Development of 100 Gbps per Wavelength InAlGaAs IA-EML with Selective Area Growth

Seungchul Lee, Namje Kim, Jun-Hwan Shin, Miran Park, and O-Kyun Kwon
Photonic/Wireless Devices Research Division
ETRI
Daejeon, Republic of Korea
sclee@etri.re.kr, namjekim@etri.re.kr, jh.shin@etri.re.kr, miranp@etri.re.kr, okyun@etri.re.kr

***Abstract*—We introduce an identical active electro-absorption modulated laser (IA-EML) incorporating selective area growth (SAG) technique to enhance integration flexibility. After verifying the reliability of the normal IA-EML device, we proceeded with optimizing the conditions for applying SAG. We anticipate this study will contribute to the development of efficient integrated photonic devices for future 6G networks.**

Keywords—InAlGaAs, IA-EML, O-band, SAG

I. Introduction

The advancement of sixth-generation (6G) optical networks demands photonic solutions that enable high-speed modulation, superior thermal stability, low latency, and cost efficiency [1]. Among the critical components supporting these requirements in 6G fronthaul systems is the electro-absorption modulated laser (EML). Conventional EML has been fabricated using InGaAsP as the active layer material, typically incorporating a butt-joint regrowth structure. However, this approach involves multiple deep etching and regrowth steps, resulting in increased process complexity and reduced fabrication yield. Furthermore, the use of InAlGaAs multi-quantum wells (MQWs) structures has been limited due to the susceptibility of aluminum to oxidation during processing. Nonetheless, InAlGaAs-based (MQWs have attracted considerable attention as a promising alternative owing to favorable conduction and valence band offsets, which enable superior high-speed and high-temperature performance compared to InGaAsP-based MQWs. To overcome the limitations associated with conventional regrowth-based designs, the identical active EML (IA-EML) structure has been proposed. This structure eliminates the requirement for butt-joint regrowth, thereby simplifying the fabrication process while enhancing device reliability. However, to prevent degradation of dynamic performance caused by absorptive waveguide (WG) in IA-EML, a large detuning between the photoluminescence (PL) wavelength and the lasing wavelength is required.

Quantum well intermixing (QWI) and selective area growth (SAG), as representative bandgap engineering techniques, enable precise tuning of MQWs in designated regions [2, 3]. These methods offer the advantage of forming specific MQW regions suitable for each device section through a single epitaxial growth step, thereby eliminating the need for butt-joint conventional regrowth processes.

In this work, after validating the structure and characteristics of a normal IA-EML, we optimized the fabrication process to incorporate SAG. MQWs were precisely engineered in the WG, electro-absorption modulator (EAM), and laser diode (LD) regions to meet specific performance requirements. This approach is expected to serve as an effective strategy for the development of high-performance and simplified EML in future photonic integrated circuit devices.

II. Experimental Result

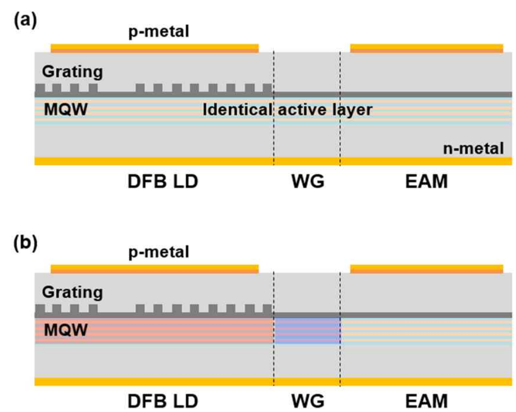

Fig. 1. Schematic structures of (a) normal IA-EML and (b) IA-EML with SAG.

Fig. 1 illustrates two schematic configurations of the IA-EML. Fig. 1(a) shows the normal IA-EML structure, in which the distributed feedback laser diode (DFB LD), WG, and EAM all share the same InAlGaAs MQW active layer. In contrast, Fig. 1(b) indicates an IA-EML structure employing the SAG technique to incorporate distinct MQW regions tailored to each unit section. It decreases the large detuning typically required in the normal IA-EML and enables enhanced gain and absorption characteristics for EML operation.

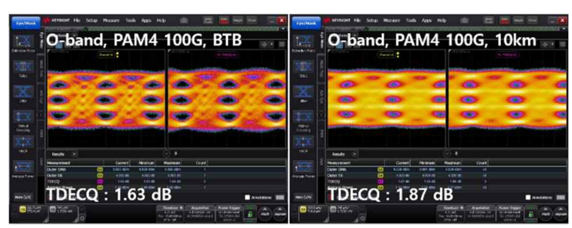

Fig. 2. EYE diagrams of normal IA-EML with PAM4 100 Gbps modulation for BTB and 10 km transmission at 50 ºC.

Identify applicable funding agency here. If none, delete this text box.

100 Gbps pulse amplitude modulation 4-level (PAM4) eye diagram measurement was conducted to evaluate the reliability of the bare MQW and the device structure in the normal IA-EML. We confirmed transmitter and dispersion eye closure quaternary (TDECQ) values below 2 dB for both back-to-back (BTB) and 10 km transmission distances, as shown in Fig. 2. These results demonstrate that the application of InAlGaAs MQW enable the identical active structure to achieve superior high-speed and high-temperature performance.

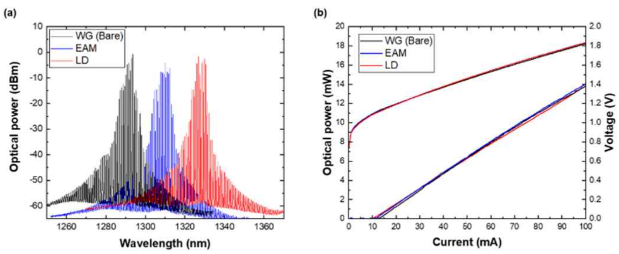

Fig. 3. (a) Optical spectra and (b) LIV curves of 300 μm FP LDs composed of three different conditions of MQWs.

Subsequently, to decrease the detuning in normal IA-EML, optimize the performance of each unit device, and improve integration flexibility, we applied the SAG technique. The WG region was maintained in as-grown state to suppress optical absorption, while the width of the dielectric thin film for SAG was precisely controlled to introduce a red shift in the wavelength of EAM and LD regions. We fabricated Fabry-Perot laser diodes (FP-LDs) on the same wafer as the IA-EML and confirmed static characteristics to assess optical properties of each MQW region. As shown in Fig. 3, the optical spectra and light–current–voltage (LIV) curves of the WG, EAM, and LD sections clearly demonstrate a distinct wavelength shift, along with uniform performance without degradation. Based on these promising results, further analysis of the static and dynamic characteristics of the SAG applied IA-EML will be conducted.

III. Conclusion

We present a 100G IA-EML that enables high-speed modulation while maintaining a simplified fabrication process. After analysis about static and dynamic characteristics of normal IA-EML, SAG was employed to further optimize the WG, EAM and LD regions. The entire MQW structure was grown in a single epitaxial step, and wavelength shifts were clearly observed without any degradation in the optical characteristics of each functional region. These results indicate that the SAG technique offers a viable solution for improving the performance of IA-EMLs without the need for complex regrowth processes, and it holds strong potential for enabling the integration of diverse photonic components in future photonic integrated circuits.

Acknowledgment

This work was supported by Institute of Information & communications Technology Planning & Evaluation(IITP) grant funded by the Korea government(MSIT; Ministry of Science and ICT). NO. RS-2024-00393685, “Development of optical components and link technologies for 6G fronthaul network”

References

[1] J. Zhang et al., “Demonstration of terabit/s LAN-WDM for the evolution of B5G/6G fronthaul networks,” IEEE Photon. J., vol. 15, pp. 1-9, 2023.

[2] S. Lee et al., “1.3-μm identical active electro-absorption modulated laser with quantum well intermixed passive waveguide,” Optics Express, vol. 32, pp. 3278-3289, 2024.

[3] F. Lemaitre et al., “Foundry photonic process extension with bandgap tuning using selective area growth,” IEEE J. Sel. Topics Quantum Electron., vol. 25, pp. 1-8, 2019.