All-optical de-multiplexing using III-V/SOI microdisk resonators

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Silicon-on-insulator technology has emerged as a promising platform for the fabrication of ultra-compact passive optical devices. But due to the indirect band gap of silicon and germanium, active photonic functionalities cannot be realized with the satisfactory performance on pure silicon or germanium-on-silicon platform, at least in the foreseeable future. To overcome this limitation, the use of III-V material integrated on top of SOI has been very widely used to realize active functionalities such as hybrid silicon lasers[1], all-optical flip-flops[2], and wavelength conversion[3] etc. Since the use of III-V-on-silicon has become necessary for the realization of fully functional photonic chips, it is also necessary that other advanced functions such as time domain de-multiplexing and logic gates etc. are implemented using the III-V-on-silicon platform. Electric-bias free implementation of optical functionalities relaxes the need of electrical pins and wires required on a chip. Although many all-optical functions can be implemented in pure silicon, the two photon absorption generated free-carrier effects in silicon [4] are slow as compared to free carrier effects in III-V materials[5]. Moreover, two-photon absorption and four wave mixing effects are energy inefficient.

Recently, we have demonstrated bias-free all-optical wavelength conversion in a 7.5 micron diameter III-V-on- silicon microdisk[6]. Application of such devices is being investigated for other bias free all-optical functions. Here, we report the time domain de-multiplexing using 10Gbits/s non-return-to-zero (NRZ) data controlled by a 5GHz clock.

To fabricate the microdisk resonators III-V material (InP/InGaAsP) is bonded on top of an SOI waveguide circuit using a molecular bonding process and the complete fabrication run is done in a 200 mm CMOS pilot line. Details about the fabrication process can be found elsewhere[7-8]. The microdisk used here has a diameter of 7.5micron while the underlying silicon waveguide has a thickness and width of 220 and 580nm respectively ensuring that the waveguide is single mode in the telecom wavelength band. The bonding layer thickness between the microdisk and the silicon waveguide is 130nm. The silicon waveguide rests on the buried oxide (silica) layer of 2 micron depth.

The transmission characteristic of the microdisk resonator around one resonance can be controlled by the use of a pump tuned around another resonance. The de-multiplexing experiment reported here is based on the same effect. The data signal is essentially a probe while the clock signal is a pump. The schematic of the experimental set-up is shown in figure 1.

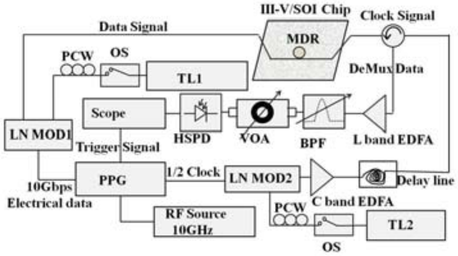

Fig. 1- Schematic of experimental set-up. OS : optical Switch, PCW : Polarization Controlling Wheels, MDR : Microdisk Resonator.

A 10Gbits/s NRZ optical data signal of the pattern 0011001100…..is generated using a pulse pattern generator (PPG), a first electro-optic LiNbO3 modulator (LN MOD1) and a first tunable laser (TL1) tuned around a longer wavelength (1580.9nm) resonance of the microdisk. An optical clock signal having a repetition rate of 5 GHz is generated using a second tunable laser (TL2) tuned around a shorter wavelength (1550.1nm) resonance, second electro-optic LiNbO3 modulator (LN MOD2) and the electric clock from the PPG. An optical delay line is used for the synchronization of the optical clock with the optical data signal. A circulator is used to collect the de-multiplexed data and an EDFA is used to amplify the de-multiplexed data. A band pass filter is used to suppress the ASE noise generated from the EDFA. A variable optical attenuator (VOA) is used to control the input power

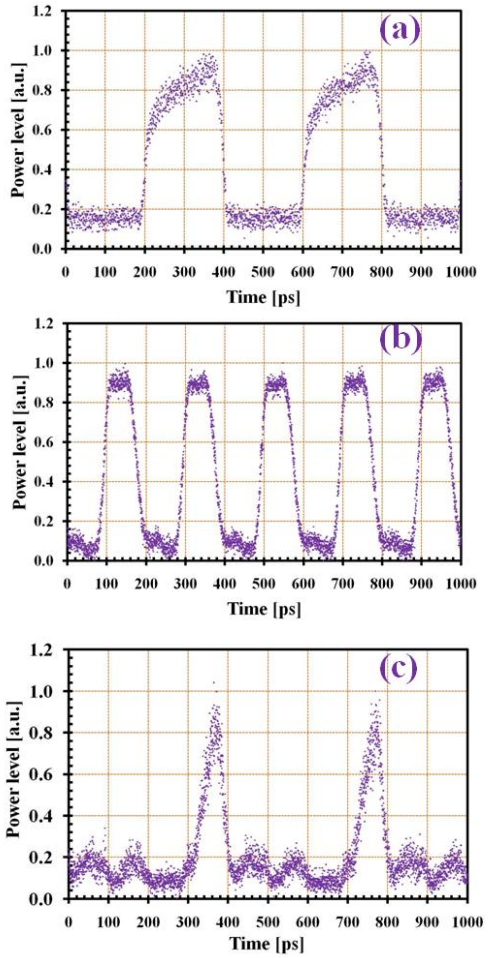

Fig. 2- Waveform of (a) input data, (b) clock and (c) output data

to the high-speed photodiode (HSPD) connected to the scope. The waveform of the optical data signal is shown in Figure 2(a) while 2(b) shows the waveform of the optical clock signal. When the optical data signal is off the resonance, it does not couple into the microdisk and just passes to the through-port. When it is on-resonance then it couples into the microdisk and the same is true for the optical clock signal.

To de-multiplex the optical data signal, the wavelength of the data signal is tuned to the longer resonance wavelength while the wavelength of the clock signal is tuned to the shorter resonance wavelength. In the absence of the clock signal, the data signal remains coupled into the microdisk and a low dc power level is seen on the scope. In the presence of the clock, the resonance of the microdisk shifts, because of the plasma-dispersion effect due to generated free carriers, causing the data signal to go out of resonance and the de-multiplexed data are seen on the scope for the duration of the clock pulses. Figure 2 (c) shows the de-multiplexed output. Comparing the figure 2(a), (b) and (c); it is clear that in the de-multiplexed data, the output is high only for the duration when the level of the clock as well as input data is high.

In conclusion we have demonstrated all-optical de-multiplexing of 10Gbits/s NRZ data controlled by an optical clock of 5GHz.

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References

1 D. Lang, and J. Bowers, Nat. Phot. **4**, 511 (2010).
2 L. Liu, R. Kumar, K. Huybrechts, T. Spuesens, G. Roelkens, E.-J. Geluk, T. de Vries, P. Regreny, D. Van Thourhout, R. Baets, and G. Morthier, Nat. Phot. **4**, 182 (2010).
3 O. Raz, L. Liu, R. Kumar, G. Morthier, D. Van Thourhout, P. Regreny, P. Rojo-Romeo, T. De Vries, H. J. S. Dorren, OFC NFOEC paper **OMQ5** (2010).
4 S. F. Preble, Q. Xu, B. S. Schmidt, and M.Lipson, Opt. Lett. **30**, 2891 (2005).
5 V. Van, T. A. Ibrahim, P. P. Absil, F. G. Johnson, R. Grover, and P.-T. Ho, IEEE J. Select. Top. Quantum Electron. **8**, 705 (2002).
6 R. Kumar, T. Spuesens, P. Mechet, P. Kumar, O. Raz, N. Olivier, J.-M. Fedeli, G. Roelkens, R. Baets Baets, D. Van Thourhout, and G. Morthier, Opt. Lett. **36**, 2450 **(**2011).
7 T. Spuesens, D. Van Thourhout, P. Rojo-Romeo, P. Regreny, and J.-M. Fedeli, accepted for publication in Group IV photonics (2011).
8 M. Kostrzewa, L. Di Cioccio, J. M. Fedeli, M. Zussy, P.Regreny, J. C. Roussin, and N. Kernevez, EMPC (2005).