

Integration of a semiconductor laser source on silicon

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I. INTRODUCTION

IT is expected that in year 2020, there will be six devices connected to the Internet for each person on the planet! The era of “Internet of Things” has the potential to optimize our way of living but doing so it will generate enormous amounts of data which has to be processed and analyzed in real time.

Conventionally, electrical interconnections in form of metal wiring are used to transfer data between different components within the chip. In modern micro processors, the time delay is associated to the metallic interconnections rather than the actual speed of the transistors.

In a photonic chip, light instead of electrons is used to transfer the data and it is believed that a photonic chip has both the potential to consume less power and reach higher bandwidths than the conventional chips. In order to establish a full optical link, the integration of electro-optical components such as detectors, switches and light sources on silicon is essential. In this report, an attempt to design and fabricate an on-chip laser light source that is compatible with established IBM developed technology is shown.

II. LASER DESIGN CONCEPT

The idea was to build a tiny laser which can emit light inside the chip! The principle of a laser is that light (or photons) can be produced by injecting charge carriers (electrons or holes) into an active gain material. The emitted photons all have the same energy, phase and direction, i. e. the light is coherent. In order to create a laser, there are a few laser components

that need to be included as shown in Figure 1 and described below:

- **Gain material** - in which the light is produced.
- **Contact material** - to provide charge carriers to be injected into the gain material.
- **Reflectors** - to trap the light inside the gain material.
- **Access waveguides** - to guide the light out of the gain material.
- **Grating couples** - to diffract light out of plane so that it can be measured.

Up to date, the focus of research has been on designs having a vertical current injection (VCI) scheme, meaning that the contacts are situated above and below the gain material. The novelty of our laser design concept is to instead use a lateral current injection (LCI) scheme where the charge carriers are laterally injected into the active region, as shown in Figure 2. The main reason for choosing such a laser design is because it is only a couple of hundred nanometers thick, making it compatible with established IBM technology which allows only a thickness of 400 nm for the laser to be integrated within.

III. OPTICAL SIMULATIONS

The threshold current of a laser is proportional to one over the overlap between the laser light beam and the gain material. Thus, in order to minimize the threshold current a large overlap is desired. The degree of the overlap depends largely on the difference in refractive index between the gain material and the surrounding

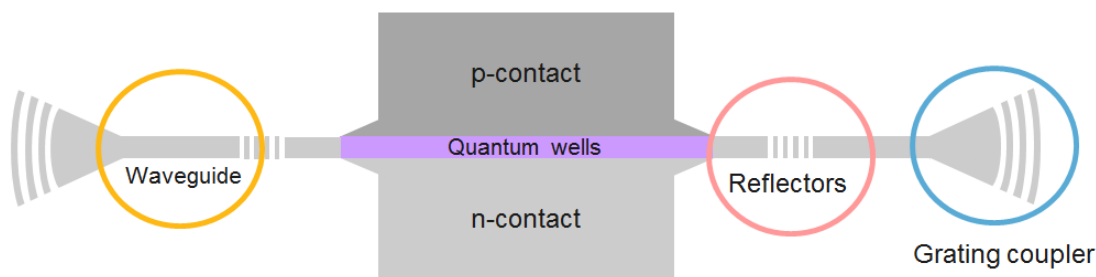


Figure 1: Schematic illustration of the topview of the active laser device.

material (a large difference results in a large overlap).

Optical simulations of the laser device revealed that the laser threshold current could be minimized if the width of the active gain material was approximately 700 nm.

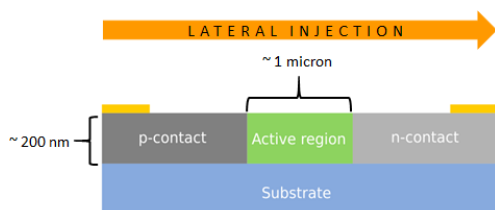


Figure 2: Schematic illustration of the cross-section of a lateral current injection laser.

IV. SUMMARY

To fabricate the full active laser, over 500 processing steps had to be conducted! Complexity was added to the fabrication process due to the fact that the laser had a lateral design, requiring three epitaxial¹ growth steps. The development of the initial processing steps, together with the results of the optical simulations has led to the establishment of a solid base from which the project can continue.

Based on the work of this thesis, I am positive that within near future, a LCI laser integrated on an IBM chip will be realized.

¹Epitaxy is a method which uses gases to grow for example nanometer thin layers with high precision.