HIGH POWER 1100-nm InGaAs/GaAs QUANTUM DOT LASERS

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OUTLINE

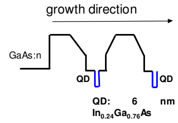
- Why high power near infrared quantum dot (QD) lasers
- Study of the laser active region
- Laser design
- QD laser characteristics
- Conclusions

Why high power near infrared quantum dot lasers

- Lack of appropriate green high power light-emitting devices for display applications
- A possible approach is frequency doubling of near infrared 1060-1100 nm high power semiconductor lasers.
- Besides beam quality, the application of frequency doubling for green light generation is especially demanding regarding output power and temperature stability.
- Up to now quantum well lasers dominate the high-power semiconductor lasers available in this wavelength region.
- Lasers using self-assembled quantum dots as gain material have been proved suitable for high power applications due to their distinct advantages over quantum well lasers in terms of reduced threshold current density, temperature sensitivity of the threshold current and emission wavelength with temperature as well as reduced mirror degradation [1]

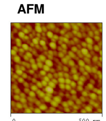
Study of the laser active region: AFM, SEM

TEST-QD



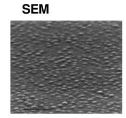
Two layers of QDs, grown in similar conditions as the dots used in our laser, one layer being embedded in cladding-like GaAs/$Al_{0.33}Ga_{0.67}$As barriers and the other, grown on top being uncapped.

AFM



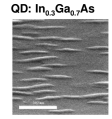
6.4×10^{10} cm^{-2}

SEM



7.2×10^{10} cm^{-2}

SEM
QD: $In_{0.3}Ga_{0.7}As$

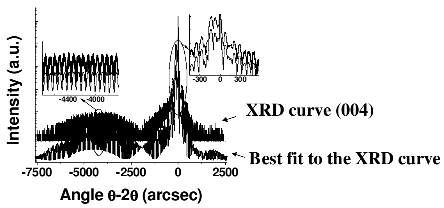


dashed dots [2]

- QDs with high surface density
- round-shape dots despite low In content [2] ⟶ the use of As_2 instead of As_4 [3].

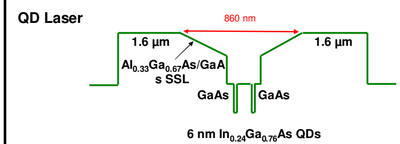
[2] A. Lo¨ffler et al. / Journal of Crystal Growth 286 (2006) 6–10
[3] C. Gilfert, E.-M. Pavelescu and J.-P. Reithmaier/ Appl. Phys. Lett., vol. 96, pp. 191903, 2010.

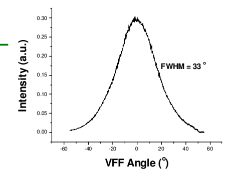
Study of the laser active region: XRD



Best fit obtained assuming a thick, 4.8 nm, wetting layer of $In_{0.28}Ga_{0.72}As$

Laser Design

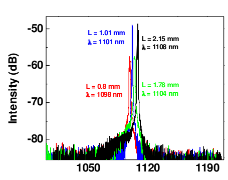


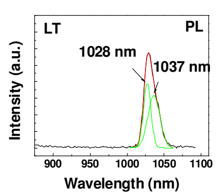


GRINSCH design: - active region (2 QDs layers),
- a LOC (800 nm) waveguide made of $GaAs/Al_{0.33}Ga_{0.67}As$ SSL
- thick $Al_{0.33}Ga_{0.67}As$ claddings

The design aimed at obtaining a vertical far field (VFF) angle at full width half maximum (FWHM) around 40°

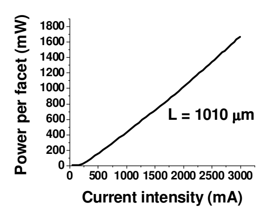
Laser Results: Broad area lasers





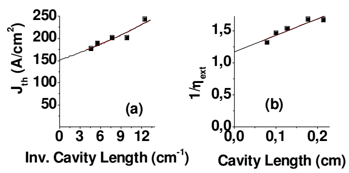
- lasing wavelengths near 1100 nm (pulsed current) from broad area (BA) lasers (100 µm) with different lengths
- close to the expected wavelength for the RT photoluminescence (PL) recorded from the laser structure
- the laser operates on the ground state emission.

Laser Results: Broad area lasers



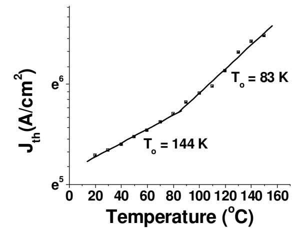
- High slope efficiency > 0.77 W/A (η_d = 68 %)
- High total output power > 3.2 W (limited by the current source)

Laser Results: Broad area lasers



- high internal quantum efficiency, η_i, of 86 %,
- low internal absorption, α_i, of 2.7 cm^{-1}
- high modal gain coefficient Γg_0 of 68 cm^{-1}
- low transparency current density of the active material of 119 A/cm^2

Laser Results: Broad area lasers



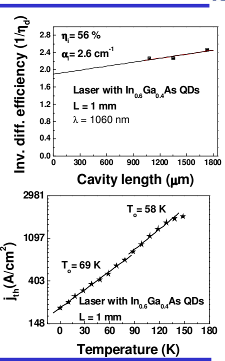
High characteristic temperatures (T_o) of 144 K (20-80 °C) and 84 K (90-150 °C).

Laser Results: Broad area laser

The high η_i and T_o are most likely due to the thick wetting layer of the QDs by comparison with a laser with *similar design* with 1.8 nm $In_{0.6}Ga_{0.4}As$ QDs emitting at 1060 nm whose wetting layer has a thickness of around 1 nm [4].

thick layer – improved carrier collection

The direct connection between the dots and the wetting layer helps relaxation of the collected carriers to the QD ground states, preventing them to occupy the excited states in the QD and the cladding/barrier layers



Conclusions

- High power 1100 nm InGaAs QD laser with low In content realized for the first time.
- The laser consists of a GRINSCH design (an active region - a LOC waveguide made of $GaAs/Al_{0.33}Ga_{0.67}As$ SSL - $Al_{0.33}Ga_{0.67}As$ claddings)
- The active region is made of 2 layers of high density round shape QDs obtained by MBE deposition of 6.03 nm $In_{0.24}Ga_{0.76}As$ material under As_2 environment. The dots have a thick wetting layer of 4.5 nm.
- A high output power > 3.2 W, a high internal efficiency of 85 % and high characteristic temperature of 144 K (20-80 °C) could be obtained for a BA laser of 1mm length (100 µm width) in pulsed current.
- The high performances of the QD laser are most likely due to the thicker wetting layer by comparison with a QD laser with similar design (emitting at a close wavelength) but with $In_{0.6}Ga_{0.4}As$ QDs which have thinner wetting layer.

Acknowledgement

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MIMOMEMS

Thank you for your kind attention