Centre d'Electronique et de Micro-optoélectronique de Montpellier

ANTIMONIDE BASED LASER DIODES IN THE 2 - 2.7 µm WAVELENGTH RANGE

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GLADIS

Nanosystems and Technologies GmbH nanoplus

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

LPN

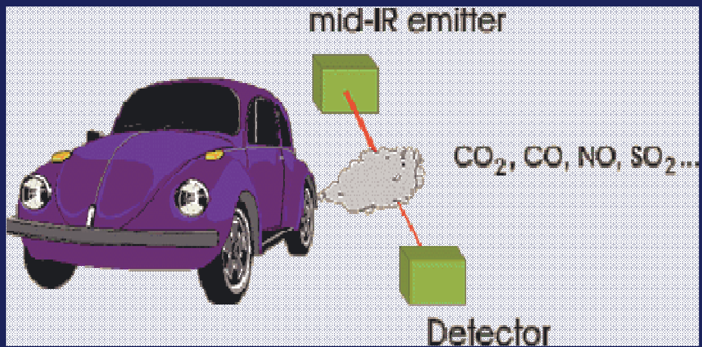
RTB

Outline

CEM2 : Antimonide based **lasers** and **detectors**

- Wavelength ranges : 2 – 2.7 µm edge emitting quantum well (DFB or not) lasers diodes
- 2.3 µm VCSLs and VECSLs
- 3.5, 4.5, 6.5 µm quantum cascade lasers

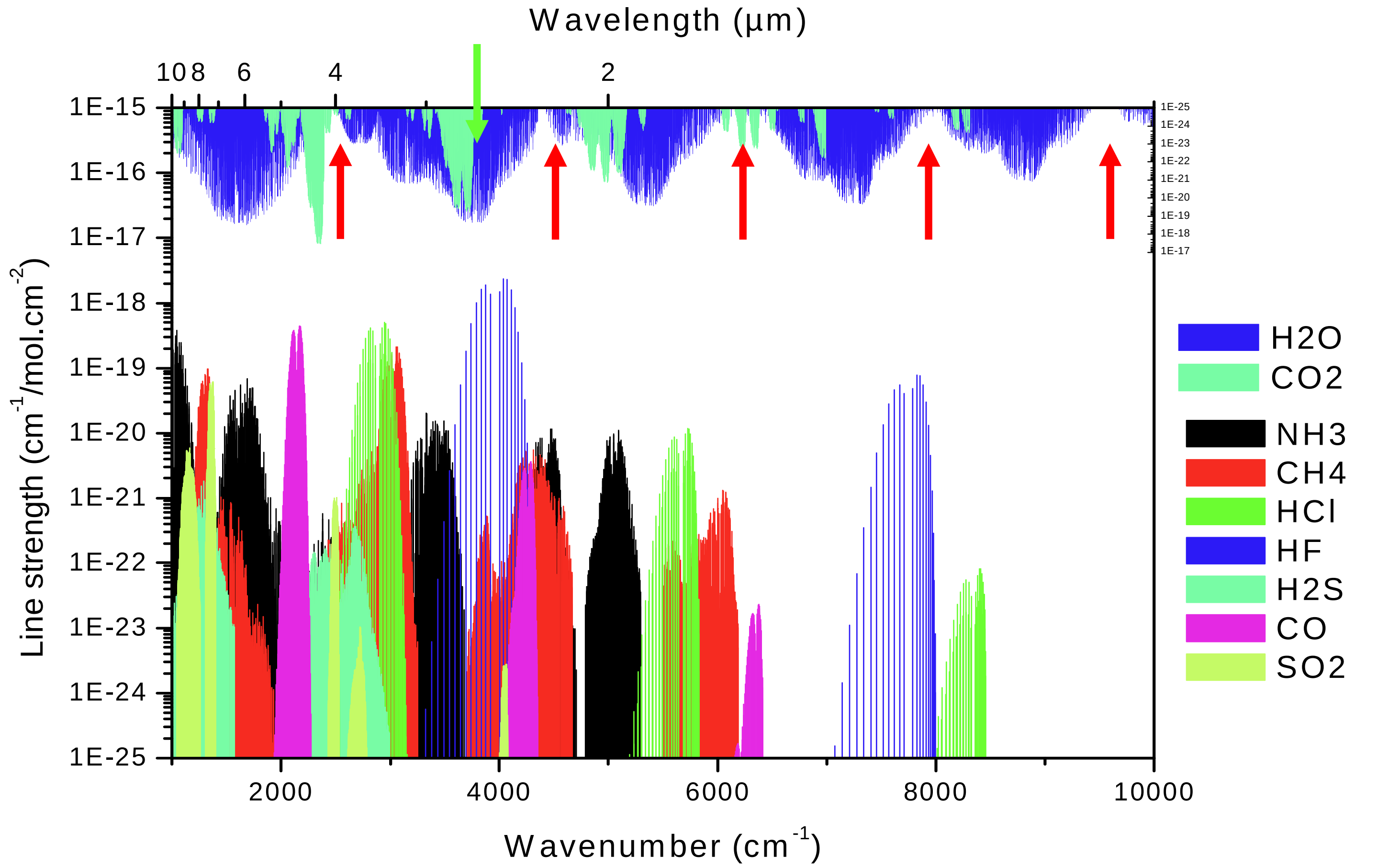
For :
- Tunable diode laser absorption spectroscopy (WMS, photo-acoustic, ICLAS…)
- Conter measures
- Free Space communications



- **TDLAS and spectroscopy**
- **Antimonide based lasers**
- **DFB process**
- **Results 2 – 2.7 µm**

TDLAS and spectroscopy

Line strengths of different species, HITRAN 96 modelisation

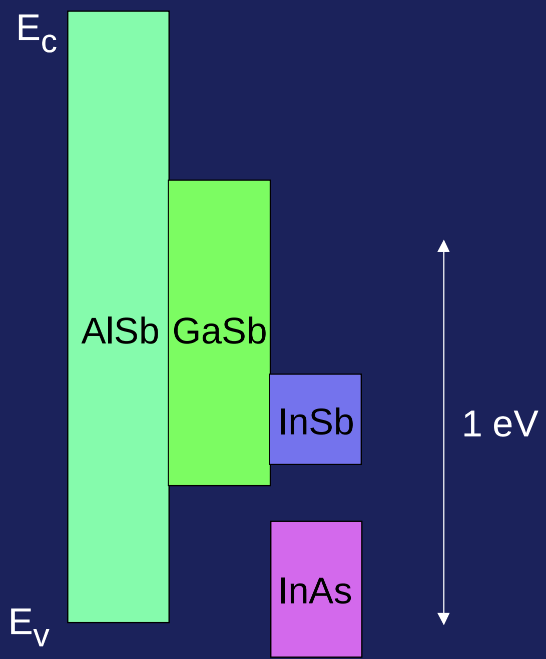


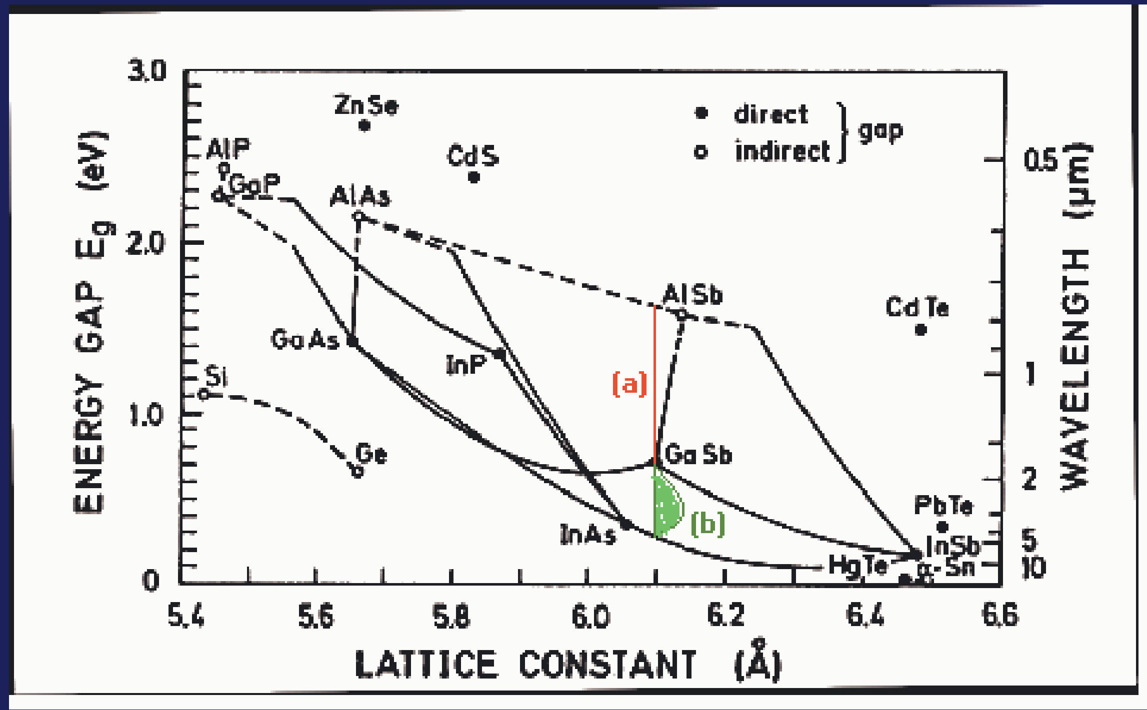
L.S. Rothman *et al*,*J. of Quantitative Spectroscopy & Radiative Transfer 82 (2003) 5–44*

Air transmission windows :

λ = 0.85 µm ; 1.0 µm ; 1.2 µm ; 1.6 µm ; 2.3 µm ; 4.0 µm ; 10.4 µm

Antimonide based lasers

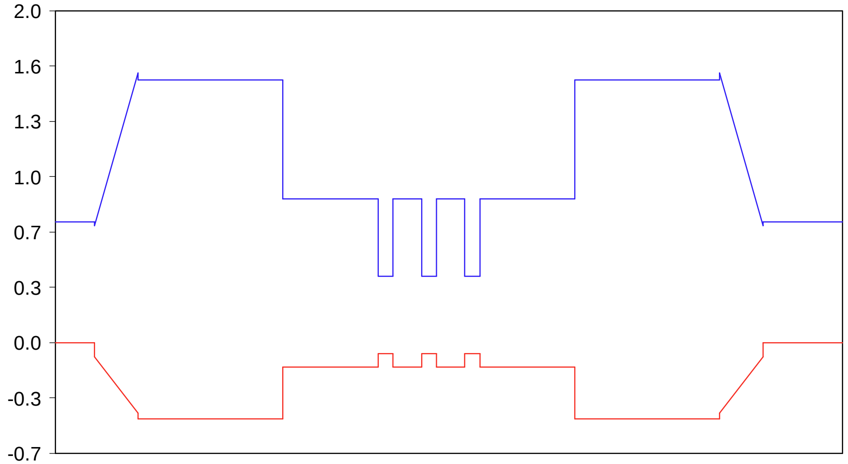


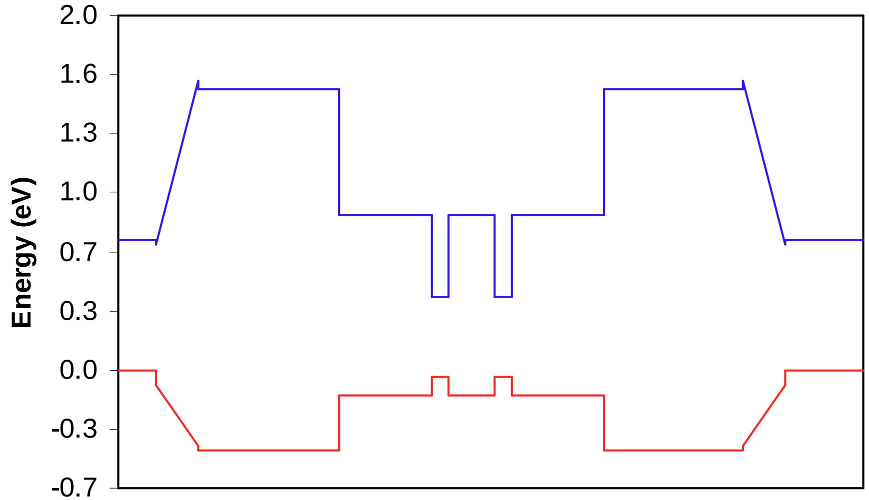


- 1.8 - 4µm spectral range can be covered
- GaAlAsSb lattice matched to GaSb for cladding layers
- Type-I or type-II band alignment for GaInAsSb QW with GaAlAsSb barriers
- High refractive index

→ **Band gap engineering**

Two laser structures for emission at 2.38 µm or 2.6 µm





2 claddings $Al_{0.90}Ga_{0.10}As_{0.08}Sb_{0.92}$ (1.5 µm)
. N-doped (2x10^{18} cm^{-3})
. P-doped (5x10^{17} cm^{-3} & 5x10^{18} cm^{-3})
1 waveguide $Al_{0.25}Ga_{0.75}As_{0.02}Sb_{0.98}$ (0.9 µm)
3 quantum wells $Ga_{0.64}In_{0.36}As_{0.13}Sb_{0.87}$ (11 nm)

2 claddings $Al_{0.90}Ga_{0.10}As_{0.08}Sb_{0.92}$ (0.9 µm)
. N-doped (2x10^{18} cm^{-3})
. P-doped (5x10^{17} cm^{-3} & 5x10^{18} cm^{-3})
1 waveguide $Al_{0.25}Ga_{0.75}As_{0.02}Sb_{0.98}$ (0.9 µm)
2 quantum wells $Ga_{0.64}In_{0.41}As_{0.08}Sb_{0.92}$ (14 nm)

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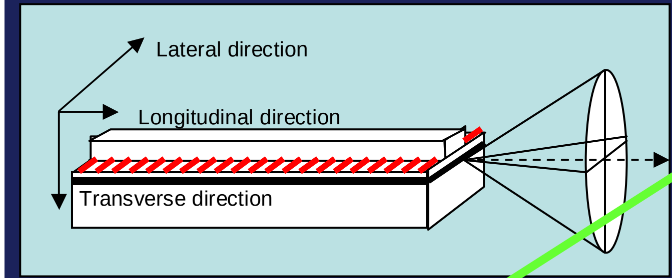
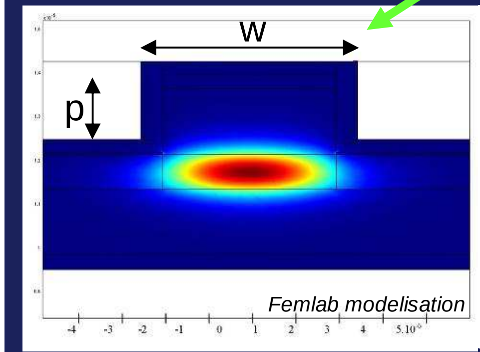
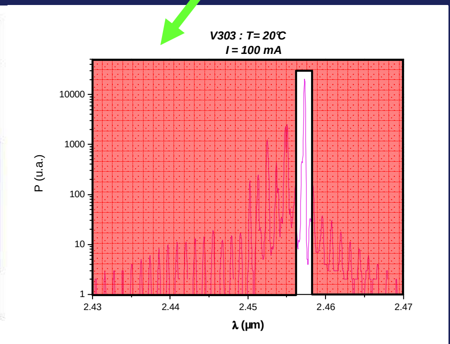
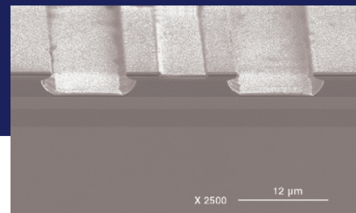
Single frequency emission



- ✓ **Transverse direction** : d active zone < 1µm → monomode
- ✓ **Lateral direction** : calculation of **w (**edched ridge) and **p(** etch depth) → monomode
- ✓ **Longitudinal direction** : need a spectral filter to get single frequency emission

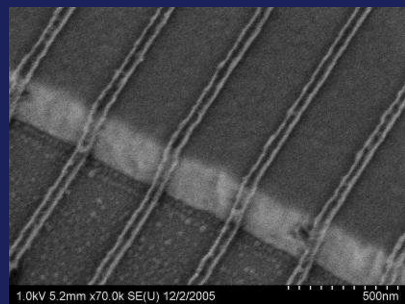






CEM2 process: wet etching,
- ✓ Mature and well adapted
- ✓ No spectral filter (or accident !)
- ✓ Isotropic etching → no vertical sidewalls

Solutions ?
- ✓ Coupled cavities (C3 lasers)
- ✓ External cavities – grating coupling
- ✓ Multi-sections lasers - DBR
- ✓ DFB



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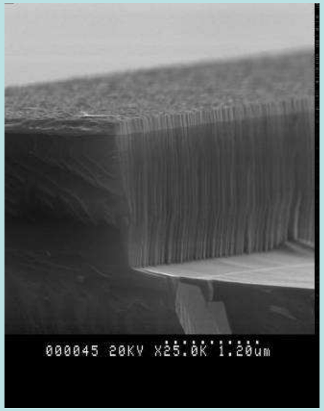
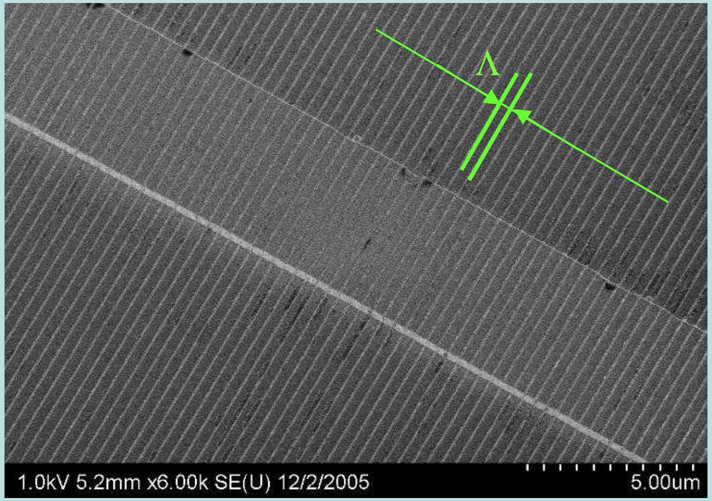
DFB process, $\lambda = 2.65$ µm

A collaboration with : cnes (Centre National d'Études Spatiales), LPN, RTB

Study and realisation of DFB antimonide based lasers

- ✓ Complete developpement of a technological process
- ✓ Lateral coupling* → Complex coupling of the evanescent part of the guided mode
- ✓ No regrowth needed
- ✓ RIE or ICP dry etching → vertical side walls
- ✓ 1^{st} order (k=1) Cr grating deposition on each side of the ridge

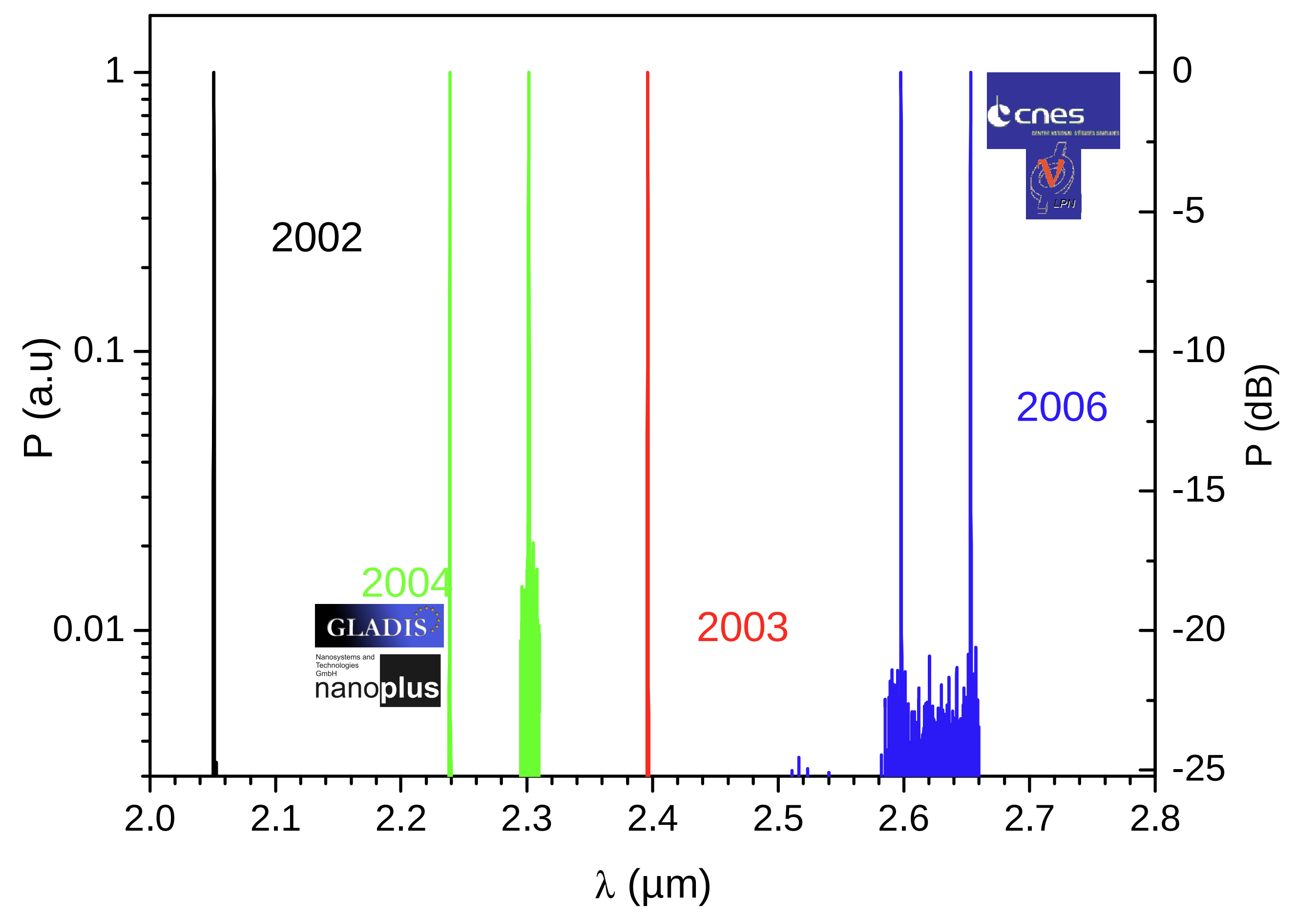




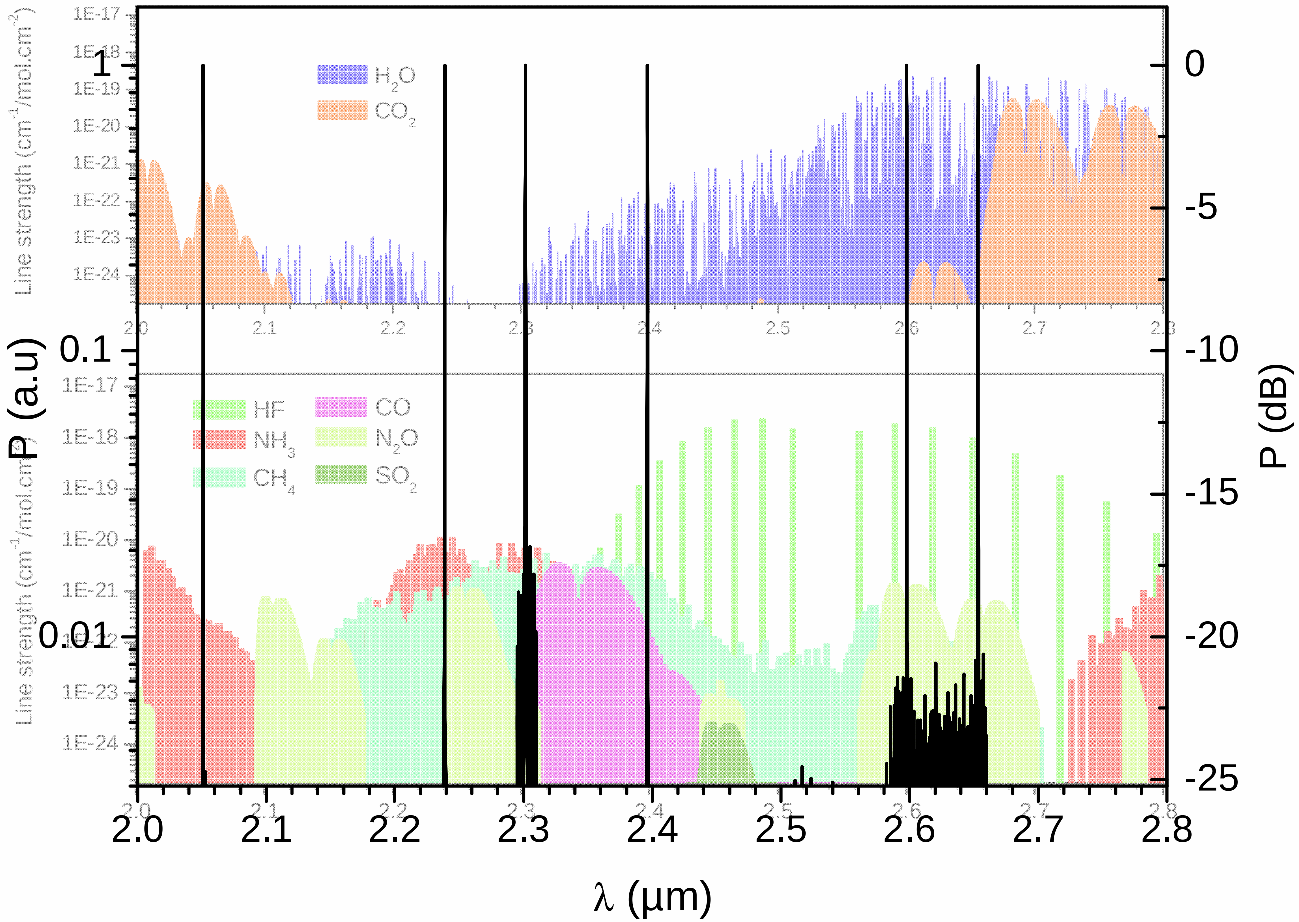
$$\Lambda = \frac{k \cdot \lambda}{2 \cdot n_{eff}}$$

* M. Kamp *et al. Optical Materials,* ***17****(1-2) (2001) pp. 19-25*

Results 2 – 2.7 µm

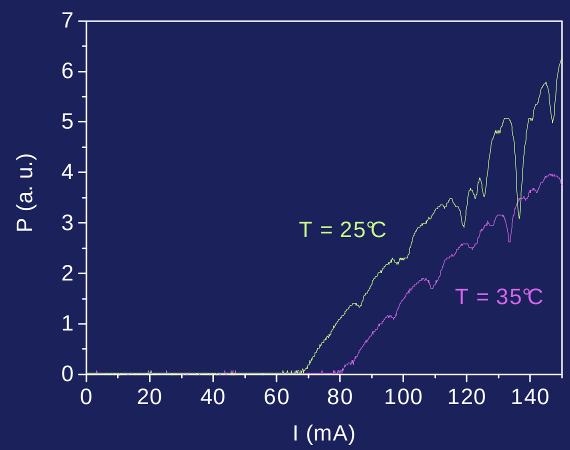


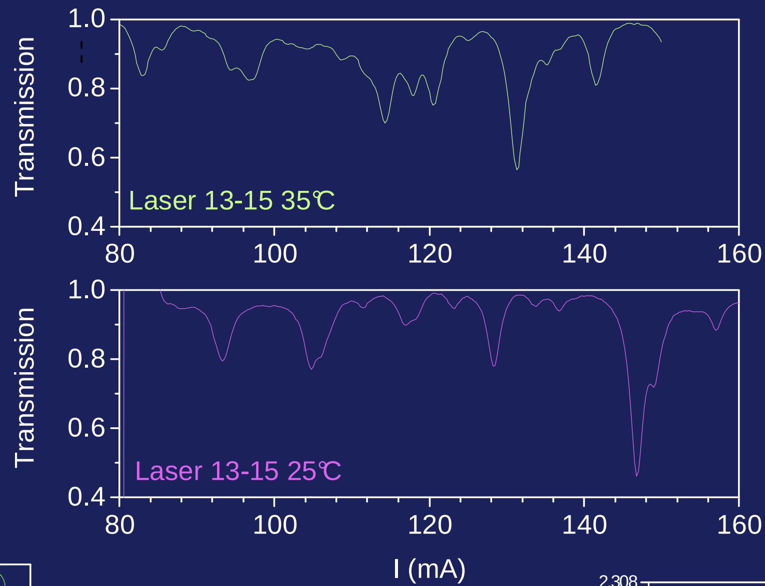
Results 2 – 2.7 µm

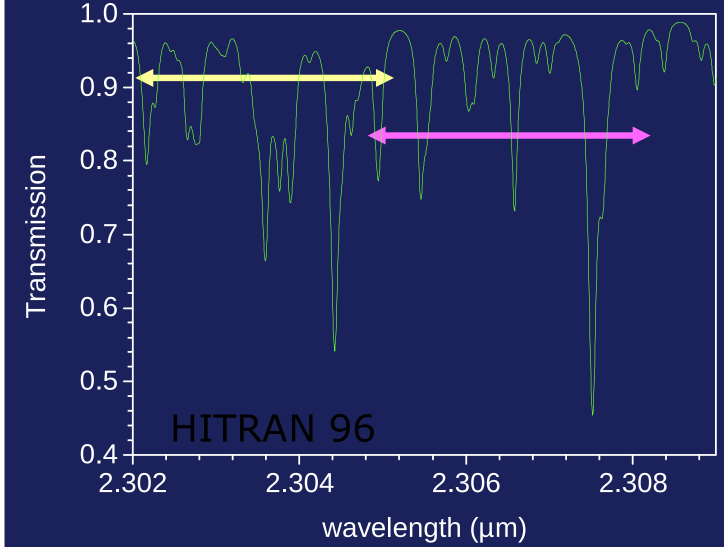


Many wavelengths between 2 and 2.7 µm – many gazeous species

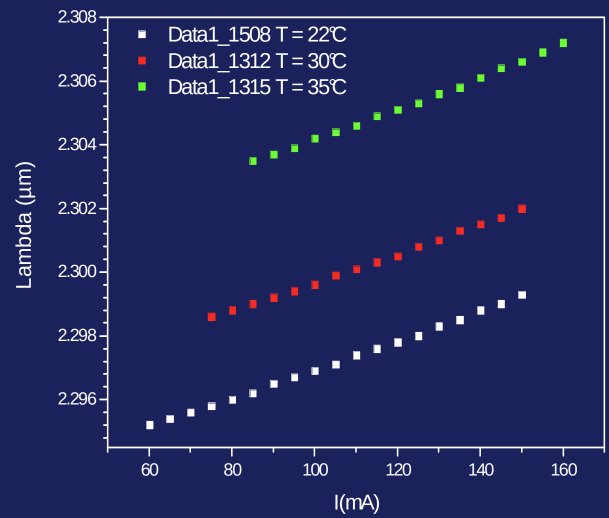
CH_4 absorption measurements, laser 13-15 (DFB)







More than 7 nm continuous with the same laser diode !



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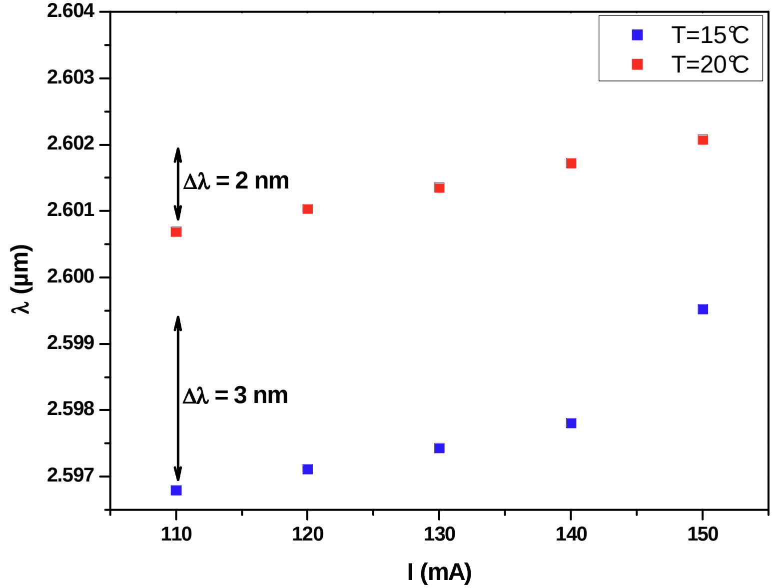
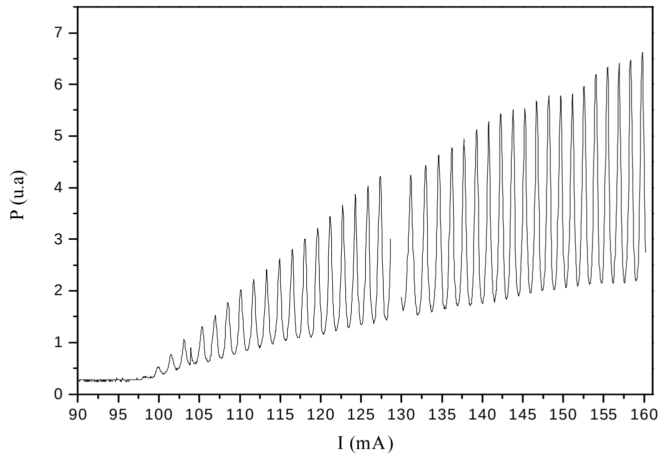
λ = 2.6 µm

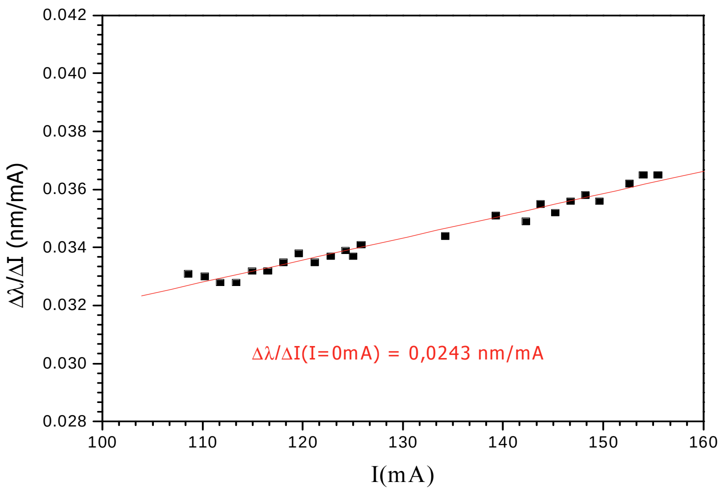
Results 2 – 2.7 µm



Diode DFB n°3



Diode down DFB n°3

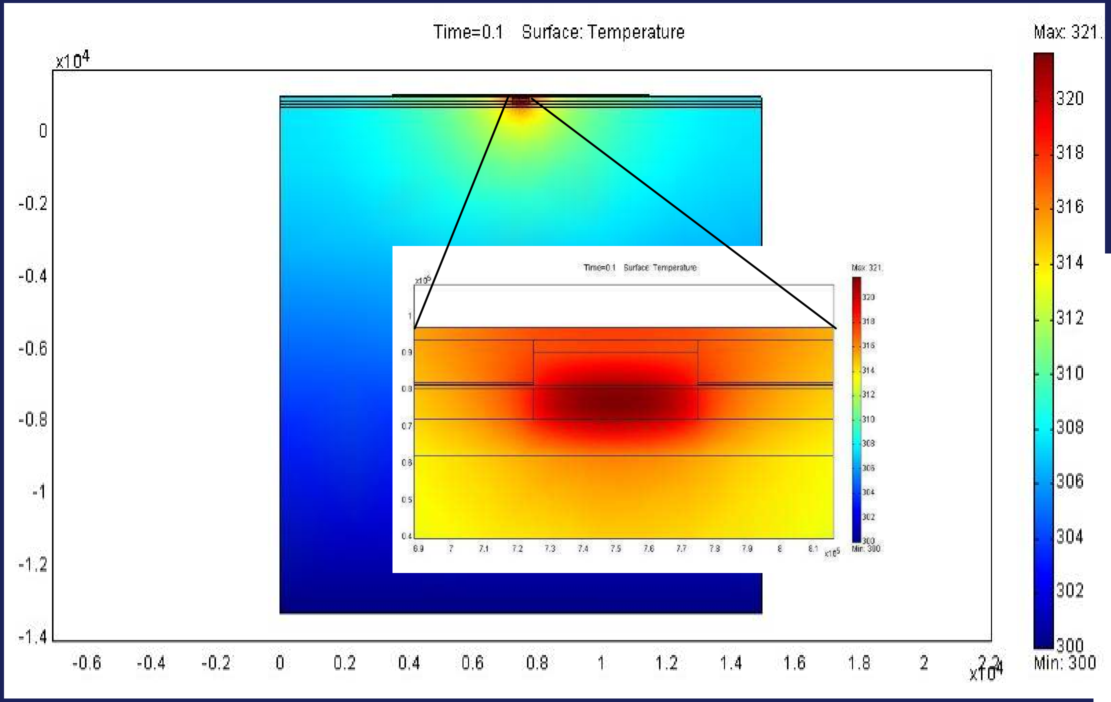


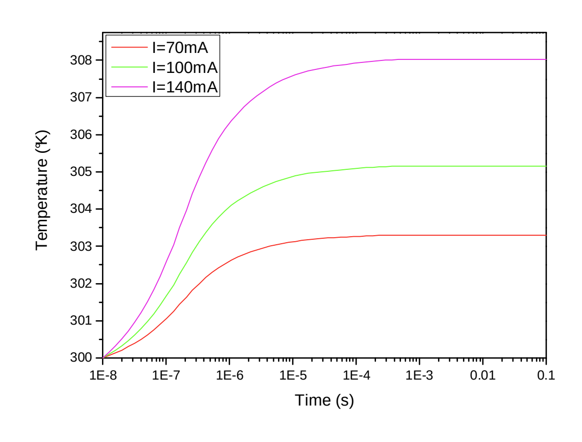
Results 2 – 2.7 µm

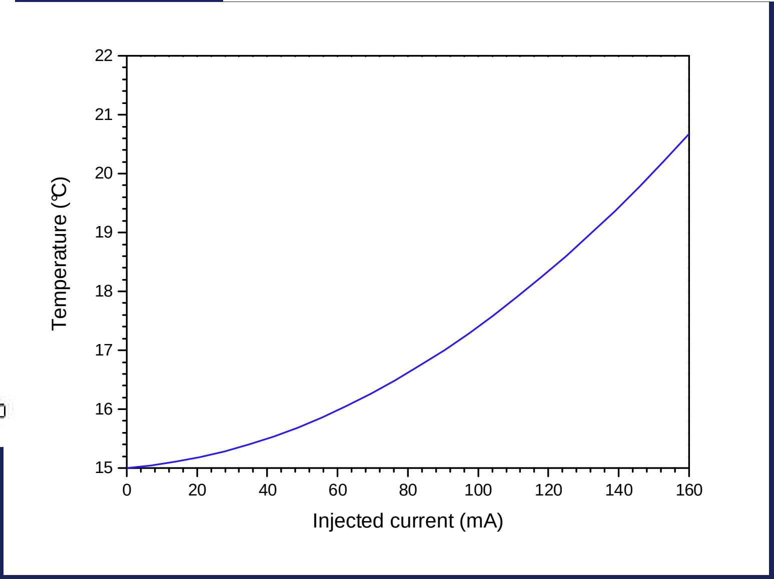
Tuning properties : mainly **thermal** effects

T↗, n_{eff} ↗, λ ↗

Give acces to thermal resistance : R_{th} $T_{laser} = T_{header} + R_{th}.P_{th}$



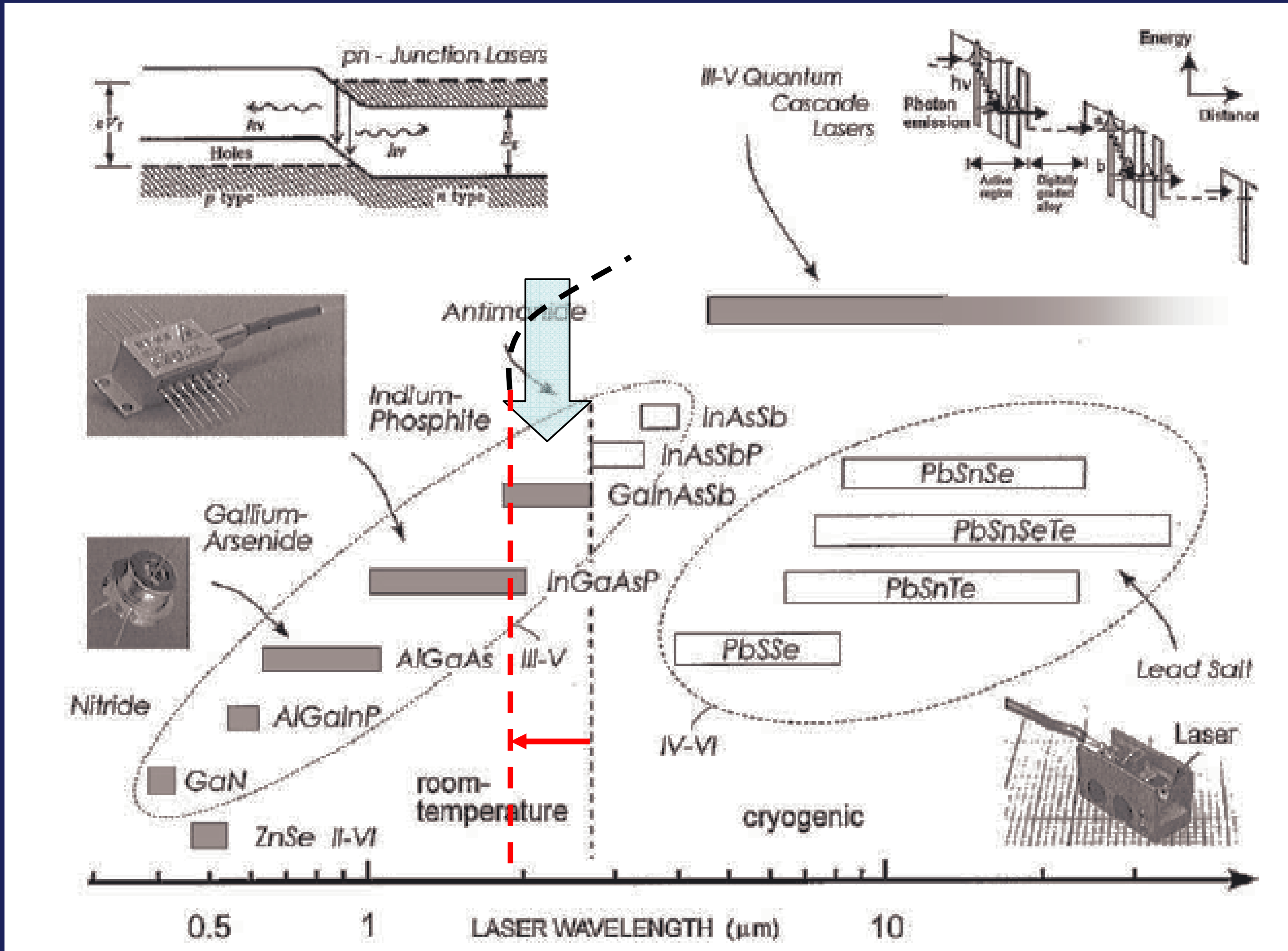




Results 2 – 2.7 µm

- ✓ Laser regime Cw and RT
- ✓ Low threshold current (< 40 mA)
- ✓ Laser linewidth = few MHz
- ✓ Temperature tuning rate (1 mode) = 0.2 nm/K
- ✓ Current tuning rate (1 mode) = 0.04 nm/mA
- ✓ High SMSR (> 25dB)
- ✓ Measured life time = 15000 h

Antimonide based lasers



P. Werle et al., Optics Lasers in Engineering 37 (2002) 101–114

Antimonide based lasers

6.1 Å semiconductors