High speed germanium and silicon optoelectronic devices

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Abstract: Silicon photonics has generated a strong interest for the development of high-speed optical transceivers The co-integration of photonics and electronics in the same circuit will allow a strong reduction of photonic system costs and the increase of the number of functionalities on the same integrated chip. In this paper, we will present recent results on 40Gbit/s optical modulators based on carrier depletion effect and germanium photodetectors integrated in silicon on insulator (SOI) waveguides.

Short-link optical communications including communications in datacentre and in integrated circuits are considered as the main application for silicon photonics [1]. For this purpose, numerous studies on the development of optoelectronic devices have been performed including III-V on silicon laser [2], germanium laser [3], electro-refraction modulators based on the carrier depletion [4-7], electro-absorption modulators based on Franz Keldysh effect [8] and quantum confined stark effect [9,10] and germanium photo-detectors [11-13].

In this paper, we present a 40Gbit/s silicon modulator based on carrier depletion in lateral pn junction and a 40Gbit/s lateral pin germanium photodetector integrated in a Silicon-On-Insulator (SOI) waveguide. Both optoelectronic devices have been separately fabricated in a 300-mm Complementary Metal Oxide Semiconductor (CMOS) pilot line. The use of such a technological platform opens the route towards high volume production for optical interconnects applications. Furthermore, the use of a 300 mm CMOS platform enables the access of state of the art technological including immersion deep-UV lithography, leading to sub-50-nm resolution.

Silicon modulators: Carrier depletion effect in lateral pn diode was used to induce phase variation in silicon waveguide. Intensity variation was obtained by inserting this diode in both arms of a 950µm long Mach-Zehnder interferometer. A schematic view of the phase shifter cross-sections is shown in Fig1a. The waveguide geometry was: 400 nm wide and 220 nm thick silicon rib waveguides. The etching depth was 120 nm. The characterization were performed for TE polarization in the 1.55µm telecom wavelength range. A modulation efficiency $V_{\pi}L_{\pi}$ of 2.2 V.cm was achieved and a -3 dB cut-off frequency as high as 26 GHz was demonstrated. Finally, a 40 Gbit/s eye diagram of MZ modulator is reported in Fig 1b. Extinction ratio of 7.8 dB was obtained for insertion loss as low as 4 dB.

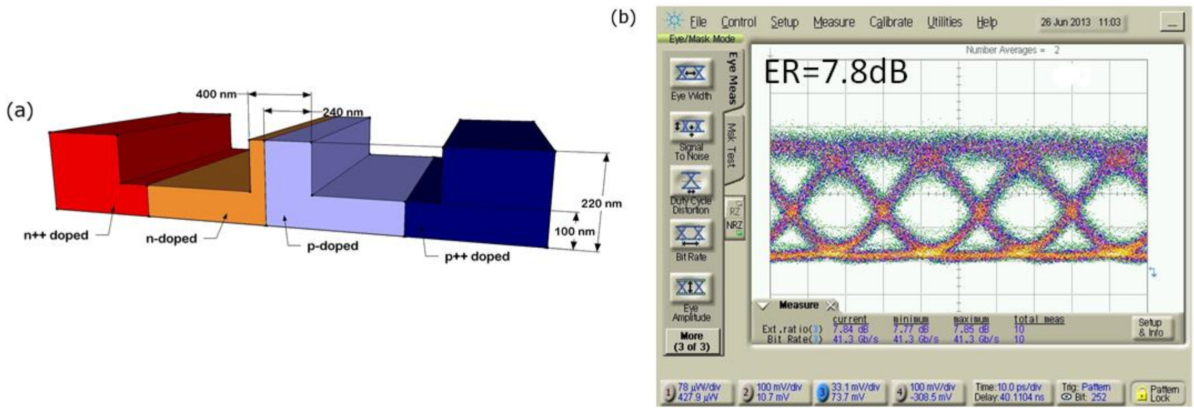

Fig. 1: (a) Schematic view of lateral pn diode; (b) 40Gbit/s eye diagram at a wavelength of 1.55µm

Germanium photodetectors: A lateral pin Ge photodiodes integrated in silicon waveguide was used for high-speed detection (fig.2) [13]. The doping levels of both p and n doped regions were 1.10^{19} cm^{-3} to ensure good contact resistances. The intrinsic region width of the pin diode was 700 nm, enabling high speed operation as well as high responsivity. Under a reverse bias of 1V, dark current was as low as 6nA. Under illumination, photo-generated current were collected with a responsivity higher than 0.5 A/W. -3 dB cut-off frequency higher than 50GHz under zero bias was achieved as well as a 40Gbit/s data transmission.

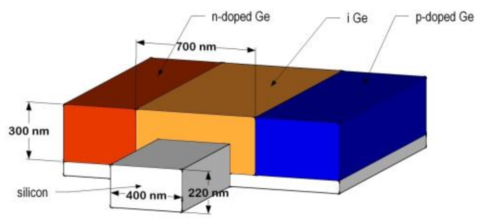

Fig. 2. Schematic view of the lateral pin Ge photo-detector integrated in a Si waveguide.

In conclusion, both Si modulator and Ge photodetector exhibited 40Gbit/s operation with competitive characteristics. A point to point 40Gbit/s optical link including one modulator chip and one photodetector chip, both connected with an optical fibre has been demonstrated [14]. The obtained overall optical loss was lower than 18dB including 4 dB losses per coupler (i.e. 12 dB for light coupling), waveguide propagation (<1dB) and 5dB insertion loss from the optical modulator.

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