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Peucheret, Christophe; Zsigri, Beata; Andersen, Peter Andreas; Berg, Kim Skaalum; Tersigni, Andrea; Jeppesen, Palle; Hansen, K. P.; Nielsen, M. D.

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Transmission over photonic crystal fiber at 40 Gbit/s using mid-span spectral inversion in a highly nonlinear photonic crystal fiber

Christophe Peucheret, Beáta Zsigri, Peter Andreas Andersen
Kim Skaalum Berg, Andrea Tersigni, Palle Jeppesen
COM, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark
Phone: +45 45253840, Fax: +45 45936581, E-mail: cp@com.dtu.dk
Kim Per Hansen, Martin Dybendal Nielsen
Crystal Fibre A/S, Blokken 84, DK-3460 Birkerød, Denmark
Phone: +45 43482800, Fax: +45 43482801, E-mail: kph@crystal-fibre.com

Abstract: Transmission at 40 Gbit/s over large mode area photonic crystal fiber (PCF) together with dispersion compensation by optical phase conjugation in a highly nonlinear PCF are demonstrated for the first time.

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Photonic crystal fibers (PCF) offer many degrees of freedom for the design of their optical properties such as dispersion, nonlinearity and polarization. Until now, demonstrations of their use for system applications have focused on the exploitation of their nonlinearity for signal processing [1-4]. However, the recent reduction in the loss of PCFs [5, 6] combined with improvement in fabrication technology allowing for the drawing of longer fibers make them worth considering for transmission purposes [6, 7]. One of the expected benefits is the possibility to design fibers with large effective area that will still remain single mode [8], resulting in reduced nonlinear limitations. Here, we report the first transmission of 40 Gbit/s signals over 5.6 km PCF. As the transmission length is beyond the dispersion limit, dispersion compensation is required. We exploit four-wave mixing in a highly nonlinear PCF (HNL-PCF) to realize dispersion compensation by mid-span spectral inversion, hence demonstrating, for the first time, an all-crystal fiber dispersion compensated transmission link.

The experimental set-up is shown in Fig. 1. A Mach-Zehnder modulator is used to modulate continuous wave (CW) light at 40 Gbit/s in the non return-to-zero format with a $2^{31}-1$ PRBS. The transmission link consists of two spools of PCF (2.6 and 3 km long) with 1.7 dB/km loss and 32 ps/(nm·km) dispersion at 1550 nm [9], separated by an optical phase conjugator (OPC). Optical phase conjugation is achieved by four-wave mixing in 50 m highly nonlinear PCF with zero dispersion at 1552 nm and nonlinear coefficient $\gamma = 18\ \mathrm{W}^{-1}\cdot\mathrm{km}^{-1}$ [10]. The pump originates from a CW laser tuned to the HNL-PCF zero dispersion wavelength followed by a high power erbium-doped fiber amplifier (EDFA) resulting in a power of 25 dBm at the fibre input. The maximum conversion efficiency is -20 dB and the conversion 3-dB bandwidth is 15 nm. The converted signal is selected at the output of the HNL-PCF using an optical bandpass filter (OBF). After transmission, the signal is detected in a pre-amplified receiver. Both the transmission PCF and HNL-PCF are spliced to standard single mode fiber pigtails.

The eye diagrams of the signal along the transmission link are shown in Fig. 2. As expected, the eye diagram is strongly deteriorated by the accumulated dispersion after propagation in the first 2.6 km PCF. An open

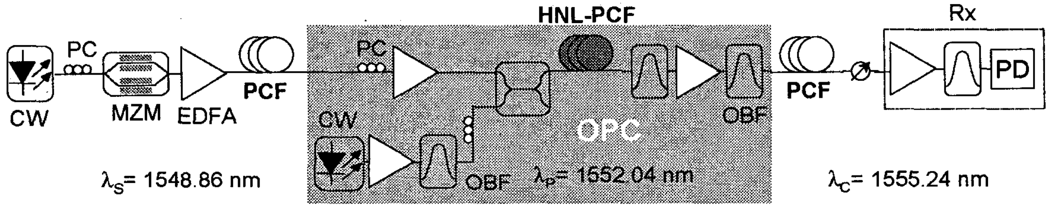

Fig. 1. Experimental set-up.

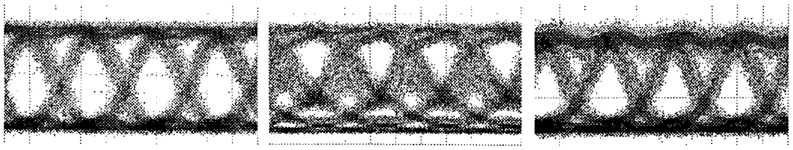

Fig. 2. Eye diagrams (50 GHz bandwidth) at the modulator output (left); after 2.6 km PCF (middle); after 5.6 km PCF + OPC (right). Horizontal scale: 10 ps/division.

eye is recovered after optical phase conjugation and propagation through the remaining 3 km of the link. Fig. 3 shows the bit-error-rate performance. The back-to-back sensitivity is -26.6 dBm and a total penalty of 0.7 dB is measured after transmission (including the OPC process). The penalty is attributed to the different amount of dispersion accumulated before and after the OPC (14 ps/nm), mostly due to the length difference between the two PCFs. It is therefore expected that tailoring the fiber lengths should result in even lower penalty.

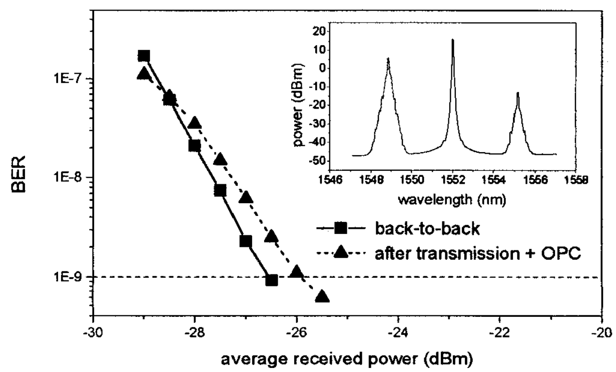

Fig. 3. BER curves. Inset: spectrum at the output of the HNL-PCF (0.1 nm resolution bandwidth).

In conclusion, we have demonstrated the first transmission at 40 Gbit/s through 5.6 km of large mode area PCF. Dispersion compensation was achieved using optical phase conjugation realized by four wave mixing in 50 m of a highly nonlinear PCF. This experiment constitutes the first demonstration of an optical link (including both transmission and dispersion compensation) based entirely on photonic crystal fibers.

References

1. P. Petropoulos *et al.*, *OFC'01*, paper TuC3.
2. J. E. Sharping *et al.*, *IEEE Photon. Technol. Lett.*, 14 (2002) 77–79.
3. L. K. Oxenløwe *et al.*, *OECC'02*, post-deadline paper PD1-4.
4. J. H. Lee *et al.*, *IEEE Photon. Technol. Lett.*, 15 (2003) 440-442.
5. L. Farr *et al.*, *ECOC'02*, post-deadline paper PD1.3.
6. K. Tajima *et al.*, *OFC'03*, post-deadline paper PD1.
7. K. Suzuki *et al.*, *Electron. Lett.*, 37 (2001) 1399–1401.
8. T. A. Birks *et al.*, *Opt. Lett.*, 22 (1997) 961–963.
9. M. D. Nielsen *et al.*,*ECOC'02*, paper 3.4.2.
10. K. P. Hansen *et al.*, *OFC'02*, post-deadline paper FA9.