【Science and engineering（Engineering Ⅰ）】

Digital Photonics –Paradigm Shift of Optoelectronics

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【Outline of survey】

Since almost all the conventional optical devices are analog devices, whenever digital processing needs to be done, one has to convert optical signals into electrical ones, to process them by electronic circuits, and to convert the electrical signals into optical ones again. However, this current way of converting O into E and E into O every time when digitally processing ultra-fast and ultra-large-capacity optical signals will soon become unacceptable in terms of speed limitation, heat generation, large size, and, most of all, power consumption. A dream of electronics engineers has been to do the digital processing, if it is not too complicated, in the optical domain by digital optical circuits in a ultra-fast and low power dissipation manner. However, there has been no such optical device available to date.

Furthermore, while in the electronic circuits unidirectionality of signals is guaranteed by transistors, in the optical circuits the reciprocity of light allows reverse signal propagation toward upper stream if it is generated by reflection, which makes operation of sequential logic circuits unstable. In order to avoid this instability in the optical circuit, non-reciprocal devices such as optical isolators become necessary everywhere. Nevertheless, there has been no nonreciprocal device or optical isolator which can monolithically be integrated on a circuit chip, and realization of such devices has been an important research target.

In this research, we are to fabricate and develop all-optical logic gates, all-optical flip-flops, and nonreciprocal optical devices which are of low power dissipation, compact, and integratable, on the basis of semiconductor monolithic optical integrated circuit technologies that the principal investigator has been incubating, as well as to search new process technologies to monolithically integrate those different devices on a single semiconductor substrate, thereby demonstrating prototype large scale digital photonic integrated circuits (PLSIs) consisting of hundreds to thousand devices for the first time in the world at the end of the project. Through this research the era of full-scale digital photonic circuits, namely, “digital photonics” is expected to be opened up, in the world of electronics.

【Expected results】

If this research ends up in success, relatively simple front-end digital processing in ultra-high-speed optical information networks will become able to be done in the optical domain without being converted into electrical signals. As a consequence, the ever-increasing tendency of electrical power consumption for communication will be reduced by several orders of magnitudes, thereby contributing to the society significantly.

【References by the principal investigator】

・M. Raburn, Y. Nakano et al., “Integrable multimode interference distributed Bragg reflector laser all-optical flip-flops,” IEEE Photonics Technology Letters, vol. 18, no. 13, pp. 1421-1423, July 1, 2006.

・H. Shimizu and Y. Nakano, “Monolithic integration of a waveguide optical isolator with a distributed feedback laser diode in the 1.5-μm wavelength range,” IEEE Photonics Technology Letters, vol. 19, no. 24, pp. 1973-1975, December 15, 2007.

【Term of project】 FY2008– 2012	【Budget allocation】 **122,900,000 yen** (direct cost)

【Homepage address】 http://www.ee.t.u-tokyo.ac.jp/~nakano/lab/