10-Gbps All-Optical Phase Shift Keying in SiC Micro-Ring

Chih-Hsien Cheng(1), Atsushi Matsumoto(1), Naokatsu Yamamoto(1), Gong-Ru Lin(2), and Kouichi Akahane(1)
(1) National Institute of Information and Communications Technology, Koganei, Tokyo 184-8795, Japan, e-mail: chcheng@nict.go.jp
(2) Graduate Institute of Photonics and Optoelectronics, and Department of Electrical Engineering, National Taiwan University, Taipei 10617, Taiwan

The high-speed and broad-linewidth devices have been developed over decades for the next-generation communication. Silicon photonic is one of solutions to study and achieve this goal due to its mature semiconductor processing. For the optical integrated circuits, the silicon photonic can suppress the cost and provide the better device performance. To enhance the nonlinear Kerr effect, the silicon carbide (SiC) is considered as a candidate for applying to all-optical modulation because of its larger nonlinear refractive index than silicon oxide (SiOx) and SiNx materials [1-3]. In general phase modulator, the material refractive index induced phase difference is generated by an electro-optical effect or nonlinear optical effect, which need a long propagation length in waveguide to induce. To shorten the active length, the micro-ring resonator is one of methods to replace the straight waveguide. In addition, the micro-ring resonator can amplify the pumping intensity to increase the nonlinear Kerr effect, which further enhances the phase difference. In this work, the SiC micro-ring phase modulator is demonstrated by using the nonlinear Kerr effect to induce phase-shift-keying (PSK) data processing. In addition, the effect of the micro-ring resonator for the phase modulations is also discussed and demonstrated.

In this work, the 10-Gbps all-optical phase shift keying (PSK) in C-rich SiC micro-ring resonator is demonstrated. Based on the transmission spectrum of the C-rich SiC micro-ring, the propagating loss, the effective group index, the radius of micro-ring, the coupling ratio and the linewidth of transmission comb are obtained as 4.5×10^{-5} cm^{-1}, 1.86, 150 μm, 0.072 and 0.15 nm, respectively. In addition, the quality factor (Q-factor), the magnification factor and the mode extinction ratio (MER) of the micro-ring resonator are attained as 11000, 1.32 and 6.9 dB, respectively. The phase (ϕ) of the CW probe passing through the micro-ring resonator can be represented as $\phi=2\pi nL/\lambda$ with the refractive index (n) of the C-rich SiCO, the length (L) of the micro-ring resonator, and the probe wavelength (λ). The phase variation before and after passing through the micro-ring resonator is related to the refractive index change and different probe wavelength. Under the intensive pumping, the refractive index in micro-ring resonator is increased by the nonlinear Kerr effect to enlarge the effective optical path length in micro-ring resonator. The phase difference of probe light under the pumping intensity of 6×10^{7} W/cm^{2} can be obtained as 0.09 rad. The PSK data stream of 11010010001 carried by the optical pump is wavelength converted to modulate the optical probe through the micro-ring resonator. The rising and falling time of the data after conversion are slightly broadened to 56 and 63 ps, respectively. With PSK-to-ASK demodulation after receiving, the analyzed eye-diagram shows SNR of >6 dB, ER of >12 dB and BER of $<2\times10^{-5}$.

1. C.-H. Cheng, *et al.*, "Strong optical nonlinearity of the nonstoichiometric silicon carbide," *J. Mater. Chem. C*, **3**, 39, Oct. 2015, pp. 10164-10176, doi: 10.1039/C5TC01791B.
2. C.-H. Hsieh, *et al.*, "Polarization-manipulated all-optical cross-wavelength data inversion in a C-rich SiC_x micro-ring" J. Mater. Chem. C, **5**, 39, Oct. 2017, pp. 10158-10166, doi: 10.1039/C7TC02854G.
3. B.-J. Huang, *et al.*, "Two-Photon Absorption-Free Ultrafast Optical Switching in Carbon-Rich Si_xC_{1-x} Microring" *Adv. Mater. Technol.*, **2**, 9, Sept. 2017, 1700095, doi: 10.1002/admt.201700095.