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An electrically driven membrane microdisk laser for the integration of photonic and electronic ICs.

J. Van Campenhout[1], *Student Member IEEE,* P. Rojo-Romeo[2], D. Van Thourhout[1], *Member IEEE,* C. Seassal[2], P. Regreny[2], L. Di Cioccio[3], and J.M. Fedeli[3], R. Baets[1], *Senior Member IEEE.*

[1] Ghent University-IMEC, Department of Information Technology- Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium
[2] Laboratoire d'Electronique, Microelectronique et Micro-systèmes, Ecole Centrale de Lyon, 36 Avenue Guy de Collongue, 69134 Ecully cedex-France
[3] CEA-DRT/LETI, 17 Rue des Martyrs, 38054 Grenoble cedex 9-France.
e-mail: joris.vancampenhout@intec.ugent.be

Abstract— **We report on electrically pumped lasing in a microdisk cavity in an InP-based membrane bonded on top of a silicon wafer. The top metal contact is placed in the center of the disk, whereas the bottom contacting is done by means of a thin lateral contacting layer. In order to avoid large optical absorption in p-type contact layers, a tunnel junction was used in combination with two n-type contacts. Lasing was observed in pulsed regime with a current threshold of about 1.5mA, for microdisks with a diameter of 8µm.**

I. INTRODUCTION

For future generation electronic circuits, a severe bottleneck is expected on the global interconnect level. With decreasing device dimensions, it is increasingly difficult to keep propagation delays and power consumption acceptable. Therefore there is a need for radically different interconnect approaches and one of the most promising solutions is the use of an optical interconnect layer. A possible approach for a compact optical link is the use of a Silicon-on-Insulator (SOI) passive waveguide layer [1] in combination with III-V semiconductor microlasers and microdetectors, which are defined in a III-V membrane bonded on top of the SOI-stack. A good candidate for the microlaser is the membrane microdisk laser: optically pumped lasing in this type of devices was already reported [2], however, electrical injection remained a major difficulty. In this paper, we report on the design, fabrication and measurement results of electrically injected membrane microdisk lasers.

II. DESIGN ASPECTS

Optically pumped lasing was reported [2] for completely etched microdisks in an InP membrane with an optical thickness of about half the lasing wavelength, bonded onto a Si wafer with an 800nm-thick intermediate SiO_2 layer. In order to make these microdisks compatible with electrical injection, a pn-junction needs to be added around the active layers as well as two metal contacts, while preserving the quality of the laser resonator. In our design, the top metal contact is placed at the centre of the disk, where the optical intensity of the laser mode is very low, thus causing no extra absorption loss. The bottom contact is placed on a very thin semiconductor layer that extends laterally at the bottom of the microdisk (see figure 2). This bottom contact layer can cause optical leakage if it is too thick. However, a 3D FDTD analysis revealed that these structures can support whispering gallery modes with quality factors over 10000 for a 50nm-thick bottom contact layer, a disk diameter of 4µm and a total disk thickness of 0.5 or 1.0µm. The total disk thickness was increased to reduce optical absorption due

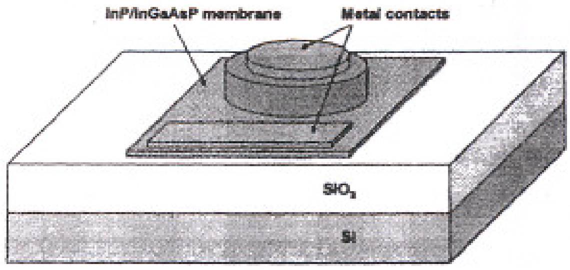

Figure 1. General layout of the membrane microdisk laser

This device had a coating of 2000 Å of SiO_2 on the top surface, which results in approximately 20% back reflection of 2 µm to 2.5 µm wavelength incident light. An anti-reflection (AR) coating can increase the responsivity and quantum efficiency of the device, as reported in [2].

In summary, we have demonstrated an InP based avalanche photodiode with response up to 2.4µm, using $Ga_{0.47}In_{0.53}As$-$GaAs_{0.51}Sb_{0.49}$ type-II quantum wells. The device achieved room temperature gain in excess of 30 and had type-II room temperature external quantum efficiency of 38% at 2.2 µm. This is the first reported InP-based avalanche photodiode with response past 2µm.

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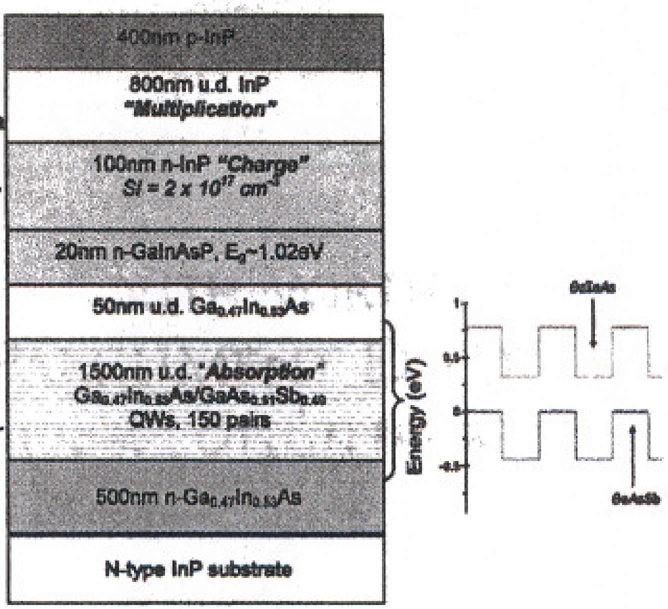

Figure 1. Schematics of the device structure and band line-up between GaInAs and GaAsSb

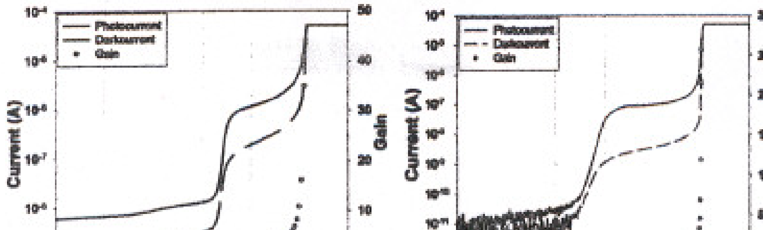

Figure 2. Reverse I-V and gain at room temperature (left), and 225K (right).

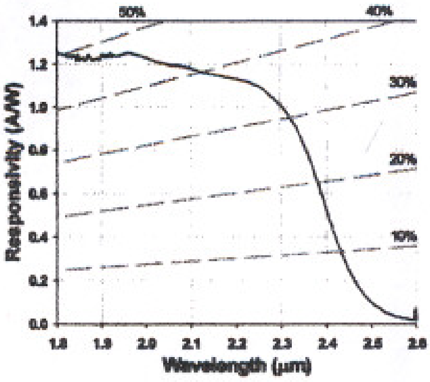

Figure 3. Room temperature responsivity measured at -37V bias. The diagonal lines (dashed) show the equivalent *unity gain* external quantum efficiency.

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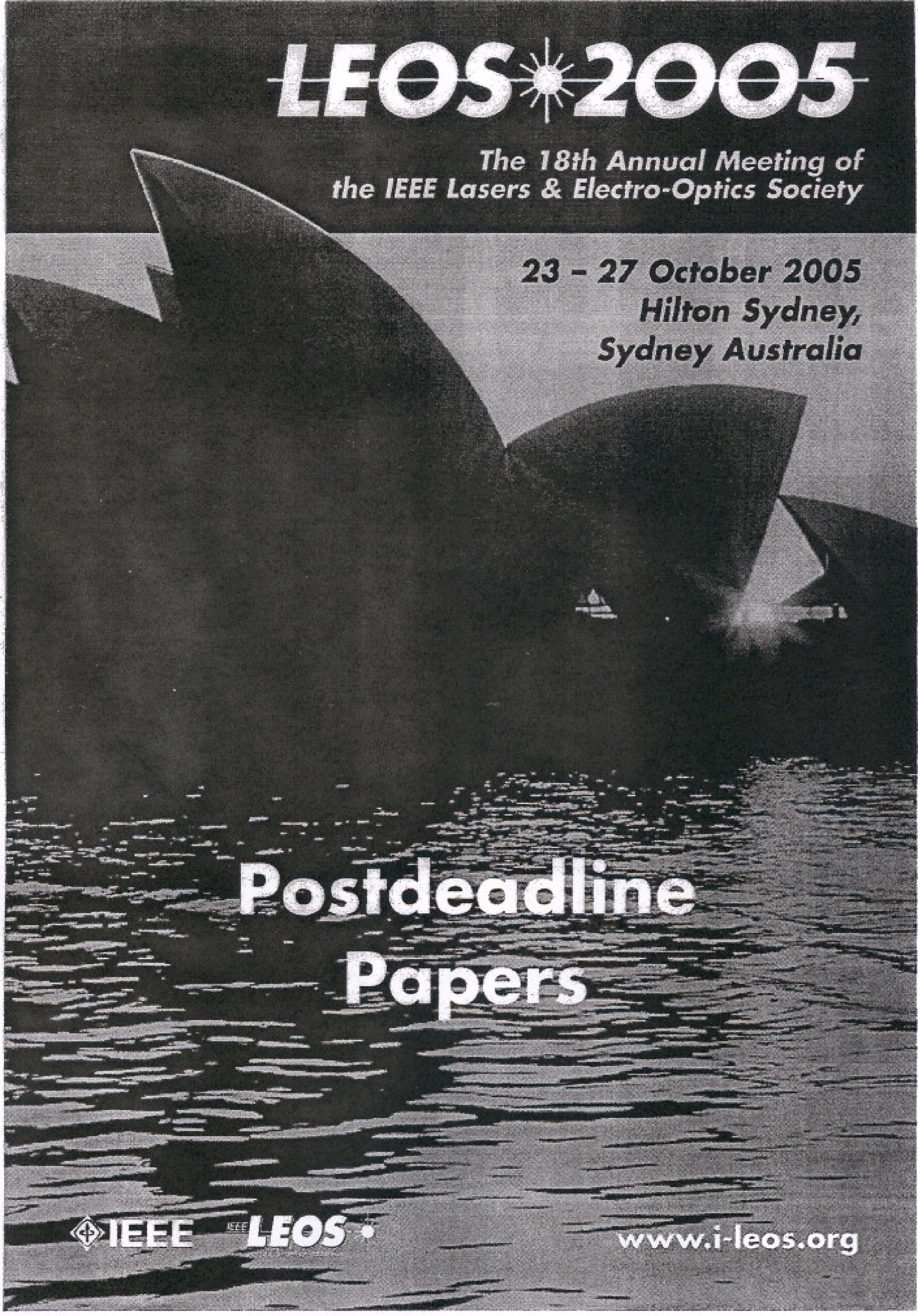

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