2013 18th OptoElectronics and Communications Conference held jointly with 2013 International Conference on Photonics in Switching (OECC/PS)

TuPO-4

All-optical, low-power 2R regeneration of 10Gb/s NRZ signals using a III-V on SOI microdisk laser

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Abstract
We demonstrate an all-optical low-power 2R regenerator of 10Gb/s NRZ data based on a 10-µm diameter microdisk laser, heterogeneously integrated onto silicon-on-insulator and processed in a CMOS pilot-line. The scheme works for sub-milliWatt input signals.

I. Introduction

Optical point-to-point wavelength-division-multiplexed (WDM) network links were able to fulfill the bandwidth capacity requirements for new internet-based services in the past. However, due to the increasing demand, the logical next step in optical network evolution will be to implement the routing and switching in the optical domain. A major concern is the accumulation of noise, which severely limits the cascadability of optical network nodes. Different techniques have been proposed for 2R regeneration such as devices based on interferometers [1] and self-phase modulation [2], [3]. Also, a broadband optical 2R regenerator based on a single distributed feedback laser has been demonstrated [4].

In this paper, we present the use of a microdisk laser as a 2R regenerator for 10Gb/s non-return-to-zero (NRZ) signals. The regenerator only requires 6mW of operational power, which makes the scheme simpler and more power efficient than opto-electronic regeneration, which typically requires several watts.

II. Device Design and Integration Technology

The light generated in the microdisk laser is coupled to an underlying waveguide through an evanescent coupling scheme. The microdisk laser consists of a 493 nm thin disk cavity on top of a 95 nm thin InP bottom contact layer. The active layers consist of three compressively strained InAsP quantum wells and are surrounded by an n-doped layer on the bottom and a p-doped layer on the top to form the diode structure. A tunnel junction is implemented on the p-side such that an n-type contact layer can be used instead of a heavily doped p-type contact layer, which would cause significant optical absorption. The tunnel junction also ensures uniform current injection over the disk.

The heterogeneous integration in the CMOS pilot-line is achieved by bonding a 2-inch InP epitaxial wafer to a SOI wafer, using molecular bonding. The 200-mm patterned SOI wafer is planarized by depositing SiO_2 followed by chemical-mechanical polishing (CMP). The unprocessed III-V wafer, which is coated with a thin layer of SiO_2, is bonded top side down on the patterned SOI wafer by means of molecular bonding. After the bonding process the InP substrate is removed down to an etch stop layer by mechanical grinding followed by chemical etching, so that only the desired epitaxial structure remains. The standard III-V processing steps comply with a 200-mm wafer scale CMOS environment. In particular, 248-nm DUV lithography is used to accurately define the structures. All etching, oxide isolation layer deposition and metallization steps are performed at 200-mm wafer scale. Two dry etching steps are needed, one to define the disk cavity and another one to make the disk laser bottom contact area. SiO_2 is deposited as cladding layer and a CMP step is performed to planarize the surface. To be able to contact the devices, all vias are etched in a single step where the III-V materials are used as an etch stop. The standard Ti/Pt/Au contacts cannot be used as gold is not allowed in a CMOS environment. Therefore a CMOS compatible Ti/TiN/AlCu metal stack is used, and demonstrates very good specific contact resistances [5].

III. Static Lasing Performance

The microdisk laser considered here has a diameter of 10µm, and light couples to one underlying waveguide. The light-current (L-I) characteristic of the microdisk laser, measured at the two ends of the SOI waveguide, is depicted in Fig.1. This measurement was undertaken under continuous wave operation at room temperature.

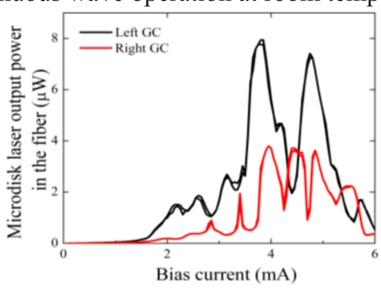

Figure 1 : L–I curves for the two competing modes (CW and CCW) of a 10µm-diameter microdisk laser.

When the threshold current of 1.6mA is surpassed, a bidirectional regime is observed. The clockwise and the counter clockwise modes are equally present in this bidirectional regime. Between 2.3mA and 2.9mA, the reflection feedback from the grating coupler and/or the fiber facet causes a small periodic oscillating regime. The unidirectional, bistable operation starts at 2.9mA. The maximum measured optical output power in the fiber is 8µW. Fig. 2 shows the output power spectrum of the biased microdisk laser (4.0mA) and illustrates lasing at 1561.60nm.

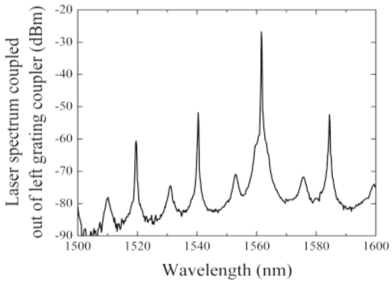

Figure 2 : Lasing spectrum for the CWmode at a bias of 4.0mA.

IV. Regenerator Concept and Demonstration

For the experiment, light from a tunable laser source at 1561.60nm is sent through a modulator, which is driven by a 10Gb/s pulse pattern generator (PPG). The PPG generates a pseudo-random bit-sequence (PRBS) of 2^{31}-1 bits. We use polarization controlling wheels after the laser source as the modulator only works in TE mode. The original signal is being attenuated, amplified using an erbium-doped fiber amplifier (EDFA), and filtered with a 3nm optical band-pass filter to decrease the optical signal-to-noise ratio. The resulting degraded signal has an input power of 3.5dBm, and is injected with an optical fiber under a 10º angle into the waveguide through the left grating coupler. Light coupling out of the right grating coupler is collected in an optical fiber under a 10º angle. Because the grating couplers give a coupling efficiency of ~30% between the SOI waveguide and the access fibers, amplification was needed from an EDFA to increase the signal power. This was implemented in combination with an optical band-pass filter (bandwidth of 0.75nm) to remove amplified spontaneous emission.

Fig. 3 depicts the eye diagrams in two configurations. Fig. 3(a) is the recorded eye diagram of the bit pattern transmitted in the waveguide at the wavelength of 1556nm, when the microdisk laser is unbiased. Light is then simply transmitted in the waveguide without coupling to the microdisk cavity. The efficiency of the grating couplers is also good at this wavelength of 1556nm. Fig. 3(b) is the recorded eye diagram of the bit pattern transmitted in the waveguide at the wavelength of 1561.60nm when the microdisk laser is biased under 4mA. The microdisk is lasing in the direction of the injected degraded signal when the latter is one. But it is lasing in the opposite direction when the injected degraded signal is zero.

We demonstrate an improvement in the eye extinction ratio. The extracted Q factor of the transmitted signal is 2.73, while the extracted Q factor of the regenerated signal is 3.12.

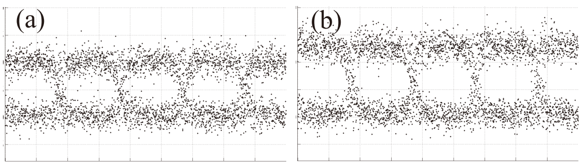

Figure 3 : Q-factor improvement between the eye diagram of the transmitted signal in the waveguide (a) and the eye diagram of the signal transmitted at the lasing wavelength of the microdisk when it is lasing (b) ; (timescale : 48ps/div).

BER diagrams can be measured by sweeping an attenuator at the input of a pre-amplified receiver. The transmitted signal is the modulated signal injected in the waveguide at a different wavelength than the lasing wavelength of the microdisk, when the microdisk is unbiased. The regenerated signal is the modulated signal that is transmitted in the waveguide at the lasing wavelength of the microdisk, when the microdisk is biased and lasing. The degraded signal refers to the original modulated signal just sent through an EDFA and an optical band-pass filter (3nm). It can clearly be seen on Fig. 4 that the BER of the regenerated signal is improved by an order of magnitude compared to that of the transmitted signal.

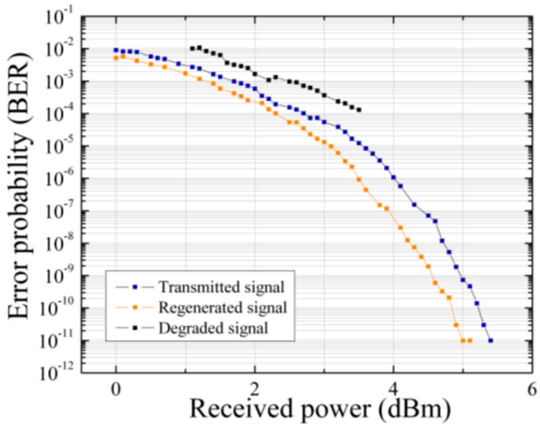

Figure 4 : BER as a function of the received optical power for the degraded signal, the transmitted signal, and the regenerated signal.

V. Conclusions and Outlook

In this paper we have demonstrated regeneration of 10Gb/s NRZ signals based on a heterogeneously integrated III-V on Si microdisk laser processed in a CMOS pilot-line, with low power consumption and operating on low signal powers. Faster operation of the device will be tested in the near future.

Acknowledgment

The authors acknowledge the support of the FP7-EU projects WADIMOS and HISTORIC. The work of T. Spuesens is supported by the Institute for the Promotion of Innovation through Science and Technology (IWT) under a specialization grant.

References

[1] D. Wolfson, A. Kloch, T. Fjelde, C. Janz, B. Dagens, and M. Renaud, “40-Gb/s all-optical wavelength conversion, regeneration, and demultiplexing in an soa-based all-active mach-zehnder interferometer,” IEEE Photon. Technol. Lett., 12(3), p. 332-334, 2000.

[2] P. V.Mamyshev and T. E. T. E. Telefon Espana, “All-optical data regeneration based on self-phase modulation effect,” in 24th European Conference Optical Communication Telefonica Espana Sa, p. 475-476, 1998.

[3] M. Rochette, L. B. Fu, V. Ta’eed, D. J. Moss, and B. J. Eggleton, “2R optical regeneration: An all-optical solution forBERimprovement,” IEEE J. Sel. Topics Quantum Electron., 12(4), p. 736–744, 2006.

[4] K. Huybrechts, T. Tanemura, K. Takeda, Y. Nakano, R. Baets, G. Morthier, “All-optical 2R regeneration using the hysteresis in a distributed feedback laser diode”, IEEE Journal in Quantum Electronics, 16(5), p 1434-1439, 2010.

[5] T. Spuesens, F. Mandorlo, P. Rojo-Romeo, P. Regreny, N. Olivier, J.M. Fedeli, D. Van Thourhout, “Compact integration of optical sources and detectors on SOI for optical interconnects fabricated in a 200 mm CMOS pilot line”, Journal of Lightwave Technology, 30(11), p.1764-1770, 2012.