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# Fibre Gratings for Dispersion Compensation

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***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.

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 40cm 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 40cm device can be as short as 400 seconds depending on the photosensitivity of the fibre used. Figure 1 shows the design profile of a typical linearly chirped grating with apodisation to reduce the time-delay ripples whilst figure 2 shows reflection and time delay characteristics of a dispersion compensating module containing a cascade of two of these gratings [12]. 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.

A technique to watch for the future includes sampled gratings where by periodically modulating the strength of the grating multiple reflection gratings can be created for WDM applications [13]. 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.

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 [14,15]

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 Captions:***

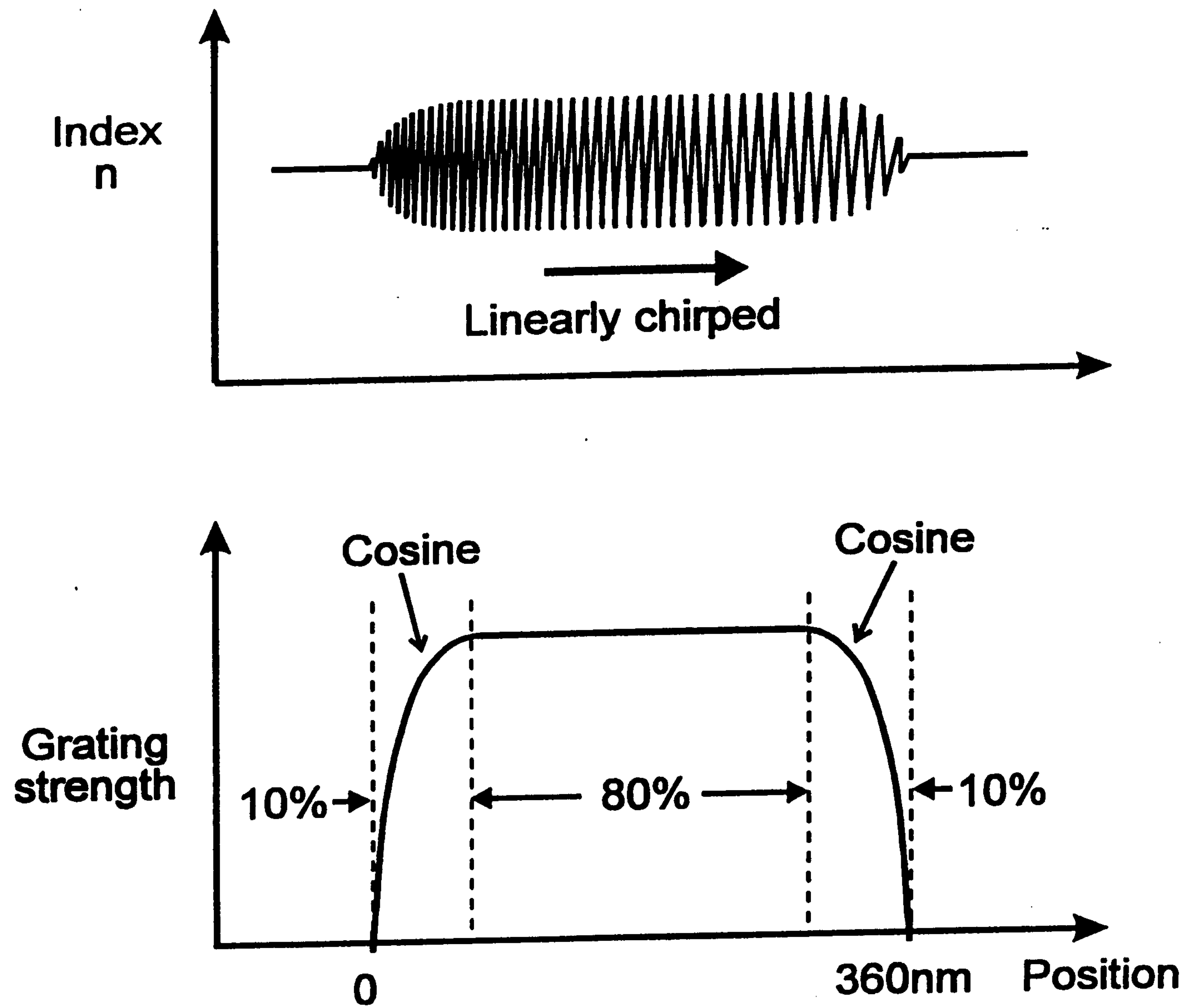
Figure 1. Profile of the 36cm chirped and apodised gratings.

Figure 2. Reflectivity and time delay against wavelength for the dispersion compensator module.

Laming et al Fig. 1

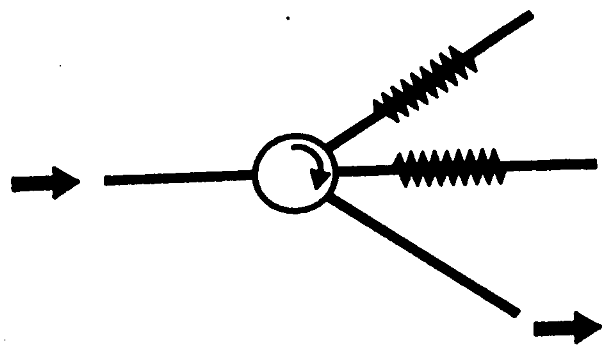
# GRATING DESIGN

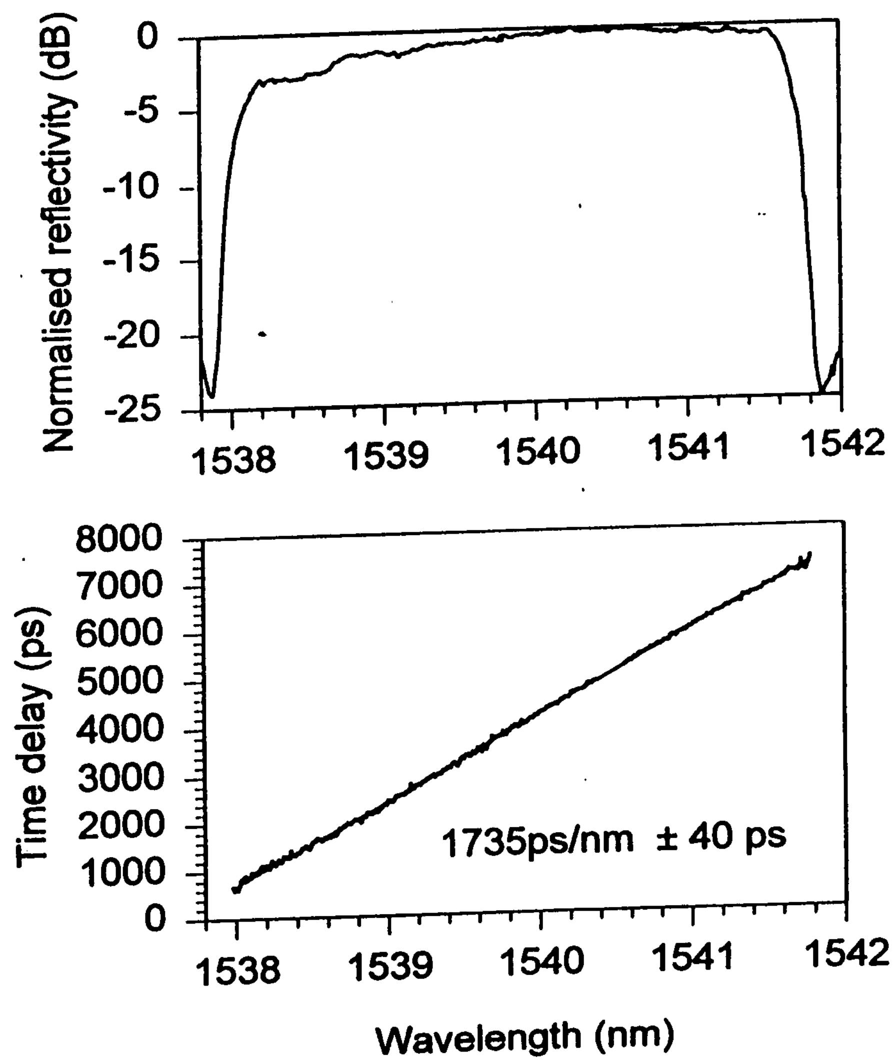
| | |
|---|---|
| Centre wavelength: | 1540nm |
| Chirp: | 4nm |
| Length: | 360mm |
| → | 880ps/nm |




Light
SOUTHAMPTON

# THE GRATING COMPENSATOR






- Gratings ~90% reflectivity
- Loss ~10dB due to splices
- PMD ~ 4ps

Light
SOUTHAMPTON