Sun, X., Cheng, W., Ye, S., Sun, Y., Marsh, J. H. and Hou, L. (2022) AlGaInAs/InP EML with Sidewall Grating Distributed Feedback Laser and Quantum Well Intermixing Technology. 2022 IEEE Photonics Conference (IPC), Vancouver, BC, Canada, 13-17 Nov 2022. ISBN 9781665434874 (doi: 10.1109/IPC53466.2022.9975652).

AlGaInAs/InP EML with Sidewall Grating Distributed Feedback Laser and Quantum Well Intermixing Technology

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***Abstract*—An electro-absorption modulated laser comprising a sidewall grating DFB laser and quantum well intermixed electroabsorption modulator with 10 nm blueshift is modelled. An extinction ratio of 40 dB and −3-dB bandwidth of 17 GHz are derived at −2.5 V and −1.6 V EAM bias, respectively.**

Keywords—*Electro-absorption modulated laser (EML), Sidewall Grating Distributed Feedback (SWGDFB) Laser, Quantum Well Intermixing (QWI), Equivalent circuit.*

I. INTRODUCTION

Electro-absorption modulators (EAMs) which operate using the quantum-confined Stark effect (QCSE) are attractive due to their low power consumption, small size, and large bandwidth. Several electro-absorption modulated lasers (EMLs), which were composed of EAMs monolithically integrated with distributed feedback (DFB) lasers, have been investigated in the InGaAsP material system [1]. Compared with InGaAsP material, EMLs based on AlGaInAs have a larger conduction band discontinuity and smaller valence band discontinuity, making them promising for uncooled device operation. AlGaInAs EMLs have been proposed using a relatively complicated and time-consuming butt-joint regrowth technique [1], where conventional buried grating DFB lasers and regrowth EAMs were used. EMLs have been reported based on the quantum well intermixing (QWI) technique, but their DFB lasers used conventional buried gratings which still needed at least two steps of Metal-Organic Vapour Phase Epitaxy (MOVPE) [2]. In order to simplify the fabrication process and increase the yield sidewall grating(SWG) DFB lasers and identical epitaxial layer (IEL) EAMs were used, where the Bragg wavelength has to be set at 1.56 μm to reduce the absorption loss in the EAM section for the DFB laser with photoluminescence(PL) wavelength at 1.53 μm [3]. In this work, a novel integrated EML is proposed, in which a SWG DFB laser and quantum well intermixed EAM will be used. Compared with conventional selective etching and re-growth techniques for photonic integration, the technique of post-growth processing based on SWGs and QWI offers a simple, flexible and low-cost alternative. For a 150 μm long EAM with a 10 nm blueshift, an ER of 40 dB was derived at 2.5 V EAM reverse bias.

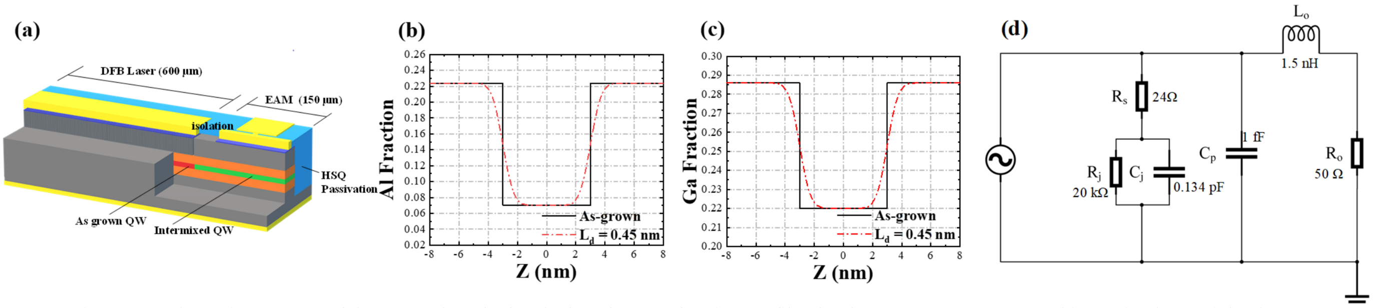

Fig. 1. (a) Schematic structure of the EML, (b) calculated Al, and Ga (c) fraction profiles for the as-grown structure and intermixed material, where L_D is 0.45 nm, (d) the equivalent circuit for *p-i-n* EAM.

II. DEVICE STRUCTURE AND MODELLING

The structure of the EML device is shown in Fig. 1(a), based on a commercially available 1550 nm AlGaInAs/InP LD structure [4]. The EAM need to be bandgap widened using QWI to reduce its insertion loss, and the extent of the QWI process is characterized by a diffusion length L_D. The experimental and calculated bandgap shifts can be fitted by an appropriate choice of L_D. Fig. 1(b) and (c) show the calculated Al and Ga fraction profiles for the as-grown structure and intermixed material where $L_D = 0.45$ nm. The equivalent circuit for a 150-µm-long EAM using the optimized parameters is shown in Fig. 1(d). L_o is the inductance of the connecting terminal microstrip, R_o is the load resistance, and R_s is the contact resistance, which can be measured from the forward current-voltage curve. R_j is the leakage resistance and C_j is the junction capacitance. C_p is the parasitic capacitance of the *p*-contact.

III. DEVICE SIMULATIONS

Fig. 2 (a) and (b) present the calculated TE-polarized absorption coefficient spectrum for as-grown QW and diffused QW with $L_D = 0.45$ nm, for an electric field bias from 0 to 200 kV/cm in steps of 50 kV/cm. Fig.2 (c) shows the calculated wavelength shift of the exciton peak as a function of L_D. As L_D is increased, the blueshift in wavelength value increases monotonically. Fig.2 (d) compares the simulated ER with the measurement result in [4] which uses the same epi-layer structure but uses an IEL EAM operating at a DFB wavelength of 1.568 µm. Good agreement between the simulation and experimental results is obtained. Fig. 2(e) presents calculated ERs for as-grown EAMs and EAMs subjected to amounts of QWI at 1.55 µm wavelength. The ER reaches −40 dB at −2.5 V bias for $L_D = 0.45$ nm. Fig. 2(f) shows the maximum ER is reduced to 27 dB for $L_D = 0.45$ nm when the length of the EAM is decreased from 150 µm to 100 µm. The simulated electrical to optical (E/O) frequency response for a 150 µm EAM and the comparable measured result from [5] at −1.6 V bias voltage are shown in Fig. 2(g), with a good agreement of a 17 GHz −3-dB bandwidth. It is found that if the length of EAM is reduced to 100 µm, the −3-dB bandwidth will increase to 22 GHz due to the reduced junction capacitance.

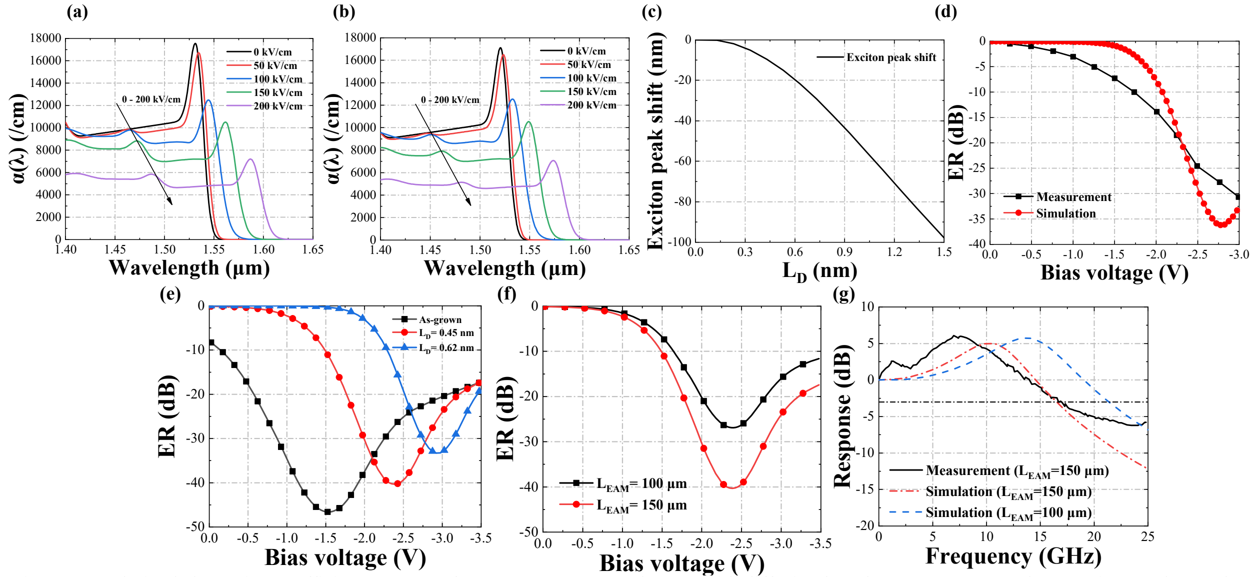

Fig. 2. TE polarized absorption coefficient spectrum for (a) as-grown QW, (b) QW with diffusion length $L_D = 0.45$ nm, and (c) Exciton peak wavelength shift as a function of L_D. (d) Simulated and measured ER as a function of the bias voltage on the EAM for as-grown QW at 1.568 µm operating wavelength, (e) Calculated ERs for as-grown and intermixed QW at 1.55 µm wavelength, (f) Calculated ERs for $L_D = 0.45$ nm at 1.55 µm wavelength with different EAM lengths, (g) Simulated E/O frequency response of the 100 µm and 150 µm long EAM, and measured response as-grown QW at -1.6 V bias.

IV. CONCLUSION

A novel AlGaInAs/InP EML with a simplified fabrication process has been proposed which consists of a SWG DFB laser and QWI EAM. For a 150 µm long EAM with a 10 nm blue-shift, an ER of 40 dB was predicted at −2.5 V EAM bias for 1.55 µm wavelength. A –3-dB E/O response bandwidth of 17 GHz at −1.6 V EAM bias is obtained, in good agreement with measured results.

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This work was supported by the Engineering and Physical Sciences Research Council (UK) under grant EP-R042578-1.