Design of InP Membrane Laser in a Photonic Integrated Circuit

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Abstract: On-chip lasers are a necessity for realizing the full potential of high index contrast photonic integrated circuits. The feasibility of this has been investigated before by simulating the optical and thermal properties. In this paper, two possible configurations for such a laser are reported. As the active and the passive layers are vertically separated, optical simulations on tapers for coupling between the two have been performed. To couple out the light, gratings for 1.55 µm have been designed. All these results have been put together in designing a Fabry-Perot type laser and two types of ring laser, differing in the MMI coupler that they have in the ring - 1x2 or 2x2. Realization of these lasers is underway.

Introduction

InP membrane on Silicon (IMOS) generic technology combines the best features of InP as well as Silicon-on-insulator (SOI). While the direct band-gap InP acts as an efficient gain material, the membrane structure provides high index contrast similar to SOI. This opens up a wide range of applications and new possibilities for photonic integration.

In this paper, the design of an electrically pumped InP membrane laser at 1.55 µm is reported. Preliminary simulations in support of its feasibility have been investigated in [1]. Based on these simulations, two types of resonator cavity configurations for a laser have been designed – with and without a ring. The Fabry-Perot (FP) type cavity laser is simple and depends on the etched facet for reflection (fig.1). The other design is the ring laser (fig.2) and can further be classified based on the multi-mode interference (MMI) coupler that is incorporated in the ring – 1x2 or 2x2.

For these configurations, the individual components necessary have been simulated for TE polarization and optimized for best performance. These include MMI couplers (1x2 and 2x2), SOA tapers and waveguide tapers.

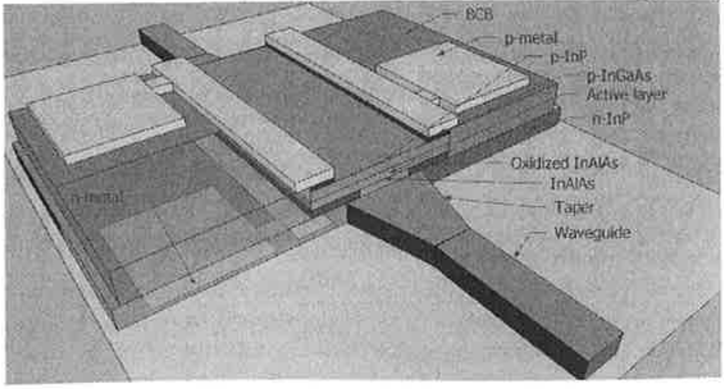

Fig.1: Schematic of the designed FP type cavity laser

Finally, to evaluate the performance of the laser, light has to be coupled-out from the chip to a fiber. To facilitate this, gratings are simulated using a full vectorial Maxwell solver tool [2]. The output of the grating is maximized by adjusting the period, etch depth and filling factor. The sensitivity of this design to fibre angle, BCB thickness variations, number of periods and wavelength shift are simulated and optimized. As a result of these simulations, coupling efficiency of 44.1% is achieved.

Design

The choice of the layer-stack and the dimensions of various structures are described in detail in ref [1]. The findings of this study are schematically represented in fig.3. To study the gain properties of the material, variations in the length and width of the gain section are included in the mask design for both the lasers. The length is distributed over a wide range starting from 5 μm reaching up to 1000 μm. The width is varied from 3 μm to 4 μm.

For efficient current injection, two metal pads for each electrode are incorporated in the mask design. Moreover, the two electrodes having the same polarity are placed on opposite ends of the gain section to enable uniform current injection in the entire mesa and hence more uniform pumping of the gain material (fig.1 and 2).

Every laser requires a resonator cavity. For the FP type laser, the cavity is formed by the two etched facets acting as reflecting mirrors. The reflectivity of these etched facets is estimated to be ~7.4% from simulations. The ring acts as the cavity in case of the ring laser. However, to be useful in applications, it is also necessary to get power out of the device. In order to achieve this, MMI couplers have been incorporated. For both 1x2 and 2x2 MMI coupler designs a splitting ratio of 50:50 is aimed at so that half the power remains in the cavity and the other half is coupled out. Fabrication tolerances are simulated for better understanding.

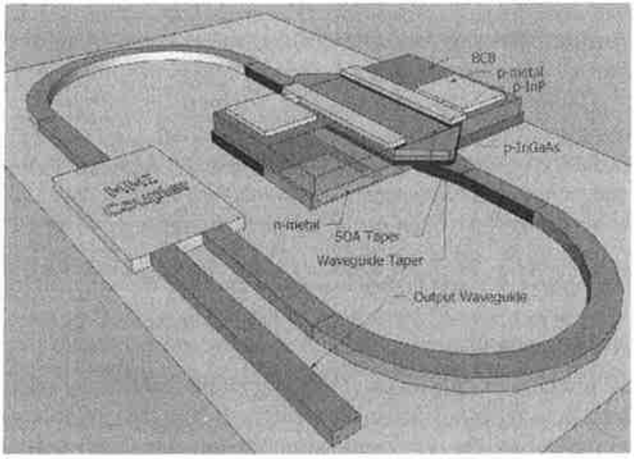

Fig.2: Schematic of the designed ring laser with 1x2 MMI coupler

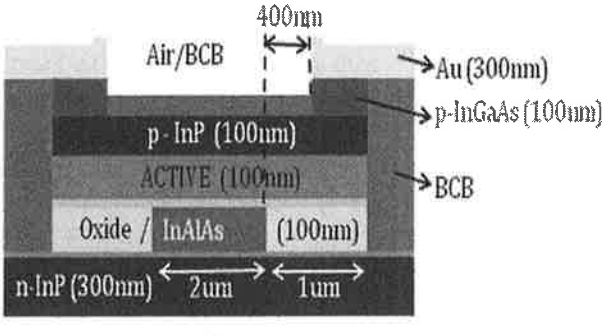

Fig.3: Cross-section of the laser showing the various dimensions

The passive layer consisting of the ring and the waveguides, and the active layer containing the SOA section are vertically separated. To couple the mode between the two with minimal losses, tapers have been designed both in the passive and the active layers. In the next sections the design of the MMIs and the tapers will be explained.

MMI Design

The MMI coupler design consists of one or two tapered input waveguide(s), a MMI section and two tapered output waveguides (fig.4). To obtain a 50:50 splitting ratio for the MMI coupler, a 3D bidirectional optical propagation tool [3] is utilized. The length and the width of the MMI section are varied to optimize the output power. Fine tuning is done by varying the width of the input/output waveguide taper at the wider end, the length of the taper and the offset of the input/output waveguides from the centre. The results of these simulations for 1x2 and 2x2 MMI coupler are shown in fig.5 and fig.6 respectively. Insertion loss in each of the output port for power in one of the input ports is found 3.19 dB and 3.13 dB for the 1x2 and the 2x2 MMI coupler respectively.

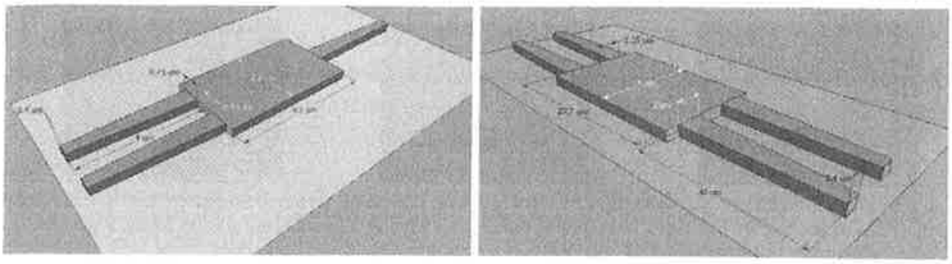

Fig.4: Schematic of the designed 1x2 MMI coupler (left) and 2x2 MMI coupler (right)

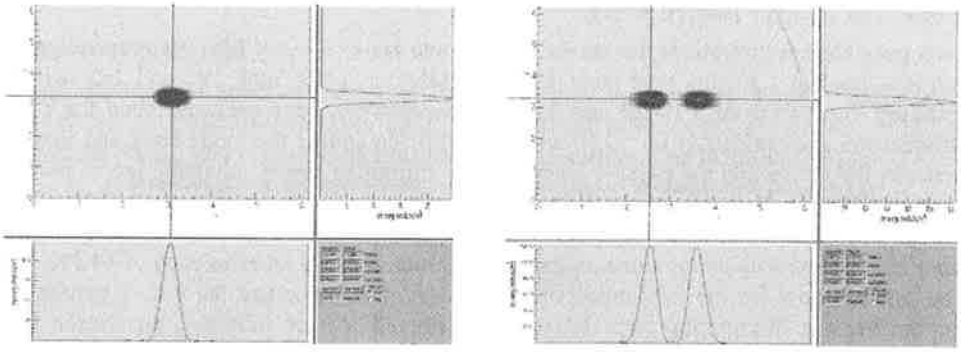

Fig.5: Simulation results showing the input (left) and the output (right) power distributions for 1x2 MMI coupler

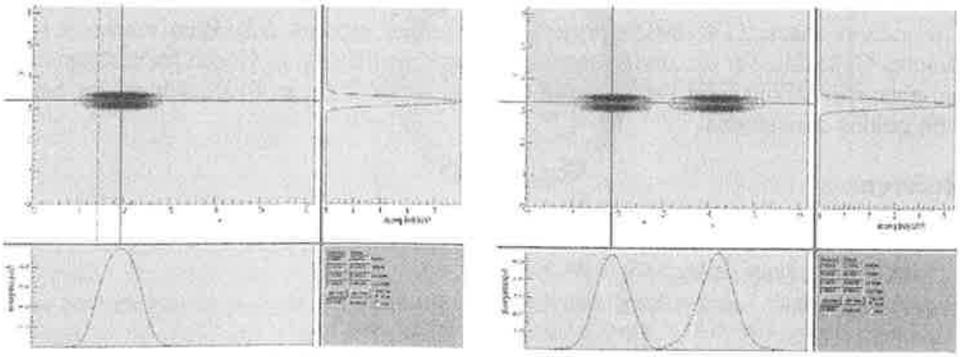

Fig.6: Simulation results showing the input (left) and the output (right) power distributions for 2x2 MMI coupler

Taper Design

One way to efficiently couple a mode between two vertically separated layers is by using a taper. In the present design, for mode coupling from the SOA to the waveguide, first the SOA section is adiabatically tapered down to 200 nm. At an optimized point along this taper, a second adiabatic taper in the passive layer is defined for smooth transition of the mode from one layer to the other. Again the optical propagation tool [3] is utilized to perform the simulations. The length of both the tapers and the wider width of the waveguide taper are varied to achieve a compromise between efficiency of mode coupling and compactness. Simulation results for the combination of the two tapers are shown in fig.7 and the throughput is found to be 94.8%.

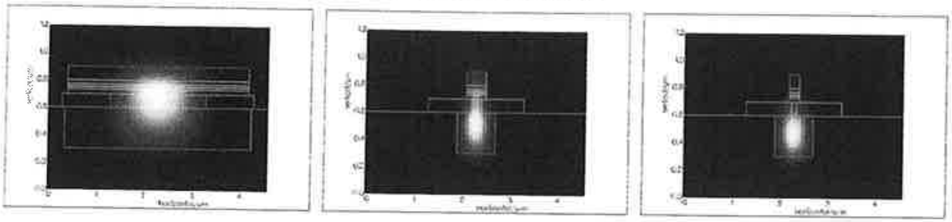

Fig.7: Cross section of the taper at different positions showing the coupling of the mode from the active layer to the passive layer

Conclusions and future work

Two possible configurations for an InP membrane laser, namely FP type cavity laser and ring laser at 1.55 μm have been designed. MMI couplers, both 1x2 and 2x2, with insertion loss values of 3.19 dB and 3.13 dB respectively, have been designed for TE polarization and optimized for 50:50 splitting ratio. To couple the mode back and forth between the active and the passive layers, and to minimize losses, adiabatic tapers have been designed in both the layers. Simulations indicate a coupling efficiency of 94.8% for the combination of these tapers. Efficient coupling of the light from the chip to a fibre is achieved with simulations on gratings. Results indicate an efficiency of 44.1%. The process flow for the fabrication of these lasers is in place and the masks required for the various lithography steps have been designed. At the moment, fabrication is being pursued for the realization of the lasers.

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References

[1] S.P. Bhat, J.J.G.M. van der Tol, G. Roelkens and M.K. Smit, "Feasibility study of an InP Membrane On Silicon(IMOS) laser," in Proceedings of the 16th European Conference on Integrated Optics (ECIO2012), Sitges, Spain, April 18-20, 2012.

[2] CAMFR (version 1.3), http://camfr.sourceforge.net/

[3] Photon Design, FIMMPROP (Opt05), http://www.photond.com.

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