1310nm Silicon Evanescent Laser

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Abstract

An electrically pumped 1310 nm silicon evanescent laser (SEL) is demonstrated utilizing the hybrid silicon evanescent waveguide platform. The SEL operates continuous wave (C.W.) up to 105 °C with a threshold current of 30 mA and a maximum output power of 5.5 mW.

I. Introduction

Many significant advancements have been made towards the realization of lasers that are compatible with silicon [1,2,3,4,5]. However, due to silicon’s indirect bandgap, several of these solutions have relied on optical pumping methods such as stimulated Raman scattering (SRS) [1,2], or have relied on complex heterogeneous integration of III-V materials [4,5]. Recently, silicon evanescent lasers (SEL) have been demonstrated in the 1550 nm regime [3,6]. These lasers utilize quantum wells bonded to a silicon waveguide to achieve evanescently coupled optical gain into the silicon mode. The optical mode of this hybrid waveguide lies in both the III-V region and silicon waveguide. The optical mode is defined by the silicon waveguide and no alignment is needed for this bonding process. This allows for a large number of SELs to be bonded to the silicon wafer through a single bonding step. We report here an SEL operating in the 1310 nm regime with a threshold current of 30 mA, a maximum output power of 5.5 mW, and C.W. operation up to 105 °C.

II. Device Structure and Fabrication

The SEL consists of a III-V active layer bonded to a silicon waveguide fabricated on a silicon-on-insulator (SOI) substrate, as shown in Figure 1. A set of silicon waveguides with a height $h = 0.69 \mu$m, rib etch depth $d = 0.52 \mu$m, and width $w = 2.5 \mu$m are patterned on the silicon before bonding.

The fabrication can be divided up into 4 major steps. First, the silicon waveguides are fabricated on the SOI wafer using standard projection lithography and dry etching techniques. Second, the III-V layer structure is transferred to the silicon wafer through low temperature wafer bonding process [7]. Third, the III-V region is processed to ensure efficient carrier injection to the active region. Finally, the sample is diced and polished, resulting in a total cavity length of 850 microns. A detailed description of the fabrication procedure can be found in references [3,6].

![Figure 1. Silicon evanescent laser structure.](image)

Table 1 shows the details of the III-V epitaxial structure. The AlGaInAs quantum wells are designed with a PL peak at 1303 nm. The quantum wells are located between a carrier blocking layer and an n-layer. The carrier blocking layer is designed to have a low valence band offset while maintaining a high conduction band offset [8]. This allows holes to flow past this layer from the p-mesa into the quantum wells while preventing electrons from flowing out of the quantum wells into the p mesa. A SCH layer and p-cladding layer are placed above the carrier blocking layer.

![Table 1. III-V epitaxial growth layer structure.](image)
of this structure for devices with 2.5 µm waveguide width. These modes are calculated by the film mode matching (FMM) method [9]. The quantum well confinement factor for the fundamental mode and 2nd order transverse mode are 2.2 % and 10.5 %, respectively. Since the 2nd order transverse mode has a higher confinement factor in the III-V region, it preferentially lases over the fundamental mode. The observed optical mode is as shown in Figure 2 (c).

III. Experiments and results

The device is mounted on a thermal-electrical cooler and biased with a C.W. current source. We collect the light on one facet of our device with a single mode lensed fiber. On the other facet, we use an IR camera to image the lasing mode. The coupled power is then sent to a spectrum analyzer or photodetector. The coupling loss was measured to be ~4.6 +/- .8 dB.

Figure 2 Optical mode simulation results of SEL and the measured mode: (a) simulated fundamental mode; (b) 2nd order transverse mode; (c) measured optical mode.

![Figure 2](image)

Figure 3. The single sided fiber coupled laser power output as a function of drive currents at different temperatures.

![Figure 3](image)

Figure 4 shows the measured lasing spectrum of the SEL under 100 mA drive current at 15 °C. The center wavelength is 1326 nm. The inset of Figure 4 shows a close up of the lasing spectrum, showing the Fabry-Perot modes. The mode spacing is measured to be 0.27 nm, which corresponds to a group index of 3.83.

![Figure 4](image)
IV. Conclusions

An electrically pumped laser on silicon at 1310nm is important for silicon-based photonic integrated circuits. Here we demonstrate the first electrically pumped 1310nm SEL on silicon with a threshold current of 30mA and maximum single sided fiber coupled output power of 5.5mW. The single sided fiber coupled differential quantum efficiency is 8% and the maximum lasing temperature is 105 °C. This technology is applicable to semiconductor optical amplifiers [10] at 1310 nm, which is important because it is outside the wavelength range of erbium doped fiber amplifiers.

V. Acknowledgements

The authors thank Jag Shah, Michael Haney, Hui-Wen Chen, Gehong Zeng, and Ying-Hao Kuo for useful discussions. The UCSB research was supported by DARPA contracts W911NF-05-1-0175 and W911NF-04-9-0001, and by Intel.

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