Tunable chirped fibre Bragg grating device controlled by variable magnetic fields

J. Mora, B. Ortega, M.V. Andrés, J. Capmany, D. Pastor, J.L. Cruz and S. Sales

A novel dynamic chirping fibre Bragg grating device based on a magnetic field applied to a magnetostrictive transducer capable of tuning its dispersion is presented. Chirping ranges up to 300 ps/nm have been demonstrated, which are suitable for several applications such as tunable transversal filtering and dynamic dispersion compensation.

Introduction: High speed optical transmission systems must overcome dispersion limitations by means of a dispersion compensating fibre [1] or a linearly chirped fibre Bragg grating [2]. However, the accumulated dispersion for a data channel may fluctuate with time. This is the case of optical networks, where lightpaths change dynamically, or in point to point transmission systems with variable operation conditions (i.e. laser or modulator chirp) [3]. For such dynamic systems, dispersion compensation must be adjustable to compensate the accumulated dispersion. Furthermore, as the line speed of each optical channel is increased these effects become more severe. This is the case for instance of the next generation of time division multiplexed systems operating at bit rates of 160 Gbit/s where small sources of dispersion variation, such as temperature variations, that are negligible at lower bit rates systems become critical for system performance [4]. In these systems, tunable dispersion compensators are required to dynamically adjust the dispersion map with an accuracy <10 ps/nm.

It has been shown that linear chirp characteristic of a fibre Bragg grating can be changed to compensate different amounts of link dispersion. Apart from previous reports on some mechanical techniques such as bonding the fibre Bragg grating (FBG) to a cantilevered beam or tapering a uniform cross-section bean [5], most of the approaches use voltage-tuned local heating [4] or piezoelectric materials to strain the gratings [5], which are more versatile and compact mechanisms than the first ones.

Previously, we worked on tuning and chirping FBG using magnetic fields [6], showing advantages such as good dynamic response and easy implementation and demonstrated their use for tunable optical transversal filtering [7]. In this Letter we propose a new system for tuning the dispersion characteristic of an original uniform Bragg grating by using a magnetic field and a magnetostrictive transducer.

Tunable dispersion device design: A uniform FBG is held on the magnetostrictive rod and subjected to a non-uniform magnetic field created inside a ferromagnetic material of variable transversal section along the z-axis. The tapered section was designed to create a linear magnetic field along the z-axis when fed with a magnetic circuit (see Fig. 1).

Suppose a magnetic field with the following axial dependence:

$$\frac{B(z)}{B(0)} = 1 - \xi z \qquad (1)$$

where ξ is the relative magnetic field gradient, B is the magnetic field and z is the axial distance. The radius profile of the ferromagnetic material, similar to a cone, that creates a magnetic field described in (1) is given by the following expression:

$$\left(\frac{b(z)}{a}\right)^2 = \left[\left(\frac{b(0)}{a}\right)^2 - \left(1 - \frac{\mu_m}{\mu_b}\right)\right]\frac{1}{1-\xi z} + \left(1 - \frac{\mu_m}{\mu_b}\right) \qquad (2)$$

where a is the magnetostrictive rod radius, 3 mm, $b(0)$ is the minimum radius of the cone, 5 mm, $b(z)$ is the cone radius along the axial distance and μ_m and μ_b are the permeability of the magnetostrictive rod and the ferromagnetic material, $\mu_m = 10$ ($\mu_m/\mu_b \ll 1$), respectively. In our device, the total length of the cone is 4 cm, $\xi = 0.24$ cm^{-1} and $B(L)/B(0) = 0.04$.

When magnetic field is applied to the magnetostrictive rod, the material suffers an elastic lengthening in the direction of the magnetic field, and, therefore, provided the grating is located in the axial area where field variation is linear, it is linearly chirped with a slope which depends on the applied current to the circuit.

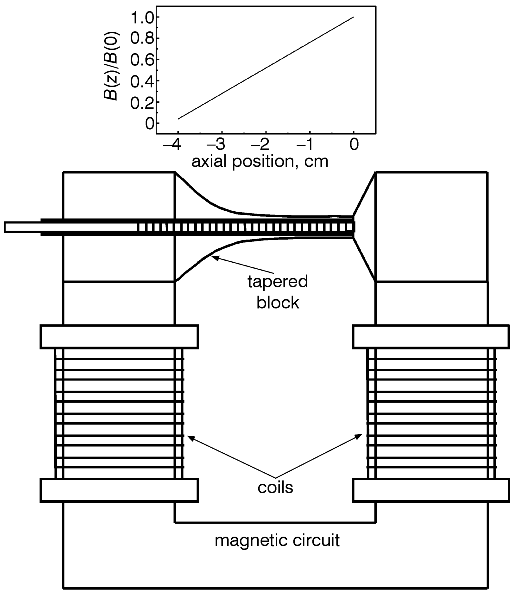

Fig. 1 *Magnetic field dependence along axial distance in magnetostrictive rod inside ferromagnetic material in a magnetic circuit*

Tunable dispersion measurements: Fig. 2 shows the original uniform FBG, which was a 5 cm-long grating of 99.5% reflectivity and a 3 dB bandwidth of 0.31 nm, and the resulting chirped gratings when different currents were applied to the coils of the magnetic circuit. Fig. 2*a* shows the reflectivity of the chirped gratings when applied electric currents were 1.0 and 2.0 A, with larger bandwidths of 0.61 and 1.08 nm, respectively. Fig. 2*b* shows the linear time delay curve with delay slopes of 80 and 290 ps/nm for 1.0 and 2.0 A, respectively. When the electric current is applied, in addition to the chirped grating, we also observe the original delay characteristic as a result of 1 cm of the grating far from the effect of the magnetic field being unaltered. Delay curves show ripples owing to the lack of apodisation of the FBG [8].

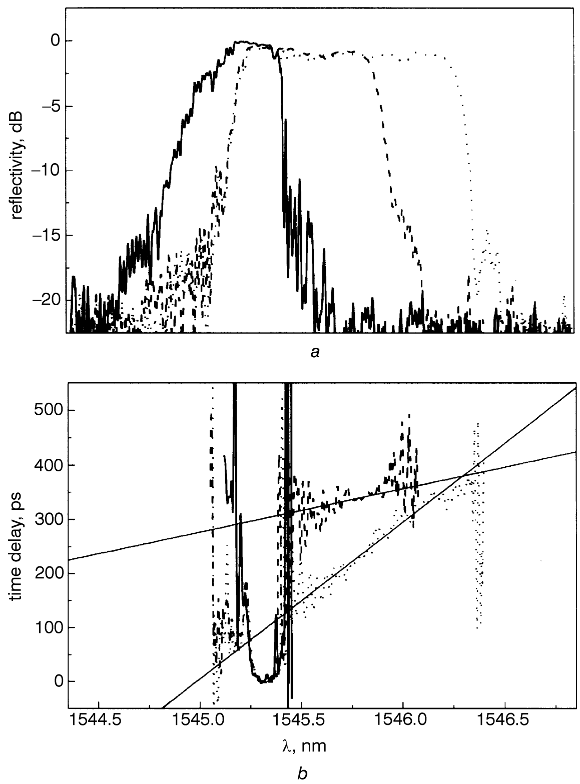

Fig. 2 *Uniform fibre Bragg grating response and when different electric currents are applied*

––––– 1 A
.... 2 A
a Reflectivity
b Time delay characteristic

Conclusions: We have demonstrated a novel dispersion tunable device using a uniform FBG and a magnetostrictive transducer under a non-uniform magnetic field, showing variable time delay slopes up to 300 ps/nm. This device shows the advantage of using a uniform FBG, not requiring any initial chirp characteristic, and overcomes heating limitations present in other electrical-driving devices [7], apart from being an accurate, compact and fast response system, since time response of magnetostrictive alloys is <1 ms.

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