29p-B3-13

Intersubband All-Optical Switch with Bandgap Tailoring by Area-Selective Ion Implantation in InGaAs/AlAsSb Quantum Wells

°Jijun Feng, Ryoichi Akimoto, Shin-ichiro Gozu, Teruo Mozume, Toshifumi Hasama, and Hiroshi Ishikawa

Network Photonics Research Center, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8568, Japan

E-mail: jijun-feng@aist.go.jp, r-akimoto@aist.go.jp

High-speed all-optical gating switch is a key component in optical-time-division-multiplexed (OTDM) system for next-generation fiber communication networks. Such ultrafast nature can be satisfied in the intersubband transition (ISBT) of doped InGaAs/AlAsSb coupled double quantum wells (CDQWs)[1]. When the transverse magnetic (TM) pump light excites ISBT, cross-phase modulation (XPM) is induced to transverse electric (TE) probe light, which excites interband transition and is immune to ISBT absorption[2,3]. This ISBT induced XPM has short relaxation time of a few picoseconds and is free from the pattern effect beyond 100-Gb/s operation. It has been found that when the interband absorption edge of TE probe light is designed near the working wavelength, high XPM efficiency can be realized. In other words, higher XPM efficiency basically corresponds to higher signal propagation loss, and XPM and signal propagation parts in a gating device have different bandgap energy requirement.

In order to achieve both high XPM efficiency and low signal loss, we developed a compact Michelson interferometer (MI) switch with varying bandgap energy based on the quantum well intermixing induced by area-selective phosphorus (P) ion implantation. The as-grown sample with high XPM efficiency and high signal loss was grown on a semi-insulating InP substrate by molecular beam epitaxy method. After the growth of an InP buffer, a 0.55-μm-thick CDQWs layer and a 1-μm-thick InP upper cladding layer were grown. The InGaAs well layers in CDQWs were Si-doped to activate ISB absorption.[2] Vacancies can be produced in the cladding InP layer, after implantation with 5×10^{14}, 350-keV P+ ions at a substrate temperature of 200 ºC and 7º off normal to minimize ion channeling. During subsequent rapid thermal annealing (RTA), the vacancies are diffused to CDQWs layer and induce quantum well intermixing, which can increase the bandgap energy and thus decrease the corresponding propagation loss. The un-implanted XPM part can be monolithically integrated with the implanted signal propagation part in a MI structure by area-selective manner. The schematic illustration of the fabricated switch is shown in Fig. 1(a). Figure 1(b) presents TE transmittance spectra for as-grown without RTA and implanted sample undergoing RTA at 760 ºC for 60 s. A 5-dB loss decrease can be fulfilled at 1545-nm wavelength. Obvious difference of the transmittance and corresponding XPM efficiency (pumped by 1560-nm TM light) can be seen from Fig. 1(c), between the as-grown and implanted samples with RTA at different temperature for 60 s. This method of connecting active and passive optical parts in an integrated manner will have a wide application prospects.

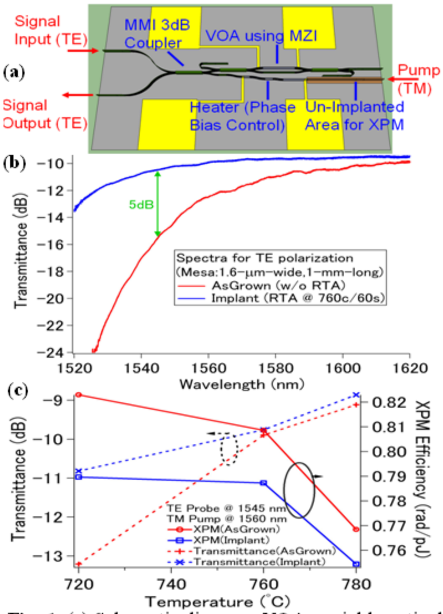

Fig. 1: (a) Schematic diagram. VOA: variable optical attenuator; MMI: multi-mode interference; MZI: Mach-Zehnder interferometer. (b) Transmitting spectra property; (c) transmittance and XPM efficiency for as-grown and implanted MQW mesa.

References
[1] R. Akimoto et al., Appl. Phys. Lett. **91**, 221115 (2007).
[2] R. Akimoto et al., Opt. Express **19**, 13386 (2011).
[3] J. Feng et al., Opt. Express **20**, B279 (2012).