20a-C1-3

Low Energy 1D Silicon Photonic Crystal Electro-Optic Modulator

Abdul Shakoor[1], *Kengo Nozaki*[1,2], *Eiichi Kuramochi*[1,2], *Katsuhiko Nishiguchi*[1], *Akihiko Shinya*[1,2], *and Masaya Notomi*[1,2]

[1]*NTT Basic Research Laboratories,* [2]*NTT Nanophotonics Center*

NTT Corporation, 3-1, Morinosato Wakamiya Atsugi, Kanagawa 243-0198, Japan

E-mail: abdul.shakoor@lab.ntt.co.jp

The growing needs of higher data processing speeds and bandwidth has prompted the interest in the research and development of low energy silicon optical interconnects. A modulator is an important component of the interconnect and hence development of an energy efficient modulator is important to keep the total energy consumption low. In the present work, we demonstrate a carrier injection silicon electro-optic modulator operating with the lowest reported switching and holding energies. The energy consumption was lowered by reducing the resistance and capacitance of the device by using a small footprint 1D photonic crystal cavity. We used a mode gap 1D silicon photonic crystal cavity having a width of only 600 nm and a loaded Q-factor of 20K. Complete details of the cavity design can be found in our previous report [1]. A small *pin* junction was created across the cavity with *p* and *n* doped fingers formed by ion implantation in the 50 nm thick side slabs. The schematic of the device with physical dimensions is shown in Fig 1.

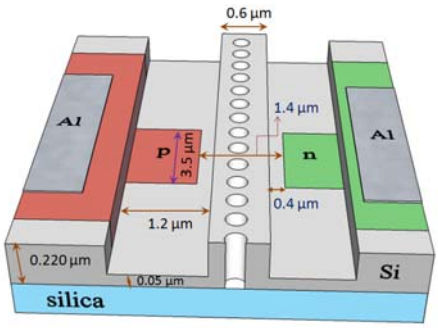

Figure 1 Schematic of the device.

The experimentally measured differential resistance of the device is only 900 Ω which is at least 2 orders of magnitude smaller than the resistance of the 2D photonic crystal cavity based modulators [2, 3]. Similarly, due to small size the numerically estimated device capacitance is just 0.08 fF including the fringe capacitance (excluding pad capacitance). By virtue of small capacitance and resistance values, the device operates with as low as 50 mV swing voltage with an extinction ratio of 3 dB, as shown in Fig 2b. According to our knowledge, this is the first ever demonstration of a silicon electro-optic modulator operating with a sub-100 mV swing voltage. The operation with an ultra-low 50 mV swing voltage leads to an extremely small 0.1 fJ/bit switching energy, calculated by using the method reported in [4], with holding energy of 42 fJ/bit. The holding energy can be reduced to 13 fJ/bit by operating the device with 400 mV swing voltage, which raises switching energy only slightly to 0.9 fJ/bit. Hence, the device consumes only 13.9 fJ/bit total energy. Increasing the swing voltage to 400 mV increases the E.R to 10 dB for 1 Gbps speed.

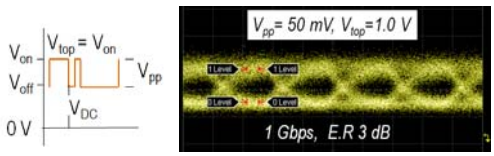

Figure 2 Schematic of the input electrical signal. Eye diagram for 1 Gbps obtained with 50 mV switching voltage.

Overall, the device operates with a maximum speed of 3 Gbps with 8 dB E.R while 11 dB E.R is achieved at 1 Gbps speed for 500 mV_{PP} and 1.1 V_{top}.

The demonstration of low energy, compact, high speed with high E.R silicon electro-optic modulator is a big step towards the development of energy efficient, fast and miniaturized silicon optical interconnects for data processing.

References

[1] E. Kuramochi et al, Optics Express, Vol. 18, Issue 15, (2010).

[2] K. Debnath et al, Optics Express, Vol. 20, Issue 25, (2012).

[3] T. Tanabe, K. Nishiguchi, E. Kuramochi and M. Notomi, Optics Express, Vol. 17, Issue 25, (2009).

[4] L. Chen, K. Preston, S. Manipatruni and M. Lipson, Optics Express, Vol. 17, Issue 17, (2009).

© 2014 年　応用物理学会