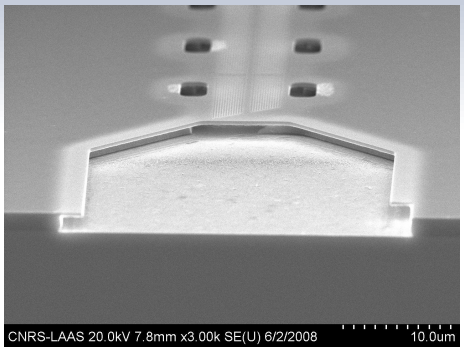


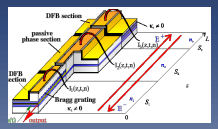
Photonic crystals for planar laser sources: new functionalities and outlook

A. Monmayrant, A. Larrue, J. Campos,

O. Gauthier-Lafaye, S. Bonnefont, F. Lozes-Dupuy

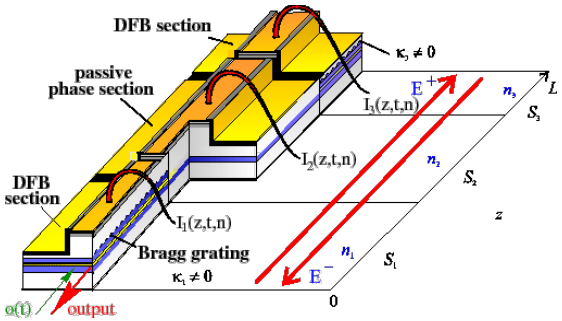
October 12, 2010

Photonics Group, CNRS-LAAS, Toulouse

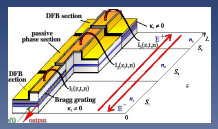


Introduction

Good old distributed feedback laser



DFB are cutting edge but:



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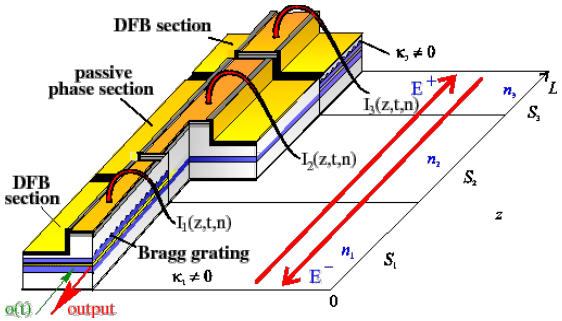
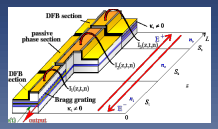


DFB are cutting edge but:

- Inherently dual-mode



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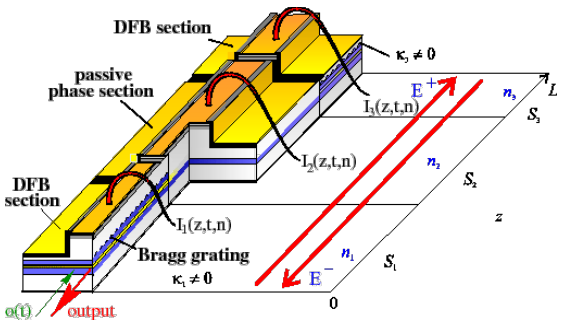
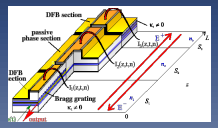


DFB are cutting edge but:

- Inherently dual-mode
- Wavelength engineering is hard



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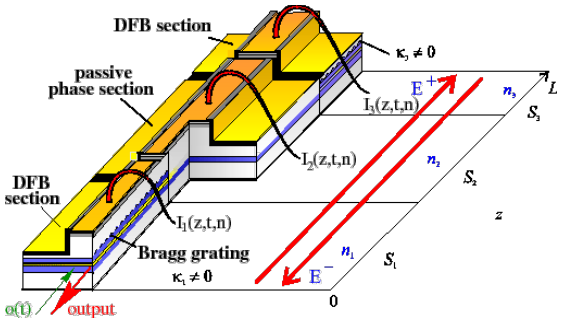

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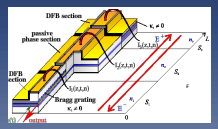

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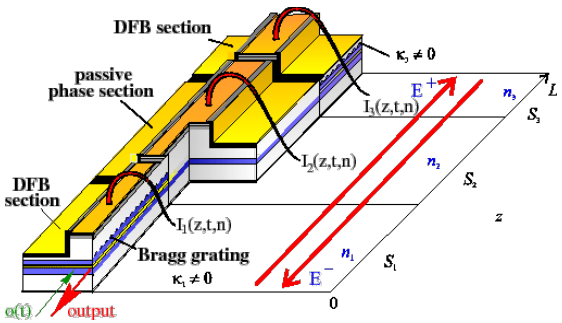
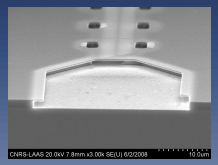
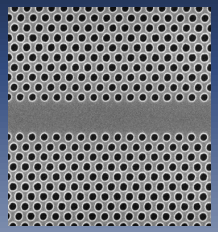


DFB are cutting edge but:

- Inherently dual-mode
- Wavelength engineering is hard
- Integration in array still a challenge
- Beware of optical feedback

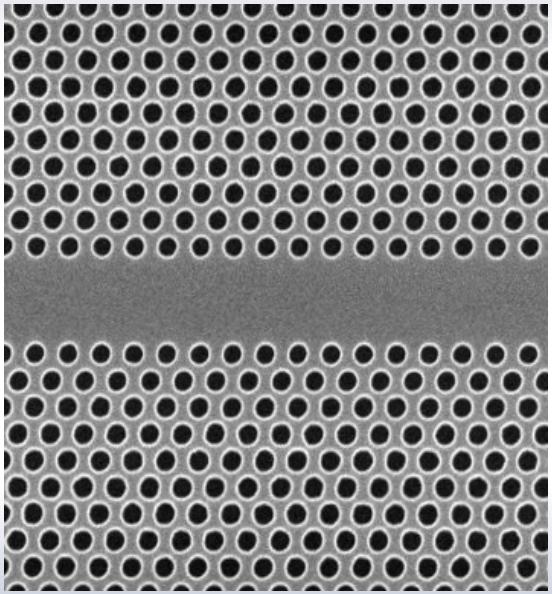


Menu

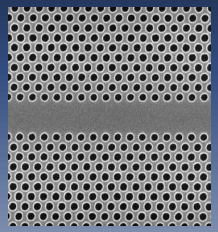


Photonic crystal waveguide for single-mode DFB laser

The waveguide we use ...



W3 ΓK PhC defect waveguide



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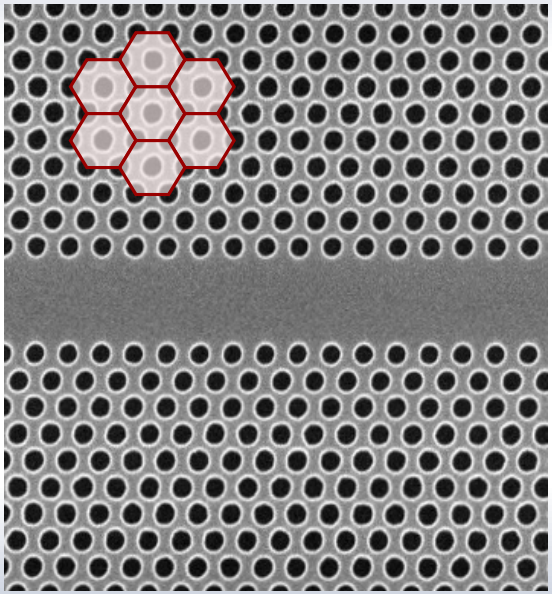
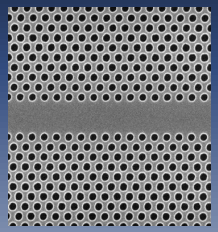


W3 ΓK PhC defect waveguide

- Hexagonal lattice Photonic Crystal



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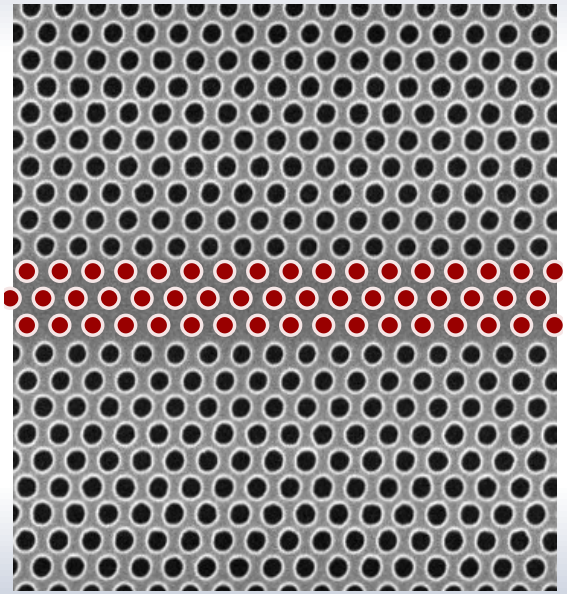
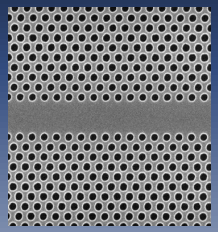


W3 ΓK PhC defect waveguide

- Hexagonal lattice Photonic Crystal
- 3 rows of holes missing



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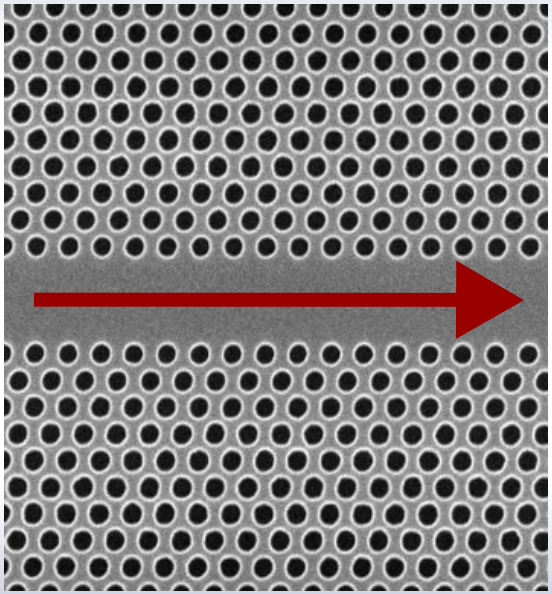
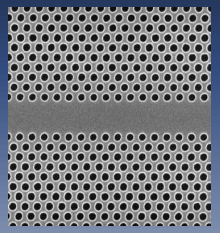


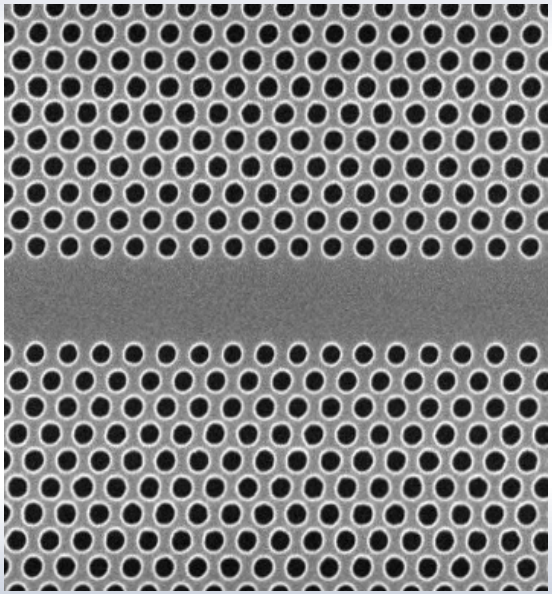
W3 ΓK PhC defect waveguide

- Hexagonal lattice Photonic Crystal
- 3 rows of holes missing in ΓK direction



Photonic crystal waveguide for single-mode DFB laser

The waveguide we use ...



W3 ΓK PhC defect waveguide

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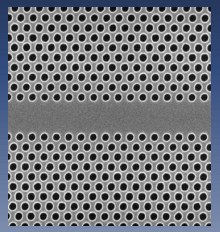
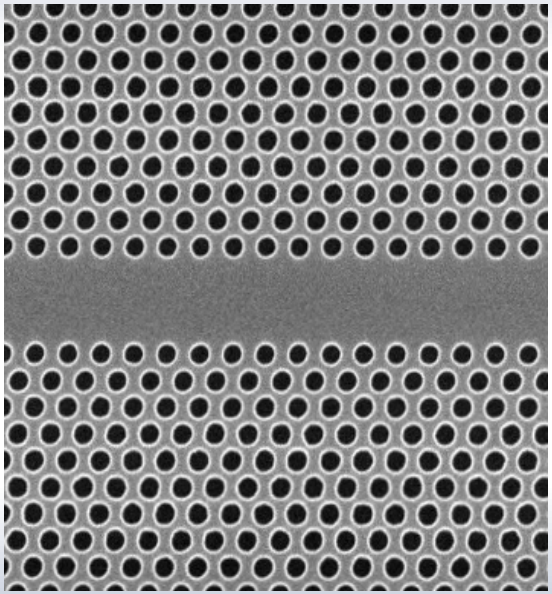
Guiding and DFB properties?



Photonic crystal waveguide for single-mode DFB laser

The waveguide we use ...



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- Hexagonal lattice Photonic Crystal
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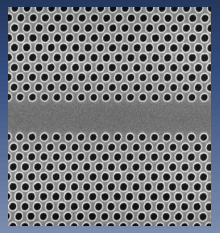
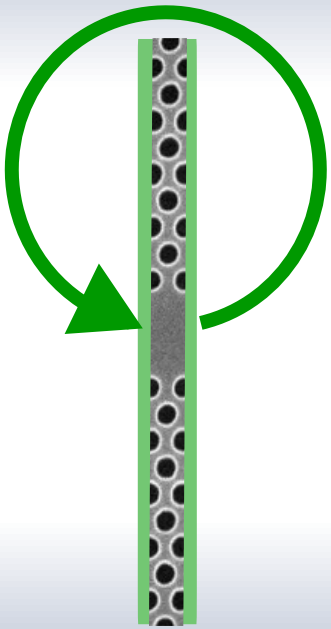
Guiding and DFB properties:

- band diagram from PWEM (mpb from MIT)



The waveguide we use ...



W3 ΓK PhC defect waveguide

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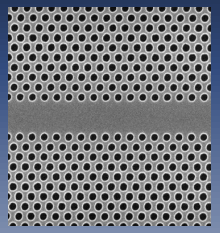
Guiding and DFB properties:

- band diagram from PWEM (mpb from MIT)
- infinitely long waveguide (periodic boundary conditions)



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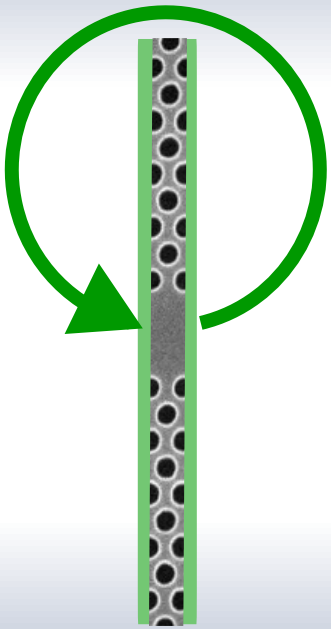

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- Hexagonal lattice Photonic Crystal
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Guiding and DFB properties:

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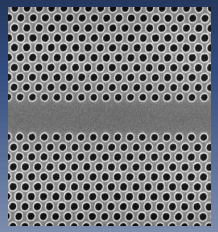
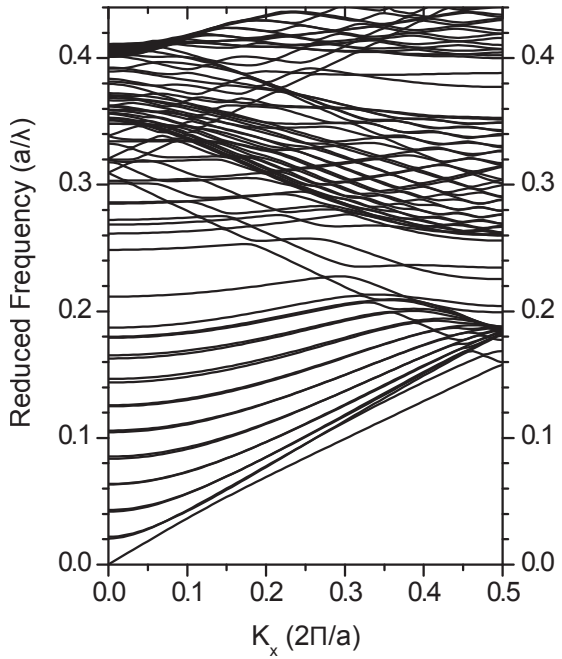
- infinitely long waveguide (periodic boundary conditions)
- $n_{eff} \simeq 3.27$ / hole filling factor $\simeq 0.25$

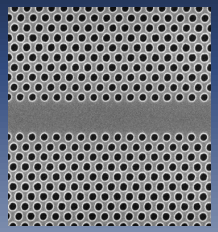


Photonic crystal waveguide for single-mode DFB laser

W3 ΓK band diagram



Guiding ?



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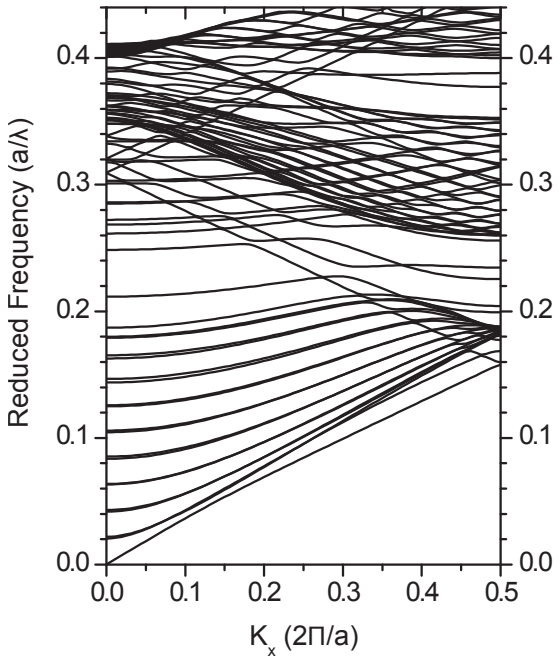
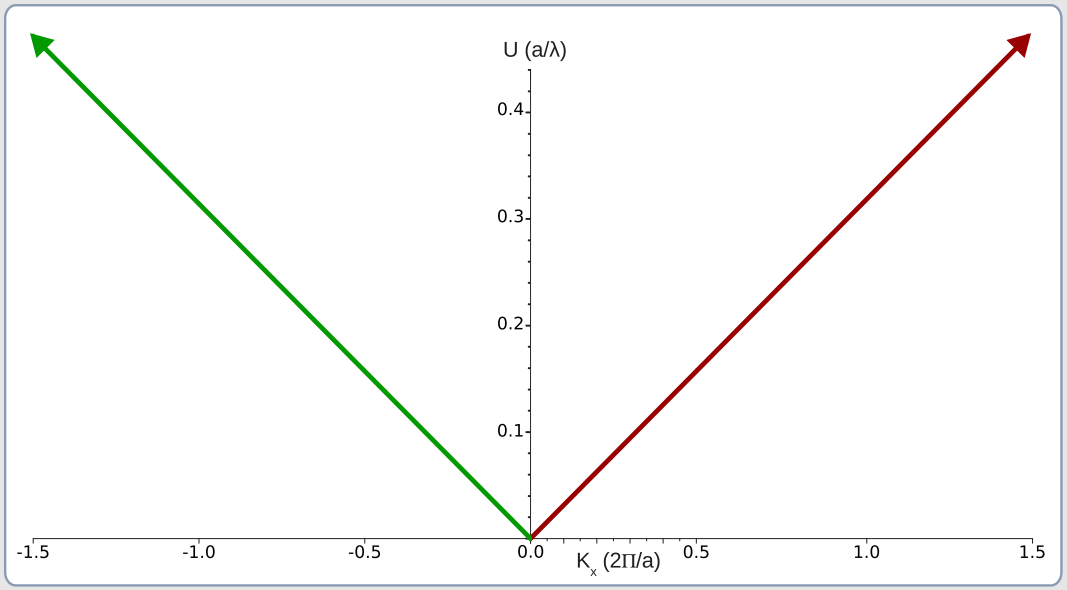
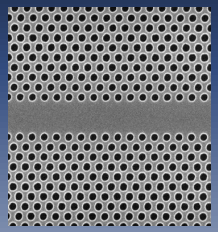


Guiding : ideal waveguide





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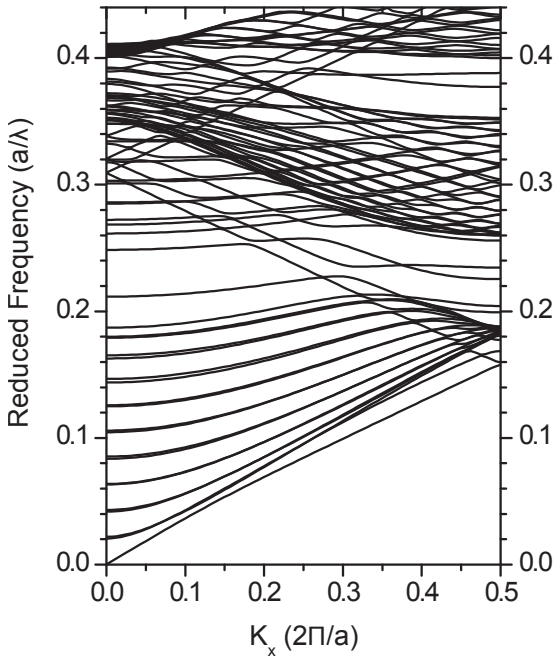
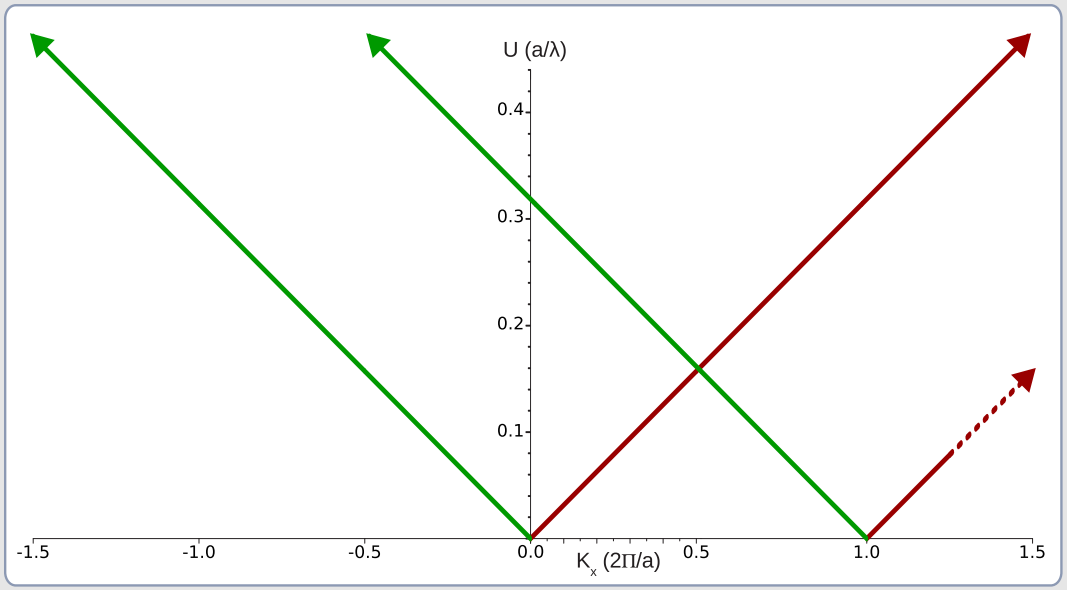
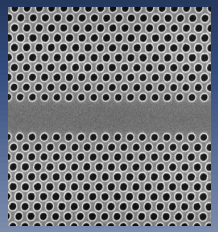


Guiding : ideal periodic waveguide





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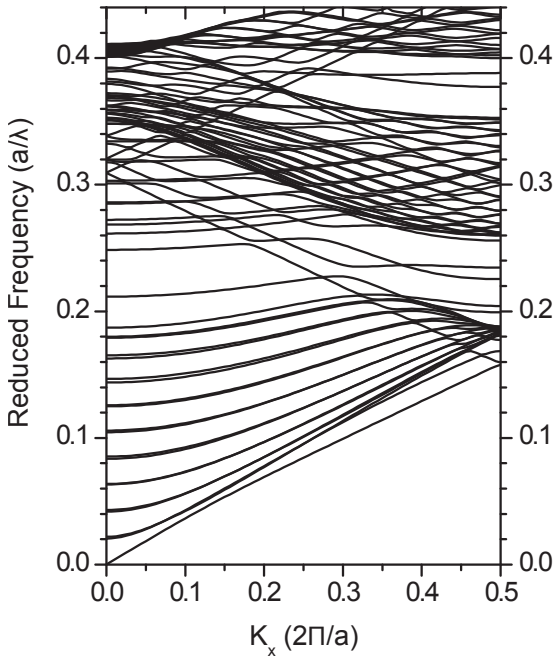

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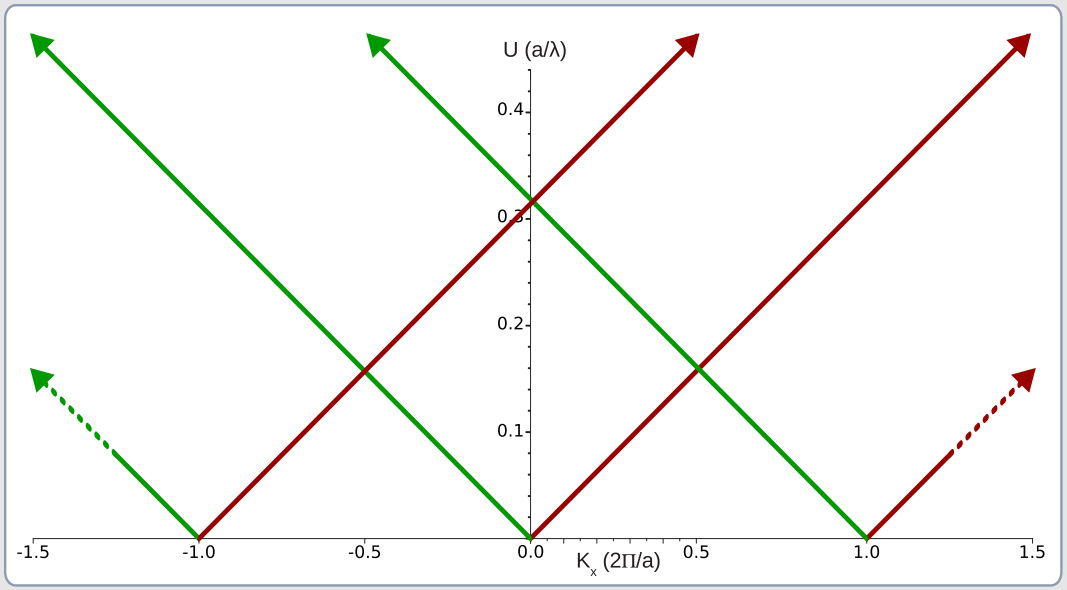

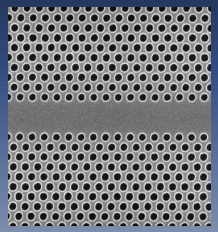

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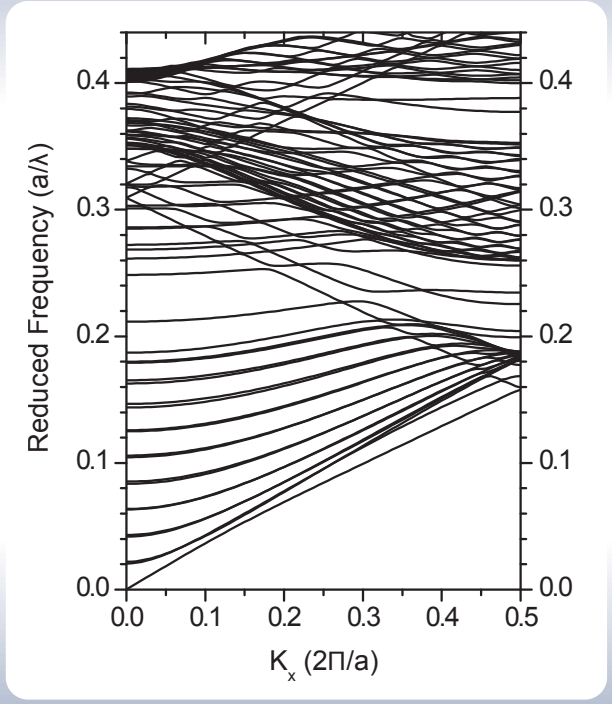

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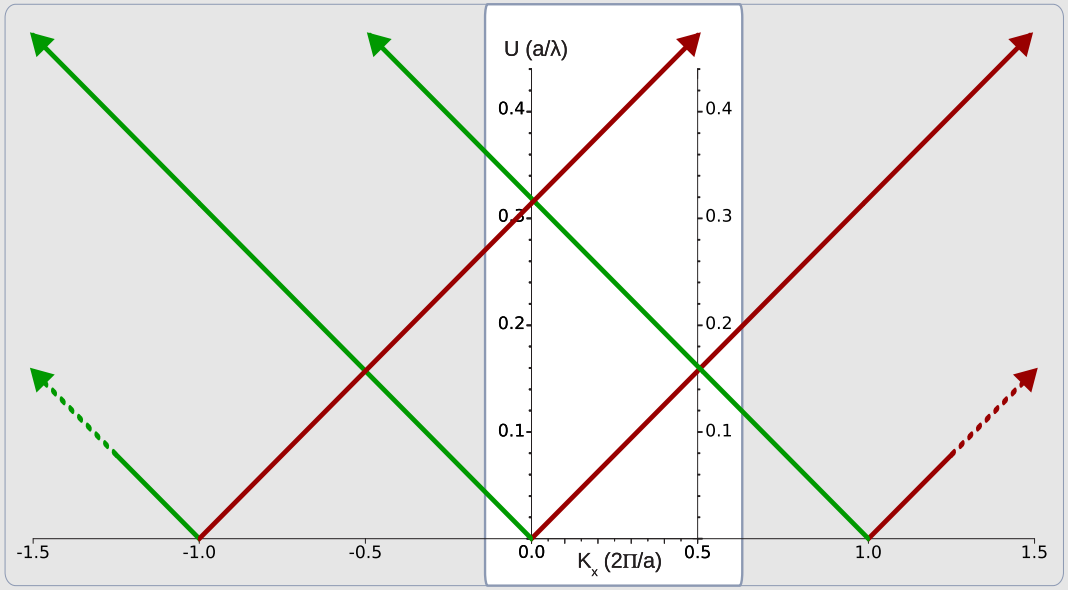

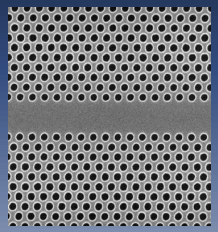

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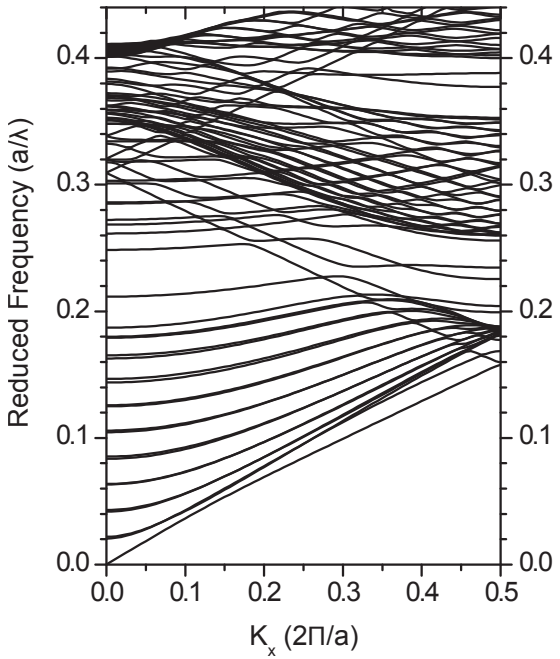

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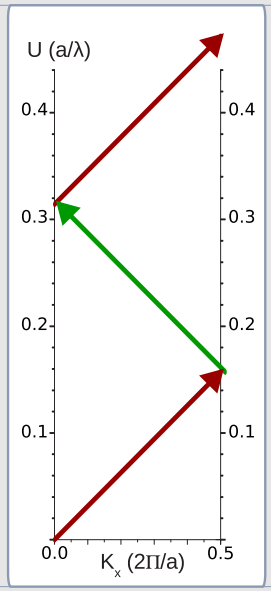

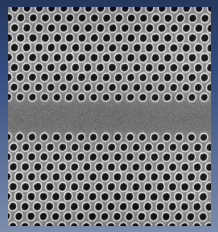

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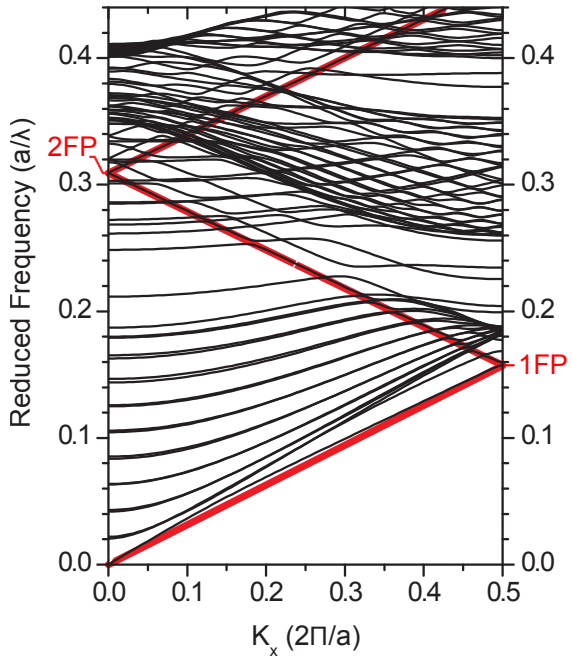

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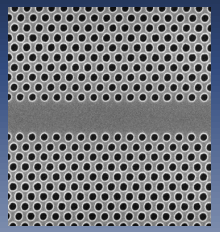

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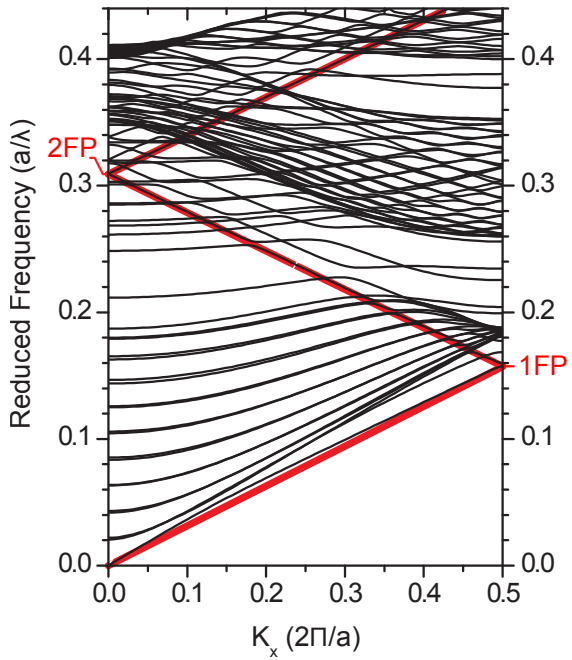
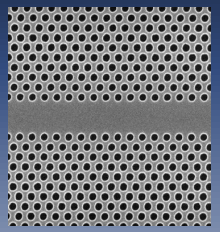
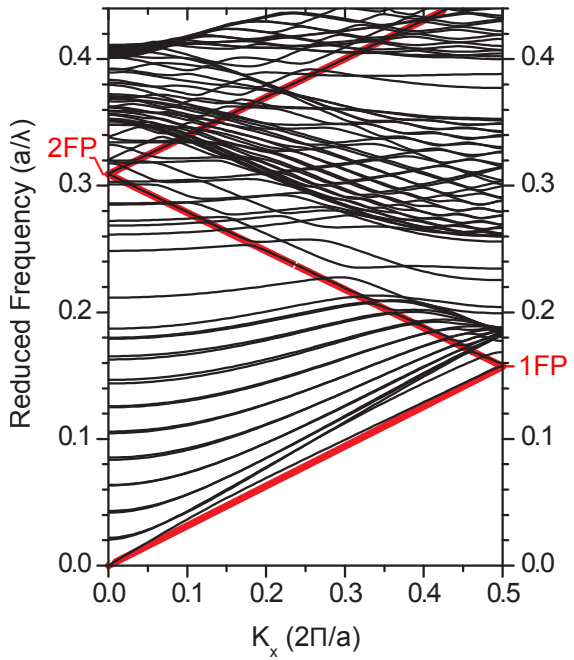


Guiding : W3 ΓK

- W3 ΓK acts like a waveguide

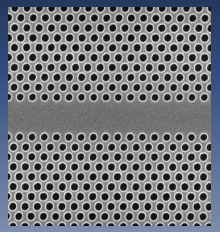


W3 ΓK band diagram



Guiding : W3 ΓK

- W3 ΓK acts like a waveguide
- Magic occurs at the Folding Points (1FP, 2FP, ...)



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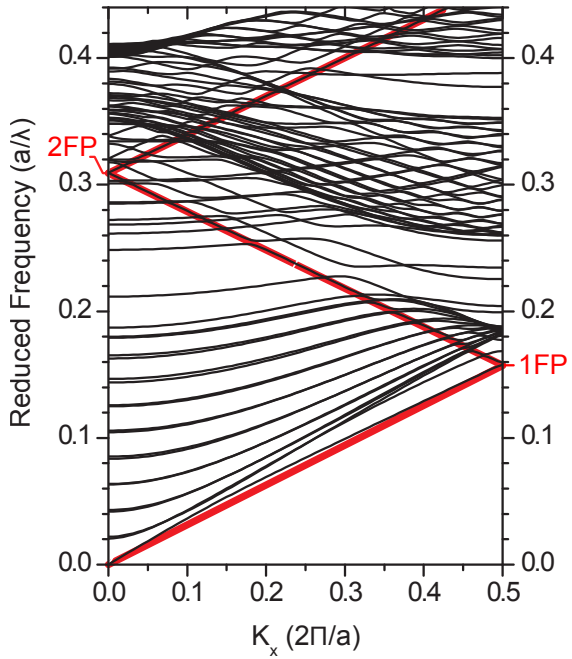
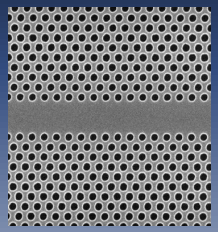
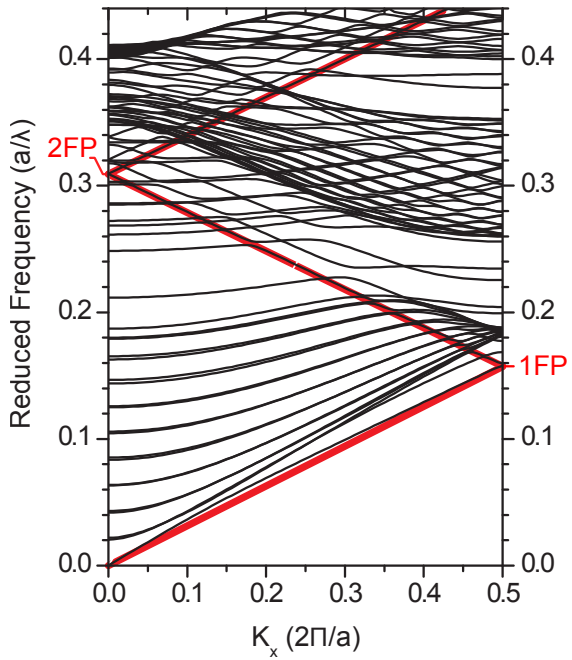


DFB ?



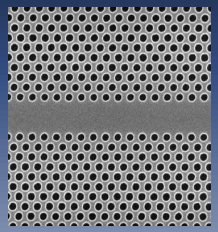
Photonic crystal waveguide for single-mode DFB laser

W3 ΓK band diagram



DFB : at the Folding Points

- Coupling of counterpropagative waves



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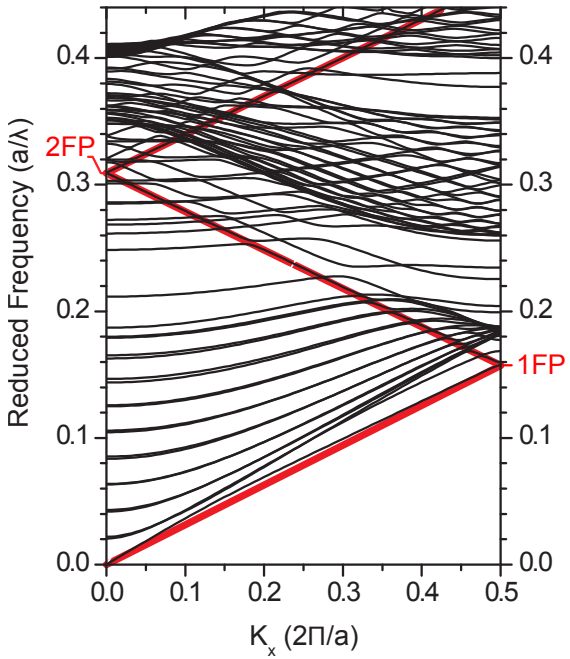
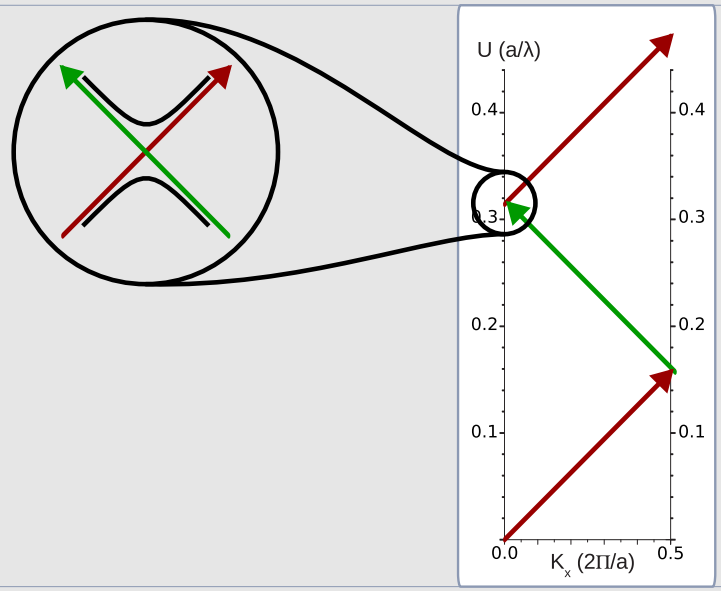
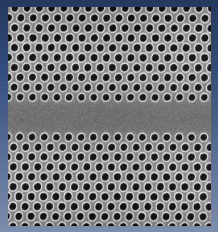


DFB : at the Folding Points





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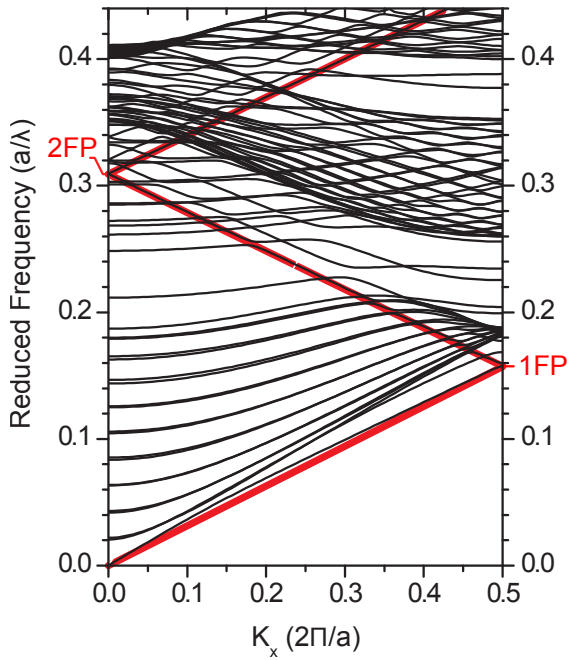

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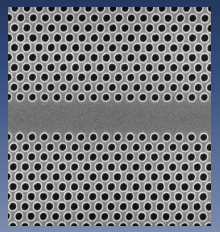
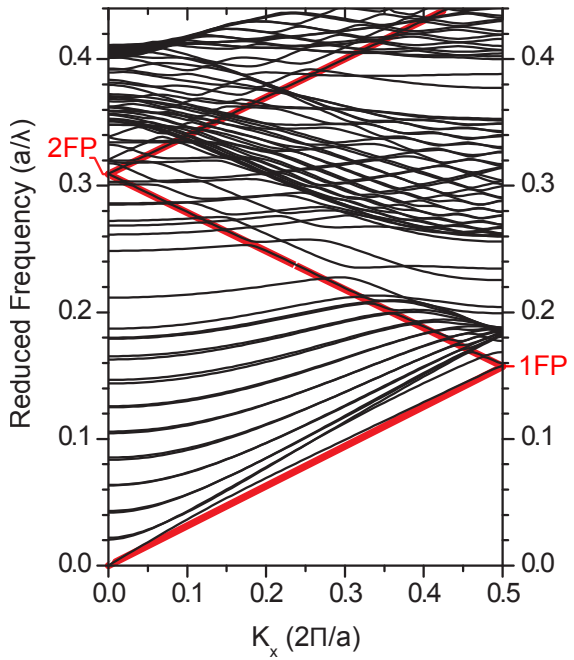


Photonic crystal waveguide for single-mode DFB laser

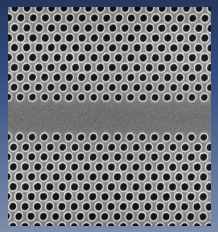
W3 ΓK band diagram



DFB : at the Folding Points

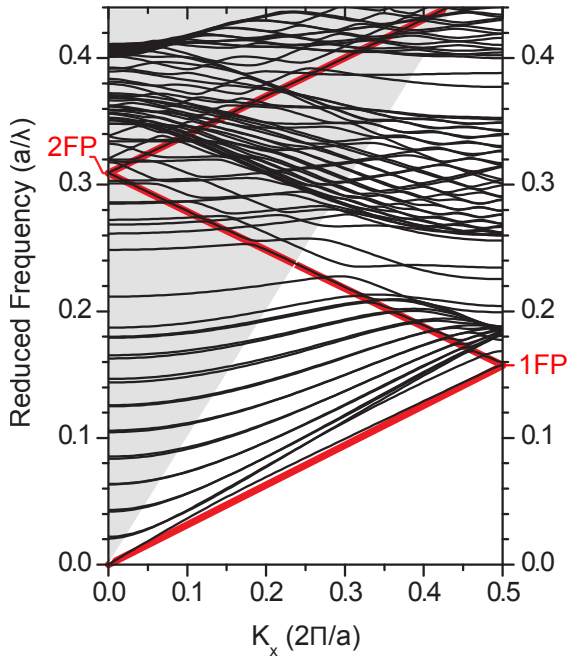
- Coupling of counterpropagative waves
- Two degenerated DFB modes[a] ...

[a] X. Checoury et al, APL 85, p5502, 2004



Photonic crystal waveguide for single-mode DFB laser

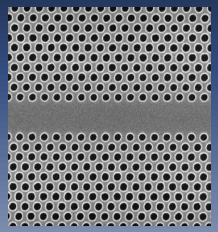
W3 ΓK band diagram



DFB : at the Folding Points

- Coupling of counterpropagative waves
- Two degenerated DFB modes[a] ...
- ... but single mode DFB at the 2FP[b] (above light cone & symmetry)

[a] X. Checoury et al, APL 85, p5502, 2004
[b] R. Kazarinov et al, JQE, 21, p144, 1985



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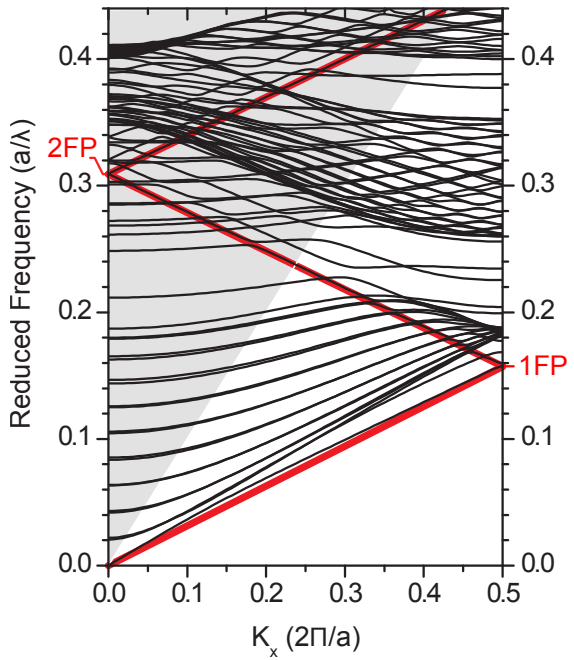
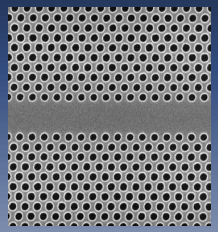
W3 ΓK band diagram



DFB : at the Folding Points

- Coupling of counterpropagative waves
- Two degenerated DFB modes[a] ...
- ... but single mode DFB at the 2FP[b] (above light cone & symmetry)
- $\lambda \simeq 1000\,\text{nm}$, $a \simeq 300\,\text{nm}$, $r \simeq 80\,\text{nm}$

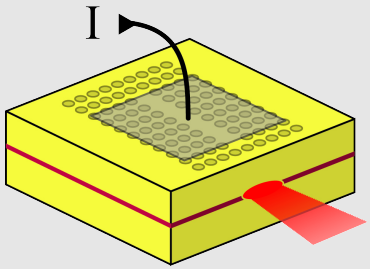
[a] X. Checoury et al, APL 85, p5502, 2004
[b] R. Kazarinov et al, JQE, 21, p144, 1985



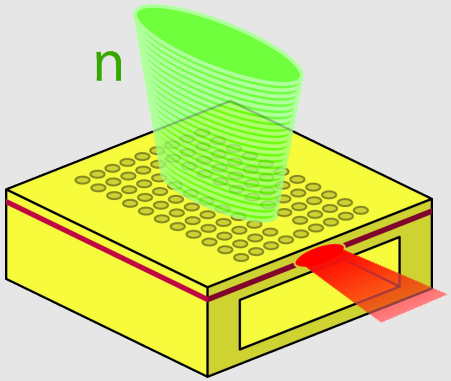
Photonic crystal waveguide for single-mode DFB laser

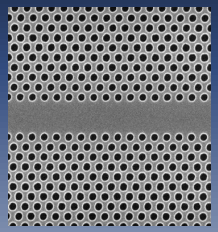
In practice: experimental demonstration

Bulk & e- pumping



Membrane & optical pumping

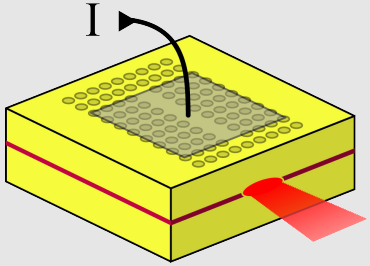




Photonic crystal waveguide for single-mode DFB laser

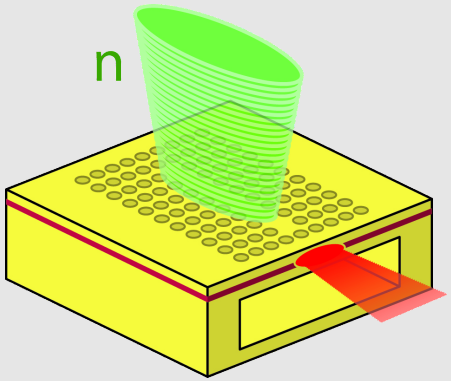
In practice: experimental demonstration

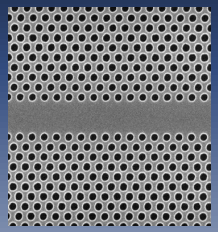
Bulk & e- pumping



- integration / applications

Membrane & optical pumping

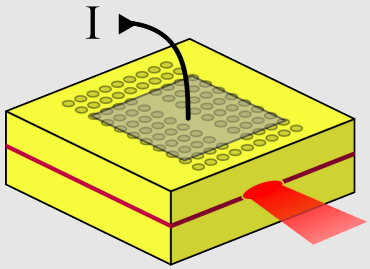




Photonic crystal waveguide for single-mode DFB laser

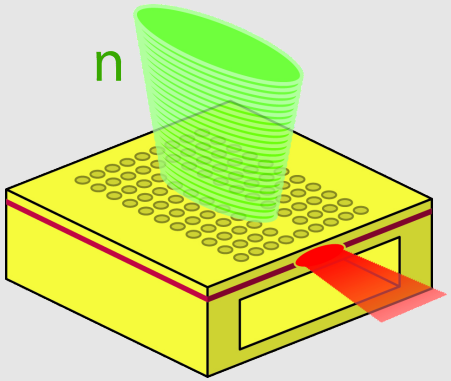
In practice: experimental demonstration

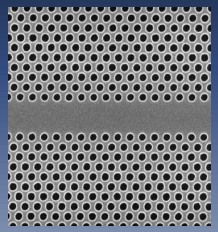
Bulk & e- pumping



- integration / applications
- deep etching:

Membrane & optical pumping

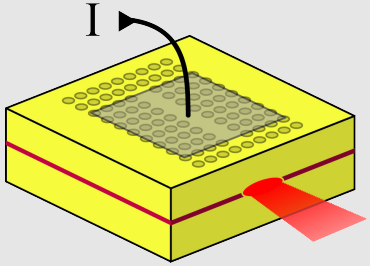




Photonic crystal waveguide for single-mode DFB laser

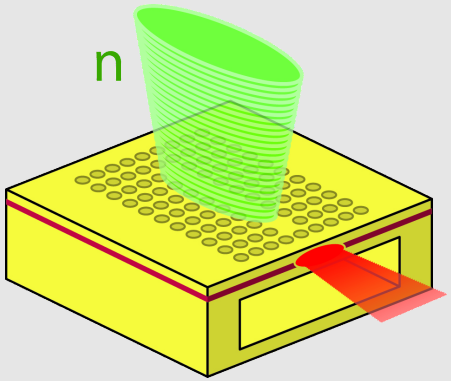
In practice: experimental demonstration

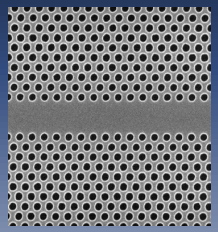
Bulk & e- pumping



- integration / applications
- deep etching:
- ... time consuming

Membrane & optical pumping





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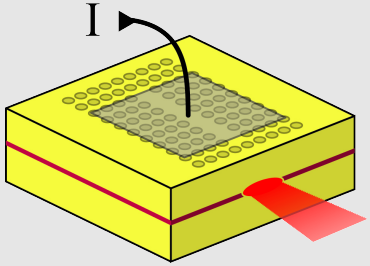
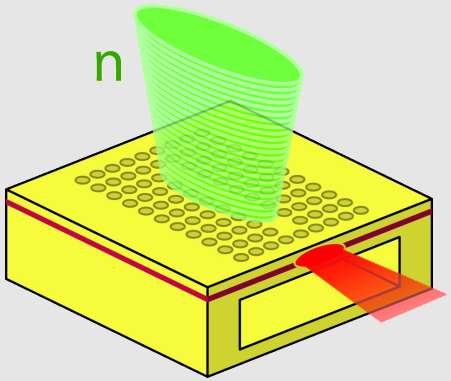
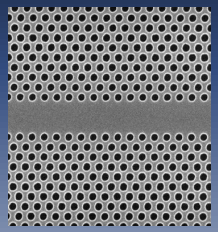
Bulk & e- pumping



- integration / applications
- deep etching:
- ... time consuming
- ... open problem on GaAs

Membrane & optical pumping





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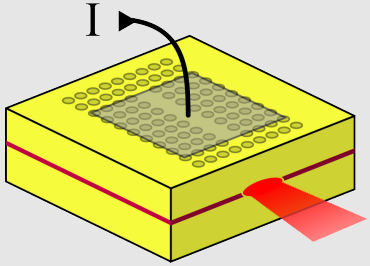

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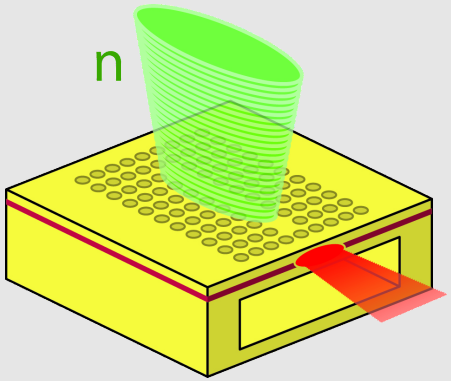
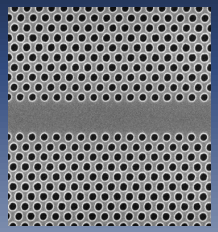
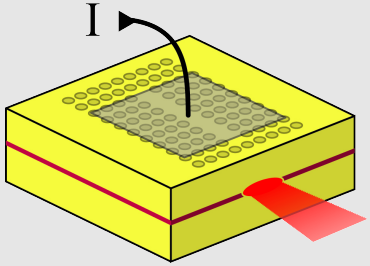


- fast and easy



In practice: experimental demonstration

Bulk & e- pumping



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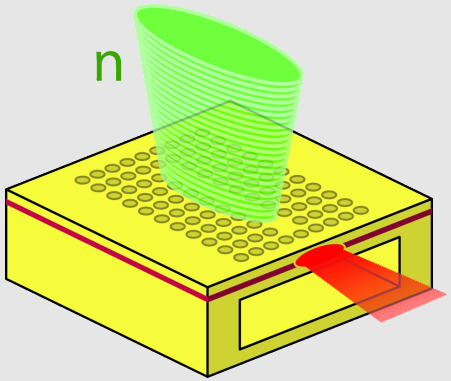
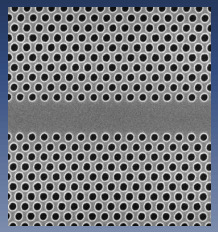
Membrane & optical pumping



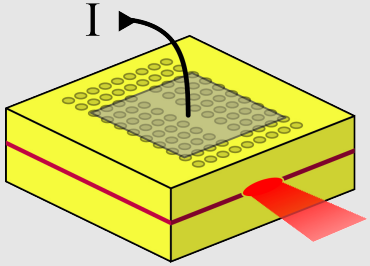
- fast and easy
- systematic studies



Photonic crystal waveguide for single-mode DFB laser

In practice: experimental demonstration

Bulk & e- pumping



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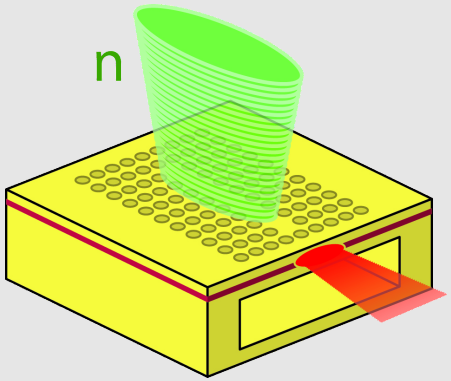
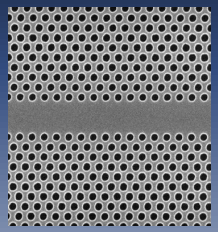
Membrane & optical pumping

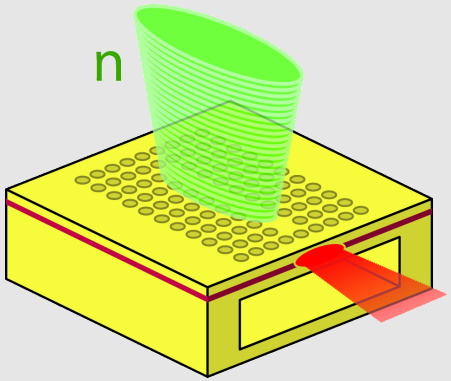


- fast and easy
- systematic studies
- proof of principle



In practice: experimental demonstration

Membrane & optical pumping



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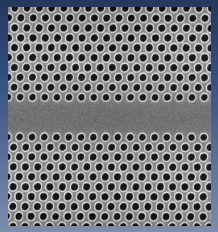
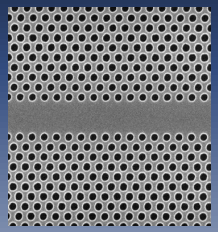


Photonic crystal waveguide for single-mode DFB laser

Membrane Fabrication: 5 steps



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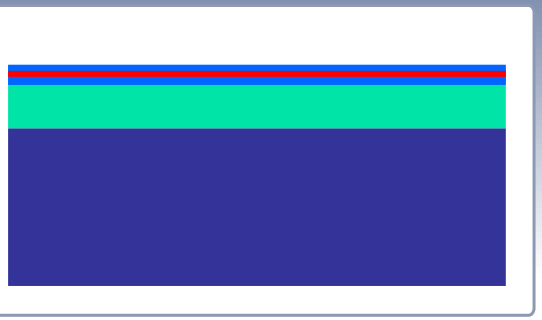
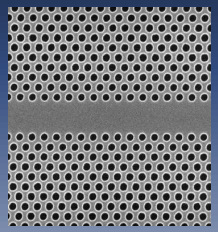


MBE Growth
(In)GaAs/AlGaAs



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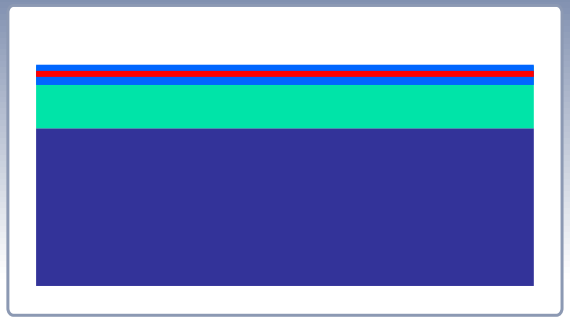

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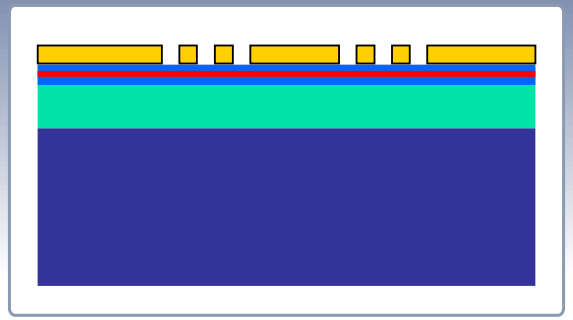
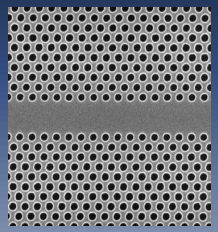


Resist spin coating
& e-beam



Photonic crystal waveguide for single-mode DFB laser

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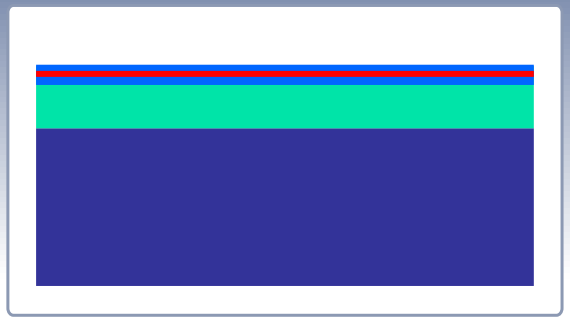

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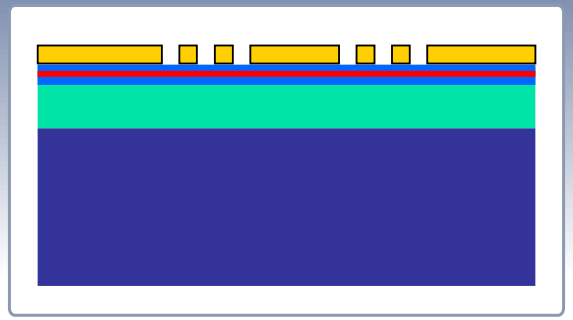

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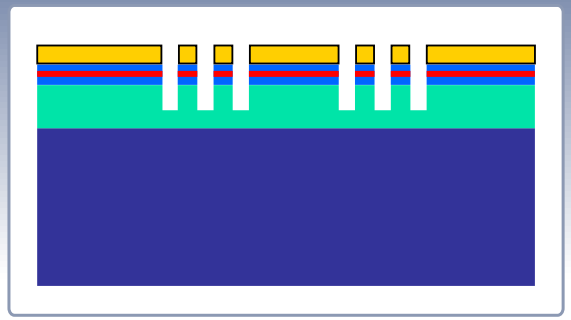
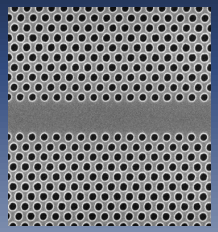


PhC etching
(ICP Cl_2/N_2)



Photonic crystal waveguide for single-mode DFB laser

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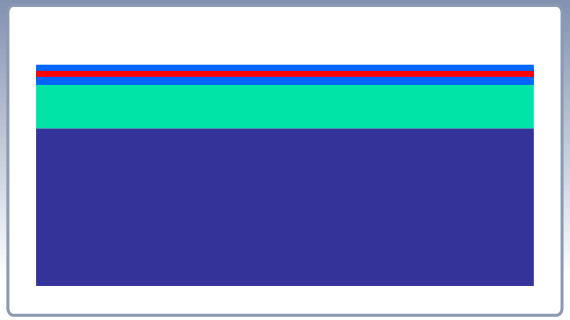

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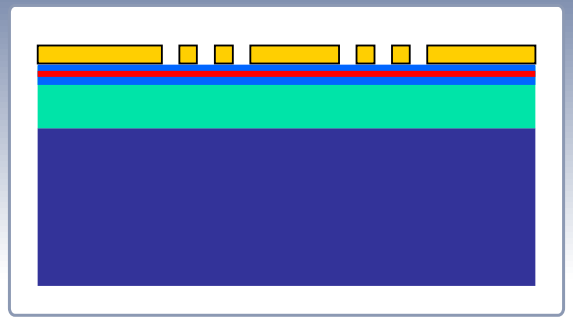

Resist spin coating
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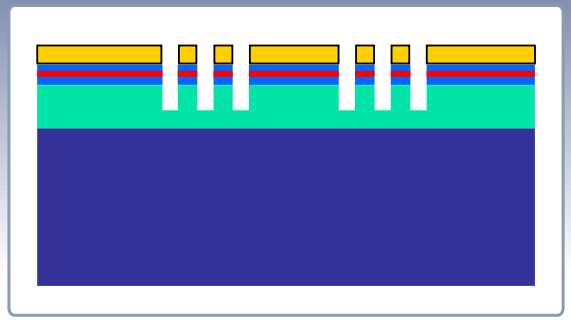

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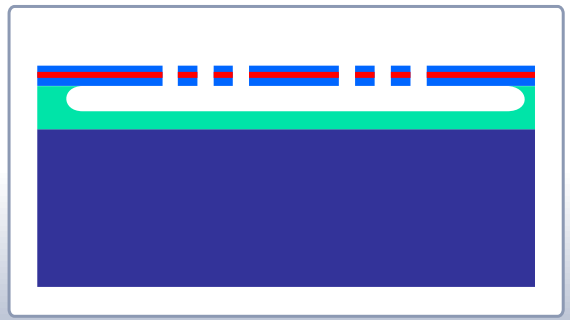
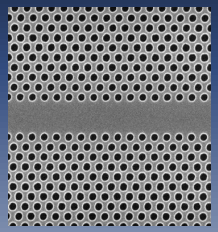
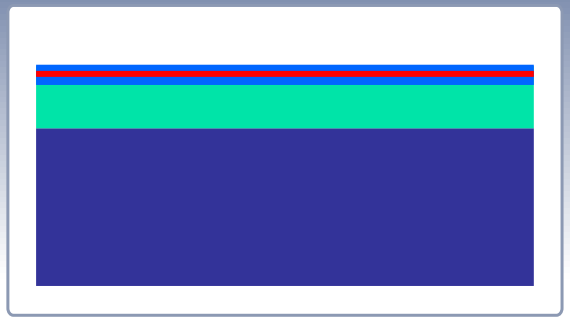


Membrane freeing
(HF etching)

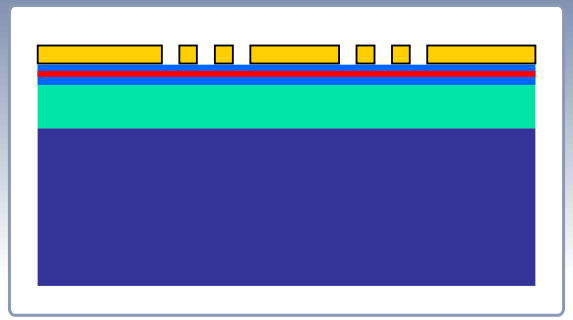


Photonic crystal waveguide for single-mode DFB laser

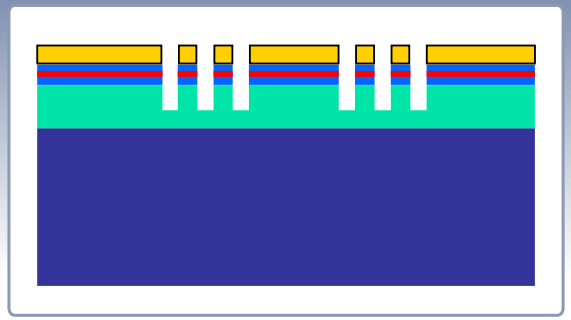
Membrane Fabrication: 5 steps



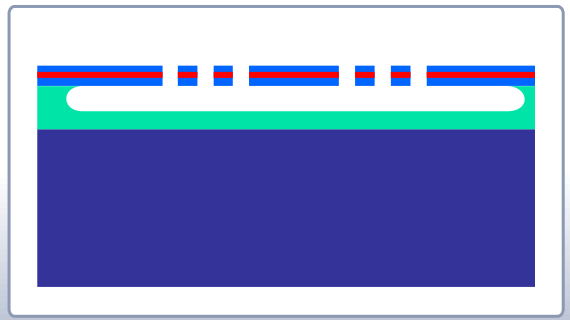
MBE Growth
(In)GaAs/AlGaAs



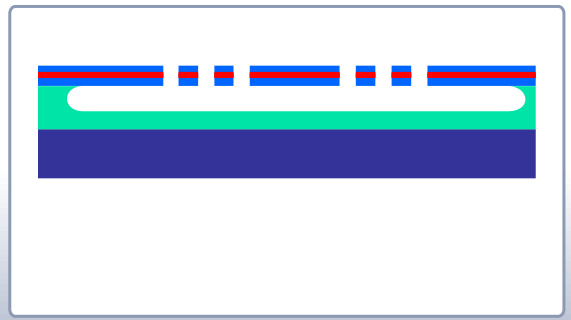
Resist spin coating
& e-beam



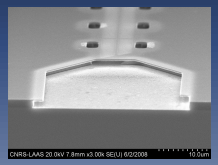
PhC etching
(ICP Cl_2/N_2)



Membrane freeing
(HF etching)

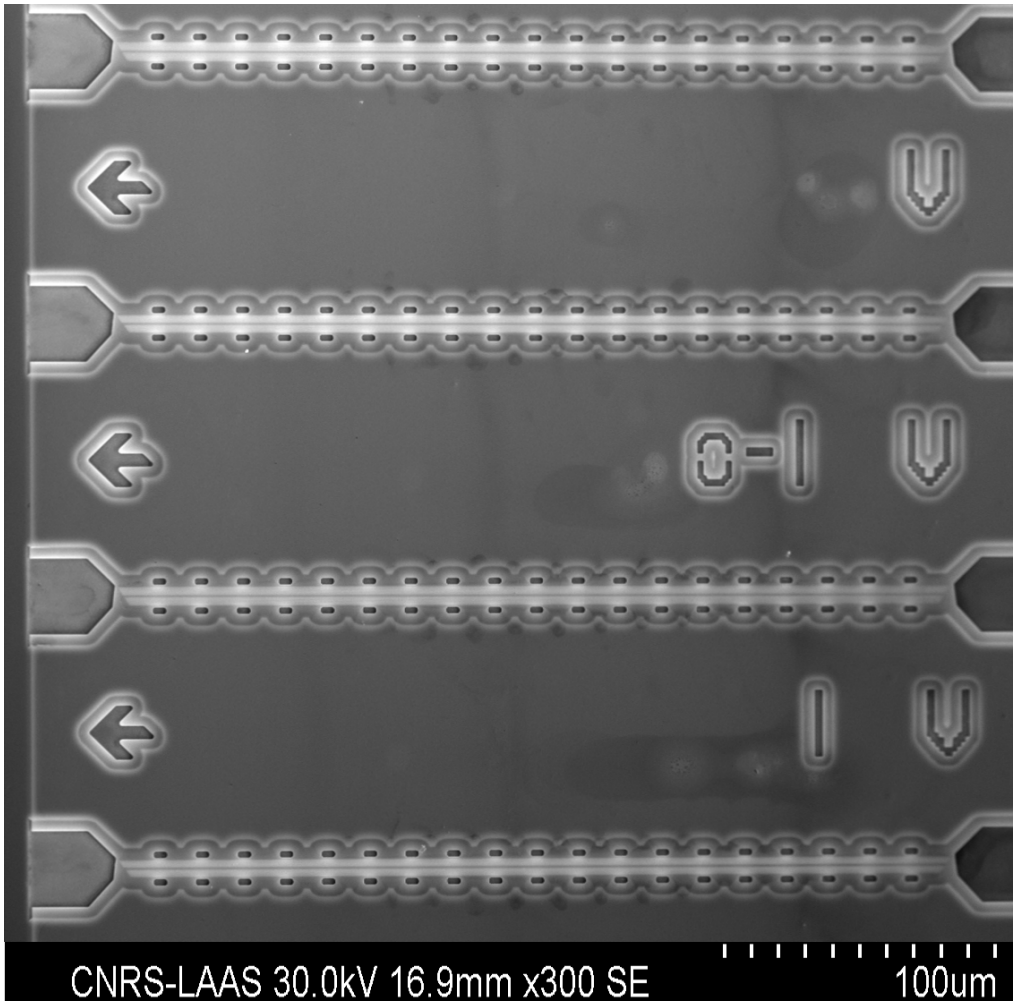


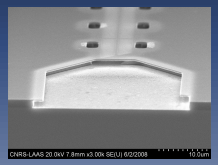
Thinning
& Cleavage



Photonic crystal waveguide for single-mode DFB laser

PhC DFB laser on a membrane





Photonic crystal waveguide for single-mode DFB laser

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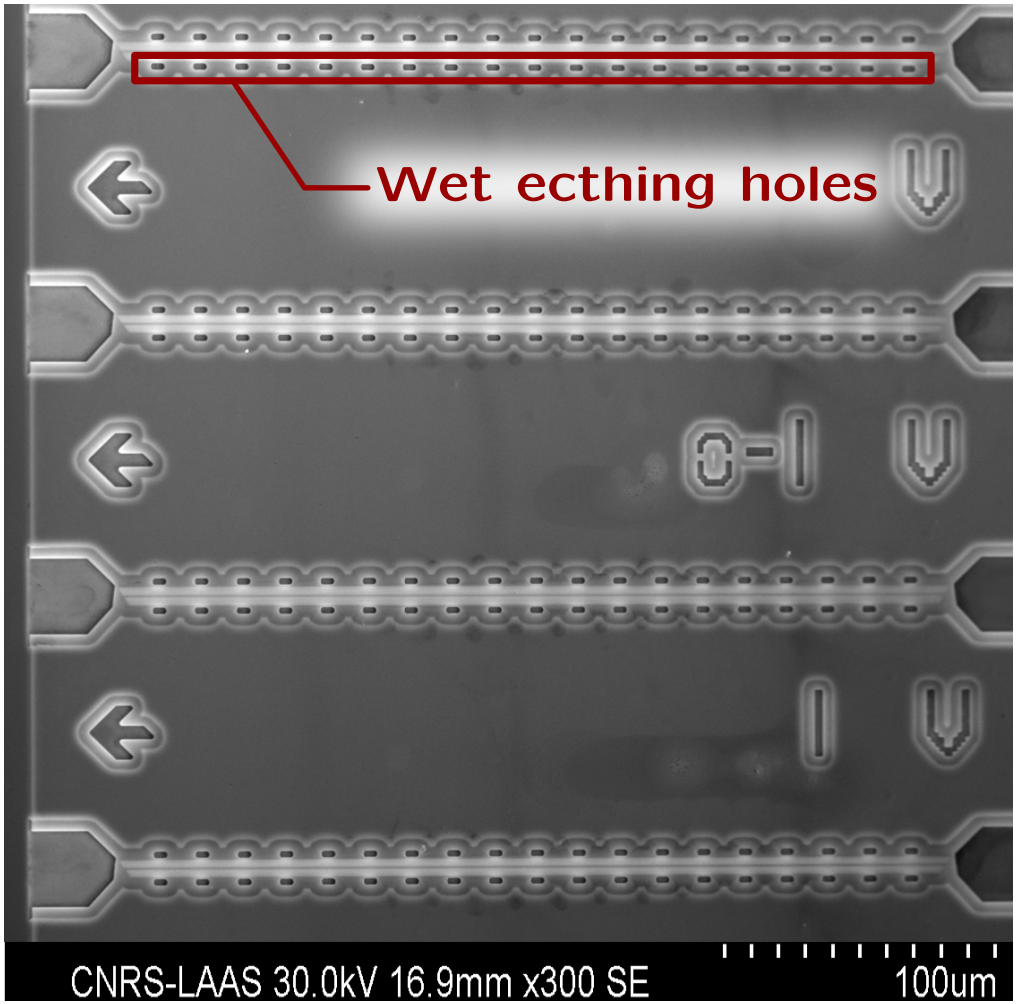
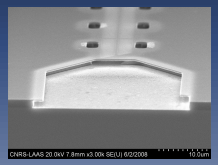
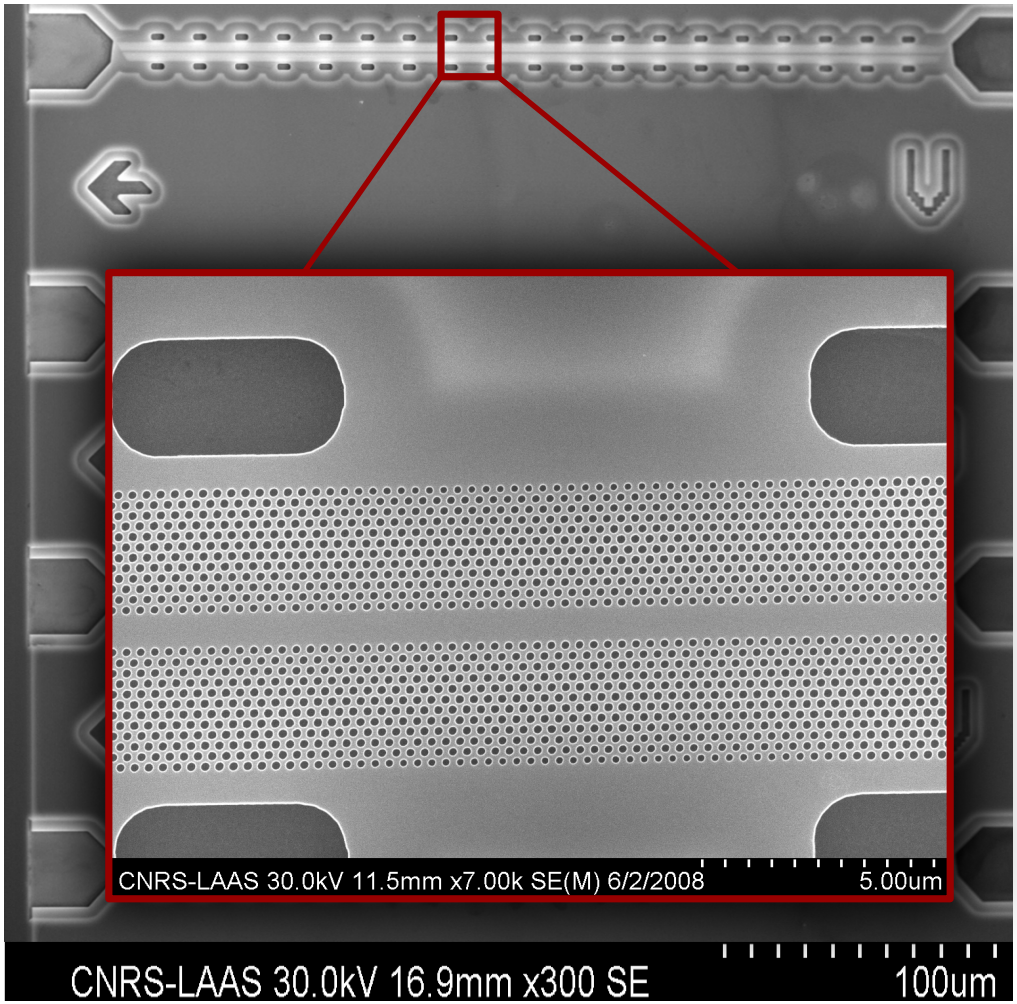
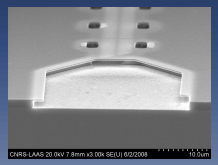




Photonic crystal waveguide for single-mode DFB laser

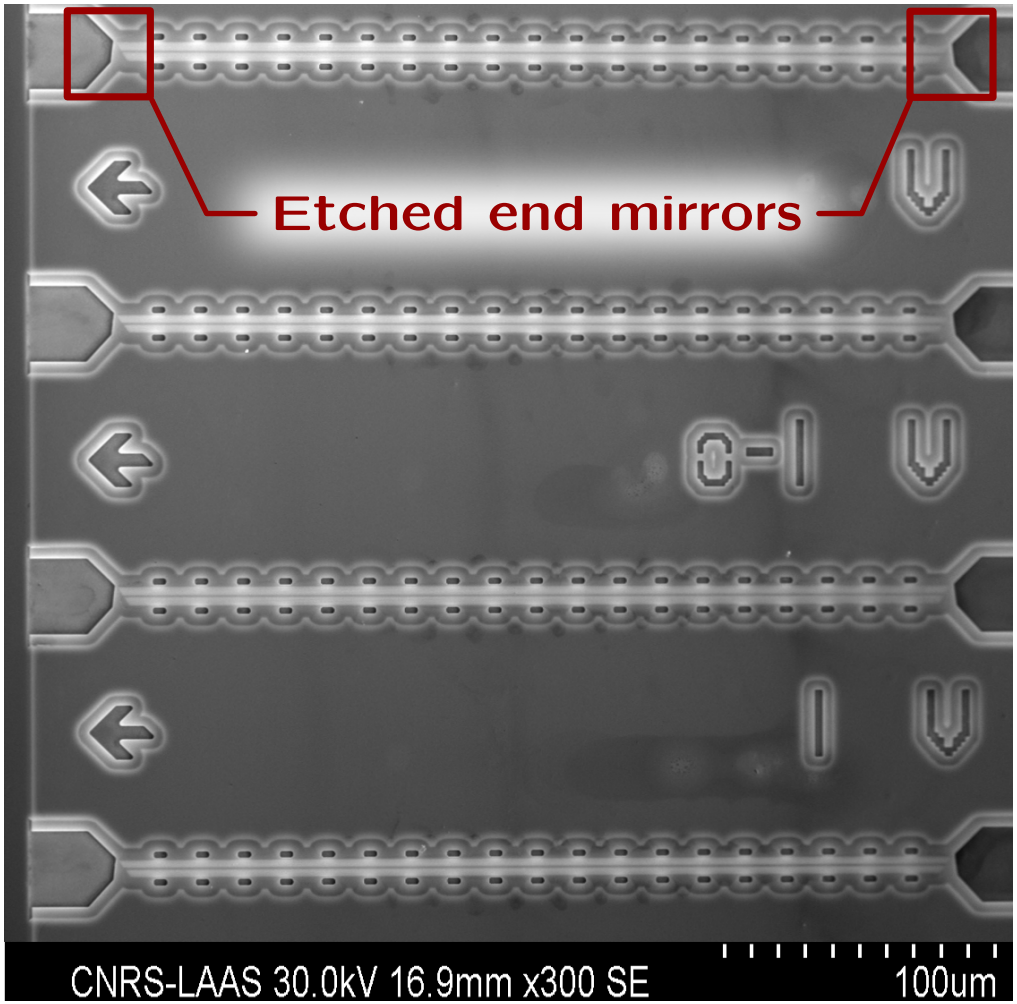
PhC DFB laser on a membrane

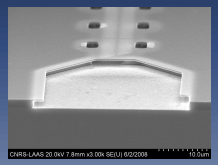




Photonic crystal waveguide for single-mode DFB laser

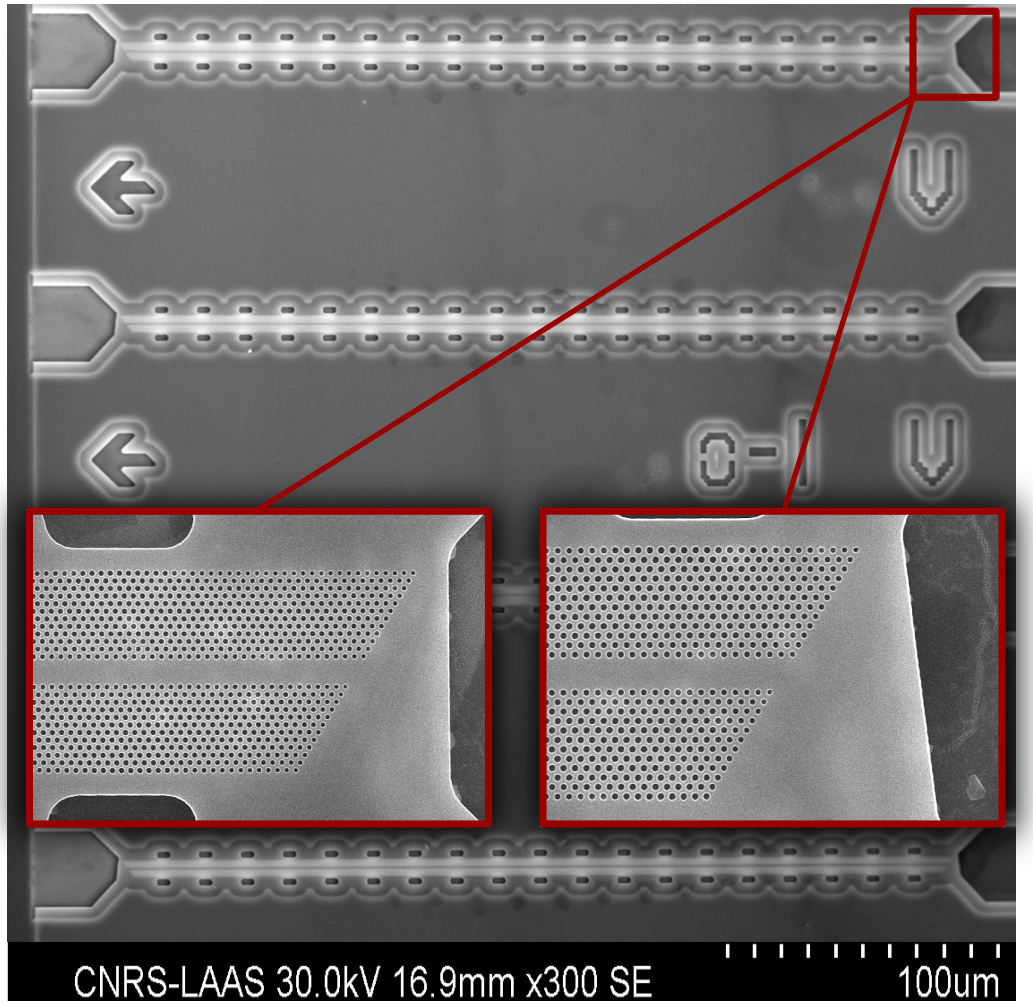
PhC DFB laser on a membrane

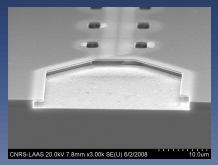




Photonic crystal waveguide for single-mode DFB laser

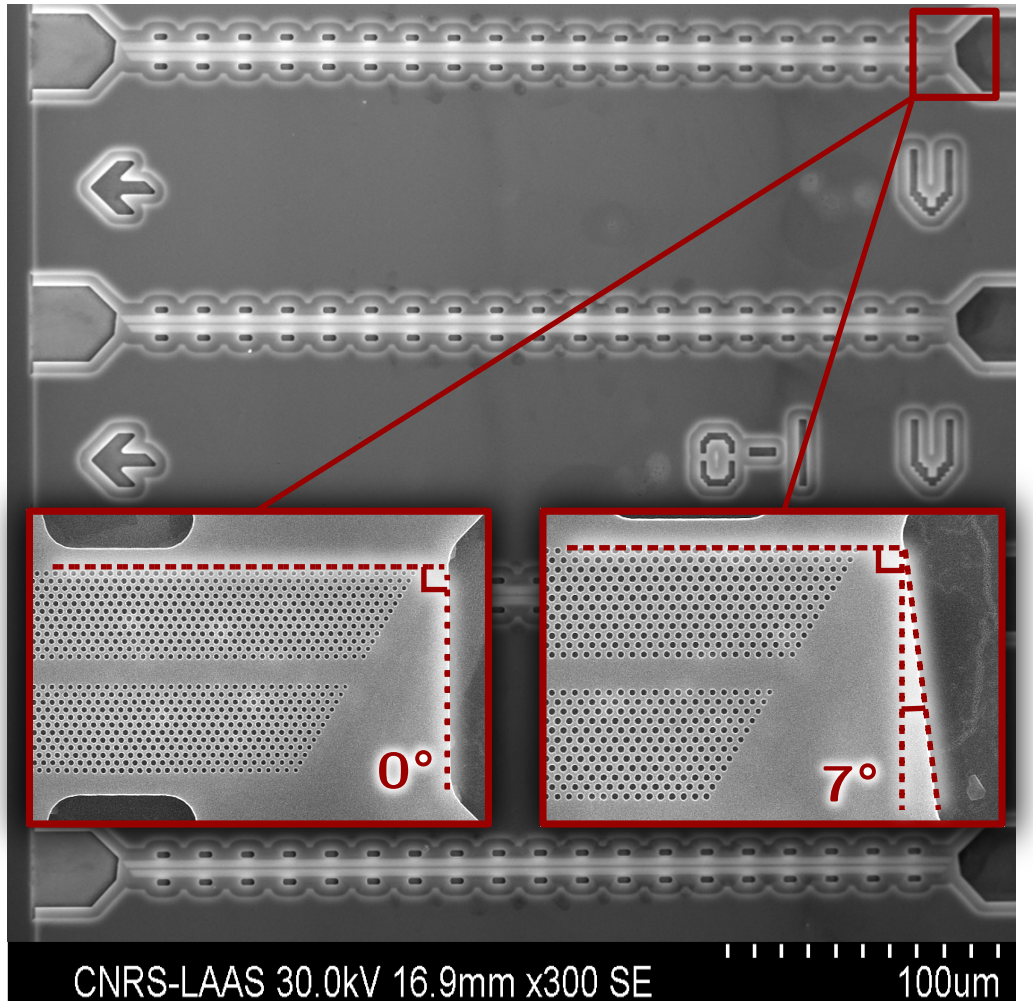
PhC DFB laser on a membrane

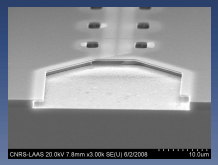




Photonic crystal waveguide for single-mode DFB laser

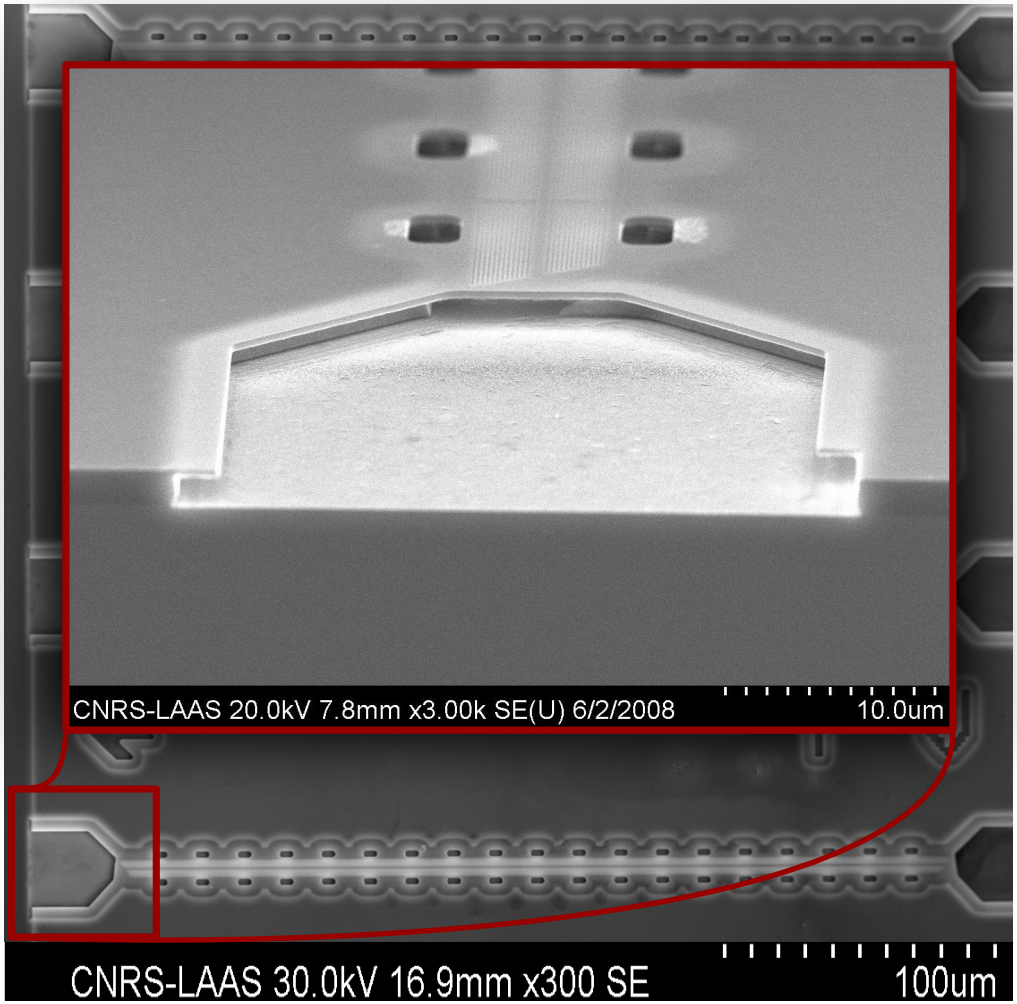
PhC DFB laser on a membrane

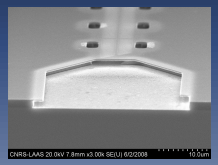




Photonic crystal waveguide for single-mode DFB laser

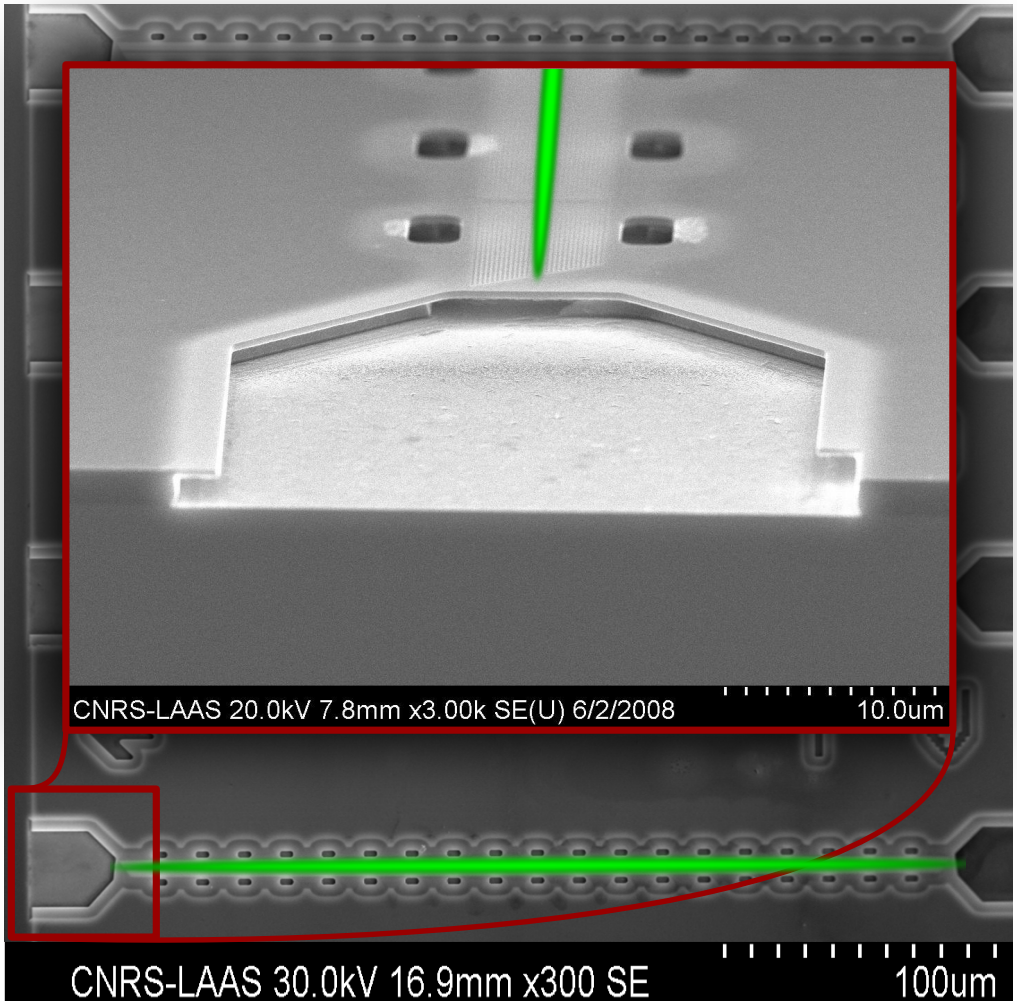
PhC DFB laser on a membrane

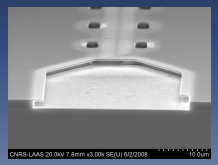




Photonic crystal waveguide for single-mode DFB laser

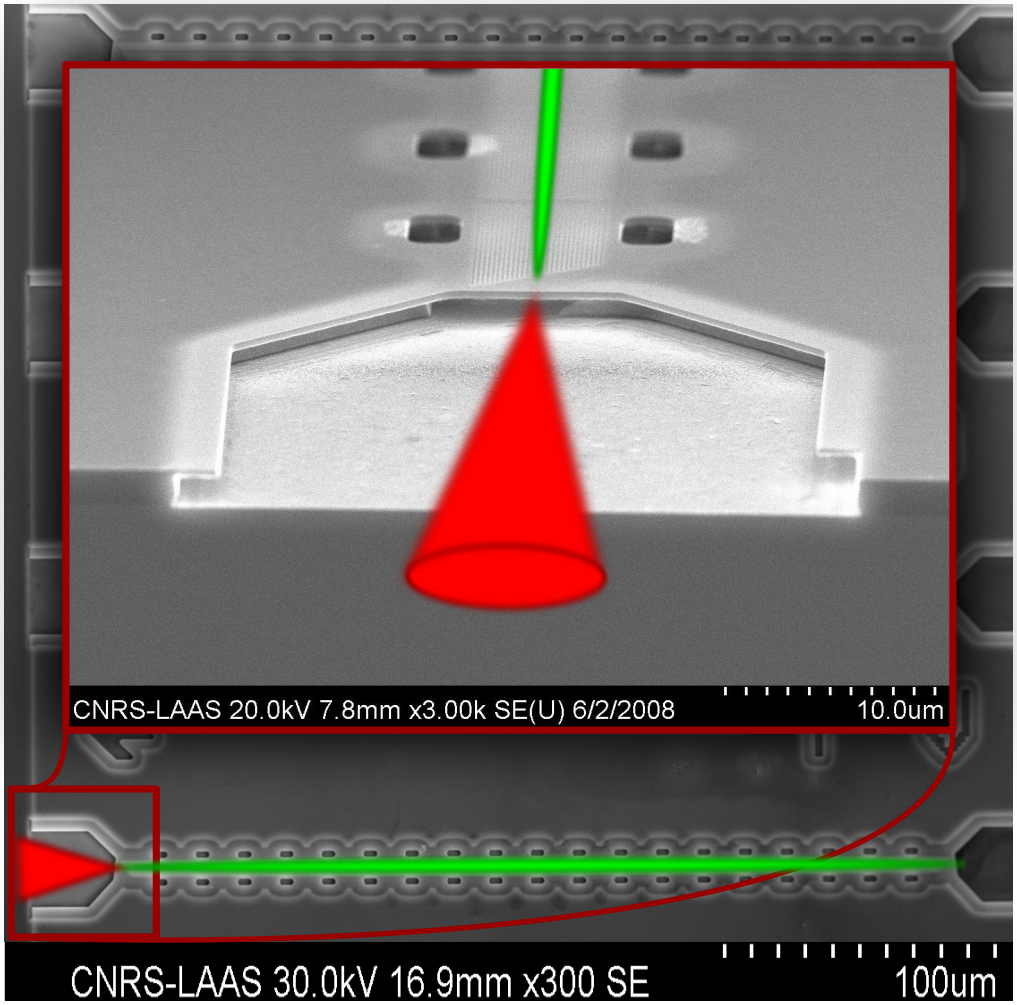
PhC DFB laser on a membrane

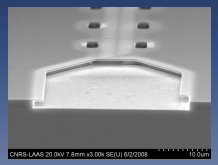




Photonic crystal waveguide for single-mode DFB laser

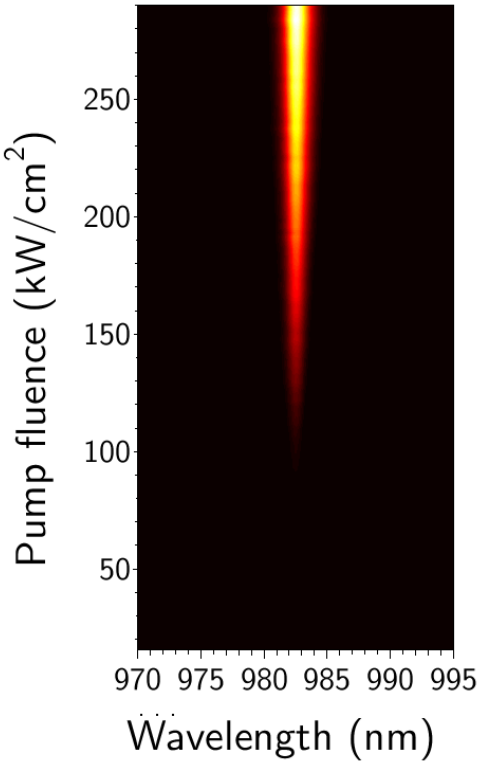
PhC DFB laser on a membrane

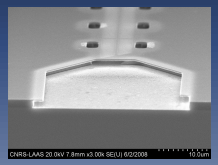




Photonic crystal waveguide for single-mode DFB laser

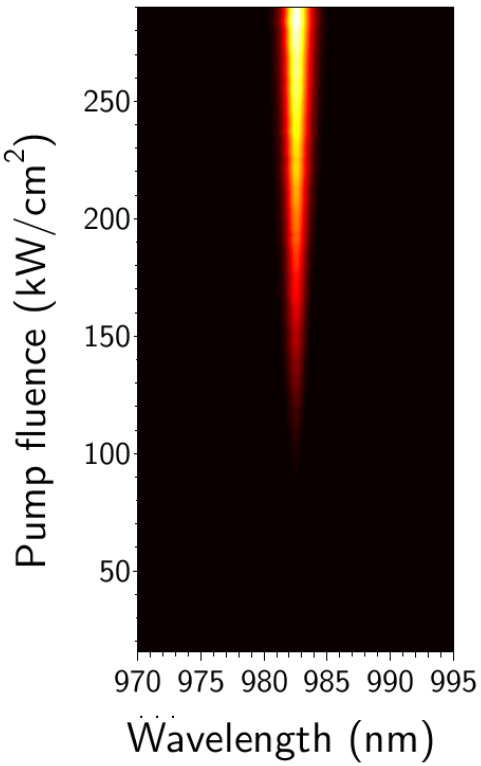
Typical light-light characteristic

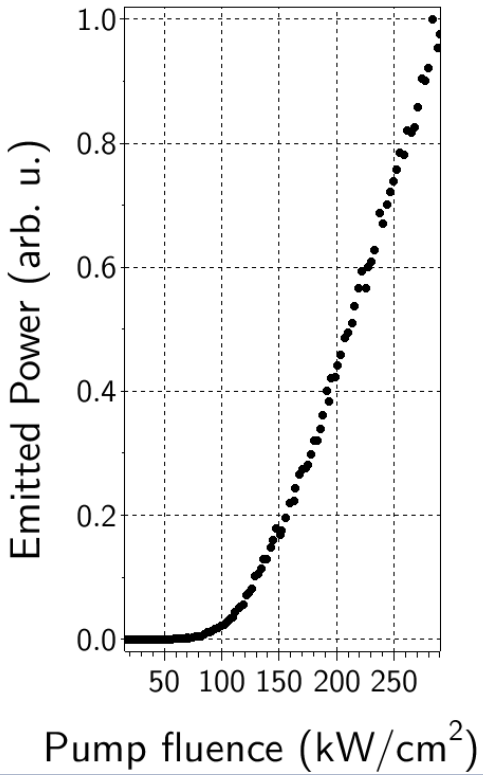


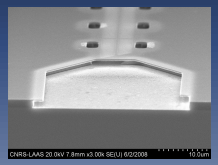


Photonic crystal waveguide for single-mode DFB laser

Typical light-light characteristic

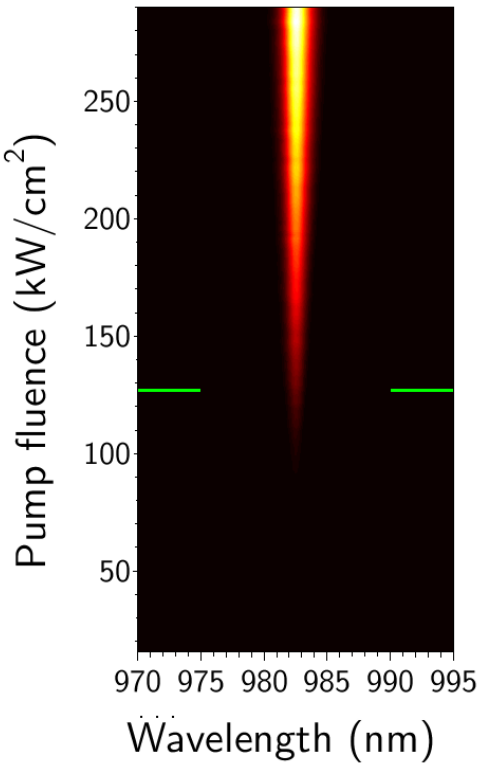


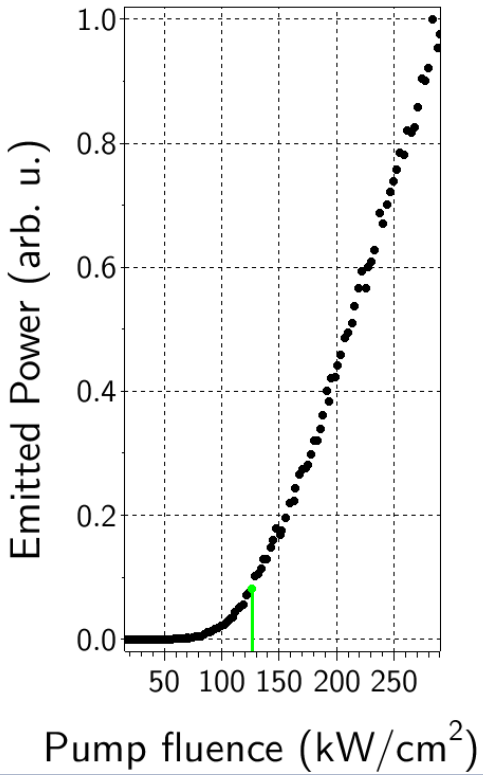


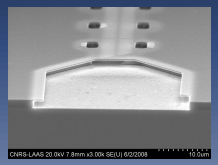


Photonic crystal waveguide for single-mode DFB laser

Typical light-light characteristic

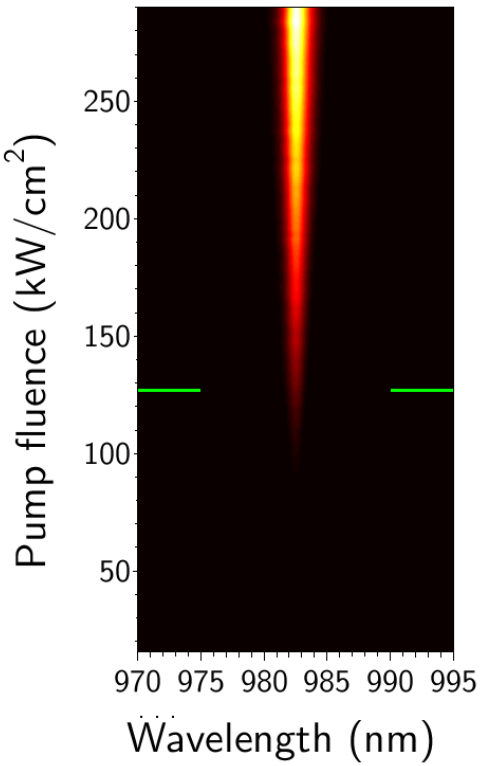


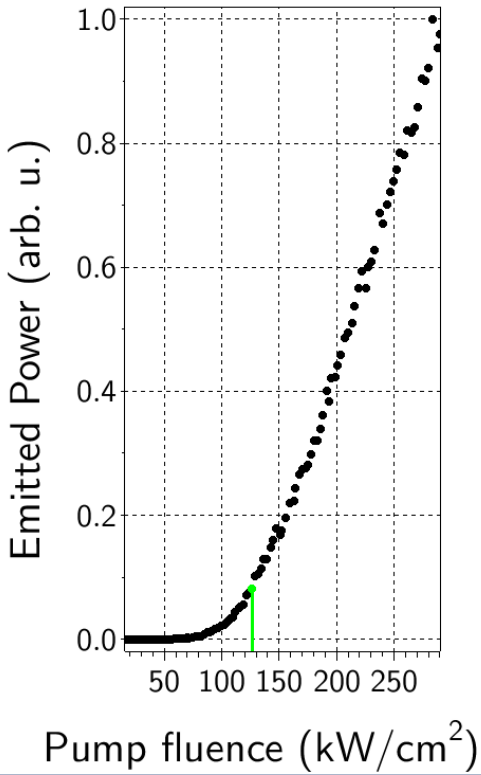


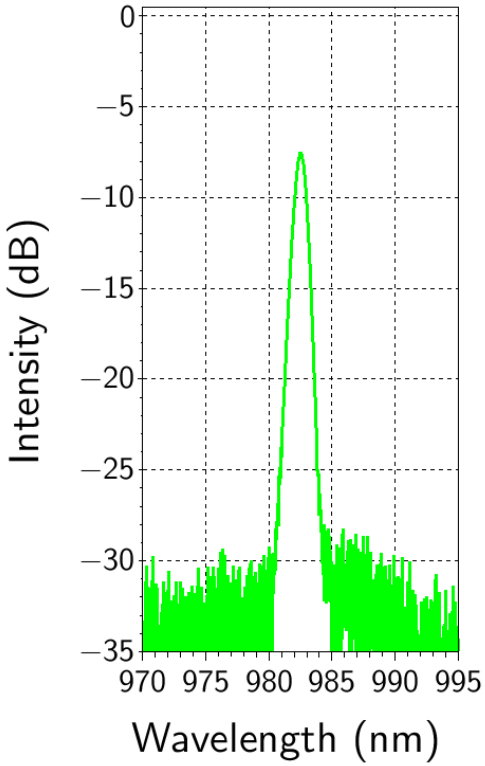


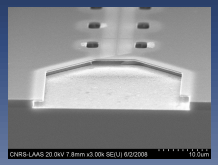
Photonic crystal waveguide for single-mode DFB laser

Typical light-light characteristic



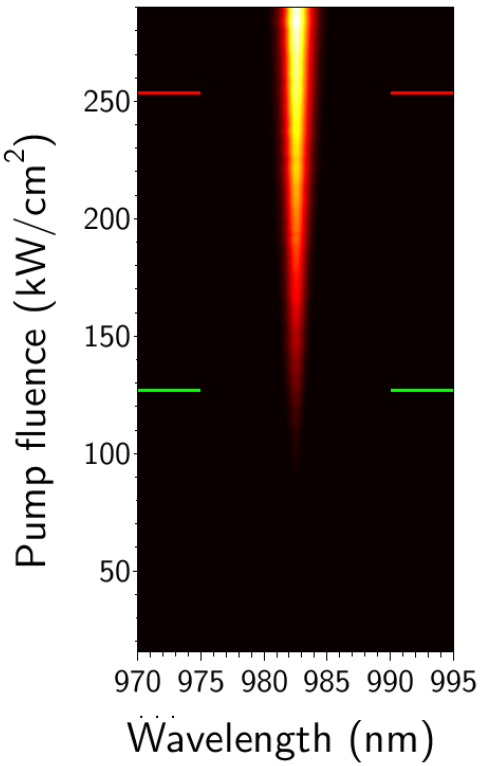


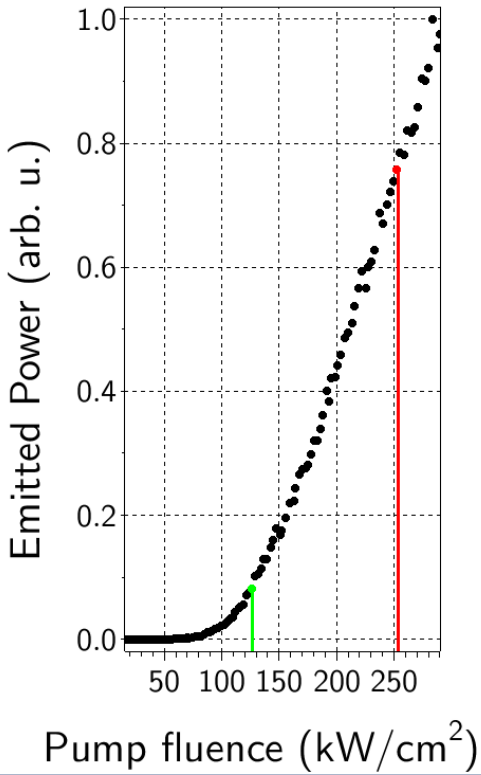


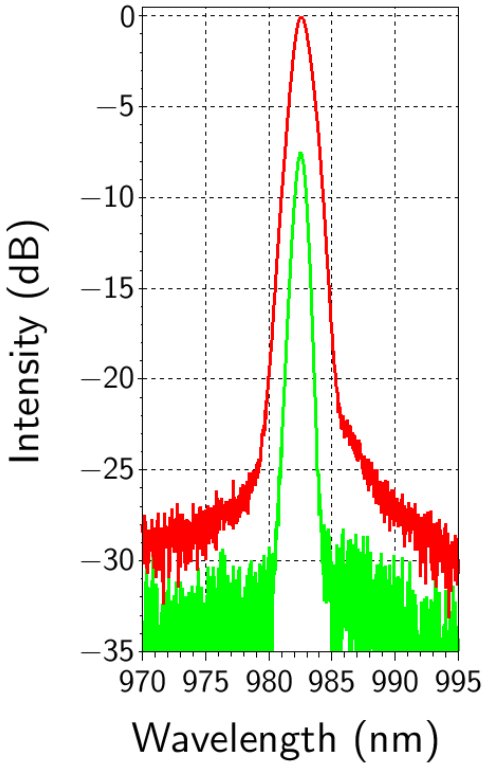


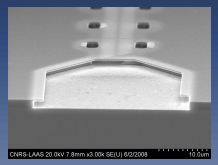
Photonic crystal waveguide for single-mode DFB laser

Typical light-light characteristic



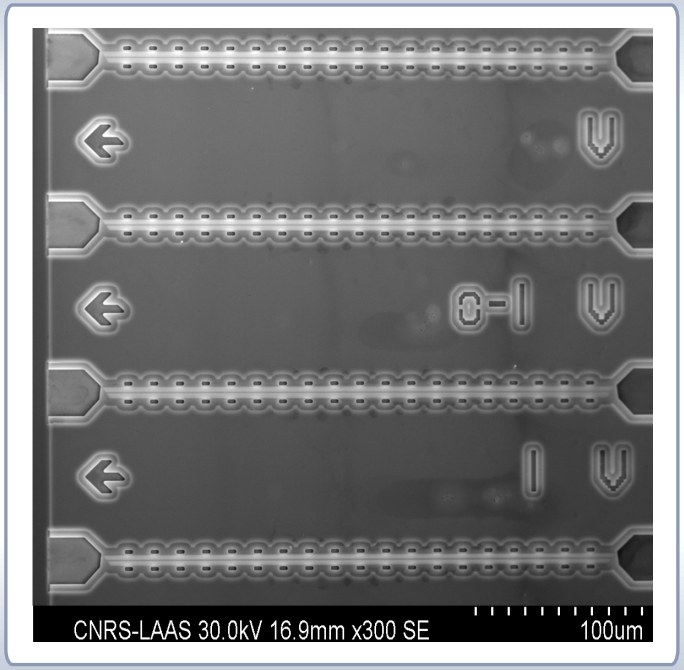




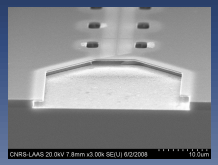


Photonic crystal waveguide for single-mode DFB laser

W3 ΓK waveguide laser:

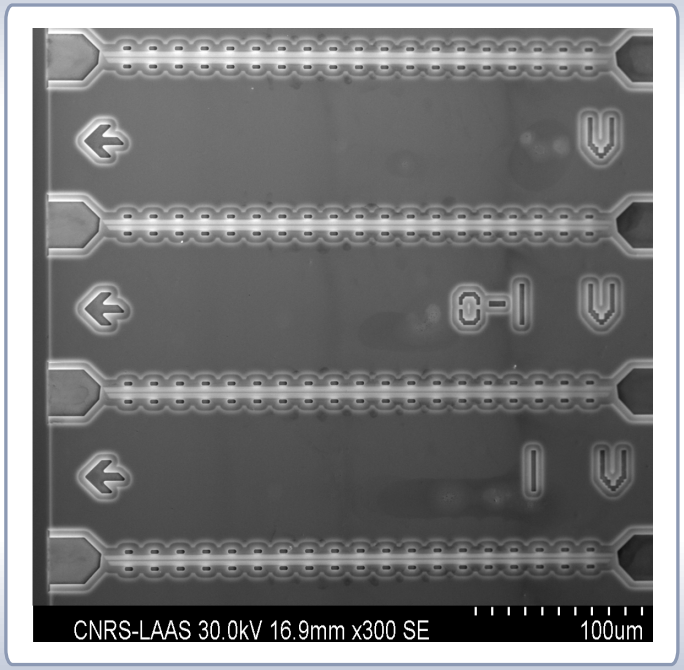


Let's sum it up!



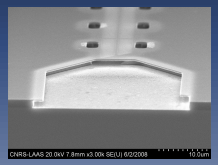
Photonic crystal waveguide for single-mode DFB laser

W3 ΓK waveguide laser:



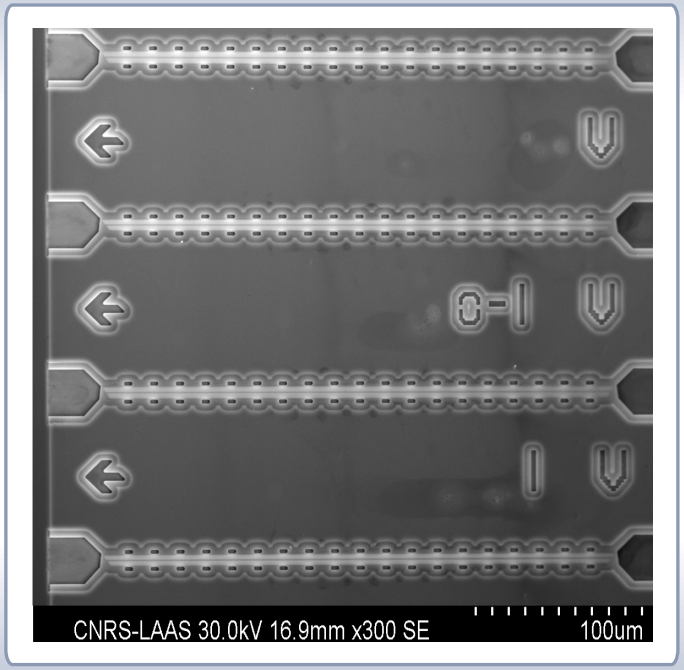
Let's sum it up!

- Inherently single-mode DFB lasing



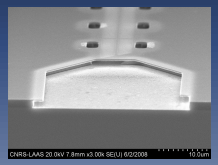
Photonic crystal waveguide for single-mode DFB laser

W3 ΓK waveguide laser:



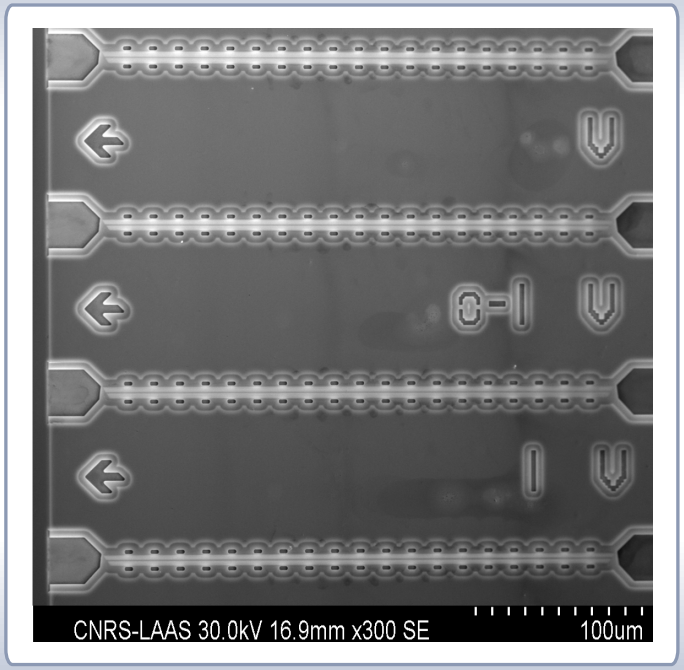
Let's sum it up!

- Inherently single-mode DFB lasing
- No mode-hoping, low chirp



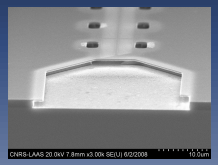
Photonic crystal waveguide for single-mode DFB laser

W3 ΓK waveguide laser:



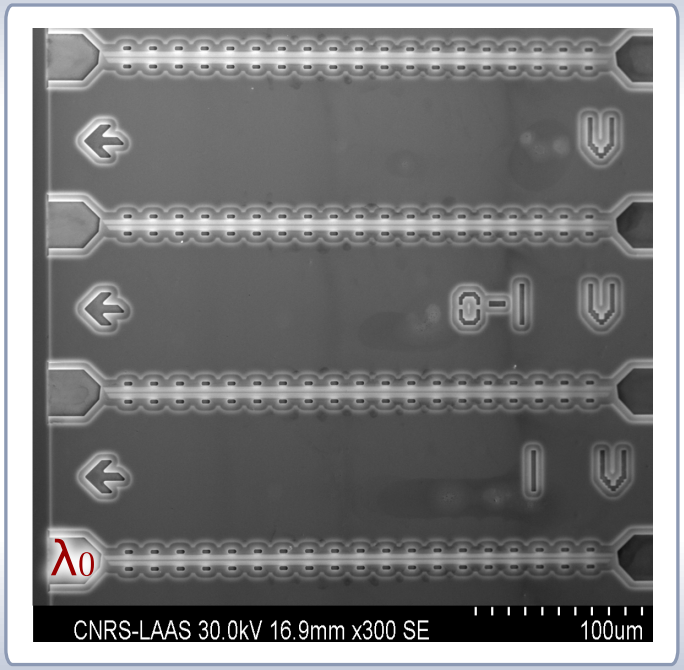
Let's sum it up!

- Inherently single-mode DFB lasing
- No mode-hoping, low chirp
- 2D PhC allows for array integration



Photonic crystal waveguide for single-mode DFB laser

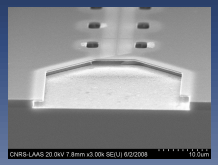
W3 ΓK waveguide laser:



Let's sum it up!

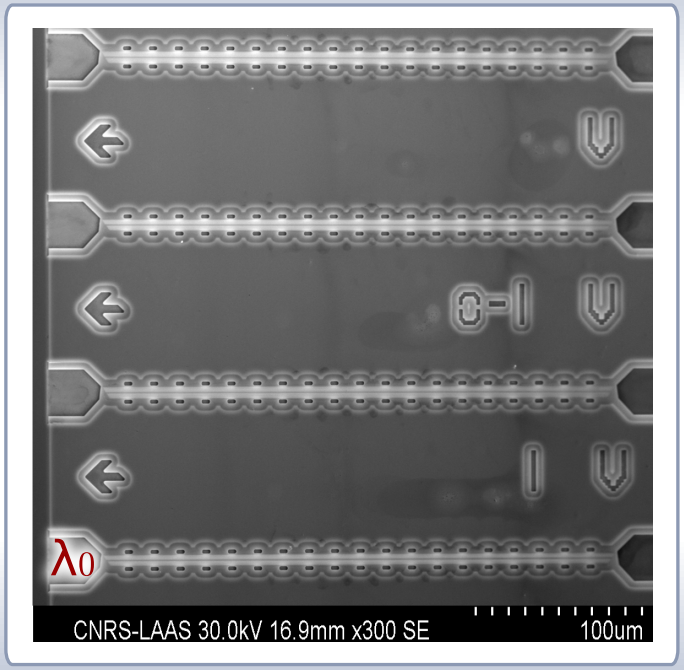
- Inherently single-mode DFB lasing
- No mode-hoping, low chirp
- 2D PhC allows for array integration

Wavelength engineering ?



Photonic crystal waveguide for single-mode DFB laser

W3 ΓK waveguide laser:

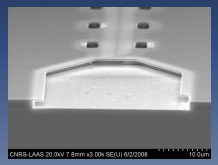


Let's sum it up!

- Inherently single-mode DFB lasing
- No mode-hoping, low chirp
- 2D PhC allows for array integration

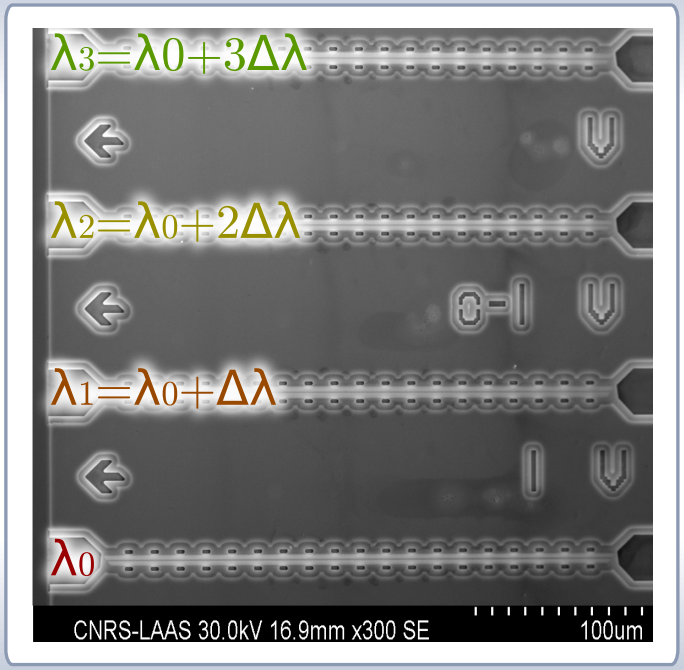
Wavelength engineering ?

- Integrated array of DFB lasers



Photonic crystal waveguide for single-mode DFB laser

W3 ΓK waveguide laser:

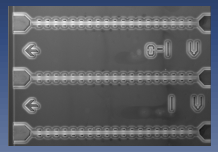


Let's sum it up!

- Inherently single-mode DFB lasing
- No mode-hoping, low chirp
- 2D PhC allows for array integration

Wavelength engineering ?

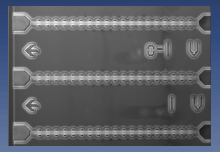
- Integrated array of DFB lasers
- Fine and controlled λ spacing



Wavelength control using affine deformation

λ control through lattice constant

Maxwell to the rescue!



Wavelength control using affine deformation

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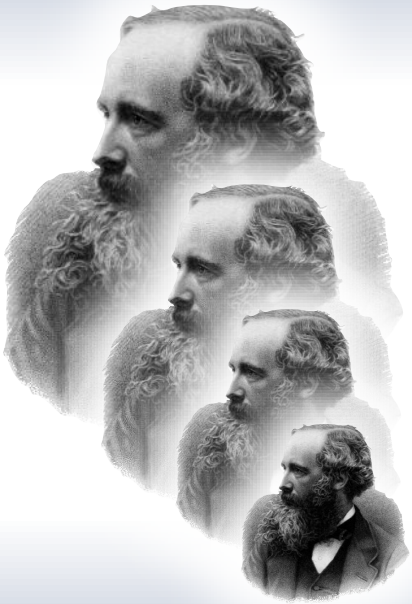
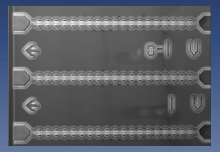


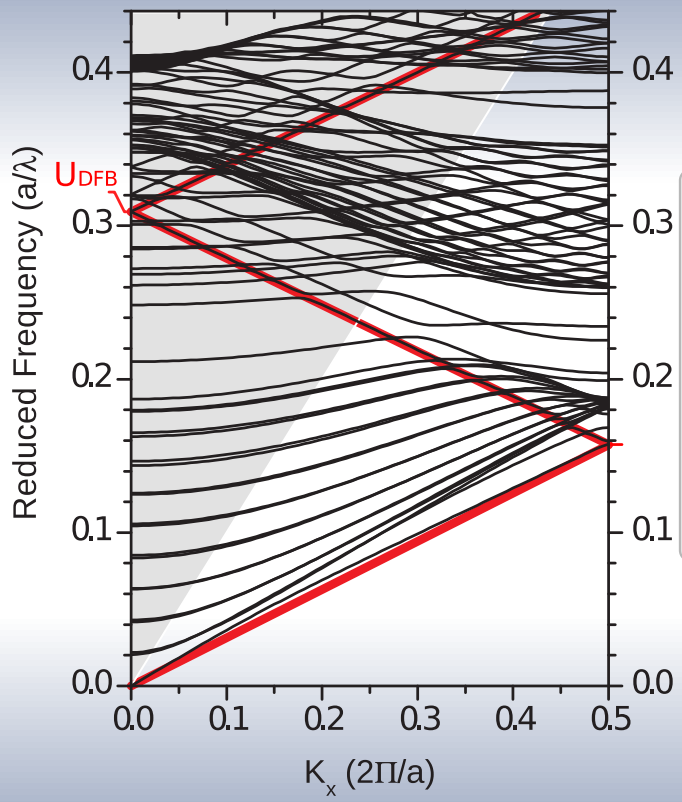
Maxwell to the rescue!

- Maxwell's equations are scale invariant



Wavelength control using affine deformation

λ control through lattice constant



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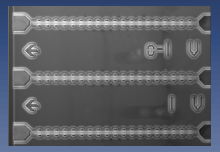

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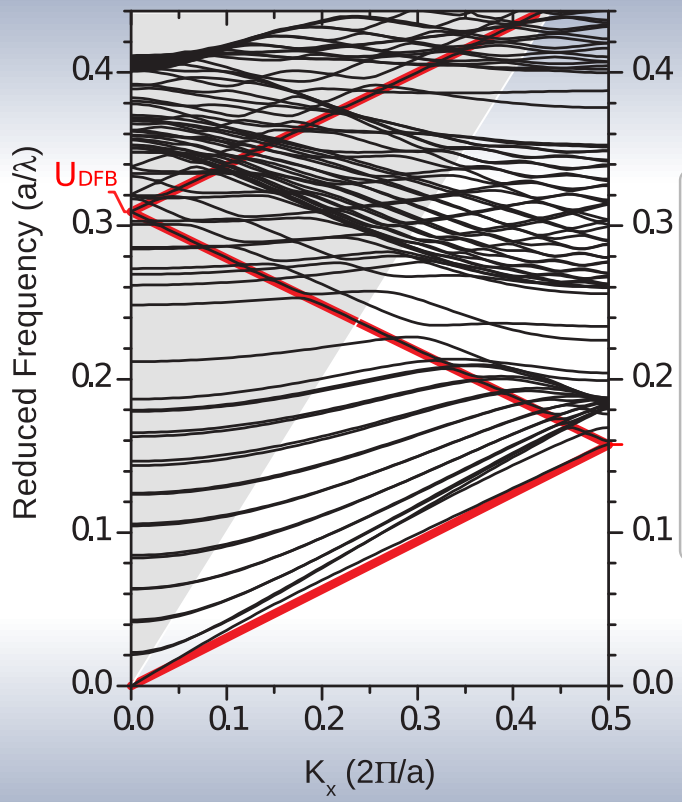

Maxwell to the rescue!

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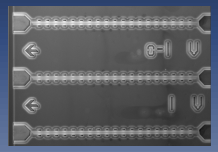
- Reduced frequency $U_{DFB} = a/\lambda_{DFB}$
- Scaling $a \Rightarrow$ Scaling λ

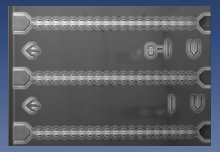


Wavelength control using affine deformation

λ control through lattice constant

Numerically

Experimentally



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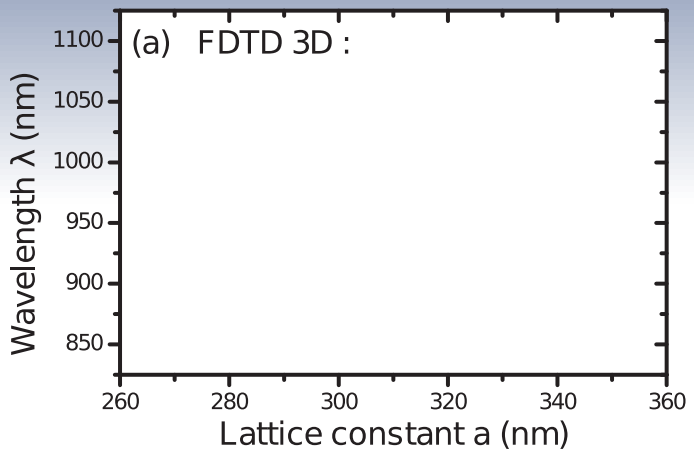
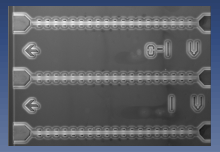


Numerically

- Finite Difference in Time Domain

Experimentally



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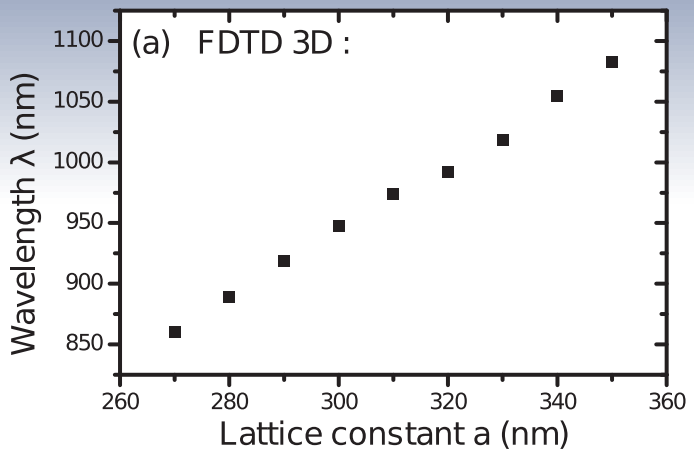
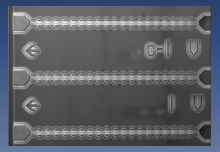


Numerically

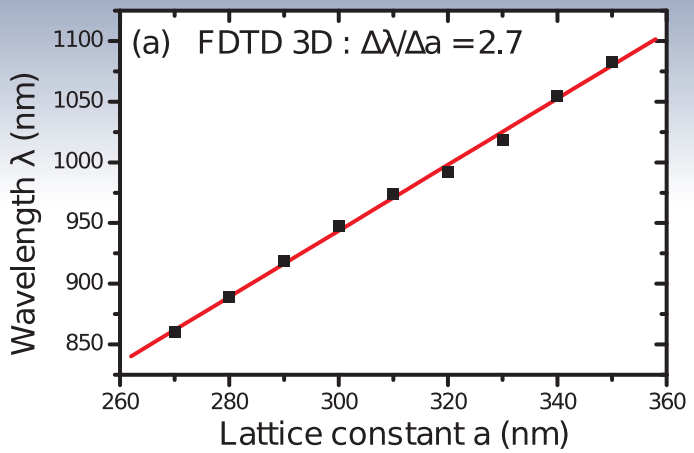
- Finite Difference in Time Domain
- Linear control of λ with a

Experimentally



Wavelength control using affine deformation

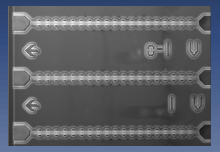
λ control through lattice constant



Numerically

- Finite Difference in Time Domain
- Linear control of λ with a
- $\Delta a = 1\,\text{nm} \Rightarrow \Delta\lambda \simeq 2.7\,\text{nm}$

Experimentally



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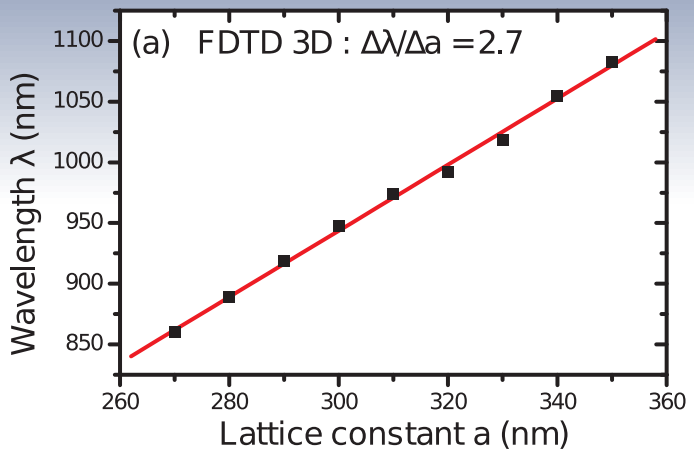

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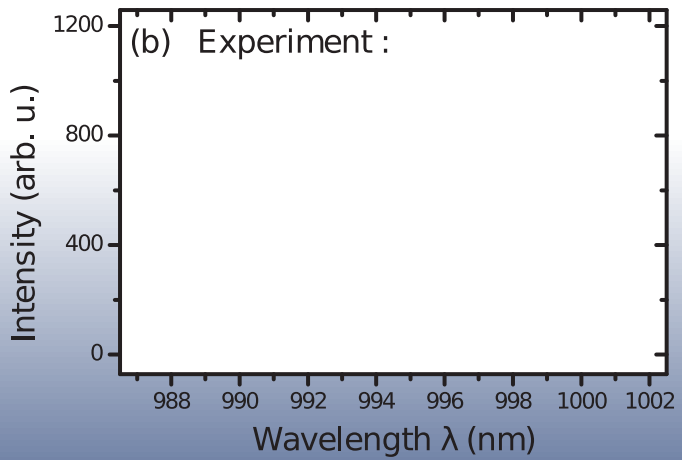
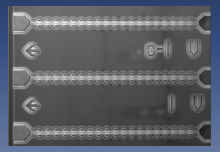


Experimentally

- Array of DFB with varying a



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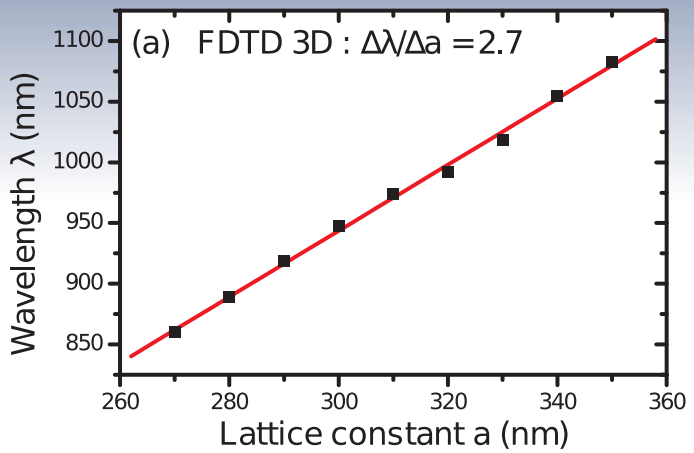

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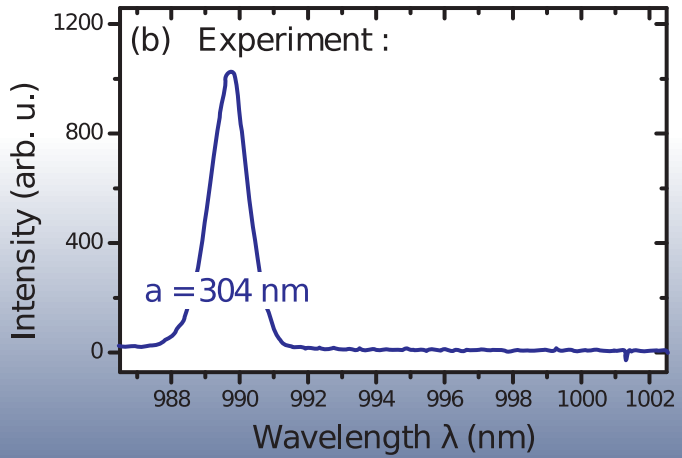
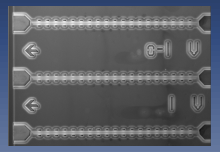


Experimentally

- Array of DFB with varying a
- ... from $a = 304\,\text{nm}$



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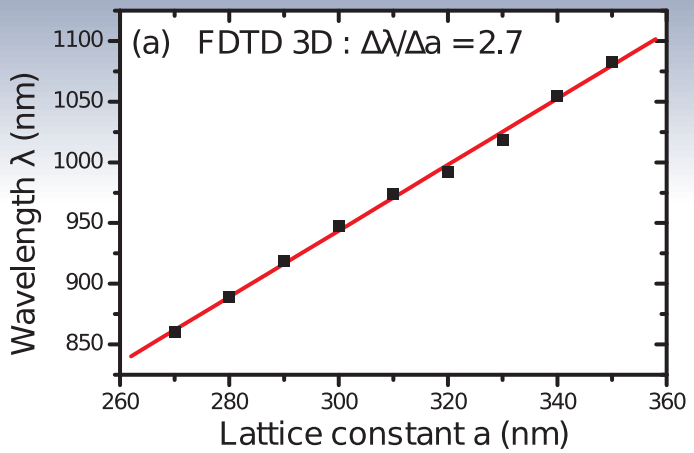

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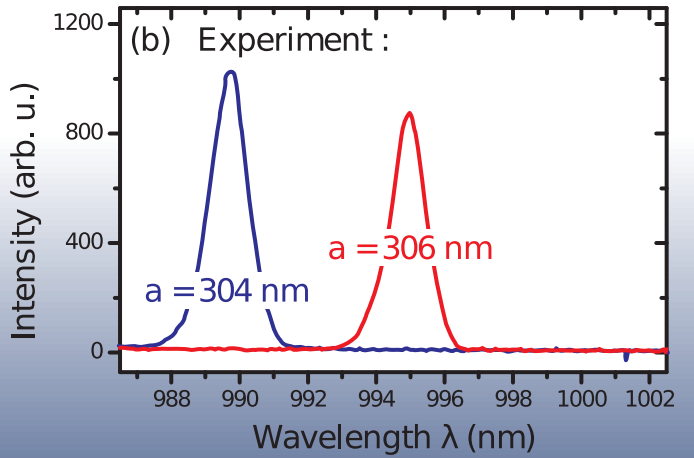

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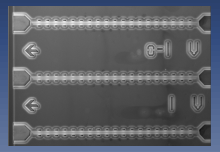

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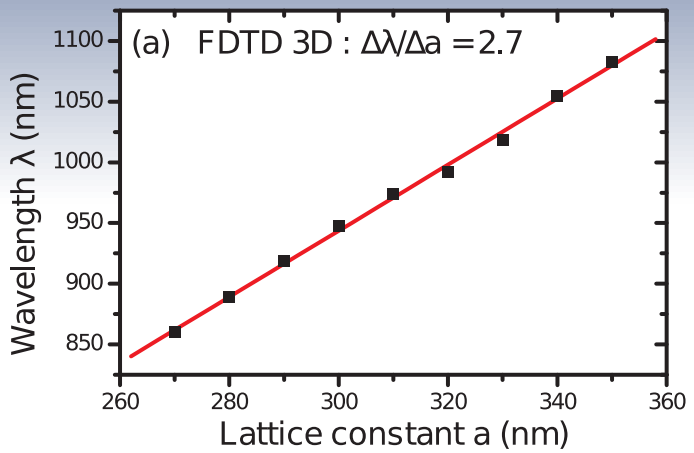

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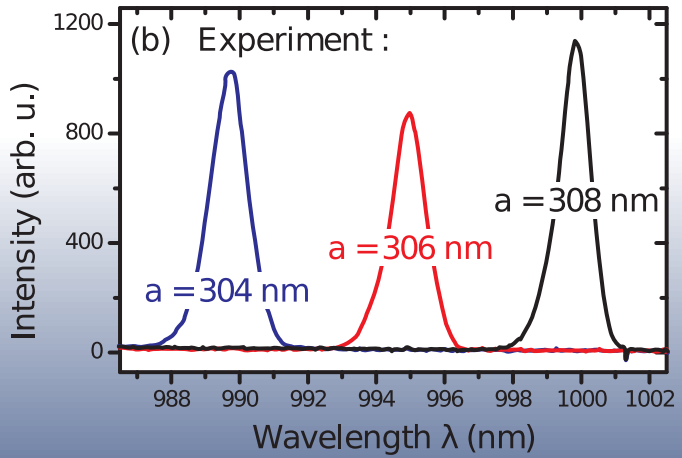
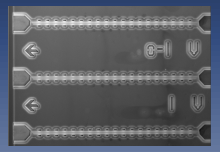


Experimentally

- Array of DFB with varying a
- ... from $a = 304\,\text{nm}$ to $a = 308\,\text{nm}$



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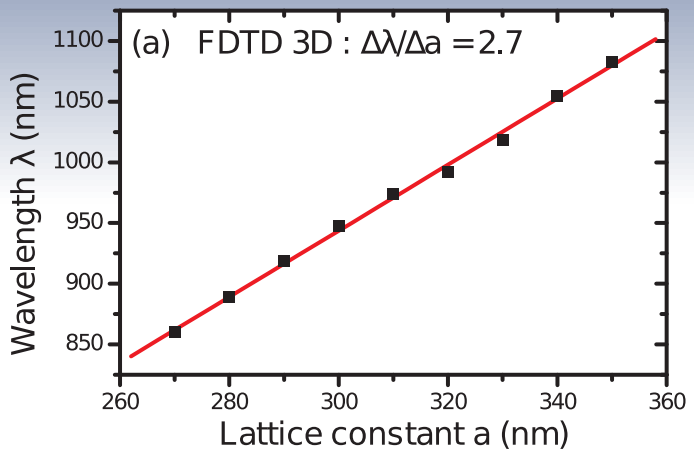

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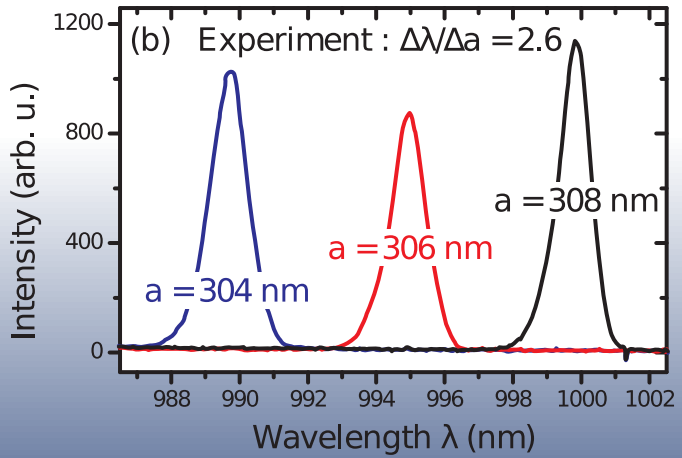

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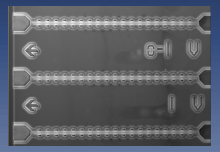
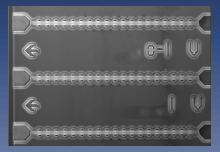


Wavelength control using affine deformation

λ control through lattice constant

It does work well



Wavelength control using affine deformation

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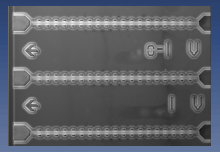
It does work well

- Smooth and linear control



Wavelength control using affine deformation

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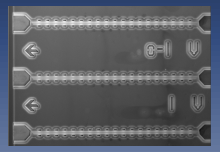

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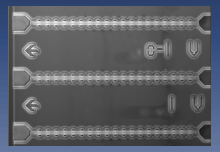

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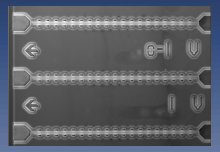

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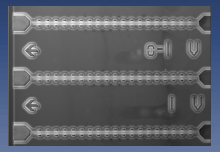

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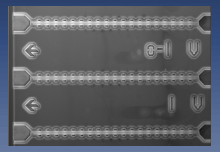
How to build dense array of single-mode DFB?



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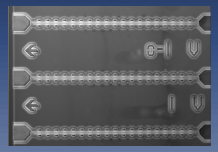
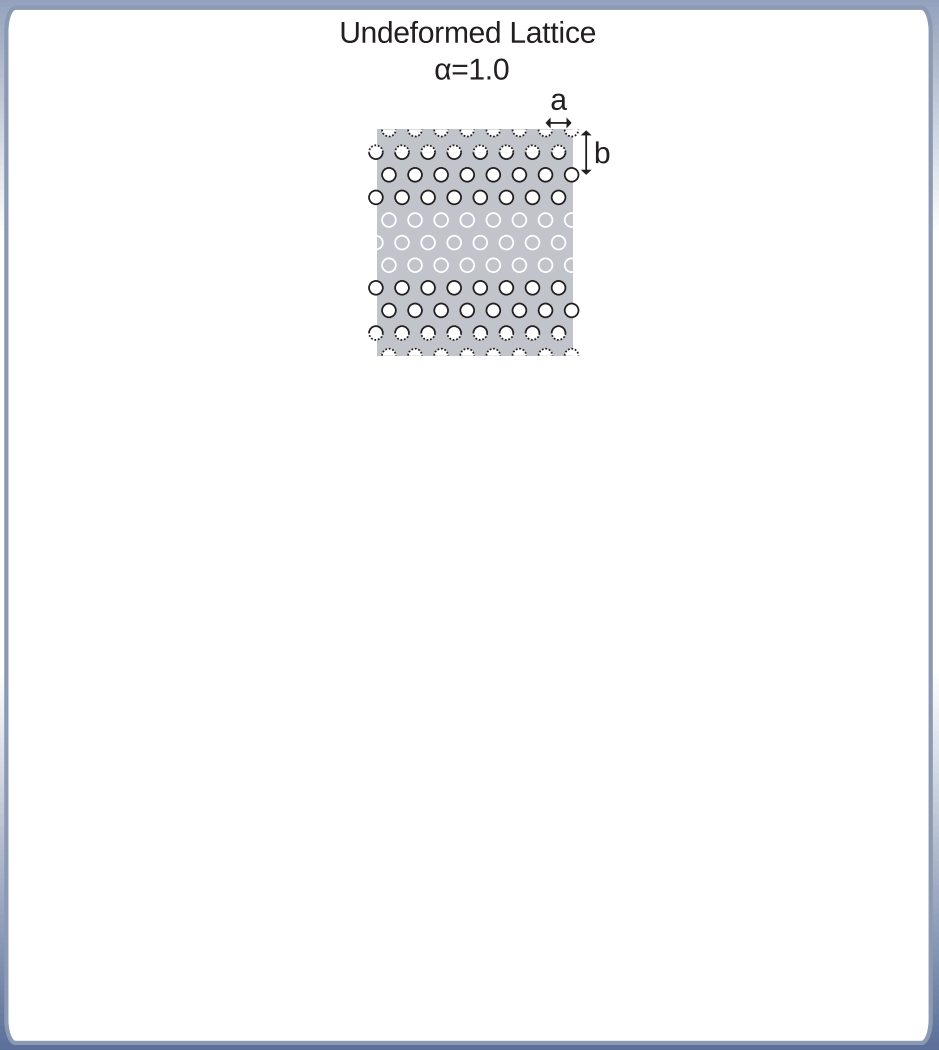
How to build dense array of single-mode DFB?

Hint: 2D PhC are 2D!

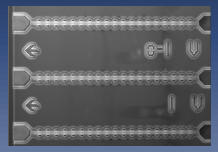


Wavelength control using affine deformation

What is affine deformation ?



Affine deformation



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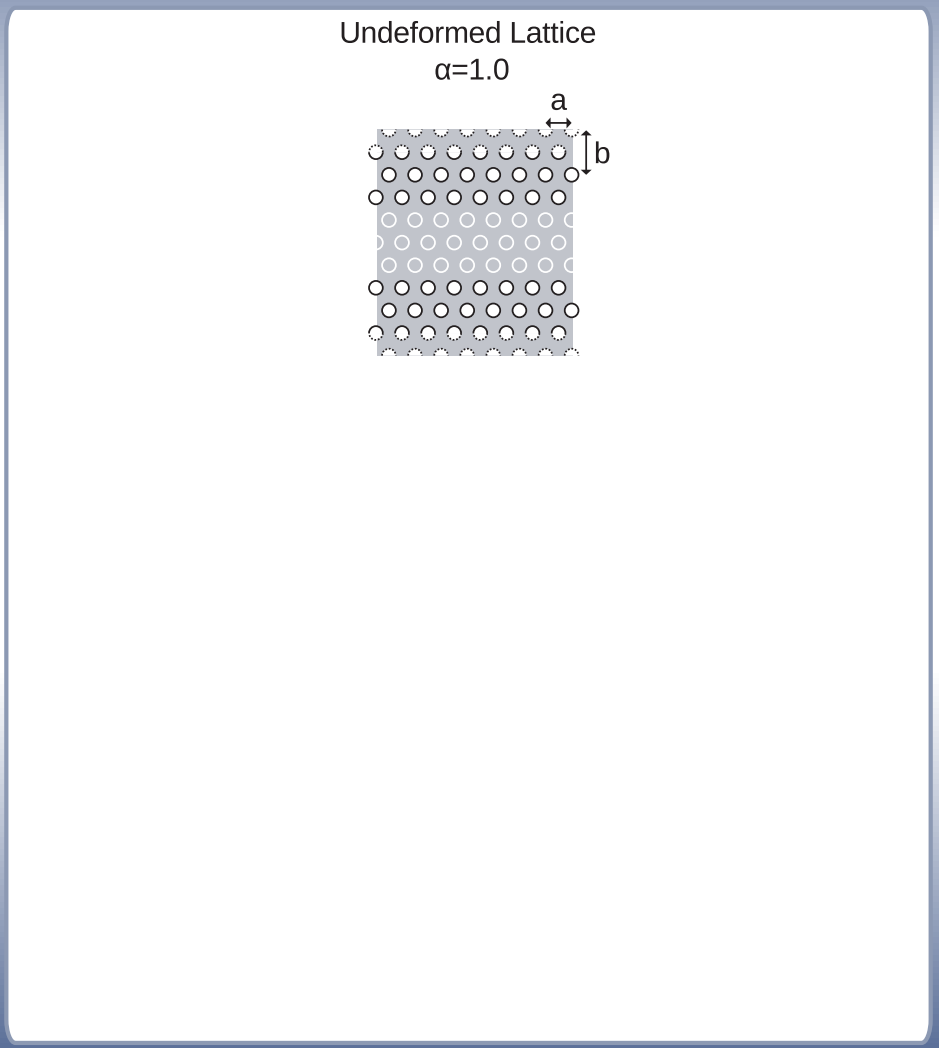
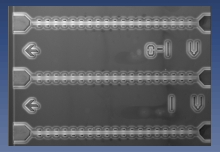


Affine deformation

- Scale $\perp$ lattice constant b



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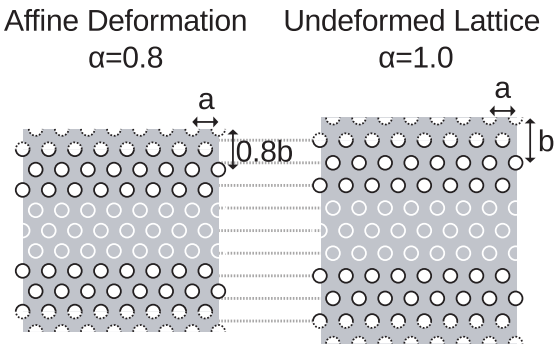

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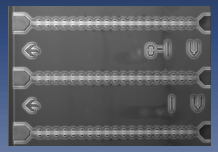

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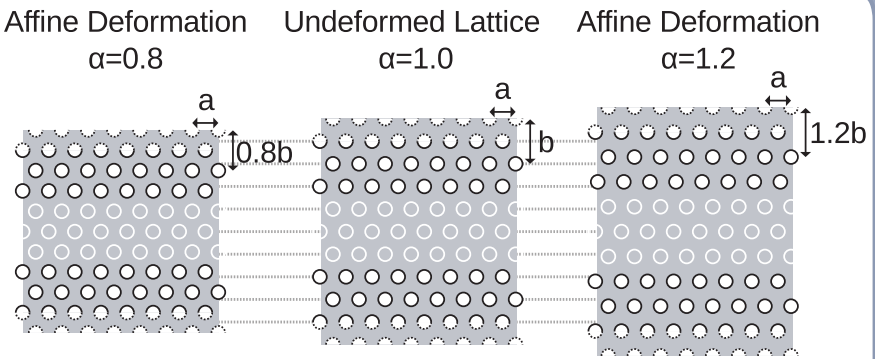

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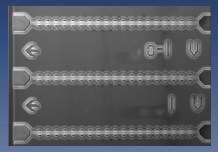

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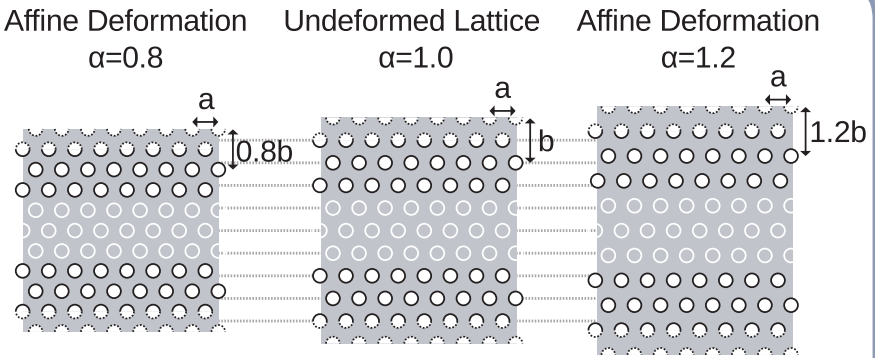
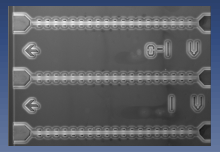


Affine deformation

- Scale $\perp$ lattice constant b
- α is the **deformation**



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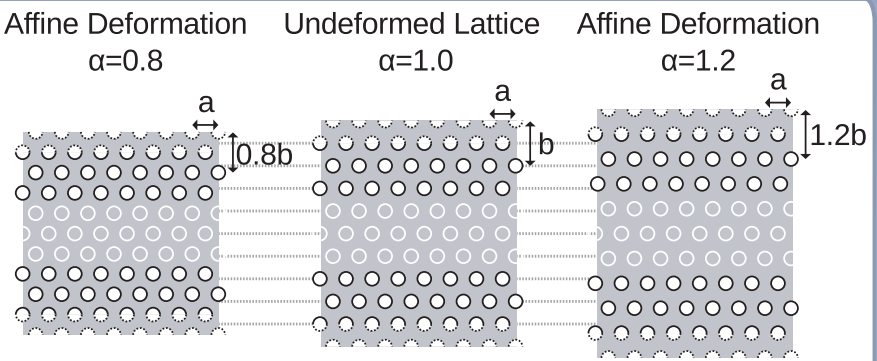

Affine deformation

- Scale $\perp$ lattice constant b
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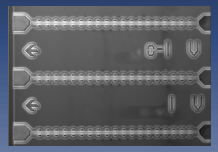
- $d = (\alpha - 1)b$ is the **displacement**



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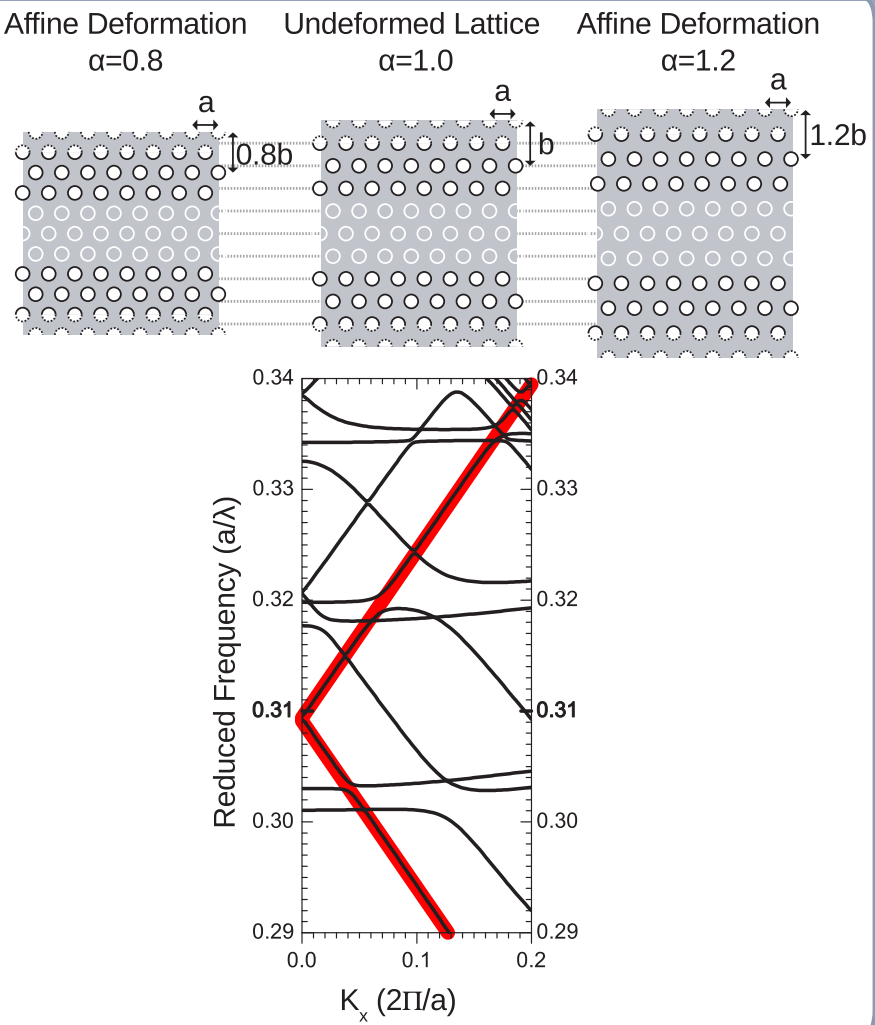

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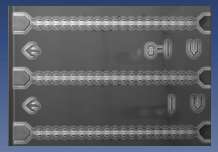

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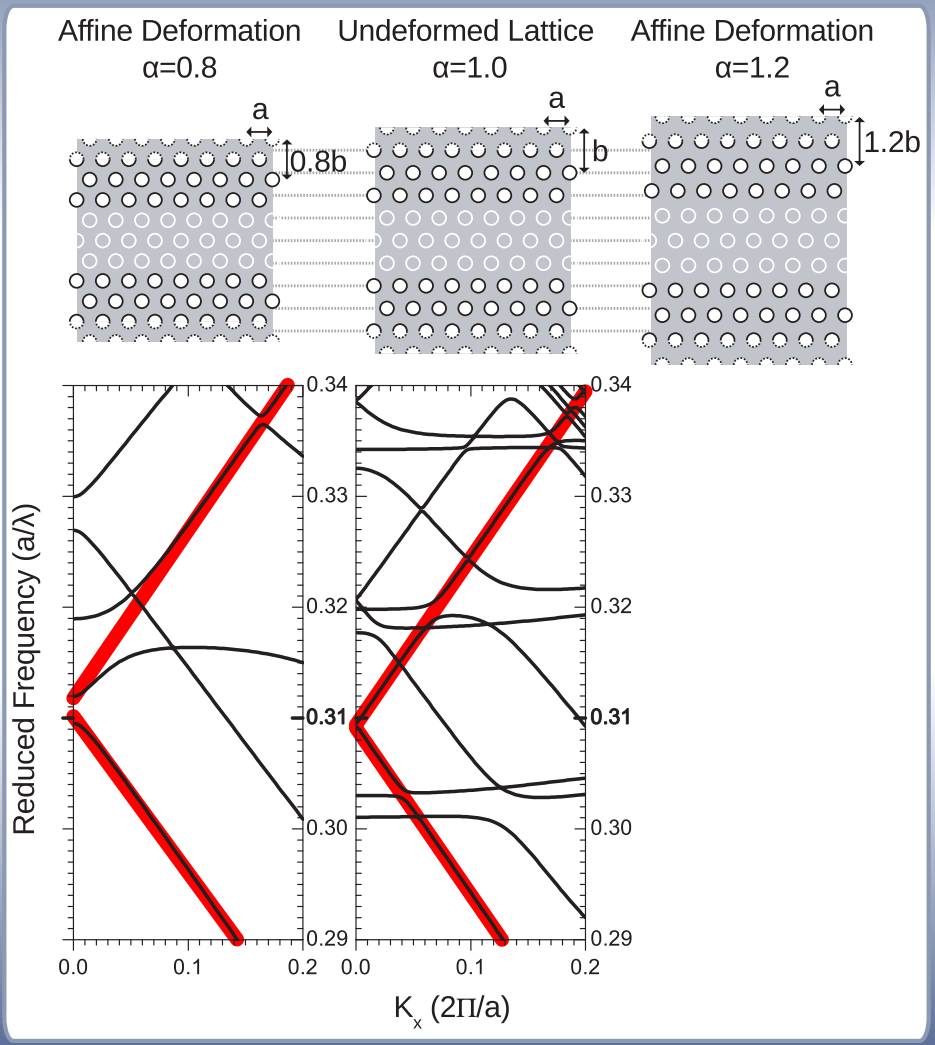

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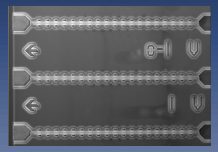
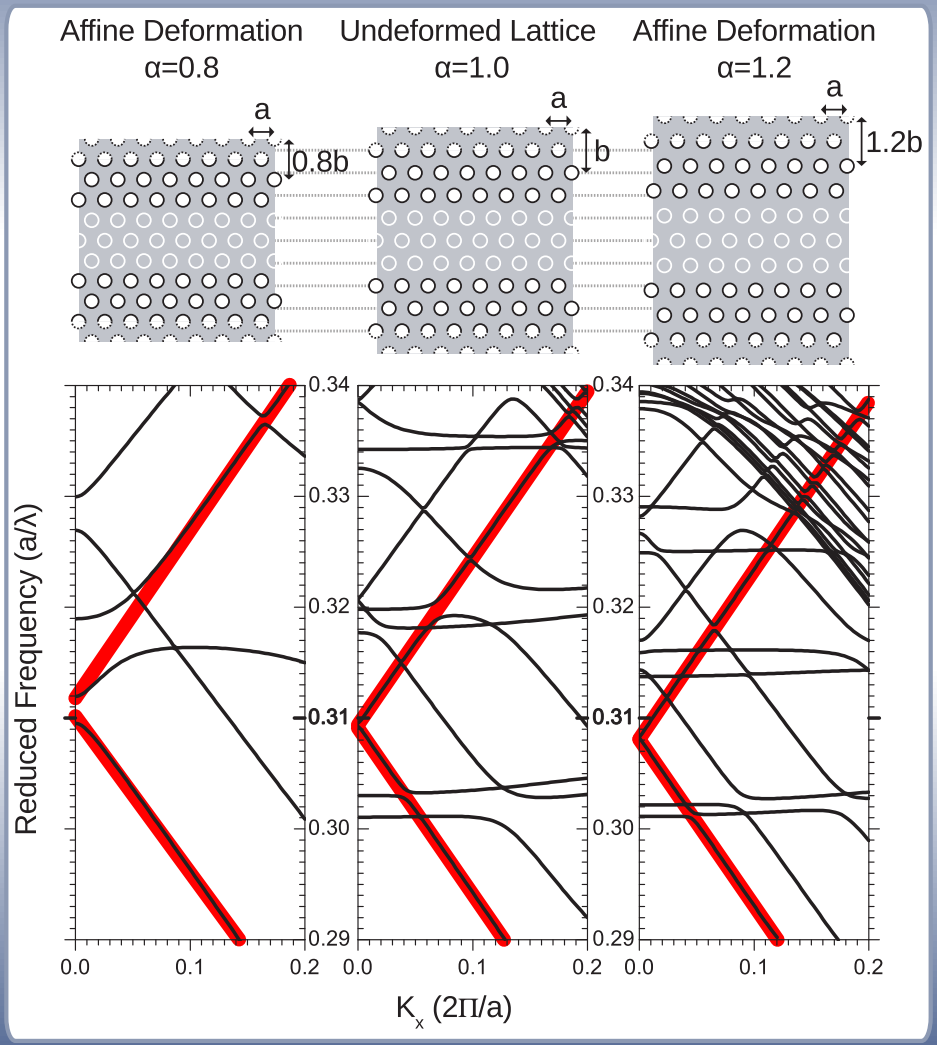


Wavelength control using affine deformation

What is affine deformation ?



Affine deformation

- Scale $\perp$ lattice constant b
- α is the **deformation**
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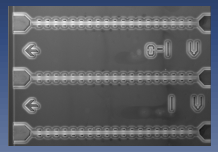

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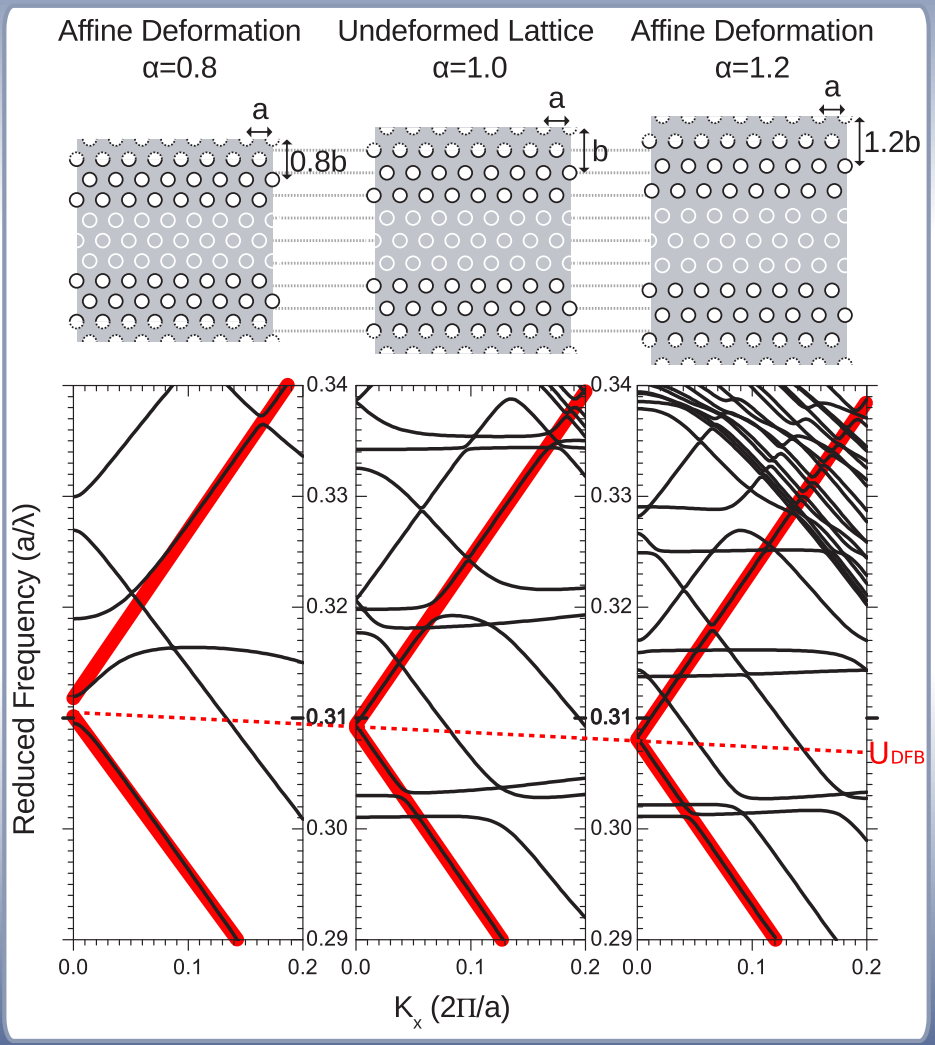
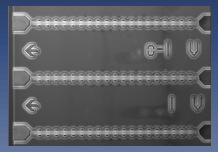


Affine deformation

- Scale $\perp$ lattice constant b
- α is the **deformation**
- $d = (\alpha - 1)b$ is the **displacement**
- U_{DFB} linear in α, d



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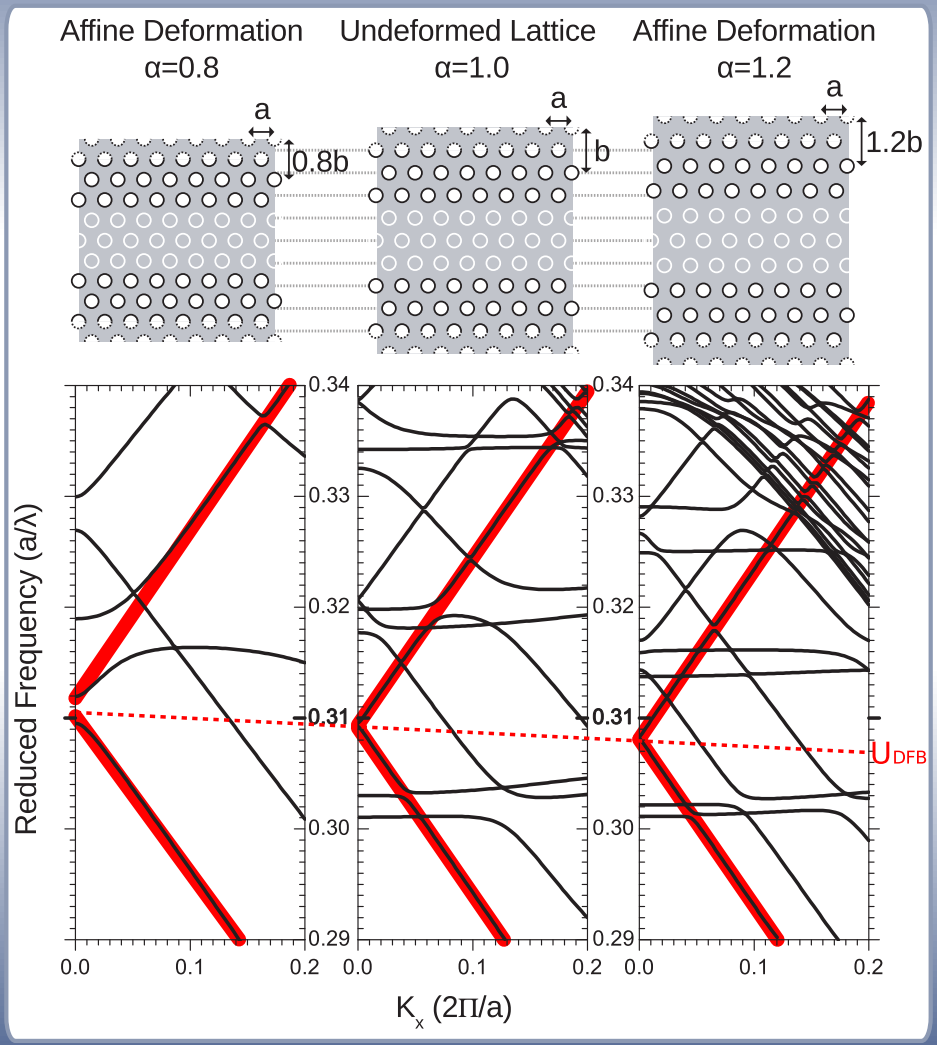

Affine deformation

- Scale $\perp$ lattice constant b
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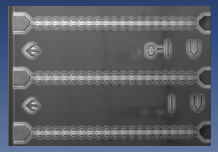
Sensitivity (theory)

- $\Delta\lambda/\Delta d \simeq 0.035$



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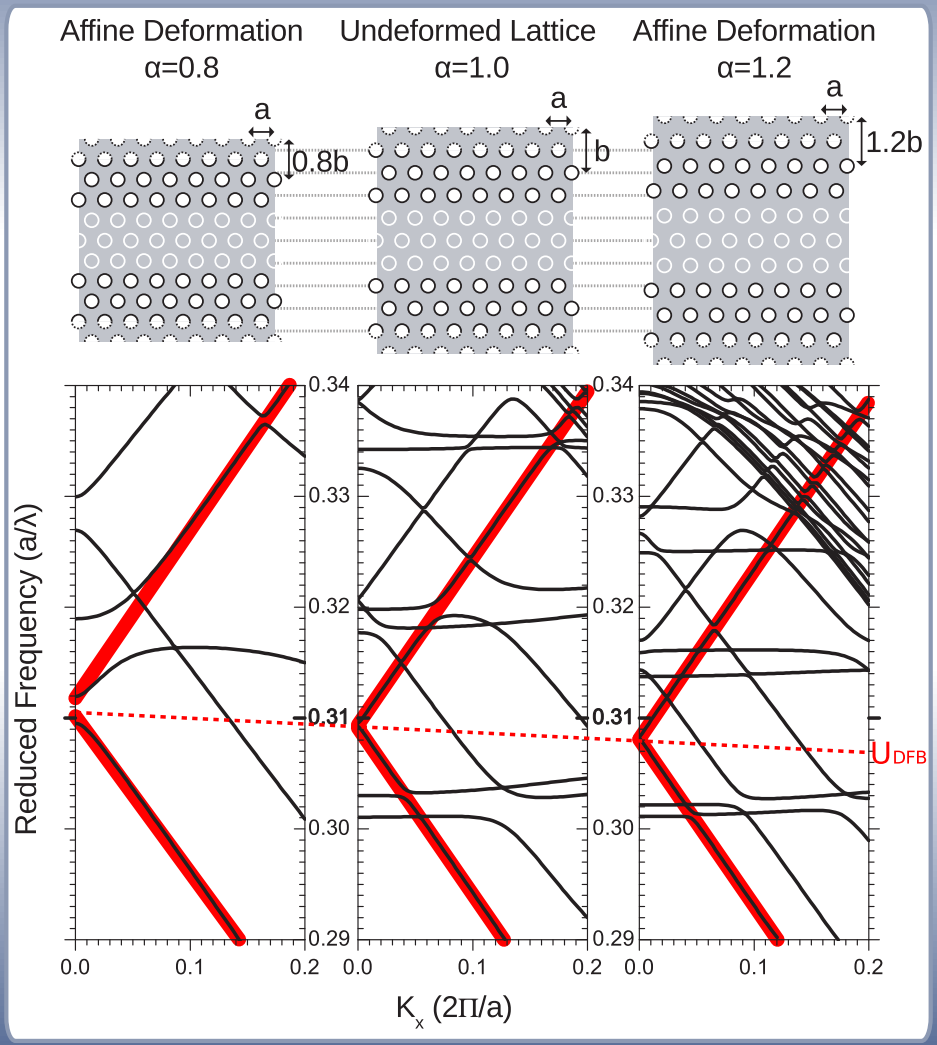
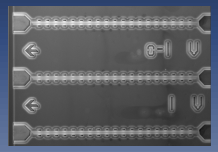


Affine deformation

- Scale $\perp$ lattice constant b
- α is the **deformation**
- $d = (\alpha - 1)b$ is the **displacement**
- U_{DFB} linear in α, d

Sensitivity (theory)

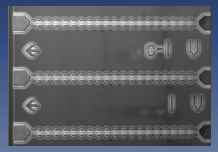
- $\Delta\lambda/\Delta d \simeq 0.035$
- **100× improvement !**



Affine deformation: experimentally

Sample

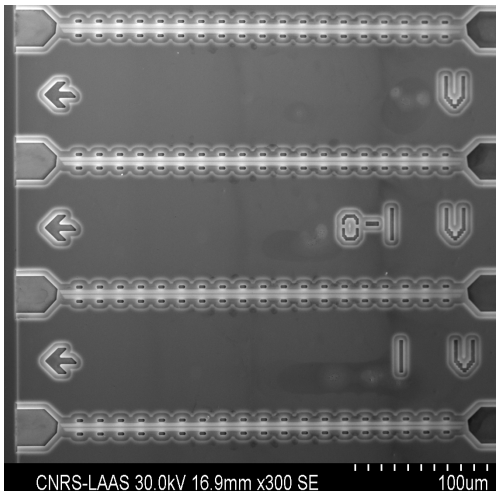
- Several DFB arrays



Wavelength control using affine deformation

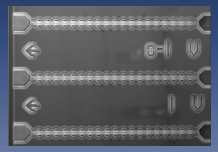
Affine deformation: experimentally

a = 306 nm



Sample

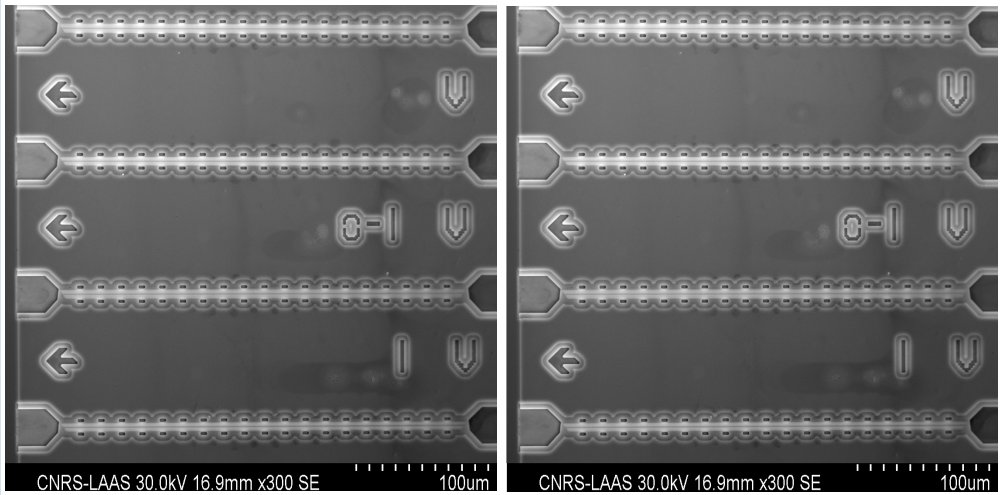
- Several DFB arrays
  $a = 306$



Wavelength control using affine deformation

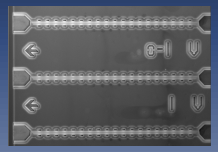
Affine deformation: experimentally

a = 306 nm a = 304 nm



Sample

- Several DFB arrays
  $a = 306$ & $304\,\text{nm}$



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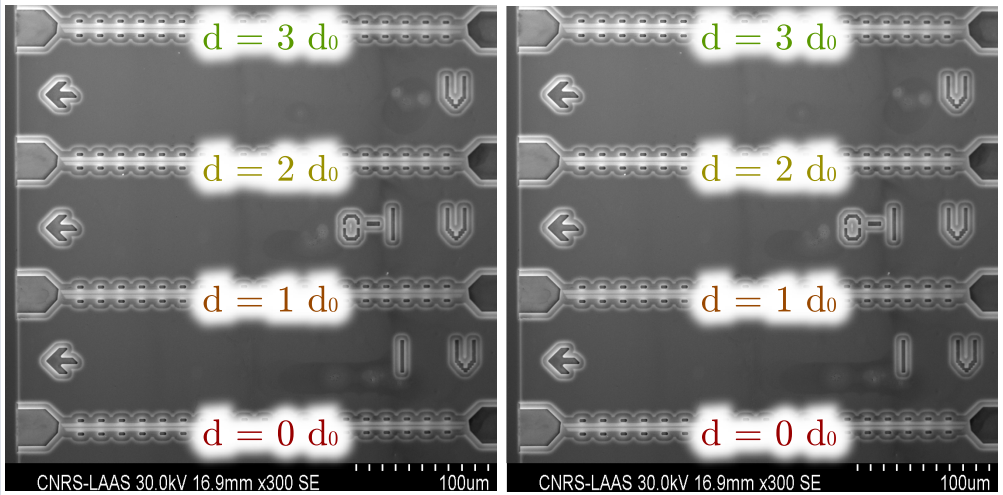
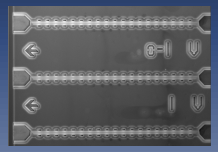


Sample

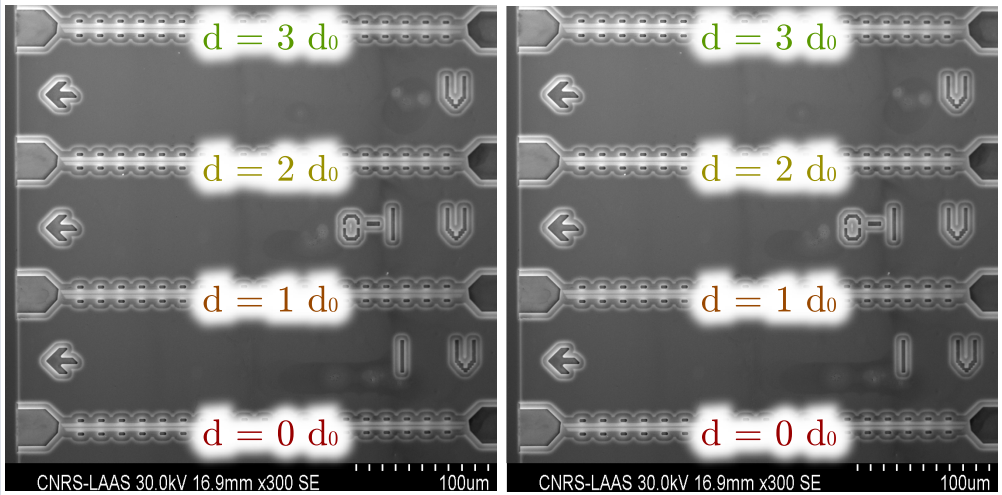
- Several DFB arrays $a = 306$ & $304\,\text{nm}$
- ↗ displacement d



Wavelength control using affine deformation

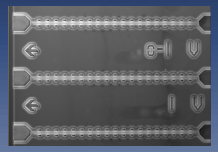
Affine deformation: experimentally

a = 306 nm a = 304 nm

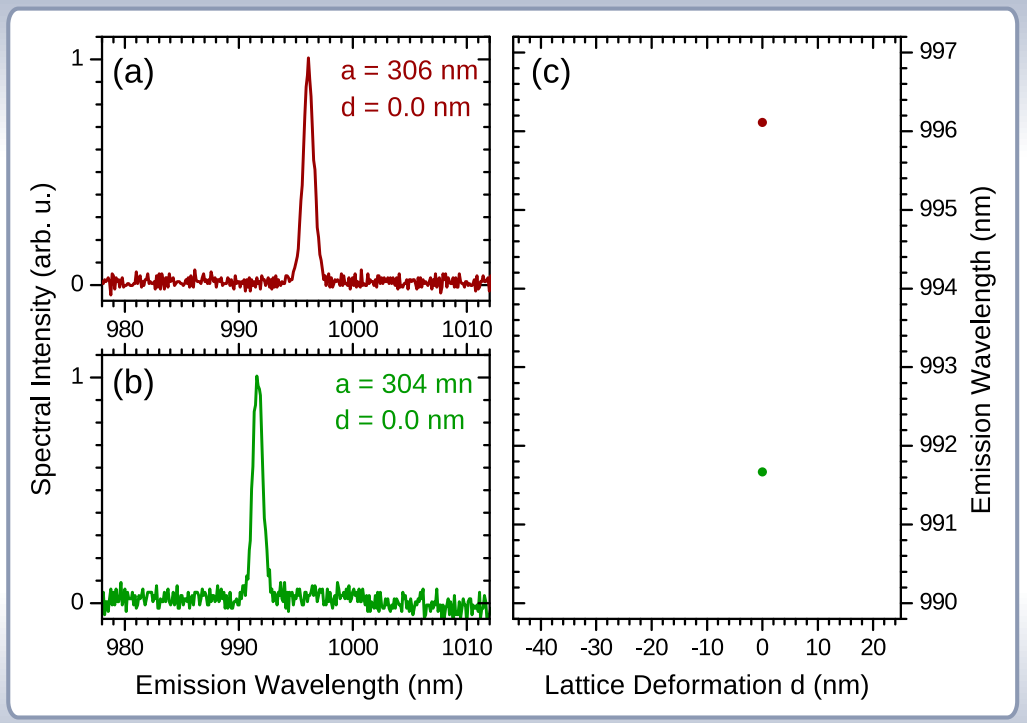


Sample

- Several DFB arrays $a = 306$ & $304\,\text{nm}$
- $\nearrow$ displacement d
- Spectrum $\Rightarrow \lambda(d)$

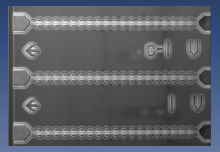


Affine deformation: experimentally



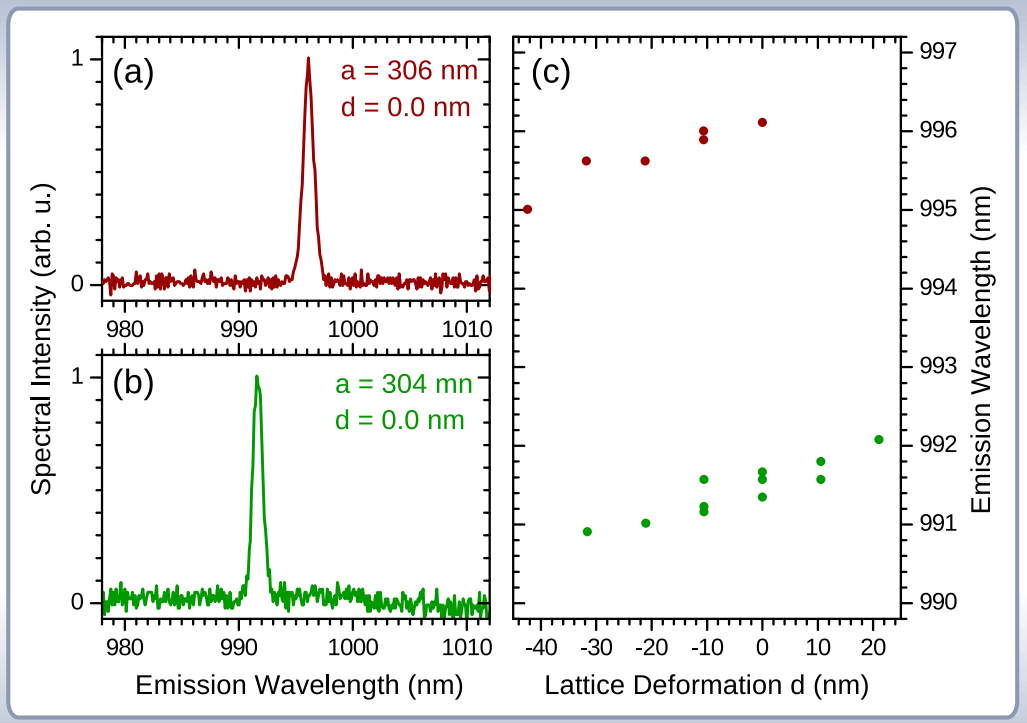
Results

A. Larrue et al, PTL, 20, pp. 2120, 2008



Wavelength control using affine deformation

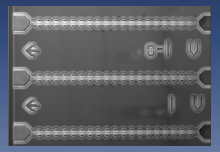
Affine deformation: experimentally



Results

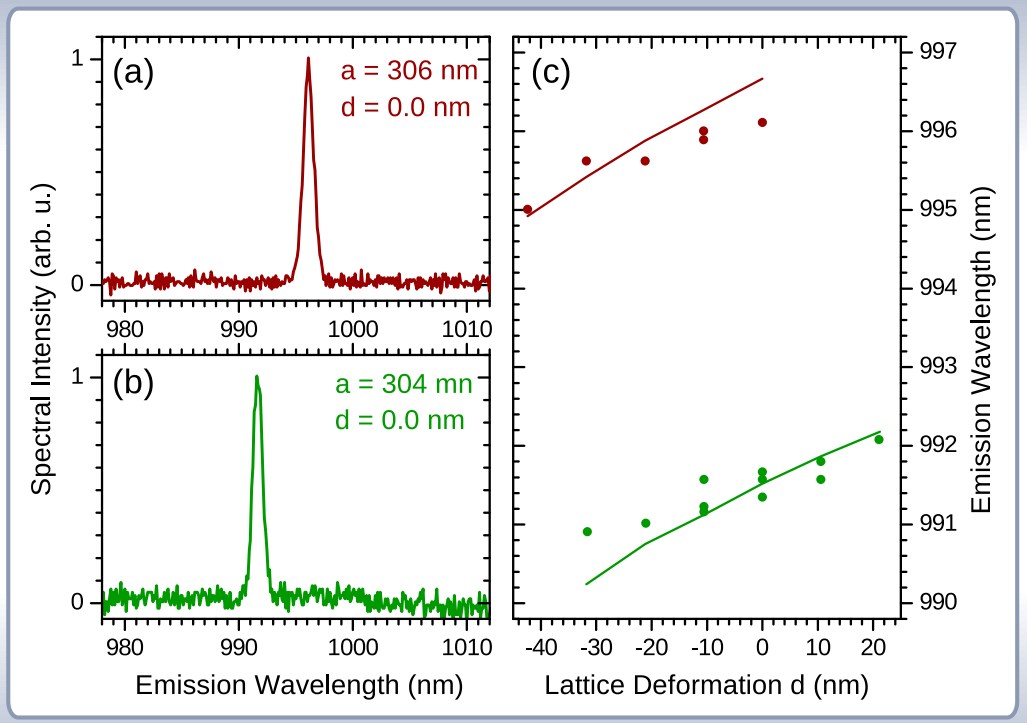
- Fairly linear control

A. Larrue et al, PTL, 20, pp. 2120, 2008



Wavelength control using affine deformation

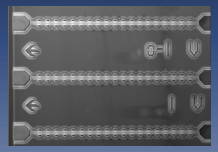
Affine deformation: experimentally



Results

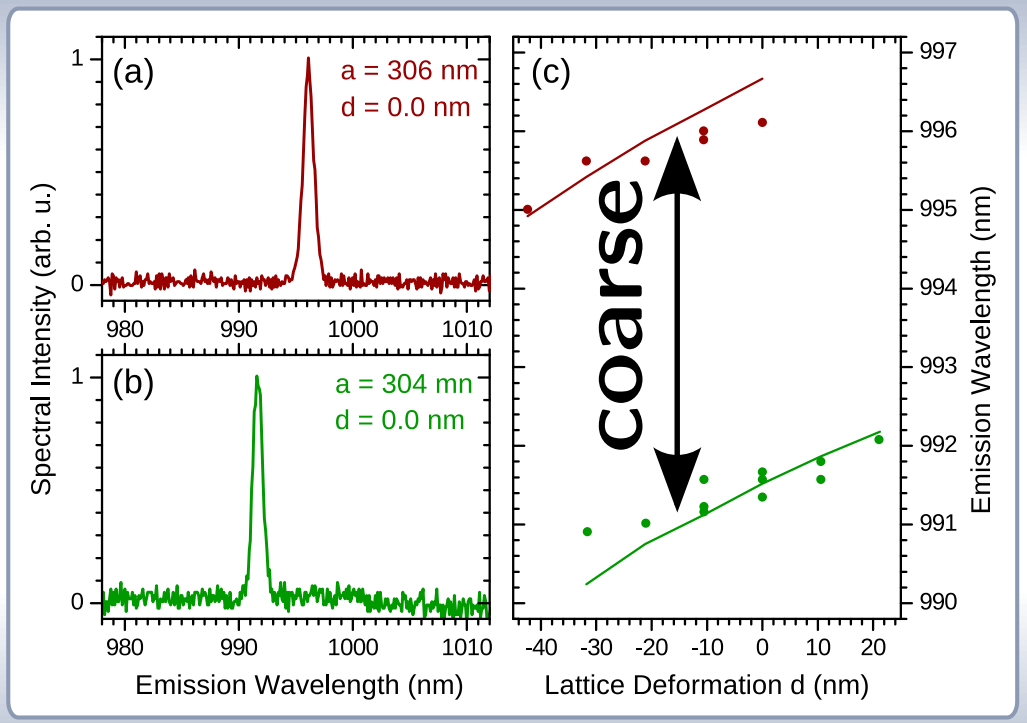
- Fairly linear control
- $\Delta\lambda/\Delta d \simeq 0.025$

A. Larrue et al, PTL, 20, pp. 2120, 2008



Wavelength control using affine deformation

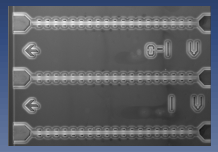
Affine deformation: experimentally



Results

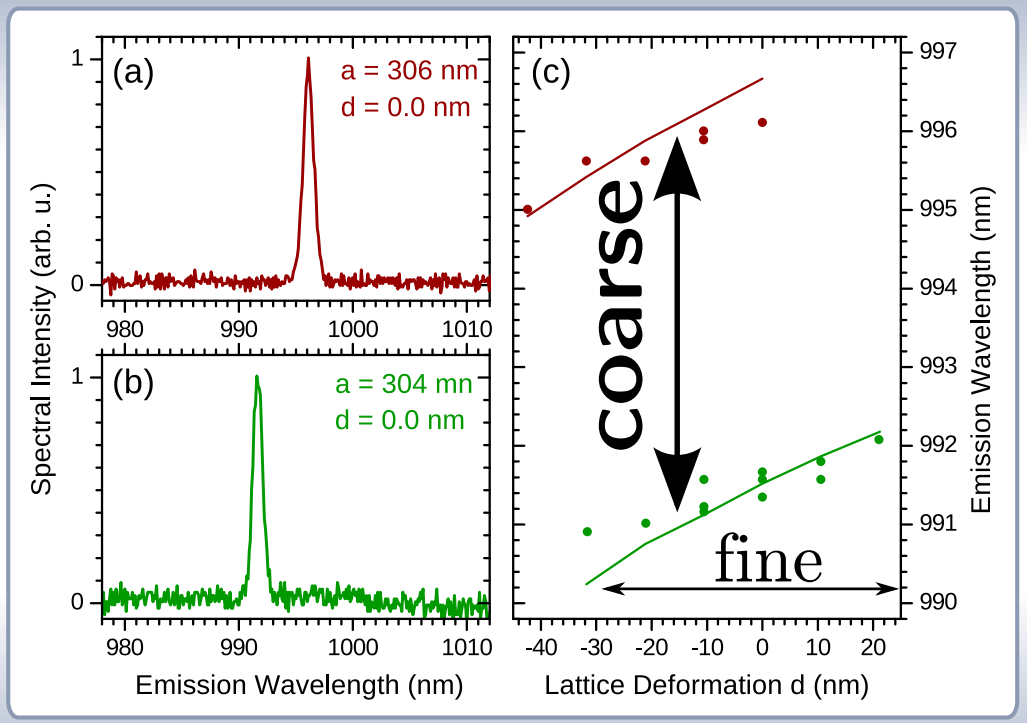
- Fairly linear control
- $\Delta\lambda/\Delta d \simeq 0.025$
- *a* for **coarse** control

A. Larrue et al, PTL, 20, pp. 2120, 2008



Wavelength control using affine deformation

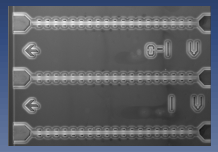
Affine deformation: experimentally



Results

- Fairly linear control
- $\Delta\lambda/\Delta d \simeq 0.025$
- a for **coarse** control
- d for fine control

A. Larrue et al, PTL, 20, pp. 2120, 2008



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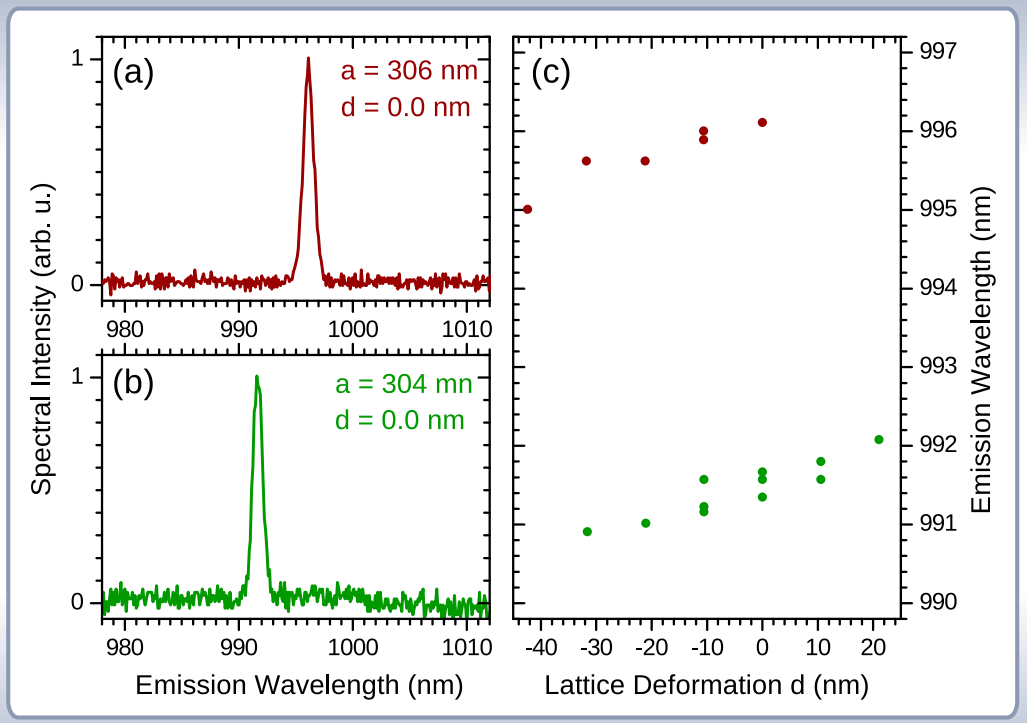

Nice results but ...

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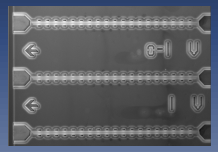

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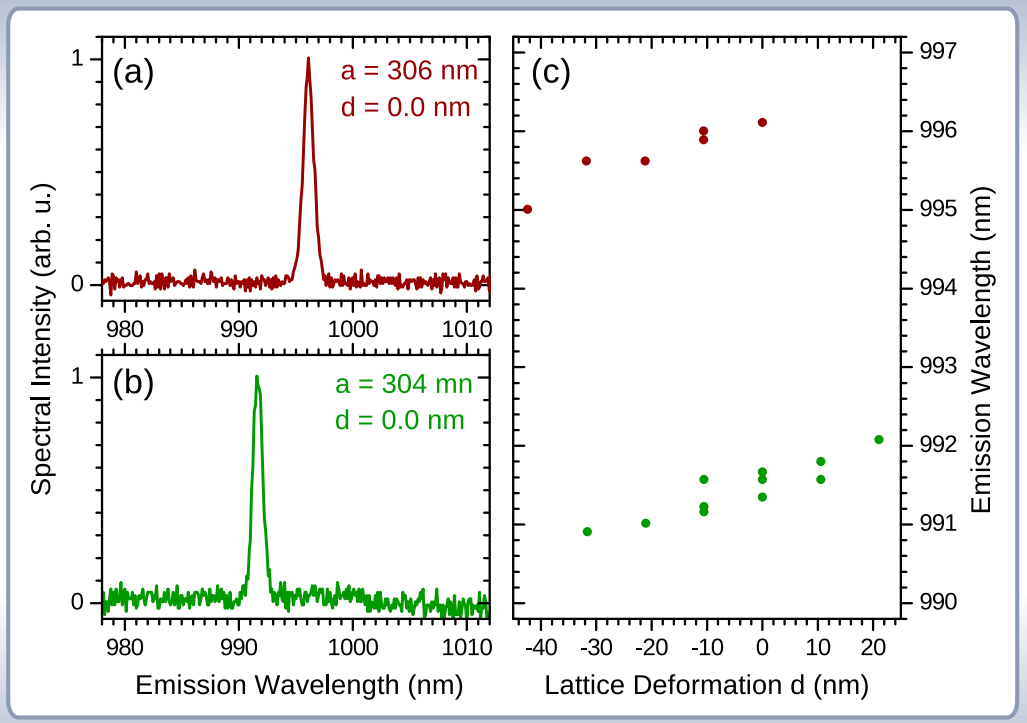

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- Random λ shift

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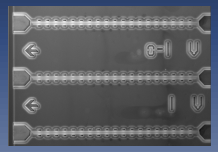

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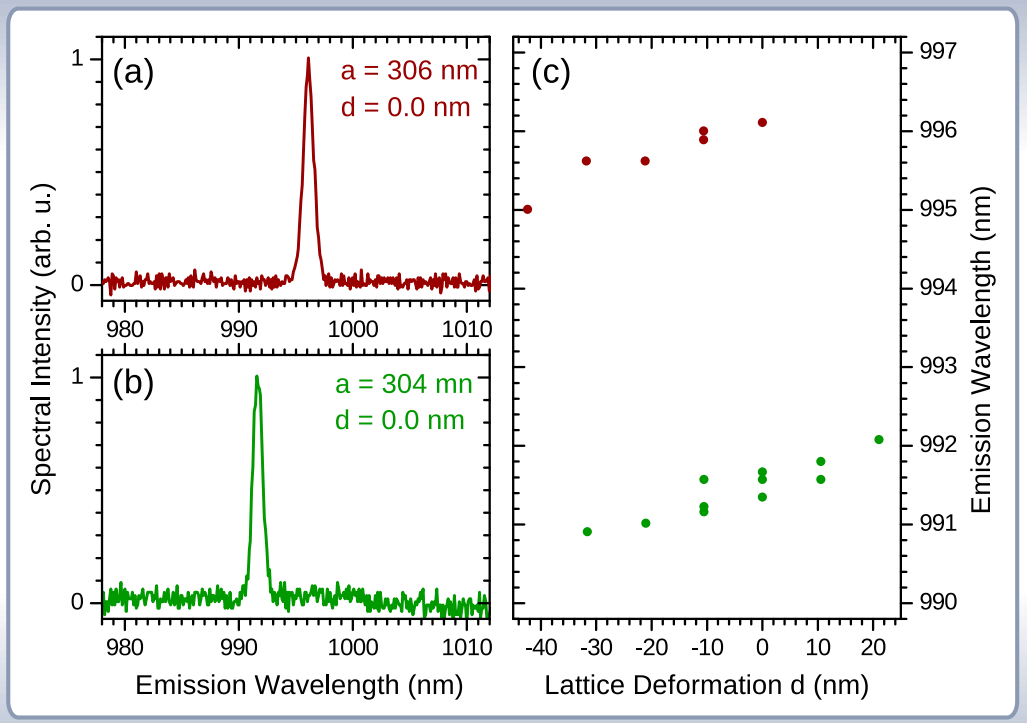
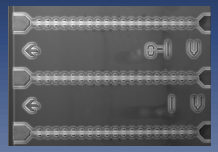
Affine deformation: experimentally



Nice results but ...

- Random λ shift
- Other lasing modes

A. Larrue et al, PTL, 20, pp. 2120, 2008



Wavelength control using affine deformation

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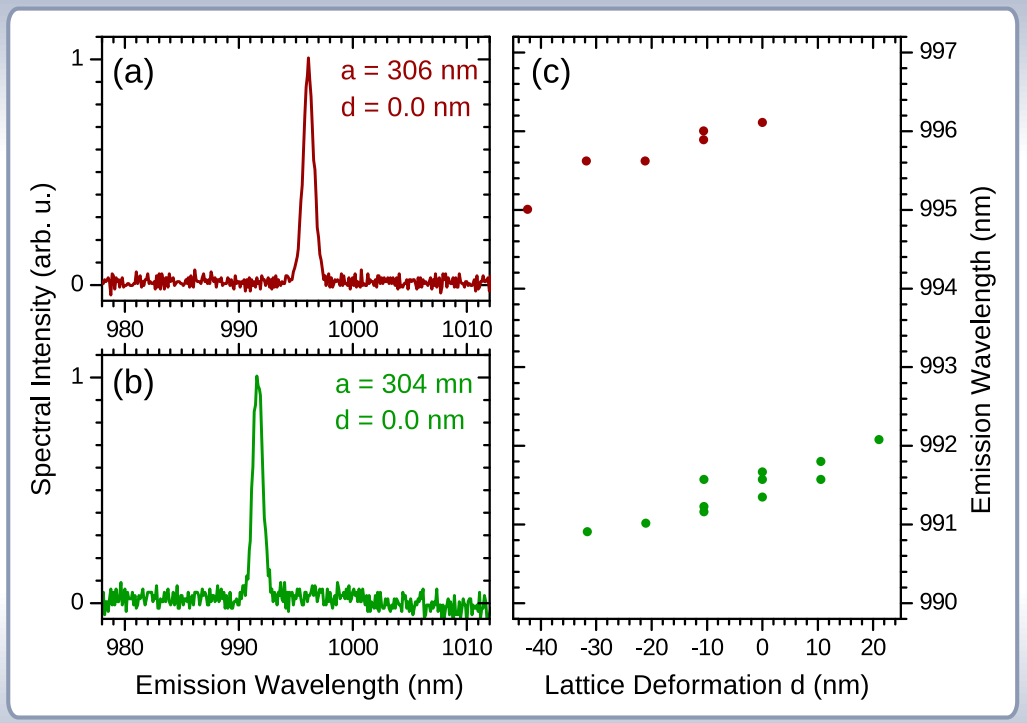
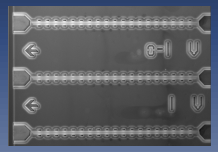


Nice results but ...

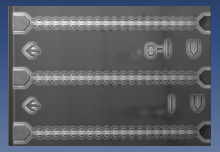
- Random λ shift
- Other lasing modes
- ... optical feedback!

A. Larrue et al, PTL, 20, pp. 2120, 2008



Wavelength control using affine deformation

Optical feedback is to blame



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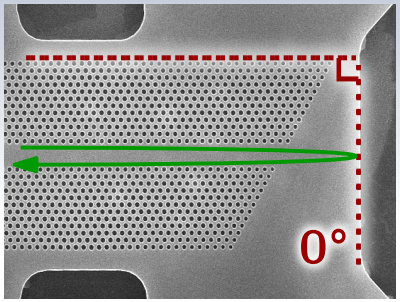

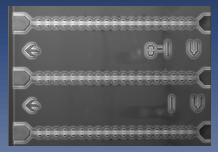

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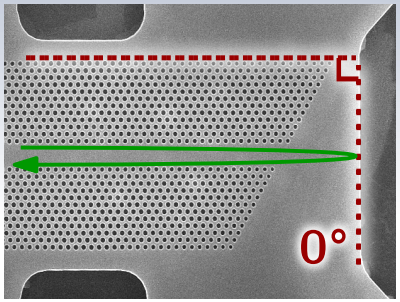

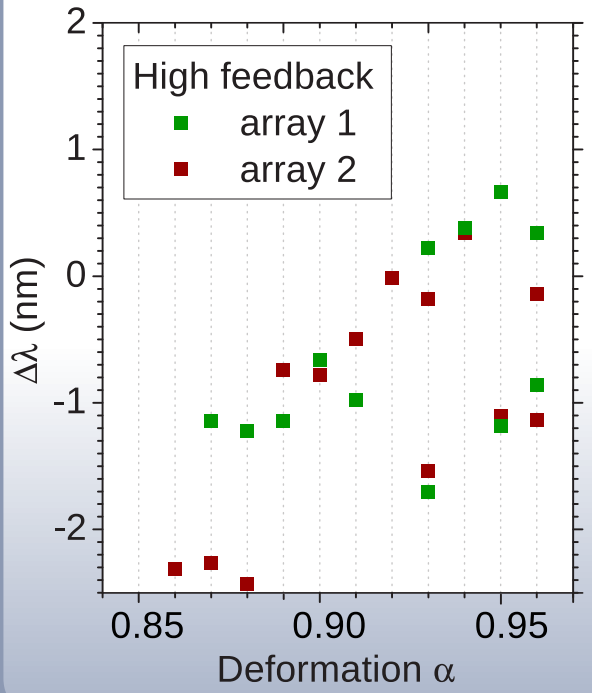

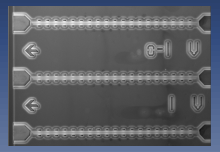

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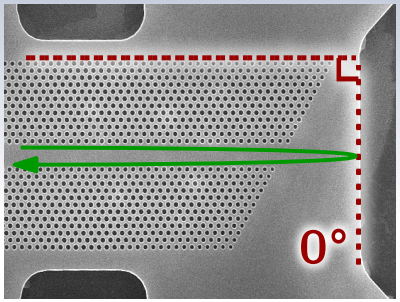

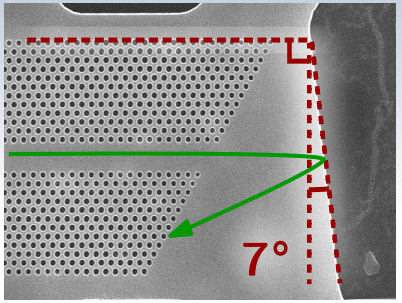

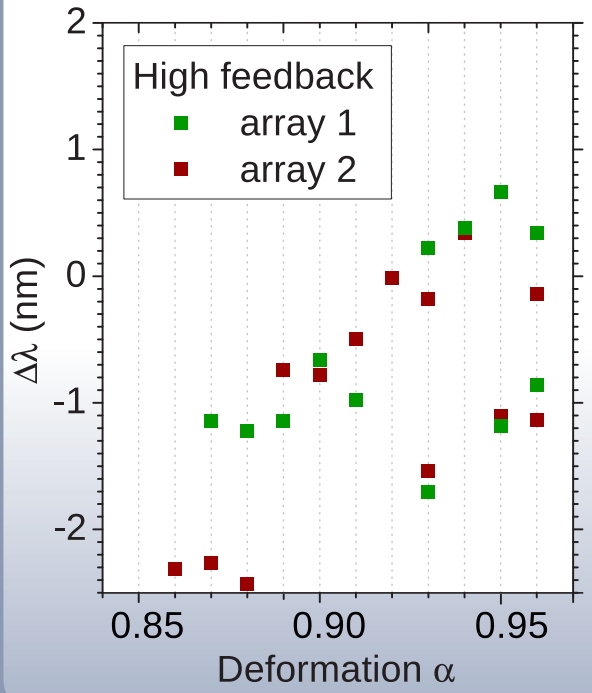

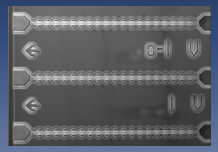

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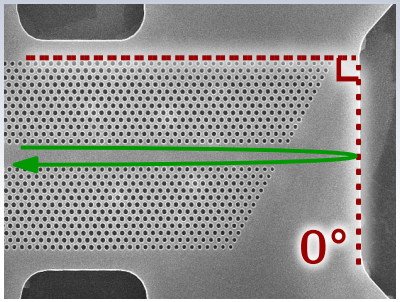
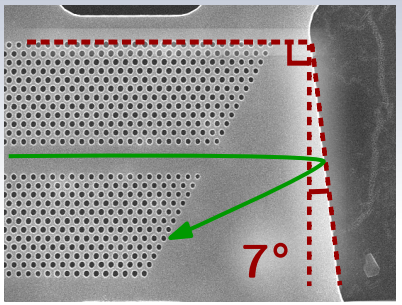
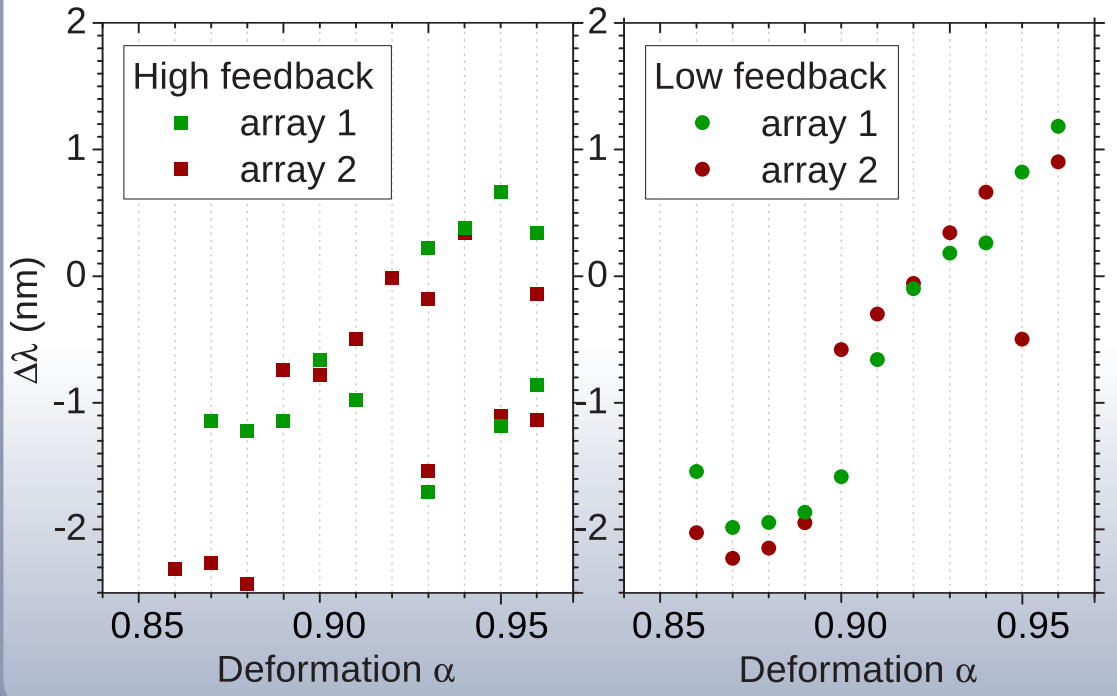
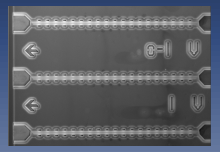




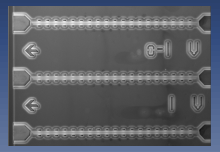




How to deal with optical feedback

Tools and recipes

- Reduce feedback to minimum (end mirror engineering)



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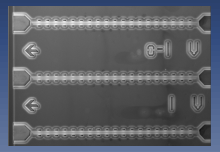

How to deal with optical feedback

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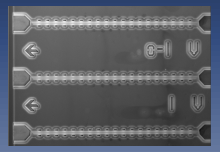
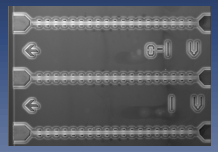
- Reduce feedback to minimum (end mirror engineering) ✓
- Increase DBF robustness towards feedback



How to deal with optical feedback

Tools and recipes

- Reduce feedback to minimum (end mirror engineering) ✓
- Increase DBF robustness towards feedback
  - Improve Q_1 (Q factor of best DFB mode)



How to deal with optical feedback

Tools and recipes

- Reduce feedback to minimum (end mirror engineering) ✓
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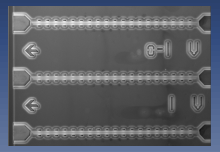

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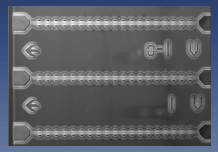
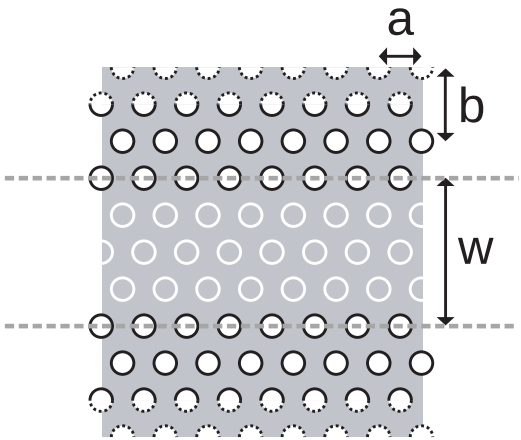
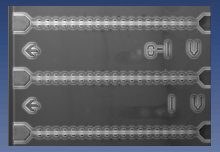
Affine deformation is not enough

1 handle (α) for 2 controls (λ and Q)



Double deformation: two handles





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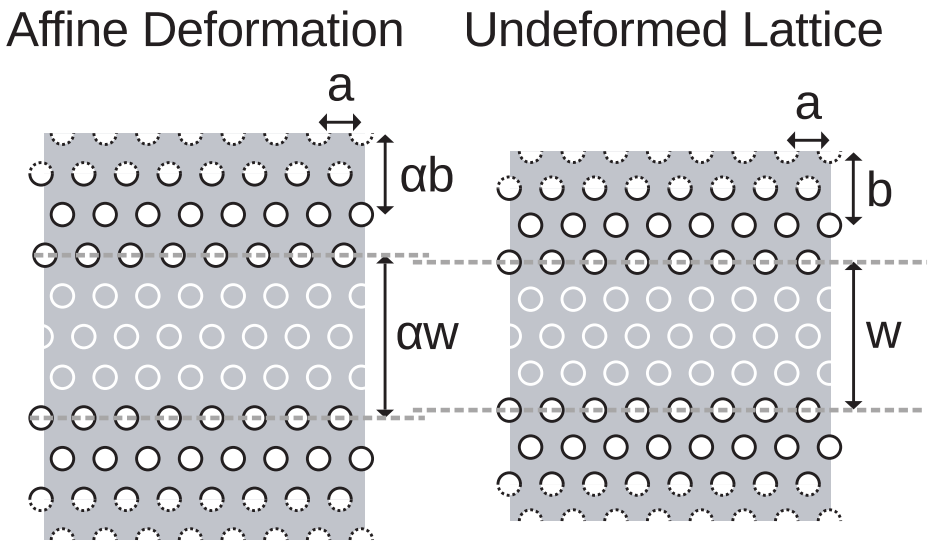
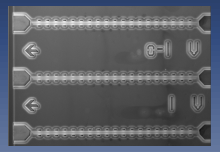
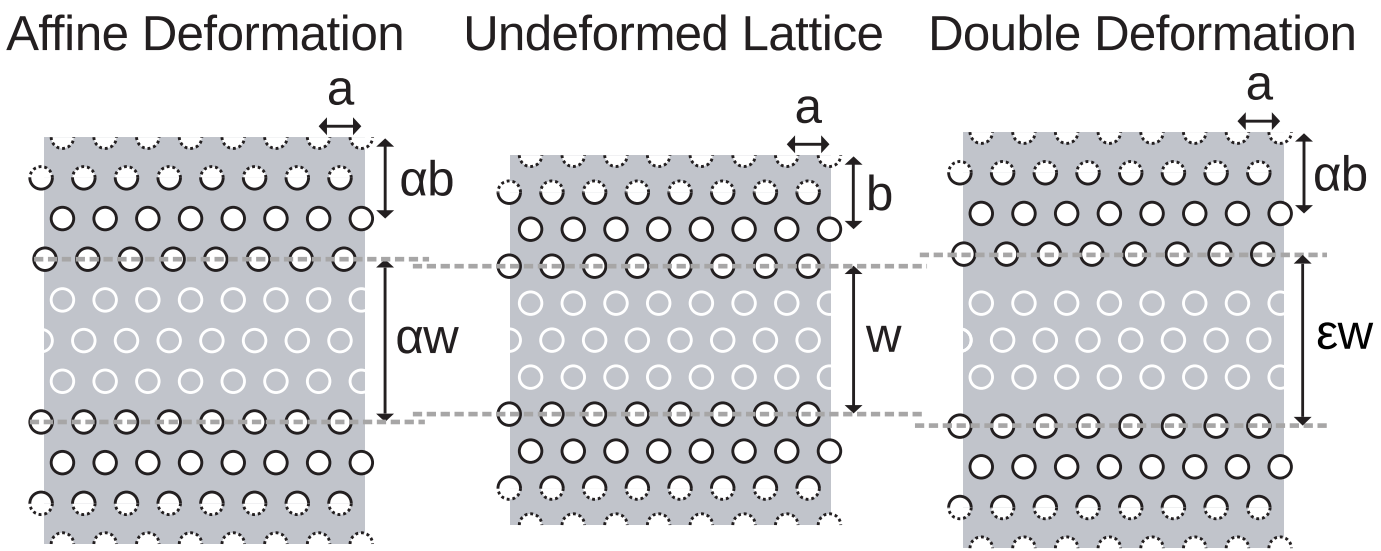


Affine deformation

⊥ lattice constant b and defect width w scaled by α



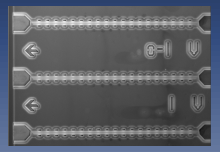
Double deformation: two handles



Double deformation

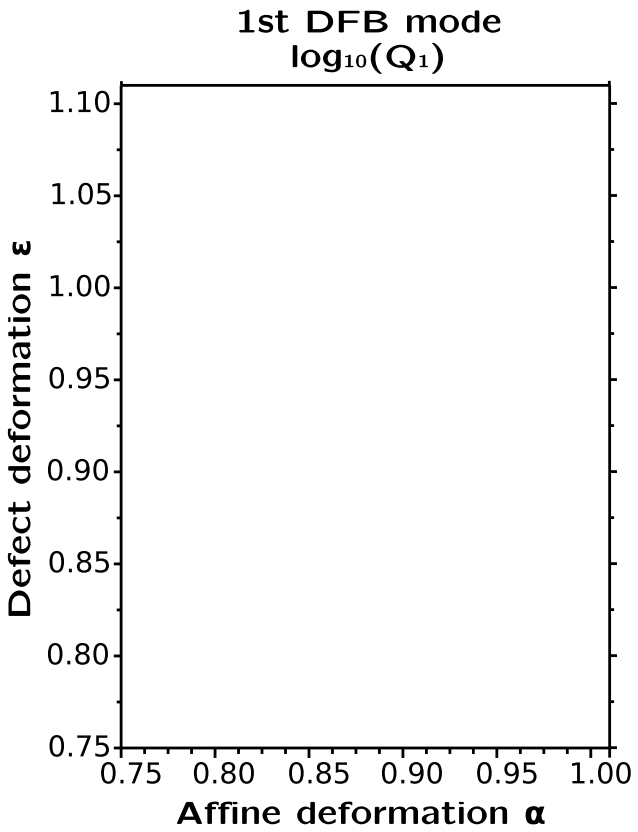
$\perp$ lattice constant b scaled by α

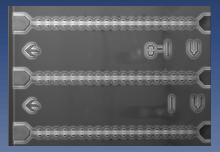
defect width w scaled independently by ε



Double deformation for Q control

Double deformation: 2D Q maps





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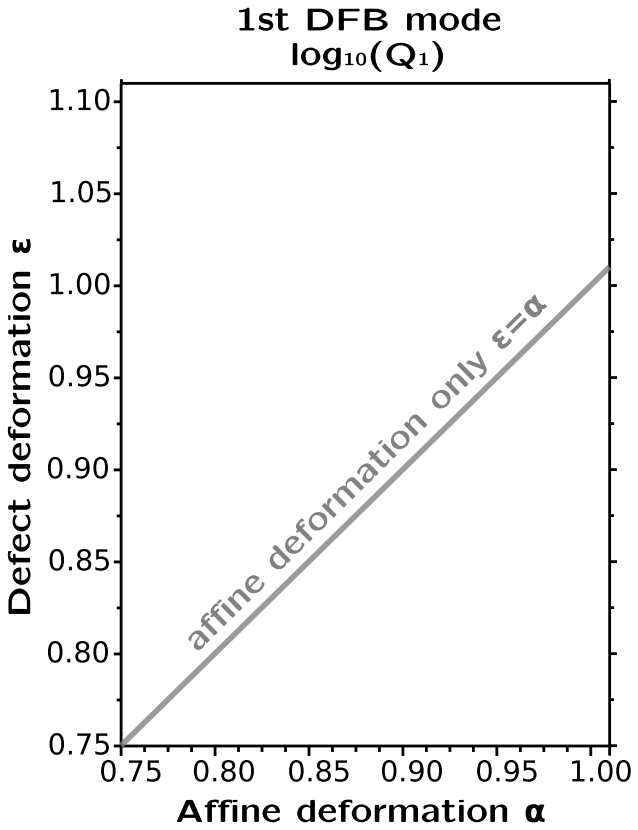

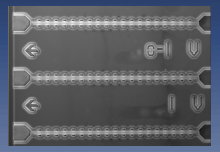

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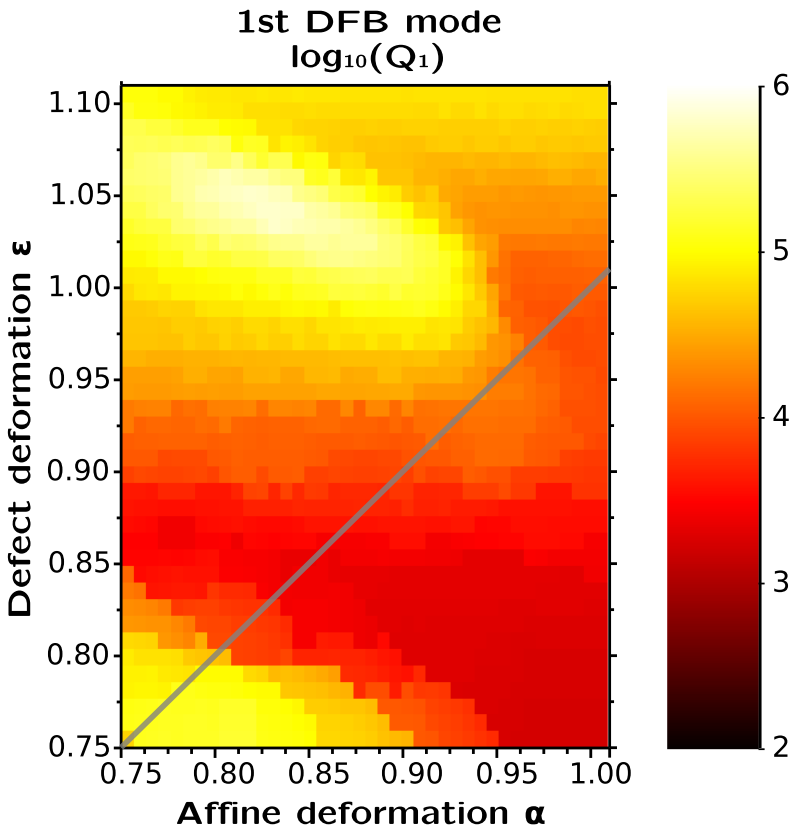

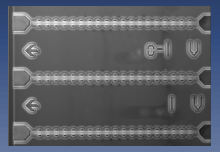

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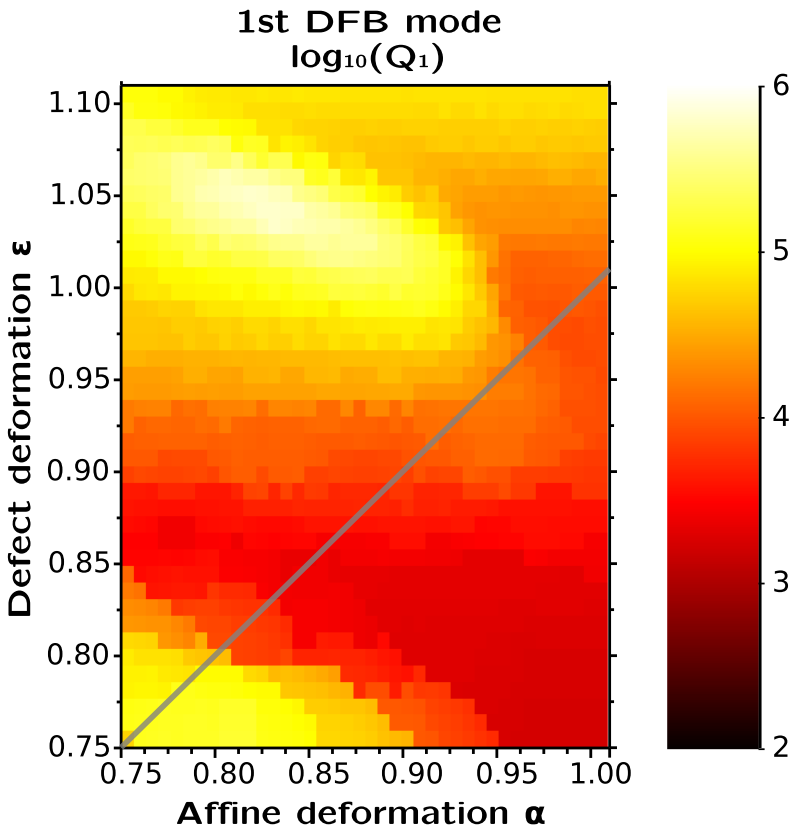
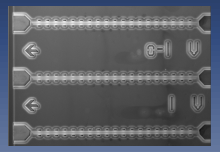


Q factor improvement

$Q_1 \simeq 6.7\ 10^5$: two order of magnitude better



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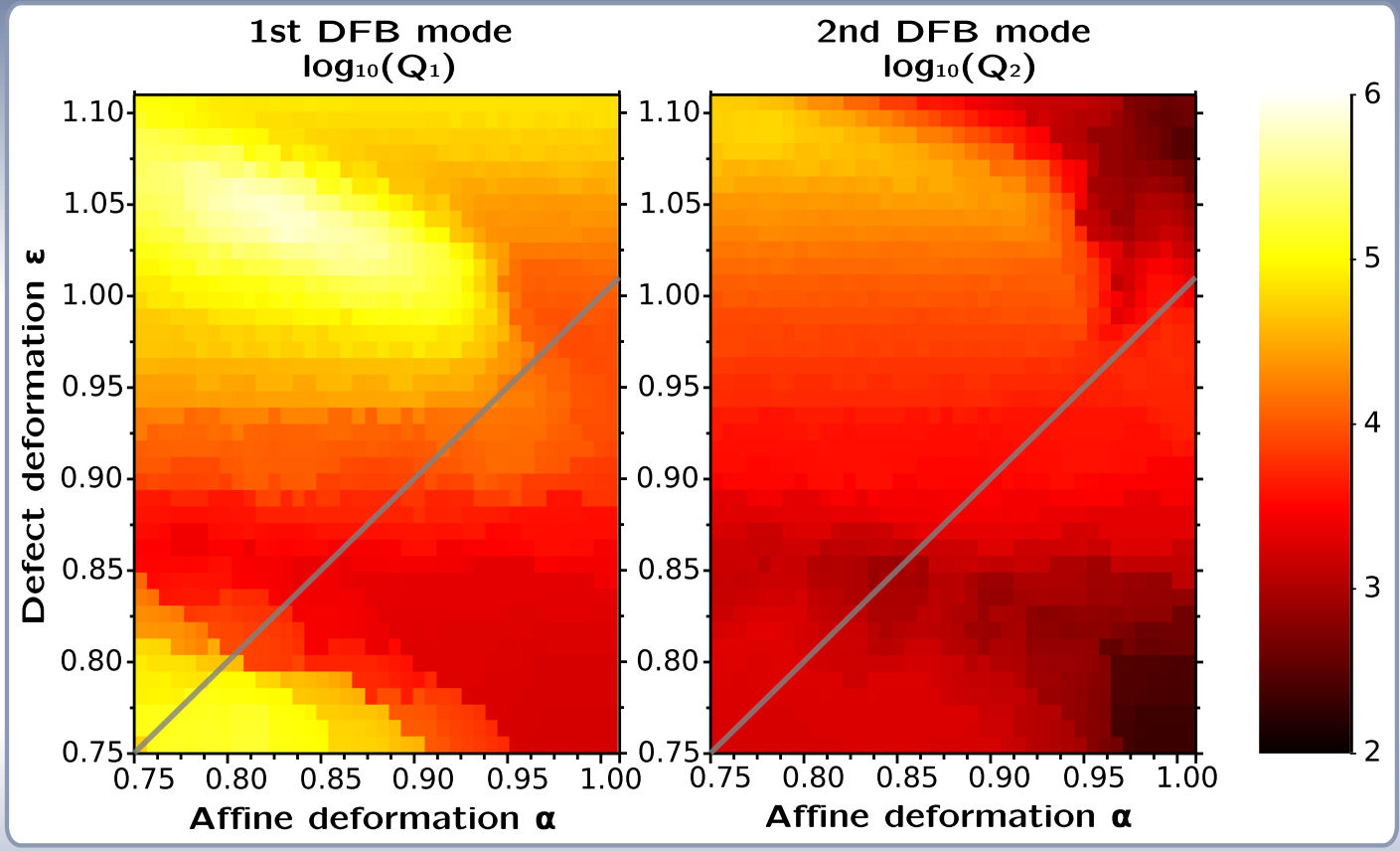

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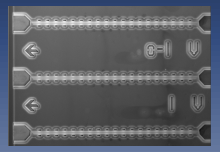

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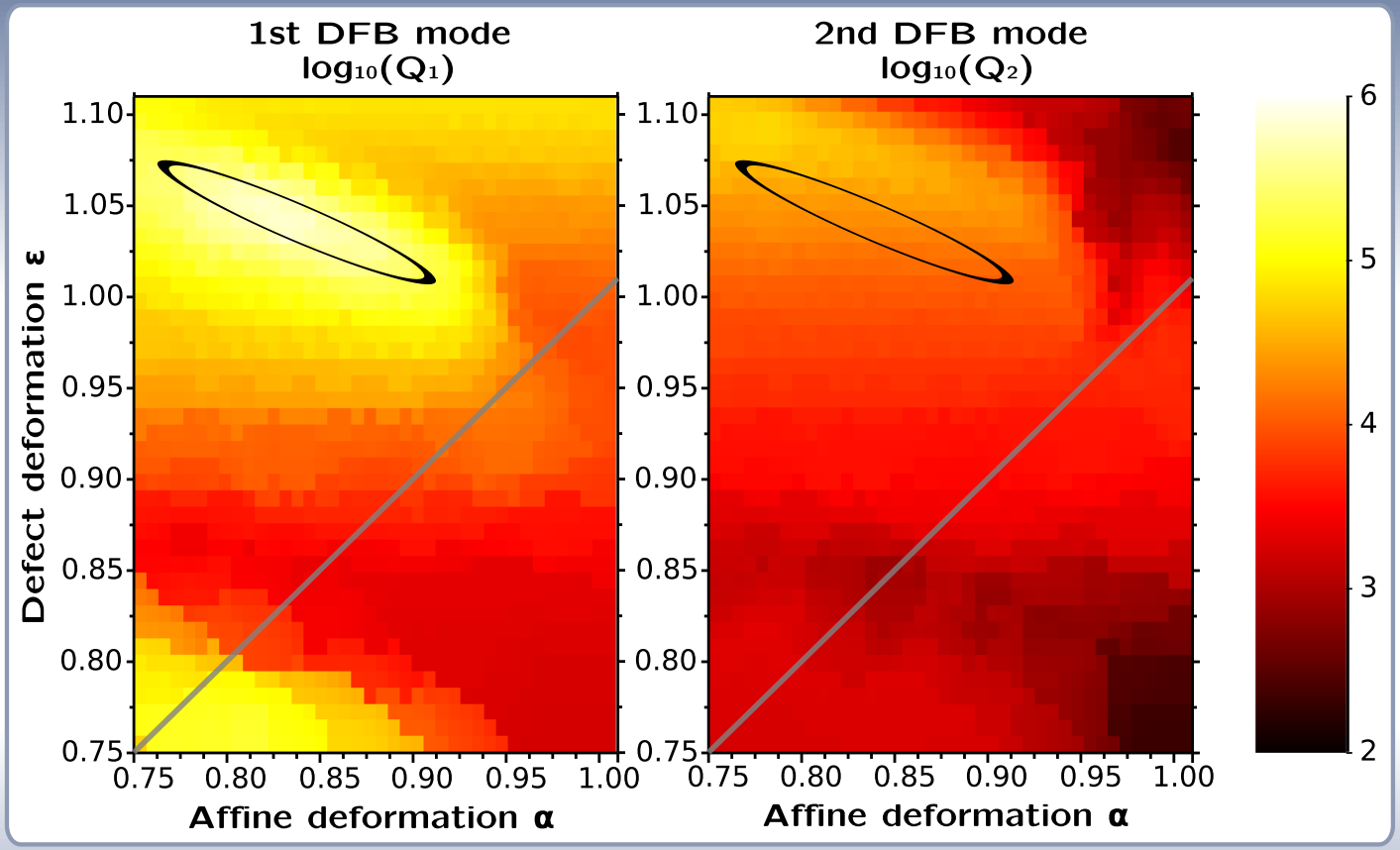

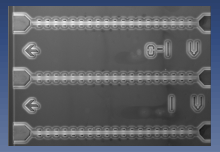

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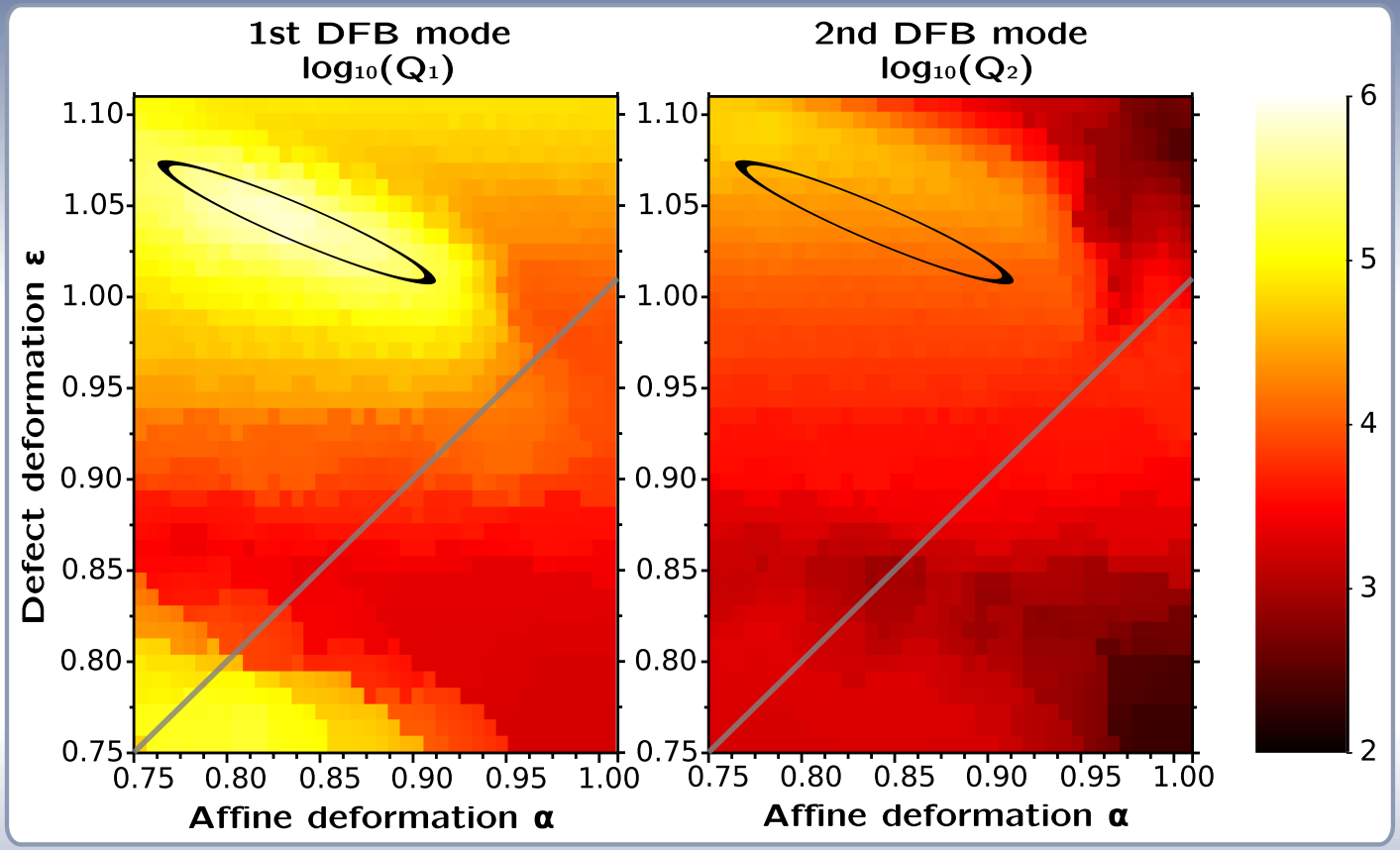
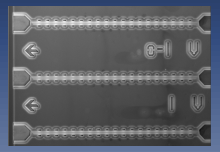


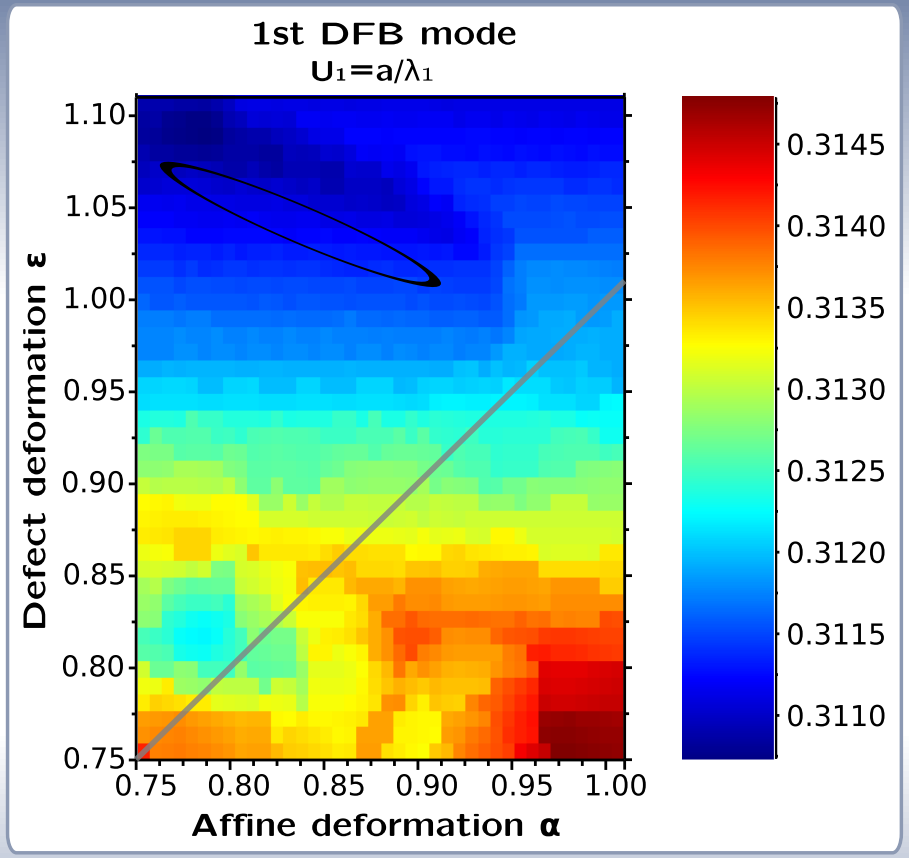
Mode selectivity improvement

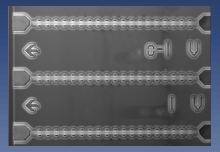
$\Delta Q > 2.4\ 10^4$: one order of magnitude better



Double deformation for Q control

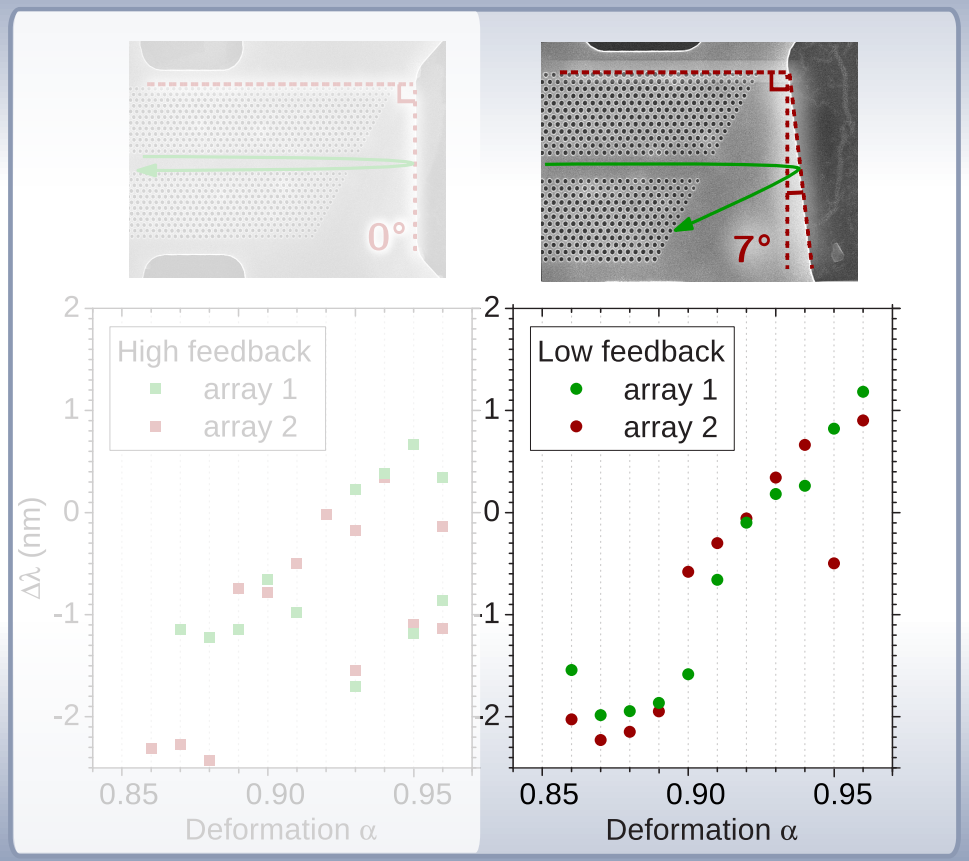
Double deformation: 2D U map

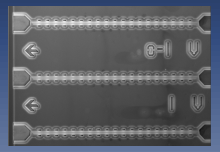




Double deformation: 2D U map

Remember affine deformation ?





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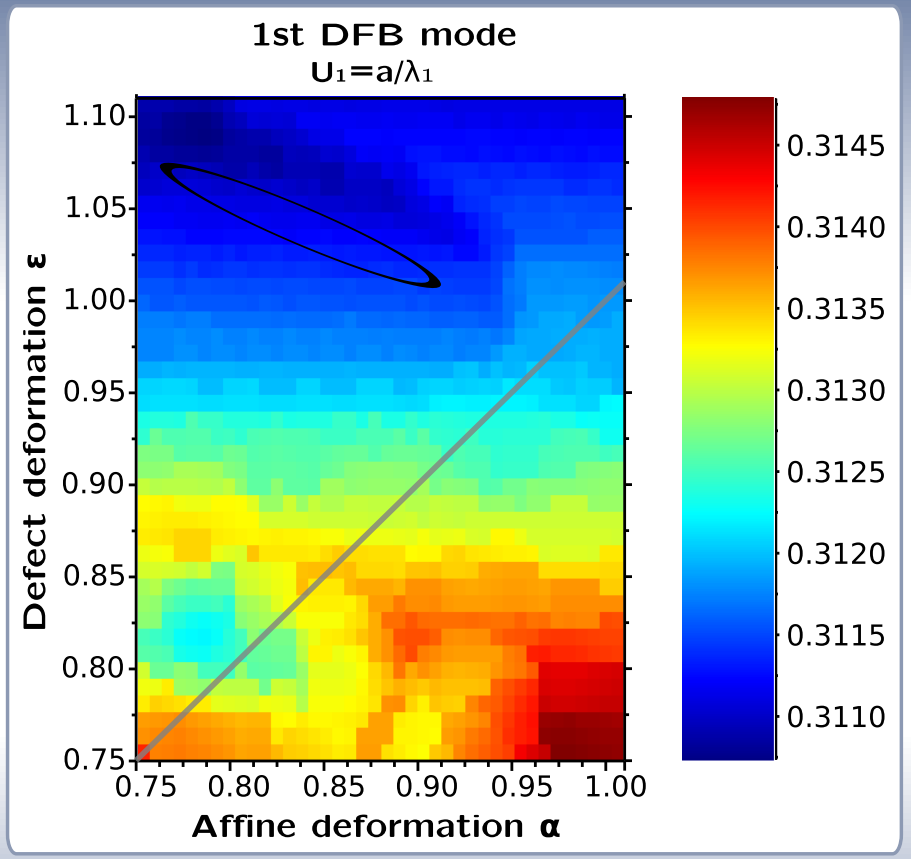
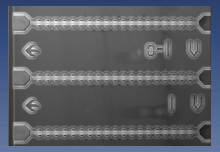


U control improvement

Slow variation and no mode-hoping



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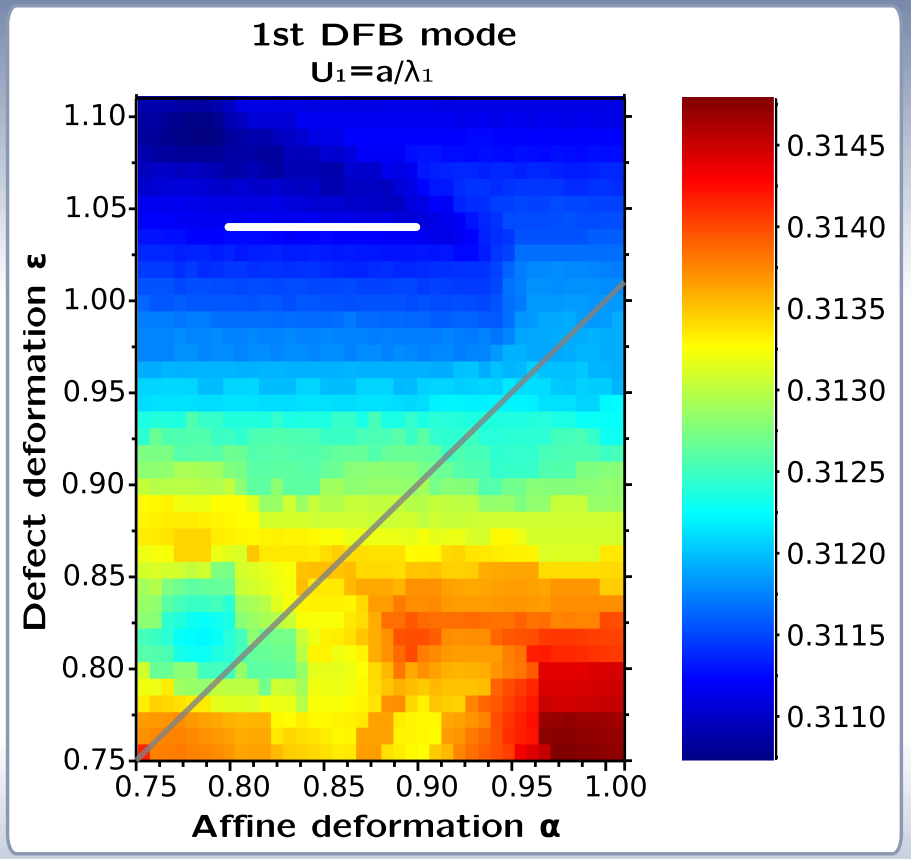
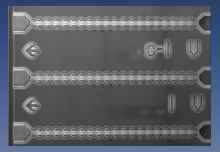


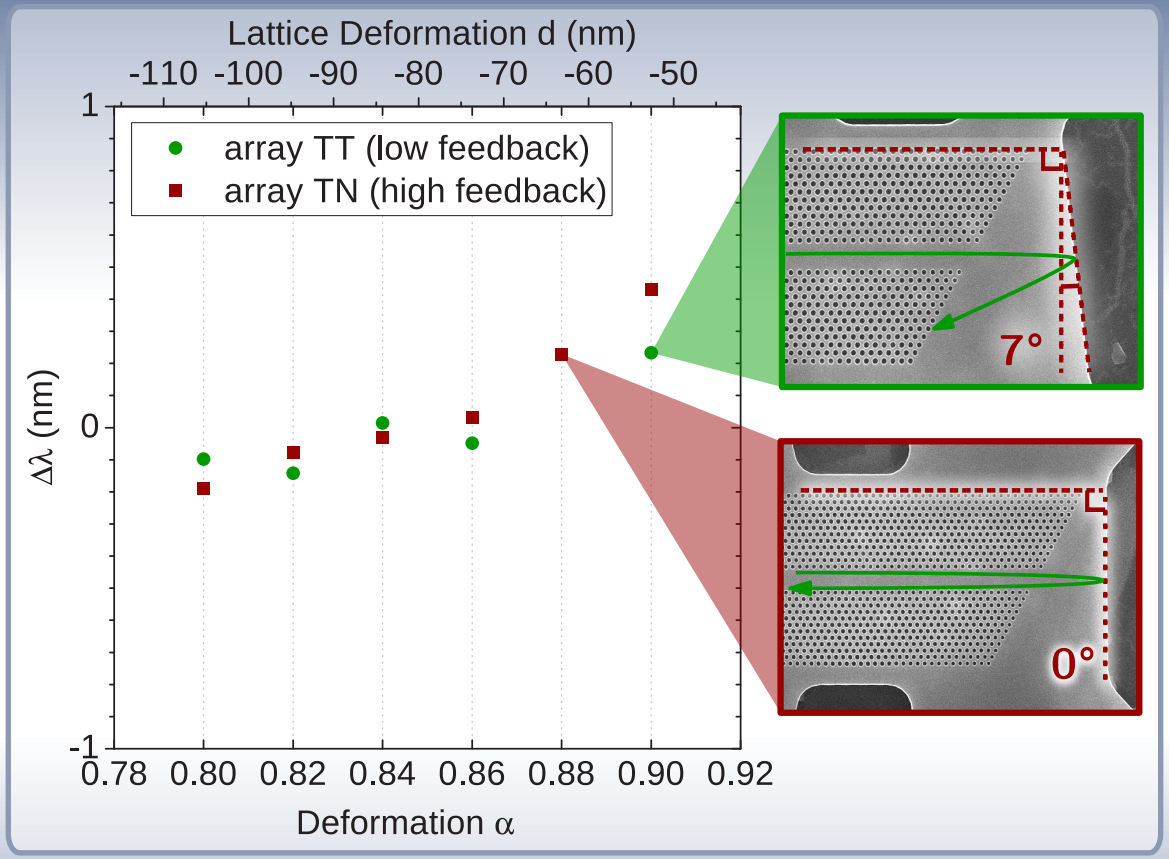
Experimental demonstration

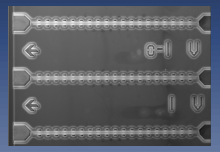
$\varepsilon = 1.04$ and α in $[0.8, 0.9]$



Double deformation for Q control

Double deformation: experimentally





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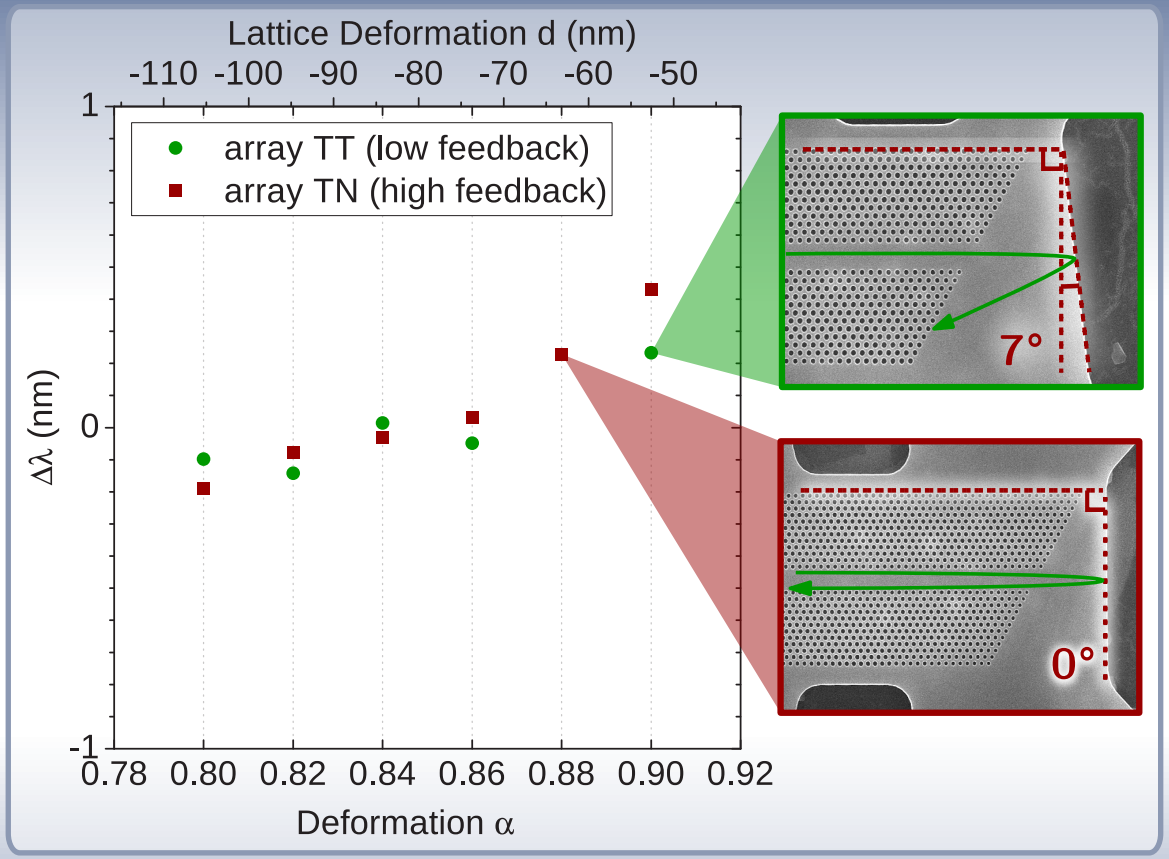
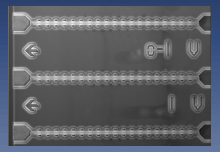


Robustness towards optical feedback

$\Delta\lambda < 0.2\,\text{nm}$: tenfold improvement



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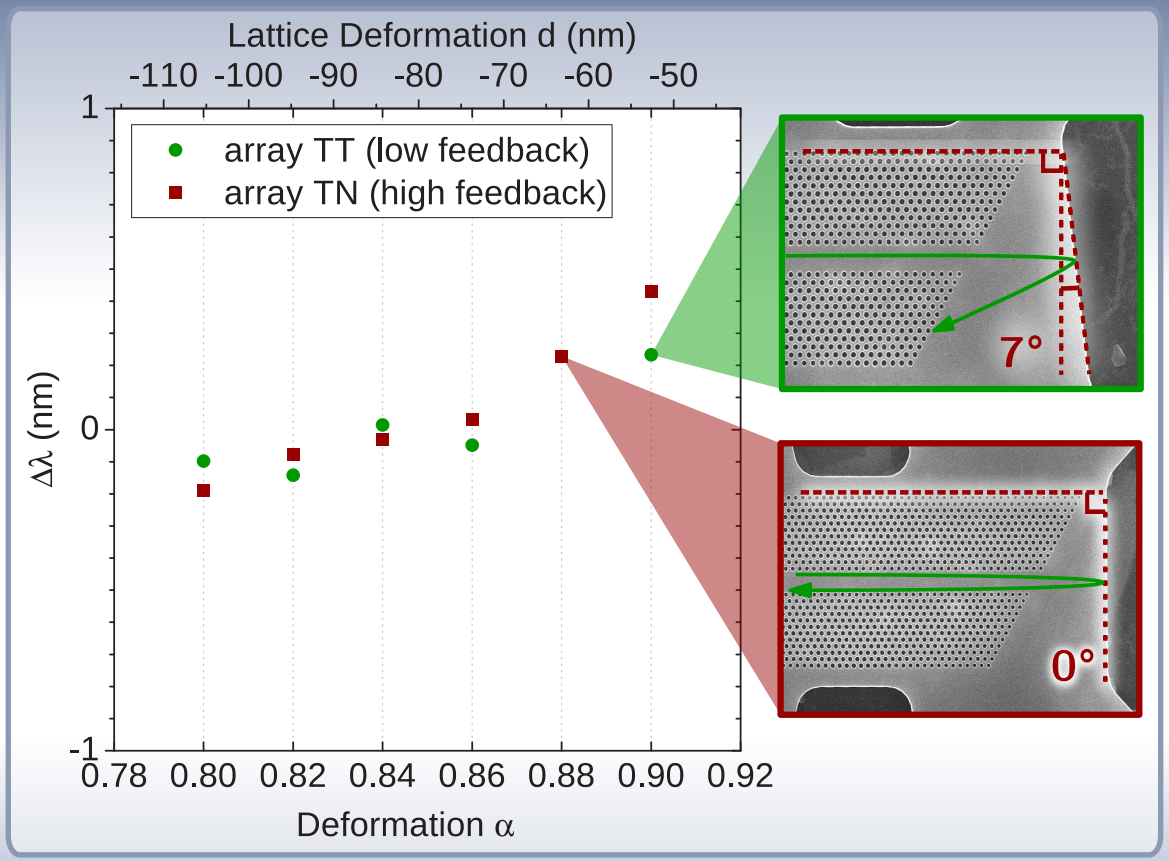
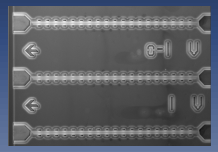


Robustness towards optical feedback

No mode hoping, all single-mode lasers



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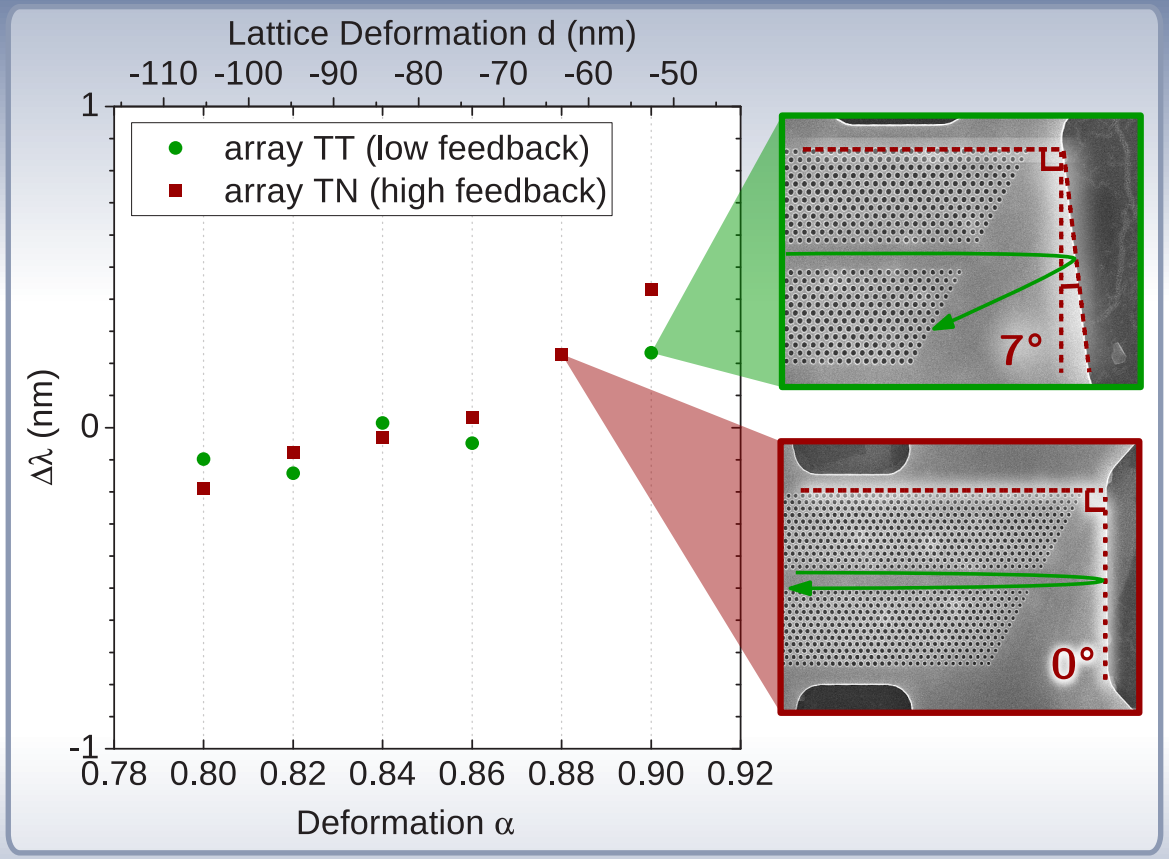
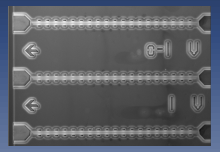


Improved λ control

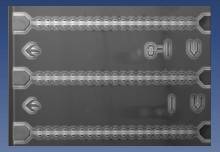
Sensitivity $\Delta\lambda/\Delta d \simeq 0.009$ $3\times$ improvement



Conclusion 1/3

2D Photonic Crystal for DFB array

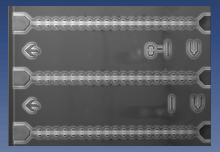
- Powerful and versatile tool



Conclusion 1/3

2D Photonic Crystal for DFB array

- Powerful and versatile tool
- Coarse, fine and finer λ control



Conclusion 1/3

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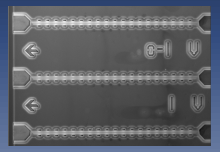

Conclusion 1/3

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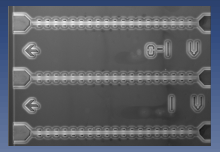
BUT ... proof of principle!



Conclusion 1/3

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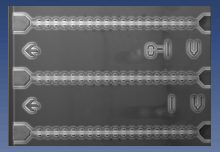

Conclusion 1/3

2D Photonic Crystal for DFB array

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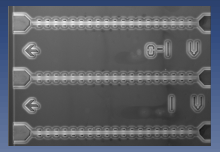
BUT ... proof of principle!

- We're on a membrane
- Integration / electrical pumping?



Conclusion 1/3

2D Photonic Crystal for DFB array

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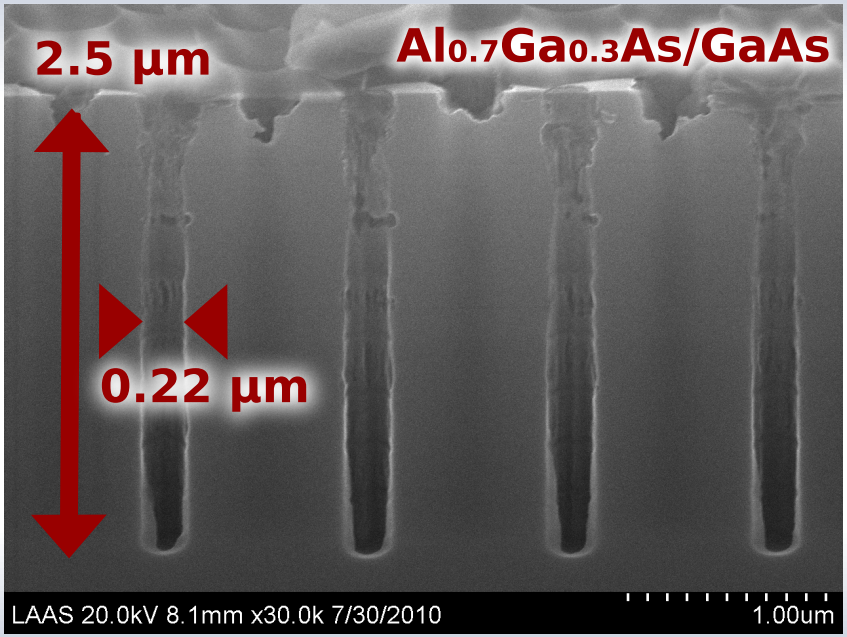
BUT ... proof of principle!

- We're on a membrane
- Integration / electrical pumping
  $\Rightarrow$ deep etching!

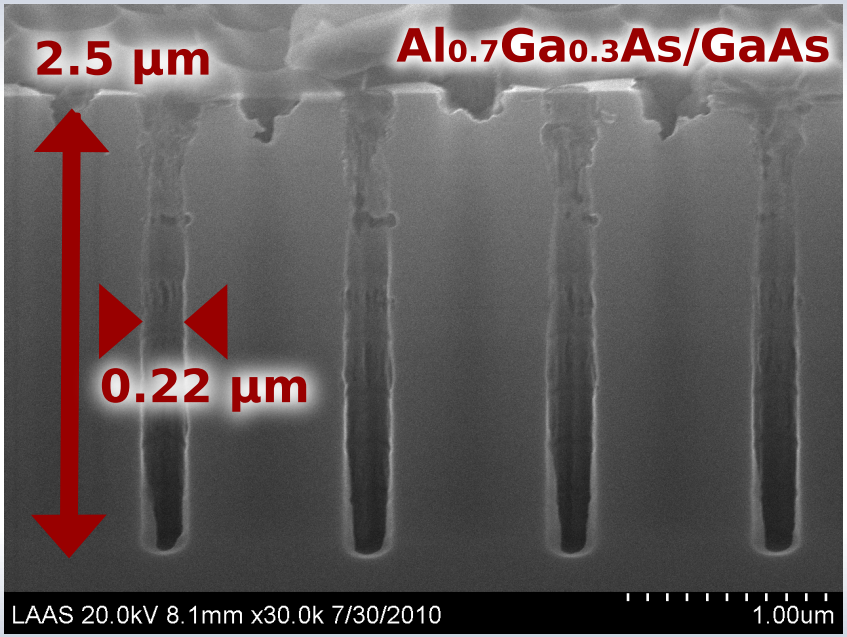
Conclusion

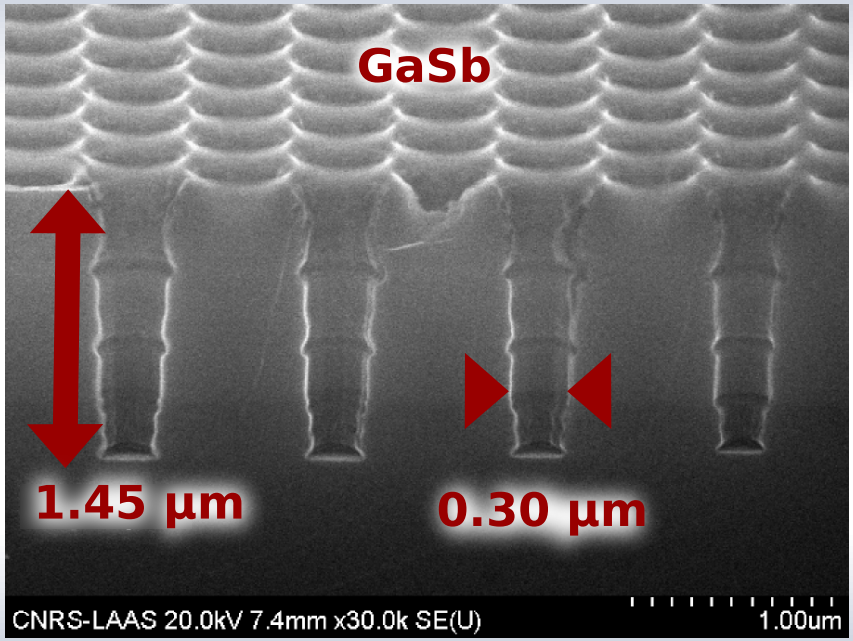
Deep etching of GaAs/GaAlAs

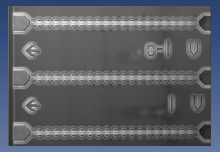


Conclusion

Deep etching of GaAs/GaAlAs & GaSb





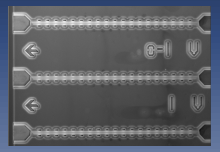


Conclusion 2/3

2D Photonic Crystal for DFB array

- Powerful and versatile tool
- Coarse, fine and finer λ control
- High robustness towards feedback

Towards bulk e- pumping



Conclusion 2/3

2D Photonic Crystal for DFB array

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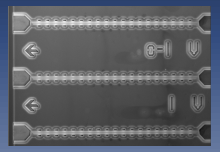
- Coarse, fine and finer λ control
- High robustness towards feedback

Towards bulk e- pumping

- Proof of principle (brick 1)



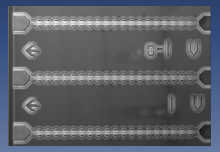
Conclusion 2/3

2D Photonic Crystal for DFB array

- Powerful and versatile tool
- Coarse, fine and finer λ control
- High robustness towards feedback

Towards bulk e- pumping

- Proof of principle (brick 1)
- Deep etching (brick 2)



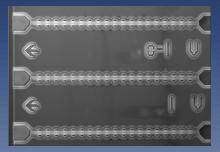
Conclusion 2/3

2D Photonic Crystal for DFB array

- Powerful and versatile tool
- Coarse, fine and finer λ control
- High robustness towards feedback

Towards bulk e- pumping

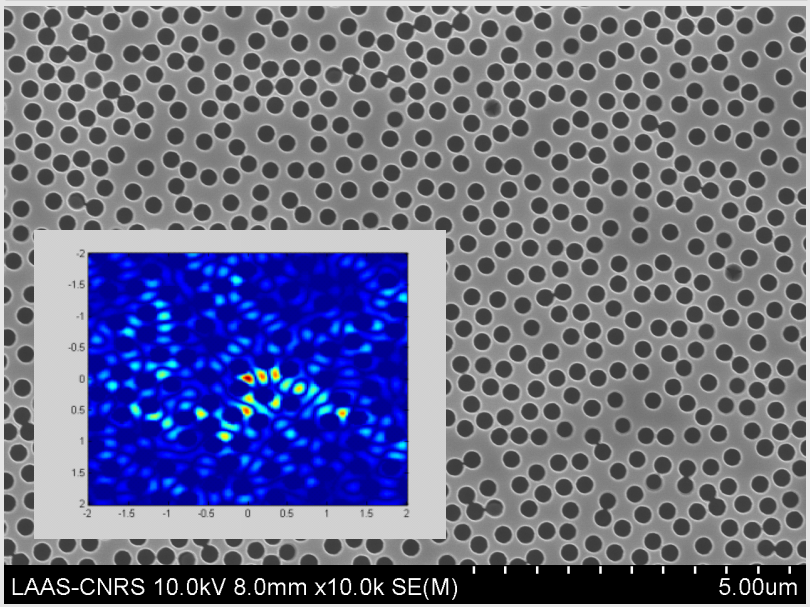
- Proof of principle (brick 1)
- Deep etching (brick 2)
- Simply merge the two !



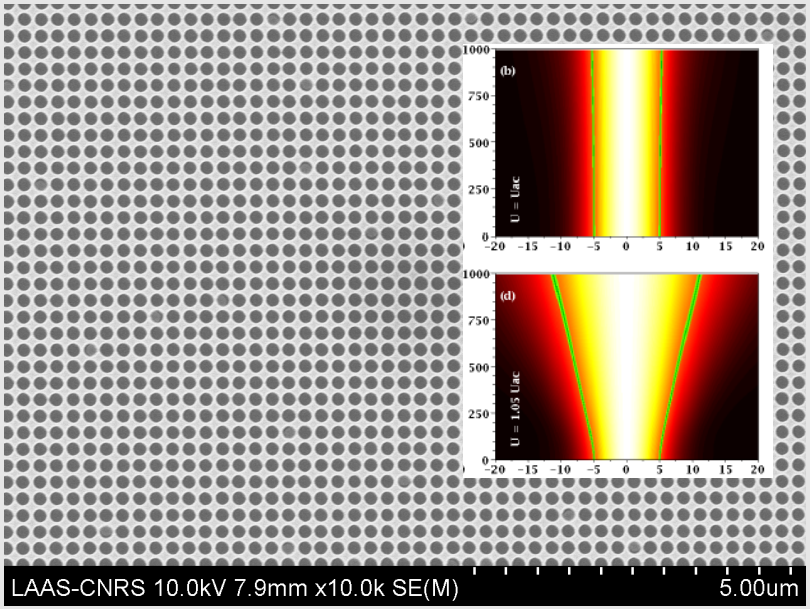
Conclusion

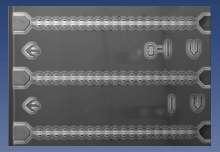
Conclusion 3/3 : beyond DFB

GLAD
lasing in random medium



CLAC
self-collimation laser cavity





Conclusion

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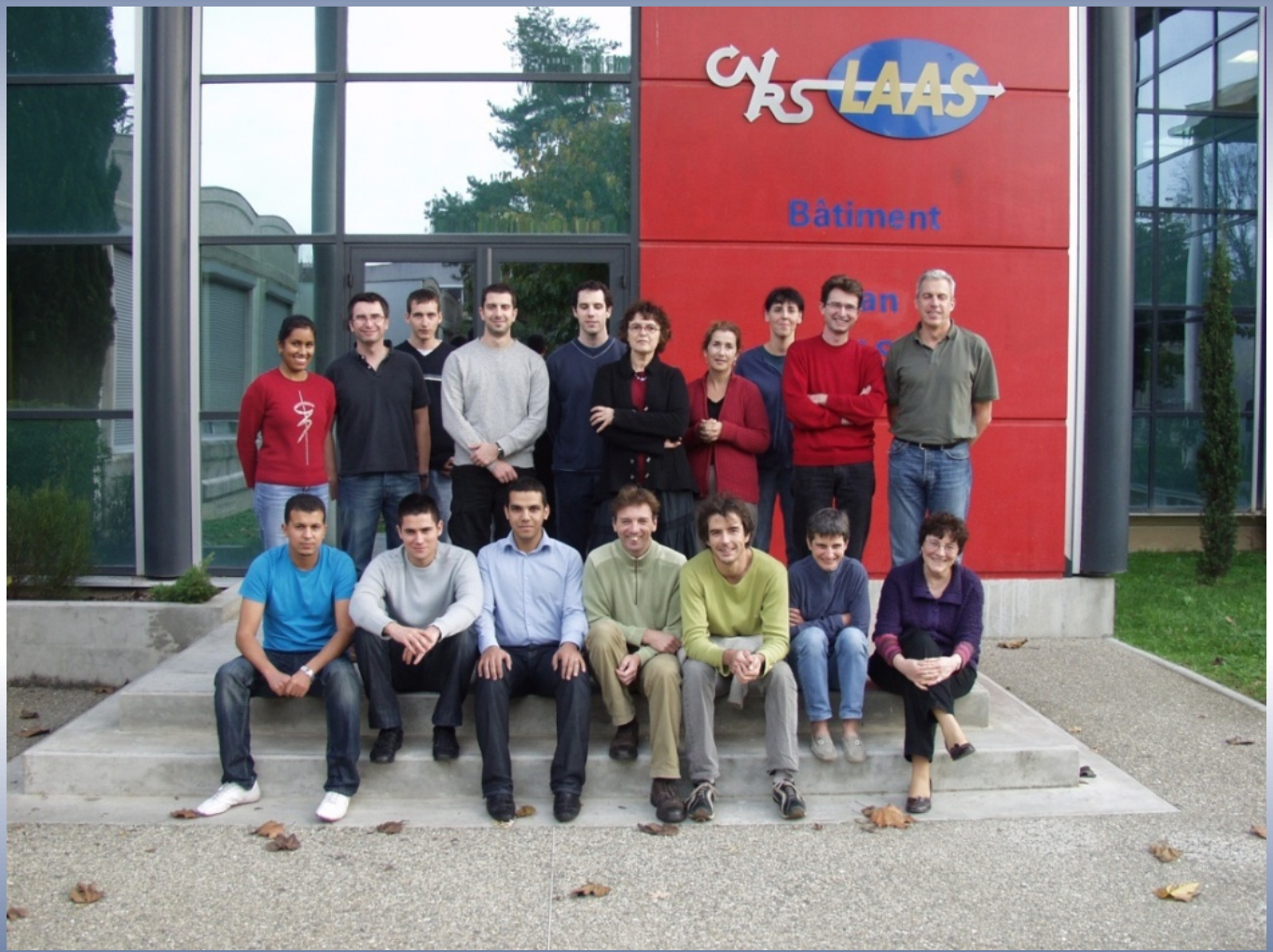

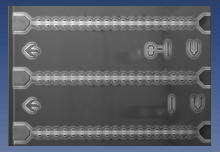

Conclusion

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Optical sensor for undersea detection of methane

Contact: lozes@laas.fr (or come and see me)