measured to achieve several advantageous features, such as widened stopband, miniaturized size, DC-blocking, sharp rejection skirts, and controllable dominant passband.

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LINEAR TUNABLE DISPERSION COMPENSATION DEVICE USING SELECTIVE STRETCHING IN CHIRPED FIBER BRAGG GRATING

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ABSTRACT: *A linear tunable dispersion compensation device based on a chirped grating (CFBG) mounted on a stretching mechanical structure is described. The tunability is obtained changing the CFBG bandwidth without modification of the total length structure.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 720–722, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22245

Key words: *tunable dispersion compensation; chirped gratings*

1. INTRODUCTION

Chromatic dispersion is one of the basic characteristics of an optical fiber, and can be described as the effect that with slightly different frequency travels down the fiber at a slightly different speed. This phenomenon has been studied for a number of years as it is one of the major impediments for signals propagating through long distances. Although it is possible to manufacture fiber with zero chromatic dispersion, it should be emphasized that such fiber is incompatible with the deployment of wavelength division multiplexing (WDM) systems, since nonlinear effects would become important. As long as WDM is employed, chromatic dispersion must exist, and therefore must be compensated.

Chromatic dispersion has been considered predominantly as a time-invariant phenomena. As such, fixed compensation will be expected to improve the data transmission system performance. This is the case of low bit rate systems (≤2.5 Gbit/s) where dynamic dispersion compensation is not needed. Future generations of communications systems will necessitate tunable dispersion compensation modules to respond dynamically to changes occurring in the network, arising from different propagation paths, repairs and maintenance of the fiber, temperature variations, and variable dispersion introduced by components such as optical filters. In this case, fix dispersion compensation is not longer enough to enhance the performance of the system and devices with variable chromatic dispersion compensation will be needed. Various schemes have been reported in the literature for linear tunable dispersion compensation using fiber Bragg gratings (FBG). The most common techniques employ changes in strain [1] or temperature [2] applied to Bragg gratings. They can also be modified applying magnetic fields [3], and other techniques use the combination of two nonlinear CFBGs [4] to demonstrate linear tunable dispersion compensation.

In this paper a linear tunable dispersion compensation device based on a chirped fiber Bragg grating and its selective stretching is presented. The linear dispersion is achieved by changing the CFBG bandwidth while the total length of the structure remains constant.

2. LINEAR TUNABLE DISPERSION COMPENSATION DEVICE

The experimental set-up is shown in Figure 1. A CFBG with a length of 60 mm and a Full Width at Half Maximum (FWHM) of 4.6 nm has been photo-imprinted in SMF-28 fiber. Several metallic capillary tubes, three of $d_i = 0.3$ mm and $d_e = 0.6$ mm and two of $d_i = 0.7$ mm and $d_e = 1$ mm, where d_i and d_e are the internal and external capillary diameters, are used to maintain the fiber straight when the CFBG is subjected to expansion or compression by the movement of the translation stages. The capillary tubes are glued to the fiber and also between themselves on the sections represented by the thick grey lines in Figure 1. The different expansion or compression of the CFBG is possible because of the fixed point (see Fig. 1), that allows separating both sides of the device. The grating bandwidth, FWHM, can be controlled independently of the grating total length if the expansion on the left side and compression on the right side have the same modulus. On this situation the total length remains constant while the FWHM decreases (assuming that the short period side corresponds to the expansion zone).

The theoretical expression for the dispersion, D, of a CFBG can be calculated from

$$D = \frac{1}{L}\frac{\Delta\tau}{\Delta\lambda}, \tag{1}$$

where $\Delta\tau$ is the total variation in group delay produced by the CFBG, $\Delta\lambda$ and L are the FWHM and length of the CFBG, respectively. The group delay produced for the CFBG to each wavelength can be given approximately by $\tau = 2L_\lambda/v_g$, where L_λ is the length that each wavelength travels into the CFBG and v_g is the group velocity of the pulse along the fiber. This values leads to an expression for the dispersion for a CFBG as follows

$$D \approx \frac{1}{L}\frac{2L}{\Delta\lambda v_g}. \tag{2}$$

When the device is expanded on the left side, the short period part of the CFBG shifts to longer wavelengths. On the other hand when the structure is compressed on the right side, the longer wavelengths are shifted to shorter wavelengths. The amount of extension and compression is almost the same, producing a small variation on the length of the CFBG. This variation can be calculated by the data represented in Figure 2. This figure represents the amount of extension and compression for both sides of the structure, ΔL. It can be noticed that the maximum variation in length is 0.08% (0.05 mm in the total length of 60 mm).

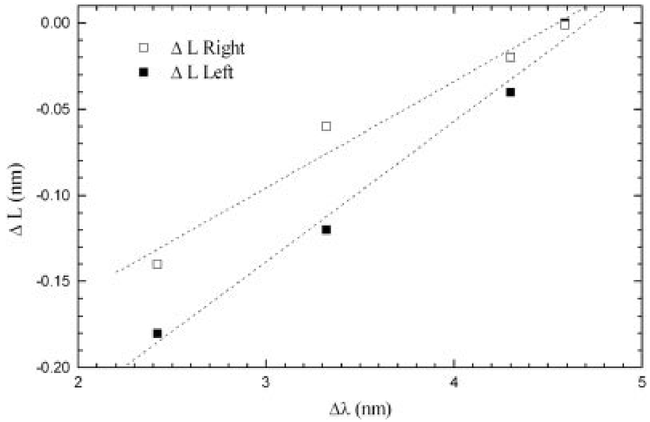

Figure 2 Evolution of the FWHM with the CFBG length variation

Figure 3 shows the response in group delay and dispersion of the tunable device for the different bandwidths obtained. The solid lines in Figure 3(a) represent the linear fit of the group delay. It can be noticed that the slope of the group delay, the dispersion, increases with the FWHM as it was expected from the relation shown in Eq. (2). This figure also shows that there is a step change in the group delay response and ripples in the reflection spectra. This is caused by the fixed point in the central part of the device that breaks the smooth transition between both sides of the CFBG.

The experimental relation between the dispersion, slope of the group delay, and the bandwidth is represented in Figure 4. For the CFBG used in this set-up the relation between the dispersion and the FWHM using Eq. (2) is

$$D = \frac{580}{\Delta\lambda}\ (\text{ps/nm}), \tag{3}$$

whereas the fit for the experimental data results in,

$$D = \frac{592}{\Delta\lambda}\ (\text{ps/nm}), \tag{4}$$

which is in good agreement with the theoretical approximation. The tunable device has shown to have a tunable dispersion ranging from 125 to 240 ps/nm.

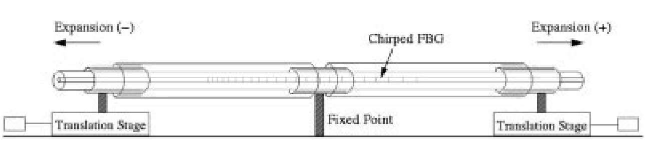

Figure 1 Linear tunable dispersion compensation device

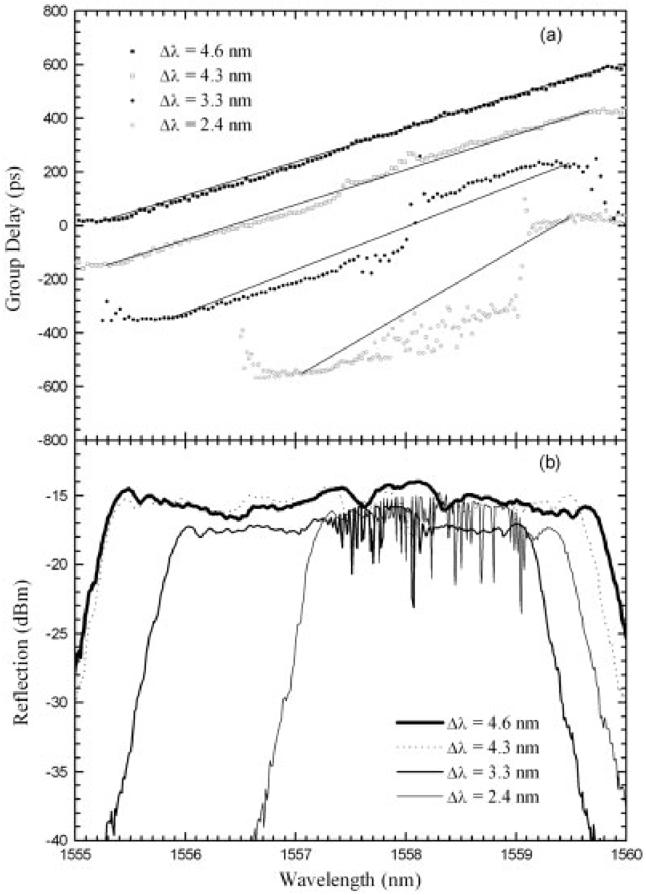

Figure 3 (a) Group delay and (b) reflection spectra for different FWHM of the device

3. CONCLUSION

A simple and low cost linear tunable dispersion compensation device for WDM systems was presented. The structure presents a tunable dispersion of 115 ps/nm. This optical device could be used in residual compensation at the end of an optical system to account for small changes in fiber length. The performance of the system is currently being studied to reduce the step changes in the group delay curves and the ripples in the reflection spectrum.

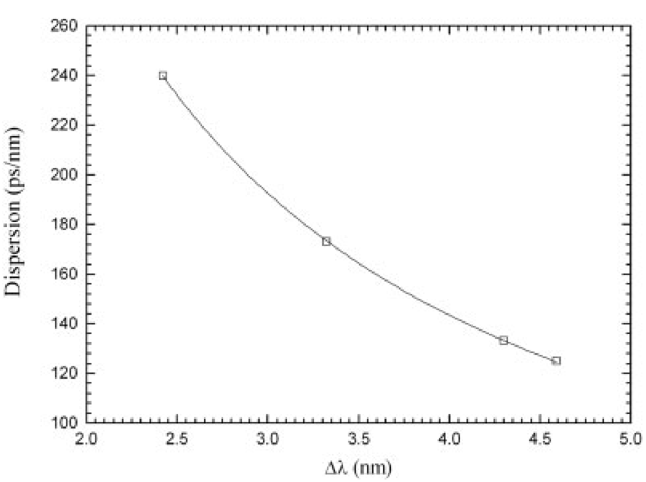

Figure 4 Dispersion achieved for each FWHM of the device

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NOVEL BANDPASS FILTER WITH WIDE STOPBAND USING DOUBLE-SIDED PARALLEL-STRIP LINE

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ABSTRACT: *A novel bandpass filter using double-sided parallel-strip line (DSPSL) is proposed in this paper. Based on the differential characteristics of DSPSL, the proposed filter has a wide stopband up to the third spurious resonance frequency. Also, this filter can achieve high power-handling capability because the linewidth of DSPSL is wider than that of microstrip with the same characteristic impedance. A demonstration filter was designed, fabricated, and measured. Theoretical and experimental results are presented and show good agreement.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 722–724, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22244

Key words: *bandpass filter; wide stopband; DSPSL; open-loop*

1. INTRODUCTION

Bandpass filters are key components in wireless communication systems for suppressing unwanted signals. Many kinds of bandpass filters, such as open-loop filters [1], parallel-coupled filters [2], have been proposed. These filters could meet the specification at the fundamental frequency band. However, they suffer from the problem of spurious passbands due to the distributed characteristics of transmission lines. To alleviate this problem, plenty of methods have been proposed and shown promising results [3–7]. Filters using a stepped-impedance resonator can move the second passband to higher frequency [3]. By using square ring resonator with open-loop arms, wide stopband can be achieved [4]. Based on parallel-coupled stacked stepped-impedance-resonators and open-loop resonators, filters can reject the harmonic passband [5]. Using open stub and spurline, filters can suppress the second harmonic effectively [6] [7]. In Ref. 8, filter using square-ring resonator and two end-open L-shaped microstrip lines was proposed for harmonic suppression.

In this paper, a novel bandpass filter using double-sided parallel-strip line (DSPSL) and open-loop resonator is proposed. The proposed DSPSL open-loop filter has a wide stopband up to the