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High-Performance Semiconductor Optical Preamplifier Receiver at 10 Gb/s

B. Mikkelsen, C. G. Jorgensen, N. Jensen, T. Durhuus, K. E. Stubkjaer, P. Doussiere, and B. Fernier

***Abstract*—A semiconductor optical preamplifier receiver for bitrates of 10 Gb / s is described. The measured sensitivity is −28 dBm, with a polarization sensitivity of less than 0.5 dB. Using the same transmitter and receiver configuration but with an 980-nm pumped fiber amplifier instead of the semiconductor amplifier, the sensitivity is −34 dBm.**

I. Introduction

SEMICONDUCTOR optical preamplifiers are expected to be key components of future high-speed optoelectronic integrated circuit (OEIC) receivers because of the gain–bandwidth limitations of avalanche photodiodes (APD's). In particular, the recent progress in semiconductor optical amplifiers (SOA's) in terms of small polarization sensitivity and small gain ripple [1], [2] have led to an increased interest in the SOA preamplifier. In addition, a receiver comprising a SOA and an optical filter can function as a highly efficient demultiplexer in a wavelength division multiplexing (WDM) system [3], [4].

In this letter a 10 Gb/s polarization-independent SOA-preamplifier receiver is described. A sensitivity of −28 dBm at a bit error rate (BER) of 10^{-9} is measured. This is more than 4 dB better than previously reported 10 Gb/s SOA- preamplifier experiments [5].

II. Experimental Setup

Our receiver and transmitter configurations are shown schematically in Fig. 1. The receiver consists of a SOA, a tunable optical filter, and a wide-band 50-Ω front end followed by an electronic amplifier with a bandwidth of 6.8 GHz. The optical amplifier is a modified double-channel planar buried heterostructure (MDCPBH) based on a two-step epitaxial growth process [1]. The mode profile at each end of the amplifier is expanded by a taper section in order to increase the coupling efficiency to optical fibers. The taper section is formed by reducing gradually the width of the waveguide from 0.7 μm to zero over a distance of 30 μm. Furthermore, as the taper section stops approximately 30 μm from the facets, a window section is formed to decrease the modal reflectivity. The measured coupling efficiency to tapered fibers at both the input and output is −3.75 dB, and facet reflectivities of less than 10^{-4} for AR-coated facets are obtained. In addition, the cross section of the active region is almost square (0.7 × 0.3 μm), resulting in a polarization-independent gain ($\Delta G < 0.5$ dB). The fiber-to-fiber gain (G_{f-f}) is approximately 18 dB at the gain peak wavelength of 1530 nm for a bias current of 70–80 mA. To reduce the spontaneous–spontaneous beat noise from the SOA, an optical fiber Fabry–Perot filter with a bandwidth of 1 nm is used. Furthermore, to minimize the influence of the back reflections from the optical filter an isolator is inserted between the SOA and the filter. The total loss through the filter and the isolator is about 3.5 dB.

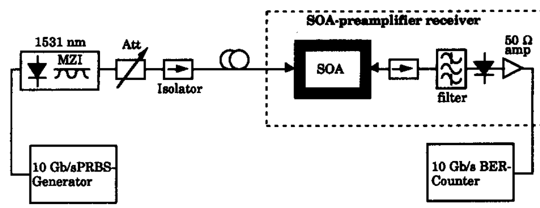

Fig. 1. Schematic of experimental setup.

The 10 Gb/s transmitter consists of a frequency-modulated MQW DFB laser followed by a fiber Mach–Zehnder Interferometer (MZI) for FM/IM conversion. With this technique, an extinction ratio of better than 10 dB is obtained with a drive voltage of only 1.2 V_{p-p}. The transmitter wavelength is 1531 nm, and the output power after the MZI is approximately −3 dBm; the excess loss through the MZI is ~ 0.5 dB.

III. Results and Discussion

The measured BER performance at 10 Gb/s with and without the preamplifier is shown in Fig. 2 for $2^7 - 1$ pseudo-random bit sequences (the word length of $2^7 - 1$ is chosen because of a low-frequency cutoff in the electronic amplifier at the receiver). Sensitivities of −27 and −28 dBm at a BER of 10^{-9} are obtained for bias currents of 66 mA (G_{f-f} = 17.5 dB) and 80 mA (G_{f-f} = 18.5 dB), respectively. The polarization dependency of the sensitivity is less than 0.5 dB. The measured sensitivity of

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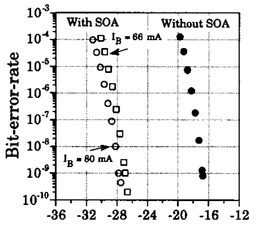

Fig. 2. Measured BER versus received power with and without SOA preamplifier. Bias current to the amplifier is a parameter.

−16.8 dBm without the preamplifier shows that the use of SOA preamplifiers improves the sensitivity by more than 11 dB corresponding to, e.g., an extra fiber span of 55 km. It should be emphasized that the sensitivities for both receivers are measured in the input fiber, so they can be directly compared to each other.

Further improvements in the SOA-preamplifier performance are likely, since 1) the progress in optimization of tapered waveguides [1] as well as new fiber-taper designs [6] are expected to improve the coupling efficiency between fiber and SOA, 2) the measured noise figure (NF) of 7.5 dB can be reduced to approximately 4 dB by the use of QW amplifiers [2], [7], [8], 3) a reduction of the optical filter bandwidth so it nearly equals the signal bandwidth reduces the influence of spontaneous–spontaneous beat noise, and 4) an increase of the effective gain will lead to a further reduction of the influence of the thermal noise. As seen from the eye diagram in Fig. 3, the noise in received marks and spaces is almost identical, which means that the thermal noise still makes a significant contribution to the overall receiver noise.

The sensitivity improvement that can be expected for a given progress in the SOA parameters discussed above is illustrated in Fig. 4. The calculated BER curves are derived from a model similar to that reported in [9]. Two calculated curves are shown: 1) with parameters identical to those in the experiments (NF = 7.5 dB, $G_{f-f} = 18.5$ dB, input/output coupling efficiency = −3.75 dB, filter bandwidth = 1 nm, filter and isolator losses = 3.5 dB, detector responsivity = 0.6 A/W, thermal noise = 25 pA/$\sqrt{\text{Hz}}$); and 2) with improved SOA parameters (NF = 4 dB, $G_{f-f} = 24$ dB, input/output coupling efficiency = −2 dB). As seen, a receiver sensitivity of approximately −33 dBm can be expected with improved SOA parameters. Also shown in the figure are the measured BER for the same preamplifier configuration but with an erbium-doped fiber amplifier (EDFA) instead of the SOA, resulting in a realistic comparison between the two types of preamplifiers. The EDFA has a gain of 30 dB and an effective NF of 4 dB. It is worth noticing that the difference in measured sensitivity between the EDFA and the SOA-based receiver is only 6 dB.

The SOA-preamplifier configuration also offers the possibility for demultiplexing WDM channels without reducing the sensitivity for each received channel. Performing the same demultiplexing with a nonamplified receiver (e.g., an APD receiver) will reduce the receiver sensitivity

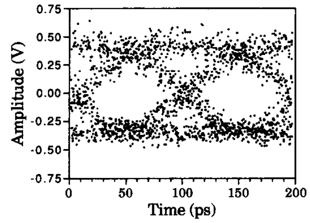

Fig. 3. Eye diagram after preamplifier receiver at BER = 10^{-9}.

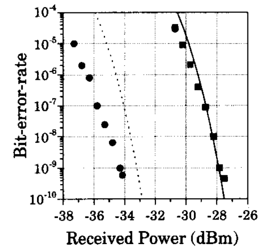

Fig. 4. Measured and calculated preamplifier sensitivities for SOA preamplifier: Measured (■) and calculated (——) with actual SOA parameters: Calculated with improved SOA parameters: (– – – –). Measured sensitivity with EDFA: (●).

with the insertion loss of the optical filter. Thus, an integrated receiver comprising a semiconductor optical amplifier, an optical filter, and a pin diode is expected to become a key component for high-speed and high-performance OEIC receivers in future WDM systems.

IV. Conclusion

A polarization-independent SOA-preamplifier receiver for bitrates of 10 Gb/s has been described. The measured sensitivity is −28 dBm at a BER of 10^{-9}. This is 4 dB better than any previously reported sensitivity for 10 Gb/s SOA-preamplifier receivers.

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