

Performance of non-fibre based dispersion compensation for long-haul 10.7 Gbit/s DWDM transmission

D.F. Grosz, D.N. Maywar, A.P. Küng, A. Agarwal and S. Banerjee

Non-fibre based in-line dispersion compensation is employed to achieve long-haul transmission of 80 channels at 10.7 Gbit/s bit rate over 1200 km of LEAF fibre. Average system margins of more than 4 dB and small transmission penalties are demonstrated. The additional penalty incurred by the periodic nature of the dispersion compensator is assessed.

Introduction: Non-fibre based dispersion compensation, based on such technologies as Gires-Tournois (GT) etalons and fibre Bragg gratings [1, 2] has recently attracted considerable attention as a means to achieve tunable dispersion compensation (TDC), a key enabling technology for 40 Gbit/s transmission [3]. In addition, fixed dispersion compensation provided by non-fibre based devices has become an alternative to fibre dispersion compensation modules (DCMs) for WDM applications. Advantages of non-fibre based DCMs over their fibre-DCM counterparts include the possibility of engineering arbitrary dispersion profiles (thus providing ‘nonlinear dispersion compensation’), the absence of nonlinear impairments allowing high-optical power handling, lower insertion loss, and smaller footprint. These non-fibre based solutions are also wideband and can operate in both the C- and L-bands.

One possible drawback of non-fibre DCMs arises from the periodic nature of their dispersion characteristics. This periodicity is shown in Fig. 1, where a magnified region of the dispersion against wavelength curve is displayed for one of the GT-based modules used in our experiment. The existence of such ‘dispersion-passbands’ (with a typical FWHM of 25 GHz for 10 Gbit/s applications) raises the question of whether deleterious effects will limit system performance when cascading many devices, thus precluding their use for in-line compensation in long-haul (> 1000 km) applications.

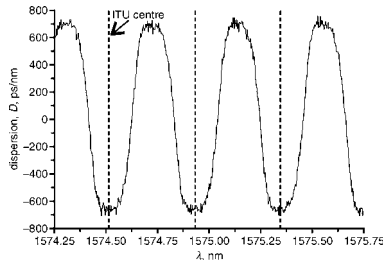


Fig. 1 Periodic dispersion structure of non-fibre DCM used in experiment

In this Letter we consider, for the first time to the best of our knowledge, the feasibility and efficacy of using etalon-based DCMs for 10 Gbit/s DWDM long-haul transmission and show that, within practical limits of operation, the periodic dispersion structure and cascading of non-fibre DCMs represent a small source of performance degradation.

Experimental setup: The experimental setup, shown in Fig. 2, consists of a recirculating loop having three spans of large effective area fibre (LEAF). The span length and loss is 100 km and 23 dB, respectively. Erbium-doped fibre amplifiers (EDFAs), having noise-figures ranging from 7 to 9 dB across the L-band, provide the span gain and no Raman amplification is used.

Eighty channels, from 1570.44 to 1603.7 nm, in a 50 GHz grid are divided in two banks of 40 channels in a 100 GHz grid. Each bank is independently modulated with a $2^{31} - 1$ PRBS sequence of 50% duty cycle return-to-zero (RZ) data, obtained by driving a single Mach-Zehnder modulator directly driven by 50% RZ electrical data. The use of long data pattern lengths ensures that the appropriate amount of cross-interactions among signal channels is fully captured in the experiment. The use of RZ modulation allows us to take advantage of its better behaviour under nonlinear propagation and its better receiver sensitivity. The two banks of

channels are combined using an interleaver before launching into the recirculating loop. The launch power per channel is 1 dBm.

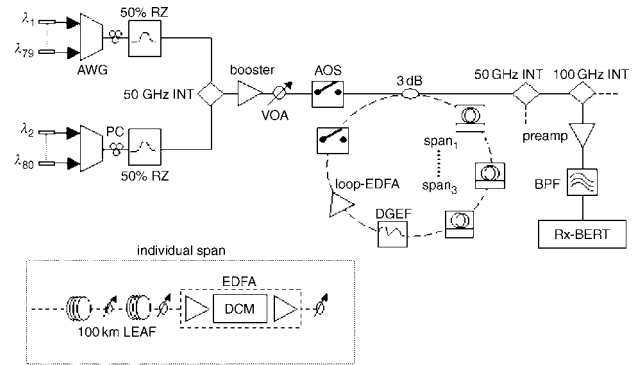


Fig. 2 Experimental setup

AWG: array waveguide router; PC: polarisation controller; VOA: variable optical attenuator; AOS: acousto-optic switch; INT: interleaver/slicer; BPF: bandpass filter; DCM: non-fibre based dispersion compensation module based on GT etalons

The dispersion map consists of no pre-compensation, no post-compensation, and full in-line dispersion and dispersion-slope compensation provided by non-fibre based GT-DCMs. The residual dispersion per span is small and flat across the transmitted band: approximately +5 ps/nm-km at 1570 nm, and +12 ps/nm-km at 1604 nm.

The recirculating loop is composed of the three-LEAF spans followed by a dynamic gain equaliser filter (DGEF) and an L-band EDFA to overcome the losses of the 3 dB coupler and acousto-optic modulator. The channel under test is demultiplexed by means of 50 and 100 GHz interleavers in series and an optical bandpass filter having a 0.25 nm bandwidth.

Results and discussion: To characterise the transmission performance, noise from a broadband source is mixed with the measured signal with a variable ratio in front of the preamplified receiver until a desired level of bit error rate (BER) is achieved. This procedure is performed in back-to-back configuration (bypassing the recirculating loop) and after transmission, and the desired BER level is set at the Reed-Solomon forward error correction (FEC) of 6×10^{-5} . This threshold corresponds to a corrected BER = 10^{-16} , i.e. the criterion for ‘error-free’ transmission. Thus we can measure the optical signal-to-noise ratio (OSNR) required to sustain error-free operation. The difference between the required OSNR after transmission and in back-to-back configuration represents the transmission penalty. The difference between the received and the required OSNR after transmission represents the system margin. More details on this system performance characterisation can be found in [4].

The transmission penalty and system margin for a target long-haul distance of 1200 km, and for a representative set of channels across the entire transmission band, are shown Fig. 3a. 1200 km is achieved after four trips around the recirculating loop; thus each of the three in-line DCMs is traversed four times.

The measured average system margin is approximately 4.5 dB above the ‘error-free’ threshold. Measured transmission penalties for the same set of channels are below 2 dB; the increased penalty at longer wavelengths is due to insufficient optical power reaching the receiver in our experimental setup, and is not related to transmission dynamics. The large margins and small transmission penalties indicate the possibility of deploying such a system in a commercial network.

The impact of laser detuning on the uncorrected BER at the target distance is shown in Fig. 3b for two channels picked randomly across the L-band. In practice, lasers equipped with wavelength lockers will exhibit a typical drift of ± 2.5 GHz. Observe that over a detuning of ± 2.5 GHz, the received BER changes by approximately half an order of magnitude, corresponding to less than 0.5 dB transmission penalty at this BER, and a negligible penalty at FEC threshold. With the large margins available even a larger detuning does not pose a problem, hence indicating the feasibility of cascading non-fibre DCMs for long-haul applications. We expect that our experiment, where the same set of DCMs are traversed multiple times, creates a worse condition than for the same number of different devices as would be found in a straight-

line system. Note also that the difference in BER performance for the two channels is not due to filter-cascading effects but rather due to the received OSNR, which is 14.7 dB (1574 nm) and 16.3 dB (1582.3 nm).

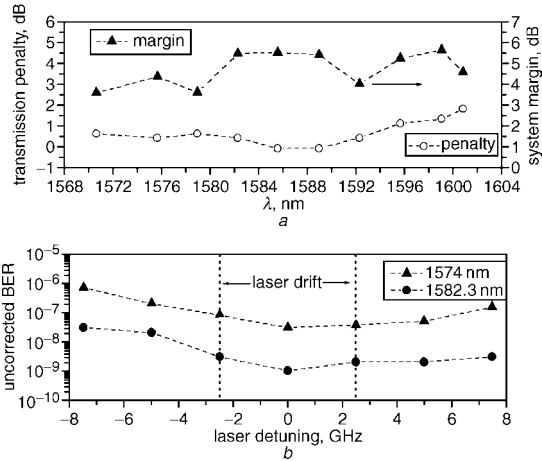


Fig. 3 Transmission performance and impact of laser detuning for two randomly-picked channels, both after 1200 km

a Transmission performance

b Impact of laser-detuning

Typical wavelength drift of transmitter equipped with wavelength locker also indicated

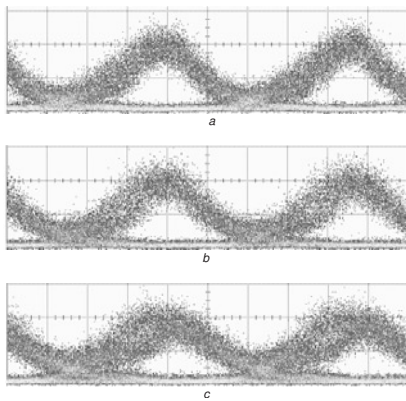


Fig. 4 Eye patterns for typical channel (1574 nm) at 1200 km for different laser detuning

a centred on ITU grid b 2.5 GHz c 5 GHz detuning

The effect of transmitter wavelength detuning on the received eye patterns at 1200 km (obtained with a fast 30 GHz bandwidth photo-

diode) is shown in Fig. 4 for the 1574 nm signal. Only slight degradations are seen at a detuning of 2.5 and 5 GHz.

Conclusion: We have evaluated the performance of an EDFA-based long-haul DWDM transmission system over 1200 km of LEAF using Gires-Tournois etalon-based in-line dispersion compensation. An average system margin of 4.5 dB and transmission penalties of less than 2 dB were measured, demonstrating the feasibility of using non-fibre based dispersion compensation for long-haul DWDM applications. Finally, transmitter wavelength drift effects were addressed and measured to add less than 0.5 dB penalty for practical system parameters.

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