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FIBRE BRAGG GRATINGS FOR DISPERSION COMPENSATION

Richard I. Laming, M.J. Cole, M. Durkin, M. Ibsen, M.N. Zervas, K.E. Ennser & [1]V.Gusmeroli.

Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK
Tel: +44 1703 592693, Fax: +44 1703 593142

[1]Pirelli Cavi SpA, Milano. Italy

Abstract: Broadband Chirped fibre gratings allow the upgrade of the existing non-dispersion shifted fibre network to high data rate operation within the 1.55μm low-loss window. The design, fabrication, performance and application of these devices is covered.

Summary: Dispersion compensation allows the upgrade of the existing non-dispersion shifted fibre network to high data rate operation (eg 10 Gbit/s) within the 1.55μm low-loss window. These data rates would otherwise be prohibited due to the high chromatic dispersion (~17ps/nm·km) associated with this fibre. Chirped fibre Bragg gratings are one of the most attractive devices for this application as they are low loss, compact and polarisation insensitive [1]. Additionally, these devices do not suffer from optical non-linearity which is the primary drawback of the main competing technology i.e. dispersion compensating fibre (DCF).

To date there have been several techniques reported for producing chirped gratings. These include post-chirping uniform gratings using UV processing [2] or by applying either a linear temperature [3] or strain gradient [4]. Alternatively the chirp can be directly imposed during fabrication [5]. At present all these techniques are limited to gratings ~10cm in length by the size of available phase masks used in production. This length corresponds to a maximum time delay or, equivalently, Bandwidth x Dispersion product, of about 1ns and, therefore, imposes a severe limitation to either the bandwidth or the dispersion of the compensator. For example, a 10cm grating could be designed with a 5nm bandwidth and low dispersion of 200ps/nm or alternatively with a narrow bandwidth of 0.1nm and high dispersion of ~6000ps/nm. By employing narrowband compensators 10Gbit/s transmission distances ranging from 100 to 700km of non-dispersion shifted fibre have been achieved demonstrating the viability of this technology [3,4,6-10]. In the latter case a 0.07nm bandwidth grating in combination with duobinary transmission was employed [10].

Although in the future transmitter wavelength tolerances will improve, for present practical applications chirped fibre Bragg gratings must exhibit both high dispersion and large bandwidth. A time delay of around 1700ps/nm would be sufficient to compensate around 100km of standard step index fibre at 1.55μm and a bandwidth of the order 5nm would cover typical semiconductor laser diode wavelength tolerances. This implies the need for either short, narrow-band and widely-tunable gratings [11] or long gratings (of ~1m in length) with a constant dispersion profile and broad bandwidth.

Kayshap et al [12] have achieved 1.3 meter gratings by concatenating many shorter gratings. However the stiching errors between section cause time-delay and reflection spectra discontinuities which may limit their usefullness. Taking some of the ideas from our earlier work [5] we have recently developed a continuous fabrication technique capable of producing arbitrary profile fibre gratings of 1 meter at present, ultimately limited by the maximum length of high quality translation stages. The phase shift is continuously added during the entire writing process and hence no glitches are present in the time-delay and/or reflectivity spectrum. Fabrication time for each 1 meter device is typically 10 minutes depending on the photosensitivity of the fibre used. Figures 1(a,b) show the design profile of a typical linearly chirped 1 meter gratings with apodisation to reduce the time-delay ripples. Theoretical simulations [13] of the wavelength dependence of the eye opening penalty for a 10Gbit/s NRZ dispersion compensated link are shown in figure 2. The results indicate that their is only a small degradation due to imperfections in the time delay characteristic of the latest gratings. This will improve further in the near future. Results from a 10Gbit/s transmission experiment confirm that the device works across the full bandwidth and confirms chirped gratings as a powerful component for use in networks [14]. Further operation of similar gratings has been demonstrated in a 4 x 10Gbit/s field trial by MCI and in a 40Gbit/s RZ experiment [15]

By periodically modulating the strength of the grating 'sampling' creates multiple reflection gratings for WDM applications [16]. The response of the super-structure can potentially be tailored to match/compliment the EDFA gain spectrum and compensate for linear and higher-order dispersion. In fact we have recently achieved 1 meter gratings optimised for third order dispersion [17].

Although fibre gratings can compensate the dispersion of several hundred km's of fibre with one device, numerical simulations have shown that it is preferable to distribute compensators throughout the link to reduce the effects of fibre non-linearity. Employing this approach high-bit-rate error-free transmission over distances in excess of 1000km are predicted using linear transmission [18,19] and further using soliton transmission. Recent experiments confirm this potential [20].

In summary, chirped gratings have been shown to be ideal for upgrading the installed standard fibre network to the 1.55μm wavelength window and high bit-rate operation. This talk will cover various aspects of their design, performance and network application.

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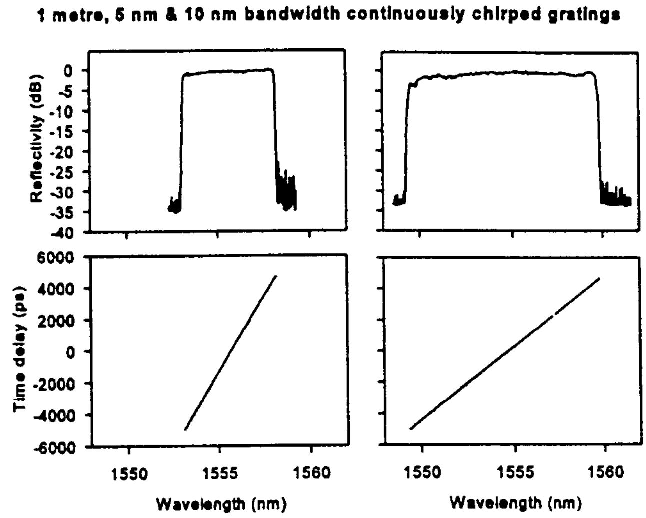

Figure 1. Characteristics of two 1 meter chirped gratings.

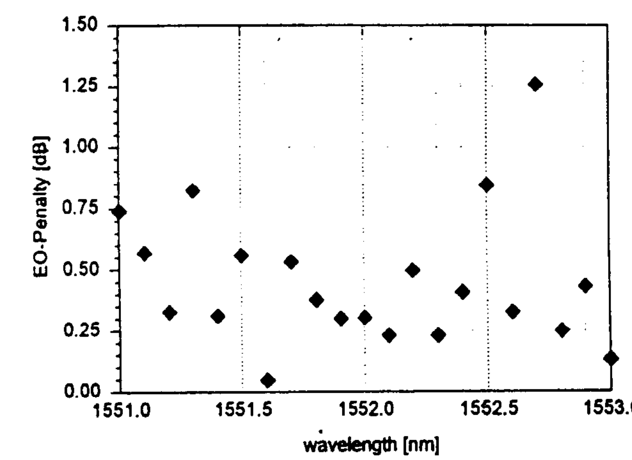

Figure 2. Simulated EO-penalty for a 1 meter grating operating in a 100km 10Gbit/s dispersion compenated link as a function of transmitter wavelength.