Highly photostable organic distributed feedback lasers fabricated by thermal nanoimprint

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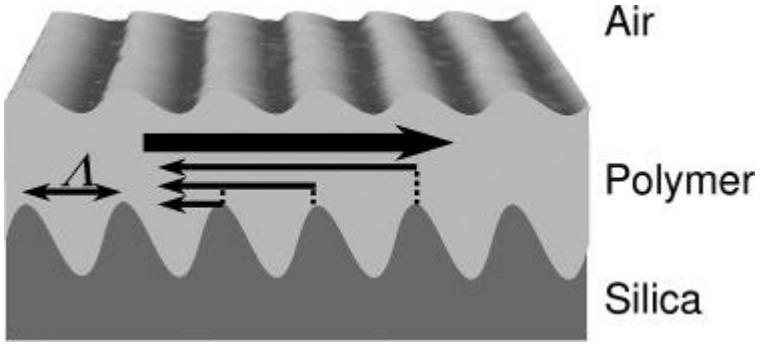
Basic elements

- **Pump** (optical): pulsed Nd:YAG laser (10 ns, 10 Hz) operating at 532 nm.

- **Active medium**: polystyrene doped with 0.5 wt% of a perylendiimide derivative (PDI).

- **Resonator**: distributed feedback (DFB) grating



Light propagating in a waveguide mode is scattered from the periodic structure to create a diffracted wave propagating in some new direction.

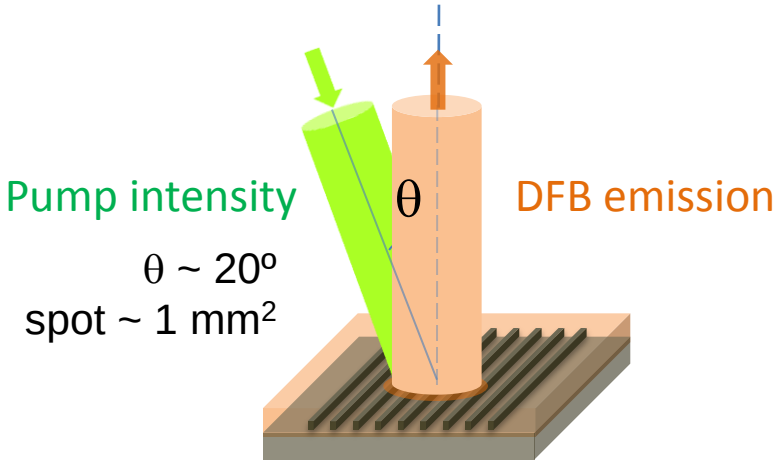
Bragg condition

$m\,\lambda_{Bragg} = 2n_{eff}\,\Lambda$

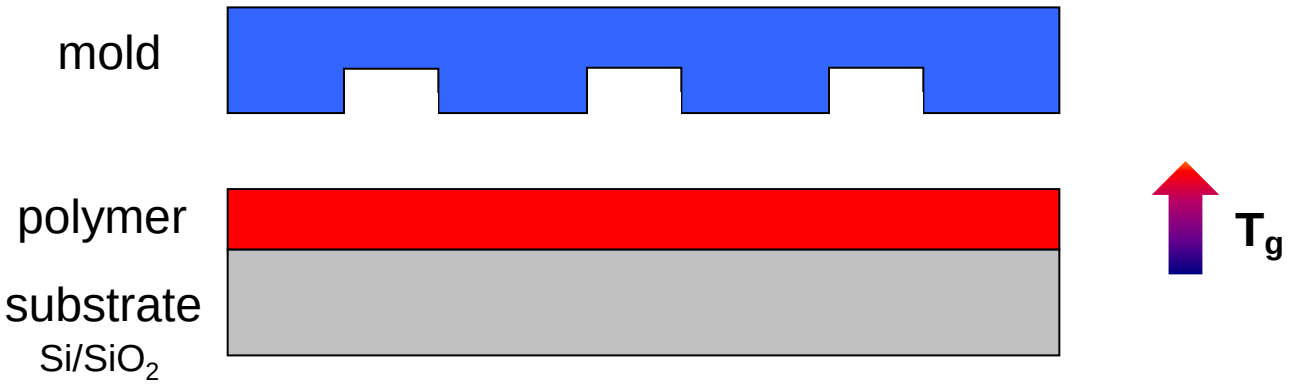
m = 2

↓

Λ = 368 nm



Fabrication of the resonator: Thermal Nanoimprint Lithography



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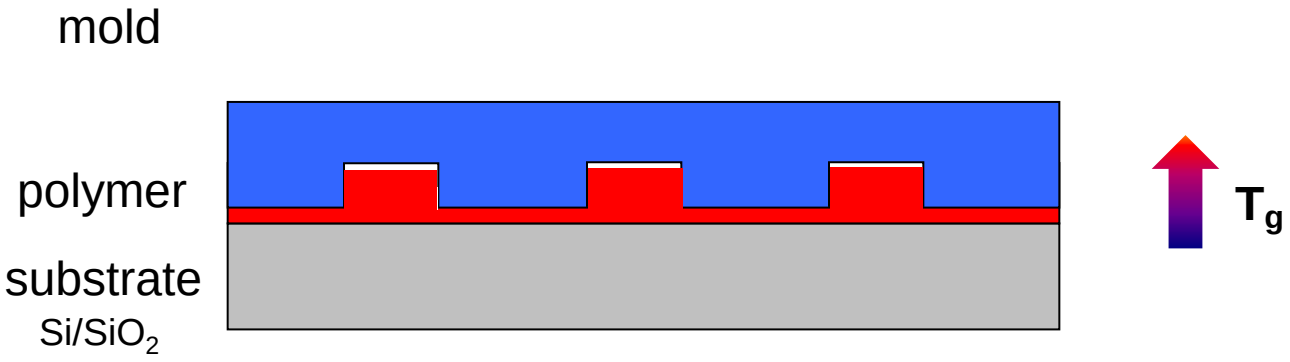

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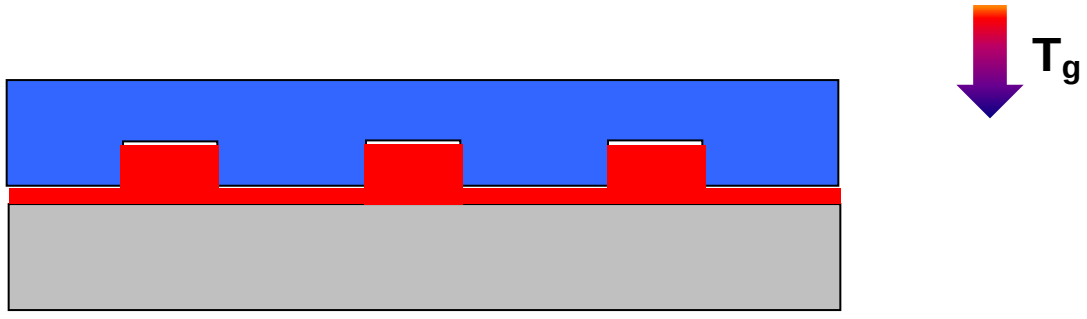

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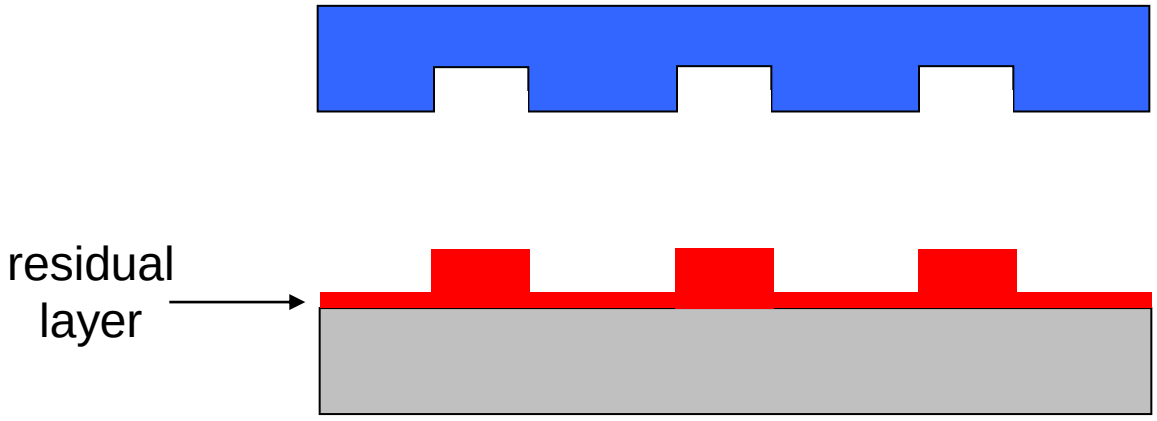

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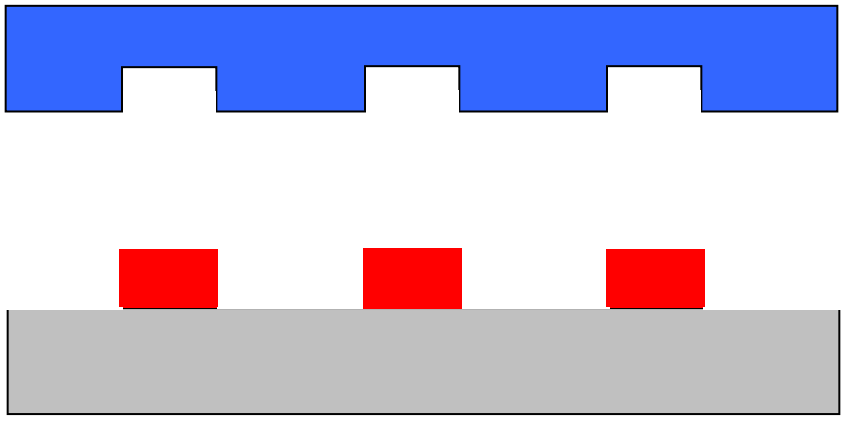
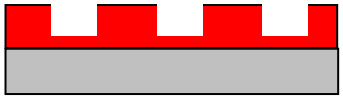
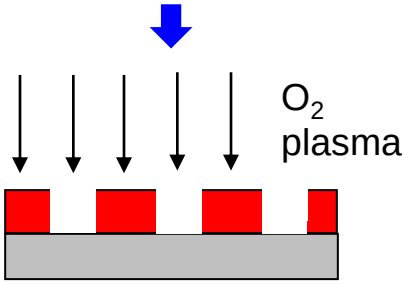


Plasma

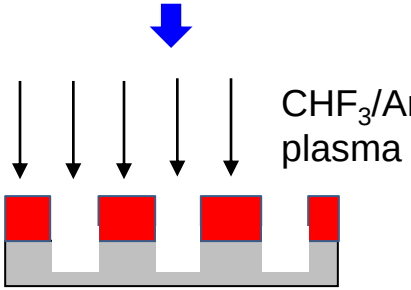
SiO_2 gratings



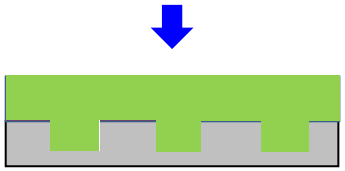
NIL onto mr-I8030E



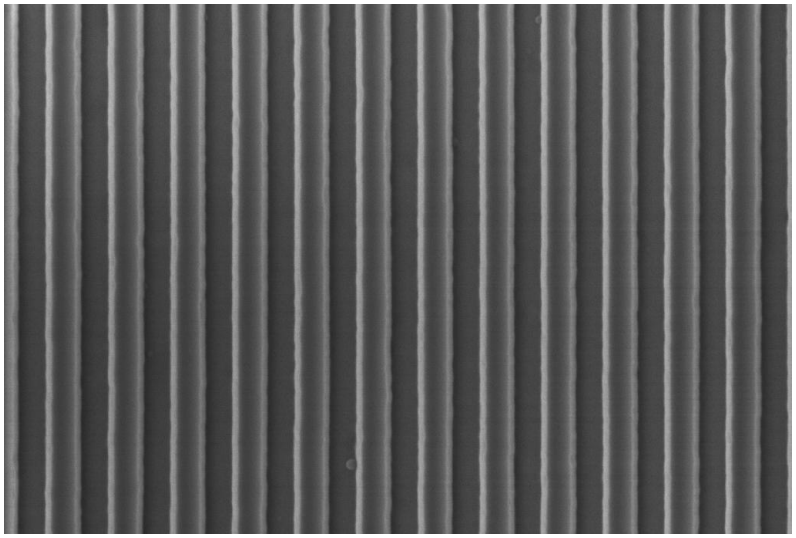
Residual layer etching



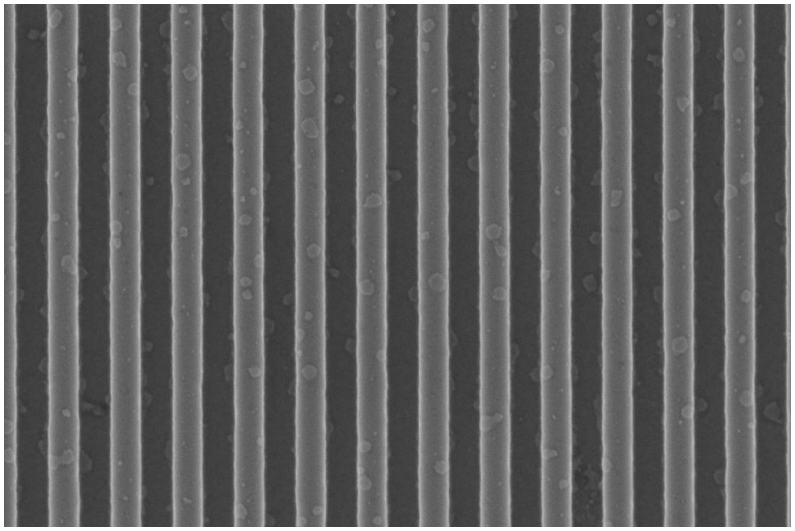
SiO_2 etching



Spin-coating of the doped PS

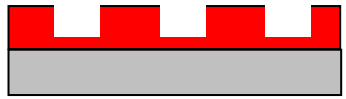


SiO_2

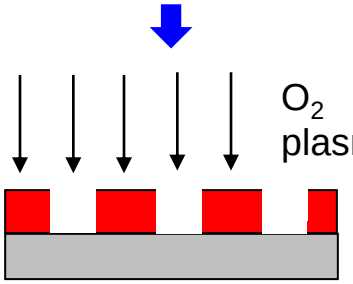


Si stamp

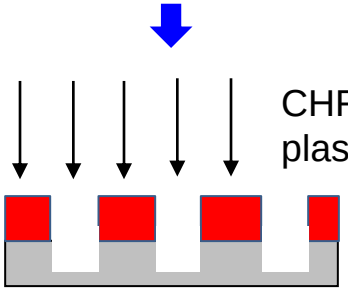
SiO_2 gratings



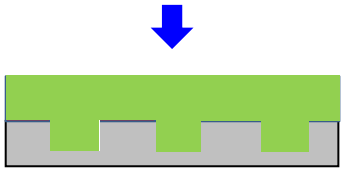
NIL onto mr-I8030E



Residual layer etching

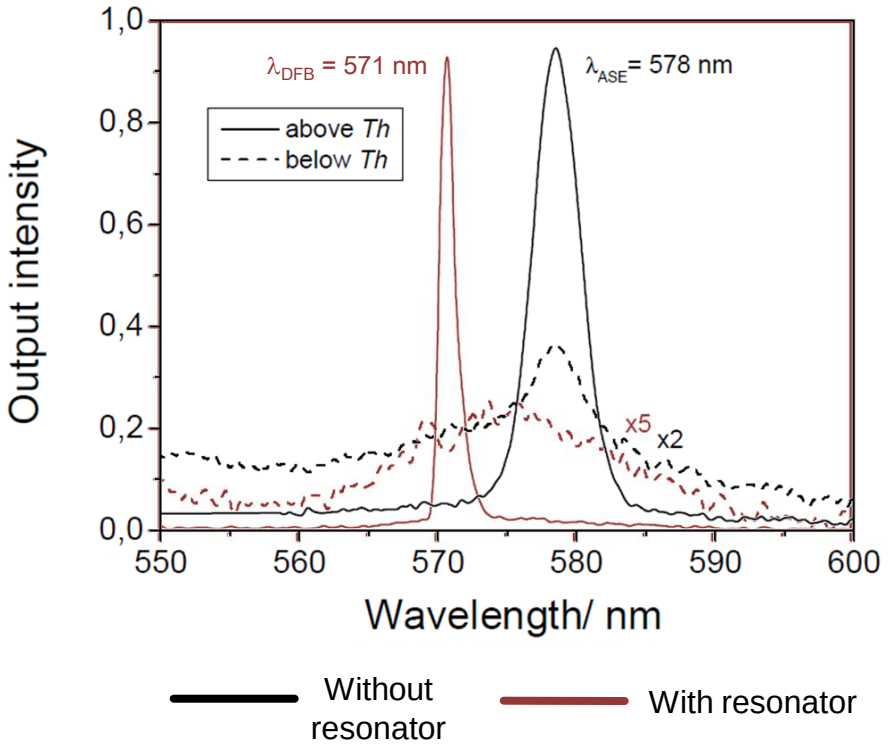


SiO_2 etching



Spin-coating of the doped PS

0.6 μm thickness



λ_{ASE} = 578 nm

FWHM 5 nm

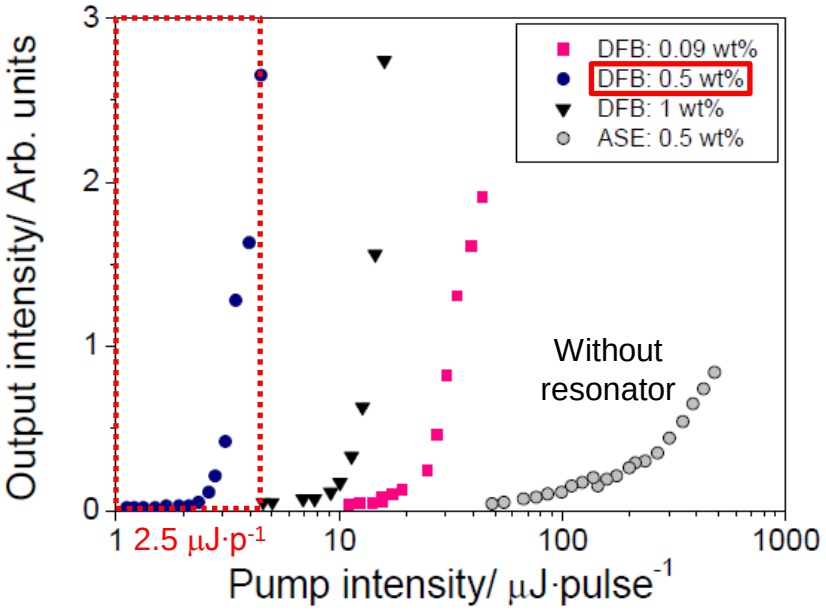
λ_{DFB} = 571 nm

FWHM < 2 nm

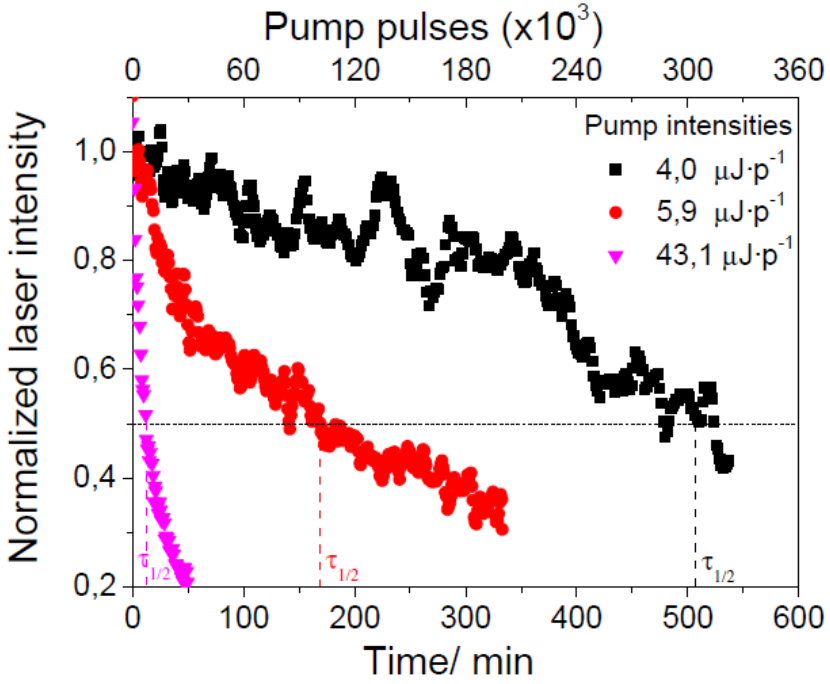
V. Navarro-Fuster *et al.*, *Appl. Phys. Lett.* **97**, 171104 (2010)

Most remarkable properties

Lasing threshold



Photostability

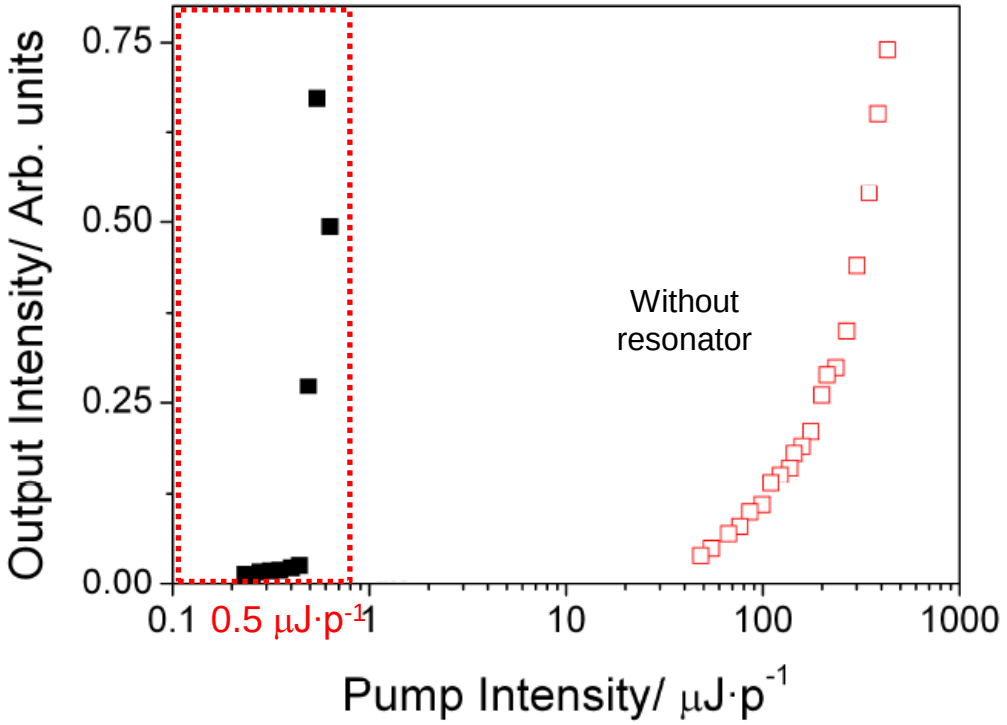


Photoestability halflife $\tau_{1/2}$:
~ 3 x 10^5 pulses (10 ns, 4 μJ·p^{-1}) at 10 Hz

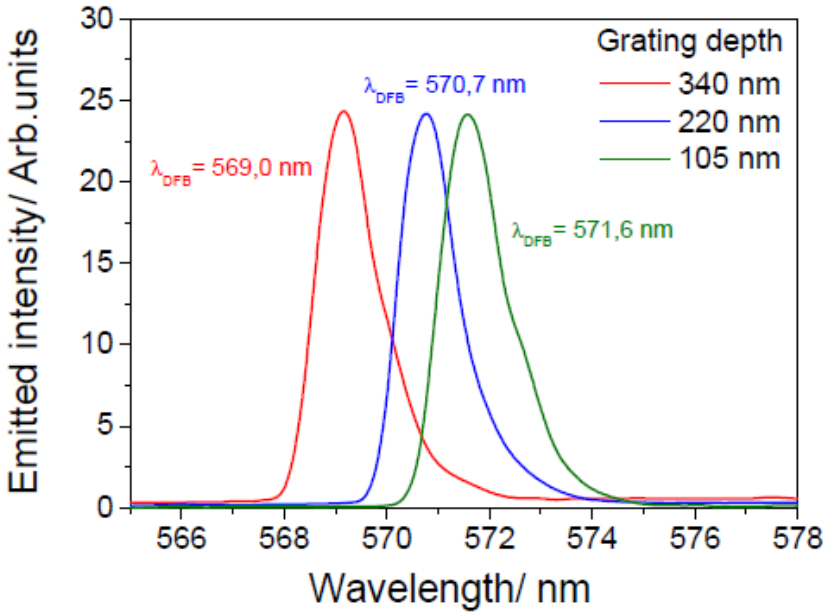
Fabrication of the resonator: gratings on doped PS

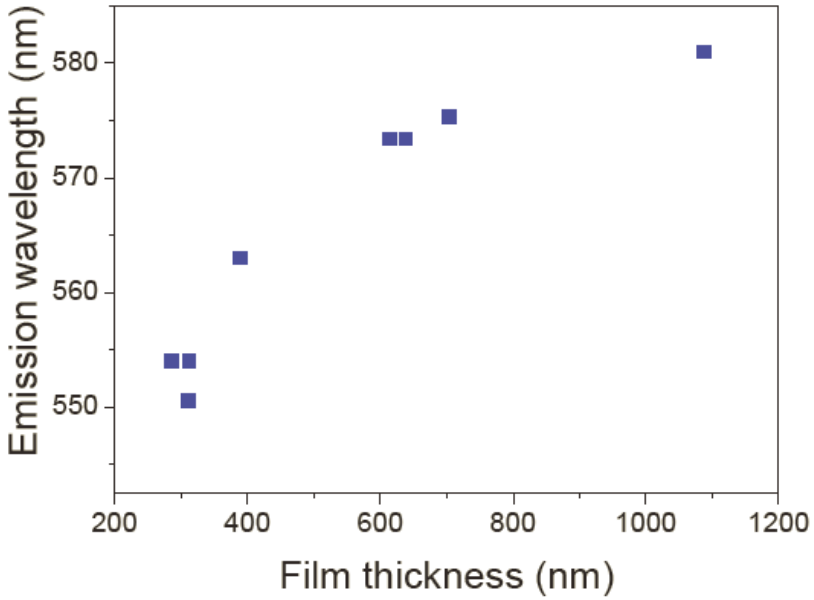
NIL onto doped PS

Lasing threshold



Last results: Wavelength tunability SiO2 gratings

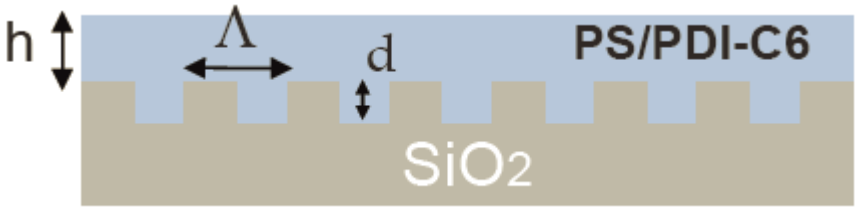




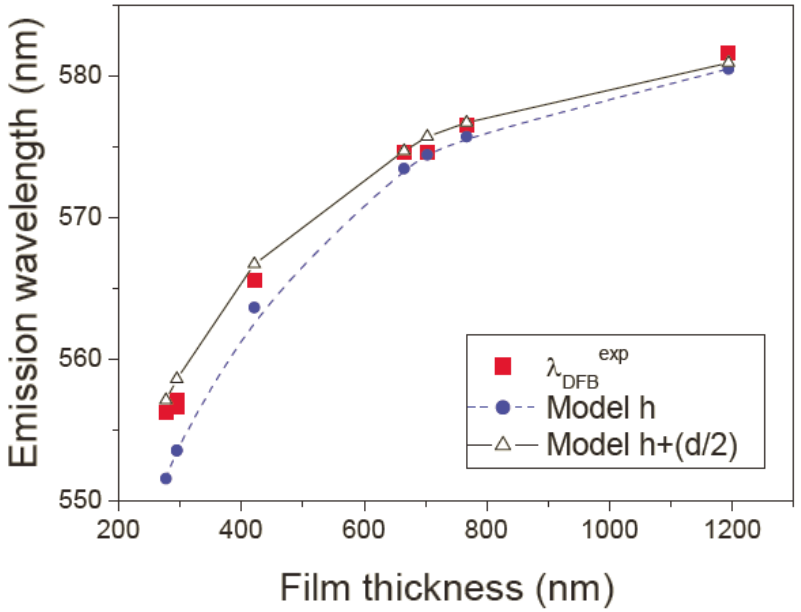
Wavelength tunning up to 30 nm

(grating depth = 220 nm)

Last results: Wavelength tunability SiO2 gratings



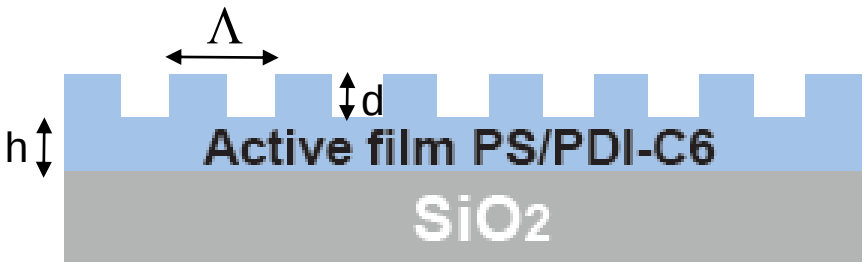
$$2\pi \frac{h}{\lambda} \cdot \sqrt{n_f^2 - n_{eff}^2} - \phi_c - \phi_s = w\pi$$



"Model h": waveguide of thickness *h*

"Model h+(d/2)": waveguide of thickness *h+(d/2)*

Last results: Wavelength tunability gratings on doped PS



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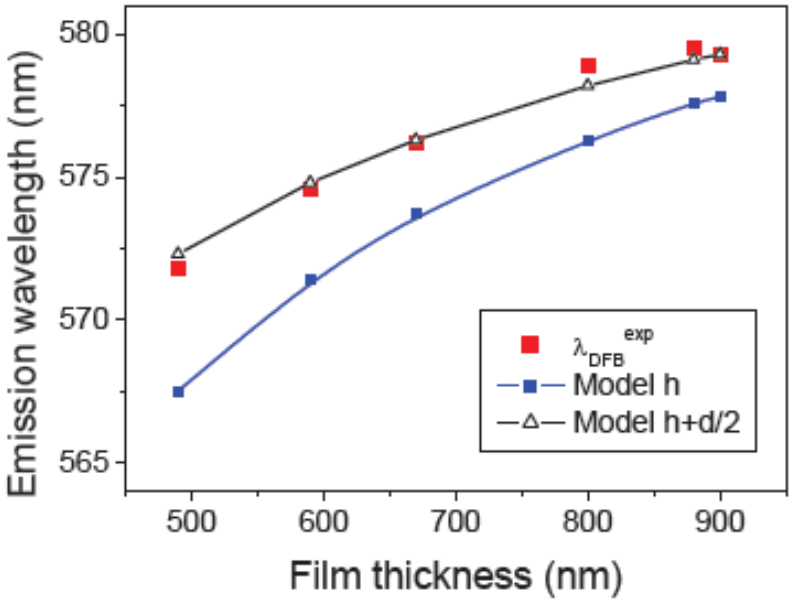
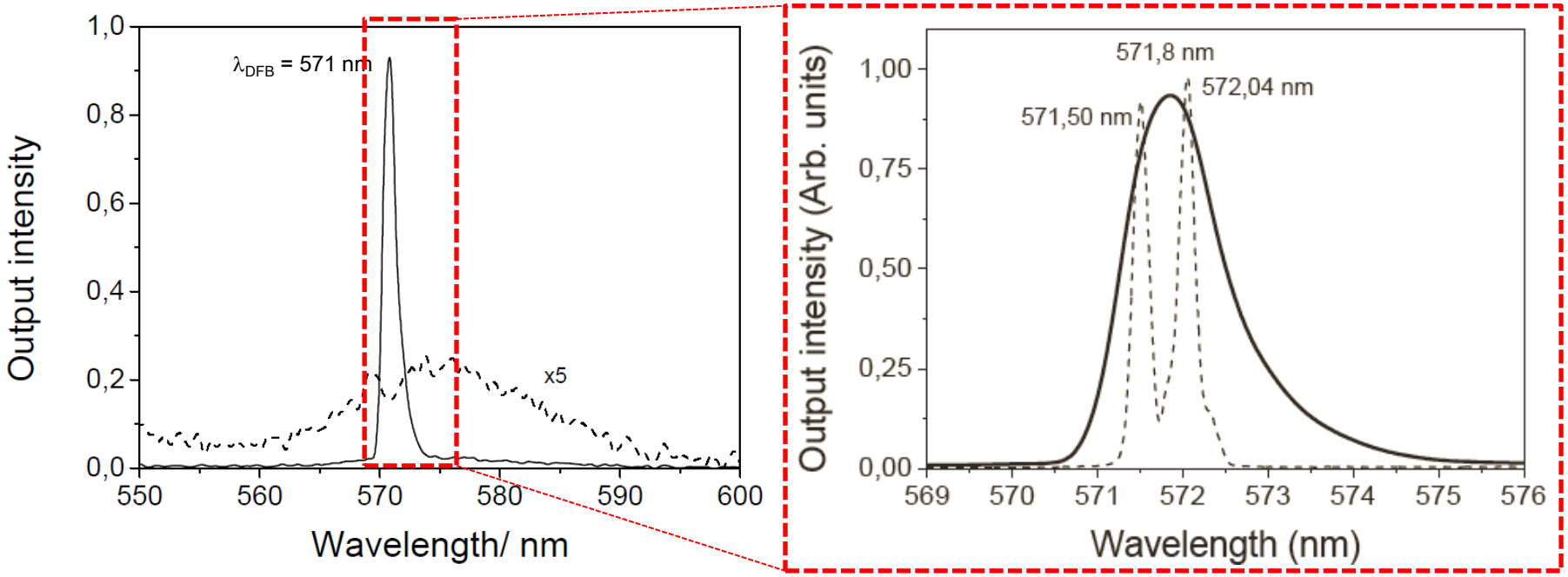


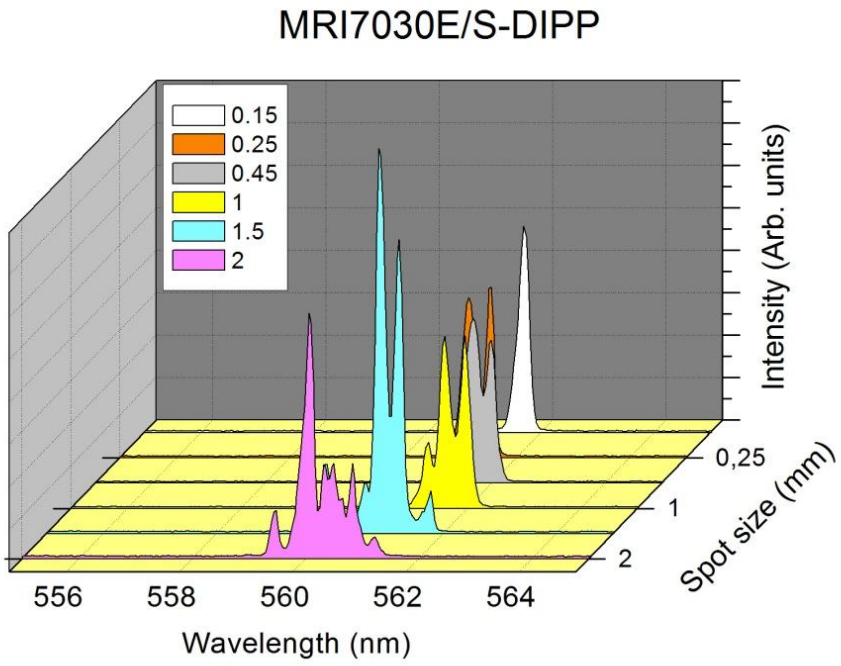
"Model h": waveguide of thickness *h*

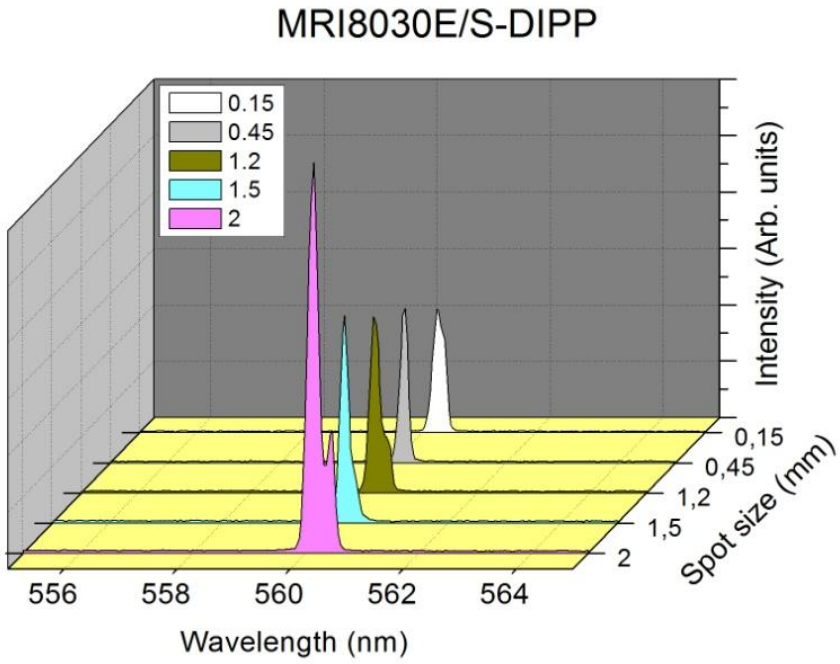
"Model h+(d/2)": waveguide of thickness *h+(d/2)*

High resolution spectra



High resolution spectra





Film thickness homogeneity

Conclusions

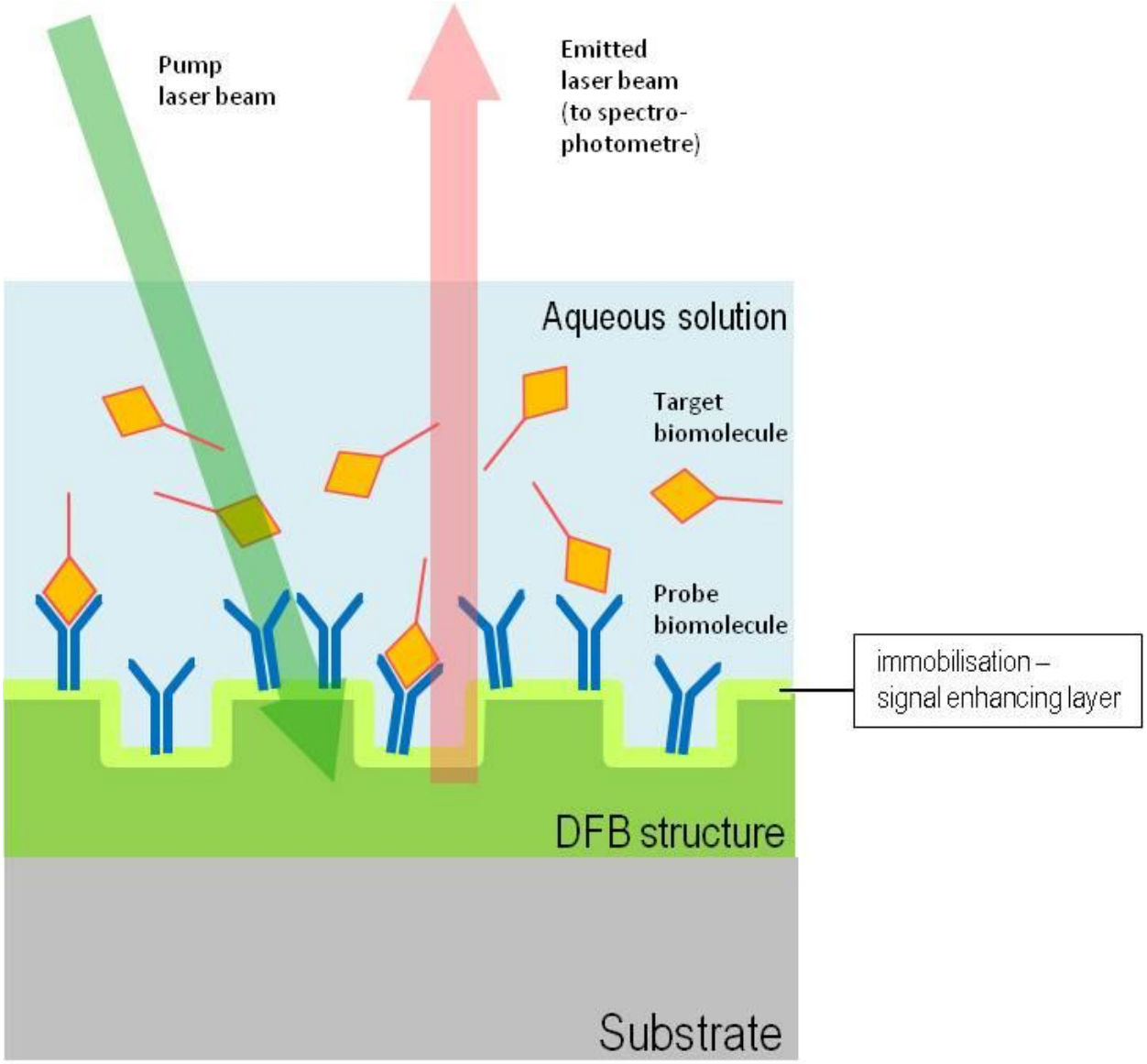
We have fabricated and characterized second-order DFB organic laser devices:

- Active medium: PS film doped with a perilenediimide derivative.
- Resonator fabricated via thermal NIL (Λ= 368 nm) in SiO_2 and active medium
- Low threshold and high photostability

Film thickness homogeneity must be improved for single-mode emission

→ Proof of concept of **biosensing** capabilities

Future work (based on work by B. T. Cunningham´s group)



Acknowledgements

➢ Financial support:

- Spanish Government MEC and the European Community (FEDER). Grant MAT2008-06648-C02.

- ETORTEK project MIBIO2 funded by the Basque Government.

- CSIC fellowship within the program JAE.

➢ V. Esteve for technical assistance.

Thank you for your attention!

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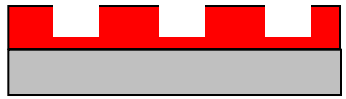
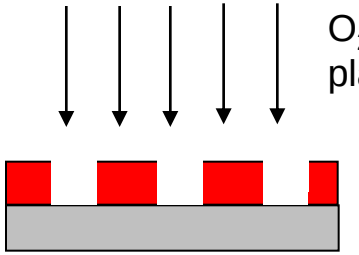
SiO_2 gratings

NIL onto mr-I8030E



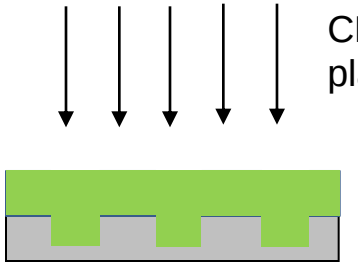
- Jenoptik HEX03
- 20000 N
- 180 ºC
- 900 s

Residual layer etching



- 20 sccm O_2
- 20 mTorr
- 20 W

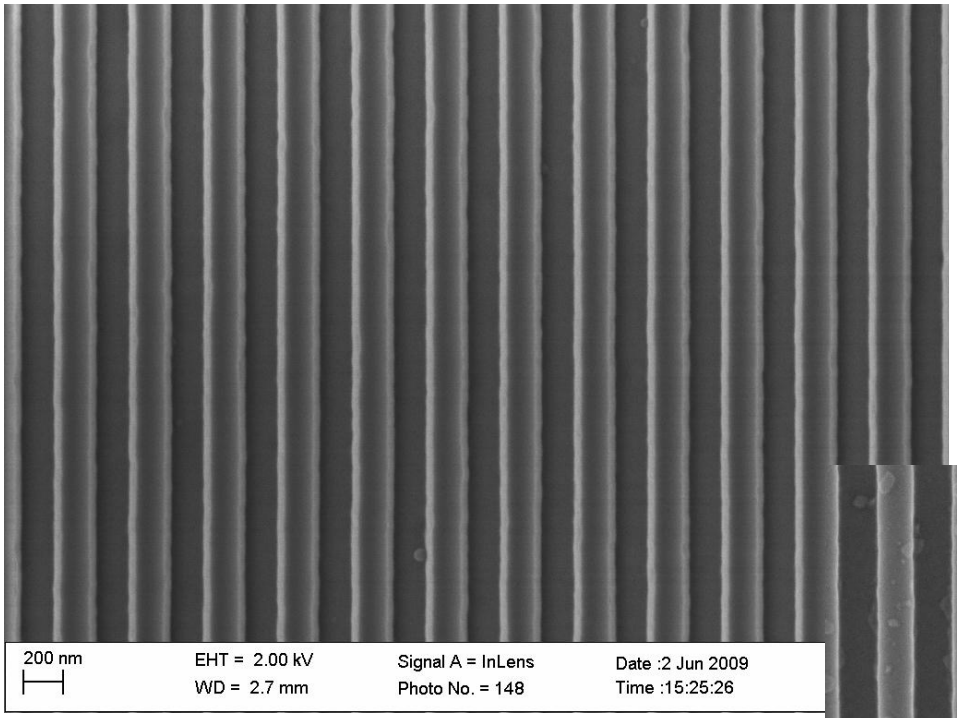
SiO_2 etching



- 25 sccm CHF_3
- 25 sccm Ar
- 30 mTorr
- 200 W
- DEPTH:
  - 340 nm (10 min.),
  - 220 nm (6 min.),
  - 105 nm (3 min.)

Spin-coating of the doped PS

Fabrication of the resonator

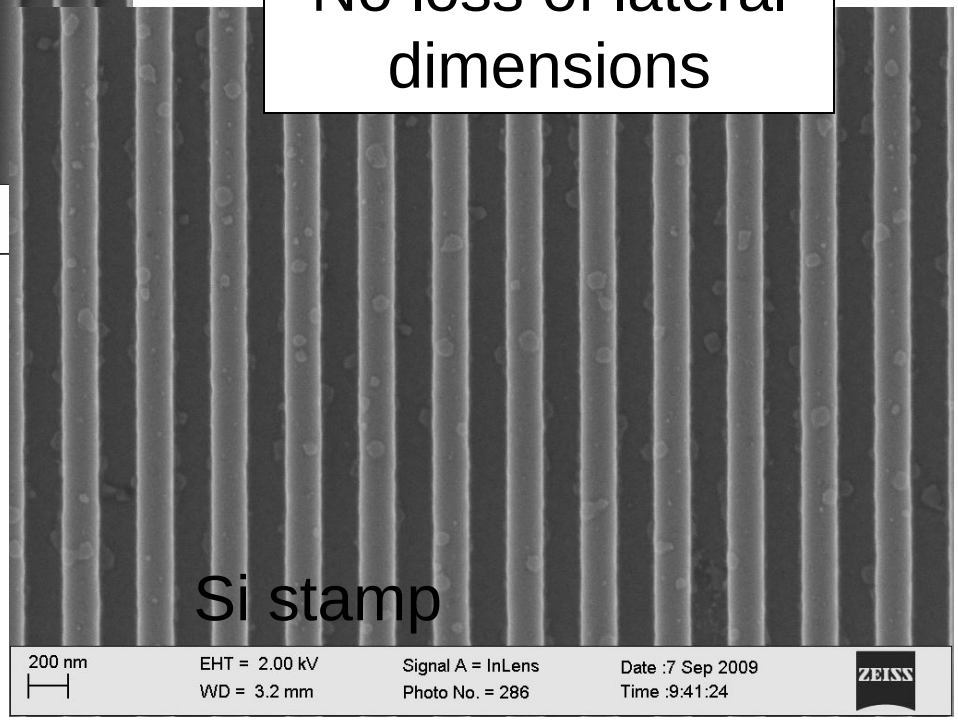


SiO_2

Si stamp

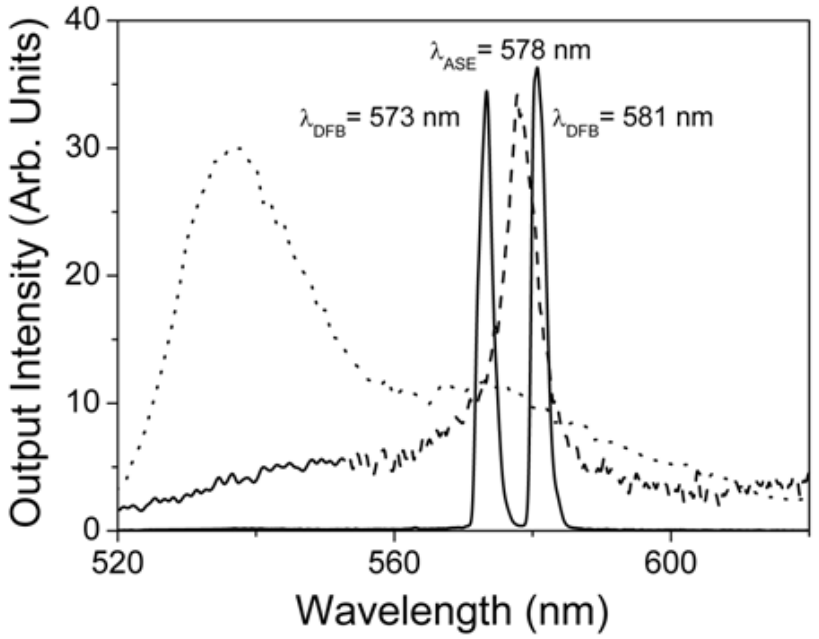
No loss of lateral dimensions

SiO_2



Optical characterization

1.1 μm thickness (0.75 wt%)*



λ_{ASE} = 578 nm

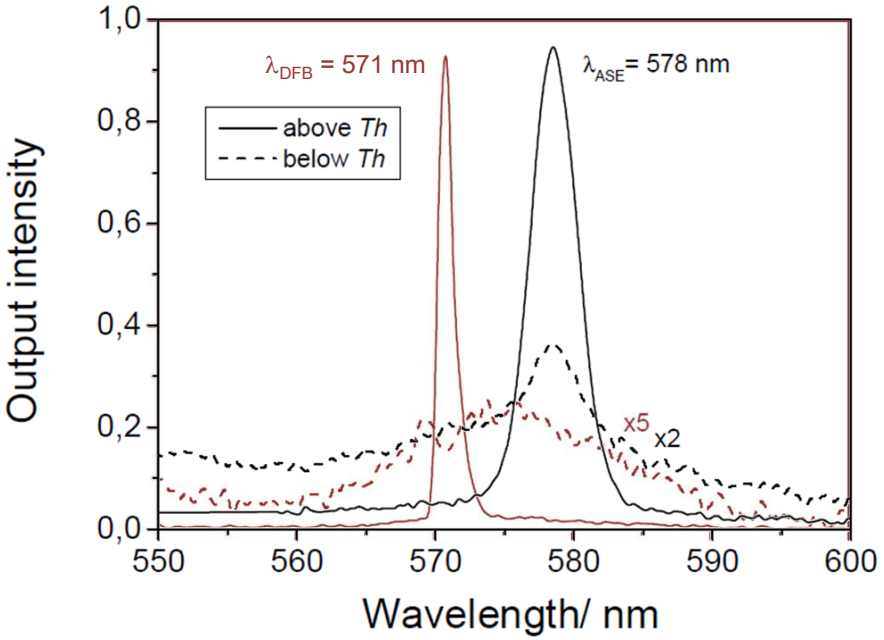
FWHM 6 nm

λ_{DFB} = 573 nm

λ_{DFB} = 581 nm

FWHM 2 nm

0.6 μm thickness



λ_{ASE} = 578 nm

FWHM 5 nm

λ_{DFB} = 571 nm

FWHM < 2 nm

* V. Trabadelo *et al.*, *Microelectronic Engineering*, **87**, 1428–1430 (2010)

Fabrication of the resonator: gratings on doped PS

NIL onto doped PS

- Jenoptik HEX03
- 15000 N
- 155 ºC
- 900 s

Easier processing!