10Gbps bias-free all-optical wavelength conversion using InP-microdisk resonators heterogeneously integrated onto SOI

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Abstract: Using InP-based microdisk lasers heterogeneously integrated onto silicon passive waveguide circuits, we demonstrate all-optical wavelength conversion of 10Gbps NRZ PRBS signals without requiring any bias or extra seeding beam. The experimental results also indicate that bitrates of 20 or 25Gbps should be achievable.
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1. Introduction

Microdisk lasers heterogeneously integrated onto SOI waveguide circuits are very promising devices as they can be at the basis of more complex multifunctional photonic integrated circuits (PICs) in the silicon photonics platform. Such complex PICs could be used in a variety of all-optical switching and optical interconnect applications and find their way in high performance computers or optical network nodes.

Basic active building blocks required for the fabrication of such PICs are all-optical flip-flops, all-optical gates and all-optical wavelength converters. All-optical flip-flops with very low power consumption have been described in the reference [1]. All-optical gating and wavelength conversion, which are both based on the same principles, have previously also been demonstrated but either with low extinction ratio and negative bias (as in [2]) or with the microdisks used as lasers and thus with dc power consumption [3].

In this paper, we show for the first time that bias free all-optical wavelength conversion can be achieved in a 7.5 μm diameter microdisk. Wavelength conversion between the two resonance wavelengths is obtained for 10Gbps NRZ signals without any bias or seeding beam and thus without any dc power consumption. We demonstrate a high extinction ratio of over 10dB at this bitrate and the required average optical pump power is 1.5mW. First experiments were also done at 20 Gbps and wavelength conversion was obtained for a sequence of alternate 0's and 1's. More results for a 20 Gbps PRBS data sequence will be shown at the conference.

2. Microdisk lasers and their static characteristics

The microdisks are fabricated using fully CMOS compatible technology where the III-V stack is molecularly bonded on top of the SOI waveguide circuit and microdisks are defined by deep ultra-violet (DUV) lithography. Full description about the fabrication will be reported elsewhere [4]. Light is coupled to and from the SOI waveguide using surface grating couplers. Coupling between the straight SOI waveguide and the III-V microdisk resonator is based on evanescent coupling. The devices did not undergo any special treatment, like ion implantation, to reduce carrier lifetimes.

The transmission spectrum at the output is given in Figure 1. Two resonances can be distinguished, corresponding to two azimuthal modes separated by an FSR of 30.8nm, one around 1550.1 nm and another around 1580.9 nm. A higher ER ratio is seen at the longer wavelength resonance since it lies closer to the band gap of the active material of the microdisk and has less absorption as compared to that of the shorter wavelength resonance. Measurements of the influence of the power on the ER are carried out to identify the critical coupling around 1580.9nm and near critical coupling occurs when -4.25 dBm power of CW light is present in the SOI waveguide. By fitting the transmittance past the resonator the coupling coefficient from SOI waveguide to disk is found to be ~6 %.

3. 10 Gbps all-optical wavelength conversion

Wavelength conversion is based on a pump-probe configuration, with the pump injected at the shorter resonance wavelength and the probe injected at the longer resonance wavelength. The injected pump power is absorbed in the quantum wells of the unbiased InP microdisk resonators, which leads to carrier generation, a wavelength shift of the resonances and thus a modified transmission at the probe wavelength.

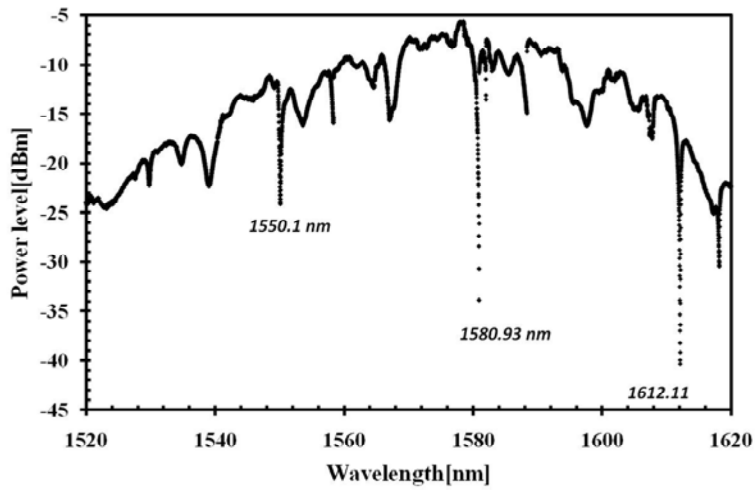

Figure 1: Static transmission characteristic for a 7.5 μm diameter microdisk resonator.

The set-up used for the wavelength conversion is given in Figure 2. The probe signal is generated from a first tunable laser (TL1), tuned at the short wavelength resonance. Electrical PRBS data at the speed of 10Gbps generated from the PPG driven by an RF source at 10GHz are converted into optical PRBS data using an electro-optic LiNbO3 Mach-Zehnder Modulator and a CW optical signal from another tunable laser (TL2) tuned at the shorter wavelength resonance. In this way, the generated optical PRBS control signal has an ER of 14 dB and a pulse duration of 85 ps (FWHM) for a logic one. A bandpass filter (BPF) with a FWHM of 1.2nm is used to suppress the ASE from the EDFA. The Wide Band Band Pass Filter (WBBPF) is used to suppress the back reflection of the control signal from fiber facets and grating couplers. Figure 3 shows the time trace and the eye diagram of the wavelength converted signal, which has an extinction ratio of 12 dB. The rise and fall times in the eye diagram of around 50 ps are partly due to the rise and fall times of the 10 Gbps PPG and modulator. Measurements with a short pulse source give rise and fall times of 18.6ps and 26.4 ps respectively. These numbers indicate that 20 Gbps operation should also be possible.

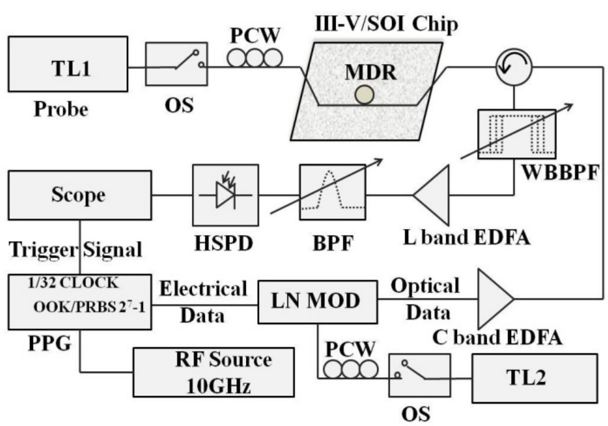

Figure 2: scheme of the experimental set-up used for 10Gbps wavelength conversion.

4. 20 Gbps all-optical wavelength conversion

First experiments were also done to test wavelength conversion at 20 Gbps. Using an alternate series of zeroes and ones, we also obtained wavelength conversion. The time trace of the output is shown in Figure 4. An extinction ratio of 14dB is obtained for an input extinction ratio of 10dB. However, one can also see some patterning effects. Wavelength conversion of a 20Gbps PRBS sequence will be reported at the conference.

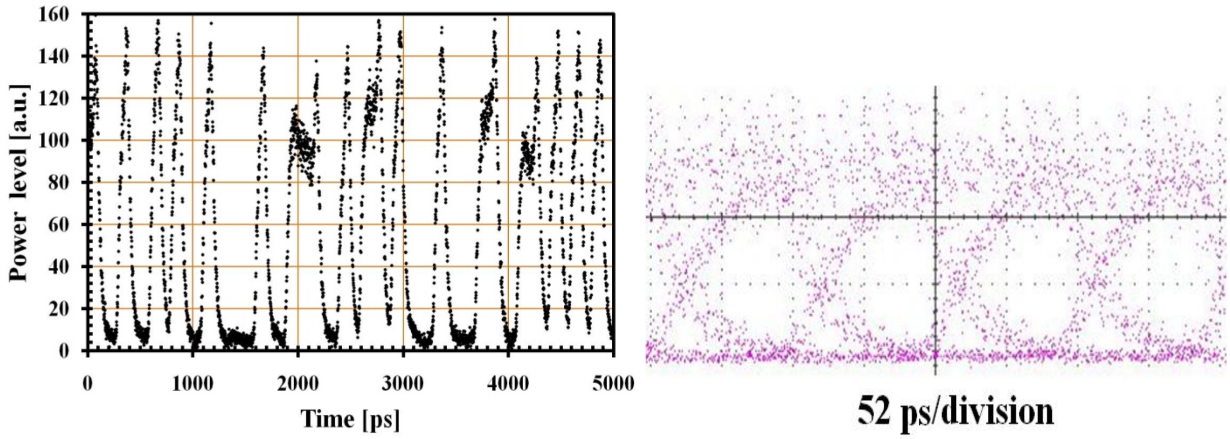

Figure 3: Time trace (lhs) and eye diagram (rhs) of the 10Gbps wavelength converted signal.

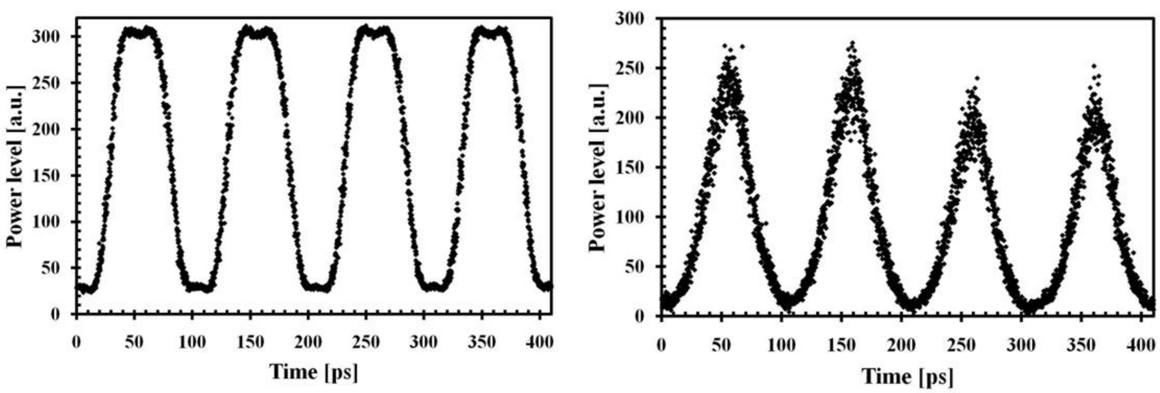

Figure 4: Time trace of a 20 Gbps wavelength converted 010101 sequence, input (lhs) and output signal (rhs)

5. Conclusion

We have demonstrated bias free all-optical wavelength conversion at the speed of 10Gbps for a NRZ-OOK PRBS data signal in a small size microdisk resonator fabricated with fully CMOS compatible III-V/SOI fabrication technology. Together with the earlier demonstration of such microdisk lasers as all-optical flip-flops, this demonstration paves the way for the realization of high speed multifunctional photonic integrated circuits based on InP microdisks heterogeneously integrated onto SOI passive optical circuits.

6. References

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