SBS Based Slow-Light Performance Comparison of 10-Gb/s NRZ, PSBT and DPSK Signals

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Abstract *We have compared system performance of 10-Gb/s NRZ, PSBT and DPSK signals transmitted in SBS based slow-light. The maximum delay-time have been obtained using DPSK format when directly demodulating DPSK signals using SBS effect.*

Introduction

In recent years, slow-light has attracted extensive interest owing to its potential applications from quantum computing to optical communications, which could enable the implementation of the optical memory or buffer [1]. Among all proposed techniques, slow-light mechanism based on Stimulated Brillouin Scattering (SBS) in optical fibre has achieved much attention [2-6]. The narrow-band SBS gain can be broadened through direct modulation of a pump laser diode using a Gaussian noise source, which makes it feasible to delay the high-speed signals [4-5]. For optical communication system applications, the system performance of 10-Gb/s signals transmitted in slow-light is in important consideration.

In this paper, we demonstrate the delay and system performance of 10-Gb/s signals in SBS based slow-light in terms of non-return-to-zero (NRZ), phase-shaped-binary-transmission (PSBT) and DPSK modulation formats. In the NRZ case, the sensitivity is degraded with the increase of the delay-time due to SBS gain filtering effect and chromatic dispersion accompanied with slow-light. For the PSBT format, the slow-light performance becomes better owing to its high spectral-efficiency and strong dispersion-tolerance [7]. Furthermore, we simultaneously demodulate and delay the DPSK signal using Gaussian-shaped filtering effect by SBS gain [8]. Compared with the 1-bit-delay demodulation case [6], the DPSK slow-light performance has been much improved. The maximal achieved delay-times with error-free operation (BER<10^{-9}) are 35ps, 50ps and 81ps for 10-Gb/s NRZ, PSBT and DPSK signals, respectively.

Experiment description

The signal transmitter consists of a laser diode (LD) operating at 1548.26nm, and a Mach-Zehnder modulator (MZM) driven by a 10-Gb/s pseudo-random bit sequence (PRBS). Based on a 10-Gb/s NRZ transmitter, a 10-Gb/s PBST modulation format can be achieved by filtering the electrical NRZ signal using a 5th order Bessel filter with ~2.7-GHz cut-off frequency [9], and optimizing the bias of the MZM and the electrical driven voltage. The DPSK modulation format is simply obtained by adjusting the MZM bias voltage at zero transmission point. The signal is launched into a 20-km long TrueWave^{TM} (TW) fibre with ~10.75GHz Brillouin frequency shift.

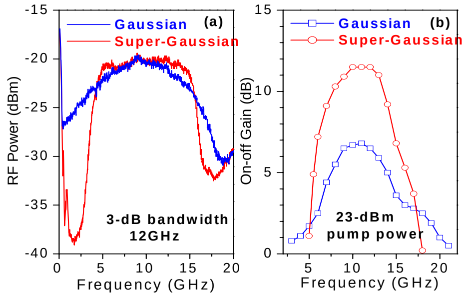

Fig. 1 The SBS pump spectra (a) and corresponding gain spectra (b) in case of Gaussian-noise and super-Gaussian noise modulation of the pump laser

The SBS pump source is a directly modulated LD, whose central wavelength can be precisely controlled by temperature. The pump spectrum is broadened through direct-modulation of the pump LD using a Gaussian noise source (Tektronix AFG3252), and the spectral width is controlled by the peak-to-peak voltage of the electrical noise. We used a high power electrical amplifier to boost the electrical noise. Fig. 1(a) shows typical pump spectra measured by coherent heterodyne technique. When the Gaussian noise is linearly amplified, the corresponding pump spectrum is also with Gaussian-shape. When the Gaussian noise is amplified to saturation regime, the Gaussian-shaped pump spectrum becomes super-Gaussian shape. Note that super-Gaussian-shaped profiles are more suitable for NRZ and PSBT modulation formats. Firstly, the power is mostly distributed at the centre of the pump spectrum, so the SBS gain is higher for the same pump power compared with the Gaussian-shape case, as shown in Fig. 1(b). Secondly, the corresponding SBS gain is like a flat-top filter, which can reduce the filtering distortion in SBS based slow-light. The Gaussian-shaped filter is preferable for direct DPSK demodulation [9]. We propose to use the Gaussian-shaped pump to generate a Gaussian-shaped SBS gain so as to simultaneously demodulate and delay the DPSK signal. We have obtained ~12GHz SBS pump bandwidth, resulting in ~7GHz gain bandwidth for a 22-dBm pump power in NRZ and DPSK cases. For DPSK demodulation and delay, the pump spectral width is set at 8GHz and the corresponding SBS gain bandwidth is about 6.5GHz for 18-dBm pump power.

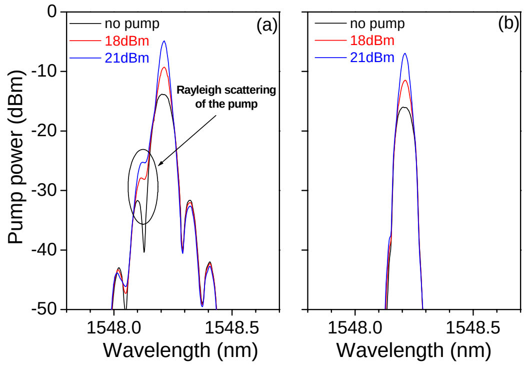

Fig. 2 The optical spectra of 10-Gb/s DPSK signal for different pump power levels. (a) before FBG, (b) after FBG.

In 10-Gb/s SBS based slow-light, coherent crosstalk between the signal and Rayleigh backscattering of the broadband pump is the dominant noise contribution. We set the input signal power at 5dBm, so the Rayleigh backscattered power of the broadband pump is ~20dB lower than the output signal power, as shown in Fig. 2(a), which still induces out-band crosstalk. Therefore we used a ~0.1nm bandwidth flat-top fibre Bragg grating (FBG) to suppress the Rayleigh backscattered noise and minimize the crosstalk, as shown in Fig. 2(b). The FBG also filters the sidebands of the DPSK signal, which accompanies with the SBS gain for DPSK demodulation.

Results and discussion

In this summary, we only present the delay-time measurements of the DPSK signal in Fig. 3. When the pump is turned off, the DPSK signal is mainly distorted by the 0.1-nm flat-top FBG, which is not optimized for DPSK demodulation. When the pump power is increased to 17dBm, resulting in a 7-GHz gain bandwidth, the DPSK signal is demodulated to a duobinary signal, and the corresponding delay-time is 31ps. With the further increase of the pump power, the gain value is enhanced but the bandwidth is decreased, which induce the delay-time increasing and signal degradation. When the pump power is 21dBm, the delay is up to 81ps, but the signal is distorted (i.e. eyes diagram closure).

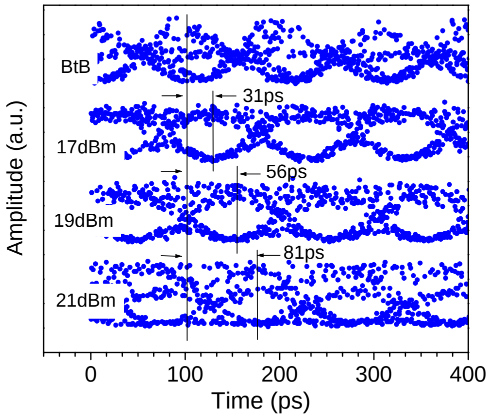

Fig. 3 The delay measurement of the 10-Gb/s DPSK signal at different pump power levels.

Finally, we demonstrate the delay versus with the signal on-off gain and the sensitivity versus the delay of 10-Gb/s NRZ, PSBT and DPSK signals, as shown in Fig. 4. For all the cases, the delay linearly increases with the on-off gain. Compared with NRZ and PSBT signals, the DPSK signal presents larger delay at the same gain owing to the narrower gain bandwidth. For the NRZ case, the sensitivity (BER=10^{-9}) is degraded with the delay due to the SBS gain filtering effect. However, for both PSBT and DPSK signals, the gain bandwidth has an optimum to achieve the best sensitivity. The maximal delay-times with error-free operation (BER< 10^{-9}) are 35ps, 50ps and 81ps for 10-Gb/s NRZ, PSBT and DPSK signals, respectively.

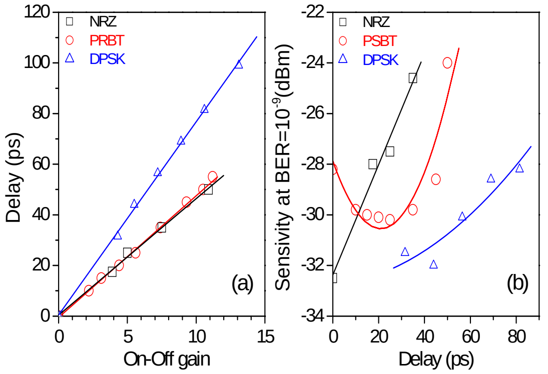

Fig. 4 Delay vs. on-off signal gain (a) and Sensitivity vs. delay for 10-Gb/s NRZ, PSBT and DPSK signals.

Conclusions

In this paper, we demonstrated the delay and system performance of 10-Gb/s NRZ, PSBT and DPSK signals transmitted in broadband SBS based slow-light delay line. The PSBT and DPSK signal has better performance than the NRZ signal owing to their high spectral efficiency and strong dispersion-tolerance. Note that the DPSK demodulation was realized by directly using Gaussian-shaped SBS gain.

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