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All-optical fiber signal processing based on balanced NOLM and imbalanced NOLM

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Abstract: *we demonstrate all-optical fiber signal processing at 10 Gbit/s, 40 Gbit/s and 80 Gbit/s including wavelength conversion, 2R regeneration and OTDM demultiplexing based on balanced nonlinear optical loop mirror and dispersion-imbalanced loop mirror.*

Introduction

All-optical signal processing as the critical function in realizing all-optical network is of considerable interest because it makes conversion between the optical and electronic domains superfluous. So far research has mainly concentrated on the design of optical gates that use either the Kerr effect in optical fiber [1] or carrier density related dynamics in semiconductor optical amplifiers (SOAs) [2]. The operating speed of SOA-based gates is limited due to the relaxation time of the carriers. For the fiber-based gates, however, without carriers involved, the operating speed is determined by ultra fast fiber nonlinearity, which provides response times of only fs. Therefore all-fiber, all-optically controlled devices have great potential in future ultrahigh-speed systems.

In this paper we demonstrate for the first time all-fiber-based all-optical signal processing including wavelength conversion, 2R regeneration and OTDM demultiplexing in three balanced or imbalanced nonlinear optical loop mirrors (NOLM). A new type of 2R regenerator based on a high non-linear dispersion-imbalanced loop mirror (HN-DILM) is investigated and accomplished. After one or two single mode fiber (SMF) span transmission, the signals at 10 Gbit/s, 40 Gbit/s and 80 Gbit/s are regenerated by the 2R regenerator. The necessary fiber loop length is strongly reduced from 6 km to 1 km by applying the highly non-linear DSF (HN-DSF) instead of the conventional DSF, and a shorter fiber loop improves stability and polarization insensitivity.

Principle

An asymmetric NOLM can act as a saturable absorber and strong filter in suppressing the amplified spontaneous emission (ASE) noise and reducing the timing jitter and pulse-to-pulse interactions. Unbalancing of the NOLM can be achieved with an asymmetrically placed EDFA close to the loop coupler [3] or by making the dispersion of the fiber loop asymmetric [4] as so-called DILM. The imbalanced dispersion elements in the loop will vary the peak power of the arms of the interferometer and therefore result in differential phase shift between the arms. The maximum transmission of the DILM occurs when the phase shift difference equals π.

In our scheme the DILM operates in a working point beyond the peak of the transmission function shown in Fig.1(a), which means the pulse energies cause greater than π differential phase shift between the arms of the interferometer. Theoretical analysis shows that this scheme is stable against small changes in the input power [5]. Globally saturable absorption provides an energy barrier to low-power components and as a consequence the background pedestal is rejected.

The dependence of the loop transmission on the fiber length of the non-linear segment is shown in Fig.1(b), when the input peak power is fixed at the working point (0.3 W). To get an optimum transmission the necessary length of DSF scheme is larger than 6 km while the HN-DSF scheme is only 1 km. The relatively shorter fiber length of HN-DSF scheme will enhance the system performance due to better stability and polarization insensitivity.

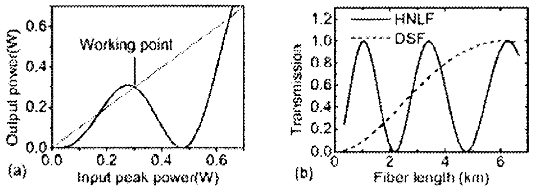

Fig.1 (a) Transmission function of the HN-DILM, (b) transmission characteristics of HN-DILM and conventional DILM as a function of the non-linear fiber length.

Experiment

The experimental set-up is shown in Fig.2. The signal source is a 10 GHz, 1557.3 nm erbium fiber ring laser (EFRL) that generates 4 ps full width half maximum (FWHM) pulses. After the modulator the pulse is modulated by a pseudorandom bit sequence of 2^7-1. Before transmission this data stream is passively multiplexed up to 40 Gbit/s and 80 Gbit/s using a fiber interleaver. The transmission fiber includes 50 km conventional SMF and 8.6 km DCF. A 10 GHz optical signal splitted from the EFRL is used as the pump for a wavelength converter made by a balanced NOLM consisting 3 km DSF. The probe for the wavelength converter is provided by an external cavity tunable laser at 1545 nm. The converted signal is then used to open the switching window of the demultiplexing NOLM which is made of 2.5 km DSF.

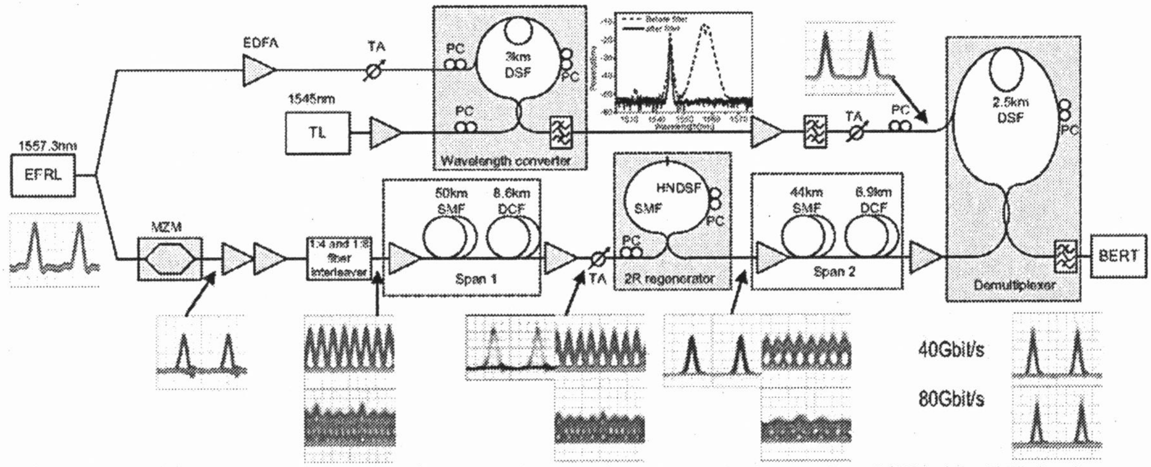

Fig.2 Experimental setup. EFRL: erbium fiber ring laser, PC: polarization controller, MZM: Mach-Zehnder modulator, TA: tunable attenuator, TL: tunable laser.

The transmitted signals are then re-amplified and put into the HN-DILM to be reshaped. The HN-DILM, constructed from a 3dB coupler and 1030 m of SMF and 1 km HN-DSF, acts as a nonlinear filter, transmitting only the part of the pulse having appropriate power and pulse duration. Due to the narrow pulse width, a consideration of peak power and typical nonlinear coefficients indicates that a very low dispersion fiber is needed to generate sufficient nonlinearity for switching. A measurement of the highly nonlinear DSF shows very small dispersion (~ -0.5 ps/nm/km) at the operating wavelength and a high nonlinear coefficient of 10.6 $W^{-1}km^{-1}$. When the signal is absent, the transmission of wideband ASE noise is shown in Fig.3. The polarization controller is used to bias the DILM to maximum reflection of in-band noise.

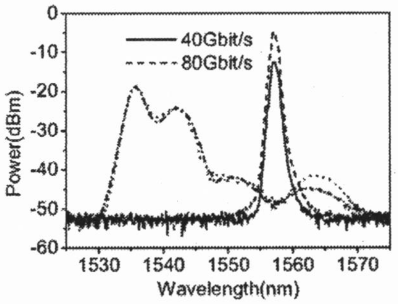

Fig.3 Transmission spectrum behaviour of the HN-DILM for wideband ASE noise and spectral output of 40 Gbit/s and 80 Gbit/s signals before transmission.

The BER performance for back-to-back, transmission and regeneration is shown in Fig.4. The receiver sensitivity at 10 Gbit/s is improved from –31 dBm to –34 dBm by the 2R regenerator after 94 km transmission. The 40 Gbit/s signal gets 0.5 dB improvement due to the regeneration. The 80 Gbit/s, however, has a relatively broad frequency bandwidth after transmission, thus it is difficult to get the whole bandwidth co-polarized simply by adjusting the bias of the polarization controller (see Fig.3); the regeneration is degraded by arbitrary polarization. It can be predicted that the improvement in receiver sensitivity would be larger if polarization maintaining fiber had been used in the loop.

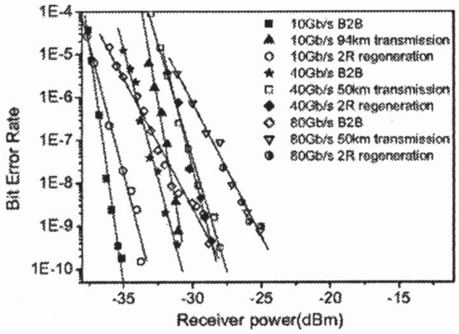

Fig.4 BER performance for back-to-back, transmission and regeneration at 10 Gbit/s, 40 Gbit/s and 80 Gbit/s.

Conclusion

We have investigated and tested a 2R regenerator for 10 Gbit/s, 40 Gbit/s and 80 Gbit/s signals based on an imbalanced NOLM with a novel configuration which has better stability and polarization insensitivity. All-optical all-NOLM-based signal processing up to 80 Gbit/s including wavelength conversion, OTDM demultiplexing, and 2R regeneration is demonstrated after one or two span of fiber transmission.

References

1 S. Bigo, et al, IEEE J. Select. Topics Quantum Electron., Vol.3, No.5, pp.1208-1223, 1997.
2 D. wolfson,et al, IEEE photon. Technol. Lett., Vol.12, No.3, pp.332-334, 2000.
3 B. Boscolo,et al, Eletron. Lett., Vol.37, No.2, pp.112-113, 2001.
4 W. S. Wong, et al, Opt. Lett., Vol.22, No.15, pp. 1150-1152, 1997.
5 J. Smith, et al, J. Opt. Soc. Am. B, Vol.12, No.6, pp.1117-1125, 1995.