シリコンの非線形キャリア分散効果を用いた全光シリアルパラレル変換

All-optical serial-to-parallel conversion by nonlinear carrier-dispersion effects in silicon

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1. Introduction

Optical label recognition schemes [1] and photonic random-access memories [2] have been given as possible solutions to the problems of increased power consumption and foreseeable saturation of processing speed of electronic circuits found in data centers, due to the increase in handling data in the digital world. Both the aforementioned examples rely on the principle of serial-to-parallel conversion (SPC), the existing approaches to which involve using devices such as polarizing beam splitters [3], making the overall system bulkier. Hence, the objective of the current study is to fabricate a monolithic SPC device that fits on a single silicon chip based on nonlinear optical effects (NLOEs) in silicon. Here, we focus on free carrier dispersion (FCD) of Si, which can be effective even with relatively low peak power of pump light as long as it has a certain pulse width. In this work, optical Kerr effect and two-photon absorption (TPA) are eluded by leaving out a delay between the probe and pump signals.

2. Principle of operation and design

The proposed setup for the discussed SPC uses cascaded Mach-Zehnder interferometers (MZIs), a probe signal consisting of original serial data and a simultaneous pump signal, as shown in Fig. 1. Without the pump pulse, the probe signals transmit to the cross port. When the pump pulse induces a refractive index change by NLOEs only in one MZI arm, the probe signal is extracted from the bar port (*E* and *F*) temporarily. The setup is adjusted so that each probe pulse is positioned exactly at *A* and *B* when the simultaneous pump signal is implemented.

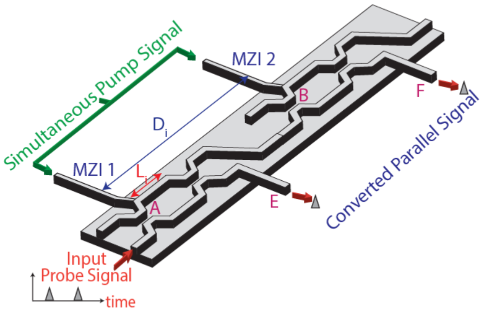

Fig. 1. Proposed setup of SPC with Si MZIs.

Cross arms (length L_i) are configured so that a certain pulse transmitting along each can gain an extra phase difference of $\pm\pi$ at each MZI as a result of the exerted pump signal, thereby enabling the proposed SPC to be implemented.

We have to treat pump and probe signals differently to achieve asymmetric phase modulation in an MZI. Since TE-polarized light is known to be hesitant to couple, compared to TM-polarized light, the proposed SPC device uses TE mode for the pump signal, and TM mode for the probe signal. The couplers are designed such that TM mode is split in the ratio 1:1 between the bar and cross arms, at the same time staying immune to TE mode coupling.

3. Experiment

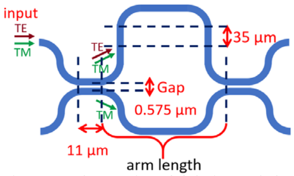

Fig. 2. Schematic of fabricated device.

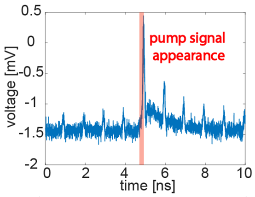

Fig. 3. Measurement result.

To verify the effect of NLOEs, an MZI with an unbalance of 70 μm between the arms was fabricated as shown in Fig. 2.

Next, pump-probe measurements were carried out on this device using a 1 Gbps RZ probe signal pulse train of pulse width 100 ps and wavelength 1563 nm. Moreover, a pump signal of wavelength 1545 nm and pulse width 200 ps having a period of 100 ns was used. The peak power of the pump pulse at the input waveguide was estimated to be 1.0 W. Both signals were input as shown in Fig. 2, and the cross output was measured. Only probe light was extracted by a band-pass filter. The measured result is shown in Fig. 3. The hatched region in Fig. 3 corresponds to the duration a pulse of the pump signal is present. When this is the case, amplitudes of the probe pulses increase, due to underwent negative change in refractive index. The probe pulse with the maximum amplitude corresponds to the pulse that underwent a phase change. Hence, with respect to this certain pulse, it can be stated that it has undergone SPC.

Acknowledgement

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References

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