Field transmission over standard fibre at 40 Gbit/s using midspan spectral inversion

S.Y.Set[1], R.Girardi[2], E.Riccardi[2], B.E.Olsson[3], M.Puleo[2], M.Ibsen[1], R.I.Laming[1], P.A.Andrekson[3], F.Cisternino[2], H.Geiger[1]

(1) Optoelectronics Research Centre, University of Southampton
(2) CSELT, Via Reiss Romoli 274, 10148 Torino, Italy.
(3) Department of Microelectronics, Photonics Laboratory, Chalmers University of Technology, 41296 Goteborg, Sweden,

Abstract:

The first field trial using midspan spectral inversion for dispersion compensation is presented. All-fibre subsystems allow optical time-division multiplexed transmission over 140 km of standard fibre (D=16 ps/(nm.km)) with polarisation dependence below 0.2 dB.

40 Gbit/s transmission on a single wavelength channel is becoming a likely prospect, in particular with the imminent availability of electrical multiplexers and demultiplexers. At this bitrate, dispersion limits transmission to a few kilometres over standard fibre, requiring compensation to utilise the majority of the installed fibre. Transmission over installed standard fibre has previously only been demonstrated in experiments employing dispersion- compensating fibre or fibre gratings [1,2]. We report here the first field trial using a third alternative, midspan spectral inversion (MSSI), for dispersion compensation.

Laboratory experiments at 40 Gbit/s have previously highlighted the potential of this technique [3,4]. As well as employing installed fibre, our MSSI field trial features novel all-fibre subsystems developed by groups in three European countries. It employs (i) a stable fibre ring laser as a pulse source, (ii) a polarisation-independent fibre spectral inverter for dispersion compensation, and (iii) a non-linear fibre loop mirror as a demultiplexer. A penalty below 1 dB relative to the back-to-back measurements and a record polarisation sensitivity below 0.2 dB have been achieved.

Subsystems & Trial Setup

The setup during the field trial is illustrated in Figure 1. A harmonically mode-locked polarisation-maintaining fibre ring laser is generating 7 ps pulses at 10 GHz repetition rate. Thermal stabilisation of the ring laser allows operation in a changing environment without retuning, and jitter is below 0.2 ps [5]. The signal is modulated by a 2^{23}-1 pseudo random binary sequence, before being multiplexed to 40 Gbit/s in a fibre multiplexer [5].

The data is transmitted over 140 km of installed standard fibre (two links of approximately 70 km each provided by Italian national host in the Turin area) with a dispersion of 16 ps/(nm.km) and a polarisation-mode dispersion of 0.07 ps/km$^{1/2}$. Excess loss is accumulated by transmission through

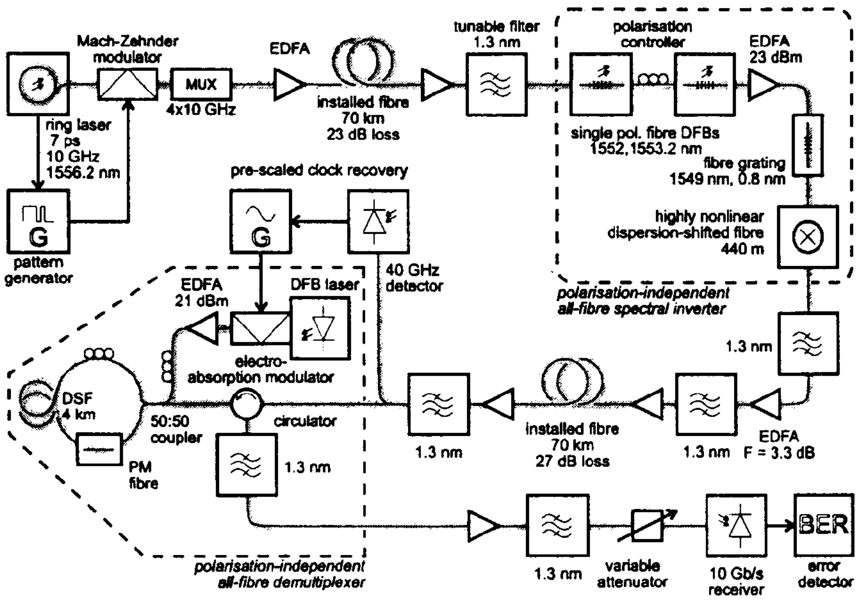

Figure 1: Experimental setup

connectors and splices in 12 switchboards, and total loss is equivalent to 250 km of fibre.

After the first link, spectral inversion is performed in a highly nonlinear fibre [3]. Two in-line fibre distributed- feedback (DFB) lasers are orthogonally polarised to supply the pump waves required for a polarisation-independent spectral inversion [6]. A fibre grating after the high-power amplifier improves the conjugate signal-to-noise ratio (SNR) [7], resulting in a robust all fibre inverter.

The inverted signal is filtered and amplified before being launched into the second link. This link has a similar characteristic to the first link, thereby recompressing the transmitted pulses.

The received signal is demultiplexed in a nonlinear optical loop mirror (NOLM, [8]). A clock recovery circuit locks the 4th harmonic of a 10 GHz voltage-controlled oscillator to the detected 40 GHz frequency in the RZ signal [9]. The oscillator modulates the CW output of a DFB diode laser in an electroabsorption modulator, generating clock pulses of 17 ps length. Their timing is synchronised to a selected channel.
The NOLM is biased so that it rejects the received signal when no clock pulse is present. However each clock pulse induces a π phase shift between the copropagating signals, changing the NOLM operation into a mirror for the selected channel.

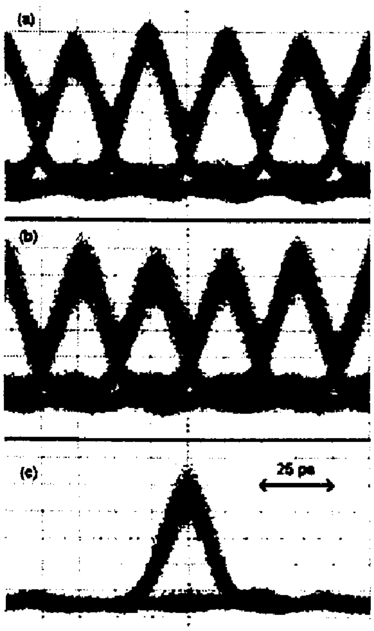

Figure 2: Eye diagrams of (a) transmitted, (b) received, and (c) demultiplexed signals

A short length of birefringent fibre inserted at one end of the loop changes the linear clock pulse polarisation into the orthogonal polarisation in one direction. Since the length is chosen to not affect the signal polarisation, polarisation- independent demultiplexing is achieved [8].

Results & Discussion

Figure 2 and Figure 3 show the eye diagrams and the error performance before and after transmission over 140 km of fibre. The demultiplexer suppresses other channels by more than 20 dB (Figure 2c) and results in an insertion penalty of less than 0.2 dB. Full pulse recompression is achieved, as shown by the autocorrelation traces (Figure 3 inset).

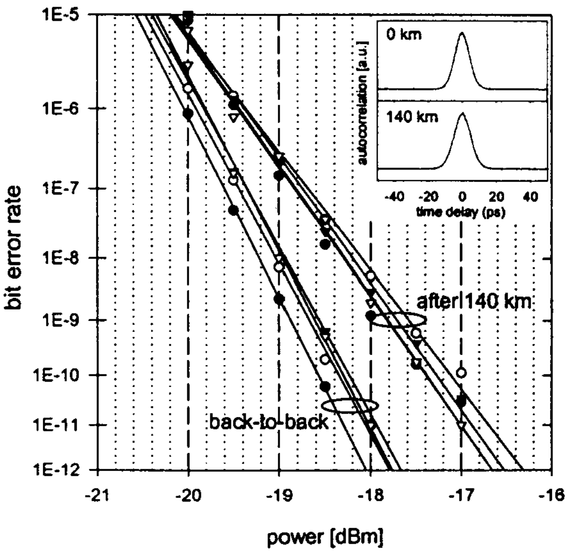

Figure 3: Performance of 40 Gbit/s MSSI transmission

At an error rate of 10^{-9}, the transmission penalty of each channel is about 1 dB (Figure 3). This low penalty is achieved by the use of the noise suppression fibre grating [7]. The main cause of this penalty is the SNR degradation in the spectral inverter, hence extra link loss can be easily accommodated. Additionally, the polarisation penalty of each channel is below 0.2 dB, while all four channels lie within 0.3 dB.

Conclusion

We have reported the first field trial of dispersion compensation using midspan spectral inversion. 40 Gbit/s transmission over 140 km installed fibre is achieved with an insertion penalty of 1 dB and a polarisation sensitivity below 0.2 dB. All-fibre processing provides a robust and low-cost approach, demonstrating the viability of this technique and its subsystems for use in future high bitrate telecommunication systems.

Acknowledgements

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