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Characteristics of Chirped Fibre Gratings for Dispersion Compensation

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Abstract

We report a detailed measurement of the properties of a chirped fibre Bragg grating with respect to the amount of applied chirp. The results demonstrate the reflection and dispersion dependencies associated with any linearly chirped grating.

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Summary

Chirped fibre Bragg gratings have recently received considerable attention due to their immense potential for use as dispersion equalizers in long haul fibre telecom links [1]. Some of their properties have been studied theoretically and demonstrated in a number of system trials [2]. We have implemented a variable-chirp grating using the temperature gradient technique [3] and systematically measured its reflection and dispersion characteristics [4] for a wide range of applied chirp. The results, which are in very good agreement with theoretical predictions, clarify those properties and will be discussed in this paper.

Applying a linear temperature gradient G [in °C/mm] to a fibre Bragg grating causes both its period and its background refractive-index to vary linearly along the length which combine to induce a linear chirp in the grating. The overall effect can be represented by an effective chirp parameter $C_{eff} = (\xi/2n_o+\alpha)\cdot(G_o-G)$ [5], where α and ξ are the expansion and thermo-optic coefficients and n_o is the average refractive index of the fibre, and G_o is the temperature gradient giving zero chirp.

The tested grating was approximately 40mm in length and, at room temperature, had approximately 0.055 nm of built-in chirp. It was written with a frequency-doubled Excimer laser and scanning interferometer. Figure 1 shows the measured reflectivity and time delay response of the grating for three different applied temperature gradients. The best-fitted straight line over the time delay and across the grating reflection bandwidth gives the mean dispersion, D_m. Several other gradients were studied and the results are summarised in Figure 2. The reflectivity and bandwidth have a symmetric behaviour whereas the mean dispersion depends on the sign of the chirp parameter. With increasing $|C_{eff}|$, the grating bandwidth increases quasi-linearly and the reflectivity drops. On the other hand, the mean dispersion, which represents the dispersion experienced on average by the transmitted data in an optical transmission system, varies maintaining the dispersion-bandwidth product constant and proportional to twice the grating length. High induced dispersion (low chirp) is accompanied by increased non-linearity in the time delay curve and stronger oscillations at the grating edges (cf. Fig 1.c), which degrades the dispersion characteristics and can be associated with BER degradation in system applications of the device, whilst an increased chirp linearises the dispersion characteristic (cf. Fig 1.b), but at the expense of reducing the mean dispersion. The 40mm grating evaluated offered a practical (linear) dispersion compensating capability up to -2010ps/nm with a 3dB bandwidth of 0.11nm.

References

[1] Ouellette F: "All-fiber filter for efficient dispersion compensation"; Opt. Lett., **16** (5), pp. 303-305, 1991.

[2] R I Laming, M N Zervas, S Barcelos, M J Cole et al; "Dispersion compensating chirped fibre gratings"; 13th Annual Conference on European Fibre Optic Communications & Networks", invited paper, Brighton, UK, June 1995.

[3] J Lauzon, S Thibault, J Martin and F Ouellette; "Implementation and characterization of fiber Bragg gratings linearly chirped by a temperature gradient"; Opt. Lett., **19** (23), pp. 2027-2029, 1994.

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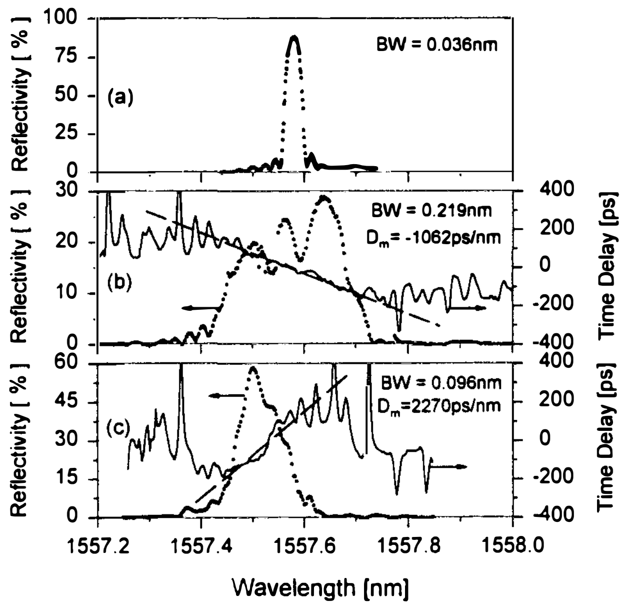
Figure Captions

Figure 1: Measured grating power reflectivity and time delay response for 3 different temperature gradients G: (a) 13°C/45mm (C_{eff} = 0), (b) −25°C/45mm (C_{eff} = −0.0025) and (c) 30°C/45mm (C_{eff} = +0.0011).

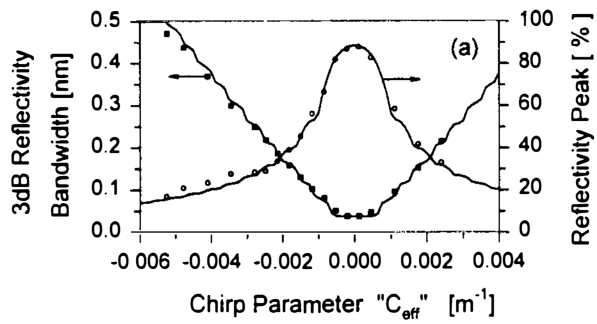
Figure 2: Measured (○ ■) and calculated (—) 3dB reflection bandwidth and maximum reflectivity of grating as a function of the effective chirp parameter (a) and mean dispersion as a function of the grating 3dB reflection bandwidth (b).

Figure 1



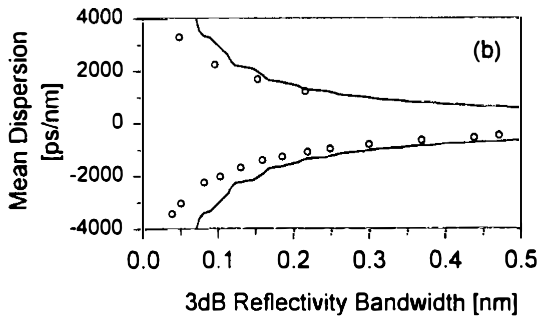
Reflectivity [%]
100
75
50
25
0
(a)
BW = 0.036nm
30
20
10
0
(b)
BW = 0.219nm
D$_m$= -1062ps/nm
400
200
0
-200
-400
Time Delay [ps]
60
45
30
15
0
(c)
BW = 0.096nm
D$_m$=2270ps/nm
1557.2
1557.4
1557.6
1557.8
1558.0
Wavelength [nm]

Figure 2(a)



0.5
0.4
0.3
0.2
0.1
0.0
3dB Reflectivity
Bandwidth [nm]
100
80
60
40
20
0
Reflectivity Peak [%]
(a)
-0 006 -0.004 -0.002 0.000 0.002 0.004
Chirp Parameter "C_eff" [m^-1]

Figure 2(b)


(b)
Mean Dispersion [ps/nm]
4000
2000
0
-2000
-4000
0.0
0.1
0.2
0.3
0.4
0.5
3dB Reflectivity Bandwidth [nm]