MIDAS : Multiplexed infrared diodes for absorption spectroscopy P2N 2011

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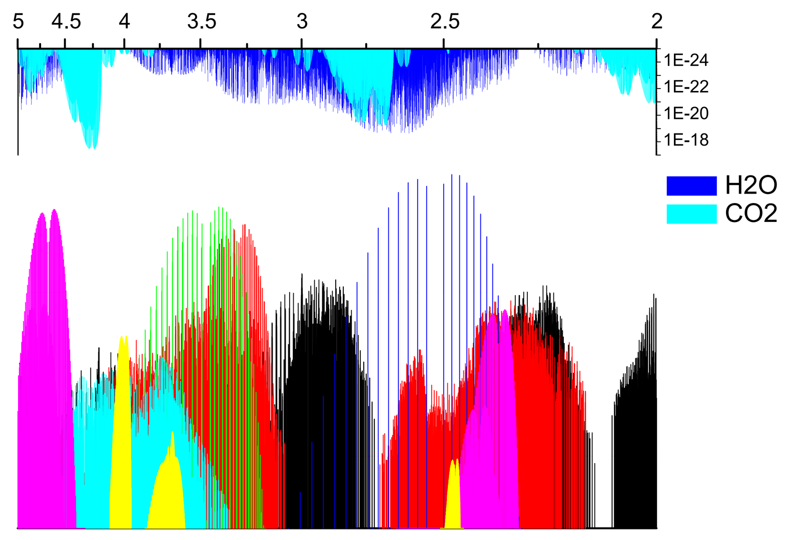
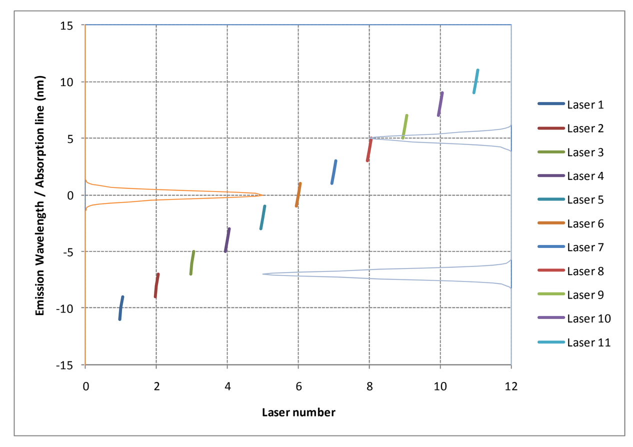
Motivations

The mid-IR wavelength range extending from 2 to 5 µm exhibits several transparency windows (around 2.3 µm and from 3.4 to 4 µm) where absorption by water vapor and carbon dioxide is very weak. In these regions, the detection of other gaseous molecules in the atmosphere can be carried out without interferences. Absorption lines of gaseous molecules are more intense at high wavelengths. For example, CH_4 absorption at 3.26 µm is a factor of 40 stronger than at 2.31 µm and 200 times stronger than at 1.65 µm. As a consequence, the 2-5 µm range is a range of choice for spectroscopy. It gives access to many applications going from pollutants detection in the neighborhood of industries or vehicles (CH_4, CO, CO_2, HCl), control of industrial processes (NH_3, HF), isotopic ratio measurement of water (HDO/H_2O) for paleoclimatilogy or tool for medical diagnostic (CO_2). For these applications, the usual approach is tunable diode laser absorption spectroscopy (TDLAS) that requires one single-frequency tunable laser covering the entire range of interest. TDLAS has proven extremely efficient in many wavelength regions, and many laser developments have been driven by that sole application. However, in the 2-5 µm range, developing a laser source fulfilling all the requirements of TDLAS remains a challenge. It is especially hard to obtain both stable single-mode emission and a wide enough tunability range. Here, we propose an alternative that relies on an array of tunable single-frequency lasers with emission wavelengths evenly spread across the range of interest. This method of multiplexed tunable diode laser absorption spectroscopy (MTDLAS) will grant access to a wide spectral range by combining several lasers offering medium tuning ranges. It is the purpose of this project to develop such an integrated array.

To realize this array, we plan to use an optimization scheme for all photonic crystal 2nd order DFB lasers [Larrue PTL 2008, Larrue JSTQE 2011], combining an affine deformation of the PhC with a waveguide width fine tuning. This optimization scheme has already been used on GaAs optically pumped lasers to demonstrate the fabrication of arrays of single-mode lasers, the fabrication of arrays with closely spaced emission wavelengths. Furthermore, it allowed the fabrication of single-mode laser array with high robustness towards optical feedback. 3D FDTD Simulations of infinitely long defect PhC waveguides show the evolution of DFB modes properties as a function of both design parameters namely defect and affine deformations. As shown on figure 5 quality factors in excess of 600 000 can be theoretically achieved for the 1st DFB mode, while keeping the quality factor of the 2nd DFB mode one order of magnitude lower. This ensures both low losses for the 1st DFB mode and a high modal selection resulting in stable, robust single-mode emission on the 1st DFB mode. More interestingly, this high Q area corresponds to a smooth area for emission reduced frequency, so lasers arrays with both high Q and smooth wavelength variations from laser to laser can be designed.



Absorption lines strength from 2 to 5 µm (from HITRAN database)

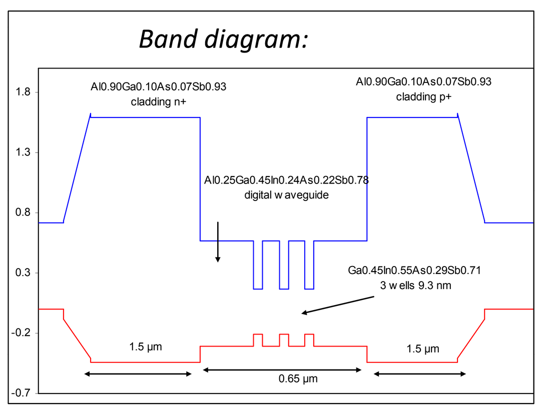


Principle of spectrometry using a single mode lasers array

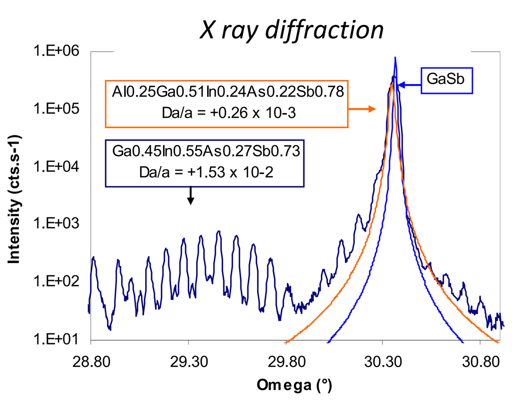
First Results

Laser structures for λ = 3.3 µm emission

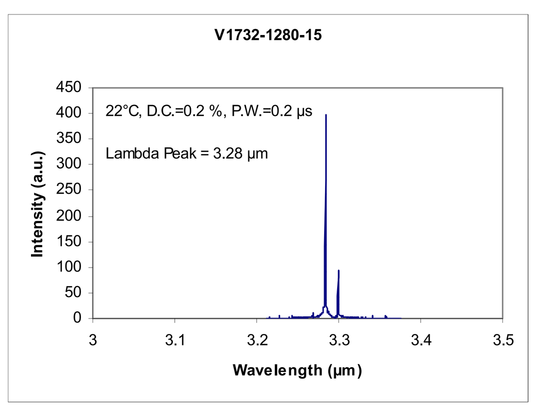
The laser structures are based on the GaSb technology which is the only semiconductor technology covering the whole mid-IR wavelength range. GaInAsSb/AlGa(In)AsSb quantum well structures are grown by molecular-beam epitaxy at IES (Institut d'Electronique du Sud, UMR CNRS 5214), in Montpellier University



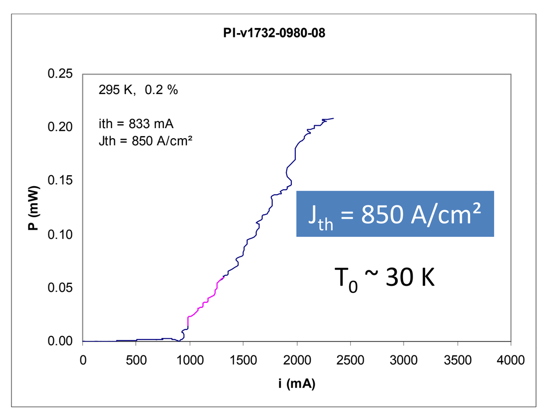
QWs and waveguide made of digital alloys



Strain less waveguide of quinary material



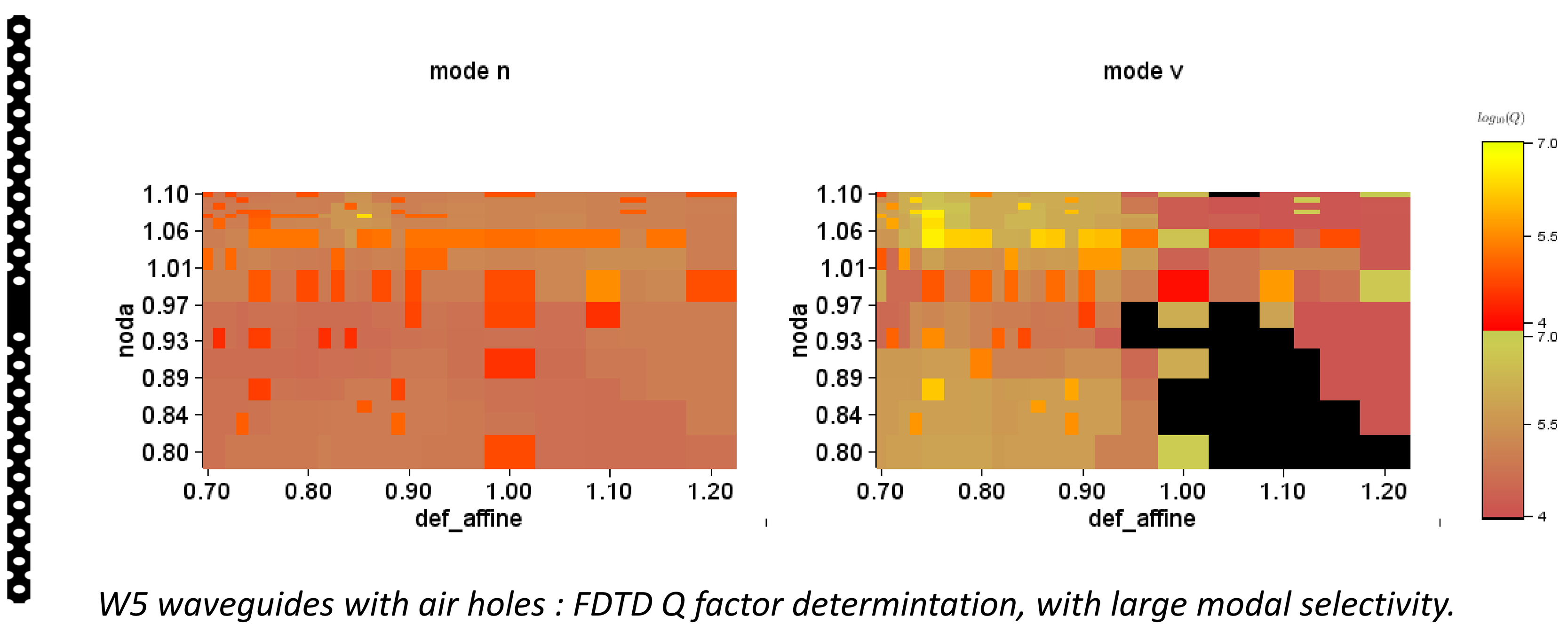
Optical emission spectrum (pulsed, 22°C)



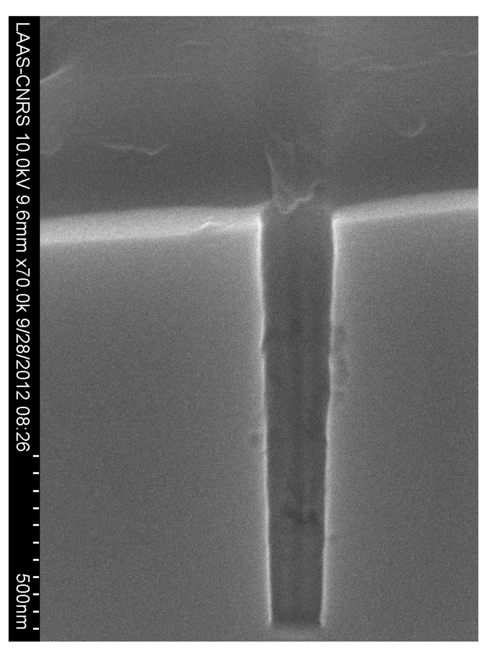
Light current curves (pulsed, 22°C)

Waveguides design and fabrication

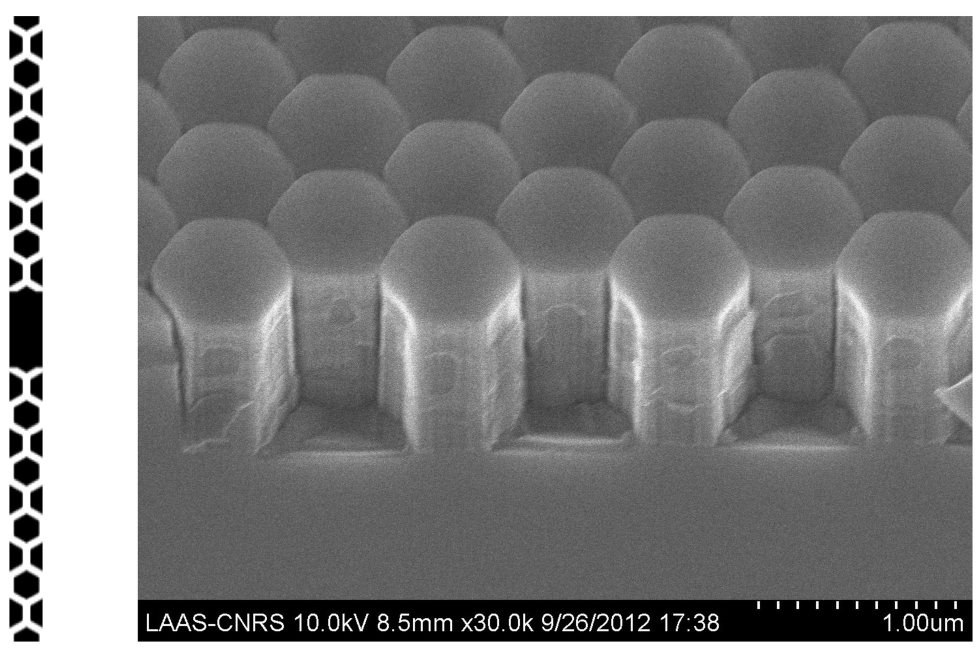
For electrical pumping, large waveguides are prefered as compared to W3 waveguides already demonstrated under optical pumping.
Theoretical investigations are then carried out to optimize W5 waveguides.
In parallel, investigations are ongoing to check the feasability of trenches based W5 waveguides, since this kind of features are easier to fabricate.



W5 waveguides with air holes : FDTD Q factor determintation, with large modal selectivity.



SEM image of deeply etched air hole in GaAs



Hexagonal lattice of trenches : first realisation in GaAs

Bibliography and acknowledgements

[Larrue PTL 2008] : A. Larrue et al., Precise frequency spacing in photonic crystal DFB laser arrays, IEEE Phot. Tech. Lett., 20 (24), pp 2120-2122, 2008.
[Larrue JSTQE 2011] : A. Larrue& al., All photonic crystal DFB lasers robust towards optical feedback, IEEE JSTQE, 17, pp1236 (2011)
Acknowledgments : FDTD calculations are carried out using MEEP software from MIT, on CALMIP cluster

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