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Dispersion Compensated 10 Gbit/s Transmission over 700 km of Standard Single Mode Fiber with 10 cm Chirped Fiber Grating and Duobinary Transmitter

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Introduction: Dispersion compensation using chirped fiber Bragg gratings[1,2] is a very promising approach to long distance, high bit rate transmission over already installed non-dispersion shifted fiber (NDSF), as chirped fiber gratings are passive, compact, fiber compatible and relatively easy to fabricate in large numbers. Recently, 10 Gbit/s transmission over 400 km of NDSF with a 10 cm chirped grating was achieved[3]. In that demonstration, the grating bandwidth, and hence maximum grating dispersion, was limited by the need to accommodate the signal bandwidth ($\geq$0.1nm). In this work, by using a reduced-bandwidth duobinary 10 Gbit/s transmitter, we show that transmission up to 700 km of NDSF is now achievable with a single 10 cm long chirped fiber grating. In addition, we find that to achieve these long distances, care must be taken with regard to the proper positioning of the compensating grating in order to minimise penalties arising from nonlinearity in the fiber.

Experiment: The experimental configuration is shown in Fig. 1. The 1558.8 nm 10 Gbit/s

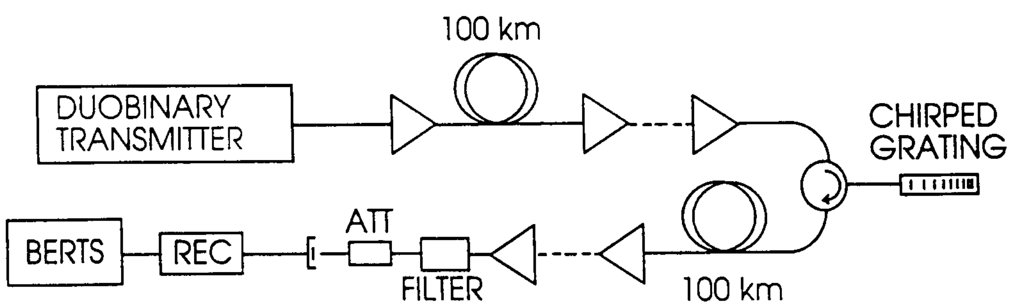

Fig. 1 System configuration. ATT: Attenuator, REC: Receiver, BERTS: Bit Error Rate Test Set.

transmitter is based on a duobinary waveform driven Mach-Zehnder modulator biased about the point of maximum extinction, generating narrow bandwidth 10 Gbit/s optical data compatible with standard binary IM-DD receivers[4,5]. The amplifier spacing was nominally 100 km (90-110 km), and the average optical power launched into each span +5.8 dBm. With this duobinary approach, transmission over 200 km of NDSF was achievable without the need for any dispersion compensation, due to the reduced optical signal bandwidth (Fig. 4) The apodised chirped fiber grating was fabricated via the moving fiber-scanning beam technique with a uniform phase mask[6]. Two gratings (Fig. 2) were tested in the system over various distances. The first, grating 1, has a bandwidth of 0.12 nm and dispersion 5000 ps/nm (≡300km of NDSF). Grating 2 has 0.073 nm bandwidth and a correspondingly higher dispersion of 8000 ps/nm (≡500 km of NDSF).

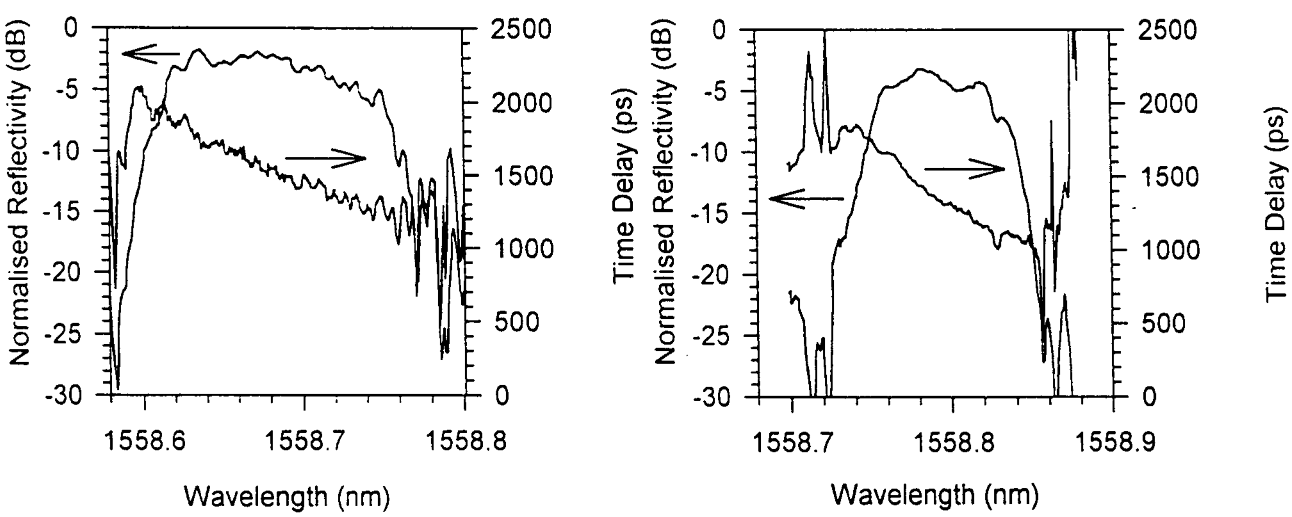

Fig. 2 Reflection and dispersion characteristic of (*left*) grating 1 and (*right*) grating 2.

Results: Fig. 3(*left*) shows the BER data obtained for transmission over various distances up to 500 km of NDSF. For transmission to 400 km, grating 1 was used, placed at the beginning of the link. Close to 1 dB improvement in sensitivity (at BER=10^{-9}) was observed compared with the back-to-back data. For 490 km transmission, however, pre-compensation with grating 2 resulted in a severe penalty of ~6 dB. Numerical simulations indicate that this is related to nonlinear effects in the fiber[7], and that proper positioning of the grating is crucial to reducing this penalty. Indeed, by simply moving the grating to the middle of the link, near-penalty-free transmission was recovered. Fig. 3(*right*) shows the BER for distances up to 700 km. At 590 km, the performance is still similar to the back-to-back case, while 1.4 dB and 4 dB power penalties (at BER=10^{-9}) are incurred for 650 km and 700 km transmission respectively, as the total fiber dispersion continues to exceed the grating dispersion.

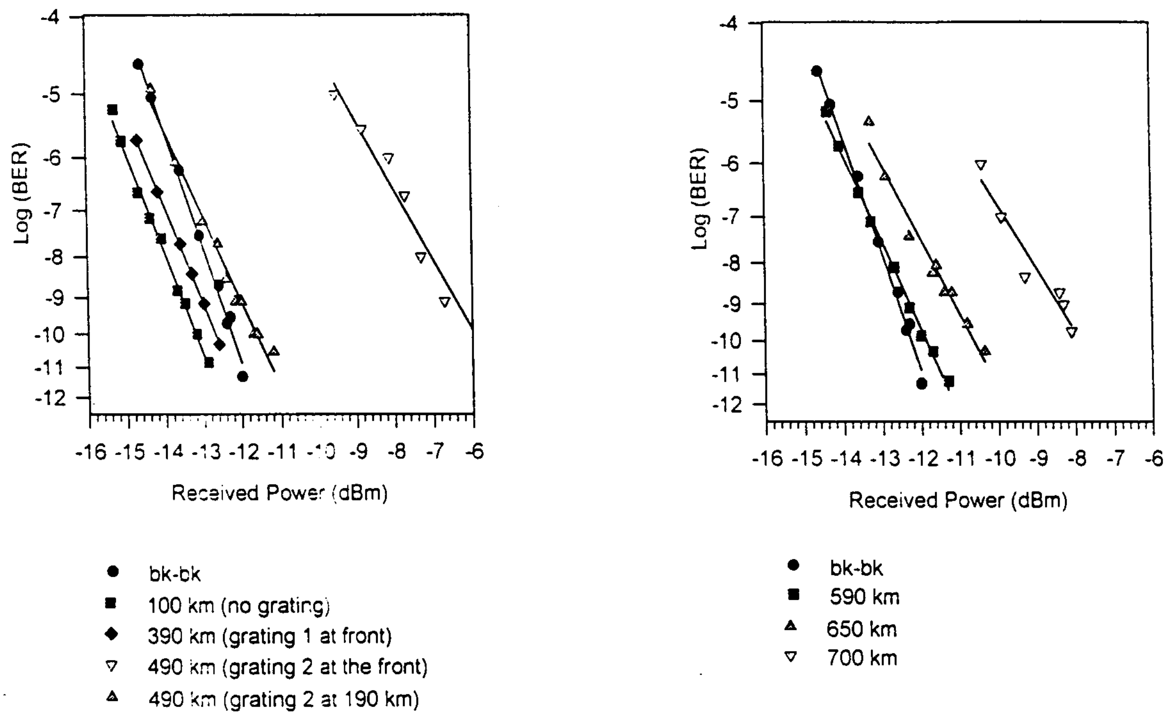

Fig. 3 BER data for transmission (*left*) to 500 km, showing the improvement obtained by moving the grating from the front to the middle of the link, and (*right*) to 700 km. Grating 2 is positioned at or near the middle of the link for the longest distances (≥ 600 km).

Fig. 4 summarises the results by showing the plot of the sensitivity (at BER=10^{-9}) against transmitted distance from 0 to 700 km. It is seen that without the grating, transmission up to 200 km is possible, with a 1.5 dB improvement in sensitivity at 100 km. With grating 1, transmission over the range 300 - 450 km is achievable, while grating 2 enables transmission from 500 -700 km. Looking at the optimum distances for each of the 3 configurations, we note a slight degradation in sensitivity with distance, which is likely due to increased noise and nonlinear effects resulting from the greater number of amplifier spans.

Conclusion: 10 Gbit/s transmission in standard single mode fiber at distances up to 700 km has been obtained using phase alternating duobinary (200 km) transmission format and a single 10 cm chirped fiber grating. This represents, to our knowledge, the longest distance achieved at 10 Gbit/s using a single dispersion compensating element to date. To achieve these long distances, the positioning of the compensating grating is found to be crucial.

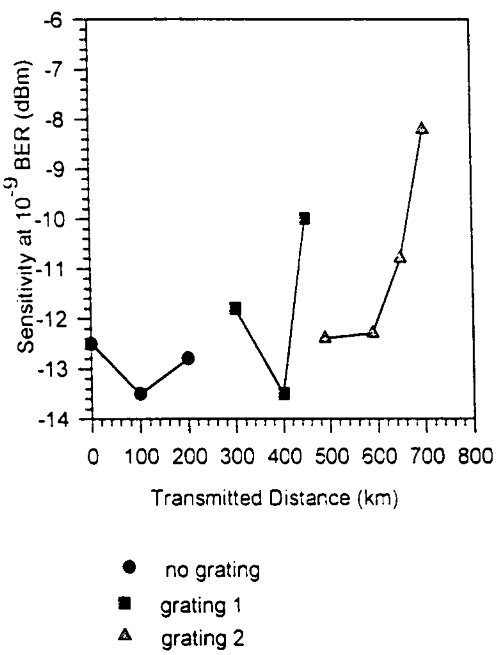

Fig. 4 Plot of sensitivity (at BER=10^{-9}) against transmitted distance.

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