Heterogeneously integrated InP microdisk lasers

Recent progress

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Abstract—**In this paper we review some of the recent results that were obtained with electrically pumped InP microdisk lasers heterogeneously integrated onto SOI. We also discuss some ideas for performance enhancement.**

Keywords: microdisk lasers, heterogeneous integration

I. Introduction

Silicon photonics has been the focus of a lot of research since well over a decade as it is possible to fabricate very compact optical waveguide circuits in large volumes using CMOS equipment and tools. However, since silicon is an indirect bandgap material, it is so far impossible to use the material for the fabrication of electrically pumped light sources. Considerable research has therefore been directed towards the heterogeneous integration of III-V light sources on silicon-on-insulator (SOI) passive waveguide circuits.

One of the first demonstrated electrically pumped laser diodes, heterogeneously integrated on SOI, was the microdisk laser [1]. With a disk diameter of 7.5 µm and a threshold current below 0.5mA, it is still one of the electrically pumped laser diodes with lowest footprint and power consumption. In this paper, we report on some recent progress with microdisk lasers, both concerning their fabrication and their use in all-optical processing.

II. Fabrication

The microdisk lasers are fabricated by bonding an InP die (or wafer) to a SOI die (or wafer), either using molecular or adhesive bonding. Adhesive bonding (using a BCB polymer) has some advantages such as relaxed requirements on surface cleanliness or roughness. Alumina or silica is deposited on the InP die prior to bonding. This leads to very high bonding yields, allows to control the bonding layer thickness and the oxide also helps with heat sinking.

After bonding, the further processing can be done using contact, e-beam or Deep UV lithography. E-beam lithography allows to accurately control the disk diameters, and lasing wavelength variations as small as a few nm have been demonstrated for nominally identical microdisks. In addition, processing of microdisk lasers has also been done in a CMOS fab using DUV lithography .

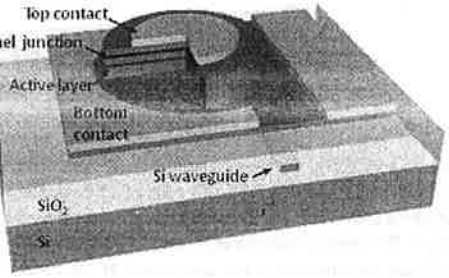

Figure 1. Schematic of a heterogeneously integrated microdisk laser.

Most microdisk lasers fabricated so far made use of InP membranes containing tunnel junctions, to avoid excessive losses associated with highly p-doped contact layers. Simulations indicate that also membranes without tunnel junctions would be possible, provided that the p-contact layers are etched away near the edges of the disk, just above the whispering gallery modes.

III. New applications and concepts based on microdisk lasers

In the past years, the microdisk lasers have moreover been demonstrated as all-optical flip-flops [2], gates, wavelength converters, modulators and resonant photodetectors, all with minimal power consumption. Recently, optical signal regeneration has been demonstrated at 10 Gbit/s [3].

Coupled to a Bragg grating, they can also operate in a predefined unidirectional mode. In this case they are rather insensitive to external reflections, as the reflections couple back into the nonlasing mode, and could be used without isolator.

Microdisk lasers are therefore very versatile devices with very low power consumption.

References

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Invited Speakers

Hans Agren (Royal Institute of Technology, Sweden)
Chih-Ming Chen (National Chung Hsing University, Taiwan)
Ya Cheng (Shanghai Institute of Optics and Fine Mechanics, China)
Yiping Cui (Southeast University, China)
Zhenchao Dong (University of Science and Technology of China, China)
Shinji Hayashi (Kobe University, Japan)
Fei Huang (South China University of Technology, China)
Hajime Ishihara (Osaka Prefecture University, Japan)
Satoshi Iwamoto (Tokyo University, Japan)
Yoshihiko Kanemitsu (Kyoto University, Japan)
Wakana Kubo (RIKEN, Japan)
Philippe Lalanne (Insitue of Optics, France)
Andrei Lavrinenko (Danmarks Tekniske Universitet, Denmark)
Laura M. Lechuga (Research Center on Nanoscience and Nanotechnology (CIN2: CSIC-ICN), Spain)
Olivier J.F. Martin (Swiss Federal Institute of Technology, Switzerland)
Masayuki Matsumoto (Osaka University, Japan)
Ting Mei (South China Normal University, China)
Arno Mussot (Universite Lille1, France)
Adriana Passaseo (Istituto Nanoscienze, Italy)
Marek Samoc (Wroclaw University of Technology, Poland)
Perry Ping Shum (Nanyang Technological University, Singapore)
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