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

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Context

Target

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

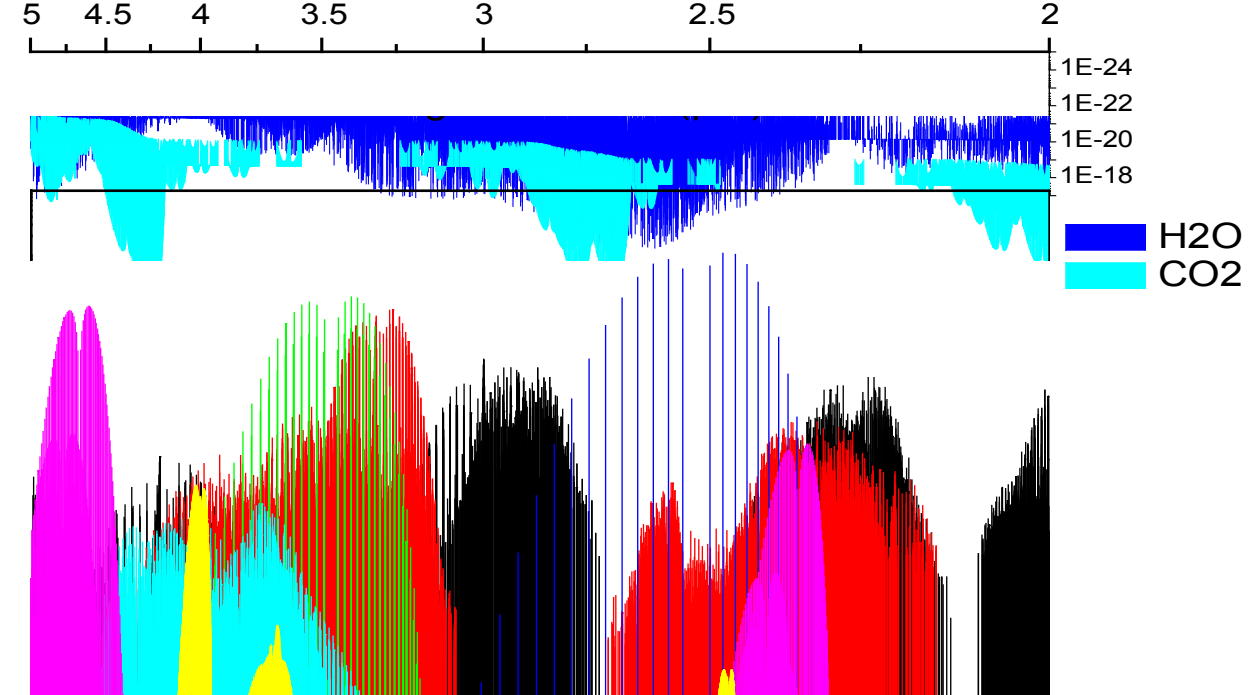
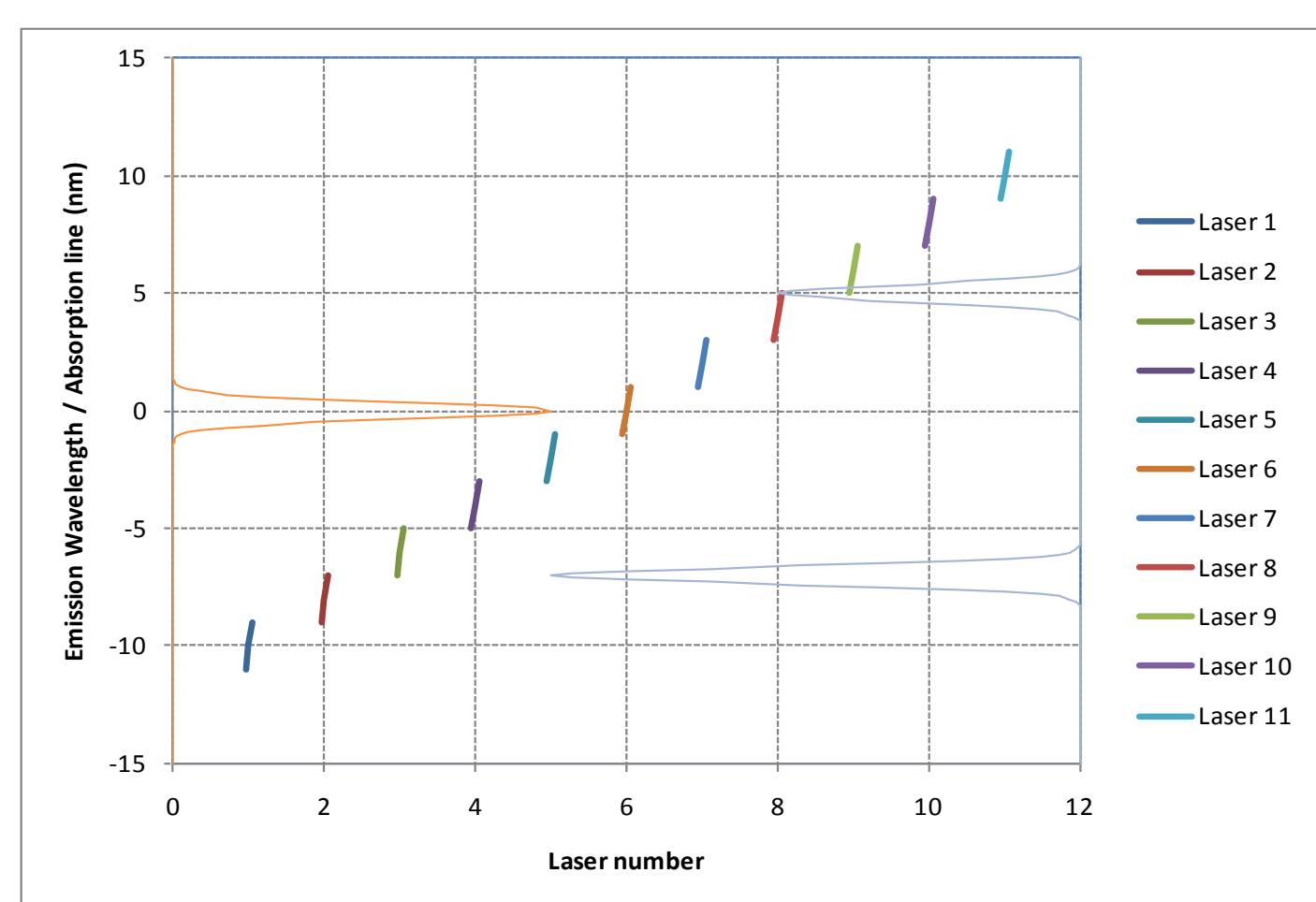


Figure 1. Absorption lines strength from 2 to 5 μ m. (HITRAN 96 database[1])

Approach

Array of 2nd-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.

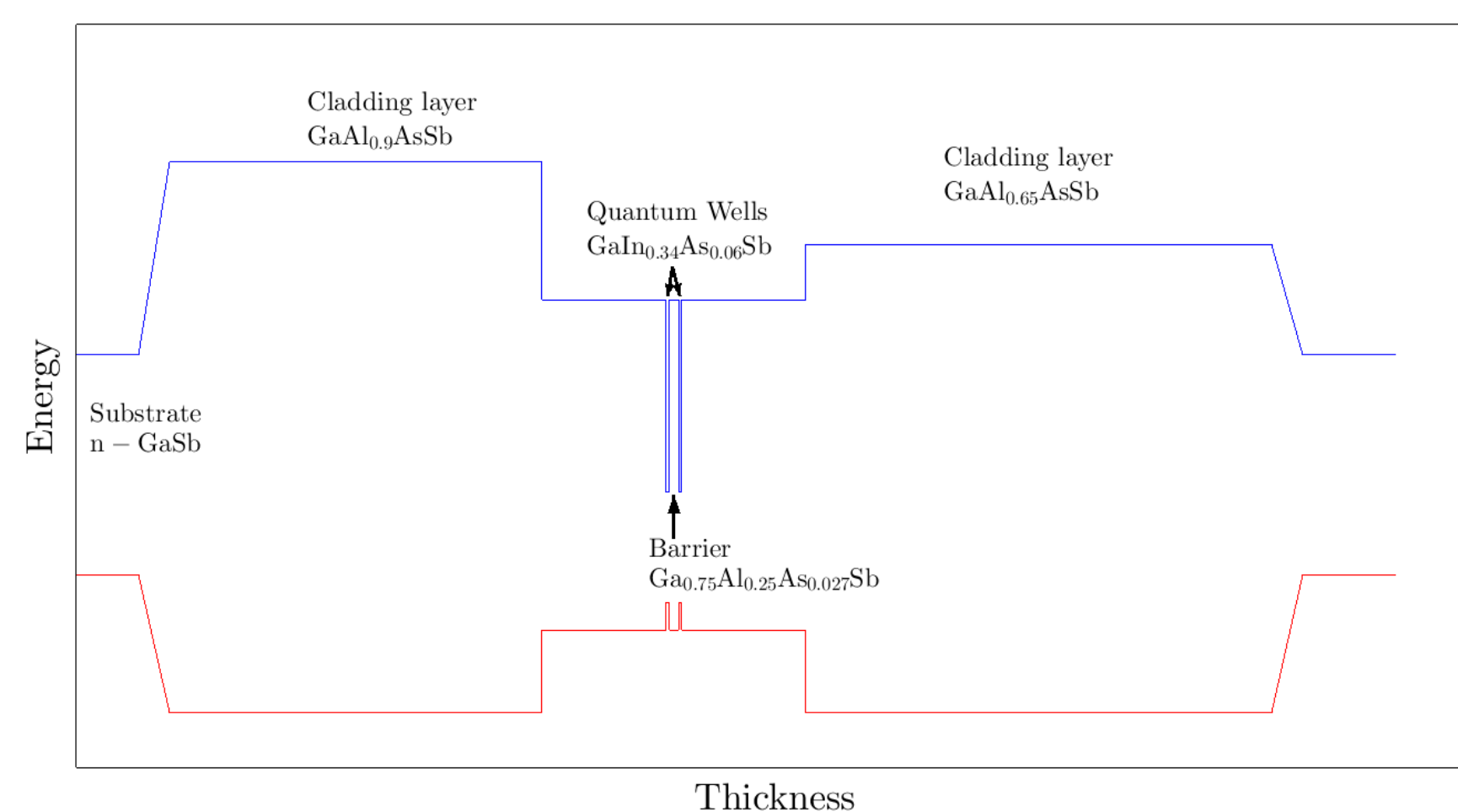


Principle of the spectroscopy using an array of single frequency lasers and tunable over a small wavelength range

Issue

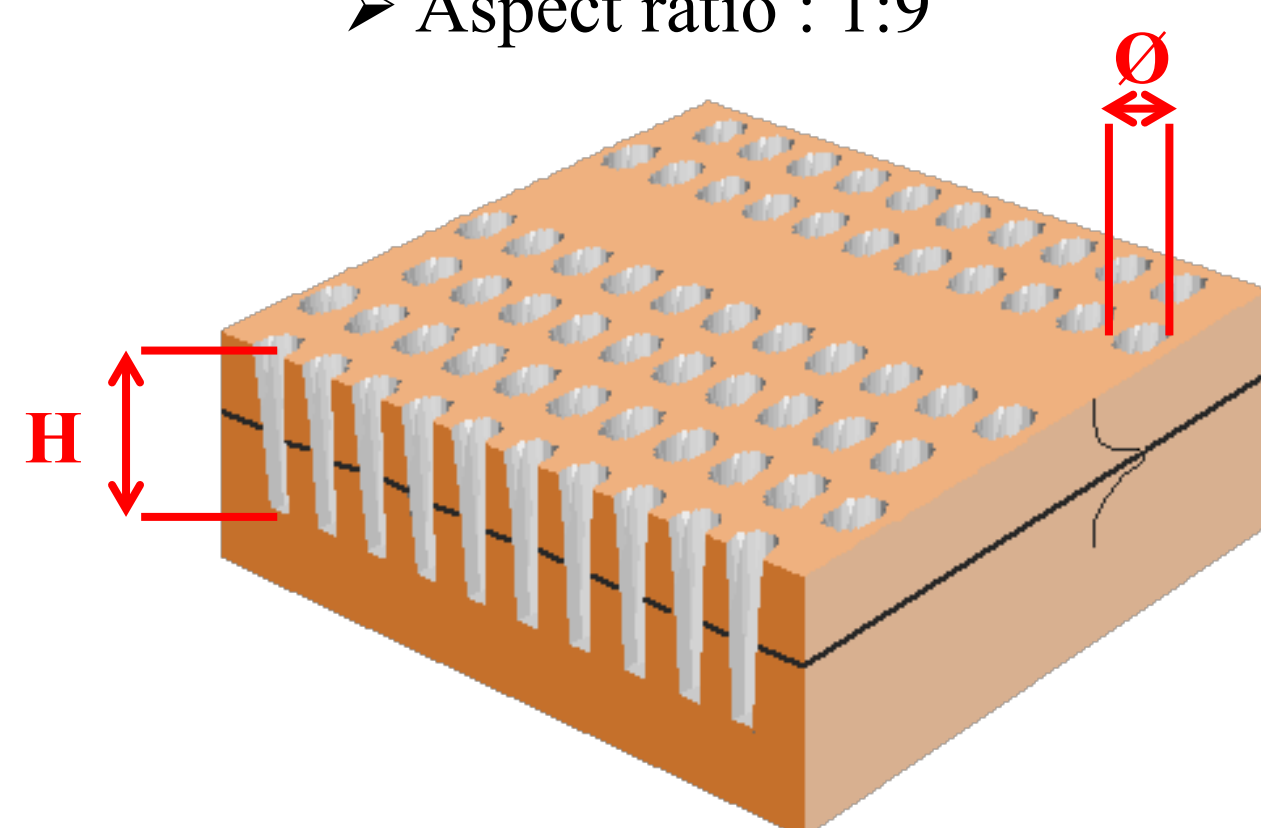
Towards the realization of laser diodes all PhC electrically pumped in GaSb system

Heterostructure AlGaAsSb / InGaAsSb for an emission around 2.3 μ m

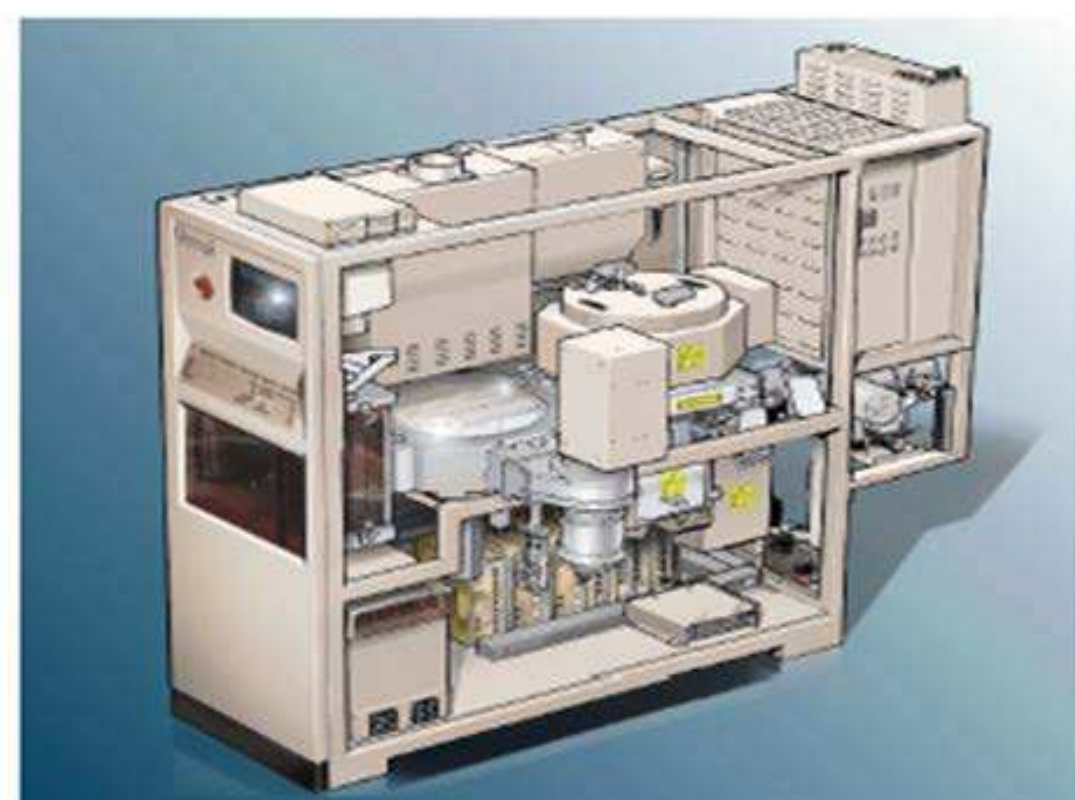


Etching of submicron patterns with high aspect ratio in the heterostructure :

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



System tool : SPTS ICP-RIE : Trikon-Omega201

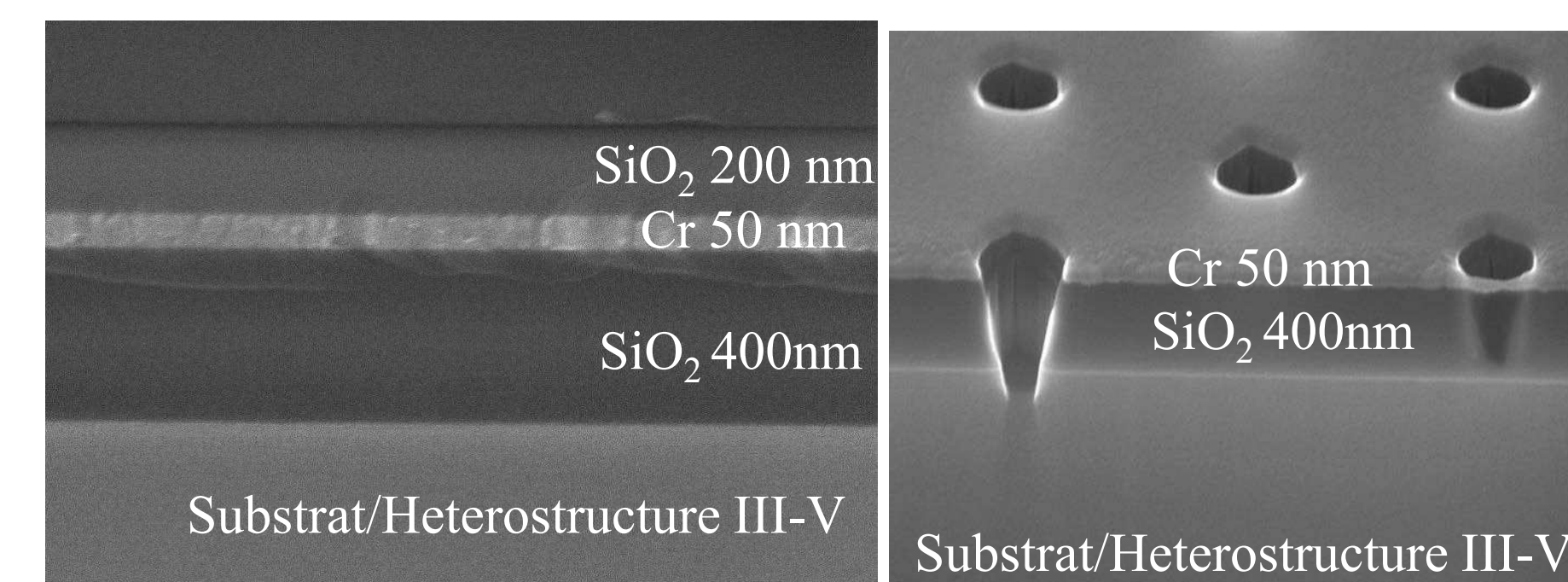


- Operating range :
 - ❖ Gas : SF6, O2, Cl2, Ar, N2
 - ❖ RF plasma powers (13.56 MHz) : $P_{ICP} < 600$ W
 - $P_{bias} < 100$ W
 - ❖ 2 mTorr < Pr < 50 mTorr

Previous work

Masking strategy adopted

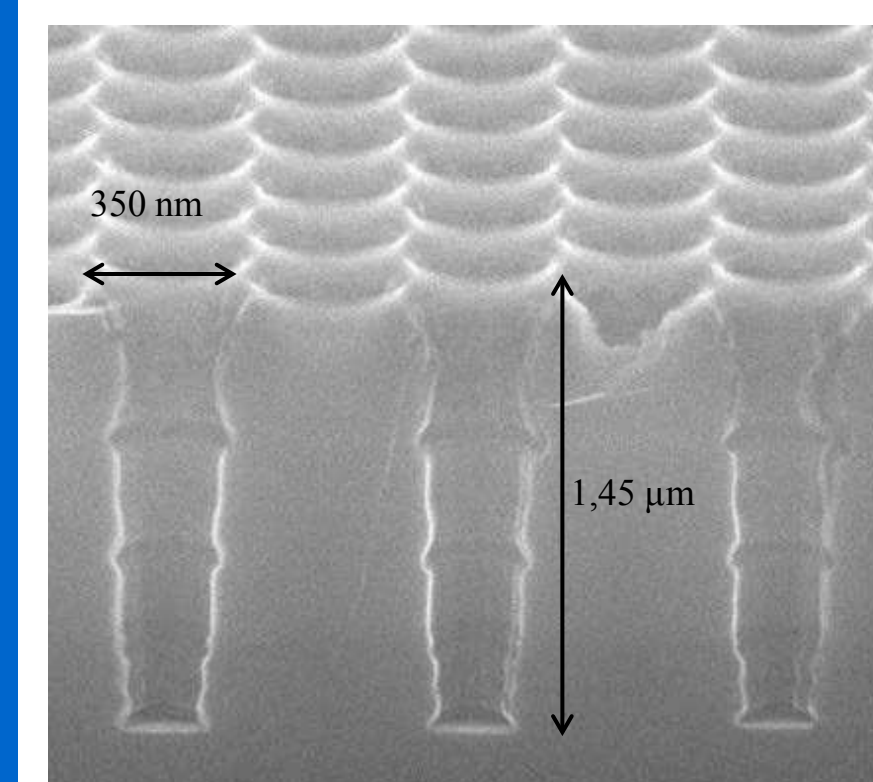
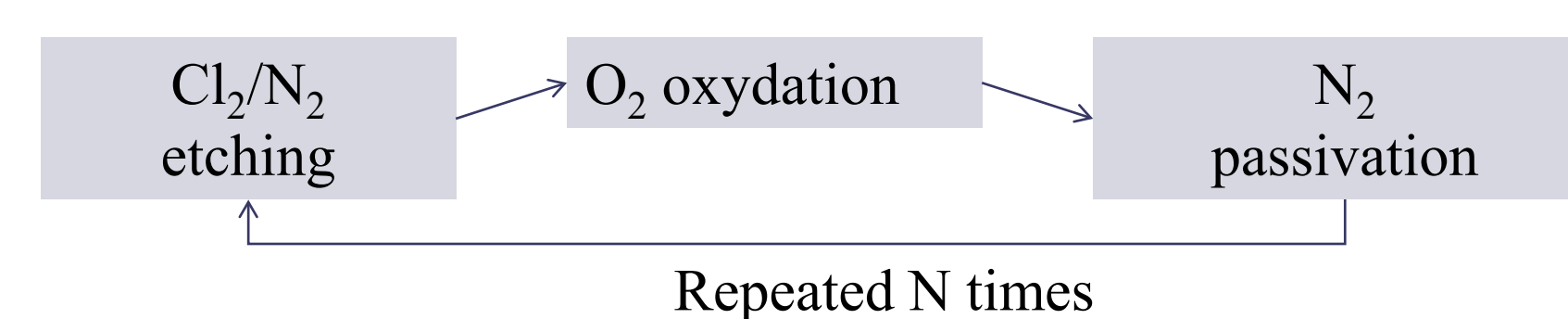
Etching process by ICP-RIE	Mask			
	PMMA	ZEP520A	SiO ₂	Cr
GaAs by Cl ₂ /N ₂	0.5	0.7	4	16
SiO ₂ by CHF ₃	< 0.5	0.5	-	50



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 Cl₂/N₂, O₂ and N₂ ICP plasma etching



Photonic crystals etched in heterostructure AlGaAsInSb/AlGaAsSb

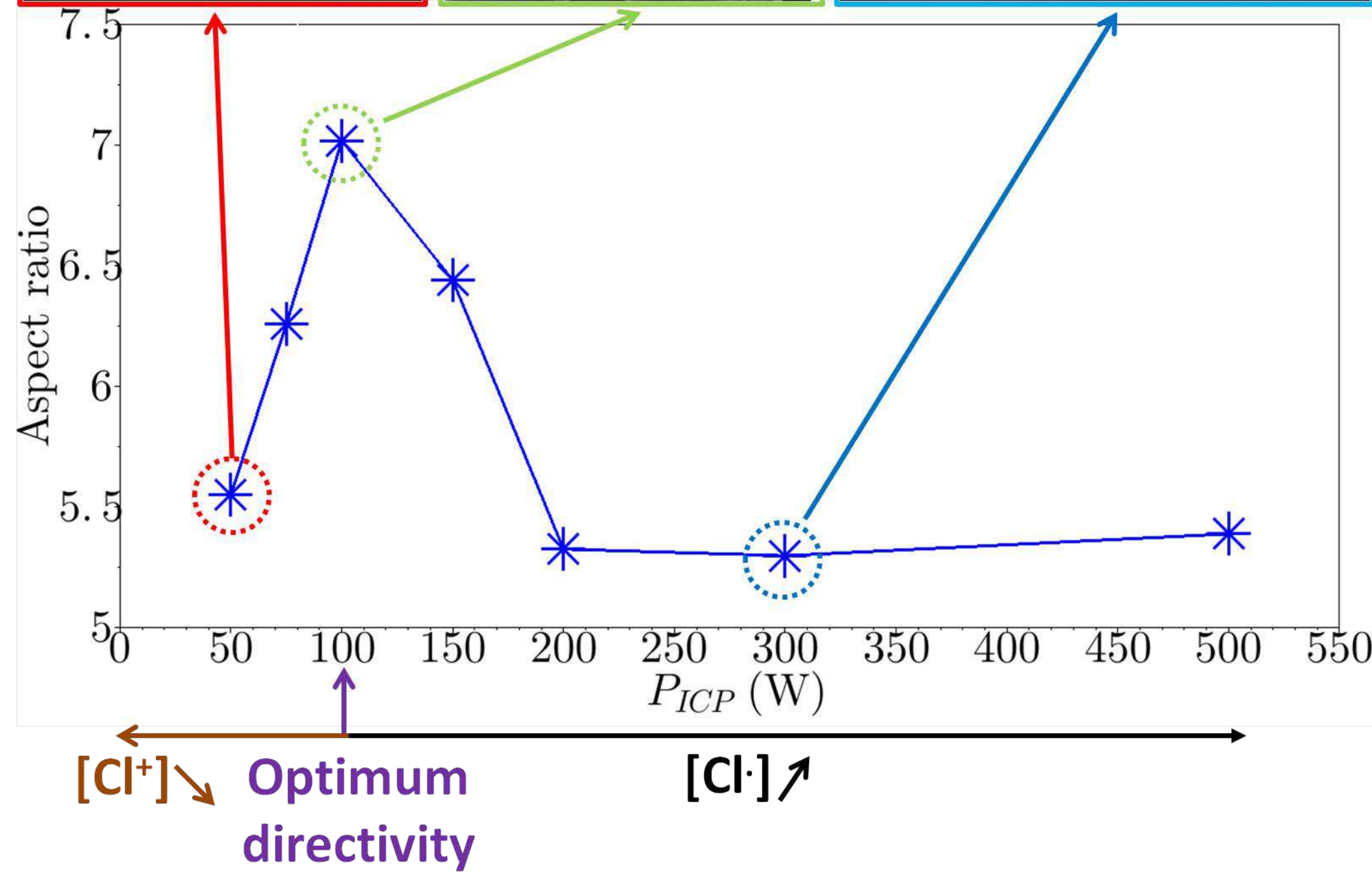
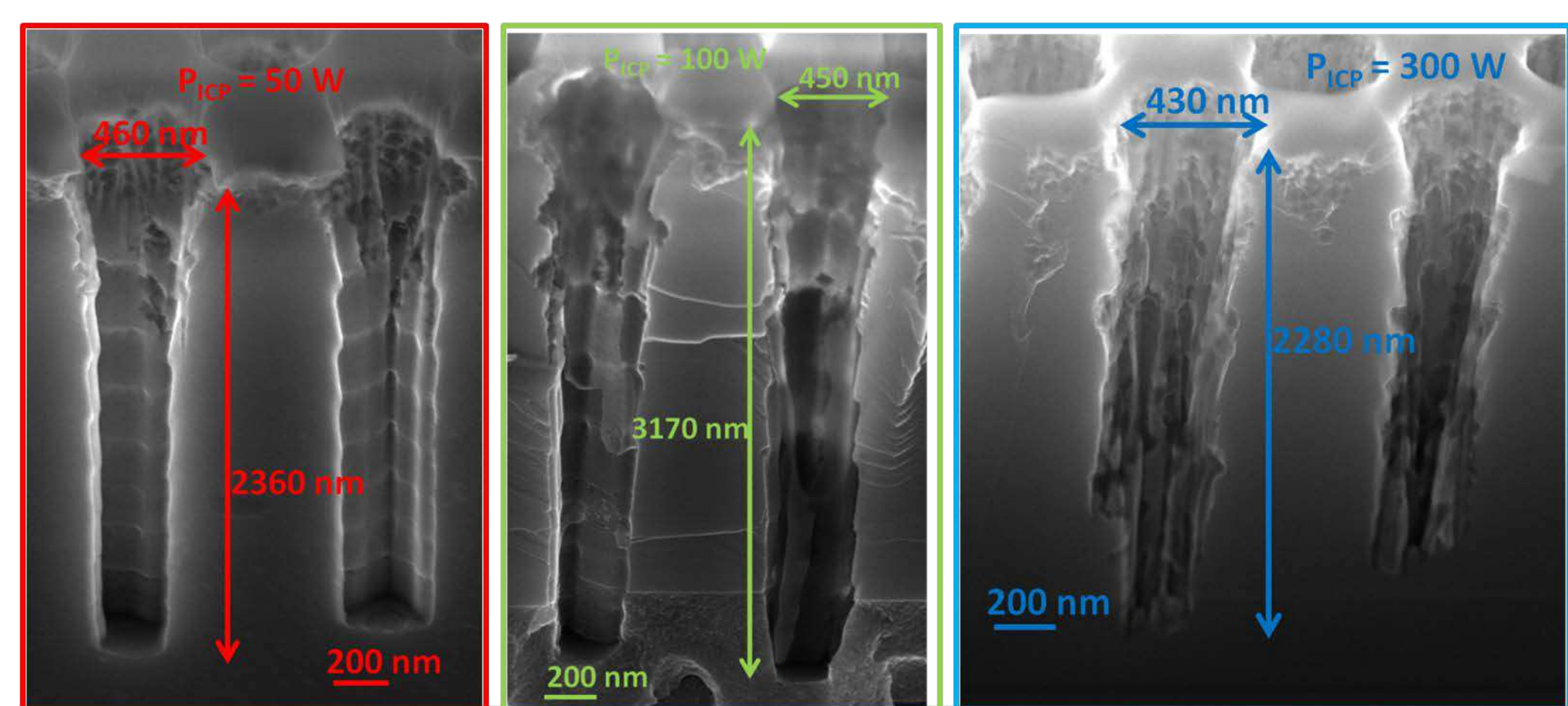
Limits :

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

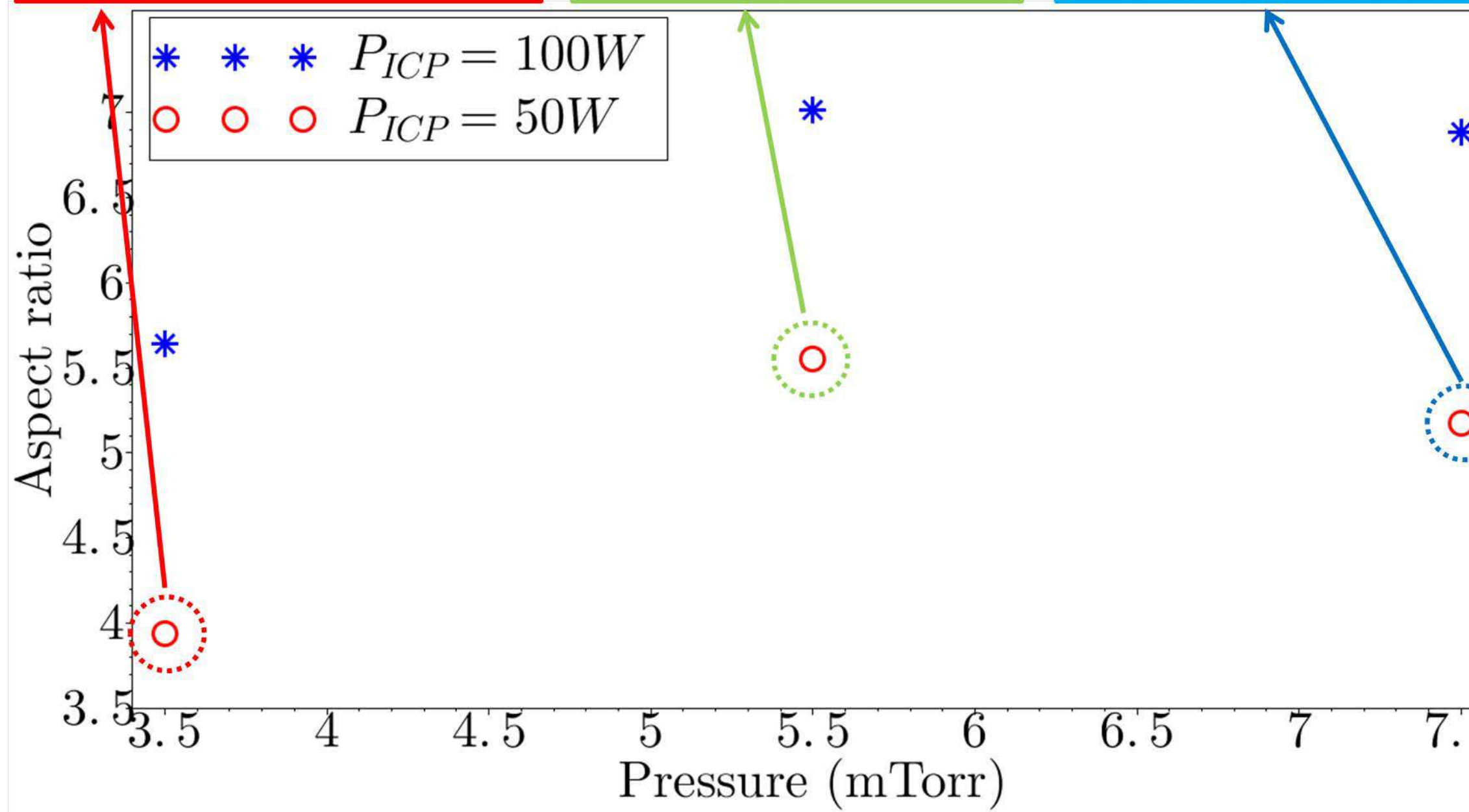
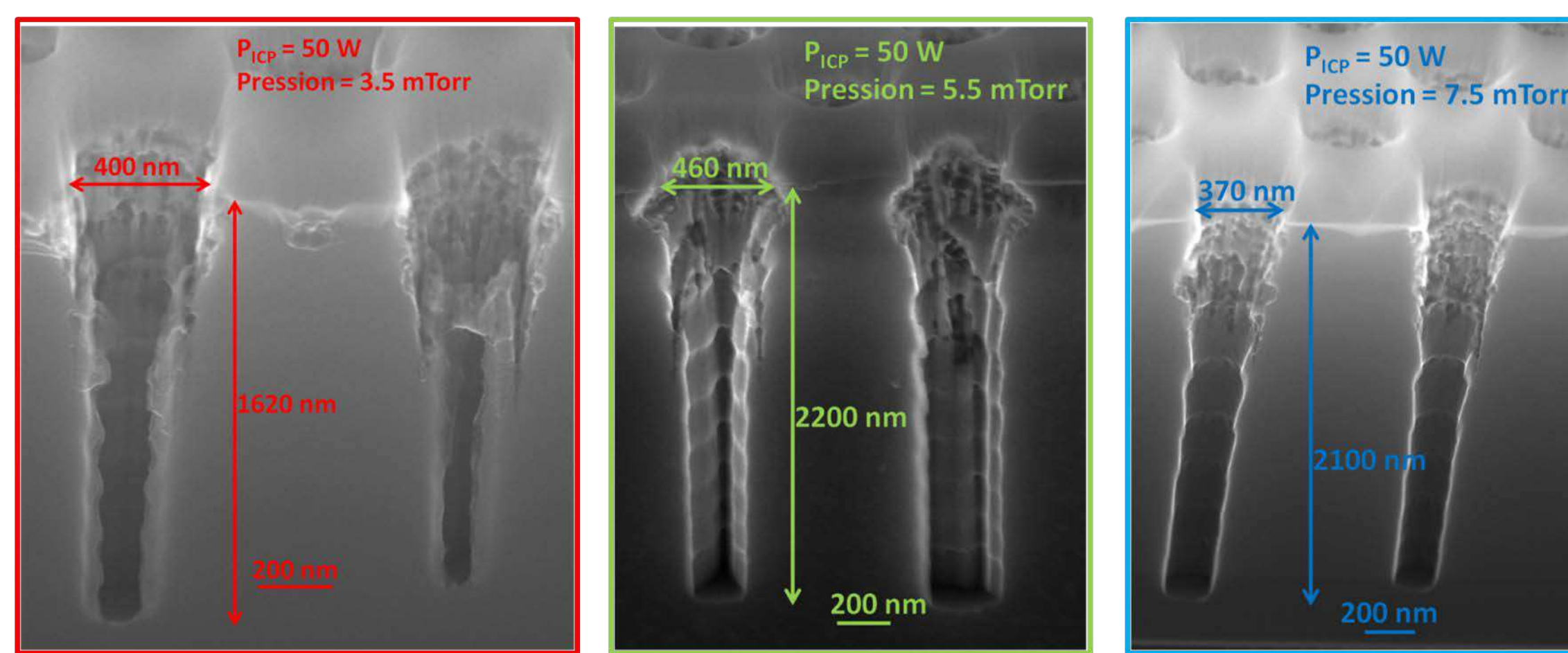
"Inductively coupled plasma etching of high aspect ratio two-dimensional photonic crystals in Al-rich AlGaAs and AlGaAsSb" A. Larrue, and al., JVSTB Vol. 29(2), pp. 021006 (2011)

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

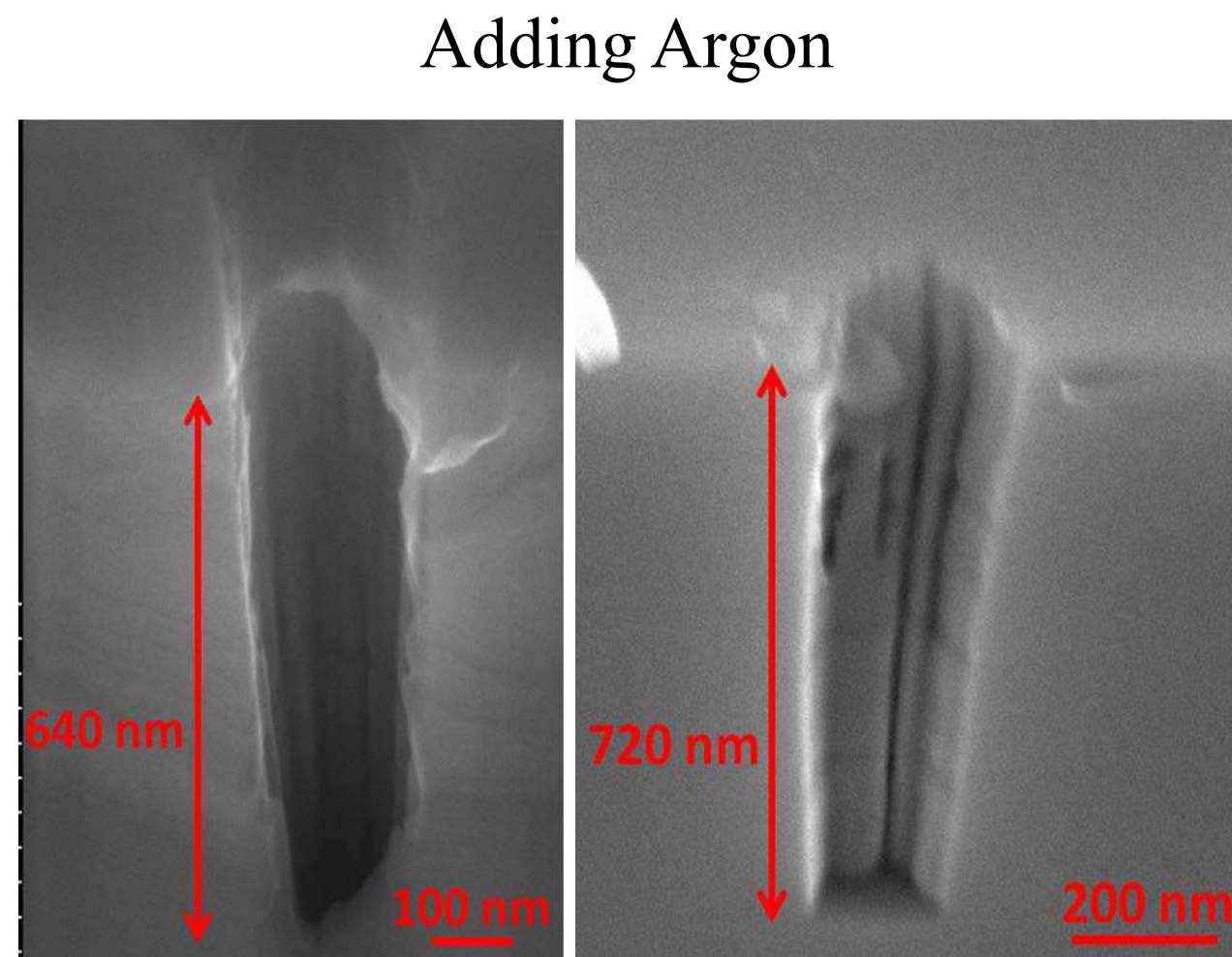
Influence of ICP power :



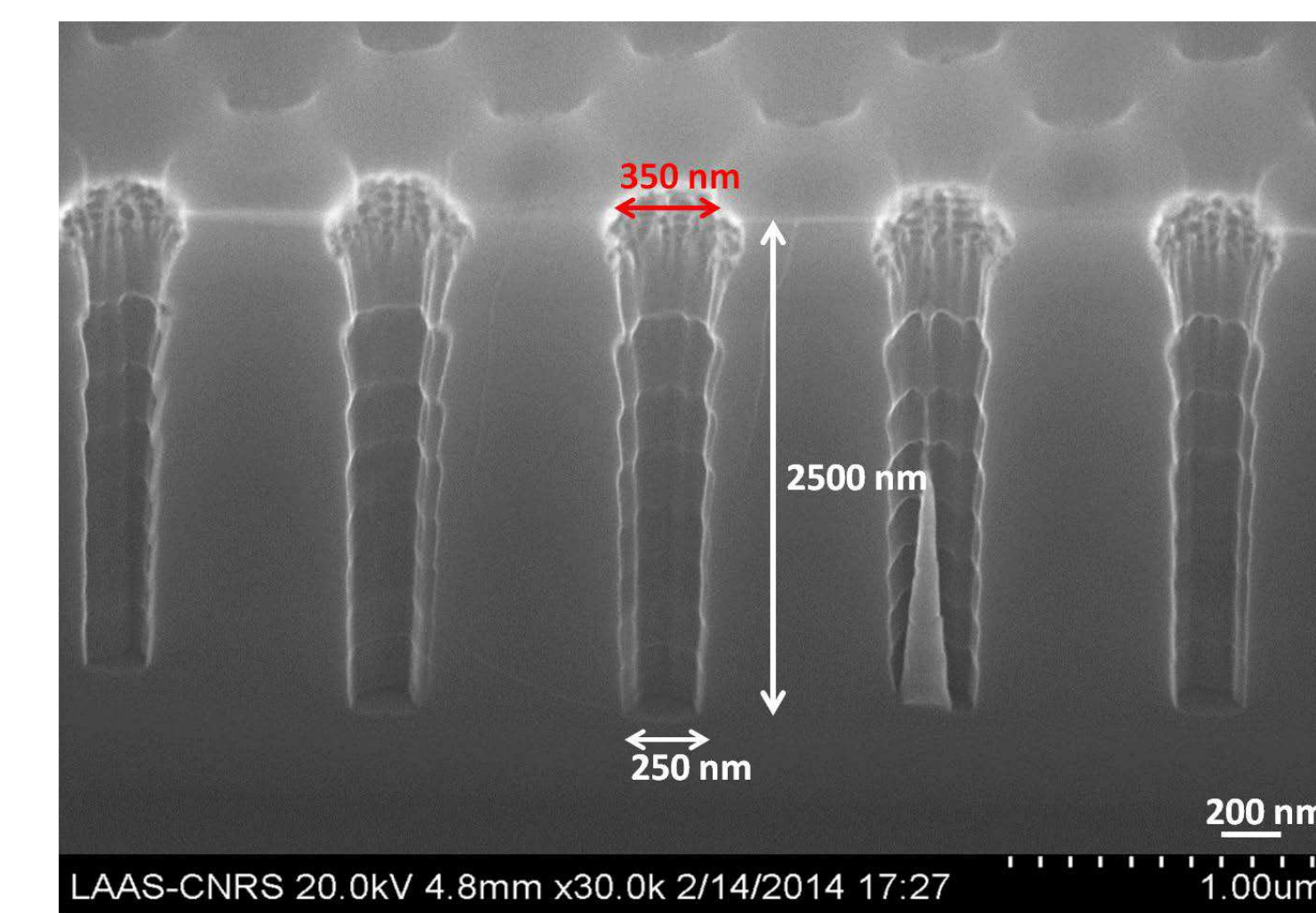
Influence of pressure :



Limit redeposition (verticality) :



Deep etching process optimized : Cl₂/N₂/Ar 45/15/5 sccm – 75 W ICP – 5.5 mTorr



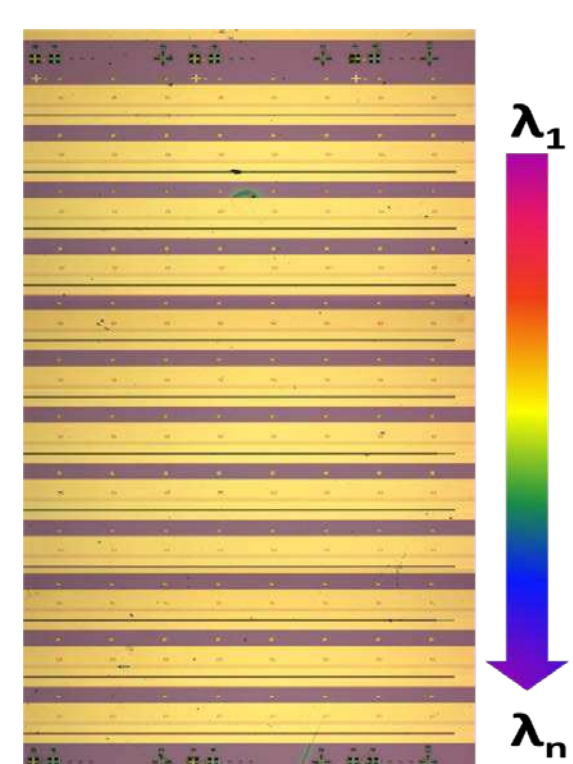
Conclusion

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