InP-based microlasers on silicon wafer : microdisks vs photonic crystal cavities

C. Monat, C. Seassal, P. Rojo-Romeo, X. Letartre, J. Brault, P. Regreny, M. Gendry, P. Viktorovitch, G. Hollinger
Laboratoire d'Electronique, Optoélectronique et Microsystèmes UMR CNRS 5512, Ecole Centrale de Lyon, 36, avenue Guy de Collongue, BP 163, F-69131 ECULLY Cedex, France

E. Jalaguier, S. Pocas, B. Aspar
LETI – CEA/Grenoble, Département de Microtechnologies
17, rue des Martyrs, F-38054 Grenoble Cedex 9, France

Highly compact microlasers integrated on silicon, emitting in the 1.3-1.6 µm range are important building blocks for future photonic integrated circuits that could be developed for applications such as optical interconnects. In-plane emission and low threshold are desired for these devices, to be compatible with dense photonic integration. To achieve this goal, structures such as microdisks [1-2] and 2D photonic crystal (PC) cavities [3] are currently developed. They can be exploited, with the benefit of small volume and high optical confinement. For the 1.3-1.6 µm wavelength range, they are based on InP and related materials.

In this paper, we will report on the feasibility of such InP laser micro-sources integrated on a silicon wafer. The basic integration procedure includes wafer scale InP transfer onto silicon via hydrophilic SiO_2-SiO_2 bonding [5] and conventional nanofabrication technologies.

Both InGaAs/InP quantum wells (QW) and self-organized InAs/InP quantum wires (QWi) heterostructures were transferred, in order to compare the effect of carrier confinement mode on light emission. The lateral optical confinement is provided either by a microdisk-like structure or by a 2D PC cavity. Vertical light confinement is achieved by the SiO_2 layers that surround the InP based heterostructure. This is an attractive alternative to air cladding in terms of thermal sinking and mechanical stability. The heterostructure itself is 250 nm thick and is therefore a monomode slab waveguide.

We have demonstrated CW room temperature operation on a 6µm diameter microdisk-like structure that includes 3 QW, under optical pumping (see fig 1 and 2). The emission wavelength is 1.6 µm and the effective threshold is around 850 µW. PC cavities are realized in a 2D triangular lattice of holes, where a few holes were omitted (figure 3). With a 550 nm lattice period and a 0.5 surface air filling factor, a photonic bandgap between 1.2 and 1.8 µm is achievable. As a preliminar result, spontaneous emission was measured and spectrally analyzed.

In summary, the integration of InP-based micro-lasers on a silicon wafer is demonstrated with a microdisk-like structure that comprises a Multi-QW. We are currently attempting to generate laser emission using 2D CP microcavities. We are also attempting to generate stimulated emission in devices containing a self-organized QWi heterostructure.

1- M. Fujita et al. : «Continuous wave lasing in GaInAsP microdisk injection laser with threshold current of 40 µA », Electron Lett., 2000, **36**, pp. 790-791

2- S.M.K. Thiyagarajan et al, « Continuous room temperature operation of optically pumped InGaAs/InGaAsP microdisk lasers », Electron Lett., 1998, **34**, pp. 2333-2334

3- C. Seassal et al, « InAs Quantum wires in InP-based microdisks: mode identification and CW room temperature laser operation », to be published in J. Appl. Phys.

4- O. Painter et al, « Two-dimensional photonic band-gap defect mode laser », Science, 1999, **284**, pp. 1819-21

5- C. Maleville et al, « Detailed characterization of wafer bonding mechanisms », Proc. 4th Int. Symp. On Semiconductor Wafer Bonding :Science, technology, and Applications, vol. 97-36, The Electrochem. Soc. Series, Pennington (1997), pp. 46-55

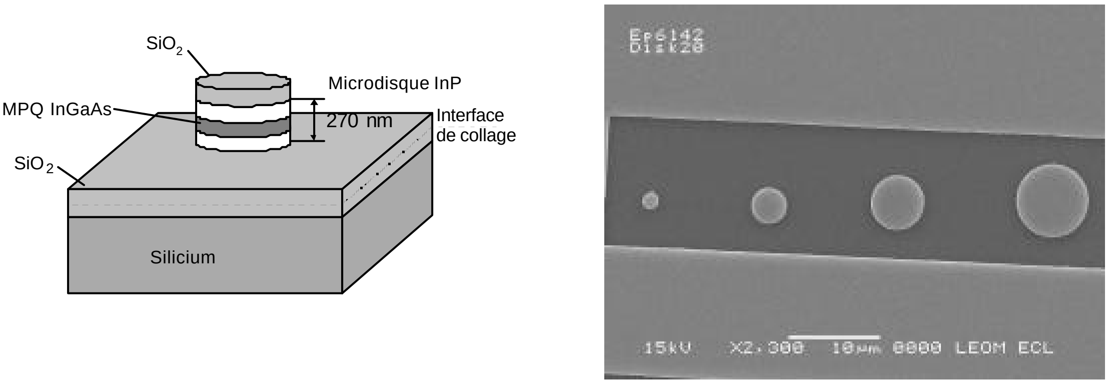

Fig 1: Schematic view (a) and scanning electron micrography (b) of the microdisk structure on Silicon

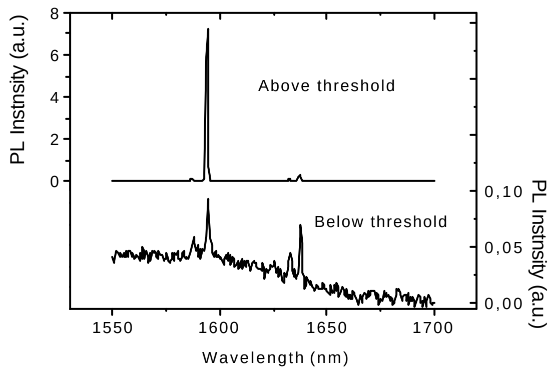

Fig 2: PL spectra of a 6 µm diameter microdisk structure above and below threshold

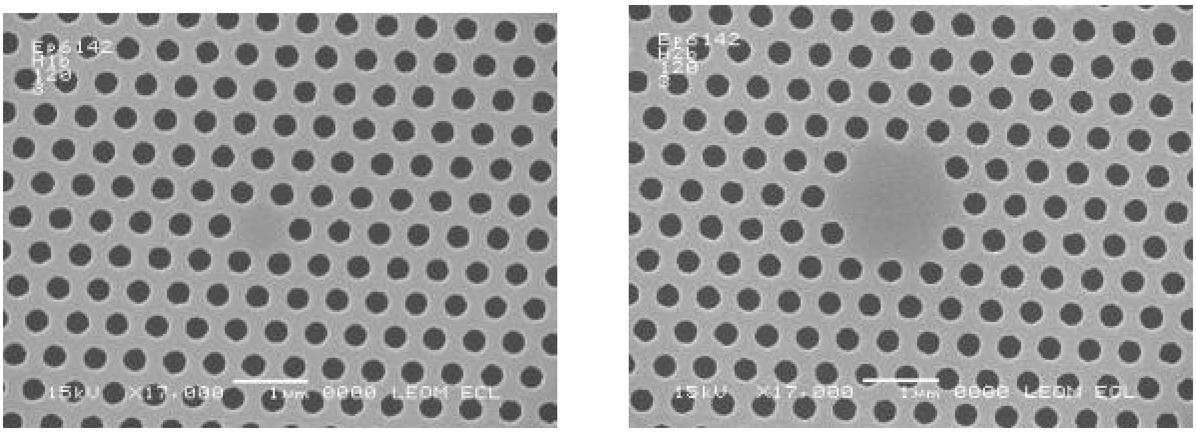

Fig 3: Scanning electron micrographs of 2D PC microcavities