Towards fast tunable InP-on-SOI laser diodes

S. Dhoore, 1,2* G. Roelkens, 1,2 and G. Morthier1,2

1Photronics Research Group, INTEC, Ghent University – imec, Ghent, 9000, Belgium
2Center for Nano- and Biophotonics (NB-Photonics), Ghent University, Ghent, 9000, Belgium
*Soren.Dhoore@UGent.be

Summary: A summary of recent progress towards the realization of fast tunable heterogeneously integrated InP-on-SOI laser diodes is presented. DFB and DBR laser structures comprising tunable twin-guide (TTG) InP membranes on SOI are discussed. Preliminary measurement results indicate promising static and dynamic lasing characteristics with self-heating being the limiting factor for fast wavelength tuning. Approaches to enhance the overall performance and modal overlap with the tuning layer are discussed, which should dramatically improve the lasing characteristics and tuning speed in future devices.

1. Introduction

Fast tunable laser diodes are expected to play a significant role in optical packet-switched datacenter and metro networks [1]. Nowadays VCSELs are still the preferred light sources for short distance interconnects, but don’t give enough optical power for distances beyond a few hundred meters nor do they allow fast wavelength switching. Edge-emitting lasers such as DFBs and DBRs can provide much higher optical output power and will thus be favored for longer distances.

2. Approaches to realize fast tunable laser diodes on silicon-on-insulator

Two main laser structures are envisioned for fast wavelength tuning. Both structures are based on the heterogeneous integration of a tunable twin-guide (TTG) InP membrane containing an active MQW layer and a passive tuning layer on SOI. Through carrier injection in the tuning layer the effective index of the optical mode can be modified (exploiting the free-carrier plasma dispersion effect), in turn modifying the lasing wavelength. Due to the electronic tuning nature, tuning speeds may be very high, with switching times on the order of nanoseconds. The first structure is a tunable DFB laser, whereby the TTG membrane is adhesively bonded on top of a quarter wave-shifted SOI grating. DFB lasers are very well suited for direct modulation up to relatively high frequencies. Recently, our group has demonstrated 56 Gbit/s direct modulation with fixed wavelength InP-on-SOI DFB lasers [2]. The second structure is a tunable DBR laser. Again use is made of a TTG membrane, whereby in this case the active layer is etched away in the passive grating and phase section. A cleaved facet or an SOI DBR mirror is used as second broadband mirror. The structure has the advantage that gain and feedback can be separately optimized but also requires an additional current for phase tuning. The tunable DFB and DBR laser structure are schematically shown in Figs. 1 and 2 respectively.

![Figure 1: Cross-sectional view of the tunable InP-on-SOI DFB laser structure.](image1)

![Figure 2: 3D schematic of the tunable InP-on-SOI DBR laser structure.](image2)

3. Preliminary results

First-generation tunable DFB and DBR InP-on-SOI lasers have already been successfully fabricated. The DFB lasers exhibit good static lasing characteristics with a SMSR of more than 40 dB and a threshold current of 40 mA for 700 µm long devices (including tapers to couple light from the InP to the silicon waveguide). Limited tuning over a 3 nm range can be achieved. The small-signal response, however, indicates promising dynamic...
characteristics with a 3 dB modulation bandwidth of about 6 GHz. With the DBR laser on the other hand a large continuous tuning range of 12 nm was demonstrated [3]. Fig. 3 shows the LI curve and lasing spectrum for the DBR laser. Tuning characteristics are shown in Fig. 4. Device parameters are mentioned in the captions. For both the DFB and DBR lasers tuning is, however, mainly thermal (and thus slow) as the lasing wavelength redshifts upon current injection.

![Figure 3: LI curve and lasing spectrum (inset) for a tunable DBR laser with 300 μm long gain section and 350 μm long Bragg section.](image)

![Figure 4: Lasing wavelength as a function of Bragg current at a gain current of 120 mA (tunable DBR laser).](image)

4. Design optimization

The cause for the dominant self-heating effect is twofold: on one hand the devices exhibit a large thermal resistance, which is a common issue in heterogeneously integrated III-V-on-SOI devices. On the other hand, the overlap of the optical mode with the tuning layer is poor in current laser designs. Therefore effort has been put in the optimization of the device structures. For the tunable DFB laser structure a thicker tuning layer naturally leads to a larger overlap of the optical mode with the tuning layer. However, care must be taken to keep the optical mode sufficiently confined in the active layer and underlying silicon waveguide as well. A trade-off is in place. For the tunable DBR laser structure, the most promising approach is to increase both the thickness of the tuning layer and the n-InP cladding layer in the epitaxial layer stack. This not only increases the confinement factor in the tuning layer, it also decreases the sheet resistance. Even more importantly, the use of a thick (i.e. around 800 nm) n-InP layer enables the use of a symmetric structure in the Bragg and phase section, with the n-contact metal on top of the n-InP instead of an asymmetric structure with the n-contact metal at the side. This gives much better overlap of the optical mode with the tuning layer and prevents strong lateral carrier diffusion away from the optical mode. Currently work is put in the fabrication of the optimized DFB and DBR laser devices. So far successful realization of the proposed devices has been prevented mainly because of issues with the grown epitaxial layer stack.

5. Conclusions

In conclusion we have given an overview of the progress towards the realization of fast tunable InP-on-SOI laser diodes. By making use of the optimized designs we are hopeful to realize fast wavelength tuning in the near future.

6. References


European Semiconductor Laser Workshop 2017

Welcome to European Semiconductor Laser Workshop 2017 (ESLW 2017)

Following a long tradition since 1978, the European Semiconductor Laser Workshop (ESLW) 2017 will be held at the DTU Campus in Kgs. Lyngby (5 km north of Copenhagen), Denmark, on September 15 and 16, 2017, just before the 33rd European Conference and Exhibition on Optical Communication (ECOC 2017) in Gothenburg, Sweden.

The workshop is jointly organized by Chalmers University of Technology (Sweden) and Technical University of Denmark (DTU). It aims at providing an informal discussion forum on exchanging recent research results and achievements in the field of semiconductor lasers, related devices and technology. Furthermore, it is a great opportunity to find new collaboration partners and strengthen our existing friendships. The workshop is arranged in the form of invited talks and contributed presentations. We are looking forward to your participation and the vivid and fruitful discussions at the workshop.

Page manager: Published: Tue 27 Jun 2017 11:04:02 UTC; Last updated: Mon 17 Jul 2017