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Advanced Fibre Bragg Grating Devices for WDM Applications

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Abstract: Fibre Bragg Grating design and writing technologies offer unique flexibility and can provide a wide range of high performance all-fibre passive and active devices that can dramatically increase the performance of current and future telecommunication systems.

I. Introduction

High speed, high capacity optical transmission networks rely critically on the development of high performance fibre-optic components and devices. System and network architectures can significantly changed, improved and simplified by the advent and development of appropriate key components. UV-written Fibre Bragg Gratings (FBG's) [1,2] are proving to be one of the most important emerging technologies finding an increasing number of diverse applications throughout the field of Optical Fibre Technology. FBG's are simple versatile devices exhibiting extremely low polarisation sensitivity and insertion loss, easily controllable characteristics, wavelength stability and longevity. Their unique reflection and dispersion characteristics permit their use almost throughout the field of optical communications [3]. Passive and active FBG-based devices have also revitalised the fibre sensor field [4].

A number of different grating design techniques and algorithms have been proposed over the past few years that enable the implementation of grating-based devices with unique spectral characteristics. Recently, we reported on a new inverse scattering (IS) layer-peeling technique [5,6] and demonstrated its effectiveness in designing high quality grating devices, such as narrow bandwidth linear dispersion compensators [7] and square dispersionless filters [8]. These advanced grating designs require sophisticated and accurately-controlled FBG writing techniques.

In this presentation, we report on recently developed advanced high performance passive and active FBG devices and discuss their impact on future telecommunication systems.

II. FBG Linear Dispersion Compensators

Using the recently developed layer-peeling IS technique [5], we designed a grating structure with the following characteristics: –1dB bandwidth of 0.3 nm; –30 dB bandwidth of 0.4 nm; 90% reflectivity; dispersion compensation for 80 km of NDSF with a dispersion of 17 ps/nm/km; maximum length 10 cm [7].

Figure 1 shows the reflection and dispersion characteristics of the device. The reflection and the group delay measurements closely match the theoretical response. Notably the bandwidth utilisation factor (-1 dB bandwidth / -30 dB bandwidth) of the experimental grating is 70%: this is significantly greater than the 41% theoretical value for the linearly-chirped grating designed using conventional apodisation. This grating offers a –1dB bandwidth of 0.29 nm for a full (-30 dB) bandwidth of 0.41nm. The group delay of the grating is also shown in comparison to the theoretical results for both the inverse scattering and the conventional apodisation designs.

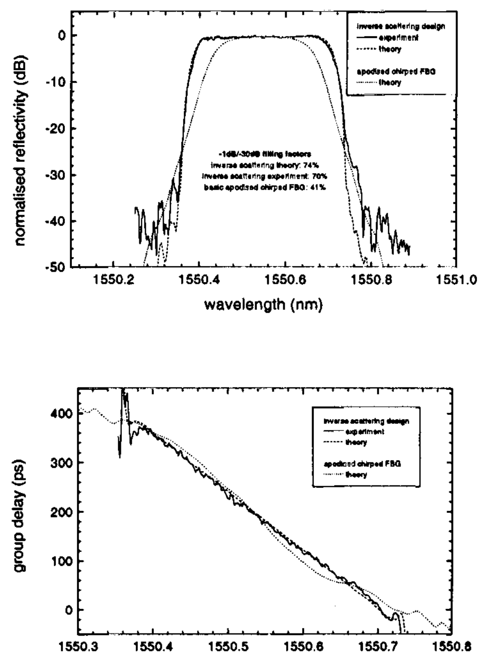

Figure 1: Reflectivity and Group Delay response of 50GHz linear dispersion compensator.

Using the same inverse scattering algorithm, we have also designed and demonstrated experimentally dispersionless (linear phase) square FBG filters for use in 50GHz-spacing systems [8]. A typical filter reflection spectrum is shown in Figure 2. The filter shows bandwidths of 50GHz and 37.5GHz at the -30dB and –1dB transmission, respectively, (filling factor of 75%) and transmissivity of –30dB (over 37.5GHz bandwidth). Back-to-back filter measurements at

10Gbit/s showed errorless performance (BER<10^{-11}) over the entire –1dB bandwidth.

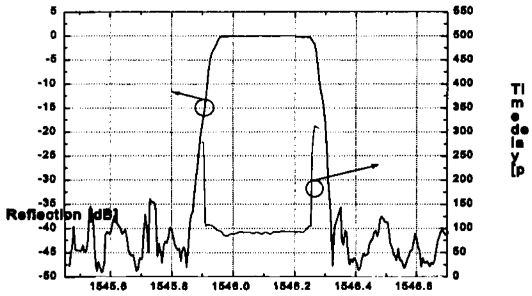

Figure 2: Reflectivity and Group Delay response of a dispersionless square FBG filter, suitable for 50GHz channel-spacing operation.

IV. Fibre DFB Lasers and Laser-Array Modules

Fibre-DFB lasers now can be designed to provide single-polarisation, single-sided, high power CW output (~20mW) and high signal-to-noise-ratio (SNR) [9]. These characteristics therefore make them strong rivals to their semiconductor counterparts. Recently, in a 4x10Gbit/s WDM transmission experiment, we have demonstrated that fibre-DFB lasers indeed successfully can replace semiconductor lasers without any deterioration in system performance [10].

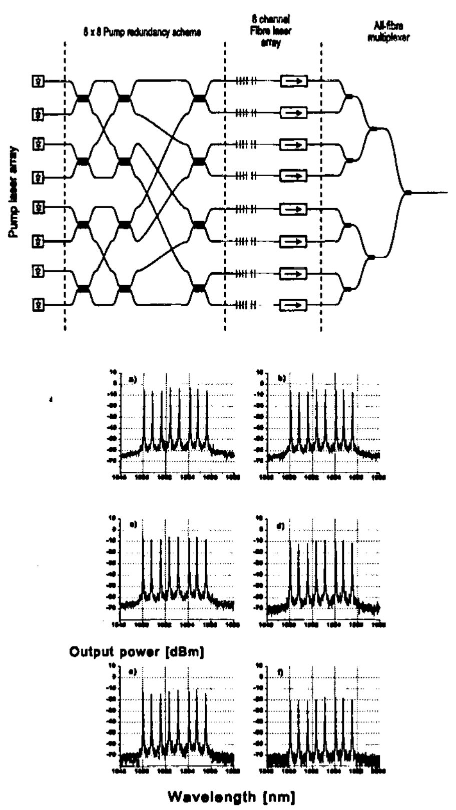

Figure 3: (Top) 8-channel fibre-DFB laser WDM transmitter module with 8x8 pump redundancy scheme. (Bottom) Output spectra of the 8-channel, 100GHz spacing WDM transmitter unit with (a) 8 pumps, (b) 7pumps, (c) 6 pumps, (d) 4 pumps, (e) 3 pumps, and (f) only 1 pump live.

We have also demonstrated a new concept of 8- and 16-channel (100GHz and 50GHz spacing) all-fibre laser WDM transmitter modules with integrated pump redundancy [11]. The employment of a pump redundancy scheme safeguards against the failure of one or more pump diodes. We show that with 8x8-pump redundancy circuitry, the power reduction to each of 8 WDM channels resulting from the failure of the 1 out of 8 pumps is just 2 dB. All WDM channels remain in operation despite the drop of 7 out of 8 pump-diodes. Figure 3 shows the schematic of an 8-channel transmitter module (top) and the channel survival after the pump failures (bottom).

The extension of this scheme to provide 16 DFB fibre laser transmitter module, with 50GHz channel spacing, and only 8 pumps, has also been demonstrated [9]. This pump redundancy scheme has been realised by splitting the 8 outputs from the previous 8-channel scheme, with an additional set of 3-dB couplers at the output. The module showed similar behaviour against pump failures.

V. Conclusions

We have reviewed the various uses of FBG devices as high performance dispersion compensators and fibre-DFB laser and laser arrays. It is shown that grating design and writing technologies offer unique flexibility and can provide a wide range of high performance all-fibre passive and active devices that can dramatically increase the performance of current and future telecommunication systems.

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