# COMPARISON OF DISPERSION COMPENSATING FIBRE GRATINGS AND DISPERSION COMPENSATING FIBRE IN MULTISPAN STANDARD FIBRE WDM LINKS

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*Abstract: Transmission of 10 Gbit/s per channel WDM over standard fibre using dispersion compensating fibre gratings and dispersion compensating fibre is investigated. The performance of the two techniques in the presence of self- and cross-phase modulation and for RZ and NRZ signal formats is compared.*

**Introduction**

Future upgrades of the per-channel bit-rate to 10 Gbit/s and above in WDM systems operating over already installed standard fibre (D = +17 ps/nm/km) will require the use of dispersion compensation. Two contenders for this role are dispersion compensating fibre gratings (DCG) /1/ and dispersion compensating fibre (DCF) /2/. In this paper, we describe experiments, using a recirculating fibre loop, comparing their performance in multispan WDM applications, for different signal powers, numbers of channels and signal formats. The effects of fibre nonlinearity in the DCF and standard fibre, such as self-phase modulation (SPM) and cross-phase modulation (XPM), and ripples in the reflectivity and group delay spectra of the DCGs were determined.

**Experiment**

Multi-span WDM 10 Gbit/s per channel transmission was experimentally investigated using a recirculating fibre loop as shown in Figure 1. The loop comprised 40 km of standard single mode fibre and the compensator, either 8 km of DCF (D=-90 ps/nm/km) or a DCG and optical circulator. The bandwidth of the DCG was 4.2 nm. The compensator loss was around 6 dB in both cases. The total loop loss of 21 dB was offset using using a gain flattened EDFA giving a launch power +14 dBm after the attenuator. In the transmitter, the output of MQW-DFB lasers was modulated, firstly with a semiconductor Mach-Zehnder modulator (MZM), driven with a 10 GHz sinusoidal signal to obtain RZ pulses, prior to data encoding with a $2^7$-1 word length using an electroabsorption modulator (EAM). Alternatively, the laser output could be modulated with the EAM alone, to obtain NRZ pulses. At the output, the channels were demultiplexed using a free-space concave grating. The correct positioning of the compensator within each span is important to minimise distortion due to fibre nonlinearity. The DCG was placed after the EDFA, its loss reducing the power launched into the fibre, and the optimum positioning for the DCF has been shown to be after the EDFA also /3//4/, as the SPM occurring in the DCF leads to pulse compression by the positive dispersion of the following standard fibre, opening the signal eye at the receiver. This was confirmed by measurements of the Q figure for a single 8 dBm NRZ channel, plotted in Figure 3. The Q was determined by measuring the bit error rate as a function of decision voltge level. Placing the DCF after the EDFA rather than before it resulted in an increase in the transmission distance for a 4 channel system from 1 span to 7 spans before Q = 6 (BER = $10^{-9}$) was reached.

**Figure 1: Schematic diagram of the experimental set-up**

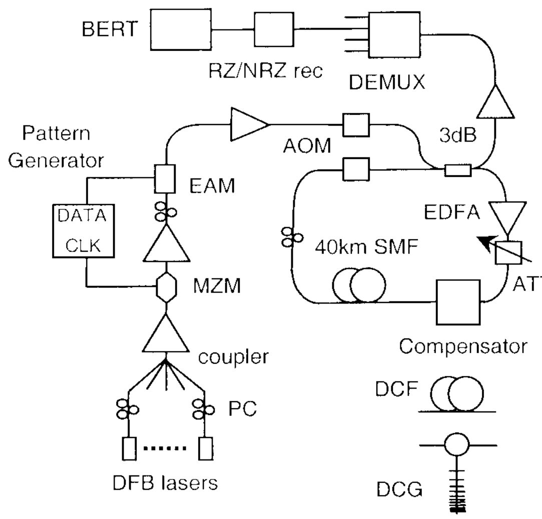



**Figure 2: Fibre grating reflectivity and group delay**

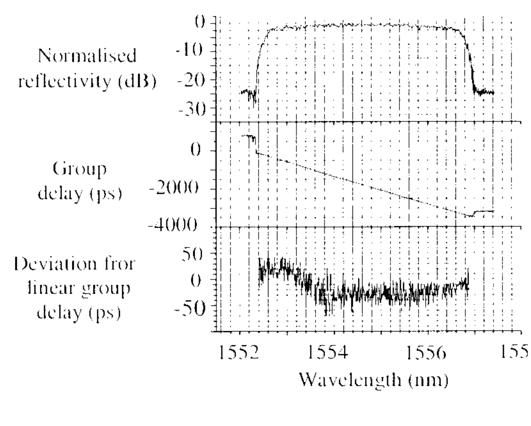
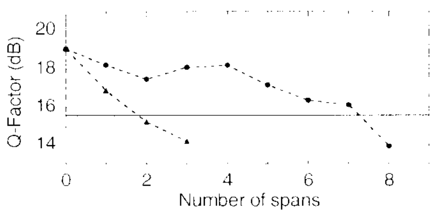


**Figure 3: Q-factor measurements for pre- (• ) and post-**



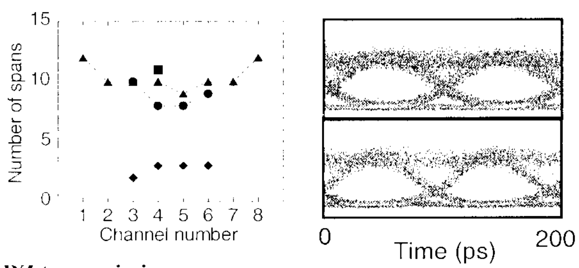

**(• ) compensated transmission. Solid line corresponds to BER = $10^{-9}$**

### NRZ transmission

Initially, NRZ format transmission was considered, with measurements of a single channel and 4 channels with average channel power of +8 dBm. A channel spacing of 50 GHz was used, and the maximum transmission distances with Q > 6 are plotted in Figure 4. A distance of 11 spans was achievable for the single channel with DCF, but this decreased when four channels were transmitted, resulting from XPM induced pulse distortion and jitter. The nonlinear distortion with 8 channels is lower due to a 3 dB reduction of the channel power.

The maximum single channel transmission distance using a DCG was 3 spans. This remained unchanged when 4 channels were transmitted. The limit is due to ripples in reflectivity and group delay spectra and the effect of these deviations is exacerbated by operation in a single span loop, as they are reinforced from one recirculation to the next. In straight line transmission, as the ripples are random, their effect would be reduced.

**Figure 4: (a) Maximum transmission distances for NRZ pulses: single (• ), 4 (• ) and 8 (• ) channels compensated with DCF, 4 channels (• ) with DCG. Signal eyes after 4 spans with: (b) DCF, (c) DCG**




### RZ transmission

Next, the two configurations were tested with RZ modulation format (Figure 5). With DCF, it was found that the shorter pulses and higher peak powers resulted in increased distortion due to SPM and XPM, reducing the distance from 11 to 7 spans for single channel and from 10 to 7 spans (best channel) for 4 channels. The inner channels suffered the worst distortion, due to the proximity of a larger number of other channels.

In contrast, the use of RZ pulses increased the transmission distance for the DCG, from 3 spans to 7 spans for both 1 and 4 channel transmission. As this signal format employs a single pulse shape, the effects of reflectivity and group delay ripple are the same on all pulses, reducing eye closure. The effect of XPM is minimised compared to the DCF case, and so the performance is less dependent on the number of channels and the signal power.

**Figure 5: Maximum RZ transmission distances: top DCF, bottom: DCG.**

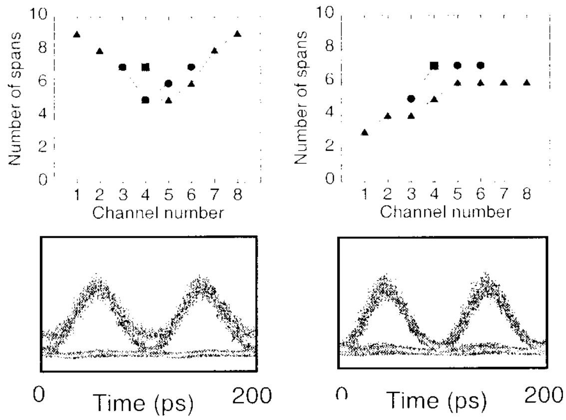
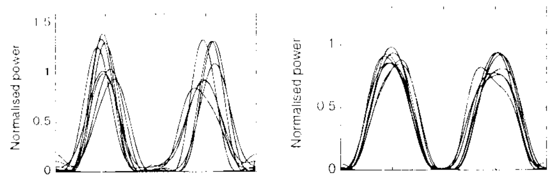



Figure 6 shows eye diagrams for the received signal after 5 spans for 4 channel, 8 dBm per channel RZ transmission, comparing ideal DCGs with DCF and calculated using the split-step Fourier method. Signal distortion due to XPM in the case of DCF is greatly decreased with the use of linear DCGs.

**Figure 6: Calculated RZ transmission: (a) DCF, (b) DCG.**




**In conclusion,** the use of DCF and DCGs have been compared for compensating multispan standard fibre WDM links, at a channel rate of 10 Gbit/s. The maximum transmission distance was achievable for a single channel using DCF and NRZ pulses. However, the addition of extra channels reduced this distance, due to XPM. With the DCG, in which the distance was limited by ripples in the reflectivity and group delay spectra rather than fibre nonlinearity, the transmission distance was unaffected by the number of channels, desirable in practical optical networks. The suppression of XPM effects by using a DCG resulted in similar performance to the DCF when RZ pulses were used, and would give better performance in straight-line transmssion. Consequently, the use of DCGs may be attractive in optical time division multiplexed WDM systems.

### References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