Bi-directional four wave mixing in semiconductor amplifiers for mid-span spectral inversion: theory and experiment

Bischoff, Svend; Buxens, Alvaro A.; Poulsen, Henrik Nørskov; Clausen, Anders; Mørk, Jesper

Published in:
Proceedings of CLEO'99

Link to article, DOI:
10.1109/CLEO.1999.834101

Publication date:
1999

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
CTuW2 5:00 pm
Bi-directional four wave mixing in semiconductor amplifiers for midspan spectral inversion: theory and experiment

S. Bischoff, A. Buxens, H.N. Poulsen, A.T. Clausen, J. Mark, Center for Communications, Optics and Materials, The Technical University of Denmark, Building 349, DK-2800 Lyngby, Denmark; E-mail: sbi@mic.tu.dk

Mid Span Spectral Inversion (MSSI) is a powerful technique for compensating fiber dispersion in transmission of high-bit rate optical signals. It has previously been used to successfully model the fast gain dynamics of SOAs. The results for various asymmetries of up- and down-conversion are discussed.

In Fig. 2 we display the calculated eye diagrams for the down- and up-converted signals for 10, 20, 40 and 80 Gbit/s. The difference in FWM efficiency for up- and down-conversion can be balanced by increasing the CW pump power injected together with the 1556 nm signal. This results in almost equal eye diagrams for the up- and down-conversion. The input signal powers are kept equal.

The best eye diagrams (small fluctuations in the transmitted pulse peak power) for increasing bit rates are obtained for an increasing small signal gain from 5 dB at 10 Gbit/s to 7 dB at 80 Gbit/s. This corresponds to a decreasing CW pump power from 7 (8) dBm for down- (up-conversion) at 10 Gbit/s to 5 (6) dBm at 80 Gbit/s. The average signal power is found to be around -7 dBm, except for the 20 Gbit/s where the worst performance was observed at a signal power of -4 dBm.

The FWM efficiency is found to decrease for lower signal peak power. Accordingly, the FWM performance decreases when the bit rate is doubled while the average power is kept fixed. The simulations indicate good performance at 40 Gbit/s, whereas the eyes start to close at 80 Gbit/s.

Residual facet reflections are found to decrease the system performance, since the reflected signals coincide with the co-propagating FWM signal. This results in a significant cross-talk between the two signals. The calculations in Fig. 2 are performed for a reflection coefficient of 10^(-4), for higher values the system performance decreases significantly.

Measured eye-diagrams for the bi-
directional MSSI swapping at 10 and 20 Gbit/s are shown in Fig. 3. The coupled CW pump power in the experiment was 6 to 7 dBm. The coupled signal power was around -6 to -7 dBm. The difference in CW pump power for equal FWM output power for up- and down-conversion was 2-3 dB. These values are in good agreement with the model predictions. In conclusion, large signal simulations of a novel scheme of bi-directional FWM are shown to be in good agreement with experiments and identify critical aspects of the system performance.

2. A. Buxens et al., ECOC'98, 3, 95 (1998).

**CTuW4** 5:15 pm

**Demonstration of four wave mixing in an integrated pump laser and semiconductor optical amplifier for mid-span spectral inversion dispersion compensation**

M.F.C. Stephens, K.A. Williams, R.V. Penty, I.H. White, Department of Electrical and Electronic Engineering, University of Bristol, Queens Building, University Walk, Bristol, United Kingdom BS8 1TR; E-mail: M.F.C.Stephens@bristol.ac.uk

Non-degenerate four wave mixing (NDFWM) has been studied extensively in recent years as both a method for compensating against the dispersion of standard single mode optical fibre via mid-span spectral inversion (MSSI) and as a transparent wavelength conversion mechanism. NDFWM has been reported in many devices, including semiconductor optical amplifiers (SOAs), distributed feedback (DFB) lasers, nonlinear waveguides and optical fibre itself. SOAs are promising devices for NDFWM due to their small size, large gain bandwidth and high speed (>100 Gb/s). However, an external pump laser and EDFA are required which adds both cost and complexity to the system. Recently, an integrated DFB laser and SOA has been reported for wavelength conversion under static conditions. Here, for the first time we believe, the use of a similar device for dynamic MSSI dispersion compensation is demonstrated.

The experimental arrangement is depicted in Fig. 1.

A 10 GHz train of 18 ps pulses is generated by gain-switching a 1555.2 nm DFB laser. These pulses are amplified by an EDFA and injected into a 75 km span of standard fibre. The output of the span is passed via an optical circulator into another EDFA and filter before injection into the DFB laser section of the phase conjugator. A polarisation controller is used to match the polarisation of the incoming signal to that of the DFB pump beam. The DFB pump wavelength is at 1553.6 nm and has a linewidth of ~2 MHz when both it and the SOA are biased at 250 mA. The newly generated phase conjugate signal at 1552 nm is filtered to remove the pump and original signal before being amplified, filtered again and transmitted back over the span. The received signal is analysed after traversing an additional 1 km of standard fibre, which compensates for the dispersion induced by the wavelength difference on the two spans. The pulses are examined using a 32 GHz photodiode and 50 GHz sampling oscilloscope.

The optical spectra produced from the output of the phase conjugator are shown in Fig. 2 before and after filtering. The average injected signal power to the phase conjugator is +3.5 dBm. After filtering it can be seen that the residual peak pump level is over 30 dB lower than the phase conjugate.

The back to back and final received pulses are shown in Figs. (a), (b). It can be seen that there is some degradation of the signal after the 150 km span. In addition, a highly chirped laser is modulated at 2.5 Gb/s and transmitted over the system. The received eye is shown in Fig. (c) with no significant degradation. Without MSSI, the same eye diagram is completely closed (Fig. (d)).

In conclusion, for the first time, an integrated DFB/SOA laser has been shown to operate as an MSSI dispersion compensator via NDFWM with a 10 GHz pulse train and 2.5 Gb/s data. Although the former does show some degradation, it is believed that further optimisation of the device (such as reduced DFB linewidth) will lead to far superior performance. A full bit error rate analysis and results at 10 Gb/s will be presented at the conference.