Microdisk lasers as integrated sources for optical interconnects

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I. Introduction

The increase of computational power in multicore CPU's comes together with a tremendous increase in required bandwidth for on-chip interconnects. Until now electrical interconnects can still keep up the pace, but in the near future physical limits will be reached and new types of interconnects will be required [1]. Optical interconnects in the form of photonic integrated circuits (PICs) are a promising solution because of their huge bandwidth and immunity to electromagnetic interference. Silicon-on-insulator (SOI) is an interesting platform to implement these PICs because of its CMOS compatibility. Furthermore, the high refractive index contrast of SOI makes it possible reach a very high integration density. However, one of the major problems with SOI is the difficulty to achieve light emission and amplification, due to the indirect energy bandgap of silicon. Furthermore, to reach a high integration density the active devices should also have small dimensions which means conventional laser designs are not suitable.

We propose a microdisk laser structure which is heterogeneously integrated with SOI. In the heterogeneous approach a material with a direct energy bandgap, which are mostly III-V materials like Indium-Phosfide, is bonded on top of SOI. The III-V material is used to generate light which is then coupled into the silicon waveguide.

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II. Concept

A schematic representation of the heterogeneously integrated microdisk laser is shown in Fig. 1(a). The microdisk is etched in a thin InP-based membrane and the active layer consists of 3 quantum wells. The InP-based membrane is bonded on top of SOI with an adhesive bonding process where a thin layer of Benzocyclobutene (BCB) is used as a bonding agent. A silicon wire waveguide goes underneath the disk so that light can couple from the disk to the waveguide as a result of evanescent coupling.

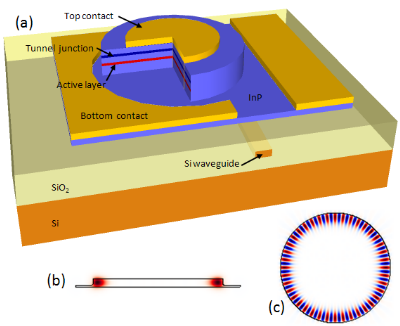


Figure 1. Schematic representation of the microdisk laser (a), vertical (b) and horizontal (c) cross-section of the field profile

Microdisk cavities support optical resonances of the whispering gallery type, which have a very low radiation loss also in very small cavities. The resonant modes propagate at the edge of the disk without the need of a guiding structure as is shown in Fig. 1(b-c). Therefore, electrical injection can be achieved by placing a top metal contact in the center of the disk and a bottom metal contact on a slab around the disk, without inducing optical losses.

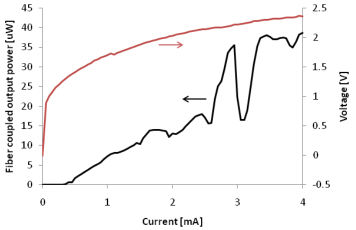
III. Towards higher efficiency

In order to improve the performance of the microdisk we used a new epitaxial structure which is significantly thinner than the previous structures. This has a positive effect on the scattering loss and the coupling efficiency. The scattering loss, which is caused by the sidewall roughness of the microdisk, scales linearly with the thickness of the device. The coupling efficiency to the underlying waveguide increases for a thinner structure, because there exists a larger exponential tail in the cladding, and thus also a larger overlap with the silicon waveguide.

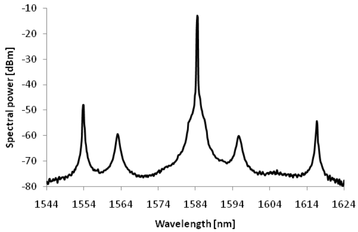
The low thermal conductivity of BCB results in severe self heating of the device. A thermal heat sink could improve the performance of the microdisk laser considerably and as a first step towards this heat sink we deposited a thick layer of gold (600 nm) on the top contact of the microdisk. Although a thermal roll-over effect is still present in this case, saturation of the output power now occurs around a drive current of 4 mA instead of 2 mA in previous devices [2].

IV. Results

DC measurements were performed and continuous-wave (CW) lasing at room temperature was observed for microdisks with a diameter of 7.5 and 10 μm. Fiber grating couplers were used to collect the light at one end of the silicon waveguide. The light-current and voltage-current curves, for a 7.5 μm diameter microdisk, are shown in Fig 2(a). A threshold current of 350 μA and a maximum output power in the fiber of 38 μW is observed, which is about 120 μW in the silicon waveguide if we take the efficiency of the grating coupler into account. This is a considerable improvement compared to the previous generation [2]. The optical spectrum when a 4 mA drive current is applied to the microdisk is shown in Fig. 2(b).



(a) LIV curves



(b) Optical spectrum

Figure 2. LIV curves (a) and spectrum (b) of a 7.5 μm diameter microdisk

V. Conclusions

We have demonstrated a new design of an electrically injected microdisk laser bonded on SOI with a considerable improvement of the performance. We observed threshold currents as low as 350 μA and output power up to 120 μW for a 7.5 μm microdisk diameter under CW operation. Compared to previous results this is an increase in output power by a factor of 10.

Acknowledgments

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References

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[2] J. Van Campenhout, et al., *Electrically pumped InP-based microdisk lasers integrated with a nanophotonic silicon-on-insulator waveguide circuit*, Optics Express, Vol. 15, no. 11, 2007.