Analysis of Label Extraction with Semiconductor Optical Amplifier for Optical Networks*

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Abstract In this paper, a novel scheme of header extraction for optical packet networks using only a semiconductor optical amplifier is proposed. Numerical analysis and simulation show, that more than 13 dB contrast ratio of the separated header at 2.5 Gb/s to the suppressed payload at 40 Gb/s could be achieved. In addition, the SOA parameters are discussed and designed to optimize the performance of the proposed scheme.

Keywords Semiconductor optical amplifier; Optical label; Manchester code; Optical networks

CLCN TN929.11 **Document Code** A

0 Introduction

In future high-performance optical network, optical data packets will require rapid routing at all-optical switch nodes. In order to accomplish high-throughput switching, the headers must be extracted and processed quickly. Recently, several header processing schemes, including bit-serial solution[1,2], subcarrier multiplexing[3,4] and orthogonal modulation[5~7] have been proposed and demonstrated. However, the bit-serial solution was utilized in most slotted optical packet-switched networks and in few unslotted optical network. In addition, the subcarrier-multiplexing scheme, requiring ultrafast components to accommodate the header, may increase the facility complexity; for orthogonal modulation, such as ASK/ DPSK scheme[7], transparent wavelength conversion must be considered to maintain the phase information, so the system complexity and the cost will rise.

To improve the header processing performance, a method based on two-pulse correlation principle in semiconductor laser amplifier in loop optical mirror (SLALOM) configuration is proposed in[2]. In this scheme, the beginning of each header is marked with a special hexadecimal, i.e. 'F00F0' or 'F000F'. It does not require optical clock recovery and thus reduces the complexity of the header recognition system. However, since each extracted header has only two pulses and may not include enough information of packet, it is not convenient to update this solution for future optical digital processing.

In this paper, a simple compact approach to extract the optical header from the optical packet is proposed, which is bit-serial coding, viz. optical header at the front of the payload. The header in this scheme is multiple pulse-coded at a lower bit-rate; in contrast, the payload is Manchester encoded at a higher bit-rate, so as to keep the SOAs in saturation state when the packet payload passes. Through numerical analysis and properly design of the parameters of the SOAs, the optimized performance of the proposed scheme is obtained and the results shows that more than 13 dB contrast ratio of the separated header at 2.5 Gb/s to the suppressed payload at 40 Gb/s will be achieved.

1 Operational principle

As shown in Fig. 1, an input optical packet signal pulses, via a coupler C1 with splitting ratio 95/5, splits into two different components that propagate clockwise (CW) and counterclockwise (CCW). The larger one viz. the CW signal, as control pulses, is reintroduced into the SOA with an appropriate time t acting as driving SOA in saturation. Simultaneously, the smaller one viz. CCW signal, as probe pulses, will undergo the gain controlled by the CW signal. The optical-header with long interval between two pulses will acquire considerable gain for the saturated SOA gain has recovered much more, while the succedent payload and with short interval and higher rate will be suppressed owing to the small saturated gain. Therefore, the output signal is only the amplified

*This study is supported by National Natural Science Foundation Project of China (No. 60372100), "863" High Technology Research and Development Program of China (No. 2003AA122530) and Doctoral Science and Research Foundation of Chinese Universities (No. 20030013004)
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Received date: 2004-11-12

optical-header.

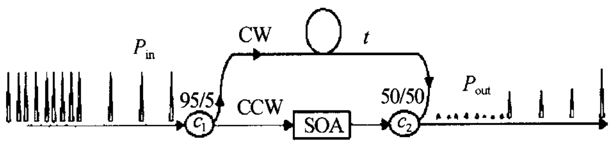

Fig. 1 Scheme of header extraction

Investigated the header extraction scheme by numerical simulation, and defined the intensity contrast ratio as the minimum peak power of the header to the maximum that of the suppressed payload.

Several keys to desirable performance of the header extraction have to be mentioned: 1) The first bit of a header has to be "1" to indicate the exact beginning of a packet; 2) The pulse should be of short width and strong energy so as to induce fast and deep gain saturation in SOA; 3) To guarantee a full gain recovery between two successive packets, a guard-time between successive packets larger than carrier lifetime is needed. The analysis of SOA dynamic characteristics has been carried in[8~14].

Considering the length effect of SOA[13,14], the function of signal gain $G(t)$ and $h(t)$ can be expressed approximately as follows

$$\frac{\mathrm{d}h(t)}{\mathrm{d}t}=\frac{1}{1+\varepsilon\exp\left[h(t)\right]P(t)}\{\frac{h_0-h(t)}{\tau_c}-\varepsilon\left[\exp\left[h(t)\right]-1\right]\frac{\mathrm{d}P(t)}{\mathrm{d}t}-\left[\exp\left[p(t)\right]-1\right]\cdot P(t)(\frac{\varepsilon}{\tau_c}+\frac{1}{E_{sat}})\} \quad (1)$$

$$G(t)=\exp\left[\frac{1}{L}\int_{-L/2}^{L/2}h(t-2z/\nu_{SOA})\mathrm{d}z\right] \quad (2)$$

Where the small signal gain $G_0=\exp(h_0)$, $P(t)$ is the signal optical power, ε is the nonlinear gain compression factor, τ_c is the carrier lifetime, E_{sat} is the gain saturation energy of SOA, L is the SOA length, $n_{SOA}=c/n_{SOA}$ is the velocity in SOA, i. e. the ratio of the light velocity to the SOA refractive index.

The parameters used in the paper are: the pulse shape is Gaussian's, wavelength λ_s is 1550 nm, ε is 0.31 W^{-1}, E_{sat} is 3.8 pJ, G_0 is 25 dB, pulsewidth is 2.0 ps, input pulse energy is 2.0 pJ, delay time t is 6 ps and the header rate is 2.5 Gb/s while payload rate is 40 Gb/s.

2 Results and discussion

The numerical simulating results can be seen in Fig. 2, the intensity contrast ratio of more than 13dB can be achieved by utilizing the scheme.

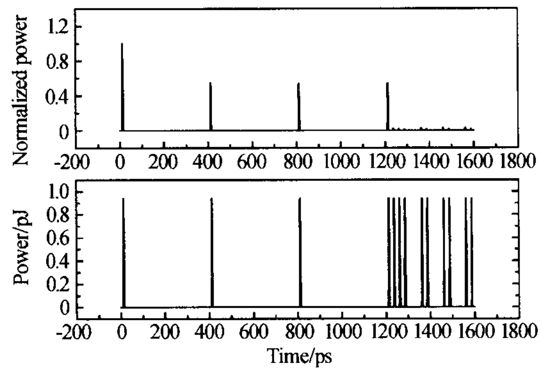

Fig. 2 Extracted optical packet header pulse (upper) and the input packet (lower)

Fig. 3. shows the intensity contrast ratio as a function of the input pulse energy. Apparently, increasing the input pulse energy can improve the intensity contrast ratio of the extracted header; low gain saturation energy of SOA is beneficial to have a good intensity ratio.

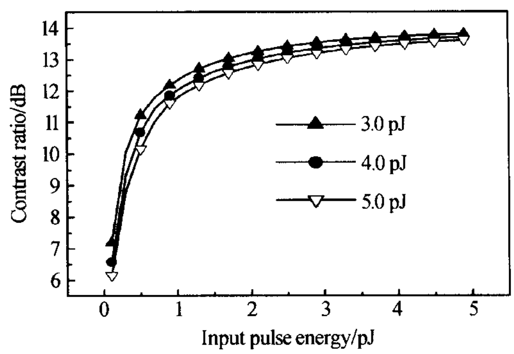

Fig. 3 Intensity contrast ratio against input energy

Fig. 4 illustrates the dependence of the intensity contrast ratio on carrier lifetime. It conveys that a large carrier lifetime is favorable to get high intensity contrast ratio. However when carrier lifetime exceeds 200 ps, the intensity contrast with increasing carrier lifetime begins to decline, for the much larger carrier lifetime will not only suppress the payload pulses but also suppress the header pulses, so proper carrier lifetime should be optimized to acquire preferable performance.

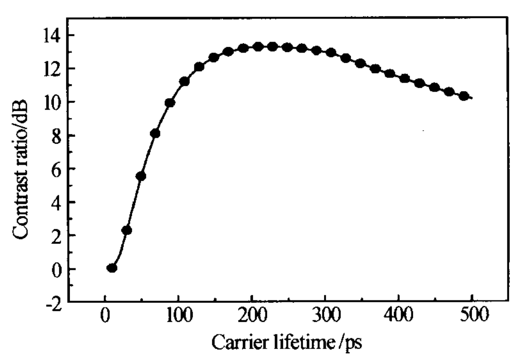

Fig. 4 Intensity contrast ratio against carrier lifetime

3 Conclusion

A novel compact header extraction scheme for high optical packet networks has been proposed. This scheme provides some advantages. It reduces the complexity of the header extraction operation, and can be extended to networks with slotted or unslotted packet length. The advantages also include low-power consumption, low latency, low cost, high stability and potential integration ability with other semiconductor optoelectronics devices.

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基于半导体光放大器进行光标签提取的性能分析

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收稿日期：2004-11-12

摘　要　利用半导体光放大器增益饱和数学模型，第一次分析了基于单个半导体放大器进行光标签提取的节点性能. 通过对半导体光放大器的参量分析和优化，仿真显示，对于标签速率 2.5 Gb/s、净荷速率 40 Gb/s 的光分组包，提取的标签消光比可达到 13 dB.

关键词　半导体光放大器；光标签；曼彻斯特编码；光网络

Niu Changliu was born in Henan province, China, in 1967. He received his B. Sc. degree in Department of Physics from University of Science & Technology of China in 1990 and entered the Department of Mathematics & Physics of Henan University of Science & Technology as an Assistant Professor. In 2000, He entered the Optical Communication Center of Beijing University of Posts & Telecommunication for his M. Sc degree. Currently he is pursuing his Ph. D. degree in Optical Communication Center of Beijing Univ. of Posts & Telecomm. His research interests include Optical packet switching, optical burst switching, optical label switching, high-speed optical signal processing, and transparent optical networks.