



Fabricage van nanofotonische structuren met gefocusseerde ionenbundels

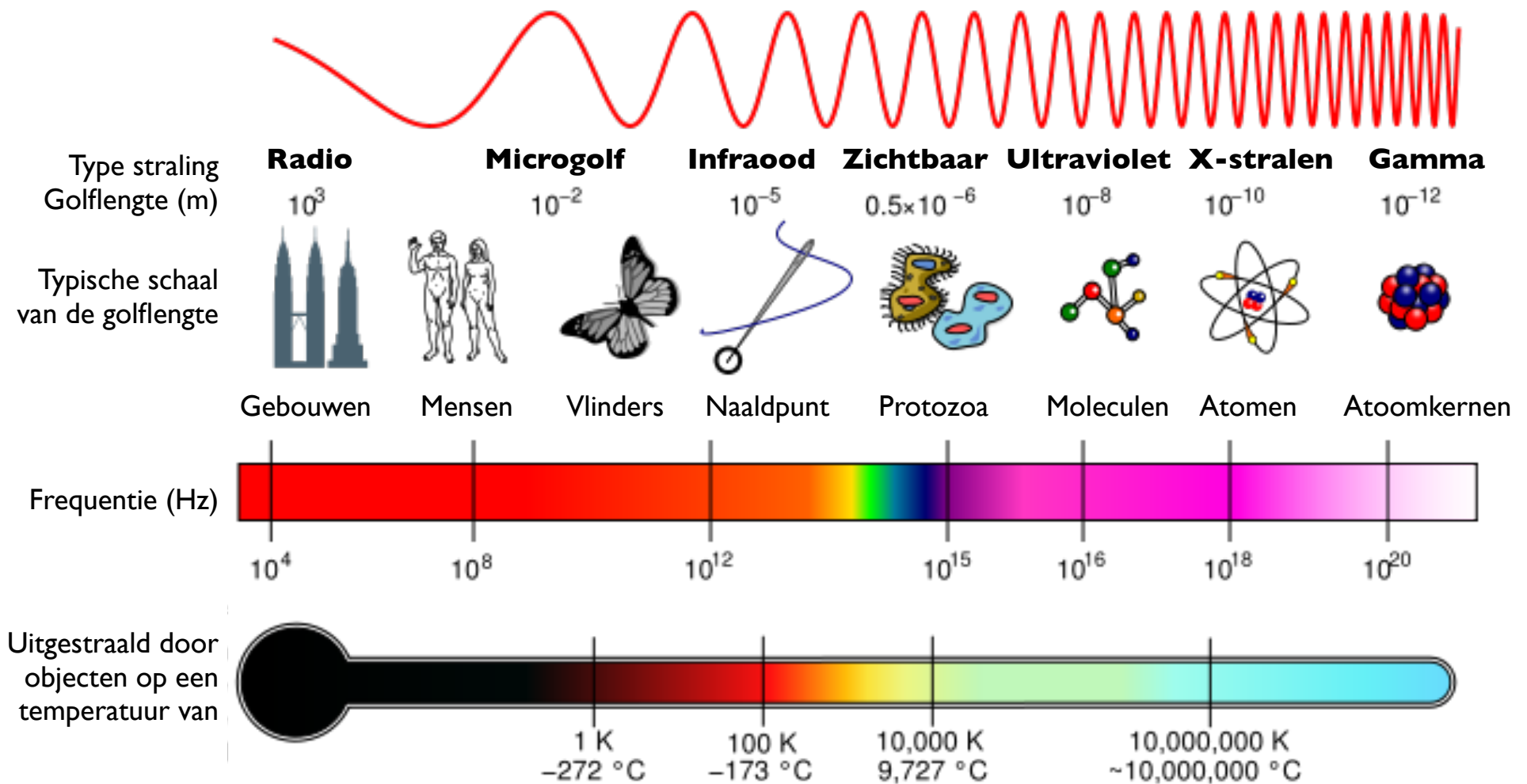
publieke verdediging
Jonathan Schrauwen

Promotor: Prof. Dries Van Thourhout

Vakgroep Informatietechnologie
Faculteit Ingenieurswetenschappen

4 februari 2009

Licht



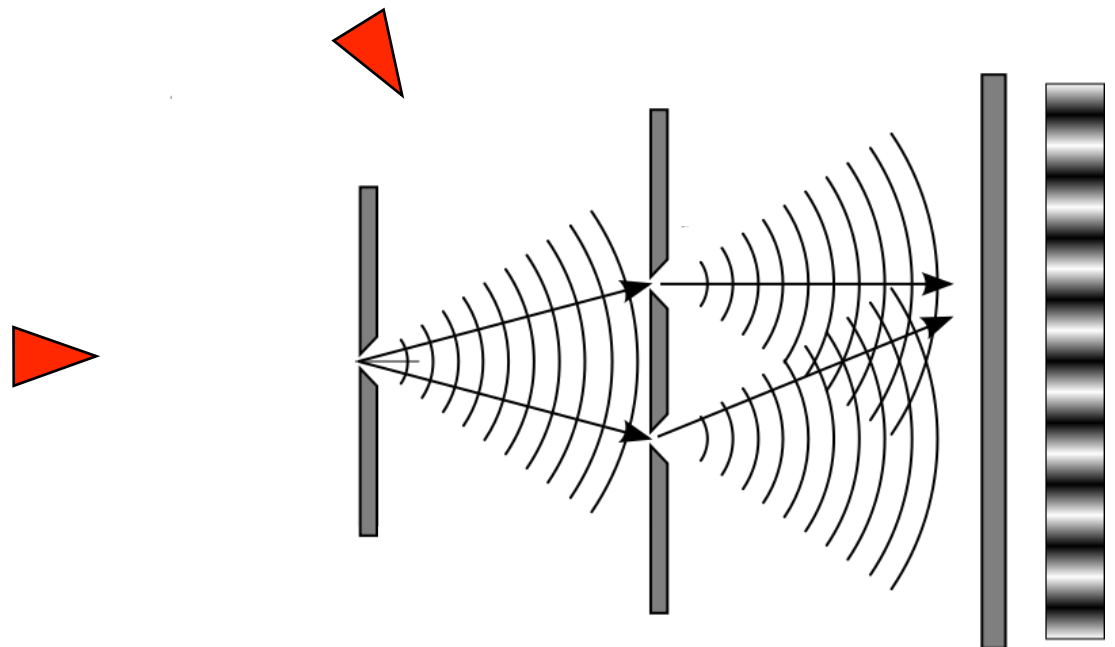
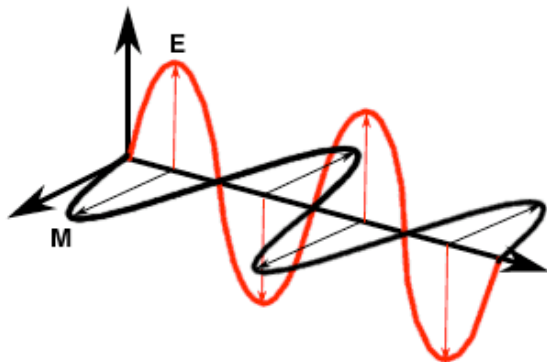
Golven of deeltjes?

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0} = 4\pi k \rho$$

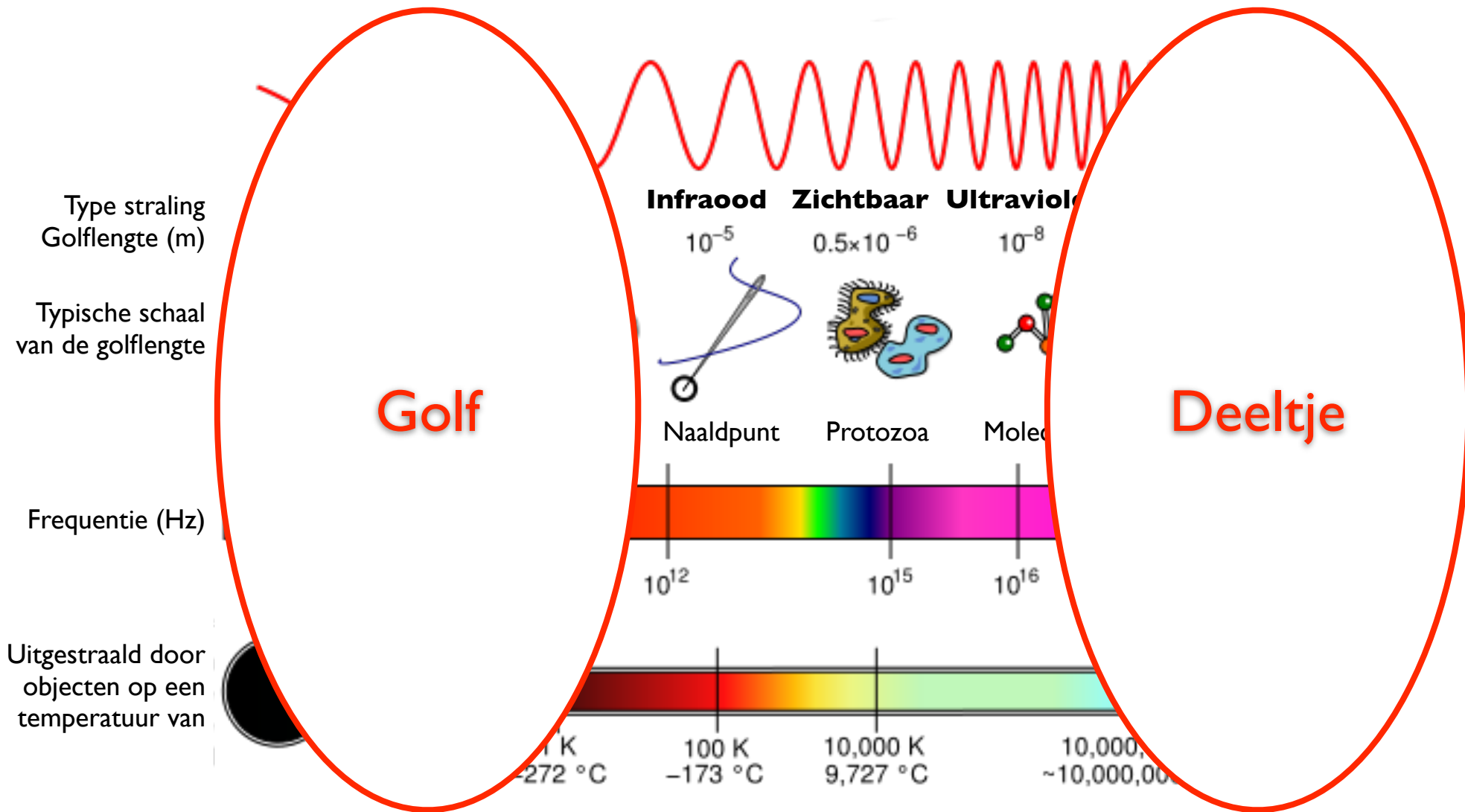
$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

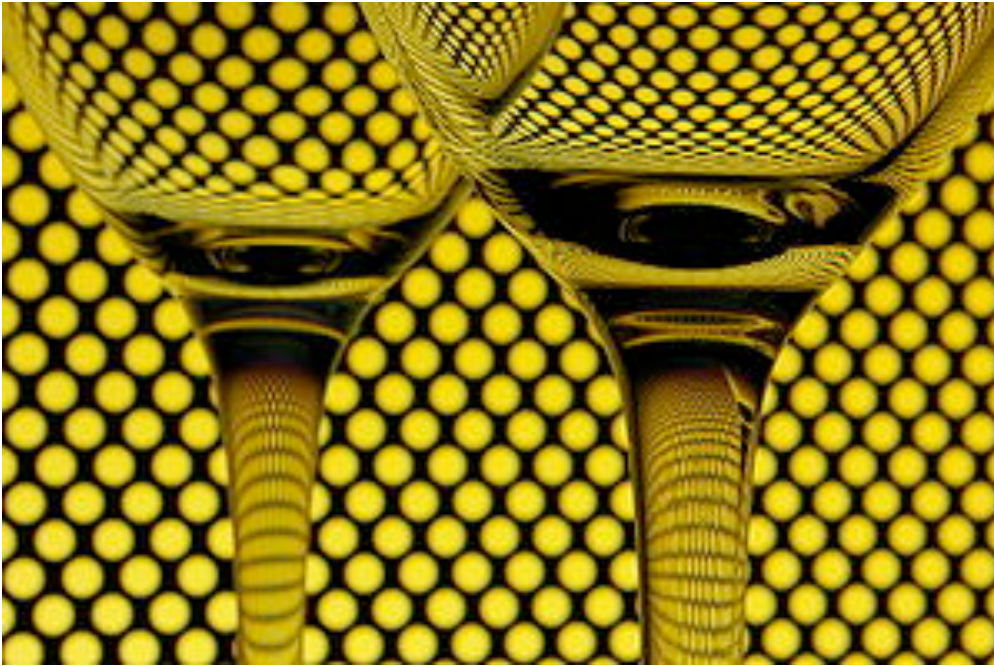
$$\nabla \times \vec{B} = \frac{\vec{J}}{\epsilon_0 c^2} + \frac{1}{c^2} \frac{\partial \vec{E}}{\partial t}$$



Golven of deeltjes?



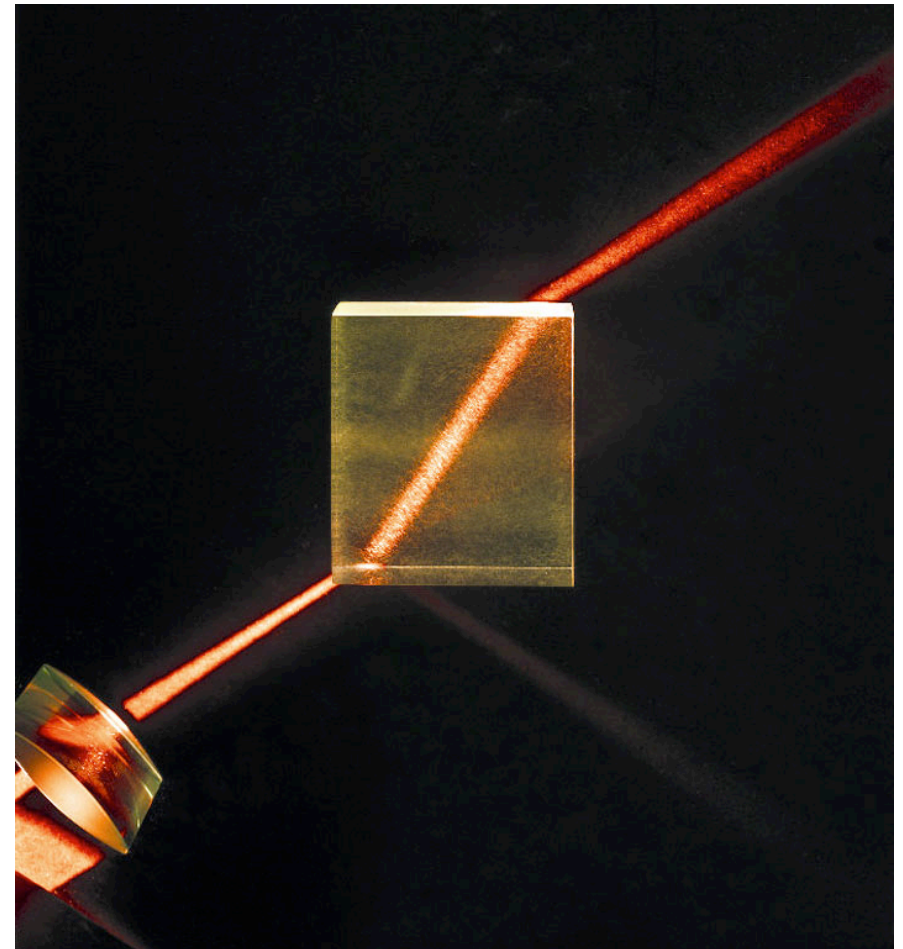
Lichtbreking



verschil in brekingsindex (Δn) \uparrow

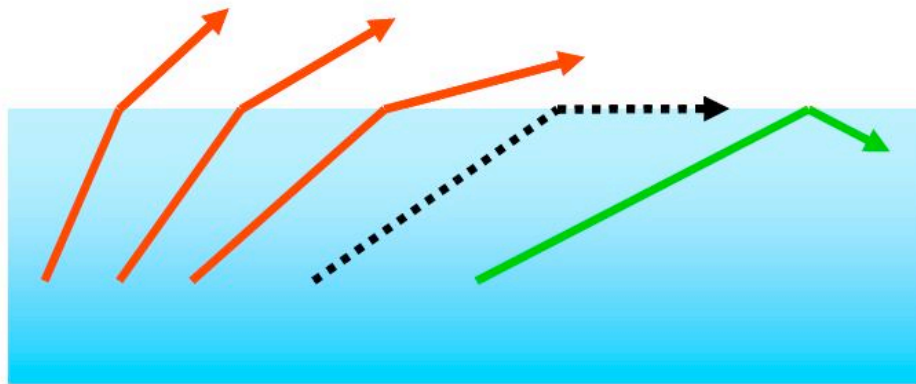


brekingshoek \uparrow



Totale interne reflectie

Principe

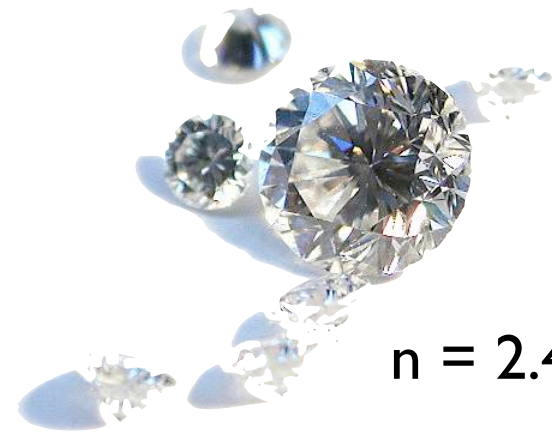


verschil in brekingsindex (Δn) \uparrow

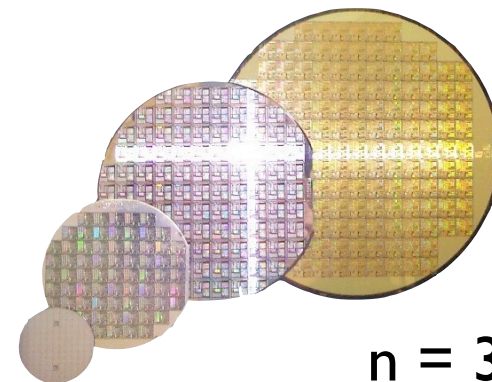

TIR hoek \uparrow



$n = 1.5$

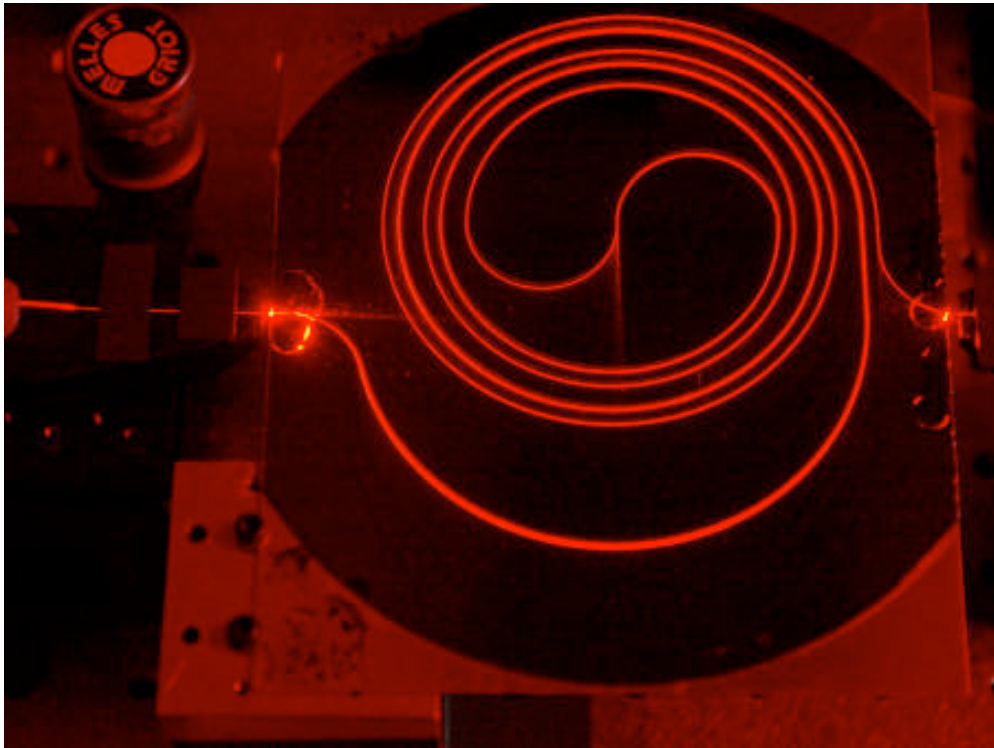


$n = 2.4$



$n = 3.5$

Lichtgeleiding in vezels en chips



verschil in brekingsindex (Δn) \uparrow \blacktriangleright Minimale bochtstraal \downarrow

Communicatie over vezel

00101010101001000111111010000



50 Mbps
1 DVD per 15 min
afstand 100 m

00101010101001000111111010000



10 Gbps
1 DVD per 5 sec
afstand 100 km

00101010101001000111111010000

00101010101001000111111010000

00101010101001000111111010000

⋮

00101010101001000111111010000

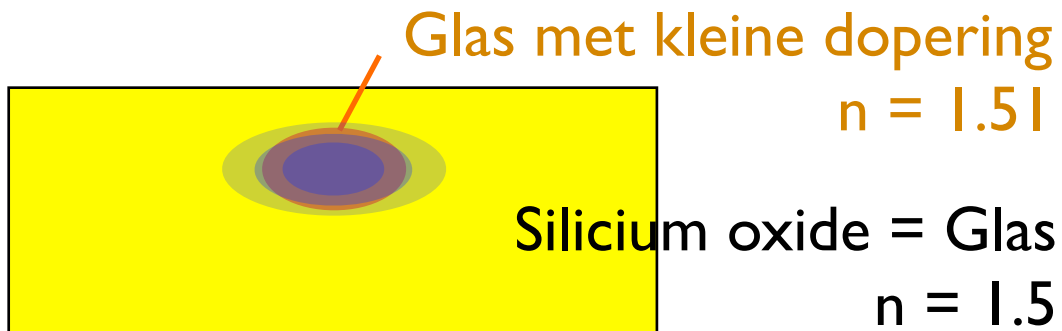


multiplexing



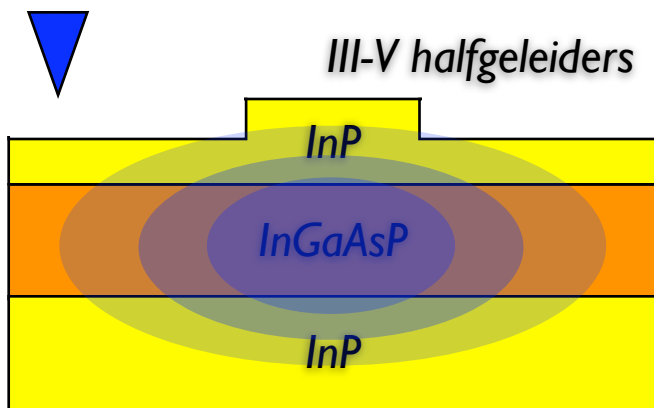
> 10 Tbps = 1000 Gbps
> 1000 DVDs per 5 sec
afstand 100 km

Lichtgeleiding op chips

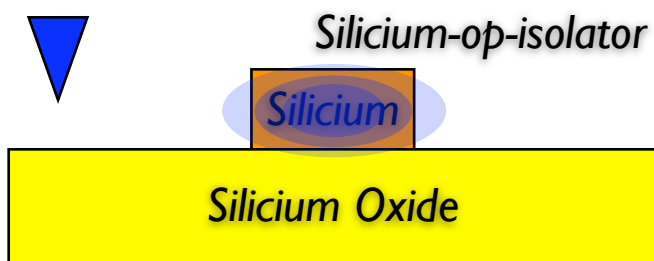


▶ Laag index contrast

▼
Grootte circuit = cm



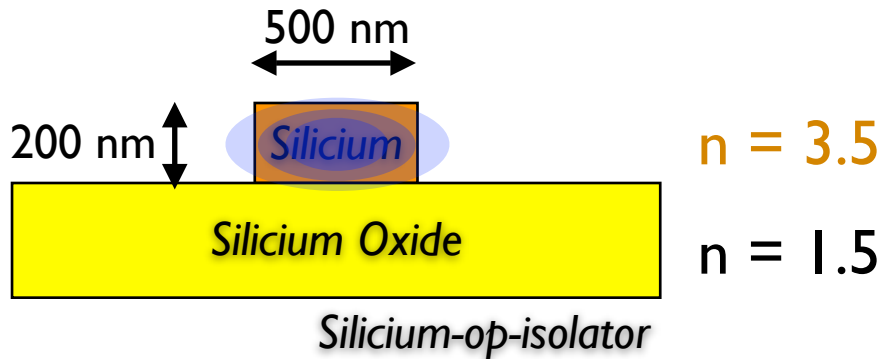
▶ Grootte circuit = mm



▶ Grootte circuit = 100 μm

▶ = meer functies
= goedkoper

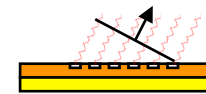
Nanofotonische structuren?



▶ Grootte circuit = 100 μm

Twee componenten in meer detail:

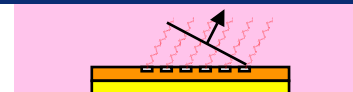
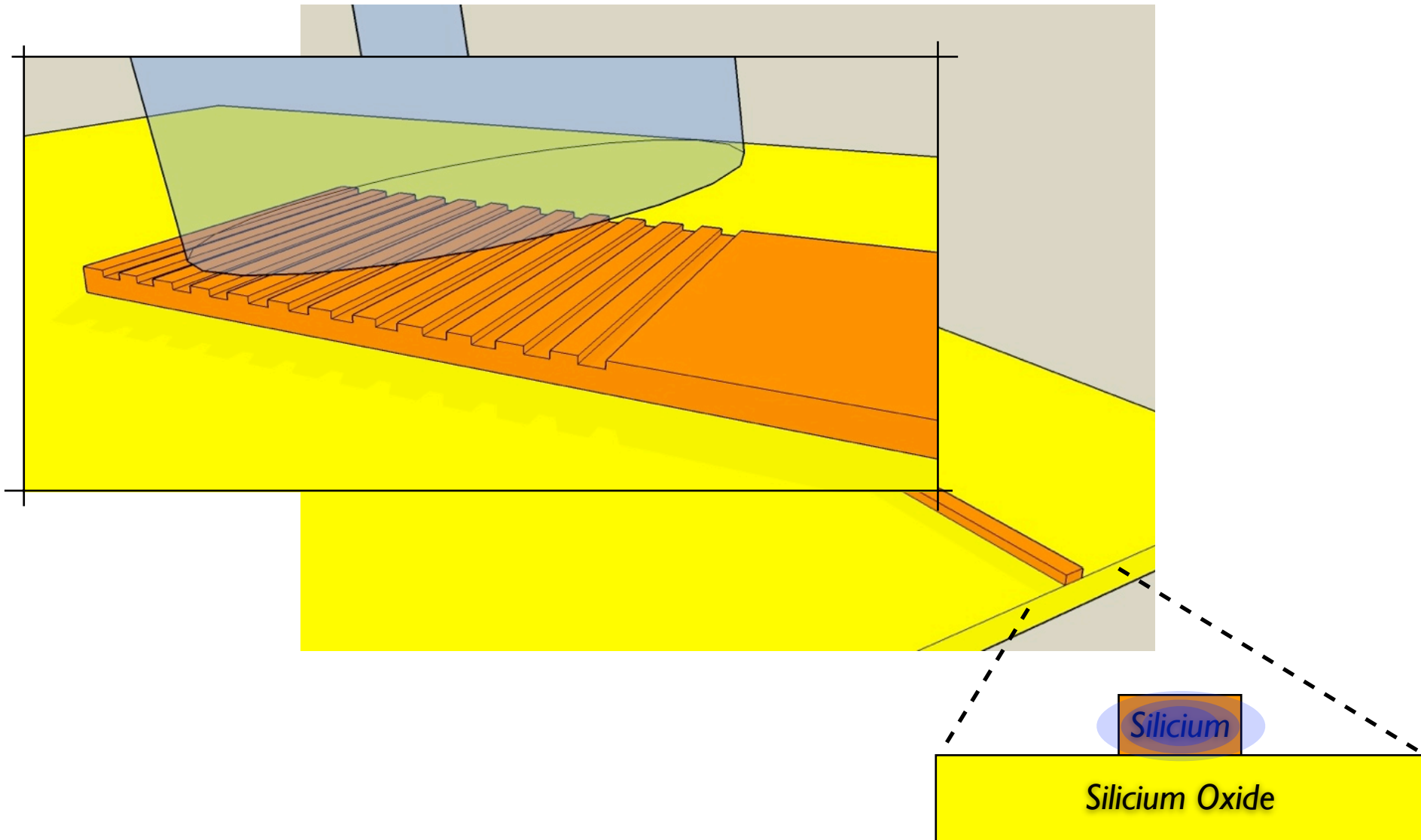
Roosterkoppelaar



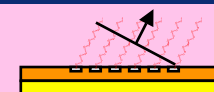
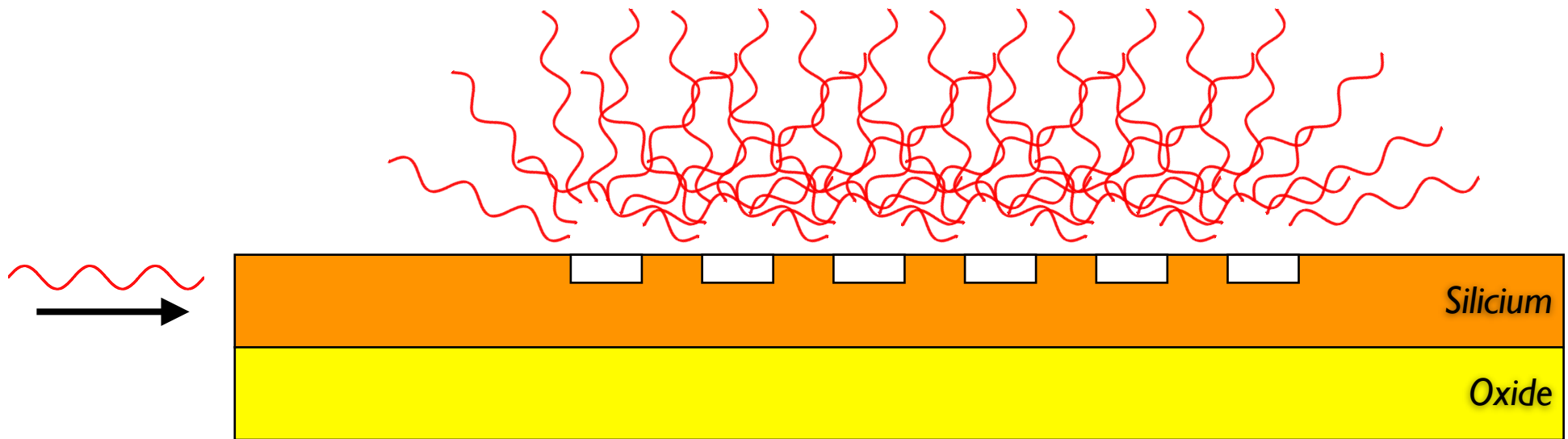
Ringresonator



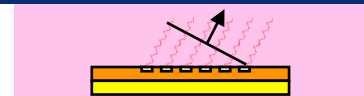
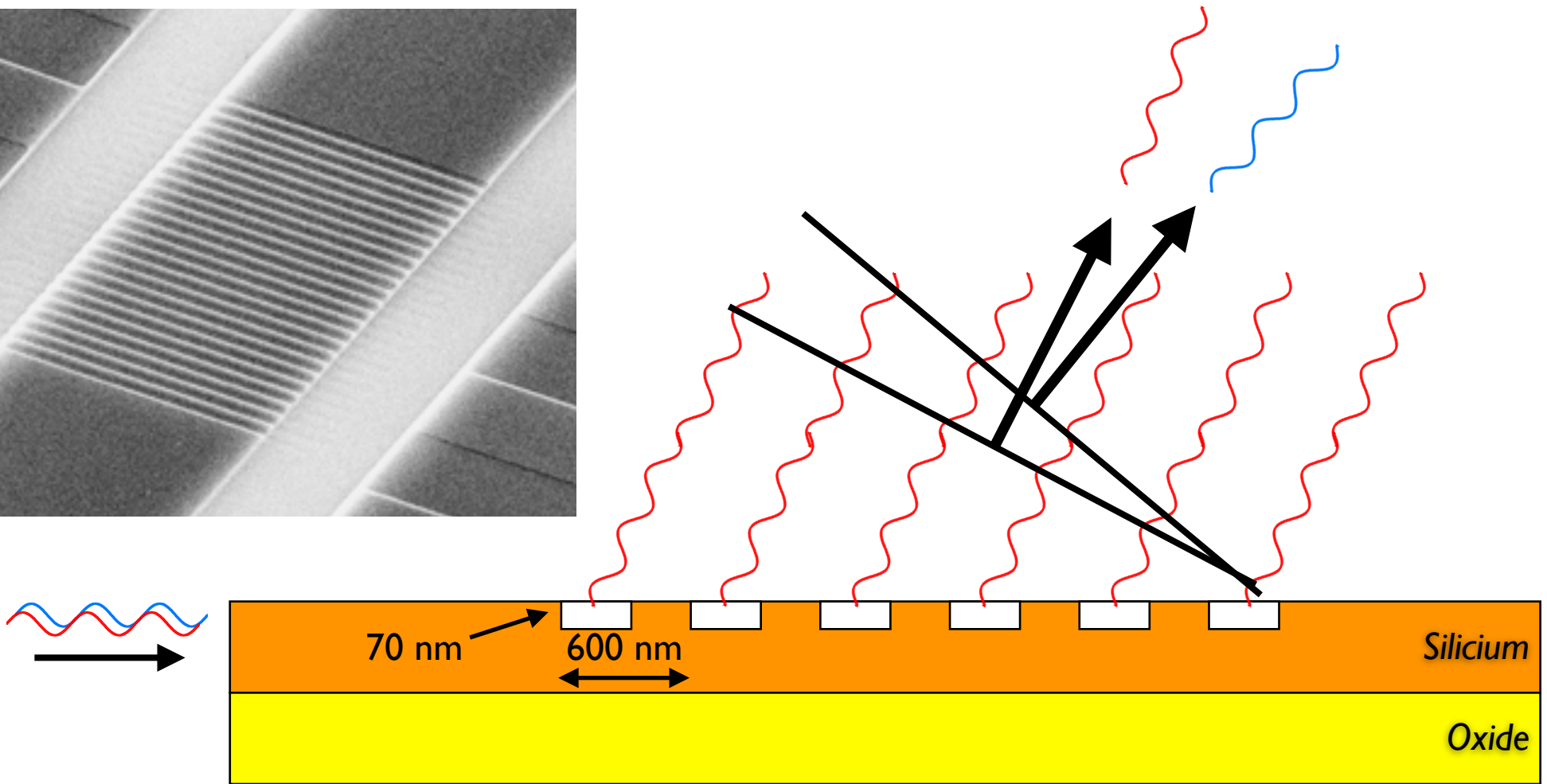
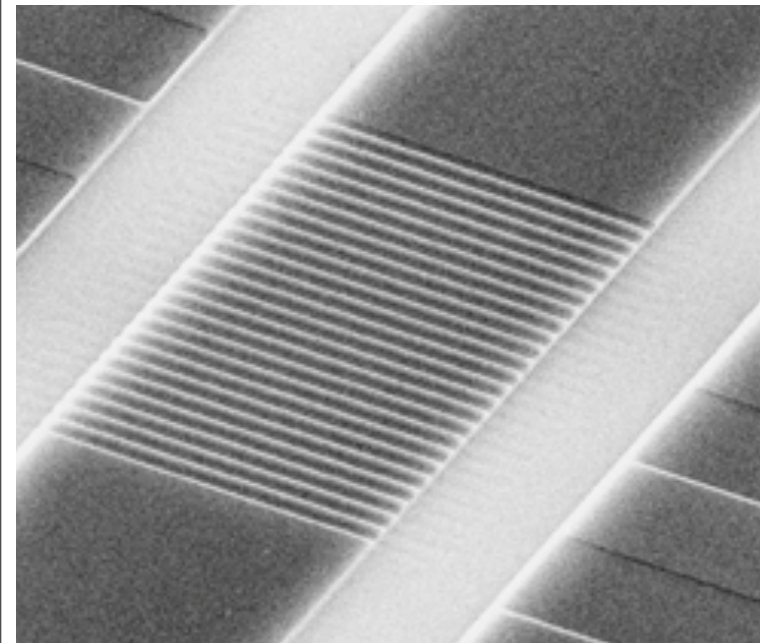
Roosterkoppelaar



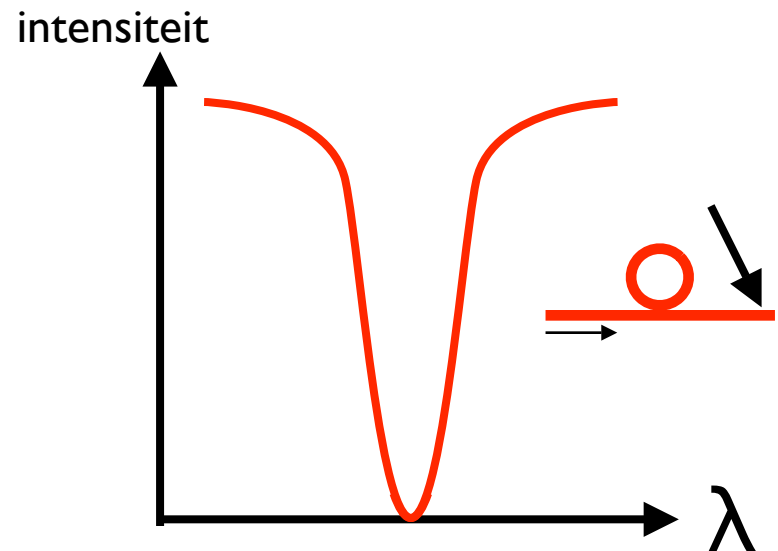
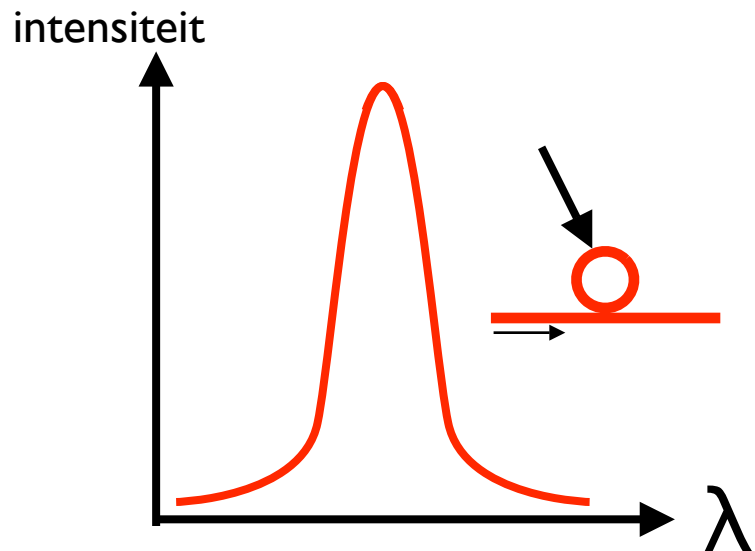
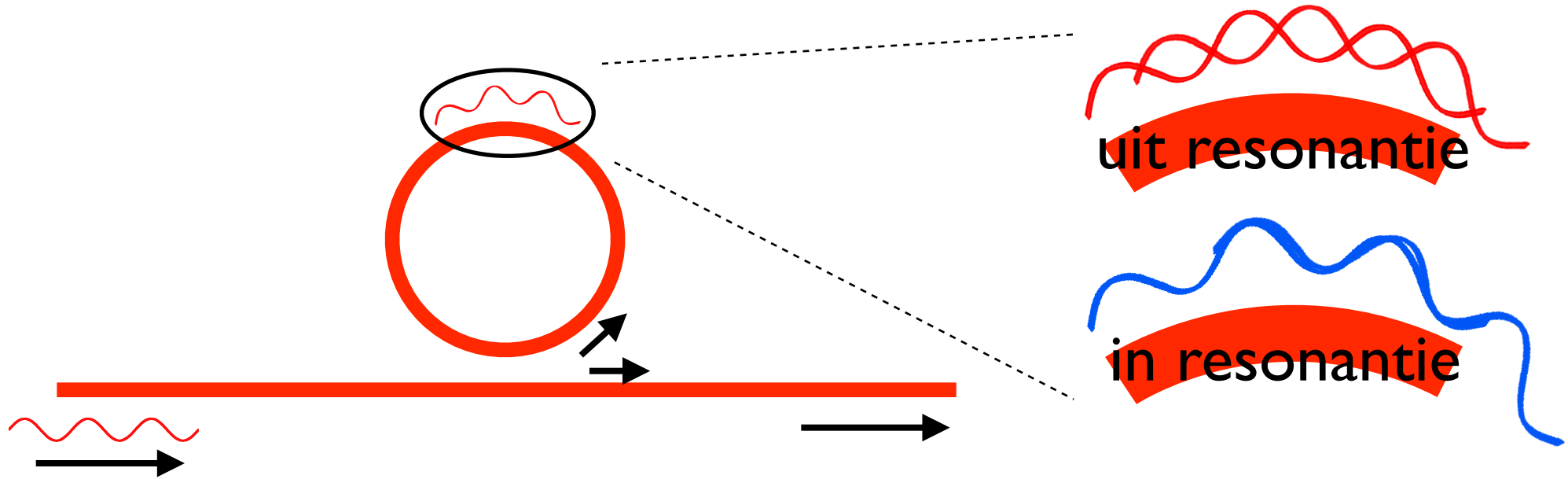
Roosterkoppelaar



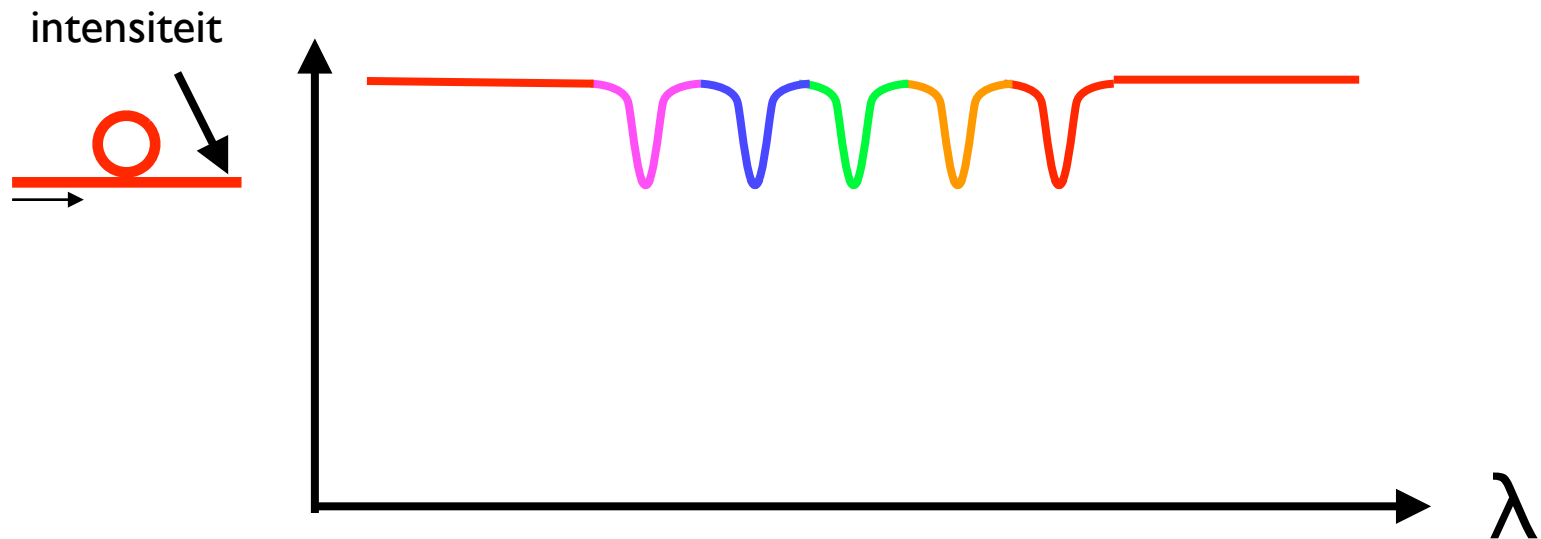
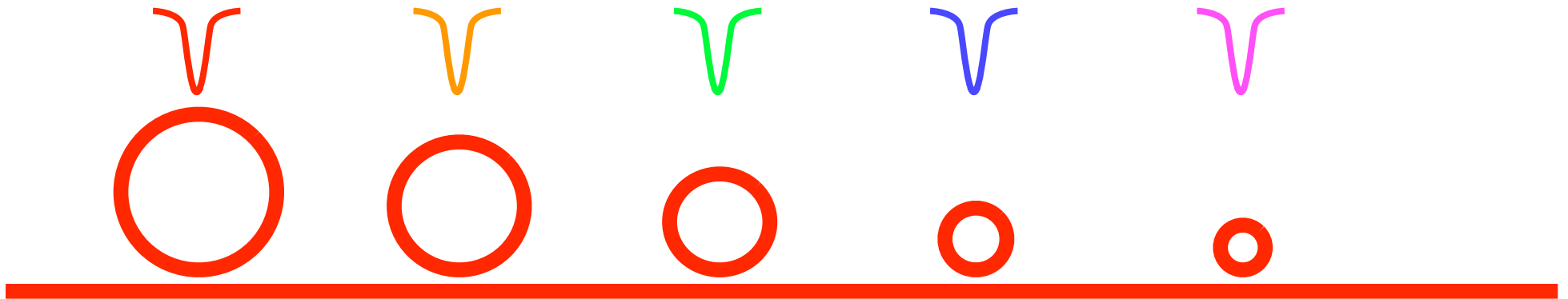
Roosterkoppelaar



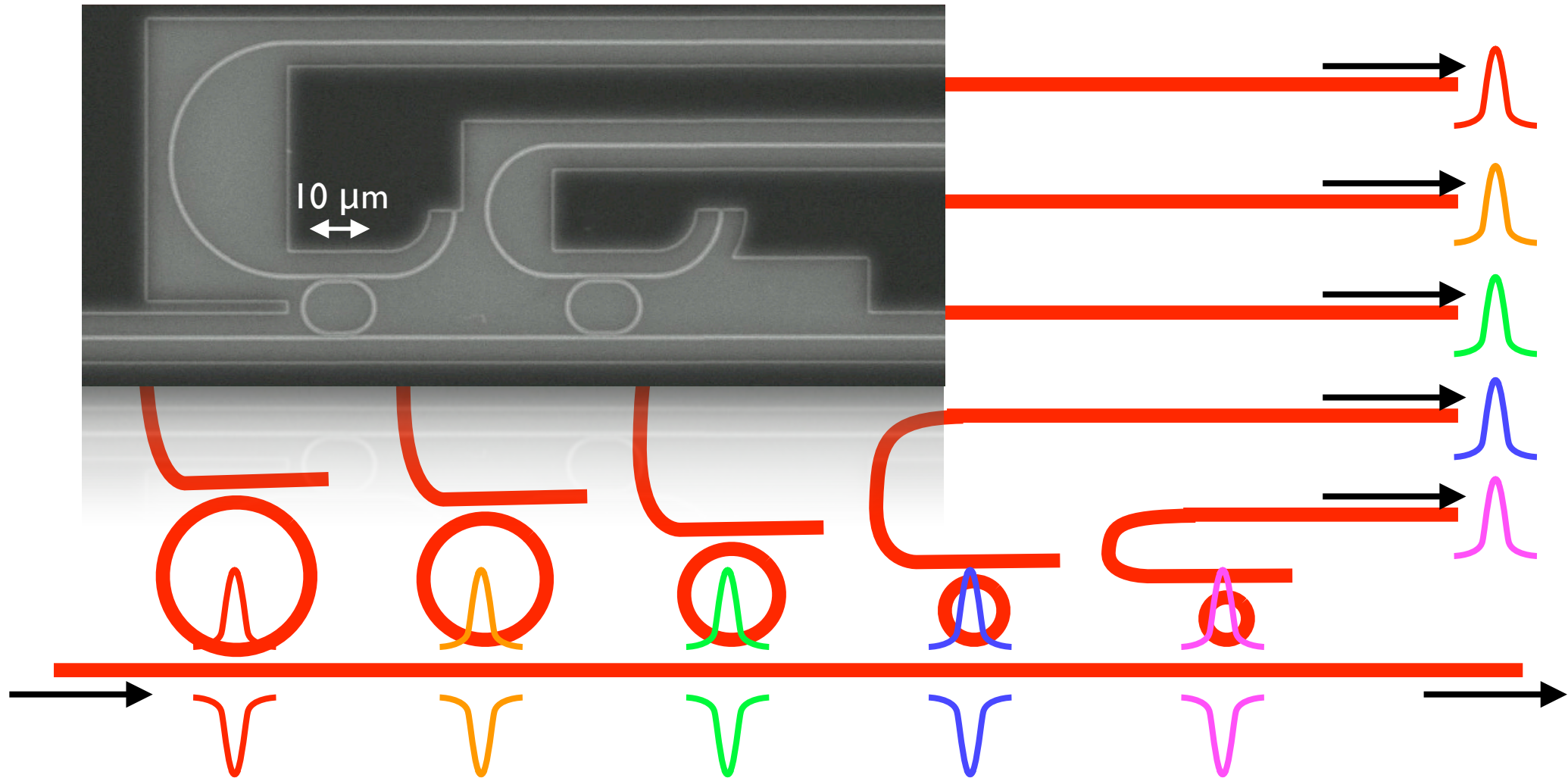
Ringresonator



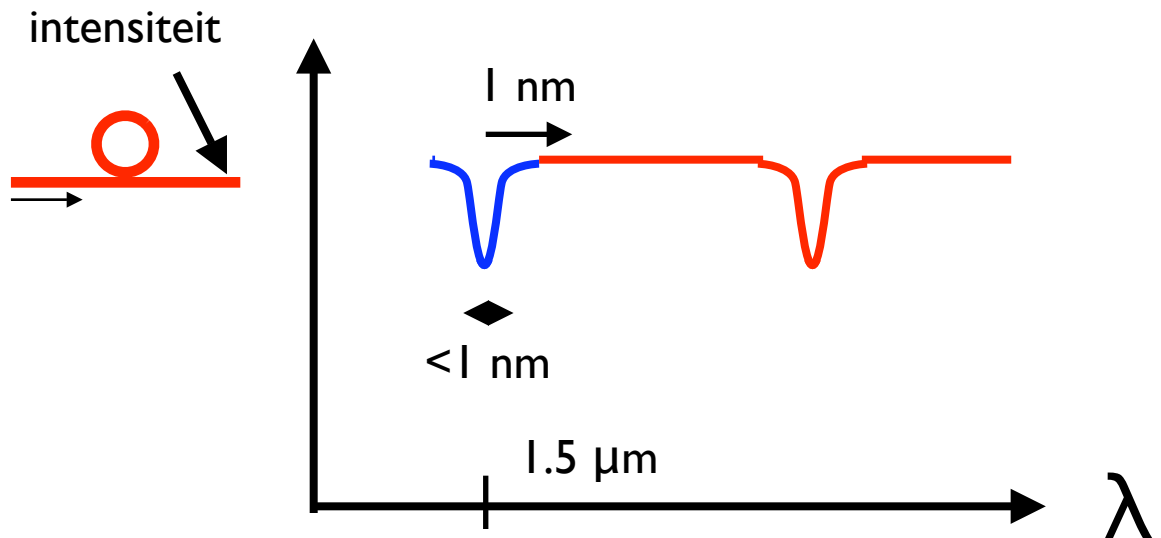
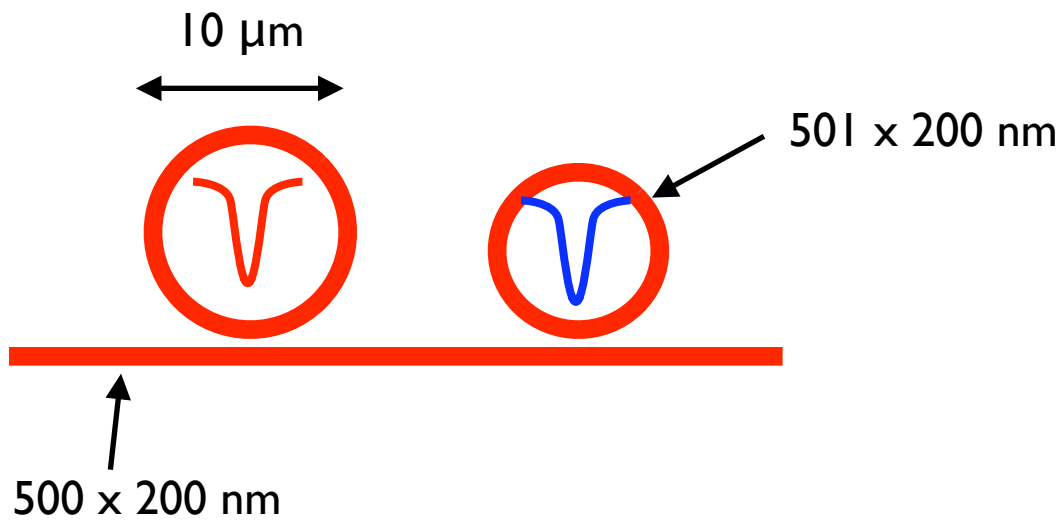
Ringresonatoren zijn filters

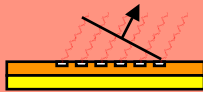
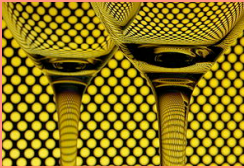


Golflengte (de)multiplexing



Gevoelig voor nanometers



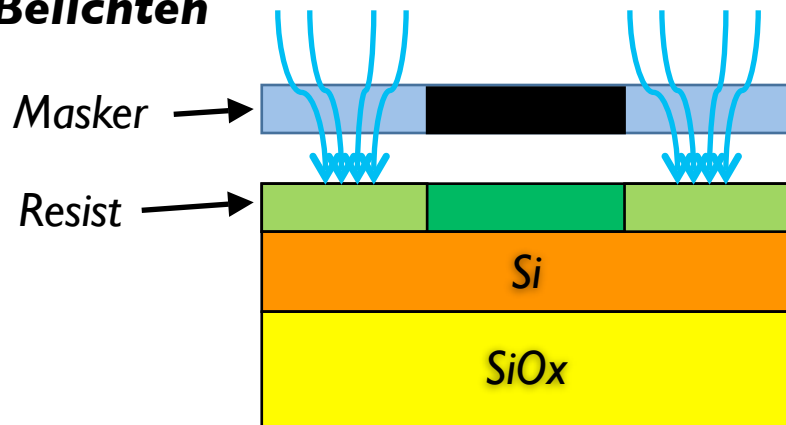


Nanofotonisch!

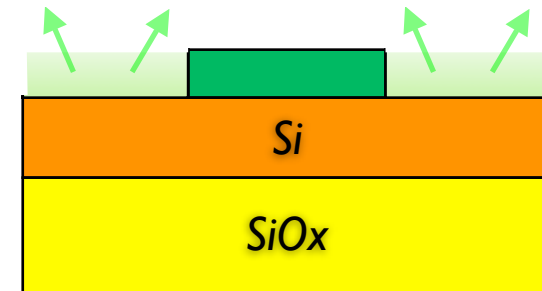
Nanofotonisch? Ionenbundels

Fabricage: optische lithografie

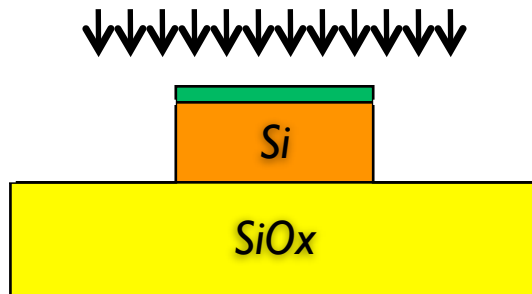
Belichten



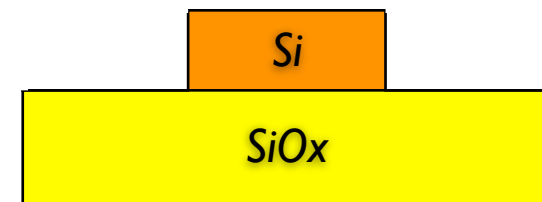
Ontwikkelen

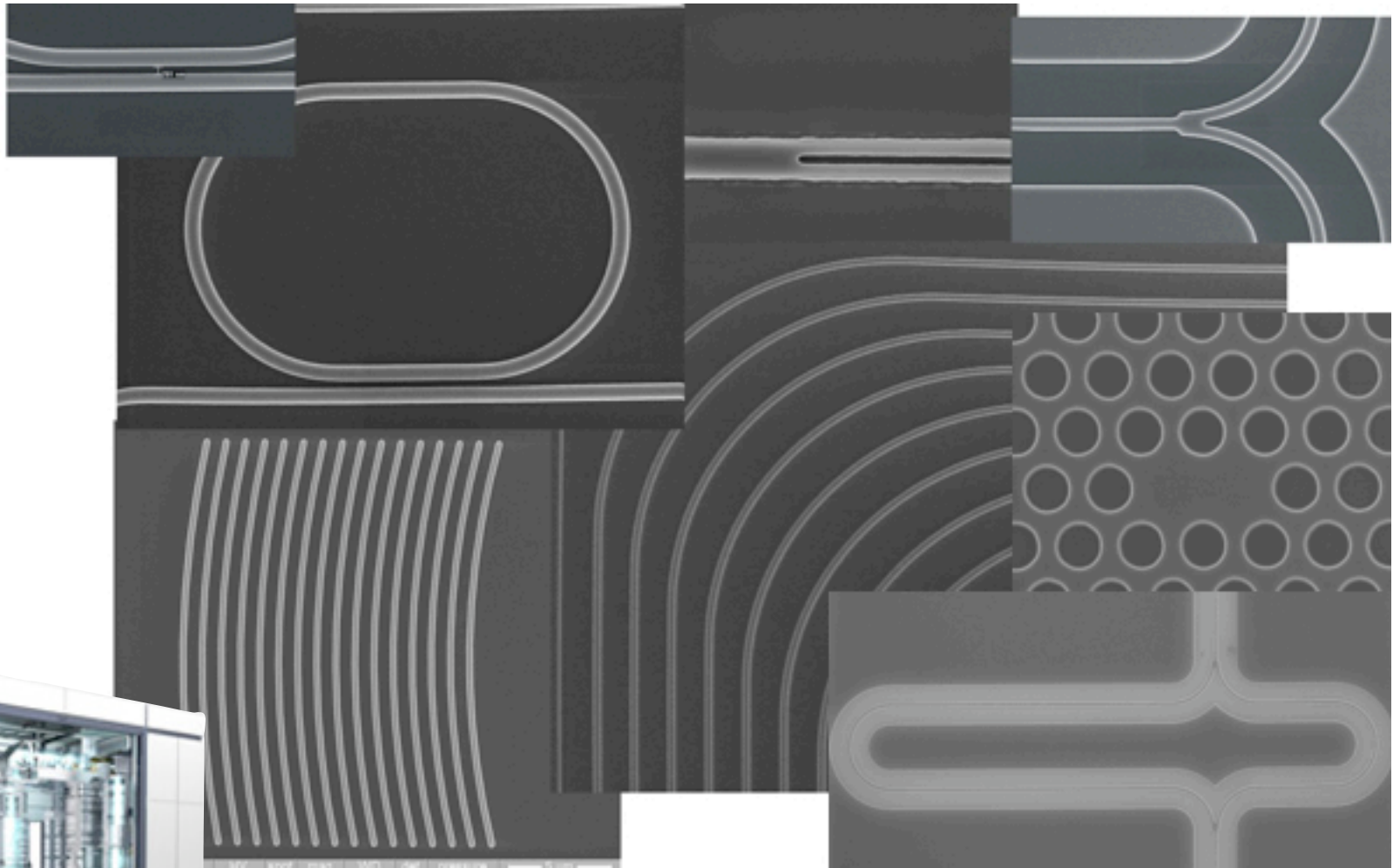


Etsen



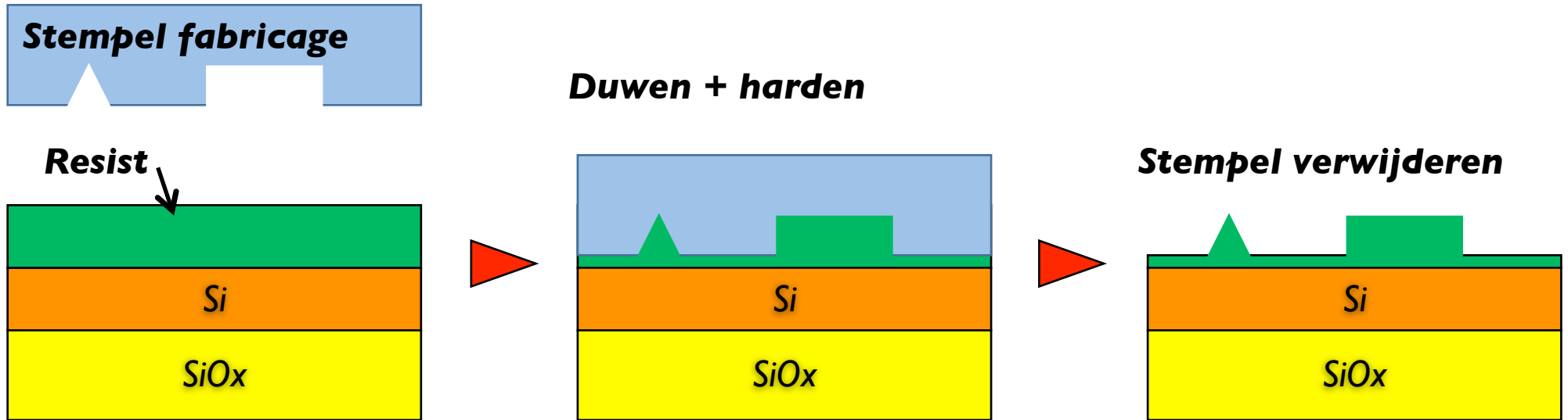
Resist verwijderen





193 nm diep-UV lithografie
(gebruikt voor Pentium4 processoren)

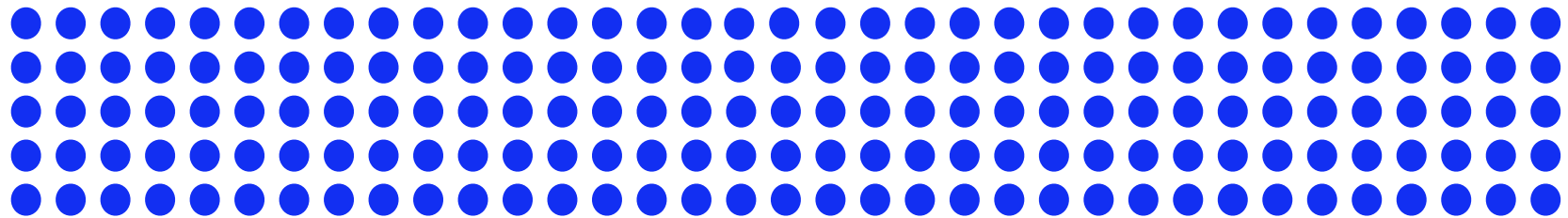
Fabricage: imprint lithografie



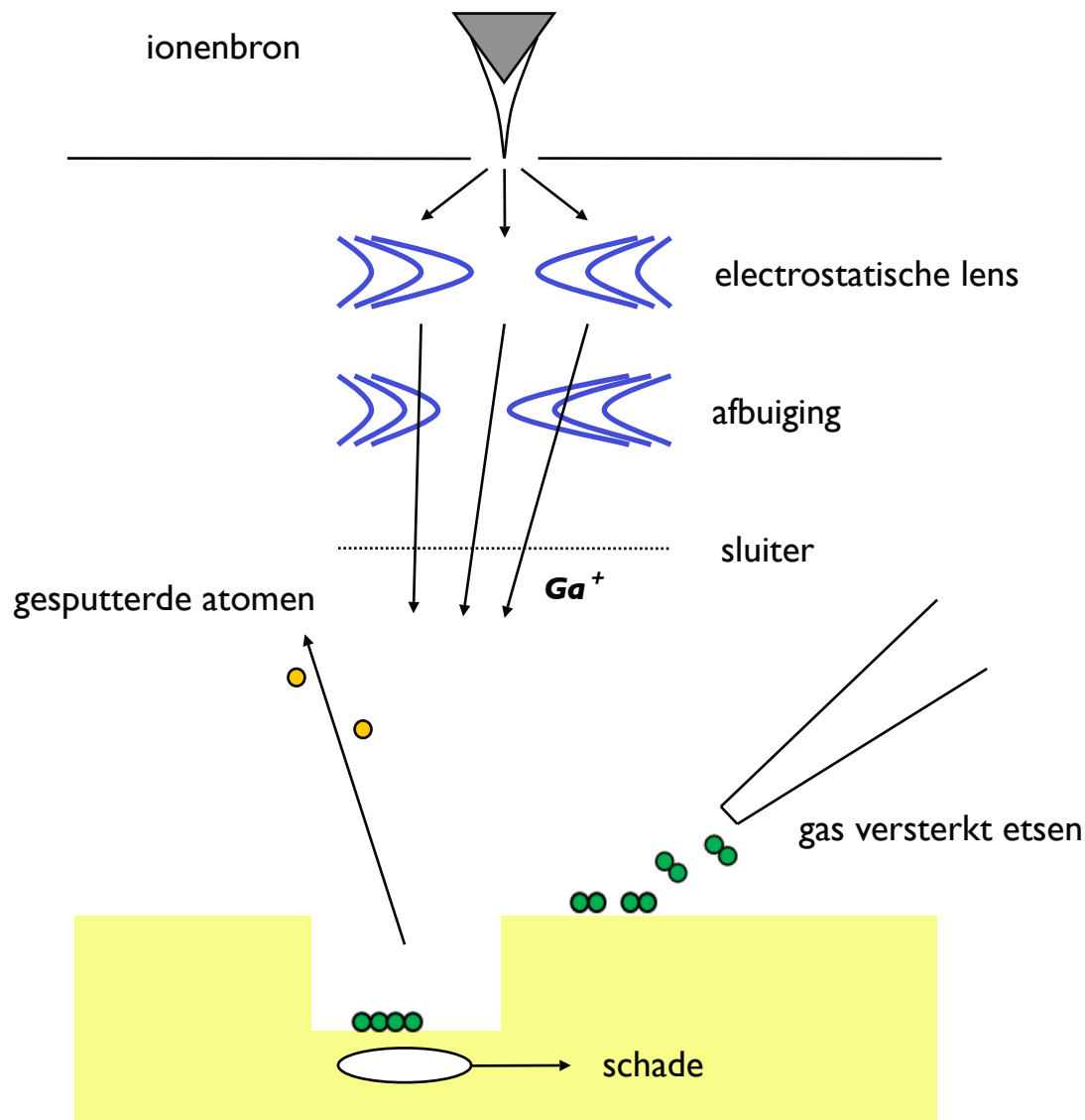
- Optische / imprint lithografie = kopiëren
 - Parallele techniek: vele structuren tegelijk
 - Goedkoop voor grote volumes, duur voor kleine volumes
- Seriële technieken:
 - voor maskers en stempels
 - voor prototypes

▶ Gefocusseerde ionenbundels

Gefocusseerde ionenbundels



Gefocusseerde ionenbundels



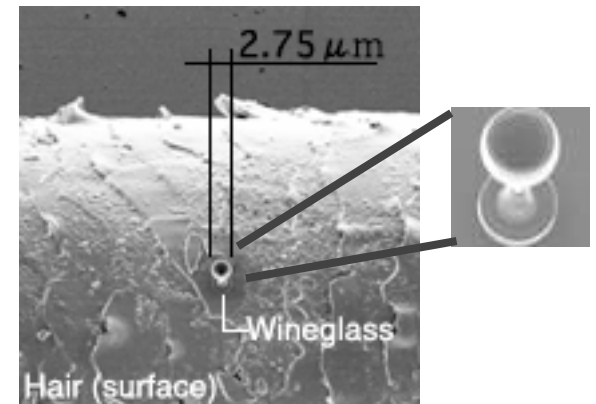
= Focused ion beam

= FIB

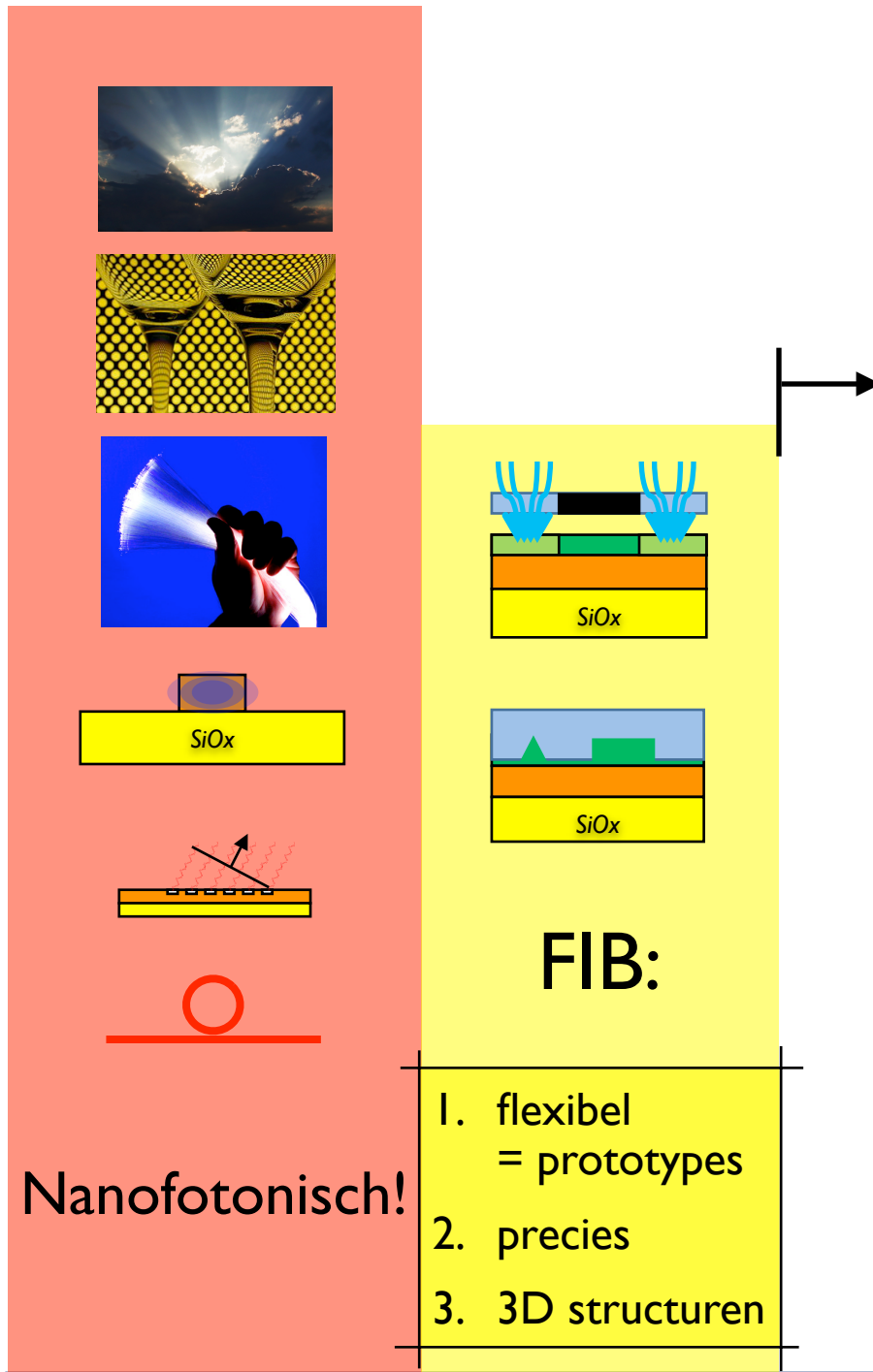
1. flexibel = ideaal voor prototypes
2. zeer hoge precisie (nanometers)
3. 3D structuren mogelijk



Gefocusseerde ionenbundels

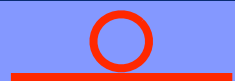
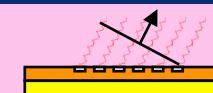


Dit doctoraat:

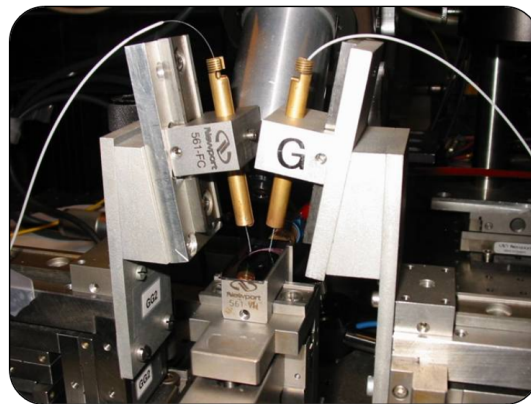
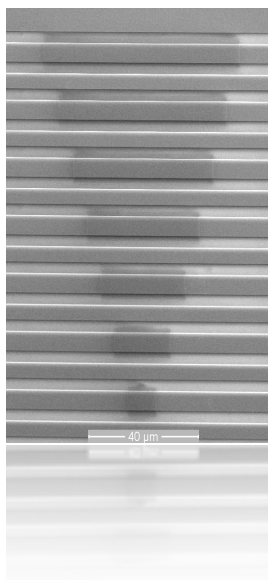


Ionenbundels

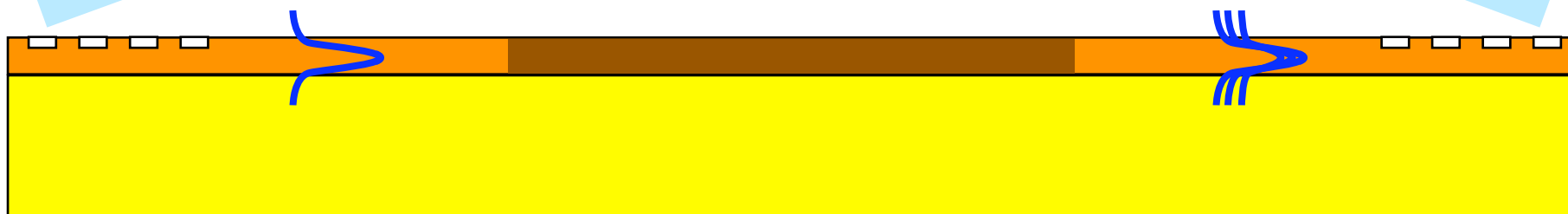
Verliezen

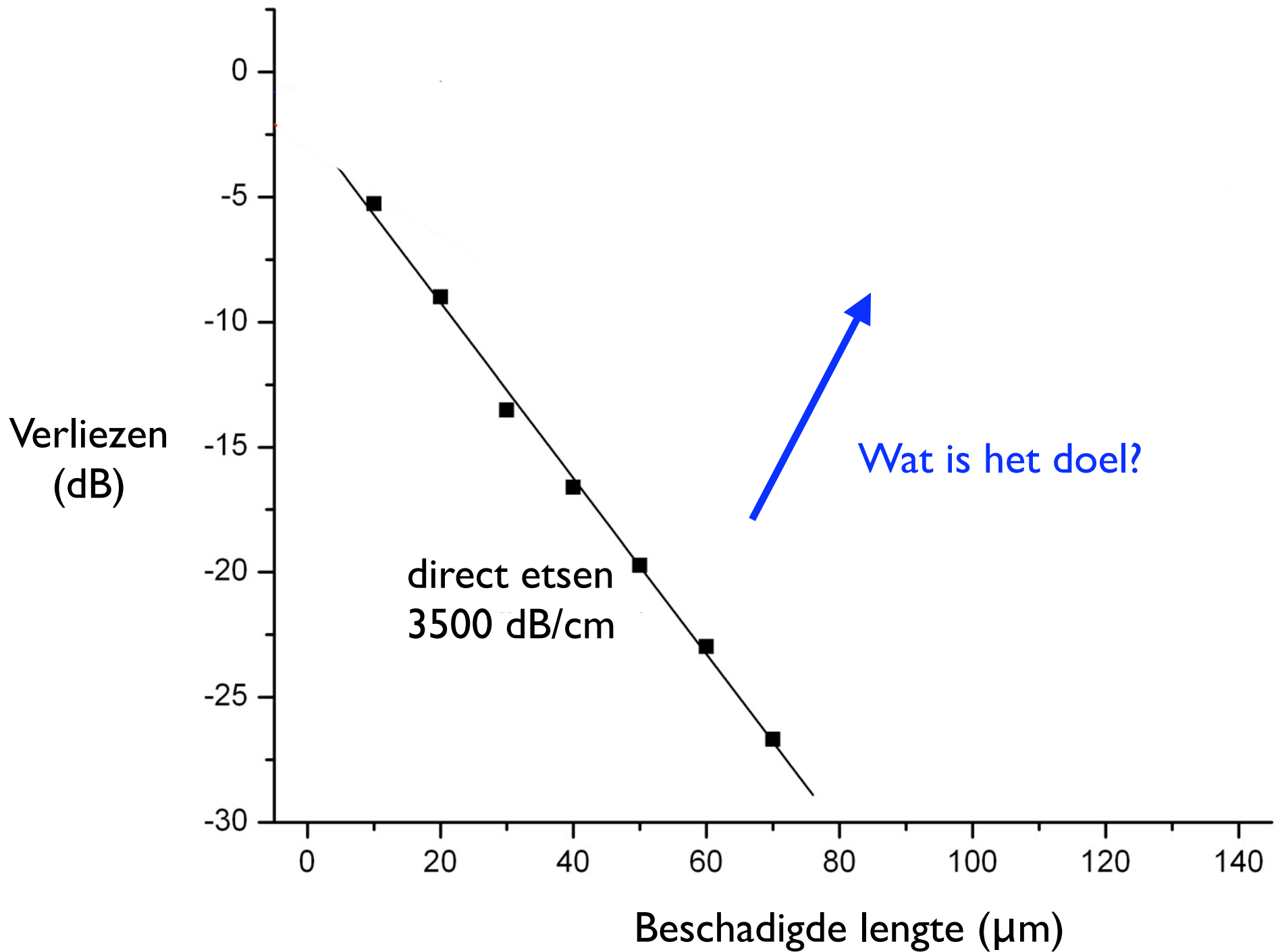


Optische verliezen



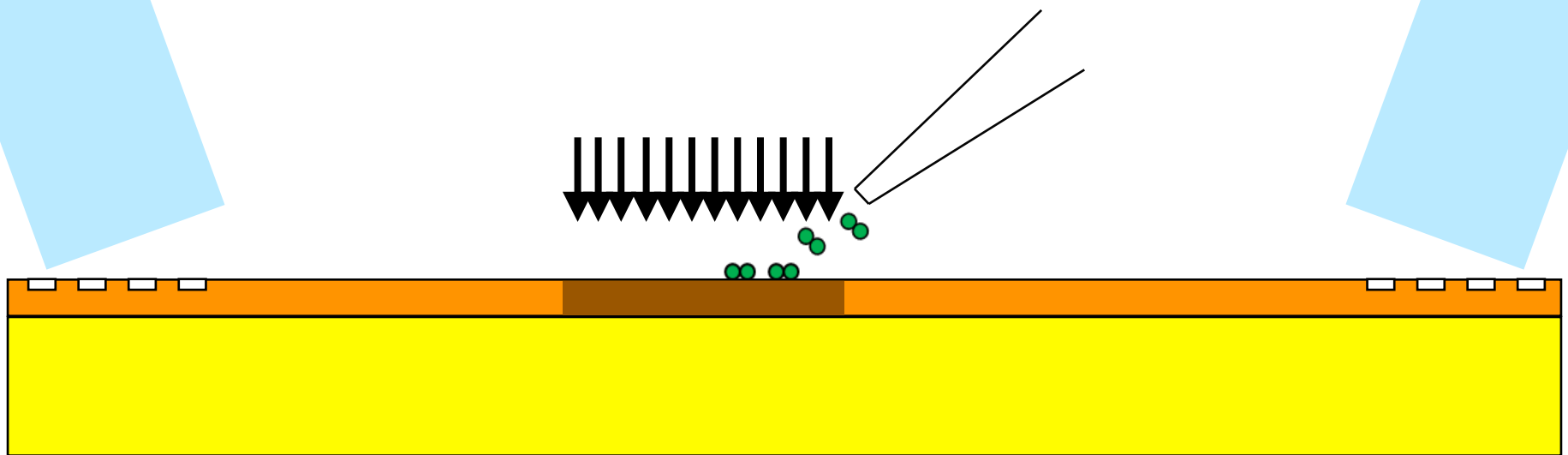
100 % = 0 dB
10 % = -10 dB
1 % = -20 dB

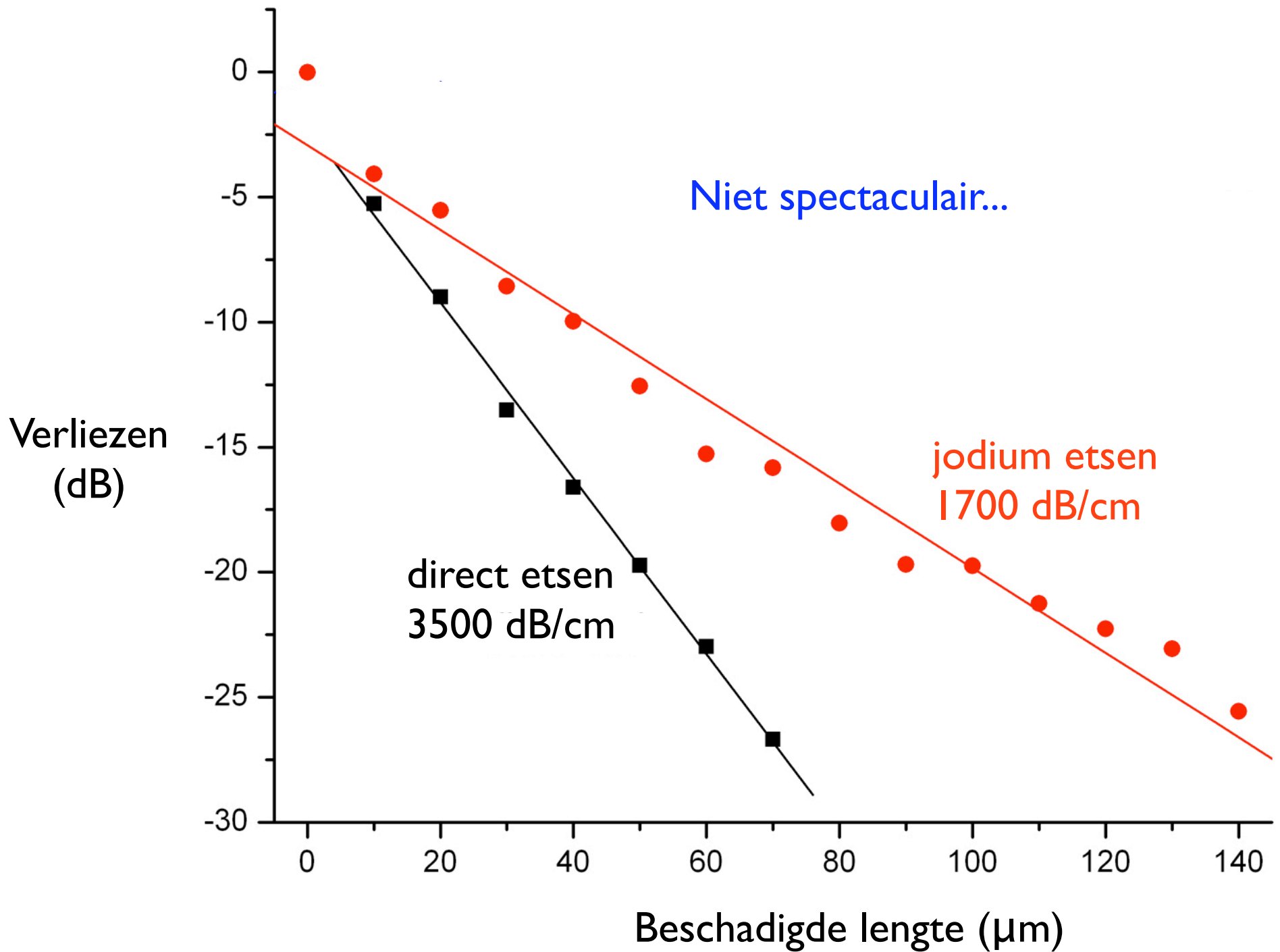




Gas versterkt etsen

- Jodium gas (dijood)
- Versneld etsproces
- Minder ionen = minder schade



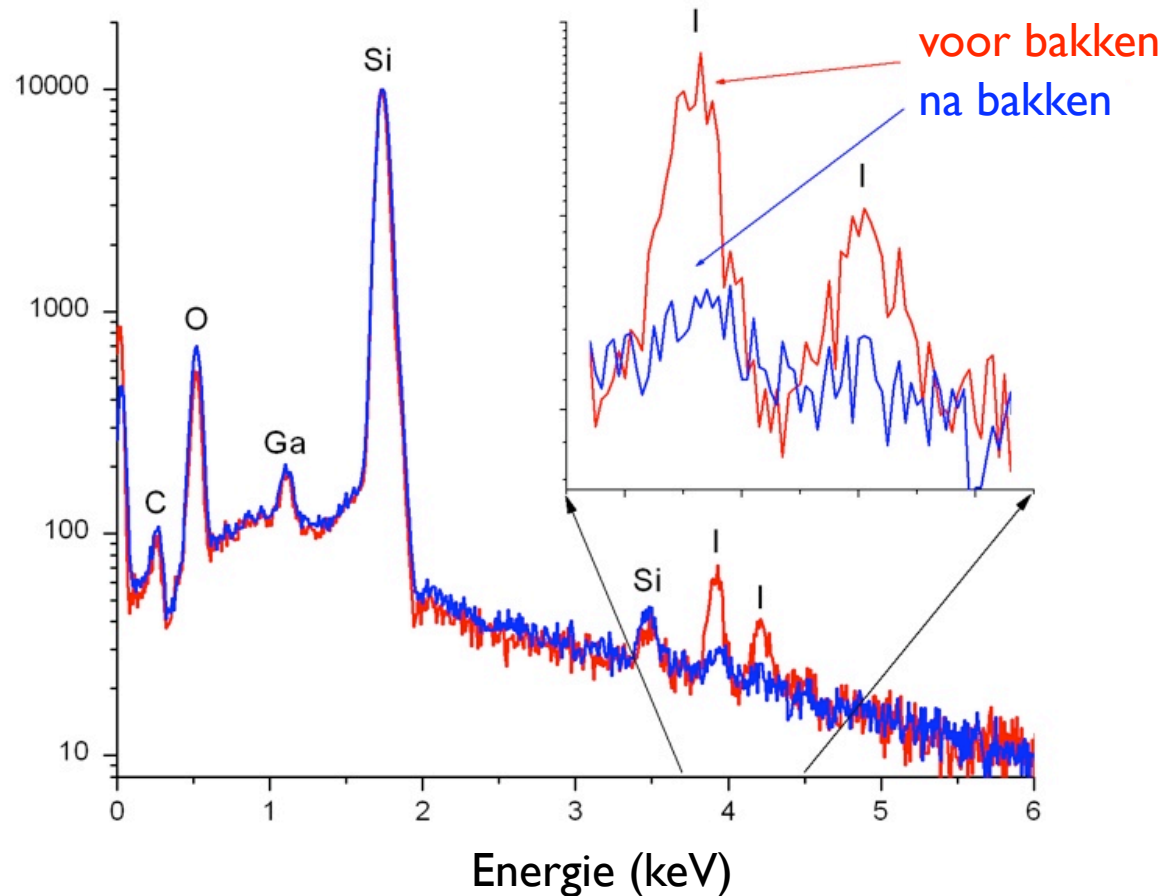


Wat is er aan de hand?

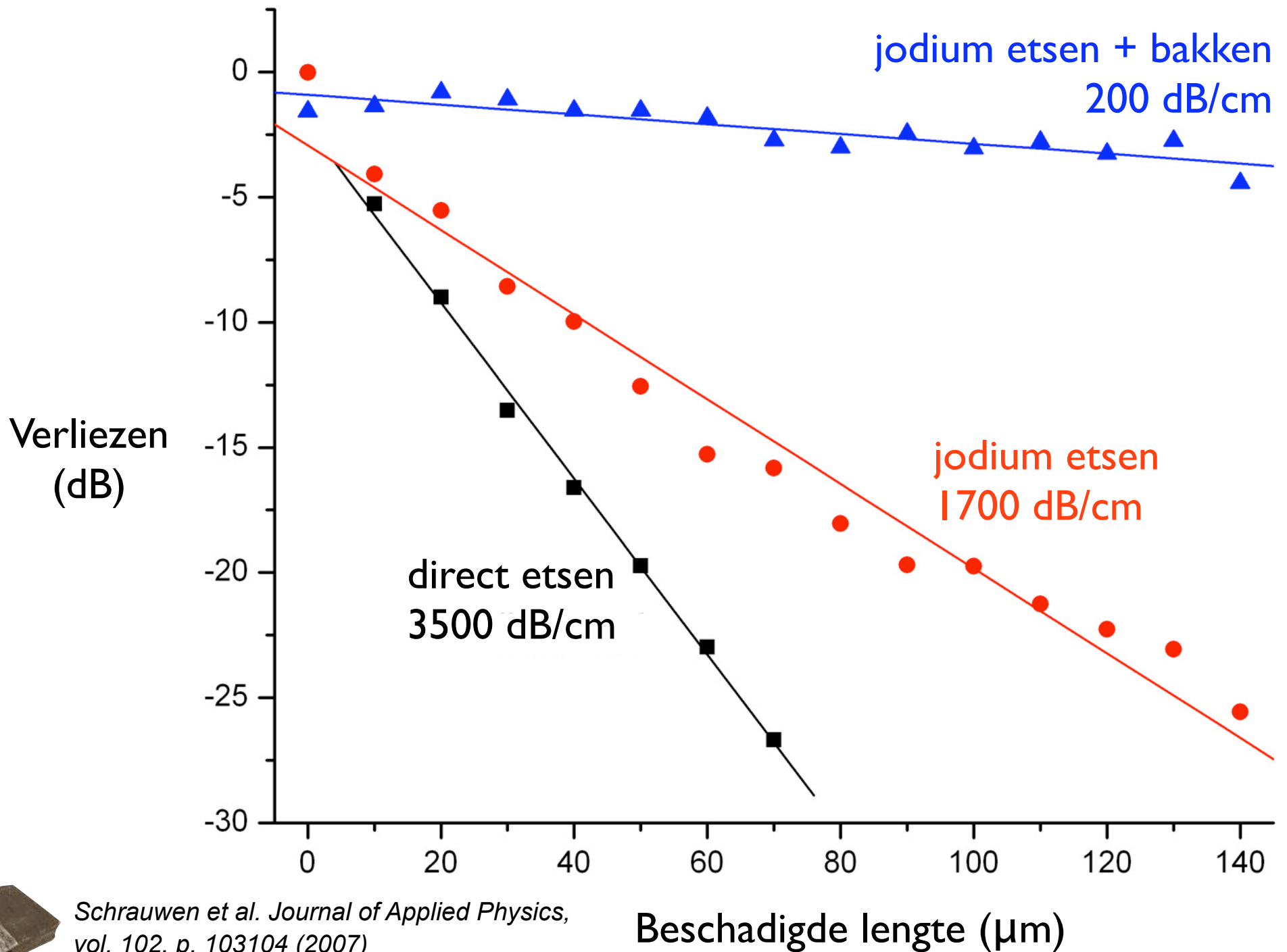
Verschillende
analysetechnieken:
EDX, EBSD, XPS



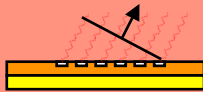
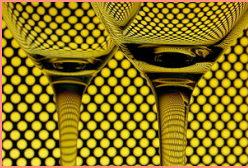
Verwijderen
door bakken op
300°C



Verliezen

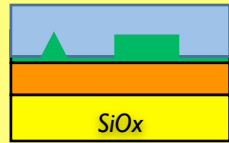
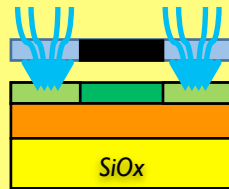


Schrauwen et al. *Journal of Applied Physics*,
vol. 102, p. 103104 (2007)



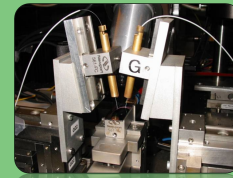
Nanofotonisch!

Dit doctoraat:

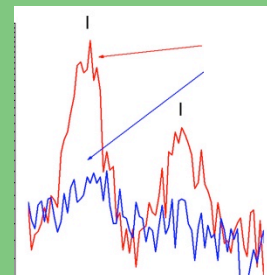


FIB:

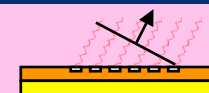
- 1. flexibel = prototypes
- 2. precies
- 3. 3D structuren



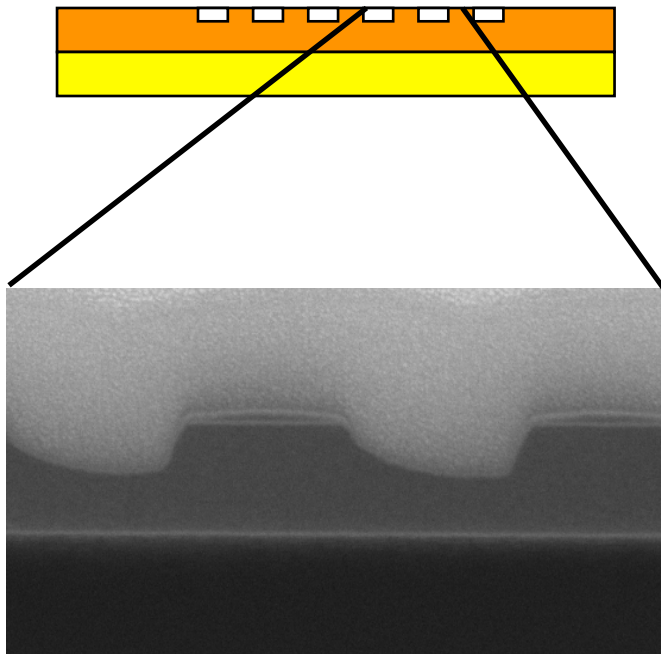
Jodium blijft plakken



Verliezen

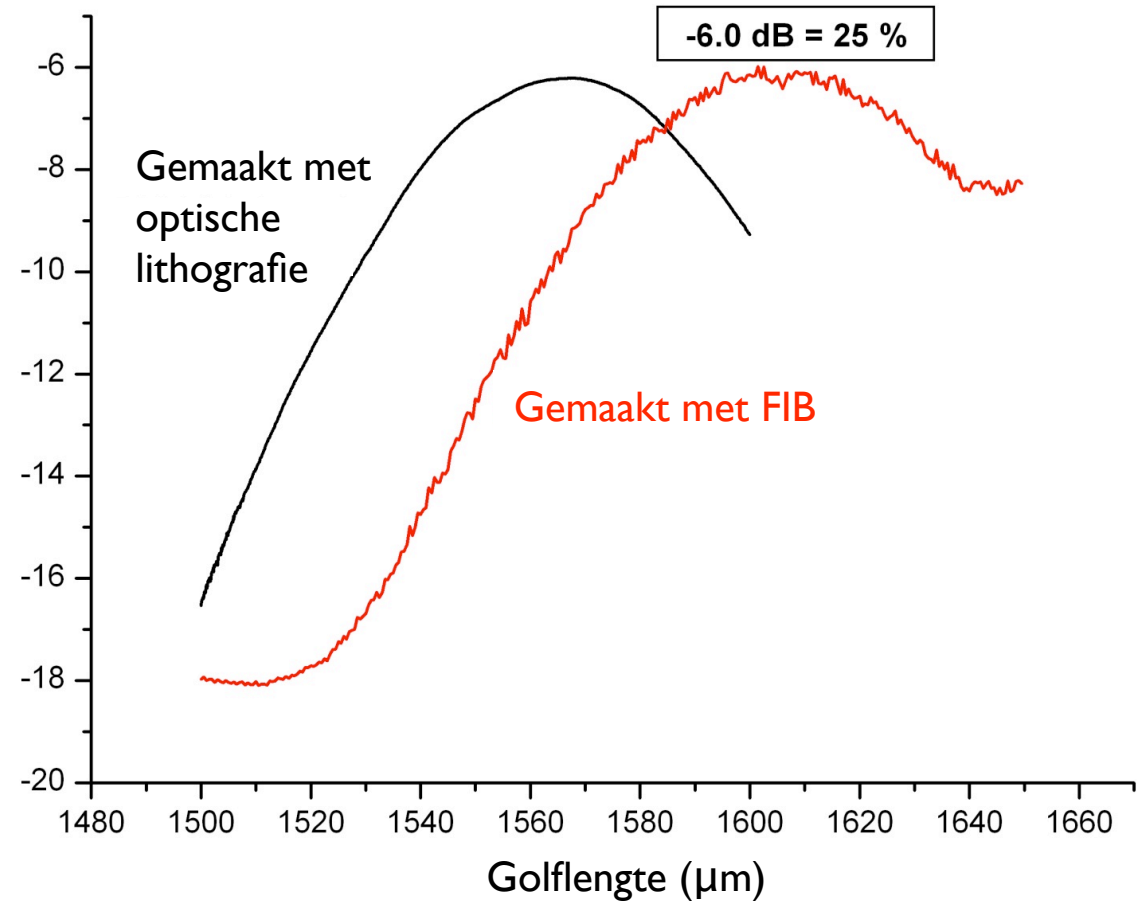


Gewone roosterkoppelaar

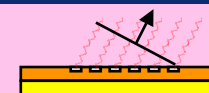


Even goed als
bestaande technieken!

Koppelefficientie (dB)

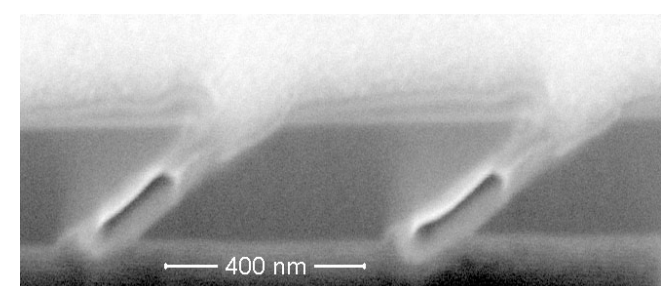
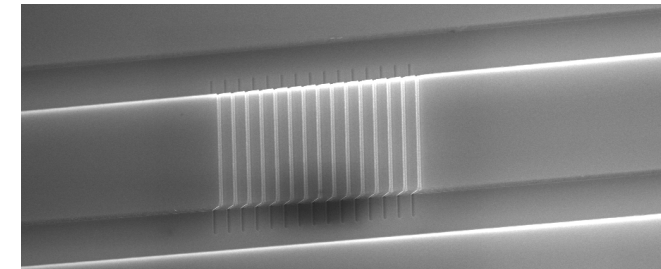
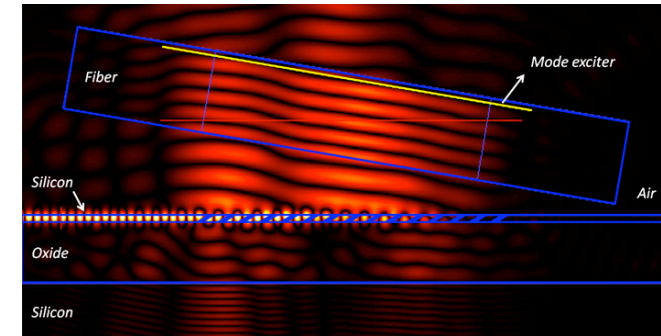
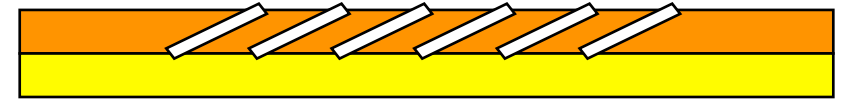
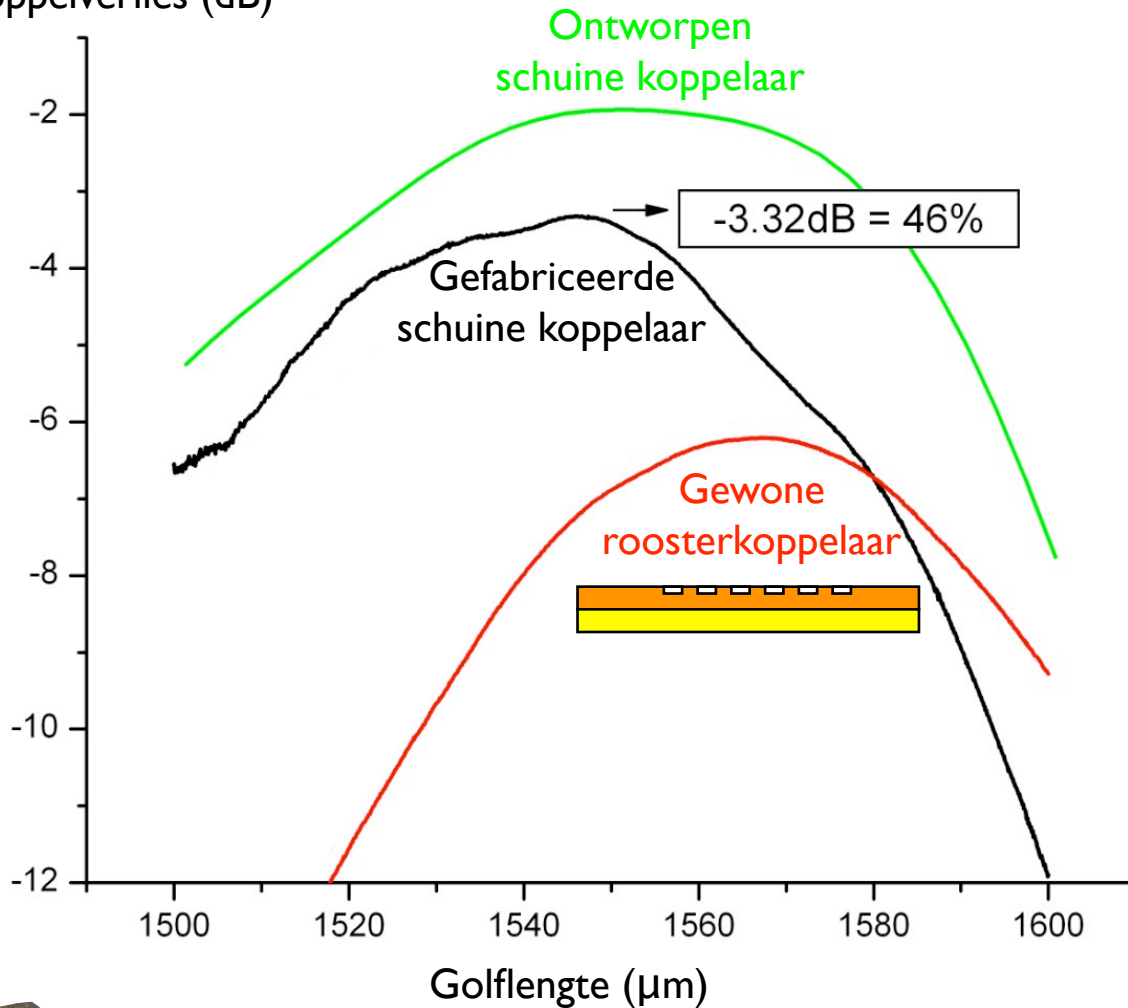


Schrauwen et al. *Applied Physics Letters*,
vol. 89, p.141102 (2006)

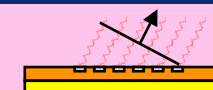


Schuine roosterkoppelaar

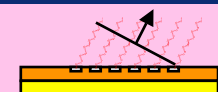
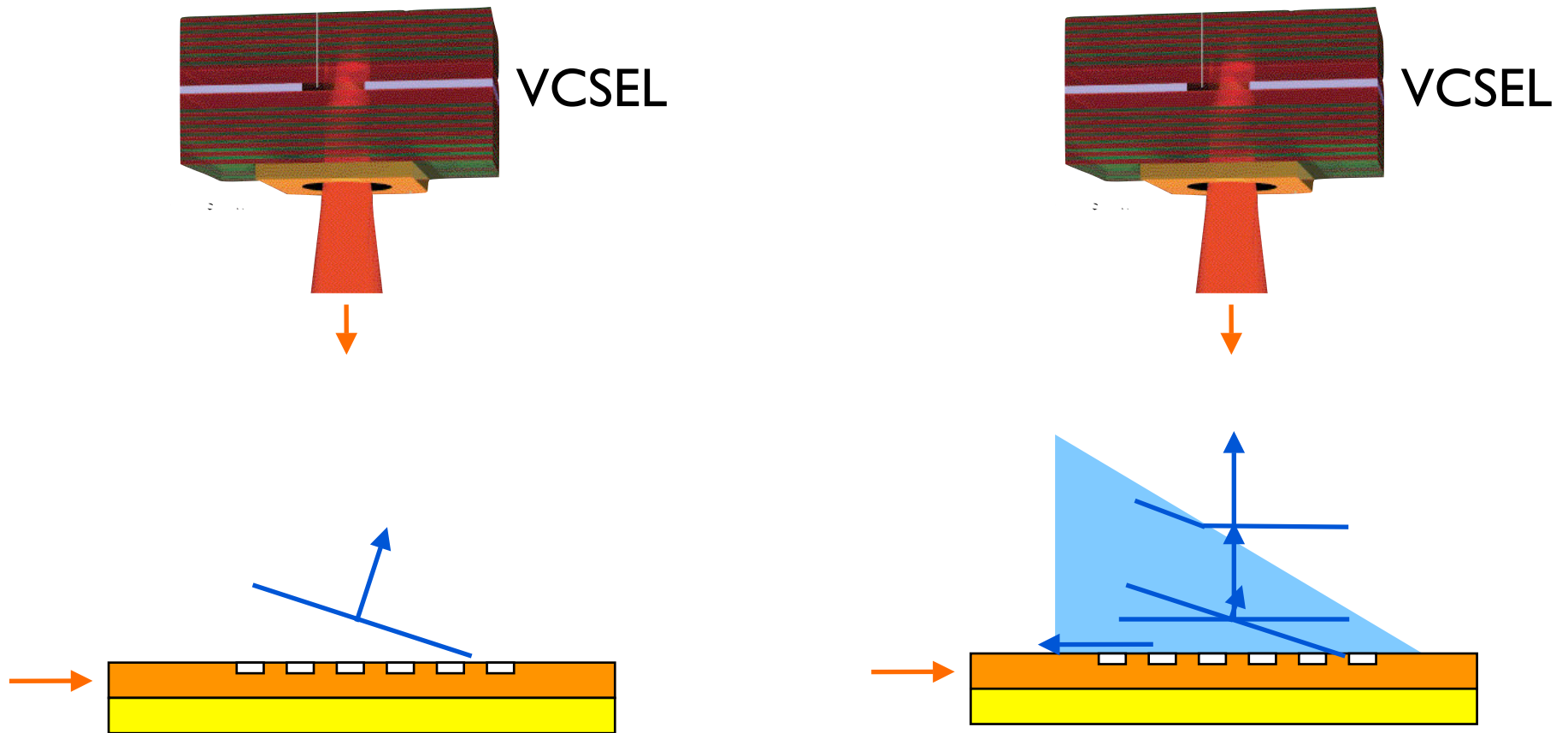
Koppelverlies (dB)



Schrauwen et al. *IEEE Photonics Technology Letters*, vol. 19(11), p.816-818 (2007)

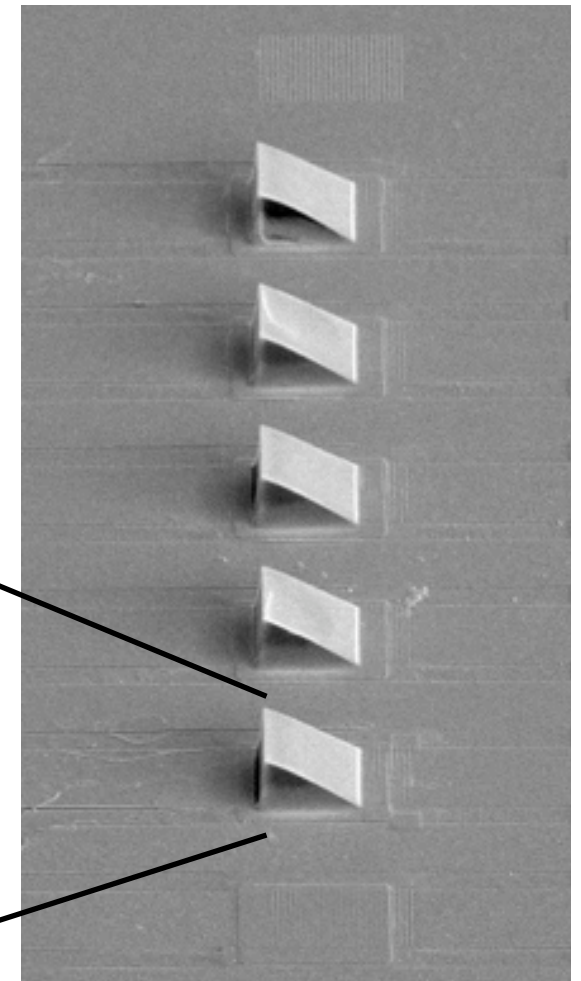
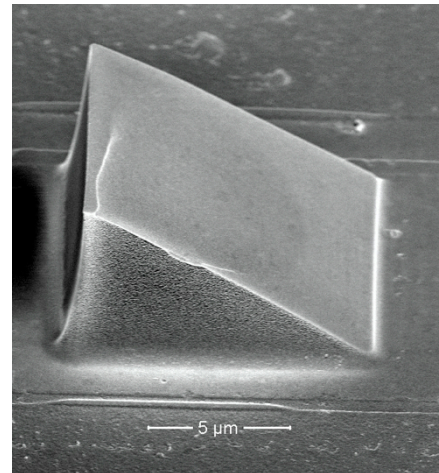
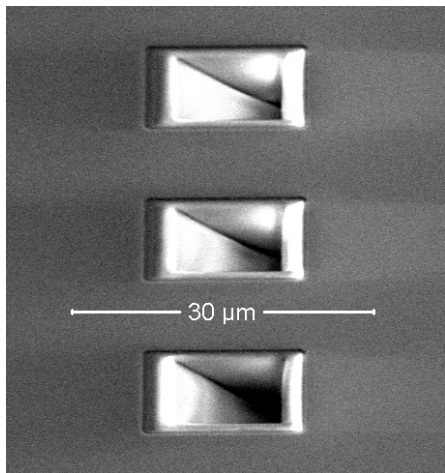
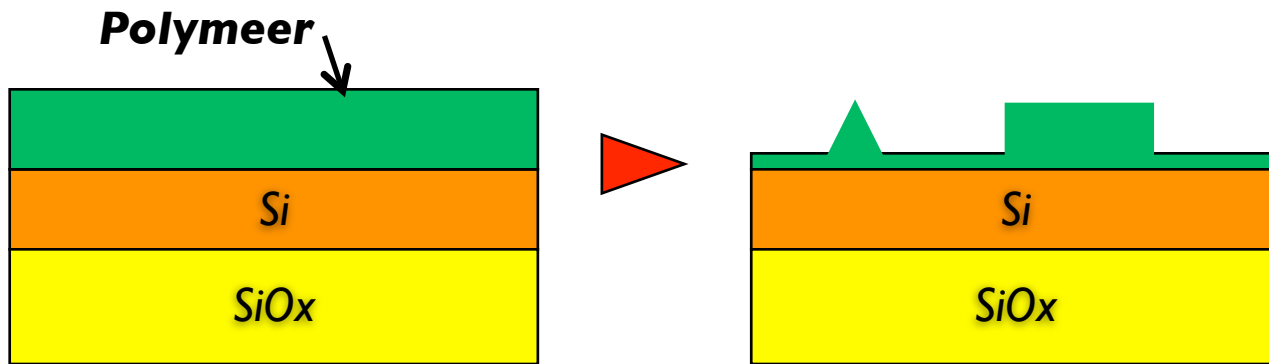


Verticale koppeling?

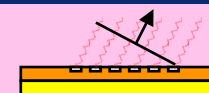


FIB schrijven stempel + imprint

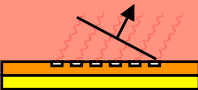
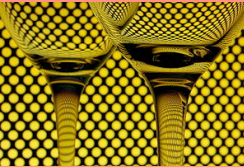
Stempel fabricage



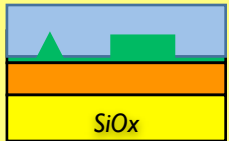
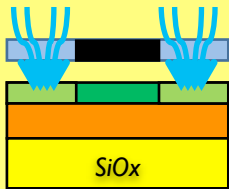
Schrauwen et al. US Patent Pending (2008)



Dit doctoraat:

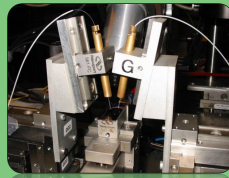


Nanofotonisch!

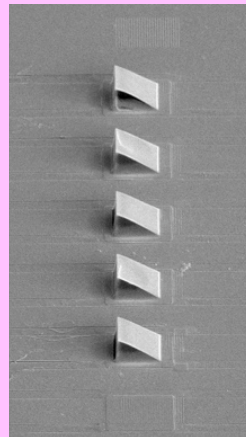
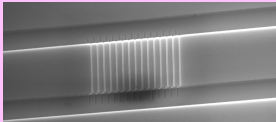
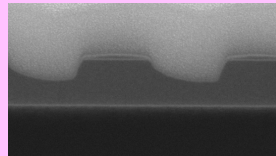
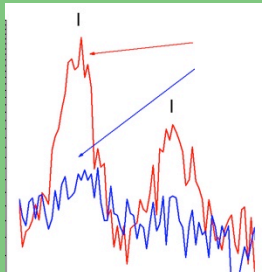


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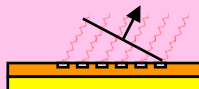
- 1. flexibel = prototypes
- 2. precies
- 3. 3D structuren



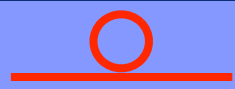
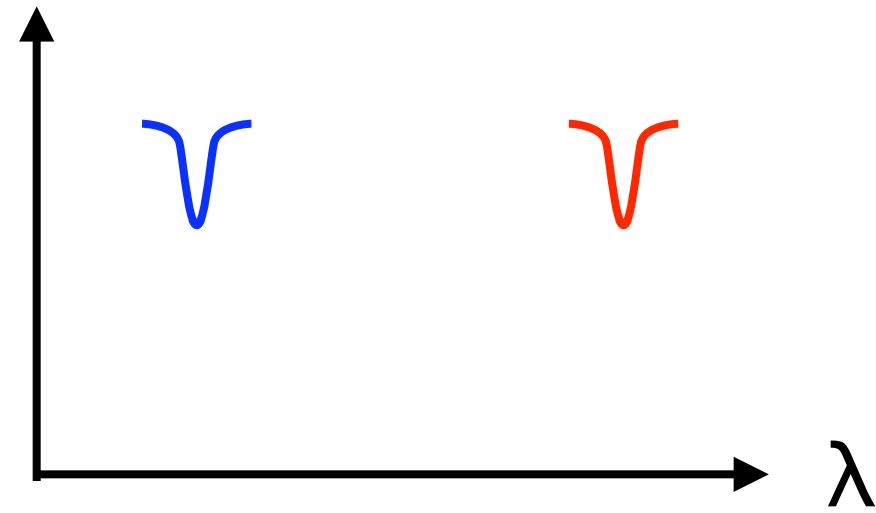
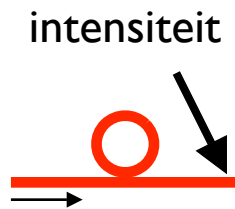
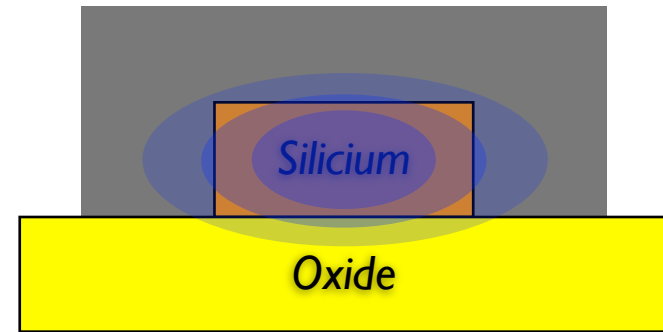
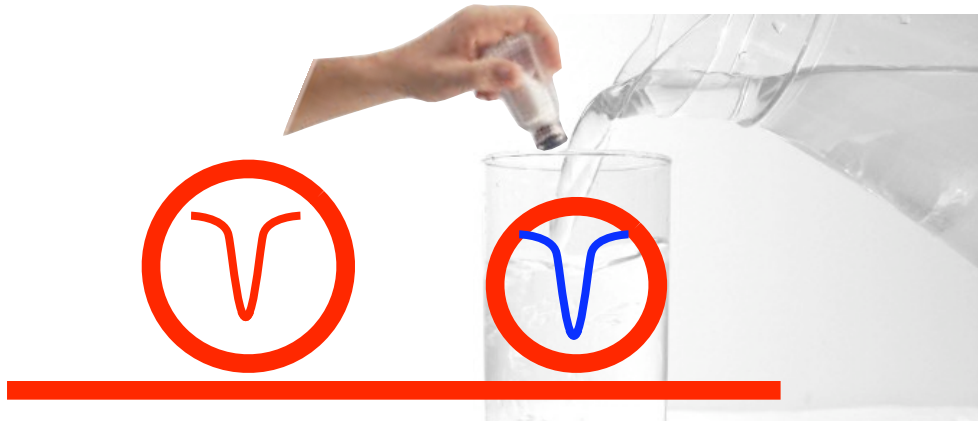
Jodium blijft plakken



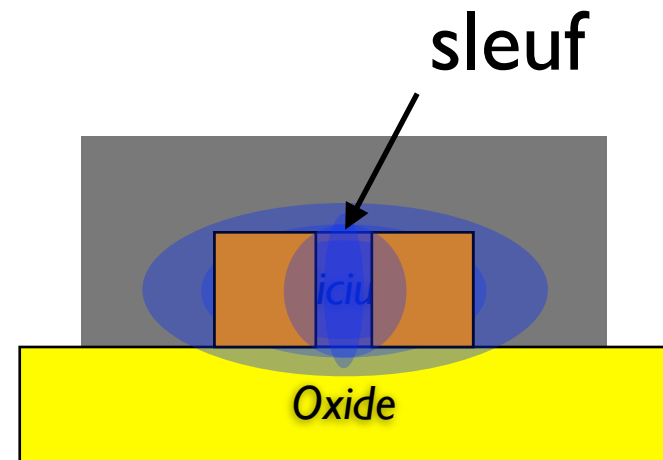
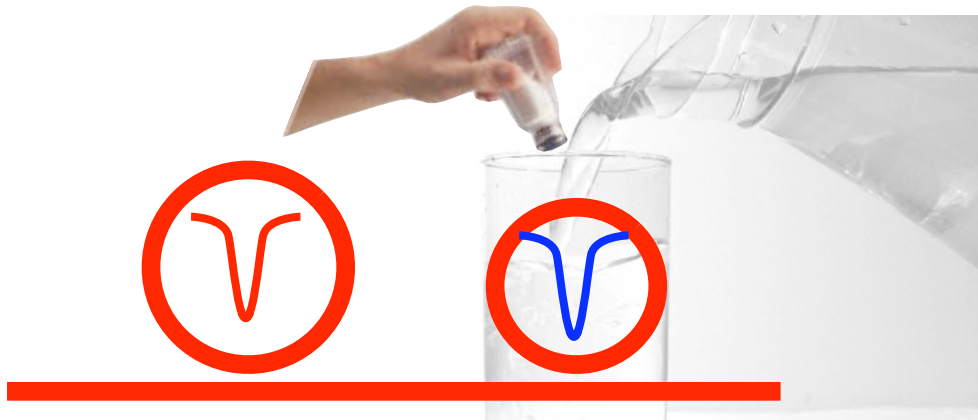
Verliezen



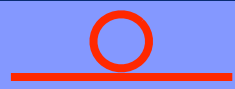
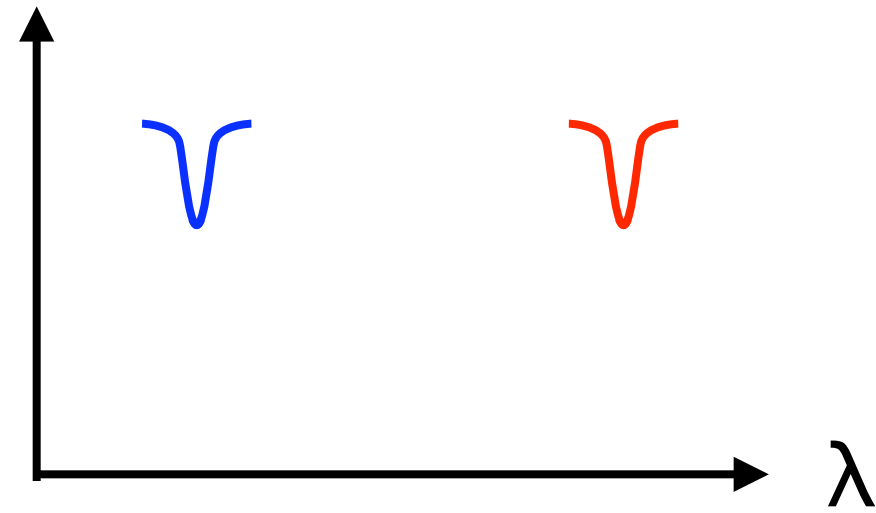
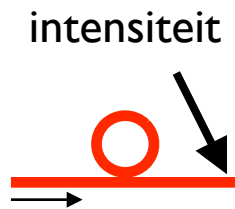
Ringresonatoren zijn sensoren



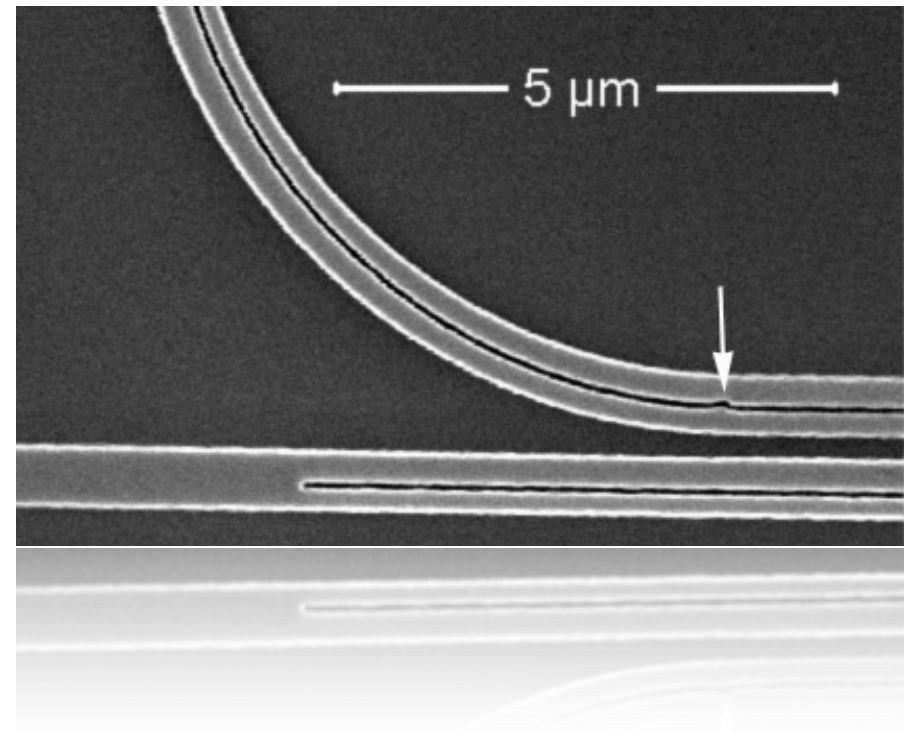
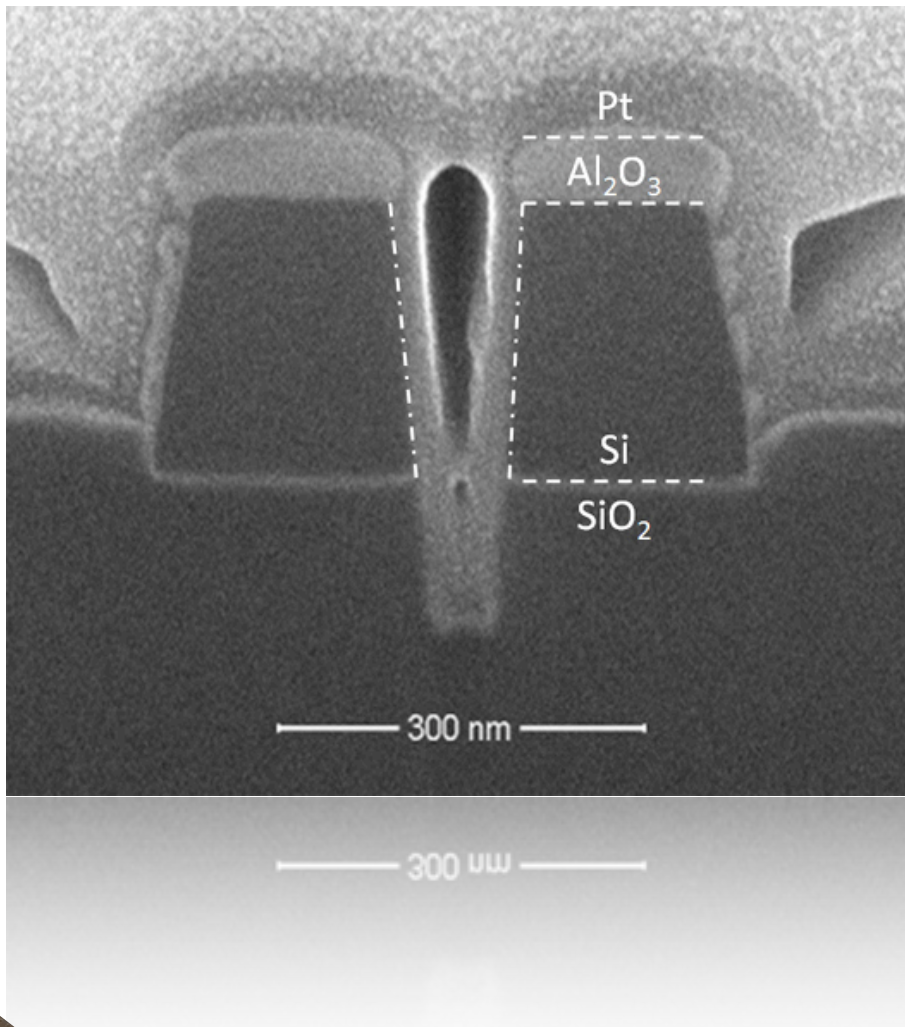
Ringresonatoren zijn sensoren



Ringen met
sleuf zijn
gevoeliger

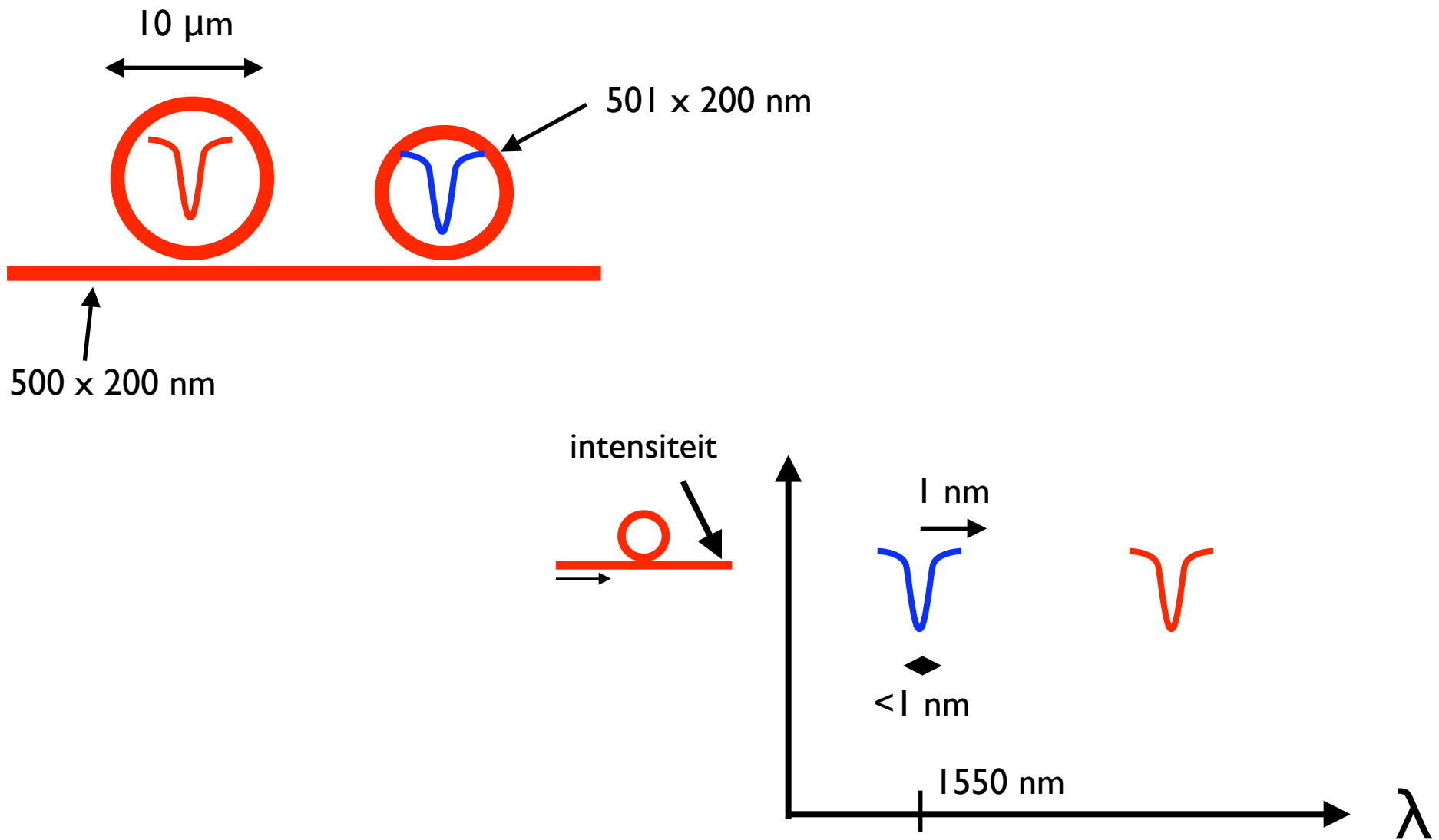


Sleuven gemaakt met FIB

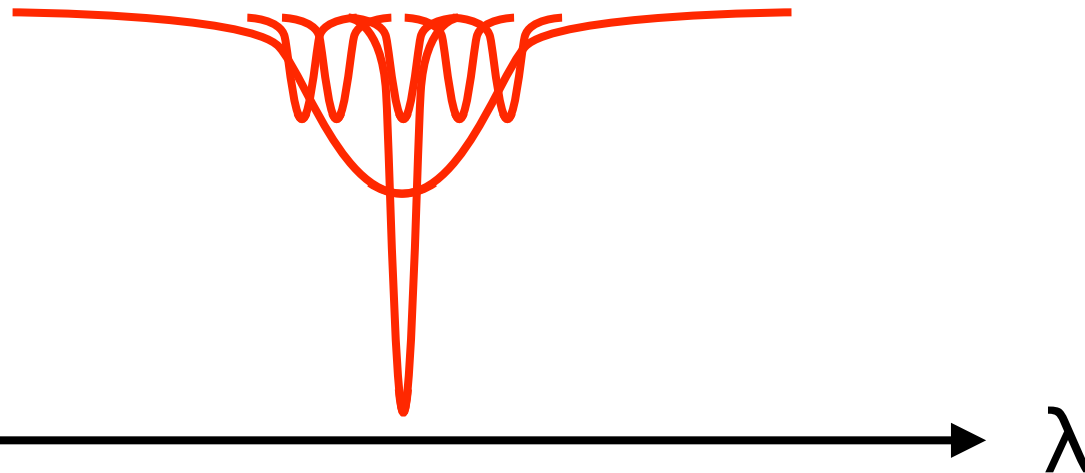
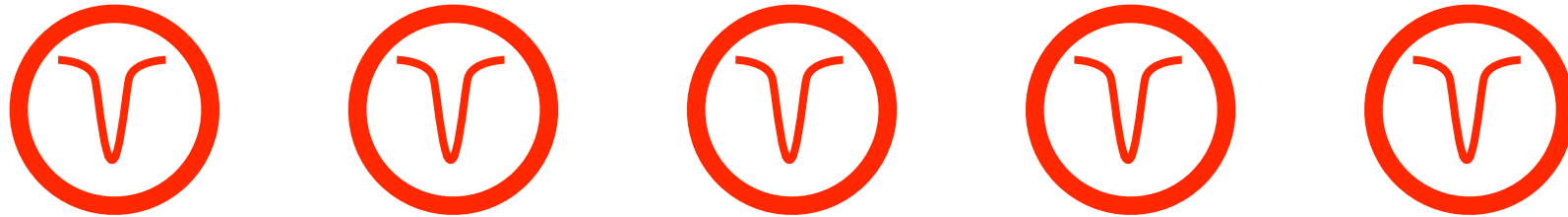


Schrauwen et al. *IEEE Photonics Technology Letters*,
vol. 20(23), p.2004 (2008)

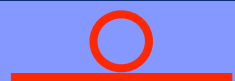
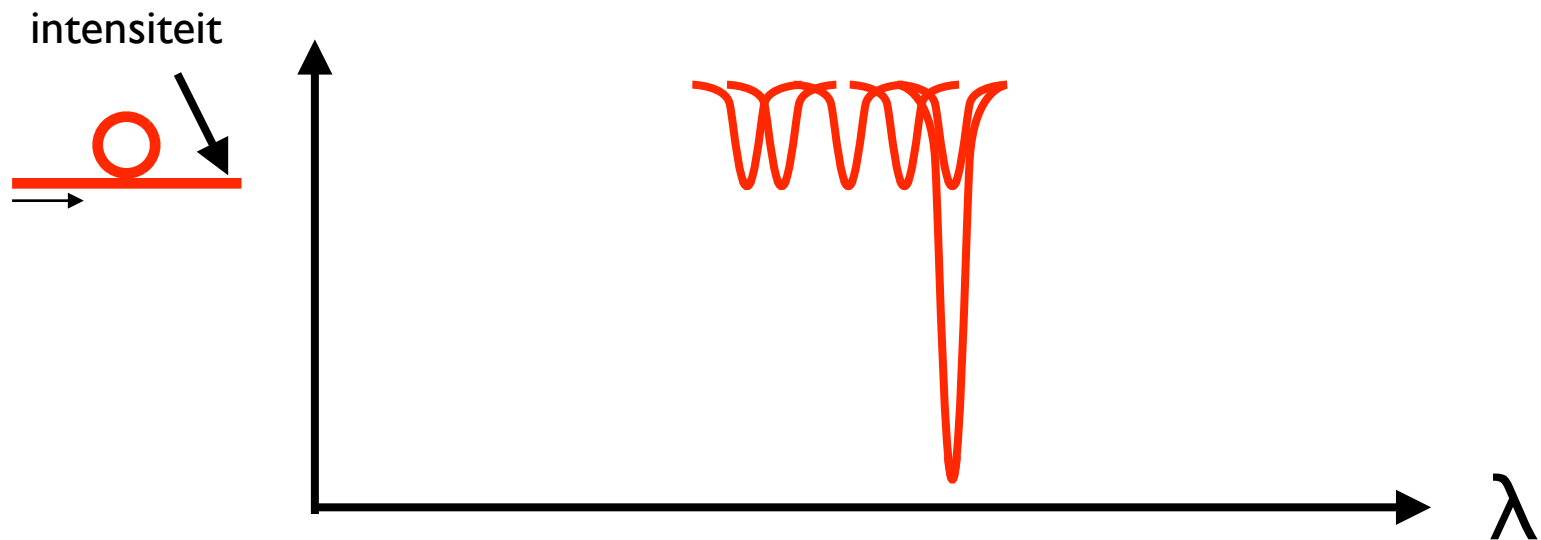
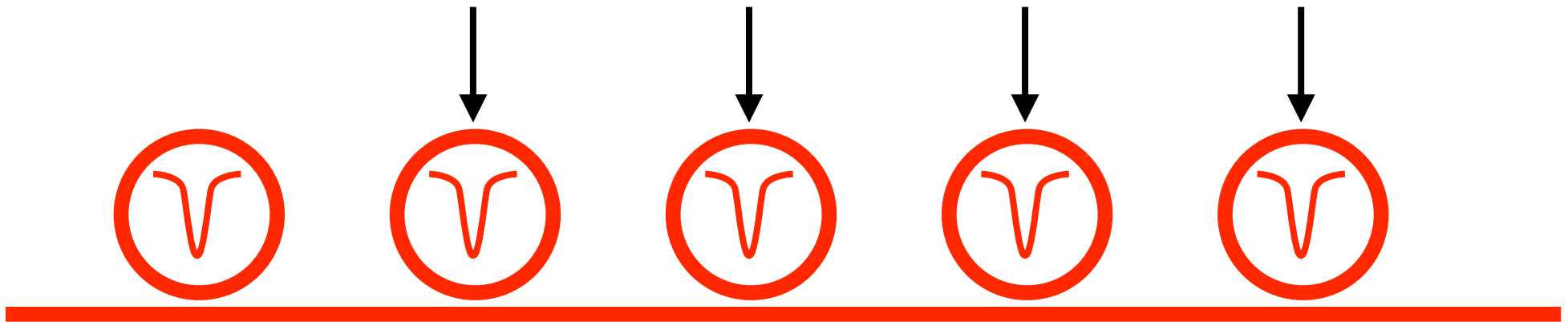
Heel gevoelig

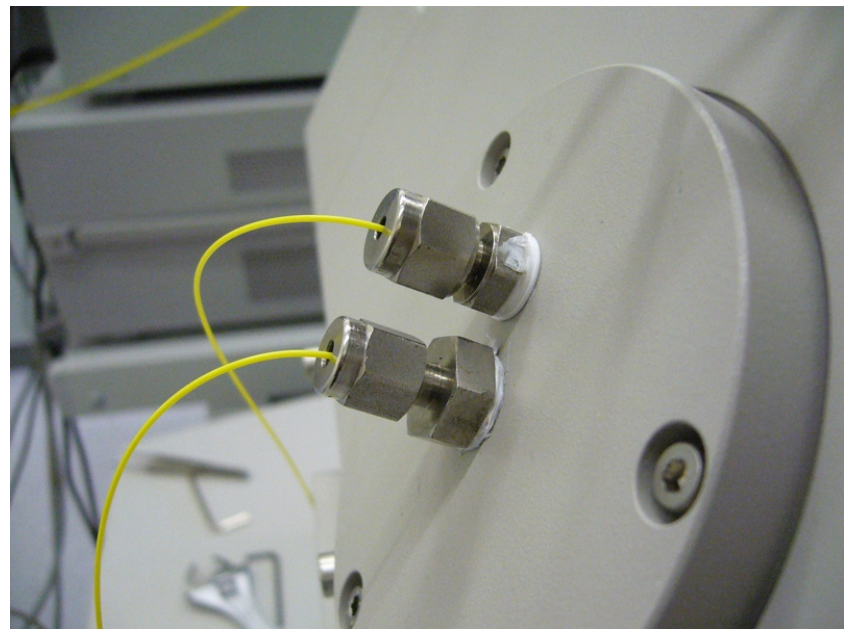
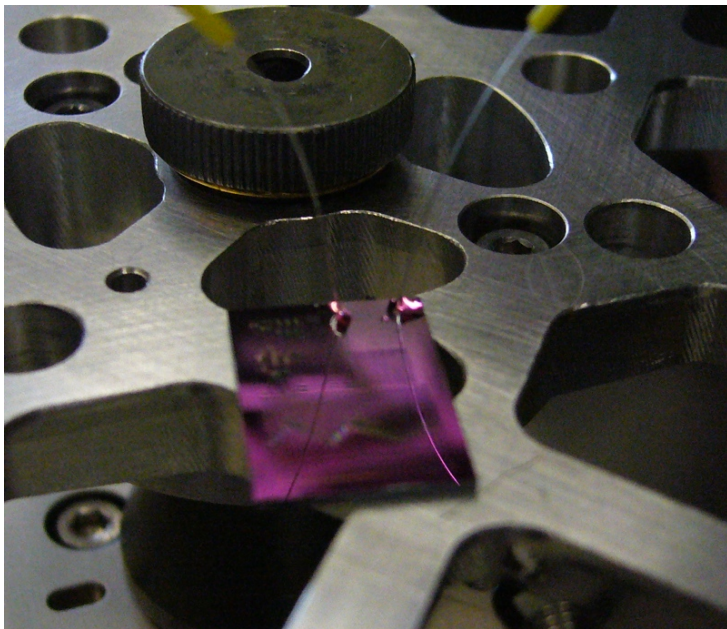
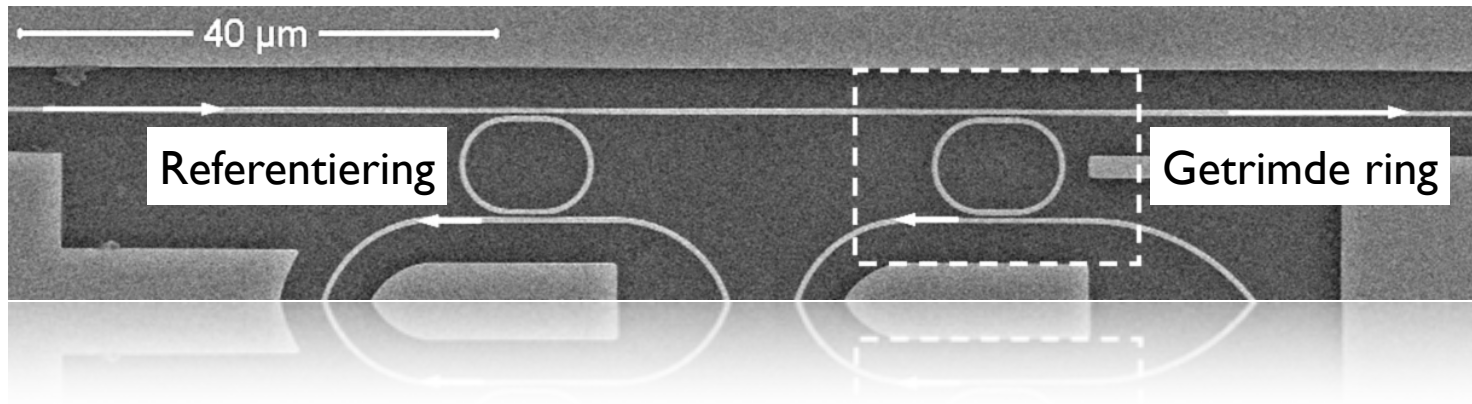


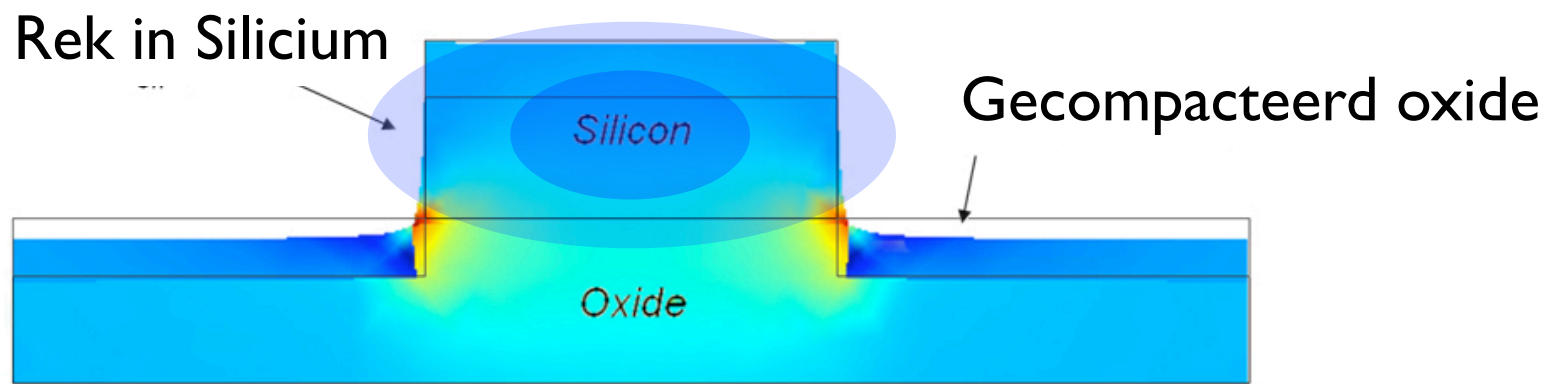
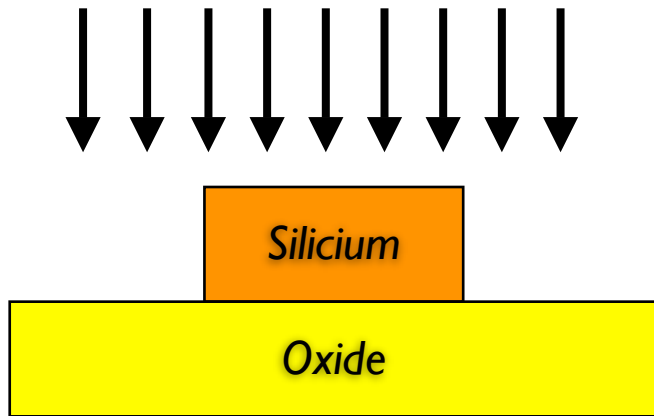
En daarom moeilijk om te maken

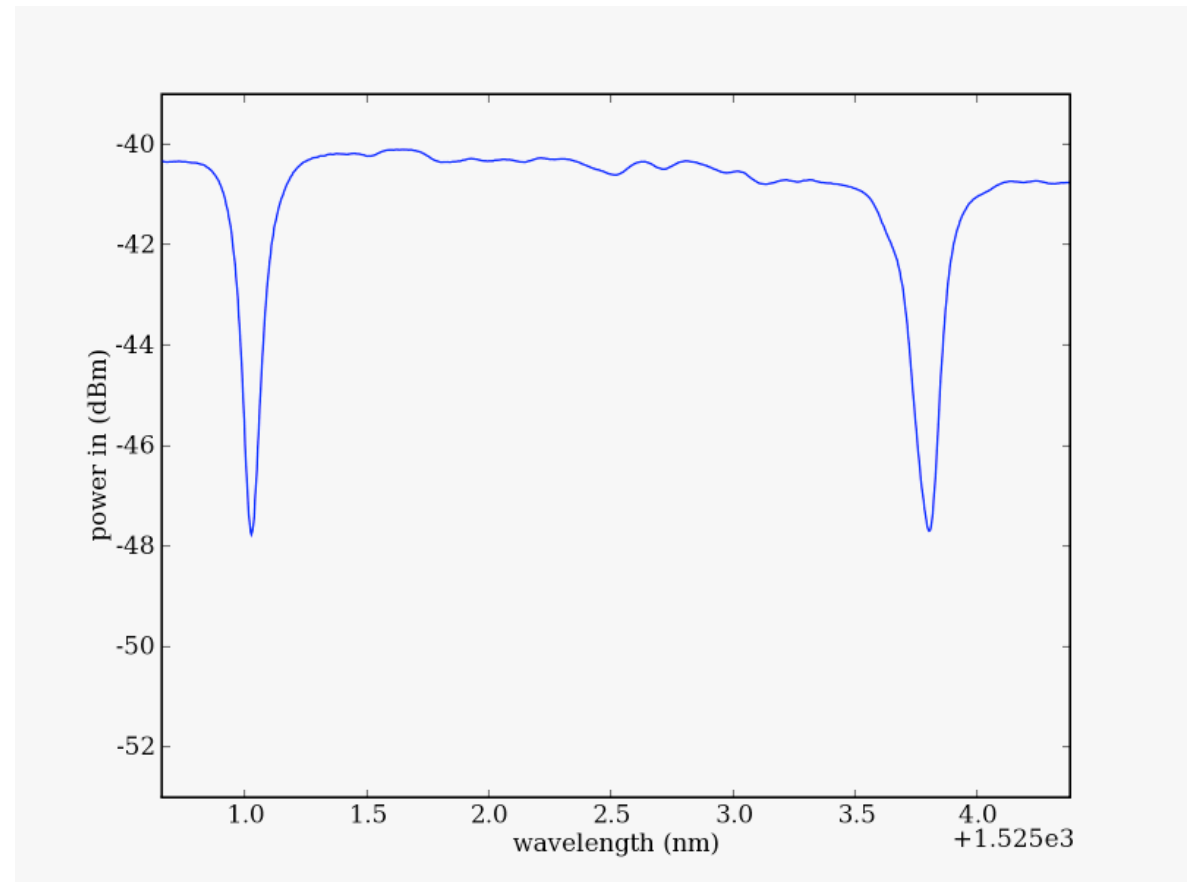
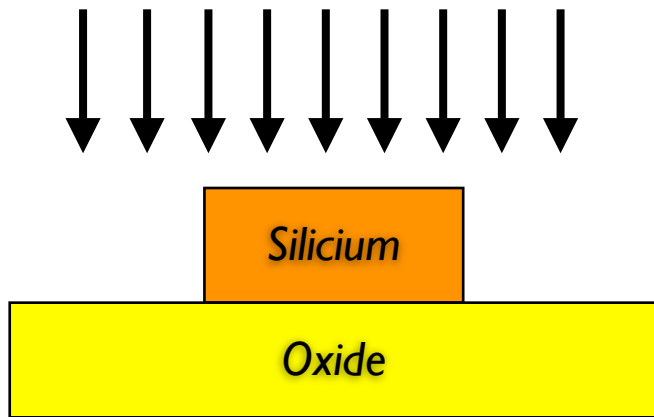


Trimmen met seriële techniek

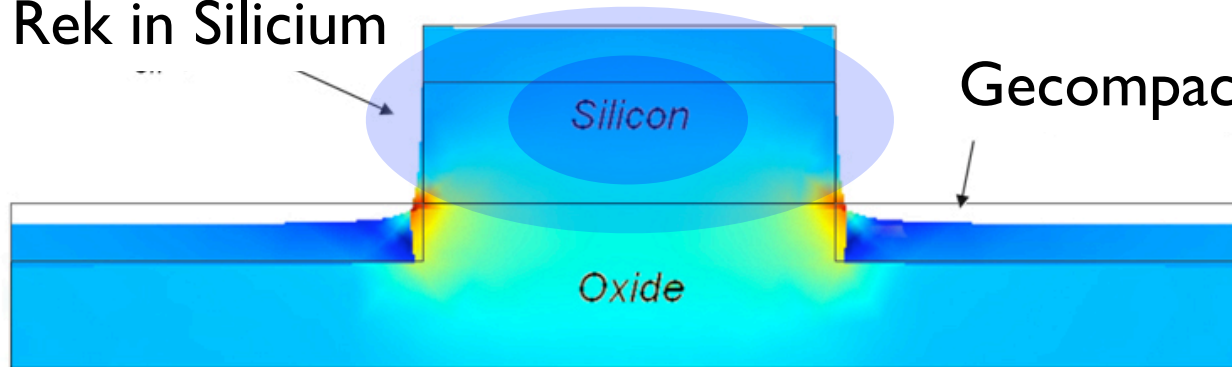








Rek in Silicium



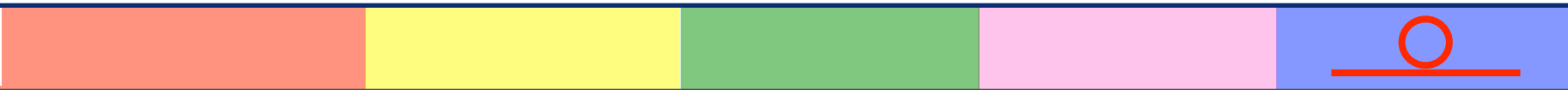
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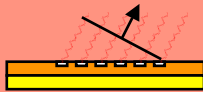
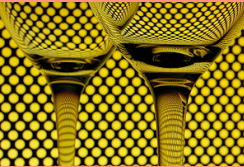
Schrauwen et al. *Optics Express*,
vol. 16(6), p.3738 (2007)



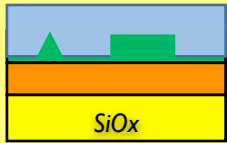
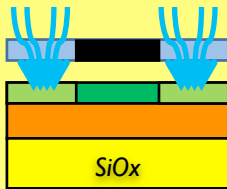
Schrauwen et al. *US Patent Pending* (2007)



Dit doctoraat:

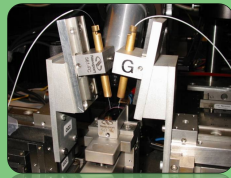


Nanofotonisch!

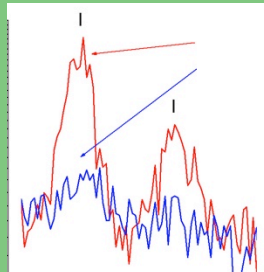


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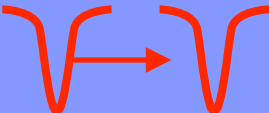
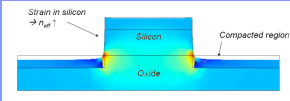
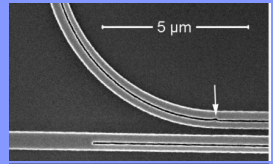
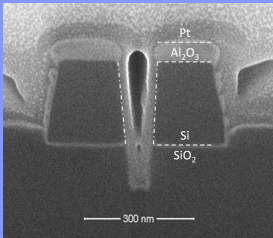
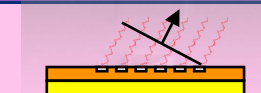
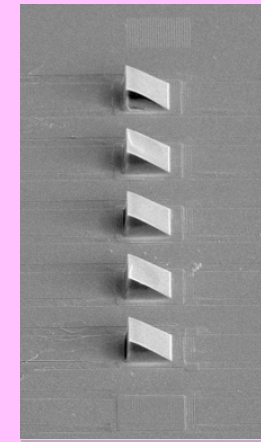
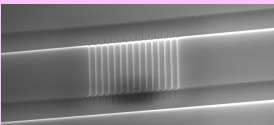
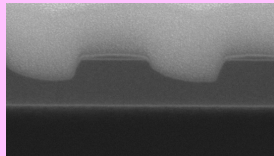
1. flexibel = prototypes
2. precies
3. 3D structuren



Jodium blijft plakken



Verliezen





Fabricage van nanofotonische structuren met gefocusseerde ionenbundels

publieke verdediging
Jonathan Schrauwen

Promotor: Prof. Dries Van Thourhout

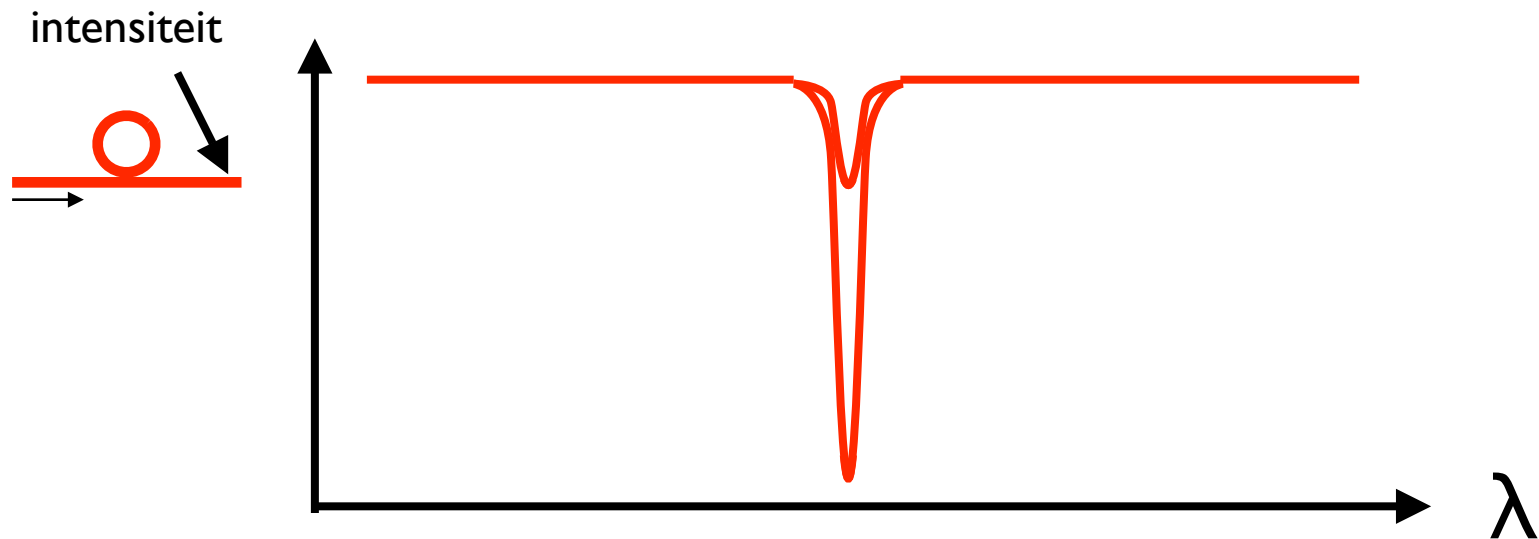
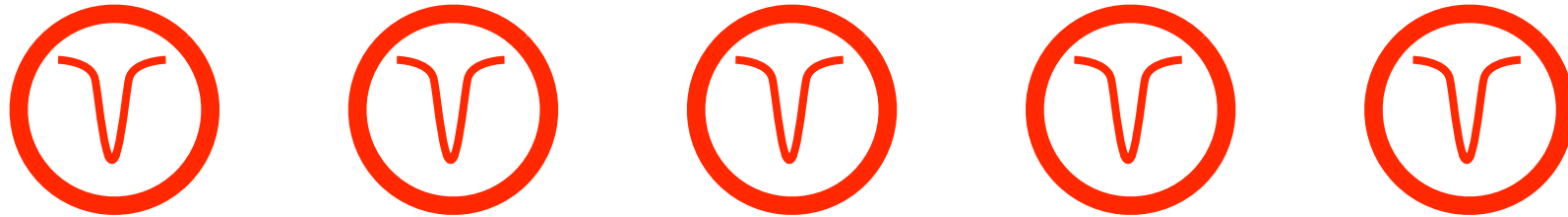
Vakgroep Informatietechnologie
Faculteit Ingenieurswetenschappen

4 februari 2009





Ringresonatoren zijn filters



Het internet

