Proof-of-concept Demonstration of an All-Optical De-multiplexer Using III-V/SOI Microdisk Resonator Fabricated in a CMOS Pilot Line

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Abstract— **We present a proof-of-concept demonstration of all-optical de-multiplexing of a non-return-to zero 10Gbps data controlled by 2.5GHz clock in an ultra-small III-V-on-silicon microdisk fabricated in a CMOS pilot line.**

Index Terms— **Microdisk resonator, All-optical de-multiplexing , III-V on-silicon technology**

I. INTRODUCTION

ALL-OPTICAL solutions for the various types of on-chip functionalities are vital for reducing the pin counts of ICs as the demand for high density and high data rate continues to grow over time [1]. The realization of all-optical functions on a chip requires the control of light with light [2]. In the past decade silicon emerged as an ideal material, due to its compatibility with CMOS fabrication processes, for the control of light with the light along with many other applications such as electro-optic modulation [3] and logic functions [4] at GHz frequencies. The indirect bandgap of Si however limits its versatility and makes it very difficult to implement active functions such as lasing, amplification or functions making use of lasing and amplification. Although there have been remarkable attempts to achieve lasing in silicon, e.g. [5], the performance of such lasers has not reached an acceptable level for advanced optical functionalities. In addition, the intrinsic slow dynamics of free carriers in silicon raises questions about its application in next generation switching and routing devices.

Taking note of the points highlighted above the combination of III-V as a host material and silicon as a waveguiding medium is the most promising way for future

ultra-high speed and compact photonic integrated circuits. We have demonstrated all-optical flip-flops [6] and gates [7] in InP-InGaAsP microdisks heterogeneously integrated on to SOI waveguide circuits using the DVS-BCB (divinylsiloxane–benzocyclobutene) polymer as a bonding layer. Recently we have demonstrated bias-free all-optical wavelength conversion [8] in an InP-InGaAsP microdisk bonded on top of an SOI waveguide circuit using molecular bonding and completely processed in a CMOS pilot line. Here, we present the proof-of-concept demonstration of an all-optical de-multiplexer using the same microdisk.
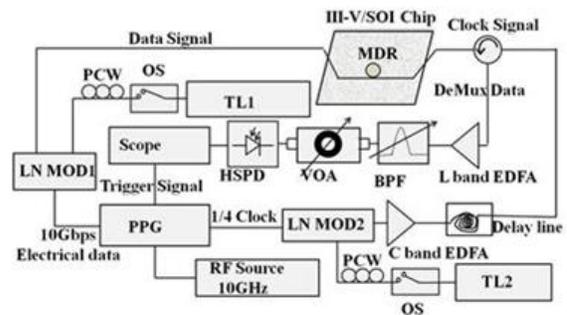

Fig.1: Schematic of experimental set-up. MDR: Microdisk Resonator, OS: Optical Switch, PCW: Polarization Controlling Wheels

II. DEVICE DESIGN AND DE-MULTIPLEXING EXPERIMENT

The diameter of the III-V microdisk is 7.5 µm and the total stack layer thickness is 580nm. An SOI waveguide with thickness of 220nm and width of 600nm lies beneath the microdisk. The bonding layer (silica) between microdisk and SOI waveguide is ~ 130nm thick. More details on the device design and the fabrication process can be found in references [9] and [10] respectively.

Measurements are carried out in a pump-probe configuration as described in references [7-8]. Figure 1 shows the schematic of the experimental set-up. A 10Gbps non-return to zero

optical data signal of alternate zeroes and ones 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 2.5GHz 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.
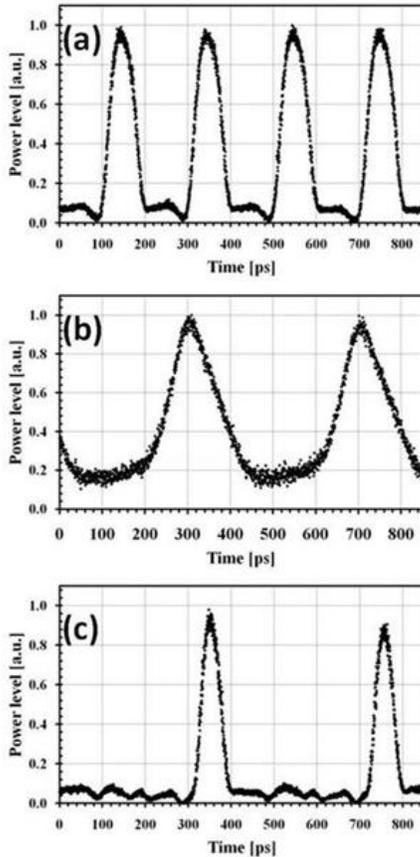

Fig. 2: . Waveform of (a) Optical data signal
(b) Optical Clock signal and (c) De-multiplexed data

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 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 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 figures 2(a) and 2(c), it can be seen that the logic 1 levels which are originally separated by 200 ps become separated by 400ps after de-multiplexing illustrating the feasibility of using microdisks in all-optical time domain de-multiplexers. Since this microdisk resonator has rise and fall time of 18.6 and 26.4 ps respectively, all-optical de-multiplexing of data rates beyond 20Gbps is possible. Further experiments are underway for different data patterns and different clock frequencies.

III. CONCLUSIONS

We have demonstrated a proof-of-concept all-optical de-multiplexing in a microdisk resonator of 7.5µm diameter using 10Gbps NRZ data and a clock frequency of 2.5GHz. Realization of bias-free all-optical functions including demultiplexing in small size devices has the potential of reducing the number of electric pins in high density photonic networks on a chip.

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