All-Optical Wavelength Conversion with Extinction Ratio Improvement of 100Gb/s RZ-Signals in Ultralong Bulk SOAs

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Abstract: The potential for all-optical high-speed wavelength conversion with extinction ratio improvement in ultralong bulk SOAs is studied. The simulations show that for 100Gb/s RZ-signals with a PRBS order of 16, no pattern effects are observed.

Keywords: All-optical wavelength conversion, extinction ratio improvement, ultralong semiconductor optical amplifiers, Bogatov effect

1. Introduction

With increasing data rates in optical communication systems and trends towards next generation optical packet switched networks, all-optical high-speed wavelength conversion with regeneration will be an important functionality [1]. Typically, integrated single-path SOA-based solutions are speed-limited to approximately 10Gb/s by the carrier lifetime [2, 3]. In [4] a first attempt was made to use the fast intraband effects of SOAs for high-speed signal wavelength conversion. In order to reduce bit pattern effects, the intraband effects’ chirp in combination with a sharp filter creates short output bits.

In this article, a novel all-optical high-speed wavelength conversion scheme with extinction ratio (ER) improvement is presented. The scheme is a single-path solution and is based on an ultralong SOA (UL-SOA). The wavelength conversion can be either achieved due to Cross-Gain Modulation (XGM) or Four-Wave Mixing (FWM), while the ER improvement is achieved due to a Bogatov-like effect in the UL-SOAs saturated section [5].

2. Concept of Operation

Due to the UL-SOAs length, the main part of the device is deeply saturated. Because of the high optical power in the UL-SOA’s saturated section only the fast intraband effects interact with the signals allowing high-speed signal processing.

Fig.1 illustrates the conceptuel setup for the presented scheme. The beating of the two co-polarised input signals creates dynamical gain and index gratings up to a wavelength detuning of several nanometres. These gratings create FWM products and a Bogatov-like effect, describing the amplification of the weaker probe signal in dependence of the wavelength detuning to the stronger pump signal (Fig.2). Furthermore, the fast intraband effects also modulate the CW signal due to XGM.

As default parameters for the simulation, the following values were used: \( P(\lambda_{\text{Data}})=1\,\text{dBm}, \, \text{ER}_{\text{Data}}=6\,\text{dB}, \, \lambda_{\text{Data}}=1560\,\text{nm}, \, P(\lambda_{\text{CW}})=2.5\,\text{dBm}, \, \lambda_{\text{CW}}=1556\,\text{nm}, \, \text{length}=5\,\text{mm} \) and \( I=300\,\text{mA/mm} \).

Fig. 3 shows the eye diagram of a wavelength converted 100Gb/s RZ50%-OOK signal after passing the UL-SOA and the bandpass filter. The signal’s “1”-level has been amplified by 6dB and the ER increased to 12dB. Since, the wavelength conversion is caused by XGM, the output signal is inversely modulated to the input signal. Similar to
[5], the ER improvement is due to a Bogatov-like effect. In the UL-SOA's saturated section, the data signal becomes the stronger signal (pump) and the CW signal the weaker signal (probe). Fig.2 shows that due to the positive wavelength detuning, the Bogatov-like effect attenuates the CW signal. Furthermore, the efficiency of the Bogatov-like effect is dependent on the pump signals intensity so that due to the inverse modulation, the CW signal states are differently attenuated resulting in an increased ER.

3. Investigation on Bit Pattern Effects

Typically, the speed of SOAs is limited to approximately 10Gb/s due to the slow intraband effects. For this reason, we will investigate in this section if the presented scheme shows bit pattern effects for data rates above 100Gb/s. Due to limited calculation capacity, critical bit sequences are used to estimate the influence of bit pattern effects. These bit sequences consist of various combinations of worst-case bit pattern.

For a 100Gb/s RZ50% constant "1"-bit sequence, the signals modulation frequency is far above the slow carrier lifetime (10ps<<300ps). Hence, the carrier density only experiences the average optical power and no bit pattern effects occur. In order to investigate the dependence of bit pattern effects on the presented scheme, the signal levels' standard deviation in dependence of the PRBS order is plotted (Fig.4). For bit pattern effects, the signal levels' standard deviation would increase with increasing PRBS order because of the accumulating number of the same consecutive bits resulting in lower modulation frequencies closer to the carrier lifetime.

Fig.4 shows that there are no bit pattern effects for the presented scheme and that the trace broadening in Fig.3 can be ascribed to ASE. The reason can be found when the carrier density along the device for minimum and maximum signal levels is investigated (Fig.5). Even in this extreme case, the carrier density's peak only shifts by 1.5% of the device length for a constant "0" and "1"-level. There are two main reasons for the small shift: First, the CW functions as a holding beam and second, due to the data signal's high optical input power in combination with a small

4. Conclusion

Our simulations have demonstrated that even bulk devices have the capability for high-speed all-optical signal processing above the carrier lifetime (>100Gb/s). With the presented scheme for all-optical wavelength conversion with ER improvement, a signal could be converted over 4nm with an ER improvement of 6dB in a 5mm-long highly nonlinear bulk SOA. Moreover, no pattern effects could be observed up to a PRBS order of 16 for a 100Gb/s RZ50% signal.

So far, no true 2R regeneration could be achieved. Due to the Bogatov-like effect, needed for the ER improvement, the converted signal is also attenuated. For this reason, saturation effects are missing which clip the signal levels.

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6. References