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41.6 Gb/s RZ-DPSK to NRZ-DPSK Format Conversion in a Microring Resonator

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Abstract

RZ-DPSK to NRZ-DPSK format conversion in a silicon microring resonator is demonstrated experimentally for the first time at 41.6 Gb/s. The converted signal eye diagrams and bit-error-rate measurements show the good performance of the scheme.

I. INTRODUCTION

All optical format conversion of return-to-zero (RZ) to non return-to-zero (NRZ) signals is a desired function to interface different parts of a future ubiquitous transparent optical network. Many schemes for on-off keying (OOK) conversion using active [1] or passive [2-4] operations have been demonstrated in the past years. Differential phase shift keying (DPSK) has received special attention over the past decade due to its improved receiver sensitivity with balanced detection and superior transmission properties. Recently, single [5] and multi-channel [6] RZ-DPSK to NRZ-DPSK conversion have been demonstrated using a delay interferometer (DI) with half bit delay. Such devices may however be bulky.

Recently, silicon photonics has received increased interest due to its compact size and compatibility with microelectronics fabrication processes. Silicon microring resonators are versatile ultra-compact devices enabling the implementation of numerous functionalities. In this paper, we propose and demonstrate for the first time a novel scheme for RZ-DPSK to NRZ-DPSK format conversion with little power penalty at 41.6 Gb/s based on a well optimized silicon microring resonator (MRR).

II. OPERATION PRINCIPLE

The principle of the format conversion is the linear filtering process at the through port of the MRR. By suppressing spectral components using a MRR with free spectral range (FSR) equal to twice the signal bit rate, RZ-DPSK can be converted to NRZ-DPSK, at the expense of some amplitude ripple, as shown in Fig. 1(c). The ripple can be efficiently reduced thanks to an additional optical bandpass filter (OBPF). The method

has already been successfully demonstrated for RZ-OOK to NRZ-OOK conversion [4]. However, its use for DPSK format conversion has never been reported so far.

The amplitude ripple of the converted NRZ-DPSK and the Q value of the demodulated signal depend on the power coupling coefficient of the MRR and the 3-dB bandwidth of the OBPF, as shown in Fig. 1(a) and (b). For good conversion performance, low ripple and high Q values are required. Those quantities have been simulated as a function of the MRR power coupling coefficient for a fixed OBPF bandwidth of 125 GHz. As can be seen in Fig. 1(e), when the power coupling coefficient increases, the ripple decreases while the Q value becomes larger. An MRR with power coupling coefficient of 0.9 results in a ripple lower than 0.5 and Q value higher than 30.

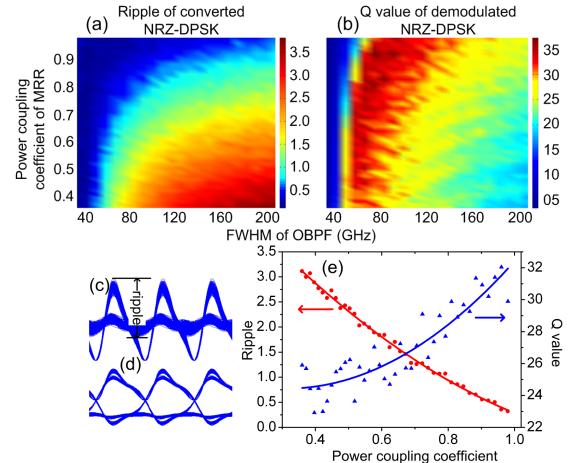


Fig. 1. (a) Amplitude ripple of the converted NRZ-DPSK and (b) Q value of the demodulated signal versus MRR power coupling and OBPF 3-dB bandwidth at 41.6 Gb/s. Eye diagrams of (c) converted NRZ-DPSK and (d) demodulated signal after balanced detection. (e) Ripple and Q value versus MRR power coupling coefficient for 1 nm OBPF.

III. DEVICE FABRICATION AND EXPERIMENTAL RESULTS

The MRR was fabricated on a SOI wafer with top silicon thickness of 250 nm and buried silica of 3 μm . Fig. 2(a) to (c) show the structure of the device. The radius of the MRR is 147 μm with waveguide width of 470 nm and coupling gap of 100 nm. To decrease the device insertion loss, a silicon nano taper, depicted in Fig. 2(c), was adopted. Fig. 2(d) shows the measured transmission spectrum of the MRR. Low insertion loss of

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8 dB is achieved with an FSR of 83 GHz and an extinction ratio (ER) of 25 dB, which corresponds to a power coupling coefficient of 0.9, as designed.

Fig. 3 shows the experimental setup for format conversion. Continuous wave light at 1549.35 nm is modulated by two Mach-Zehnder modulators to generate a 33% RZ-DPSK signal at 41.6 Gb/s. The pseudorandom binary sequence (PRBS) length is $2^{31}-1$. The signal is then amplified by an EDFA. Before being injected into the MRR, the polarization of the signal is adjusted to the TM mode with a polarization controller. The converted NRZ-DPSK signal after the MRR is filtered by an OBPF with 3-dB bandwidth of 1 nm and finally detected by balanced detection in a preamplified receiver.

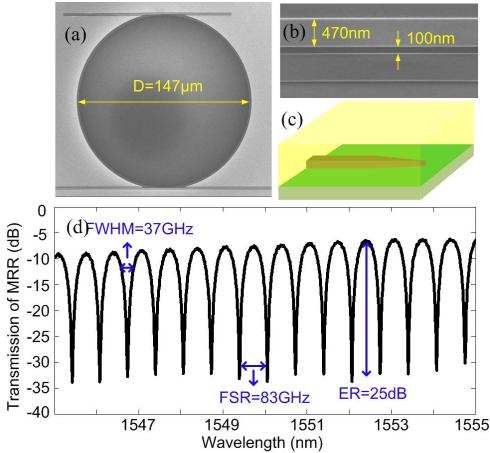


Fig. 2. Scanning electron microscope (SEM) pictures of (a) top view and (b) coupling region of the MRR. (c) Silicon nano taper. (d) Measured transmission spectrum at the through port of the MRR.

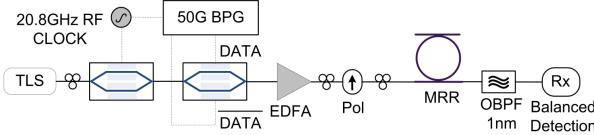


Fig. 3. Experimental setup for RZ-DPSK to NRZ-DPSK conversion.

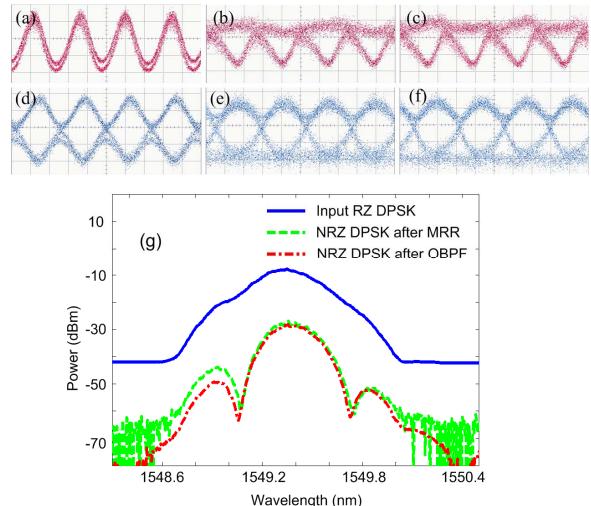


Fig. 4. Measured eye diagram of (a) input RZ-DPSK, (b) converted NRZ-DPSK after MRR, (c) converted NRZ-DPSK after OBPF and (d) to (f) their corresponding demodulated signals for balanced detection. (g) Spectra of the input RZ-DPSK, NRZ-DPSK after MRR and NRZ-DPSK after OBPF (resolution bandwidth: 0.2 nm).

Fig. 4(a) to (c) show the eye diagrams of the input RZ-DPSK, converted NRZ-DPSK after MRR and converted NRZ-DPSK after OBPF. The corresponding spectra and demodulated signals after balanced detection are also shown in Fig. 4(d) to (g). Since the bandwidth of the OBPF is relatively wide, the spectrum of the converted signal after the OBPF is not significantly modified compared with the one after MRR. However, thanks to the high MRR power coupling coefficient, low ripple in the converted NRZ-DPSK and high Q value of the demodulated signal are obtained, as expected. Fig. 5 shows the BER measurements for format conversion. There is little power penalty during the conversion process.

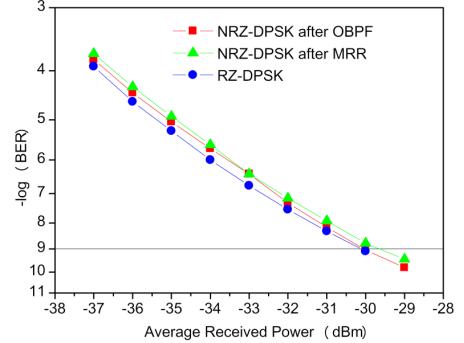


Fig. 5. BER measurements for input RZ-DPSK, converted NRZ-DPSK after MRR and converted NRZ-DPSK after OBPF.

IV. CONCLUSIONS

RZ-DPSK to NRZ-DPSK format conversion at 41.6 Gb/s has been demonstrated for the first time based on a well optimized custom-made silicon microring resonator. Little power penalty compared with the input RZ-DPSK signal is achieved in the BER measurements.

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