Analysis of filter-assisted 160 Gb/s wavelength converter using a single semiconductor optical amplifier

Citation for published version (APA):
Li, Z., Molina Vázquez, J., Liu, Y., Tangdiongga, E., Zhang, S., Khoe, G. D., Dorren, H. J. S., & Lenstra, D. (2007). Analysis of filter-assisted 160 Gb/s wavelength converter using a single semiconductor optical amplifier. In *Proceedings of the 2007 Conference on Lasers and Electro-Optics (CLEO 2007) 6 - 11 May 2007, Baltimore, Maryland, USA* (pp. CMG8-1/2). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/CLEO.2007.4452530

DOI:
10.1109/CLEO.2007.4452530

Document status and date:
Published: 01/01/2007

Document Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 04. Oct. 2023

Analysis of filter-assisted 160 Gb/s wavelength converter using a single semiconductor optical amplifier

**Z. Li, J. Molina Vázquez, Y. Liu, E. Tangdiongga, S. Zhang, G.D. Khoe,
H.J.S. Dorren and D. Lenstra**[†]

*Department of Electrical Engineering, Eindhoven University of Technology, P.O.Box 513, 5600
MB Eindhoven,The Netherlands.*
[†] *Department of Electrical Engineering, Mathematics and computer science, Delft University of
Technology, The Netherlands.*
lizhonggui@ieee.org

Abstract: We present for the first time a systematic analysis of the Q-factor and eye opening for wavelength conversion based on a single semiconductor optical amplifier and a detuned filter at 160 Gb/s.

OCIS codes: (070.4340) Nonlinear optical signal processing; (250.5980) Semiconductor optical amplifiers

Extensive research has been dedicated to semiconductor optical amplifier (SOA) based wavelength converters due to their large nonlinearity and integration potential. SOA-based wavelength converters, however, suffer from long carrier lifetime (typically several tens to hundreds of ps), which limits the maximum operating speed of the device. Recently, through combining a detuned optical filter and an delay interferometer, 160 Gb/s and 320 Gb/s non-inverted wavelength conversion have been demonstrated [1, 2]. However, despite the experimental success, little attention has been paid to better understanding of filter-assisted wavelength conversion. For example, the dependence of the output signal quality on the operating conditions remains unclear and deserves investigation. In this paper, we systematically analyze the wavelength converter behaviour. Fig. 1(a) shows a schematic setup of the wavelength converter under investigation. A modulated return-to-zero pump signal and a continuous wave probe are injected into an SOA, followed by an optical bandpass filter (OBF). At the exit of the OBF, both inverted and non-inverted wavelength conversion can be achieved depending on the OBF detuning from the probe wavelength.

The analysis is based on a comprehensive numerical model, which takes into account the inter- and intra-band carrier dynamics in the SOA [3]. To the best of our knowledge, this model is the first to include gain dispersion and group velocity dispersion, while taking into account the intra-band carrier dynamics explicitly. We extended the modified nonlinear Schrödinger equation in [4] to take into account the influence of two photon absorption and free carrier absorption. The model has been applied to simulate the gain recovery dynamics with good agreement with experiments [1]. Fig. 1(b) shows the SOA amplification gain as a function of the input pulse energy for different pulse widths, showing pulse-width dependent saturation energy. The OBF is modeled in the frequency domain and the transfer function of the OBF is assumed to have Gaussian amplitude and linear phase[5] In the simulations the full-width at half maximum bandwidth of the OBF is 200 GHz.

Fig. 2 shows the Q-factor as a function of the OBF detuning and typical eye diagrams for different OBF detuning are also presented. One can see that the output signal from the OBF is inverted when the detuning is small (in this case, -200 GHz to 280 GHz) and the output becomes non-inverted for larger detuning. One can also see that the eye diagram is almost closed when the filter is not detuned [Fig.2 (a)]. This is due to the slow gain recovery of the SOA, resulting in strong pattern effects. One can also notice that for the inverted signal, the Q-factor dependence on the OBF detuning is asymmetric. This asymmetry is caused by non-zero linewidth enhancement factor induced asymmetric chirp for the probe signal at the output of the SOA.

It is interesting to investigate the dependence of the output signal quality on the operating conditions. For non-inverted wavelength conversion, the dependences of the maximum Q-factor and the maximum eye opening on the pump pulse energy, probe power, linewidth enhancement factor and injection current are plotted in Fig.3. The maximum Q-factor and eye opening are obtained by tuning the filter center frequency while keeping the bandwidth the same. As shown in Fig. 3(a), the Q-factor drops continuously from > 30 dB to < 10 dB with increasing pump pulse energy from 2 fJ to 1 pJ.

©OSA 1-55752-834-9

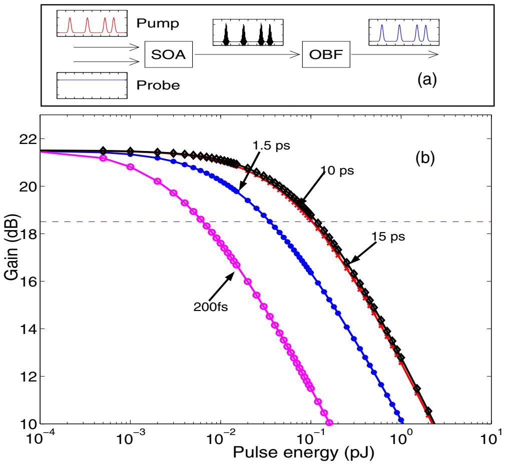


Fig 1: (a)The system setup. (b) (Colour Online) Gain saturation characteristics for different pulse width: 200fs (magenta circles); 1.5 ps (blue dots); 10 ps(red crosses); 15 ps(black diamonds).

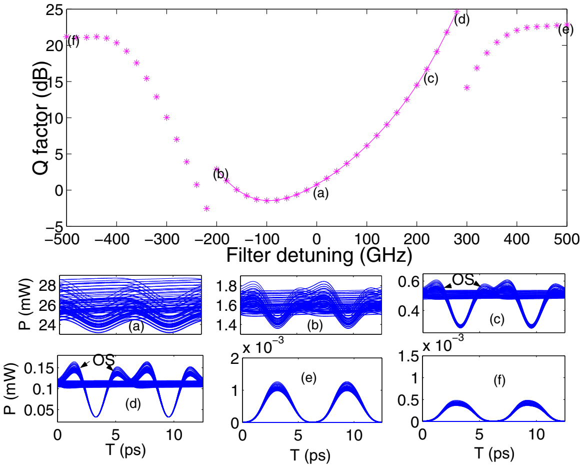
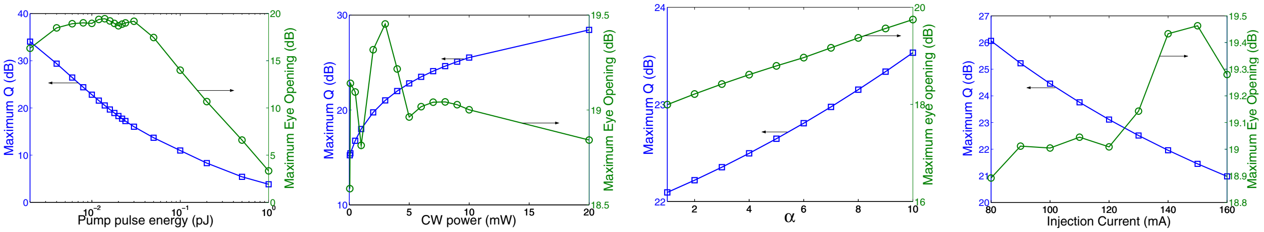


Fig 2: (Color online) The dependence of the maximum Q-factor (blue squares) and the maximum eyeopening (green circles) for non-inverted output on the pump pulse energy.

The maximum eye opening has a maximum value for a pump pulse energy around 10 fJ. Although the Q-factor is larger for small pump pulse energy, the eye opening becomes too small for too weak pump pulses and this smallest eye opening is limited by the ASE noise, which is not treated in our analysis. It can be seen from Fig. 3(b) that the maximum eye opening reaches a peak value when the probe power is around 3 mW while the maximum Q-factor increases logarithmically with increasing probe power. Larger linewidth enhancement factor leads to larger maximum Q-factor and maximum eye opening, as is shown in Fig. 3(c), although it is also seen that the improvement due to larger α is small (<0.8 dB for Q-factor and about 2.3 dB for eye opening). Fig. 3(d) shows the dependence on the injection current. While larger current leads to larger maximum eye opening, the Q-factor decreases due to larger nonlinear pattern effect [6].



(a) (b) (c) (d)

Fig 3: (Colour Online) The dependence of the maximum Q-factor (blue squares) and the maximum eyeopening (green circles) for non-inverted wavelength conversion on (a) pump pulse energy (b) probe power (c) the linewidth enhancement factor and (d) injection current.

Inverted and non-inverted wavelength conversion at 160 Gb/s based on an SOA and a Gaussian OBF are numerically investigated for the first time. Q factor higher than 24 dB eye opening of about 20 dB can be achieved through OBF detuning. The Q-factor dependence on the OBF detuning is asymmetric for inverted output. Similar Q-factors can be obtained for both detuning to higher and lower frequenciesa than the probe. Larger linewidth enhancement factors, larger CW power, lower current and lower pump pulse energy lead to a higher Q-factor. Hence, one can tune these parameters to optimize the wavelength conversion and, therefore, the output signal's quality.

References

1. Y. Liu, E. Tangdiongga, Z. Li et al., IEEE/OSA J. Lightwave Technol. **24**, 230-236 (2006).
2. Y. Liu, E. Tangdiongga, Z. Li et al., OFC2006, PDP28(2006).
3. X. Yang, D. Lenstra, G.D. Khoe and H.J.S. Dorren, Opt. commun.,**23**, 169-179 (2003).
4. N. Das, Y. Yamayohshi and K. Kuwakuchi, IEEE J. Quant. Electron.,**36**, 1184-1192 (2000).
5. J. Molina Vazquez, Z. Li, Y. Liu et al, IEEE J. Quant. Electron.,**in press**, (2006).
6. M.L. Nielsen and J. Mørk, JOSAB,**21**,1606-1619 (2004).