Self-Assembled InAs Quantum Wires Lasers On InP(001)at 1.66 microns

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ABSTRACT

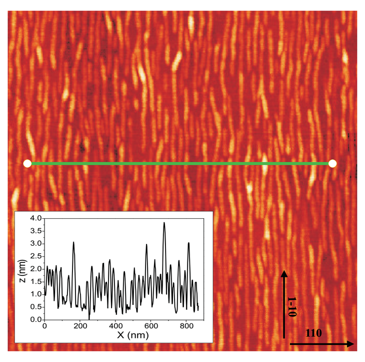
Self assembled wires on InP(001) nanostructures can potentially be used for the fabrication of lasers working at 1550 nm at Room Temperature.

We present initial structures working LASER DEVICES at temperatures as high as 250K. Laser structures with 1 and 3 stacked layers of self-assembled InAs quantum wires (QWR) in the active region and SPSL $(GaInAs)_4/(inP)_5$ as waveguide have been grown by molecular beam epitaxy (MBE) on InP(001) substrates.The QWR are formed after deposition of ~2 monolayers (ML) of InAs. The 20nm thick spacers between each layer of QWR are formed by the same SPSL used as waveguide. A control laser structure with three stacked layers of 7.5nm thick lattice matched GaInAs quantum wells has also been grown. PL measurements show emission associated with the QWR in the range 1370-2000 nm.

With these structures broad area lasers have been fabricated. The Laser devices have been characterized performing electroluminescence spectroscopy (EL) and light-current mesurements.The laser emission is observed a low temperature to 250K, with a density threshold current of 570 A/cm2 per wires layer.

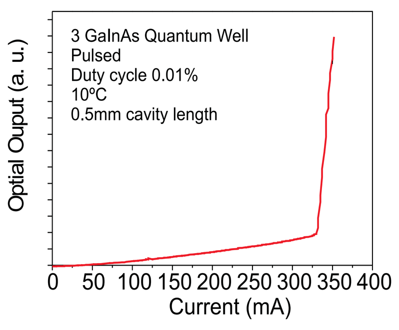
More optimiztions in the structures are necessaries to obtain laser emission a room temperature. To optimize the optical properties of the laser waveguide, we calculate the optical confinement factor as a function of the number of periods of $(GaInAs)_x/(InP)_y$ with different x and y values. Also, we calculate the energy minibands of this superlattices in order to study the confinement of the carriers into the QWR.

Motivation: Wires with 1.55 micron emission at RT

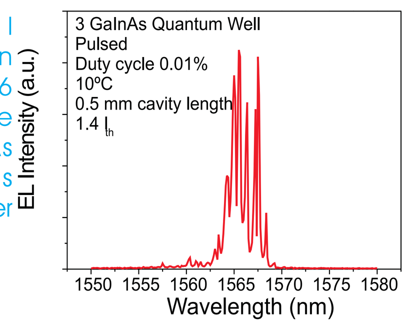


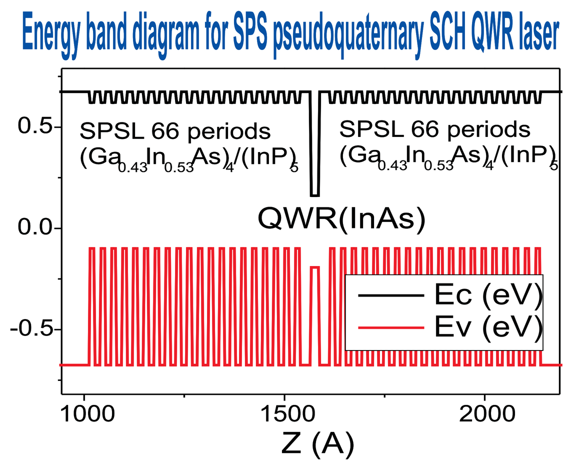
Multiquantum well of GaInAs laser on InP (001)

Light-current characteristic at 10ºC of a three stacked GaInAs Quantum wells broad area laser. The threshold current is 542A/cm² per well



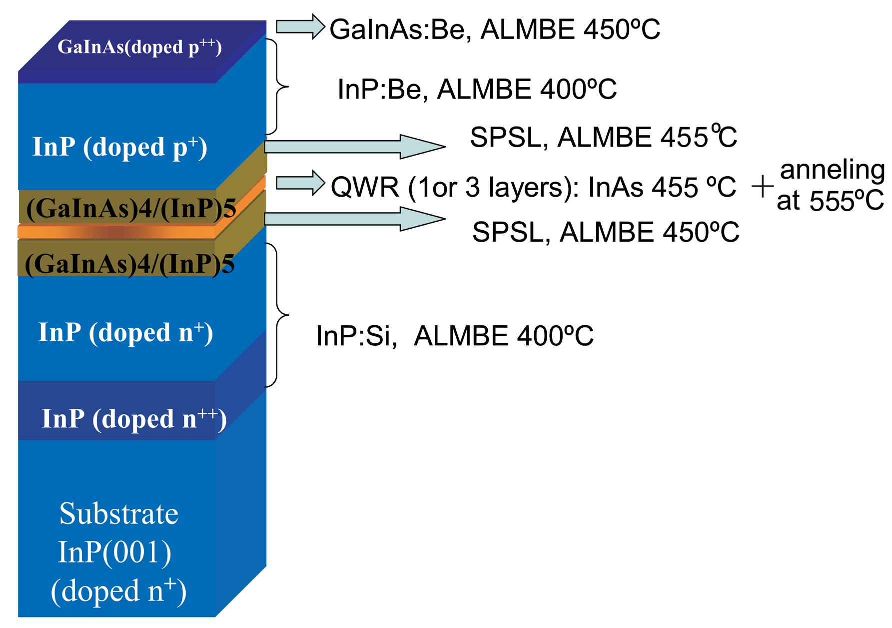
Multimodal stimulated emission centered at ~1,566 micron of a three stacked GaInAs quantum wells (7.5nm width) laser structure at I=1.4 Ith.



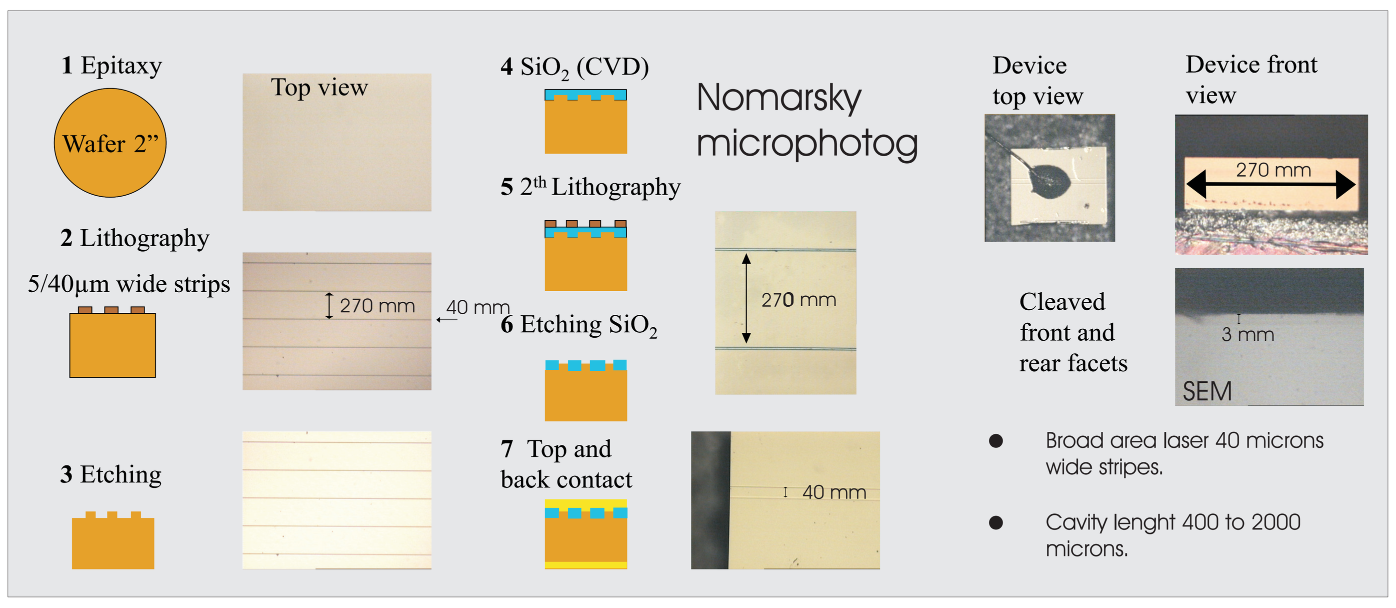


GROWTH

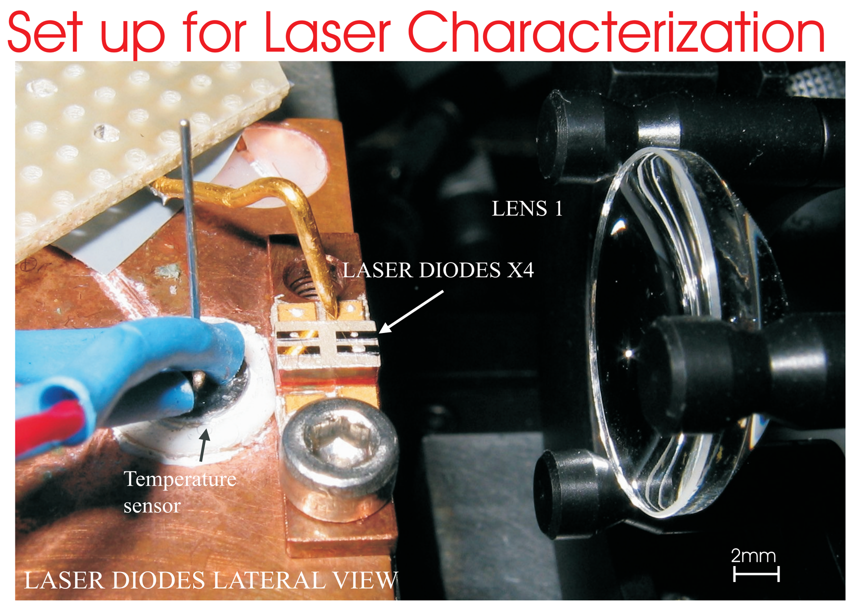
Laser structures are grown on S-doped (100)InP substrate by ALMBE at low temperature. Single or three satcked layers of QWrs are grown in the active region, and the waveguide is made of $(InP)_5/(Ga_{0.45}In_{0.53}As)_4$ superlattices (100 nm at each side of the QWrs). These layers are not doped. The InP cladding layers (1 micron each) are Si doped ($n=1x10^{18}$ cm^{-3}) and Be doped ($p=1x10^{18}cm^{-3}$). A 50 nm thick $Ga_{0.47}In_{0.53}As$:Be cap layer is grown on top of the whole structure. The use of short period superlattices (SPSL) can conveniently replace conventional $Ga_xIn_{1-x}As_yP_{1-y}$ alloy in the waveguide. The substrate temperature is optimized for each layer: claddings (InP) are grown at 400ºC, waveguides at 455 ºC and 2.3 ML of InAs at 455ºC on the last InP layer of the SPSL. The wires are formed during an annealing at 555ºC under As_4 flux , until the 2D/3D transition is observed (~1 minute) in the RHEED pattern.



DEVICE PROCESSING TECHNOLOGY



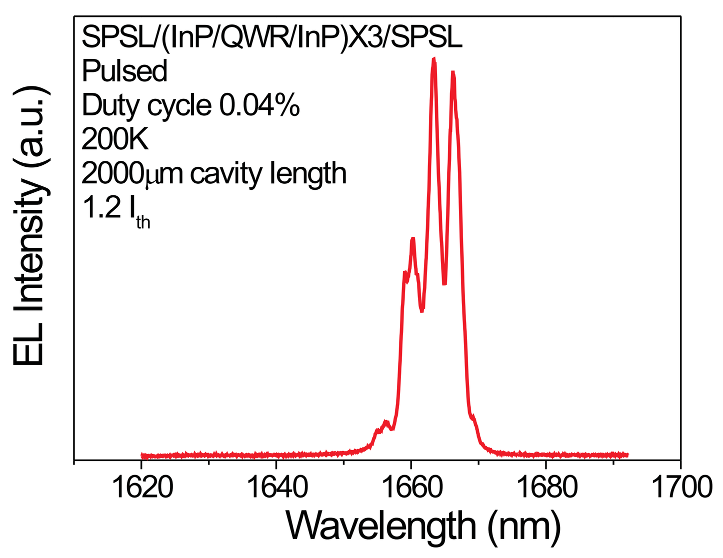
Set up for Laser Characterization



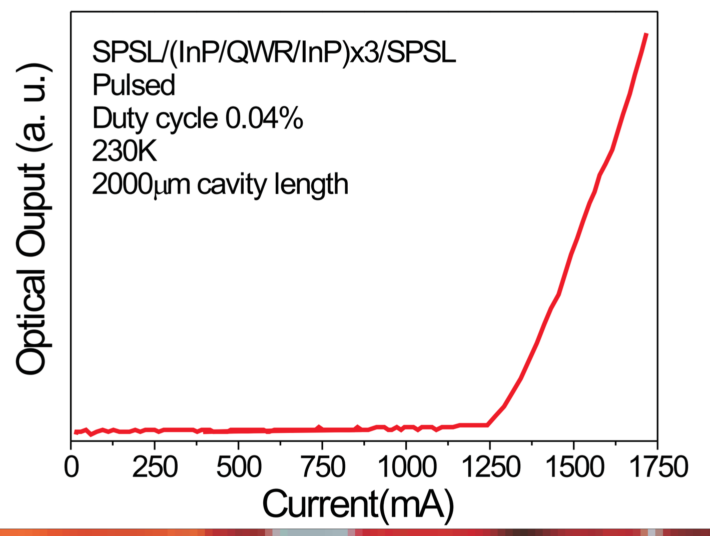
CHARACTERIZATION AT LT

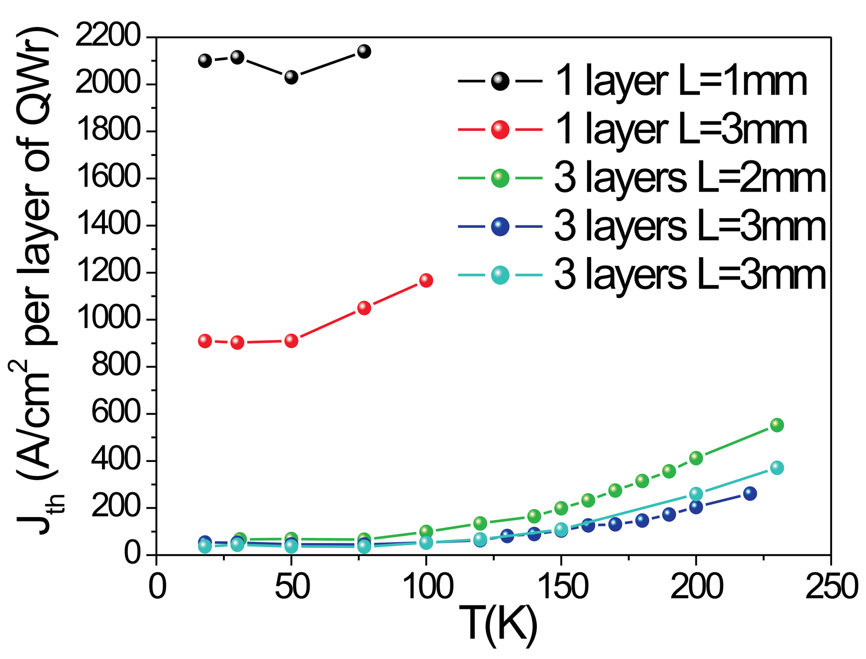
Three stacked QWR layers Laser

Multrimodal stimulated emission at 200K of a three stacked QWR layers laser structure at I=1.2Ith.



Light-current characteristic of a three stacked QWR layers Laser structure at 230K. The threshold current is 553A/cm² per wire layer.

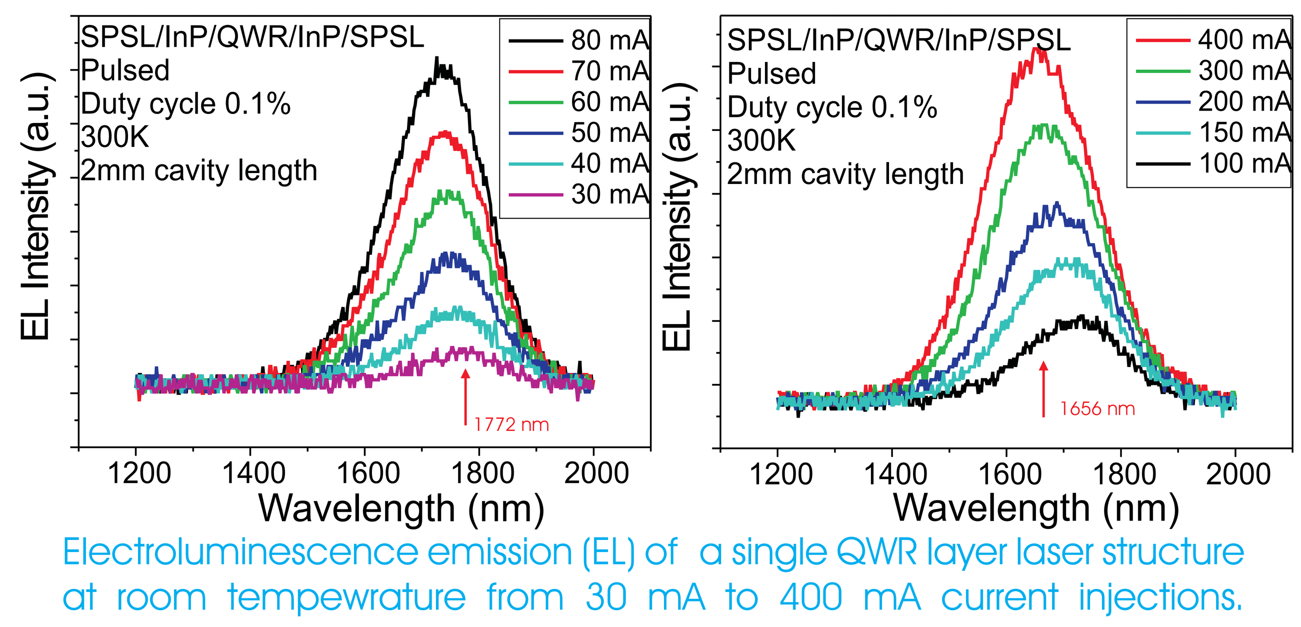




Current density (Jth) vs temperature of a 1 and 3 stacked QWR layers laser structures, with cavity length (L) of 3, 2 and 1 mm.

CHARACTERIZATION AT RT

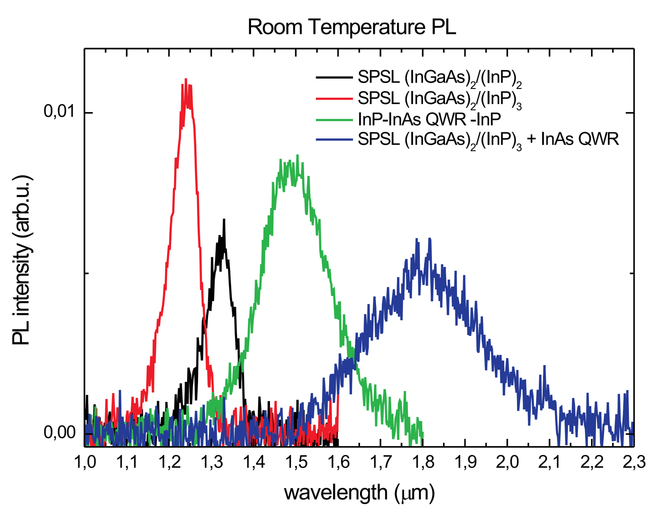
Single QWR layer laser



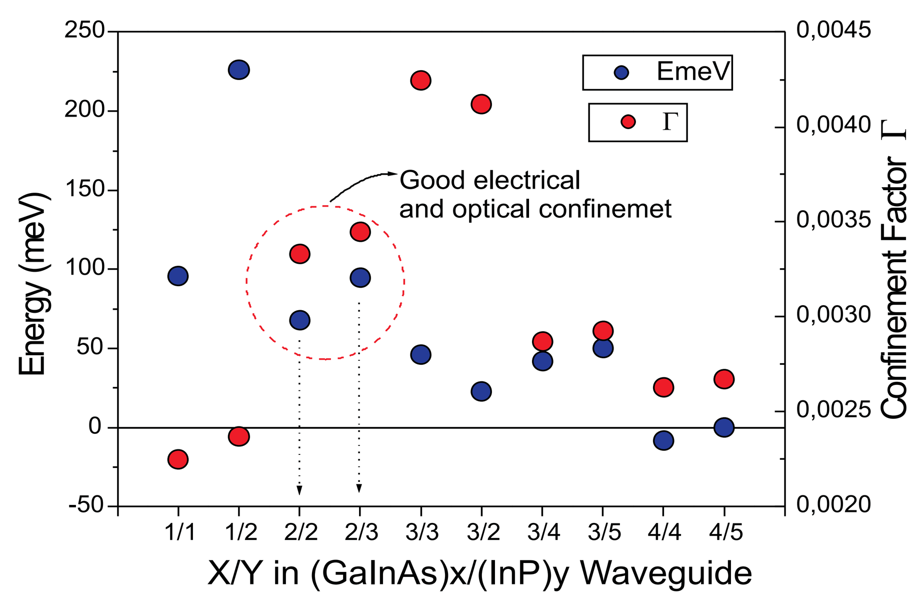
Electroluminescence emission (EL) of a single QWR layer laser structure at room tempewrature from 30 mA to 400 mA current injections. Increasing the current the peak towards blue due to the size distribution inhomogenity of the QWR .The EL peak appear in coincidence with the PL Peak at low injection currents. The same behaviour is observed in the 3 layer QWR lasers.

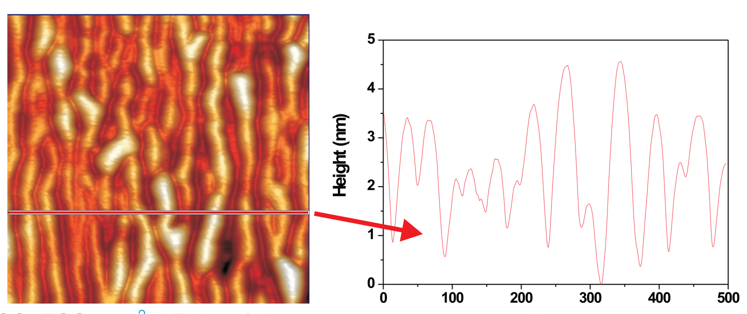
OPTIMIZATION OF ELECTRICAL AND OPTICAL

If we want to optimize both electrical and optical confinement the superlattices periods 2/2 or 2/3 are the best choices. We have grown theses superlattices and we are studing the optical and morphology properties. Also QWRs have been grown on these superlattices, and the first results shows big QWRs with a PL emission at 1.8 microns



PL spectra of superlattices 2/2 and 2/3 at room temperature. Also, PL emission of SPSL waveguide with QWRs as active zone and other InP waveguide with QWRs to compare.





500x500 nm² AFM of the QWR grown on a SPSL 2/3

CONCLUSIONS

- $(GaInAs)_4/(InP)_5$ have a poor electrical confinement to the levels of QWRS. At room temperature the scape of carriers makes difficult to obtained laser emission.
- Size distribution inhomogenity are revealed with increasing the inyections currents.
- The periods of superlattices 2/2 and 2/3 optimize both optical and electrical confinement.
- These superlattices have been grown to obtain a good optical quality and morphology.
- The QWRs formed on 2/3 superlattices show a PL peak centered at longer wavelength than on InP. PL intensity is similar in both cases, showing an improvement in the electrical confinement.
- In the future the PL emission will be tuned controlling the size and the composition of the QWR. It is necessary to form wires more small or/and to design higher barriers.

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