Hybrid III-V laser on silicon wire

Y. Halioua[1,2], A. Bazin[1], P. Monnier[1], T.J. Karle[1], I. Sagnes, G. Roelkens[2], D. Van Thourout[2],F. Raineri[1], R. Raj[1]

[1]Laboratoire de Photonique et de Nanostructures (CNRS UPR20), Route de Nozay, 91460 Marcoussis, France
[2]Department of Information Technology, Photonics Research Group, Ghent University, B-9000 Ghent, Belgium

Abstract

We report low threshold laser emission from hybrid structure composed of III-V photonic crystal wire cavity bonded on top of a silicon wire. Lasing operation is demonstrated in the waveguide configuration.

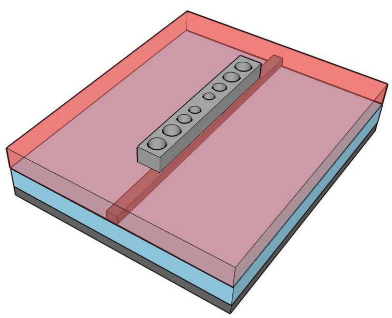

Figure 1: *Schematic view of the structure*

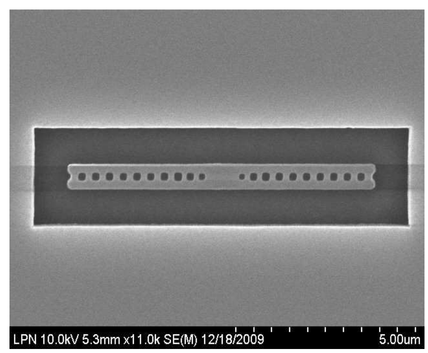

Figure 2: *MEB picture of the sample*

Recently there have been several theoretical studies and experimental demonstrations of small volume cavities based on a periodic line of holes in a waveguide. Even though this work began some time ago [1] it is only recently that impressive Q factors have been demonstrated which brings many of the predicted applications closer to reality. So far the work has been concentrated on passive functionalities in these sorts of structures. But the strong light confinement that is possible in these high Q low volume structures promise low laser thresholds. Further, the small foot print obtainable is extremely useful for high integrability. In this context, Silicon photonics is a rapidly developing platform for integrated optics. Combining the low-loss passive silicon photonic circuitry with III-V based active optical functionality, we can draw high benefits from both worlds. We have successfully fabricated a hybrid structure composed of III-V photonic crystal, made of a row of holes with a few missing holes in the center to form a cavity, which is bonded on top of a silicon wire. We obtained low threshold lasing and the emitted light is channeled through the silicon wire and coupled to a fibre.

We fabricated a platform consisting of two levels (Fig. 1) composed of SOI narrow waveguides (~500nm wide and ~220nm high) where the light propagates passively, and InP waveguide containing quantum wells. The light from the passive lower level couples in evanescently and interacts with the membrane to achieve lasing and the emitted light is then channeled out through the lower level. InP-based heterostructure is adhesively bonded to the SOI wires using the planarising polymer BCB. The success of the fabrication depends on the quality of the two parts and on the accuracy and the repeatability of the alignment of the PC structures with subjacent waveguides. The BCB thickness is set to be around 800nm in order to optimise the evanescent wave coupling without excessively degrading the Q of the cavity. Silicon waveguides are fabricated in a CMOS fab using 193nm DUV lithography on SOI, InP wafers are grown by MOCVD. Markers written on the mask level of the SOI waveguides allow us to align the electron beam lithography defined Photonic Crystal (PC) level, accurately to the Si waveguides. The PC is then patterned in the III-V membrane using reactive ion etching and inductively coupled plasma etching. Scanning electron microscopy measurements (Fig. 2) show that our PC waveguides are aligned bang on top of SOI wires with accuracies better than 30nm!

The structure is optically pumped from the surface at 800nm and the emitted light at 1.55µm is detected simultaneously from the surface of the PhC and at the output of the SOI wire. The detected light is sent to a cooled spectrometer for analysis. The results of the measurements are shown Fig. 3. As the design of the cavity is optimised for guided mode emission and it is seen in Fig. 4 (figure comparaison) that the guided emission is a factor of three higher than the vertical emission

In conclusion, we demonstrate lasing operation with fairly low thresholds. The reduction in size achieved point the way to the achievement of densely integrated waveguide structures for optical communication systems. Further, the direct coupling of the nanolasers in the guided wave configuration to the silicon waveguide renders them their incorporation in integrated optical platforms easy.

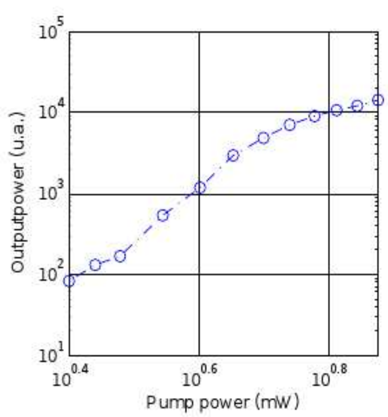

Figure 3: *Laser operation*

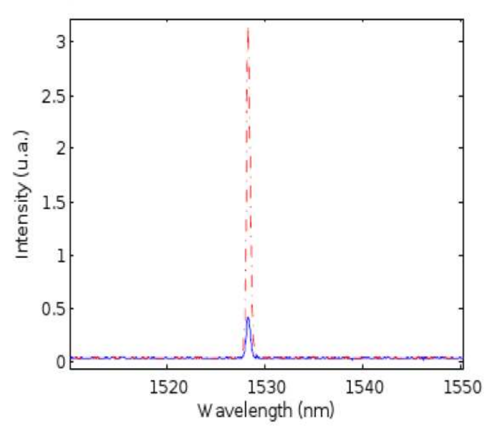

Figure 4: *Emission measured from top (blue) vs from wire (red)*

[1] Nature 390 (1997) 6656