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# High aspect ratio deep etching in GaInAsSb/AlGaAsSb system by ICP-RIE plasma

B. Adelin<sup>a,b,\*</sup>, A. Larrue<sup>a,b</sup>, A. Lecestre<sup>a,b</sup>, P. Dubreuil<sup>a,b</sup>, Y. Rouillard<sup>c</sup>, G. Boissier<sup>c</sup>, A. Vicet<sup>c</sup>, A. Monmayrant<sup>a,b</sup>, and O. Gauthier-Lafaye<sup>a,b</sup>

<sup>a</sup>LAAS-CNRS, 7 avenue du Colonel Roche, BP 54200, 31031 Toulouse cedex 4, France

<sup>b</sup>Université de Toulouse ; UPS, INSA, INP, ISAE ; LAAS ; BP 54200, 31031 Toulouse cedex 4, France

<sup>c</sup>Institut d'Electronique du Sud (IES), Université Montpellier 2, Place Eugene Bataillon, 34095 Montpellier, France

## Context

### Target

Mid infrared tunable diode laser spectroscopy for trace gas detection in the 2-5 $\mu$ m wavelength range.

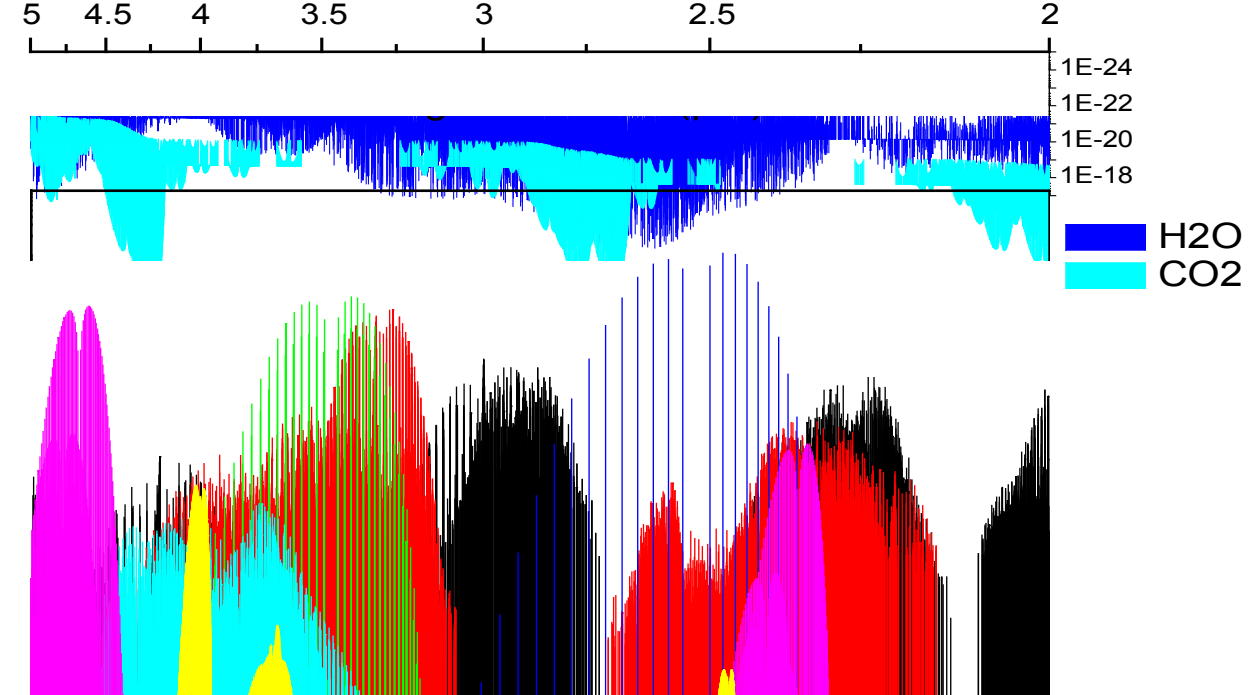
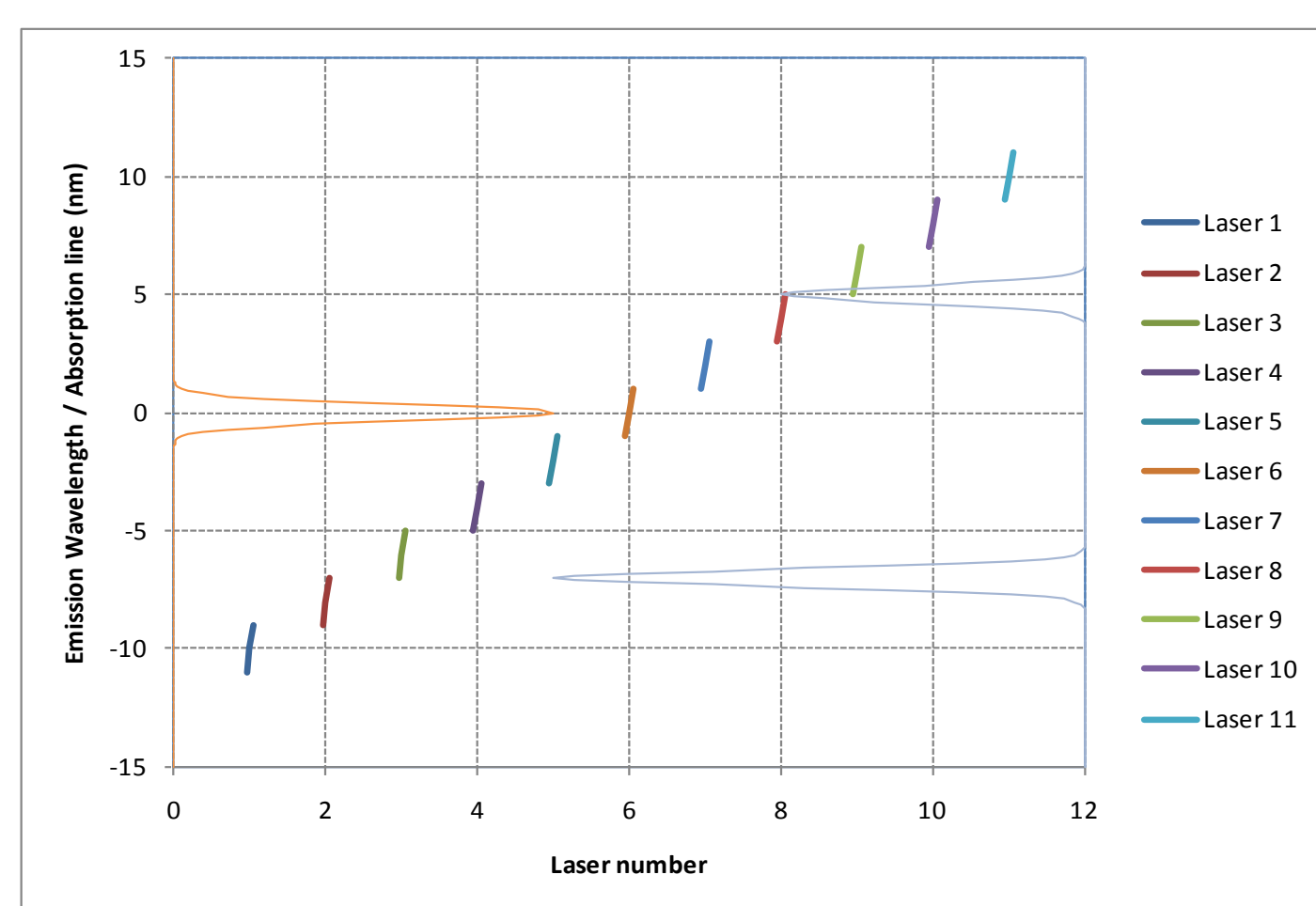


Figure 1. Absorption lines strength from 2 to 5  $\mu$ m. (HITRAN 96 database[1])

### Approach

Array of 2<sup>nd</sup>-order DFB singlemode, all-photonic-crystal (PhC) laser. We replace a laser which would be tunable over a wide range of wavelengths by an array of N lasers tunable over a range of wavelengths N times smaller. We call this method MTDLAS: multiplexed tunable diode laser absorption spectroscopy.

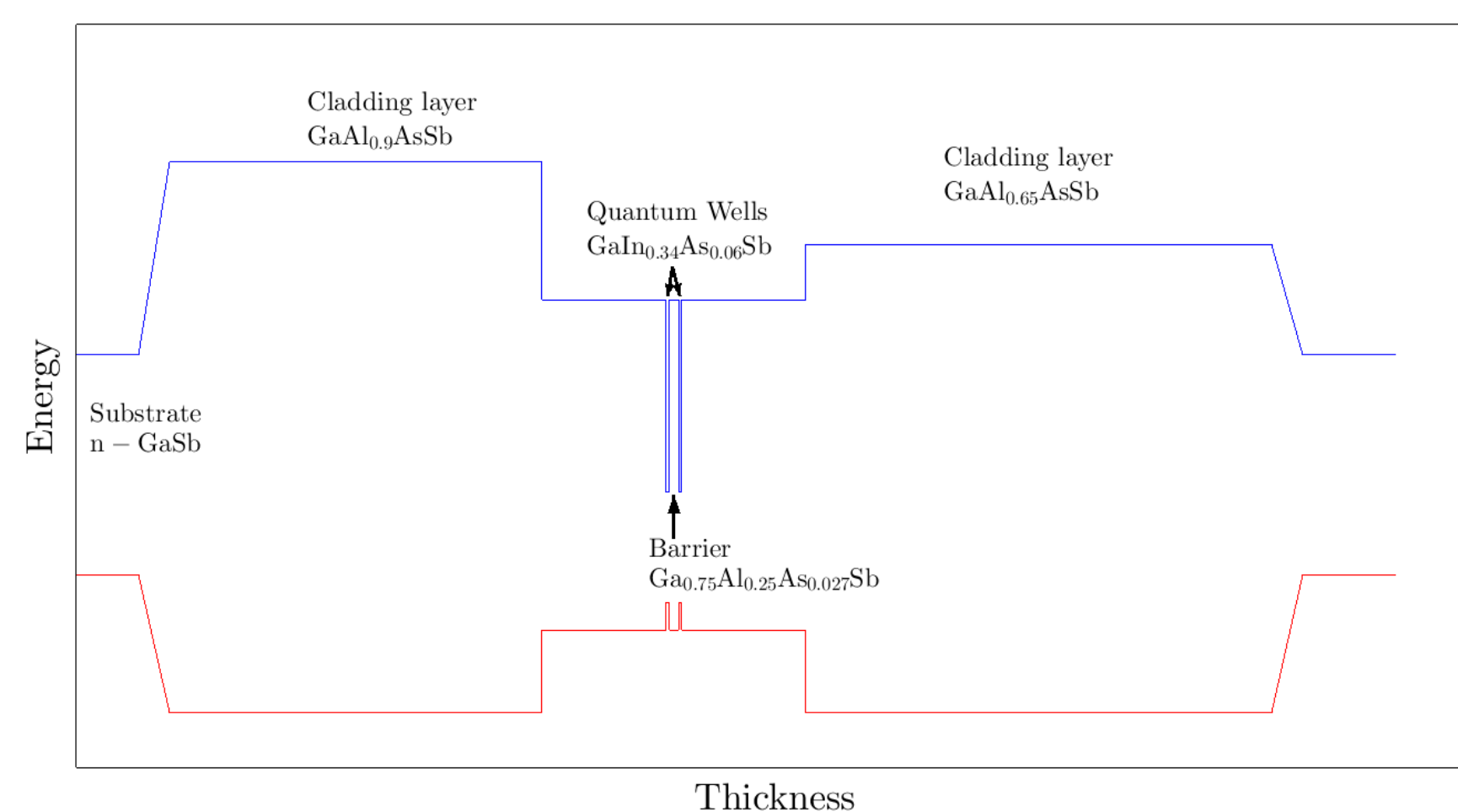


Principle of the spectroscopy using an array of single frequency lasers and tunable over a small wavelength range

## Issue

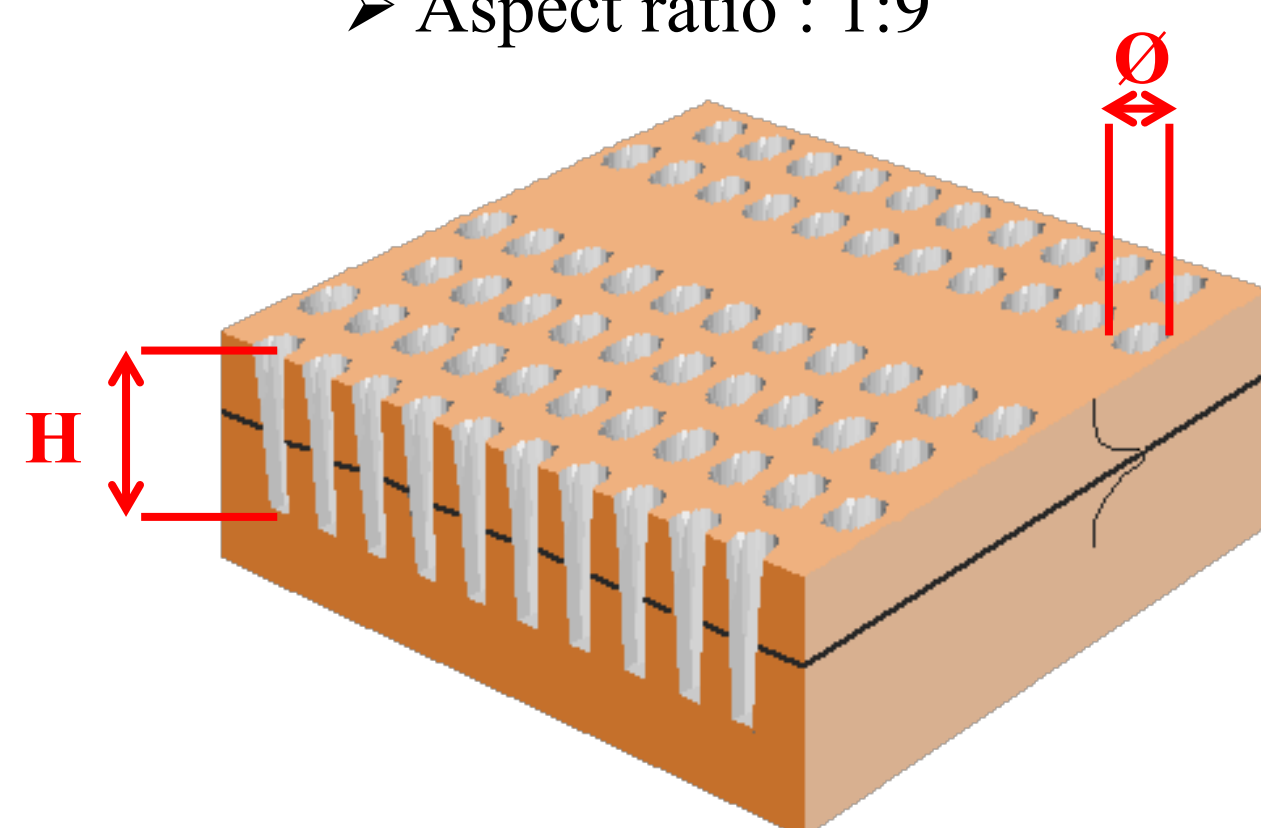
### Towards the realization of laser diodes all PhC electrically pumped in GaSb system

Heterostructure AlGaAsSb / InGaAsSb for an emission around 2.3 $\mu$ m

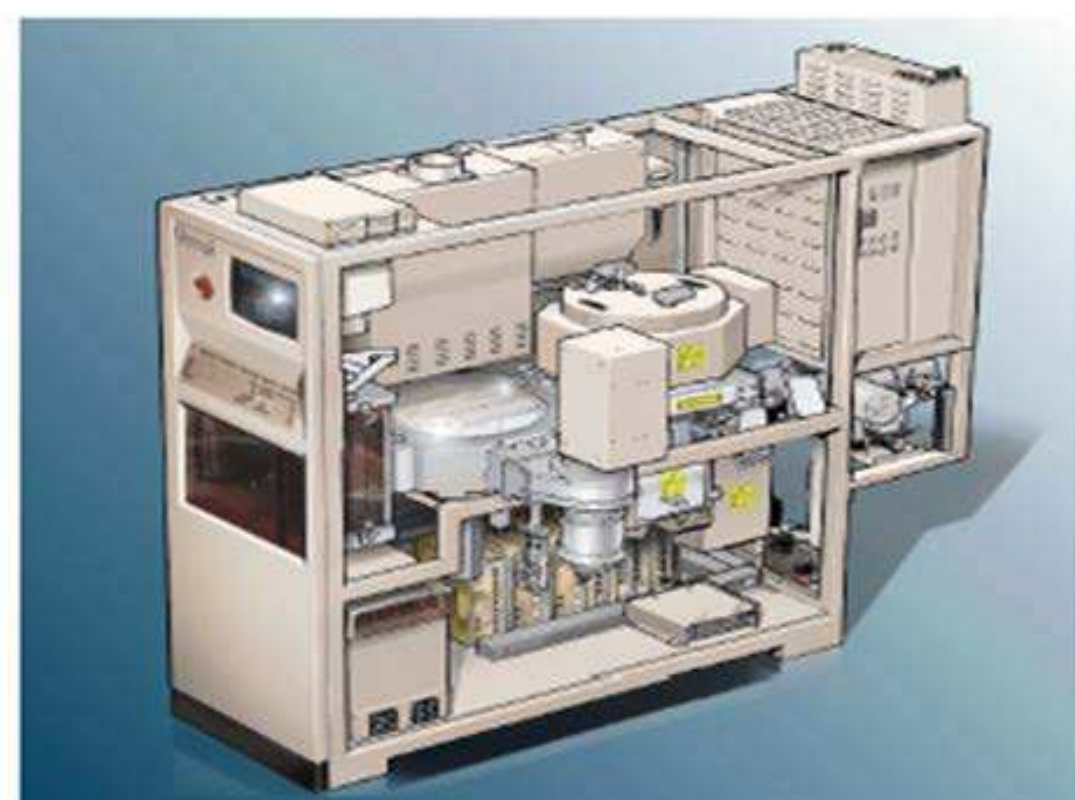


Etching of submicron patterns with high aspect ratio in the heterostructure :

- Characteristic dimensions :  $\varnothing \sim 375$  nm, H  $\sim 3.5$   $\mu$ m
- Aspect ratio : 1:9



System tool : SPTS ICP-RIE : Trikon-Omega201

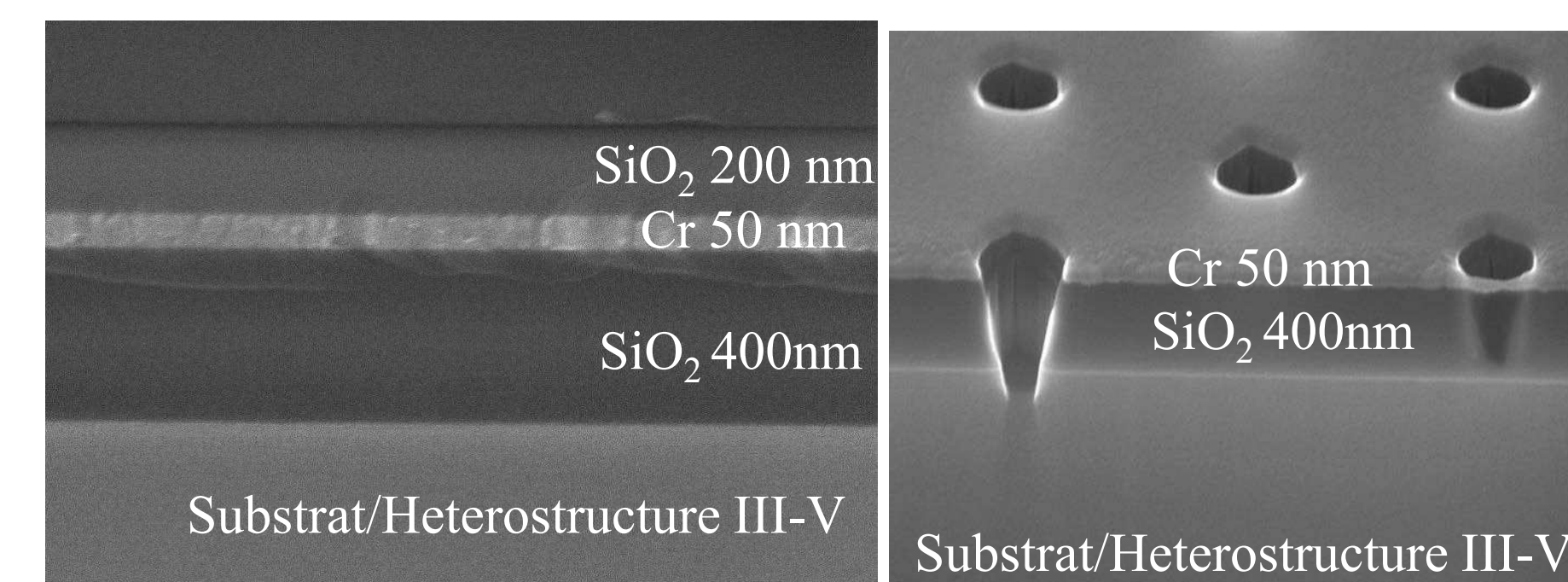


- Operating range :
  - ❖ Gas : SF6, O2, Cl2, Ar, N2
  - ❖ RF plasma powers (13.56 MHz) :  $P_{ICP} < 600$  W
  - $P_{bias} < 100$  W
  - ❖ 2 mTorr < Pr < 50 mTorr

## Previous work

### Masking strategy adopted

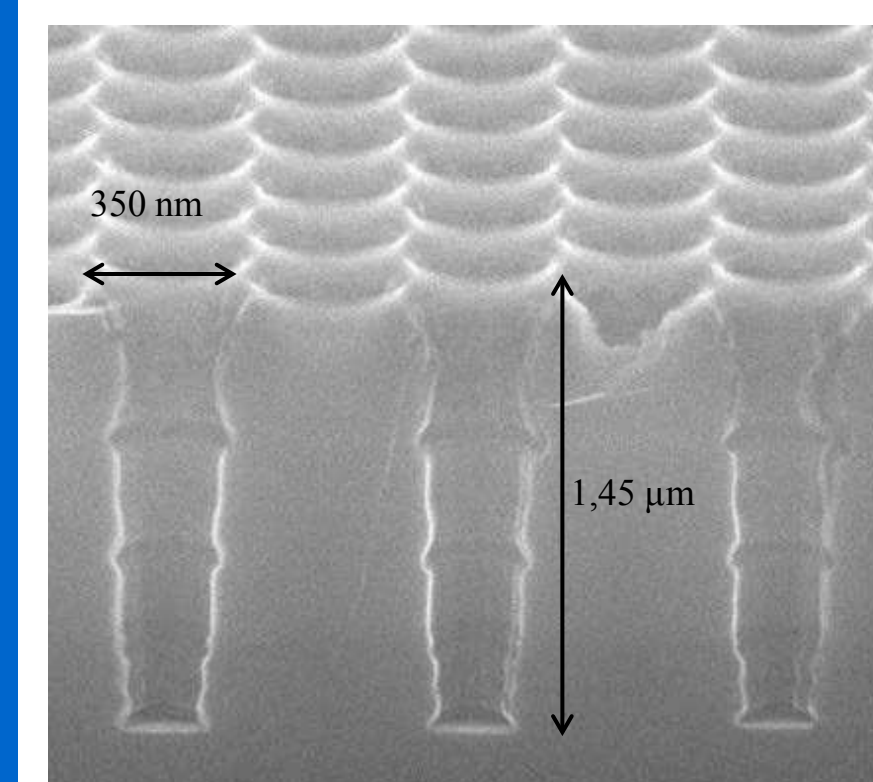
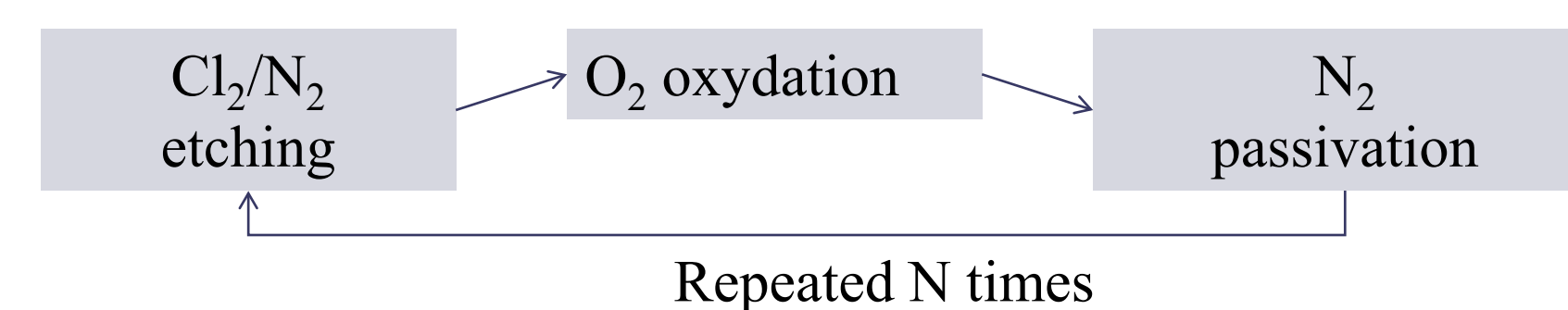
Etching process by ICP-RIE	Mask			
	PMMA	ZEP520A	SiO <sub>2</sub>	Cr
GaAs by Cl <sub>2</sub> /N <sub>2</sub>	0.5	0.7	4	16
SiO <sub>2</sub> by CHF <sub>3</sub>	< 0.5	0.5	-	50



Tri-layer mask used to open the submicron patterns in III-V substrate. Photonic Crystals FIB cut after complete transfer in the mask.

« Masking strategy for all ICP-RIE etching of high aspect ratio Photonic Crystals in GaAs » A. Larrue, and al., JNTE (2008)

### Development of a multi-step etching process combining Cl<sub>2</sub>/N<sub>2</sub>, O<sub>2</sub> and N<sub>2</sub> ICP plasma etching



Photonic crystals etched in heterostructure AlGaAsSb/AlGaAsSb

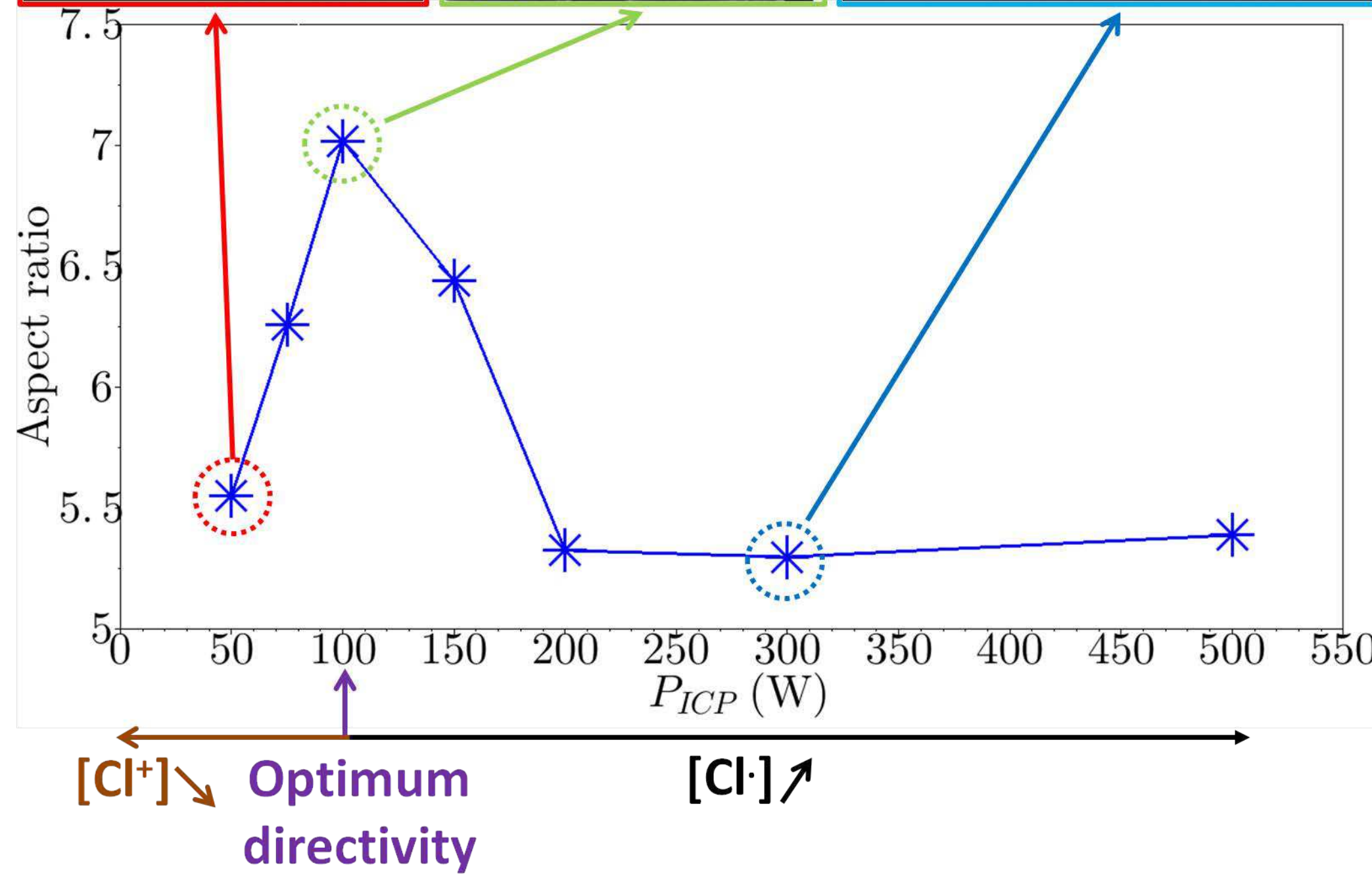
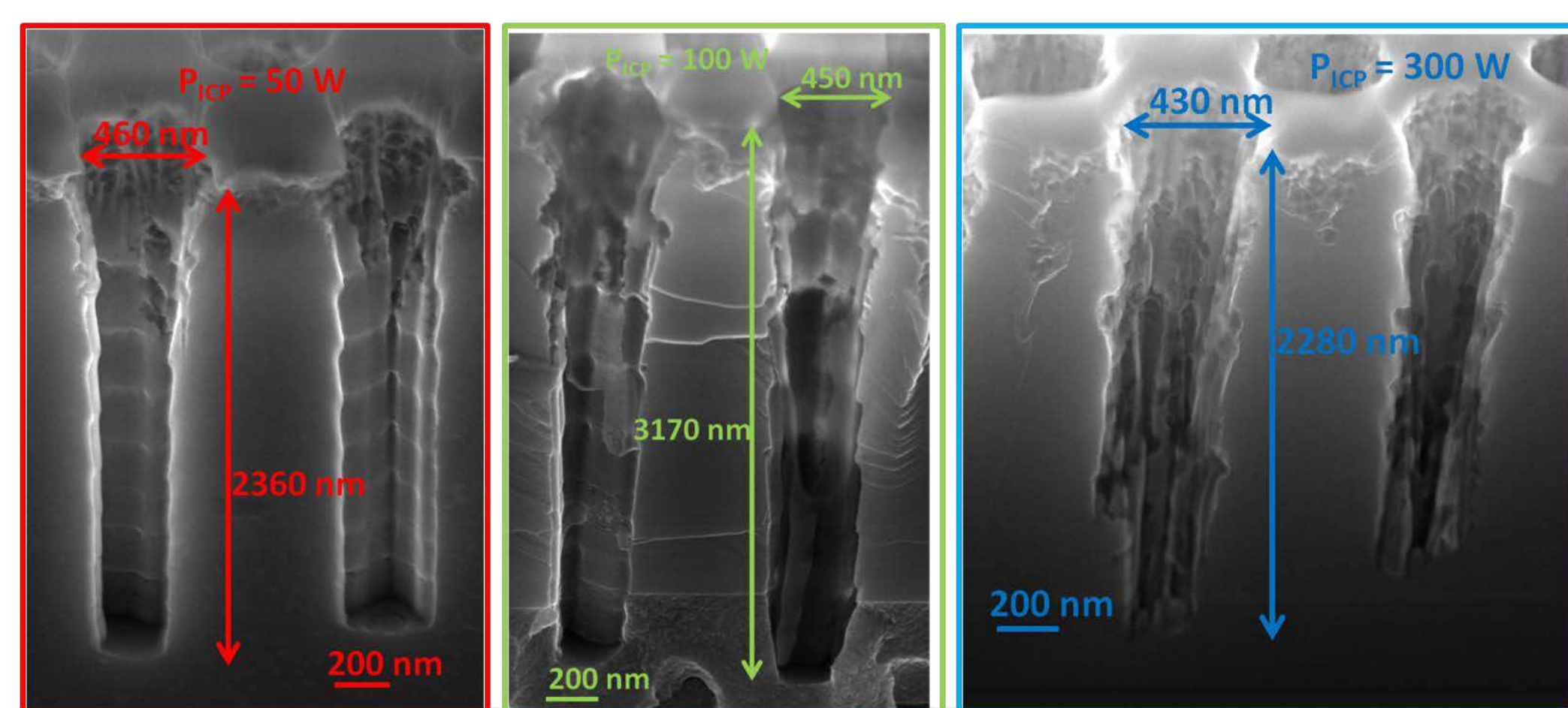
### Limits :

- Verticality  $\Rightarrow$  angle of 7°
- Depth = 1.45  $\mu$ m  $\Rightarrow$  < 4  $\mu$ m
- Etched sidewalls  $\Rightarrow$  notching

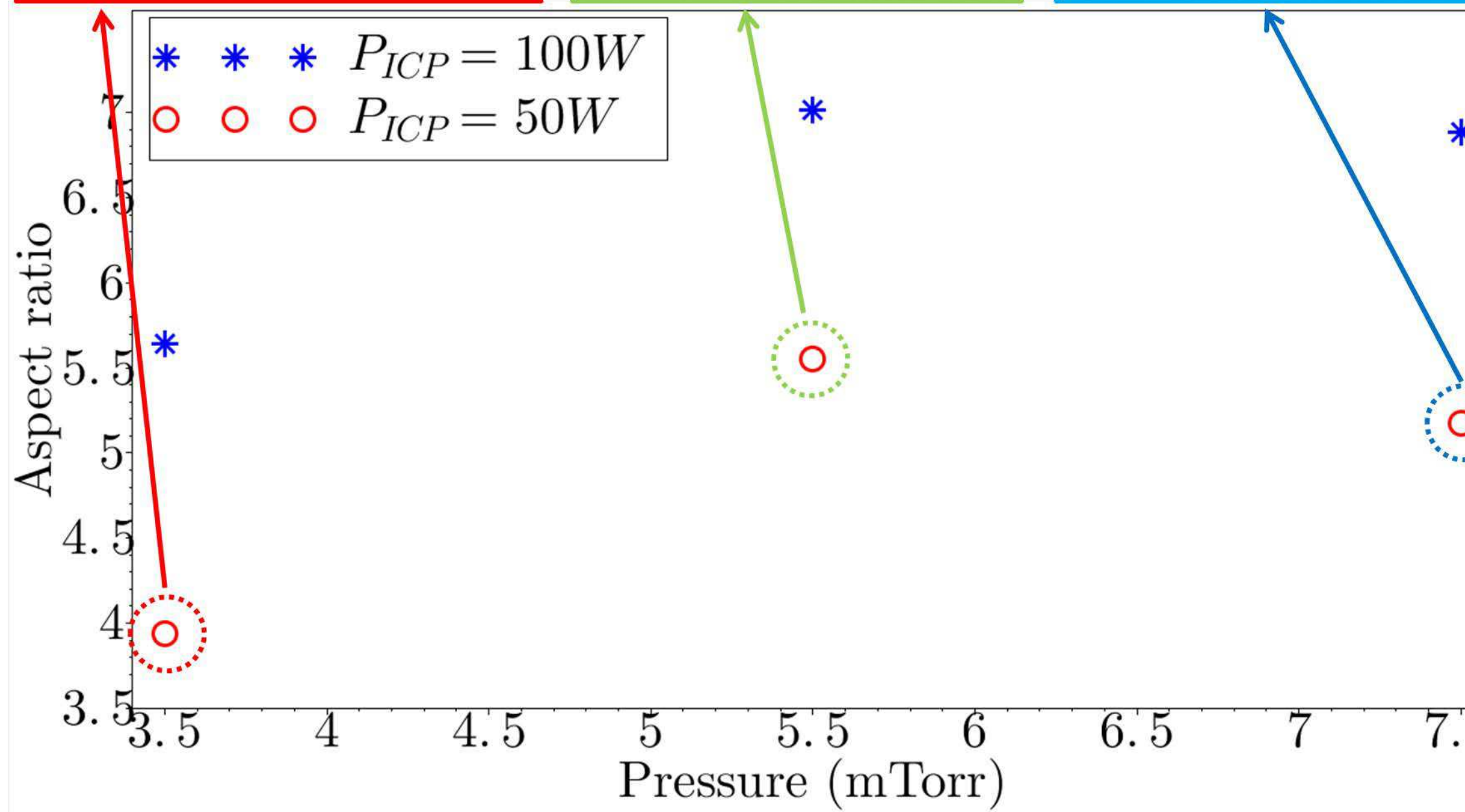
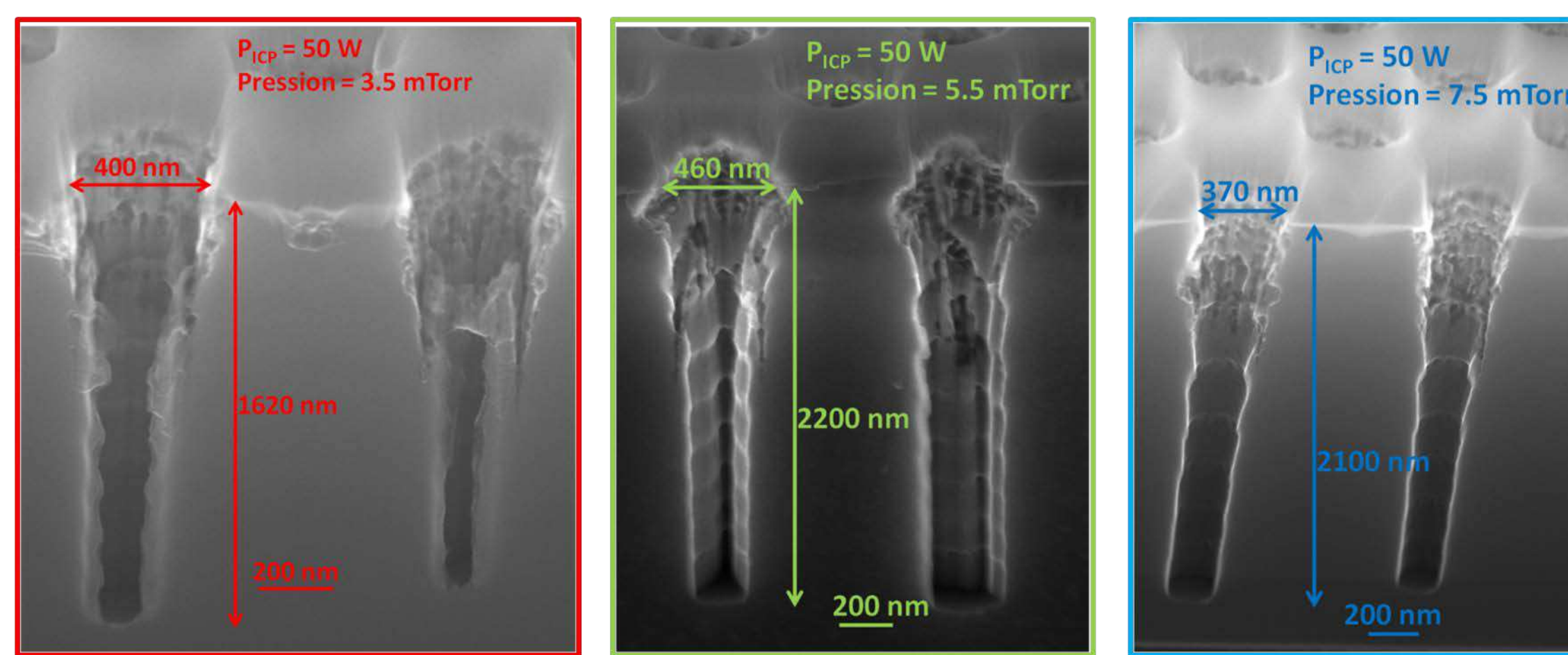
"Inductively coupled plasma etching of high aspect ratio two-dimensional photonic crystals in Al-rich AlGaAs and AlGaAsSb" A. Larrue, and al., JVSTB Vol. 29(2), pp. 021006 (2011)

## Optimization of the process of chlorinated ICP-RIE etching III-V materials

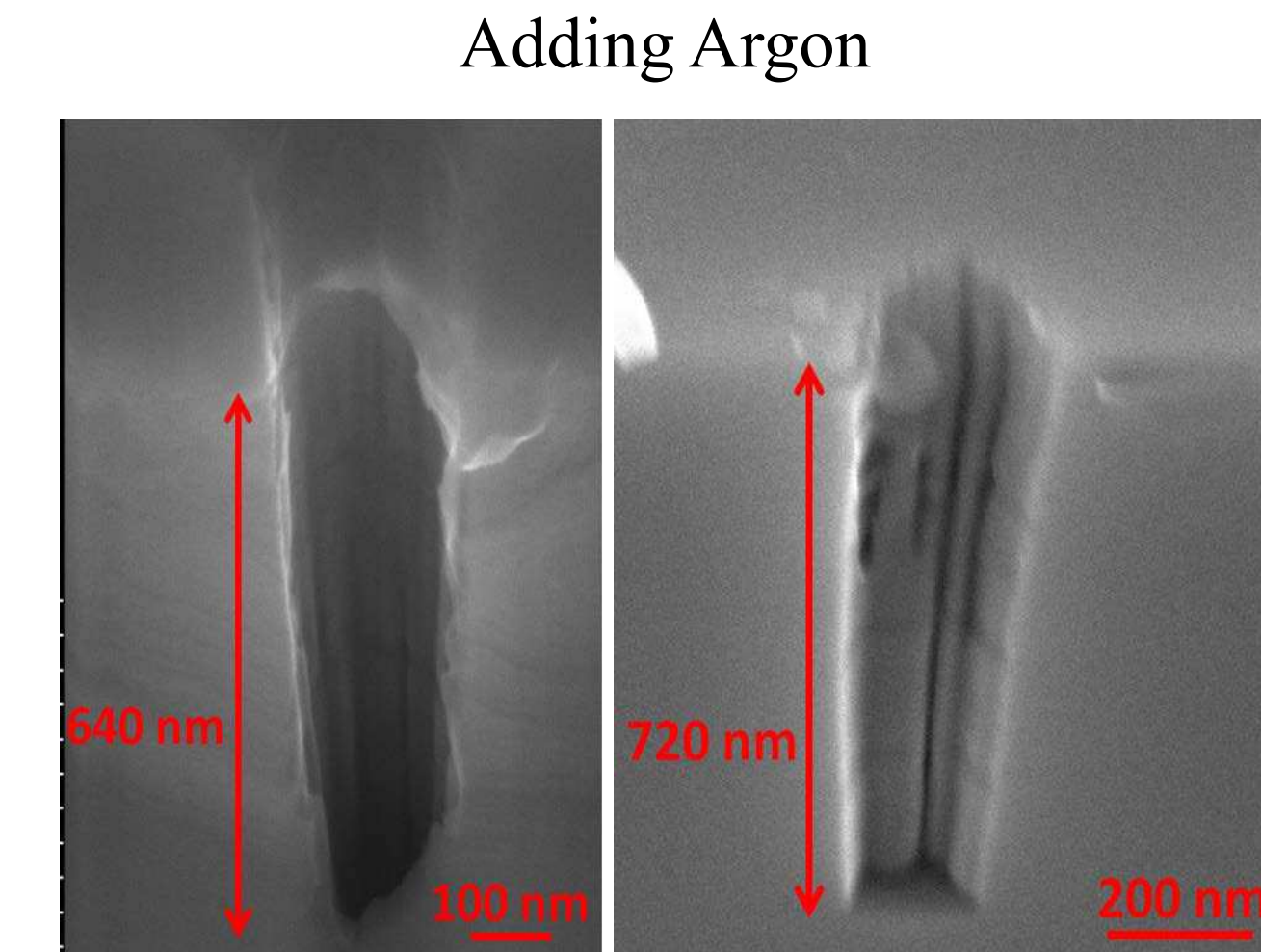
### Influence of ICP power :



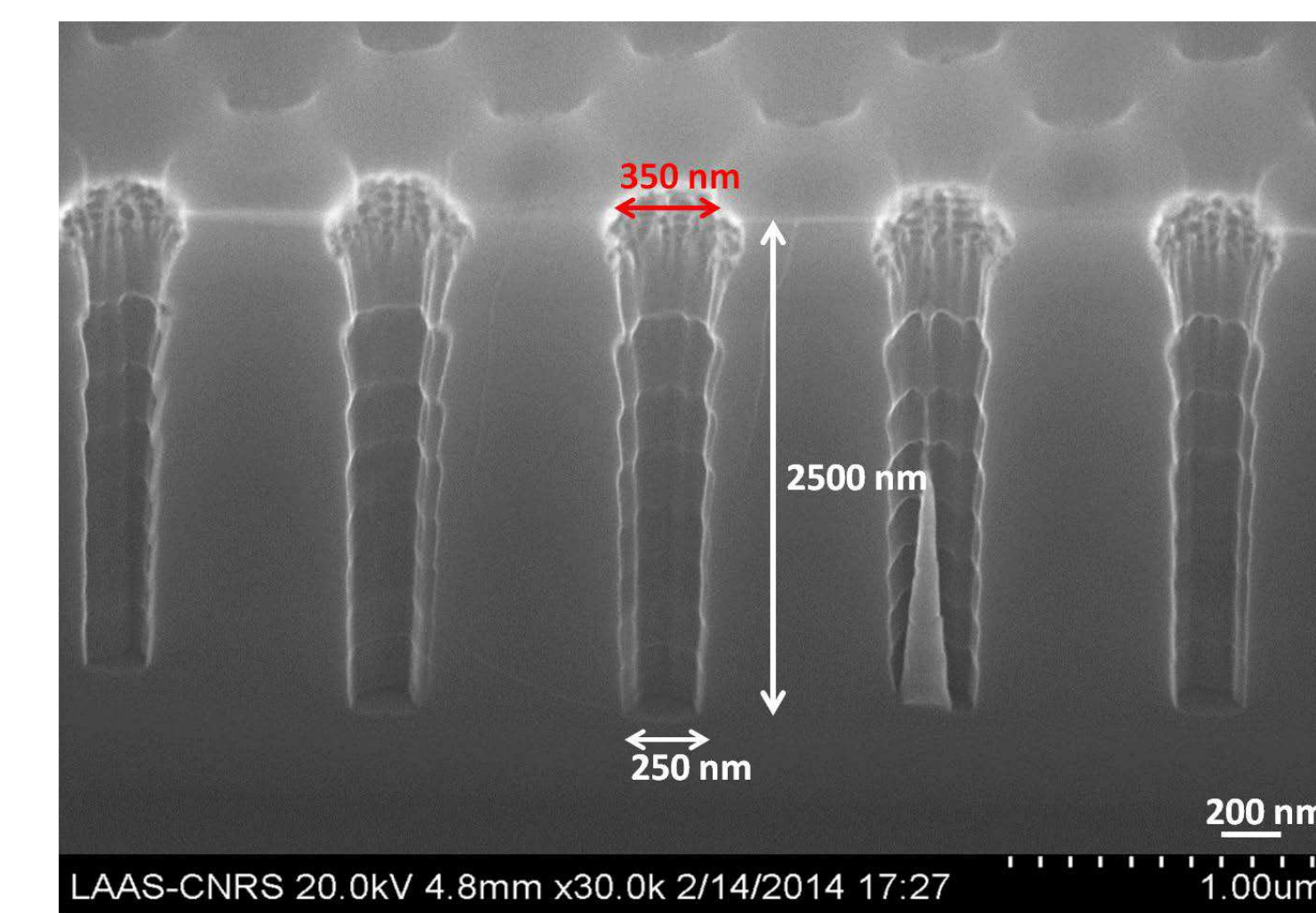
### Influence of pressure :



### Limit redeposition (verticality) :



Deep etching process optimized : Cl<sub>2</sub>/N<sub>2</sub>/Ar 45/15/5 sccm – 75 W ICP – 5.5 mTorr



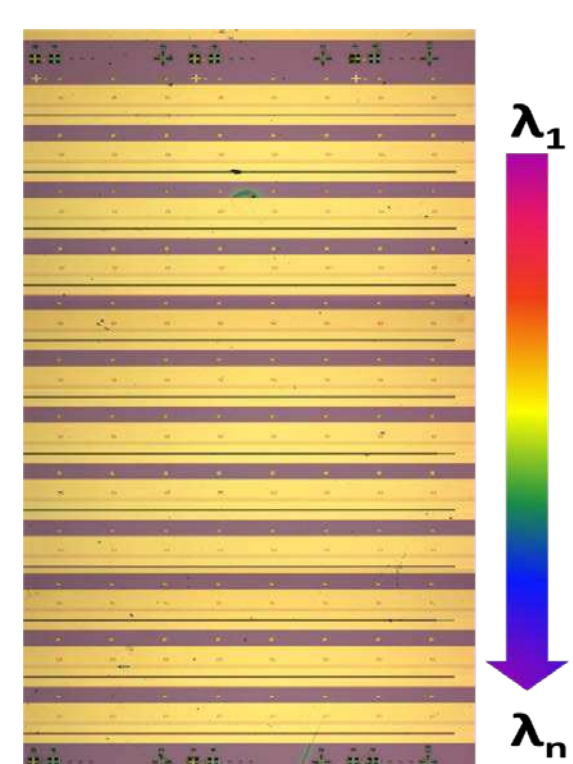
## Conclusion

Establishment of a high aspect ratio deep etching process in GaInAsSb/AlGaAsSb system

### Improvement :

- Verticality  $\Rightarrow$  angle of 2-3°
- Etched sidewalls  $\Rightarrow$  less notching
- Low roughness

Successful insertion of this technological step in a complete process



Outlook :

- Record high aspect ratio
- Sensitivity to aluminum concentration
- Profile improvement