

Technology development and implementation of a transmitter in generic technology using Buried Heterostructure Semiconductor Amplifiers

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Buried heterostructure lasers and amplifiers enable efficient current injection and improved thermal performance, but have been challenging to integrate with a wide range of shallow and deep ridge waveguide devices. This has limited their use in photonic integrated circuits. Here we present a first step towards the integration of buried heterostructure with a deep ridge waveguide which allows for compact passive circuits and ultimately use in generic integration processes. We propose and simulate a taper jointed region at the interface between the buried and deep ridge area which assures a high transmission and can tolerate a misalignment of 200 nm: this requirement can be satisfied by using deep UV lithography.

Introduction

Generic Photonic Integration enables new and diverse applications to be addressed with the same underlying fabrication processes and process design kits (PDK). Libraries of basic components can be combined together to design more complex circuits. In the library several components are available and depending on the requirement, shallow or ridge waveguides are used; for interconnections, where low propagation losses are needed, shallow ridge (SR) waveguides are often the best candidate. For small radius-bends, AWG-(de)multiplexers, compact MMI-couplers and MMI-reflectors, a high contrast is often necessary and deep ridge (DR) waveguides are used [1]. Laser and amplifiers are also available and these gain sections are based on Shallow Ridge technology. However the electrical injection efficiency is limited through current spreading, motivating the inclusion of buried heterostructures.

Buried Heterostructure SOAs (BH-SOAs) show good thermal behavior [2] and low threshold current when compared to the shallow ridge waveguide amplifiers [3, 4]. In a BH-SOA, the mesa which defines the optical cavity is obtained by etching and then the structure is buried by an InP regrown layer: the active region is therefore surrounded by higher band-gap and lower-index material so carriers are confined both laterally and transversely [5]. The formation of the active waveguide between epitaxial regrowths makes it challenging however to integrate active buried waveguides with a powerful range of passive ridge waveguide devices. This has further prevented the development of buried heterostructure building blocks which might be used agnostically for a broad range of applications in a generic process. So far a considerable amount of literature on buried heterostructure technologies has been focused on discrete BH-SOAs and BH lasers [6, 7, 8]

but their integration in complex optical active/passive circuits has been challenging. This is due to the creation of waveguides in separate mask layers, with a critical alignment tolerance between the two masks. A relatively recent innovation has been the integration of two active devices - a BH SOA and a deep ridge electro-absorption modulator- which was made possible by D.C Kime et al. [9].

In this work we explore methods to integrate a buried heterostructure technology with a generic ridge technology to enable the fullest range of optoelectronic integrated devices on the same monolithic InP platform.

Modeling the buried heterostructure to deep ridge transition

In this section we present the modeling and simulations of a structure that includes a BH-SOA and a DR-waveguide to enable low loss and low reflection optical coupling. For this purpose the commercial software FIMMPROP was used.

In order to connect the buried active part with the deep ridge waveguide, which are defined in different mask layers, it is necessary to design the transition area between these two parts. With a careful design it can be possible to maximize the transmission of the fundamental mode and reduce the reflections that could affect the performances of the active components. A schematic of the proposed structure is represented in Figure 1.

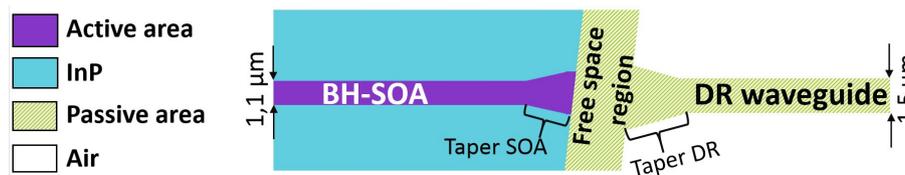


Figure 1: Proposed model of the transition area between BH and DR waveguide

In the proposed model the width of the BH-SOA is $1.1 \mu\text{m}$ and the width of the DR waveguide is $1.5 \mu\text{m}$. In the buried heterostructure waveguide the mode can spread also in the InP around the guiding area (Figure 2a top), instead the DR waveguide the mode is highly confined (Figure 2a (bottom)) due to the much higher refractive lateral index contrast.

The refractive index profile and the electric field are plotted in Figure 2b along the lateral x direction in an SOA and in a DR waveguide. The mode in the SOA is larger so it is necessary to enlarge the width of the DR in order to ensure low-loss transmission of the mode between the two waveguides. In the modeling of the transition area, the possible misalignment between active and passive waveguide masks is accommodated with a mode expansion region. The sensitivity to the misalignment along the x direction can be reduce by introducing a free space region in the passive part where the mode is not laterally confined; introducing a free space region of 500 nm allows for tolerance misalignment of 500 nm as shown in Figure 3.

To increase also the tolerance along the y direction a solution is to taper out also the active part; as can be seen from Figure 4a for the same misalignment the losses are smaller in the structure with the active taper; with 200 nm of misalignment the losses are still less than 0.2 dB.

This motivates the use of deep UV lithography which is expected to offer 100 nm mask

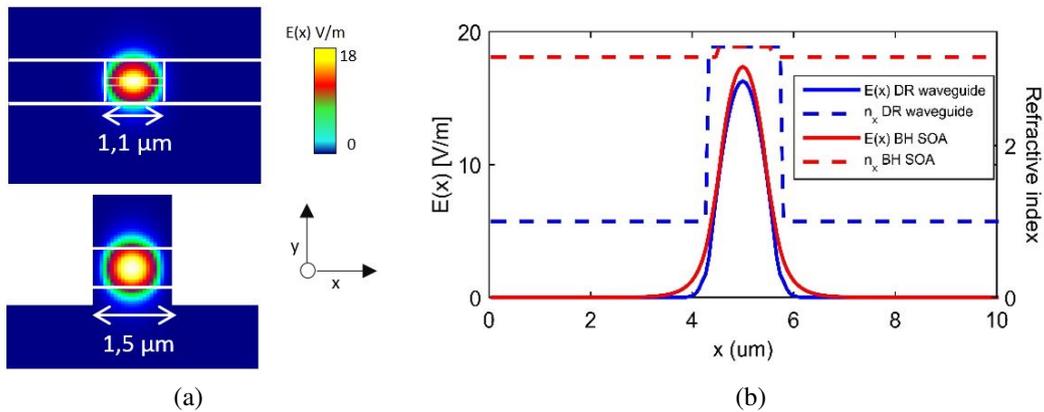


Figure 2: (a) Fundamental mode in a DR waveguide (top) and in BH SOA (bottom) (b) Refractive index profile and mode profile along the x direction in both structures

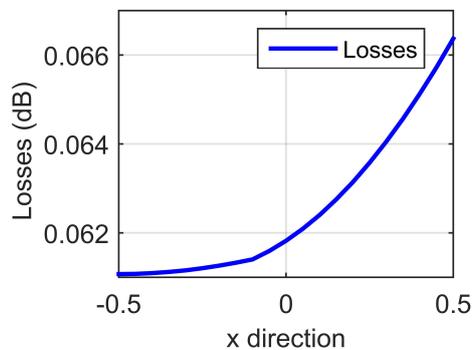


Figure 3: Influence of the misalignment in the x direction on the transmission of the fundamental mode

alignment registration accuracy. A further investigation is needed to estimate the reflections versus the mask offset: we expect a restriction on the mask alignment tolerance in order to avoid reflections.

For this simulation the SOA was tapered out to $3 \mu\text{m}$ and the DR waveguide to $3.5 \mu\text{m}$: by increasing these two waveguide widths it is possible to increase the misalignment tolerances but then a longer taper will be needed. Both SOA and DR waveguide are designed to work at a certain width (1.1 and $1.5 \mu\text{m}$ respectively); it is then necessary to design a taper and from simulations it has been found that the length of the active and passive taper are $50 \mu\text{m}$ and $30 \mu\text{m}$ respectively corresponding to a taper angle of 1.5 and 1.8 degrees. In order to avoid unstable operation it is necessary to reduce the spectral ripple by reducing the reflections at the SOA/ridge interface. This can be achieved by introducing a tilting at the slab interface; Figure 4b shows the simulated total reflections at the input facet varying the tilting of the butt-joint interface; it appears that with a tilting of 30 degrees reflections can be reduced down to -60 dB. These values are in agreement with previous experimental measurements [10].

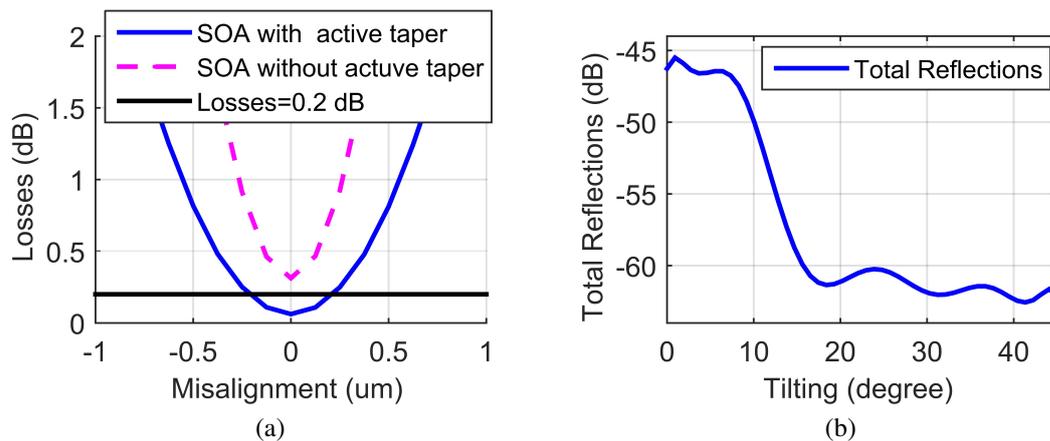


Figure 4: (a) Losses in function of the misalignment along the y-axes with and without SOA taper (b) Total reflections at the input facet varying the tilting of the butt-joint interface

Conclusion

In this work we have showed a first step towards the monolithic integration of BH-SOAs and ridge waveguides; we intend this to be fully compatible with the use of the deep UV lithography increasing the alignment precision and the resolution in comparison to the i-line lithography.

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