

## General context and recent results

COHEDIO January 2012- December 2014

This project addresses Photonic Integrated devices fulfilling optical functions not supported by Si: Electrically driven lasers and amplifiers CW operating at 1.55 $\mu$ m without the thermal drawback encountered up to now, and Optical Isolators.

### Two main topics currently addressed

- ◆ Material break-through : Hybrid integration of III-V InP-based materials on Si *without intermediate layer* through **heteroepitaxial bonding**
- ◆ Design challenge: tailored Si waveguide including a nanostructuration for mode control and optimized thermal behavior

### During the project, demonstrators will be fabricated

- Integrated Electrically driven, CW operating at 1.55 $\mu$ m DFB lasers and amplifiers
- Integrated optical isolators

### + Preservation of an embedded nanopatterned design for advanced optical functions

"High index contrast" corrugation located at the maximum field intensity for highest efficiency  
→ in-plane or out-of-plane spectral or spatial selectivity

### + No material of poor thermal conductivity or low optical index in the core of the device

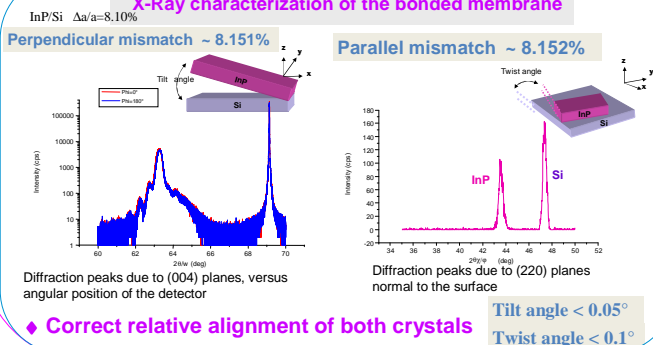
## Heteroepitaxial bonding

InP and Si have a lattice parameter mismatch  $\Delta a/a=8.10\%$

- 1 - Both materials are grown, lattice matched, on their own substrate
- 2 - Surfaces preparation : Oxide-free surfaces, contact
- 3 - Annealing: oxide-free operation under vacuum,  $T=550^\circ\text{C}$ , 1h30mn, Low Pressure 0.2MPa  
Required : smoothness, flatness, cleanliness, reactivity

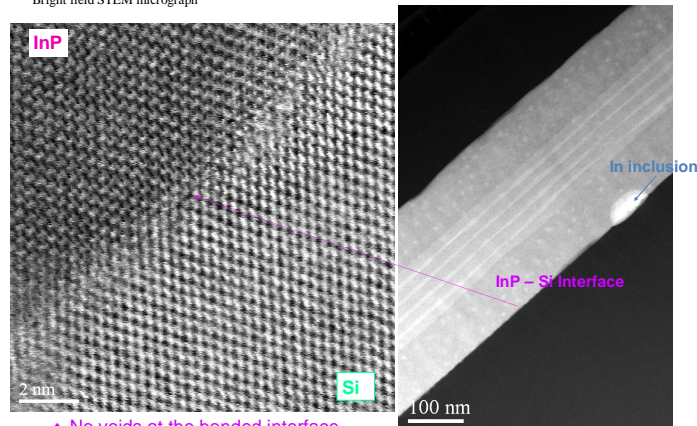
- ◆ Four GaInAs Quantum wells with Quaternary barriers embedded between two 70nm thick InP layers are bonded
- ◆ The bonded membrane is obtained after chemical removing the InP substrate and the GaInAs etch stop layer

### X-Ray characterization of the bonded membrane

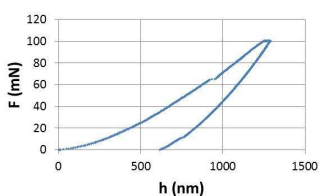


### TEM characterization of the bonded membrane and InP / Si interface

Bright field STEM micrograph

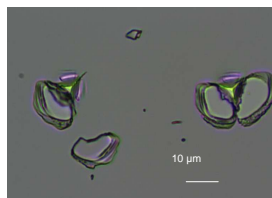


## Nanoindentation characterization



Interfacial cracking: pop-ins at  $80 \pm 10$  mN. Under higher loads: chips are formed.

Instead, buckling of a released membrane happens below 10 mN.



## Future work

- 1 - Bonding on patterned Si surfaces
- 2 - Si waveguide design for reduced thermal penalty for the integrated device
- 3 - Fabrication and characterization of active devices including tailored designed waveguides

## Publications

"Atomic-plane-thick reconstruction across the interface during heteroepitaxial bonding of InP-clad quantum wells to Si"

A.Talneau, C.Roblin, A.Itawi, O. Mauguin, L.Largeau, G.Beaudouin, I.Sagnes and G. Patriarche

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"Plasticity of semiconducting substructures" E. Le Bourhis, A. Talneau, I. Sagnes, and G. Patriarche, *Proceedings of Plasticity'13* - Ed. A. S. Khan, NEAT Press (2013)

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