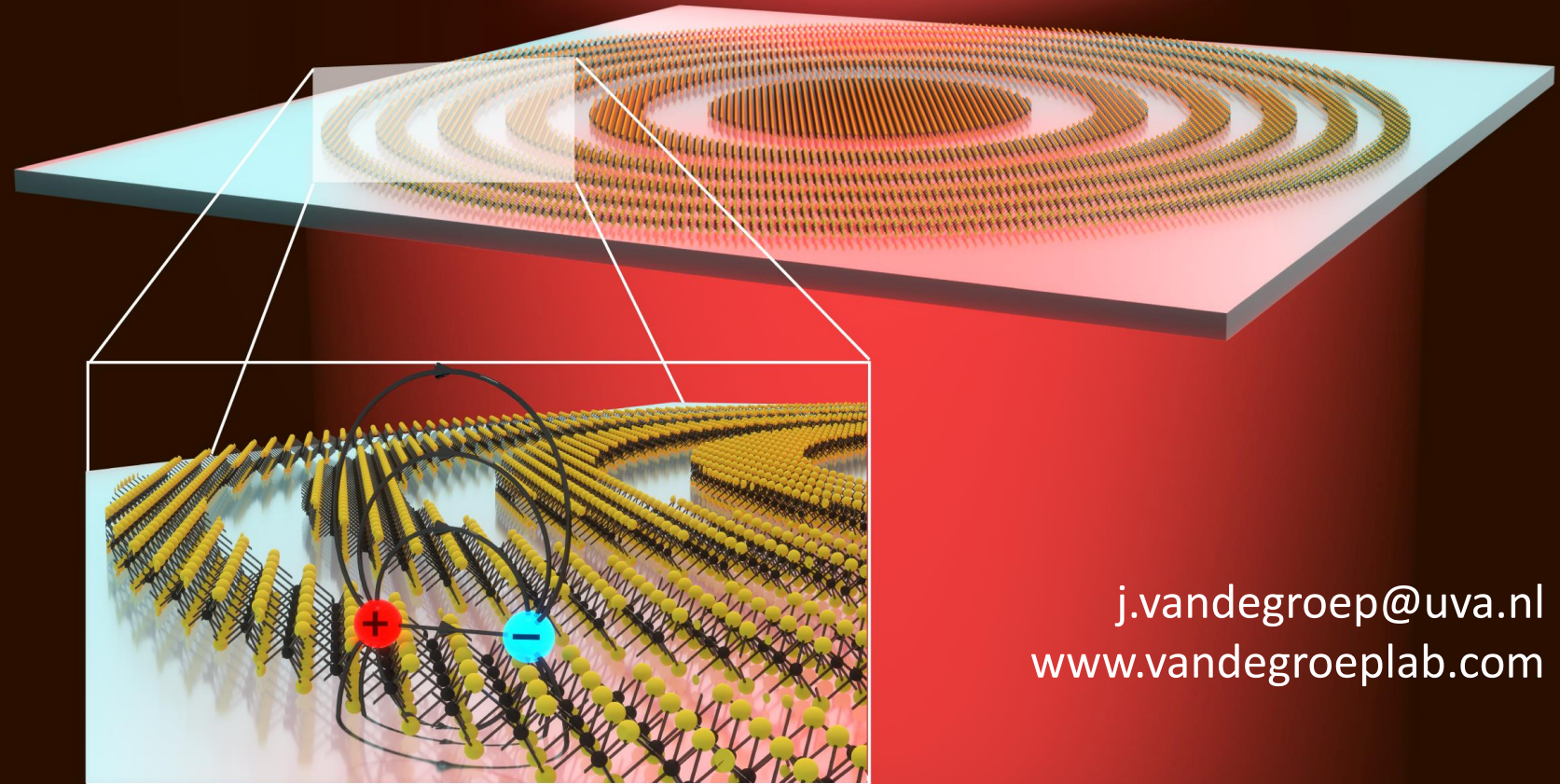


De dunste lens ter wereld

Jorik van de Groep

Institute of Physics
University of Amsterdam



j.vandegroep@uva.nl
www.vandegroeplab.com

De computer van vroeger...



De computer van nu...



Optische elementen lopen achter!



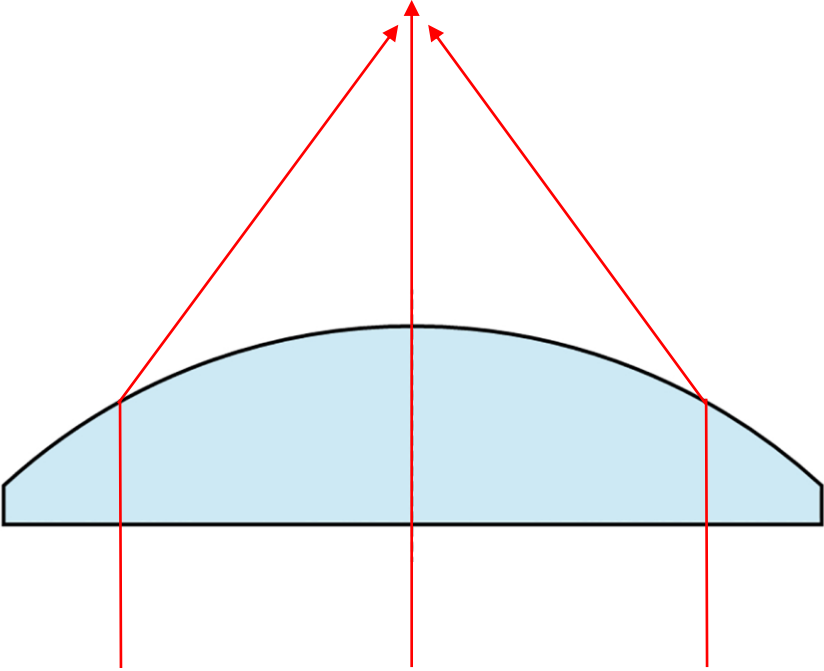
Mismatch optische en elektrische componenten



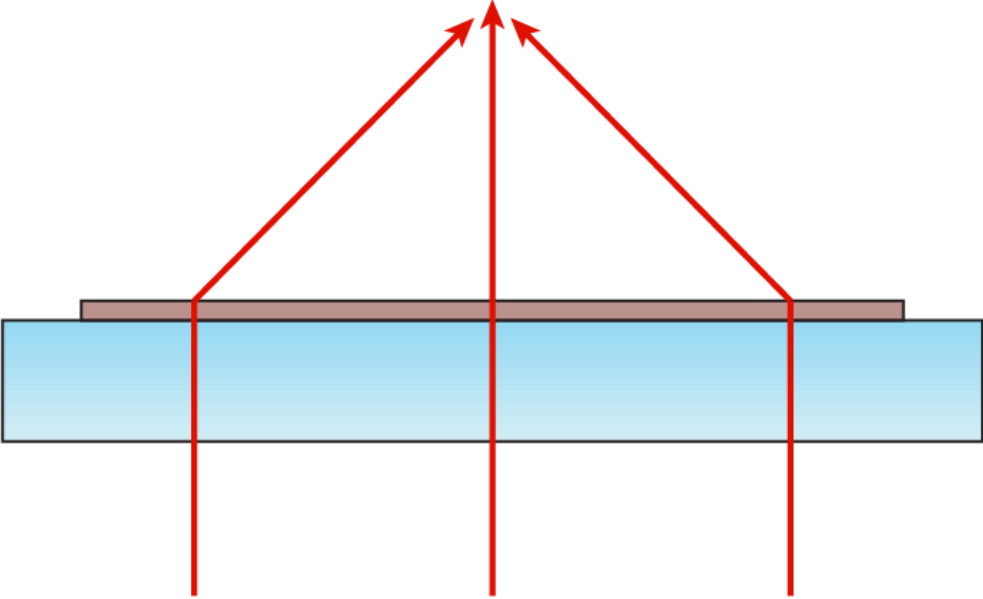
Mismatch optische en elektrische componenten



Van macroschaal naar nanoschaal



~ 1 cm



< 1 nm

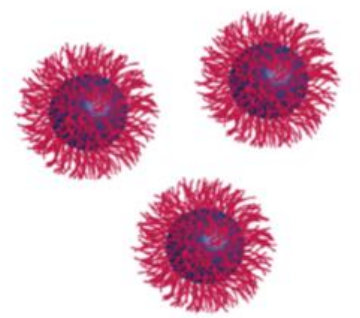
Hoe groot is nano?

voetbal



÷

nanodeeltje



aarde



÷

voetbal



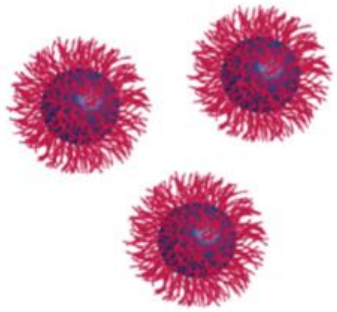
Hoe groot is nano?

voetbal



÷

nanodeeltje



aarde



÷

voetbal



Welke ratio van diameters is groter?

- (a) Voetbal/nanodeeltje
- (b) Aarde/voetbal
- (c) Even groot
- (d) Geen idee!

Hoe groot is nano?

- 4-jarig kind



1 m

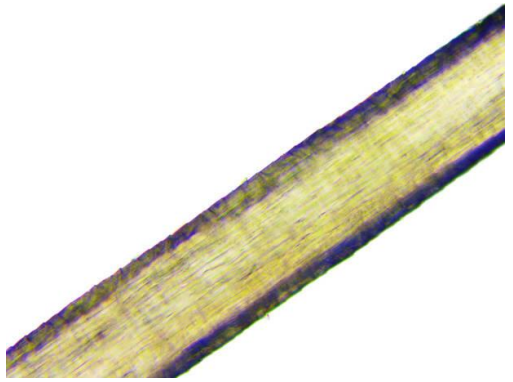
Hoe groot is nano?

■ 4-jarig kind

■ Mensenhaar



1 m



0.000,1 m
(100 μm)

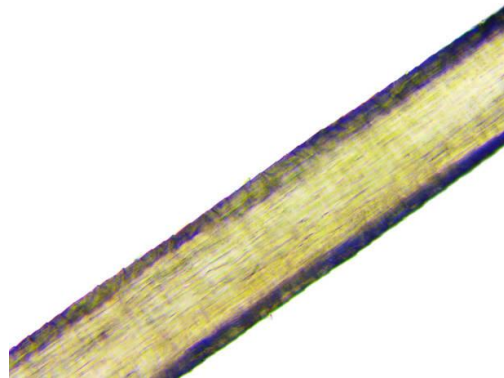
Hoe groot is nano?

- 4-jarig kind



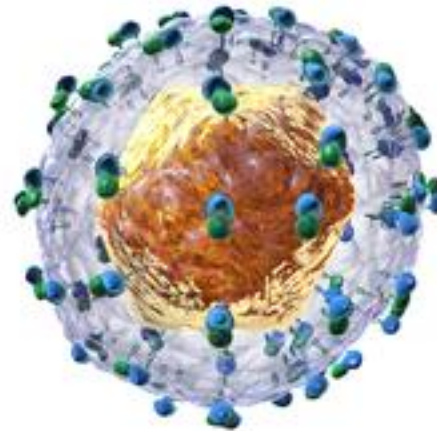
1 m

- Mensenhaar



0.000,1 m
(100 μ m)

- Virus deeltje



0.000,000,1 m
(100 nm)

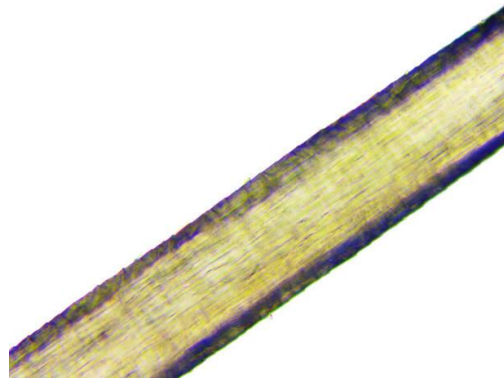
Hoe groot is nano?

- 4-jarig kind



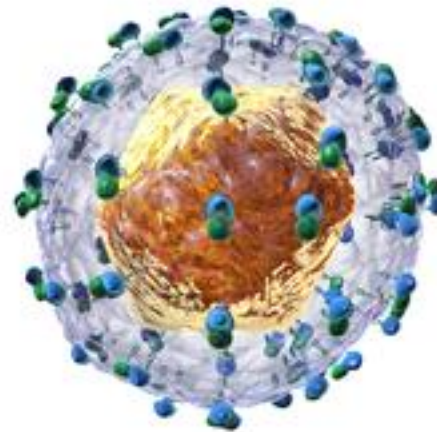
1 m

- Mensenhaar



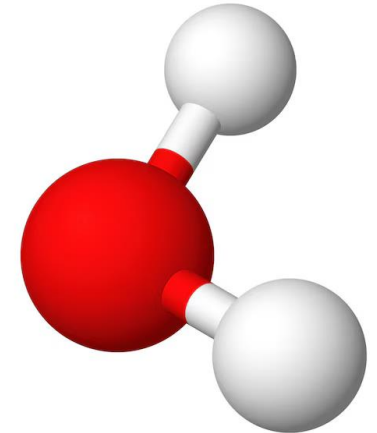
0.000,1 m
(100 μm)

- Virus deeltje



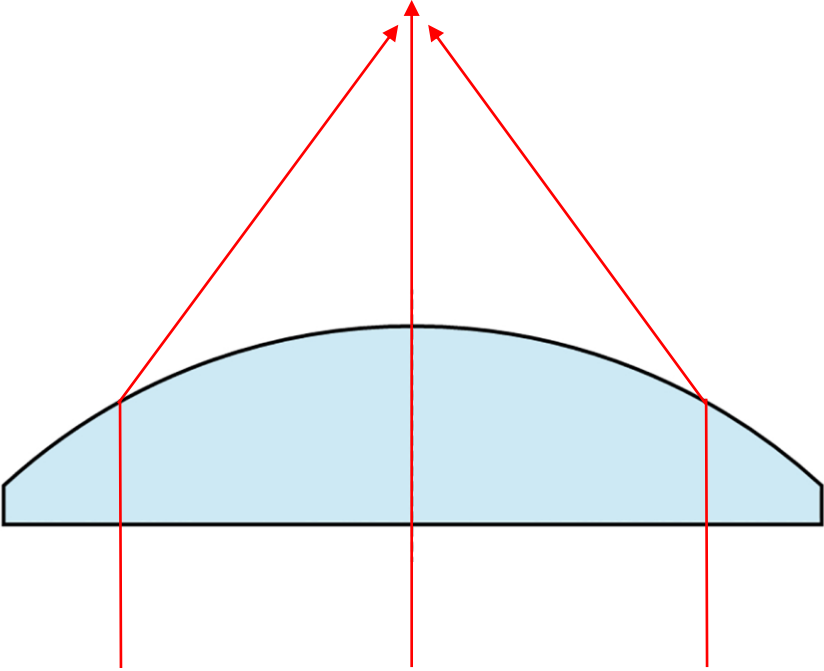
0.000,000,1 m
(100 nm)

- Water molecuul

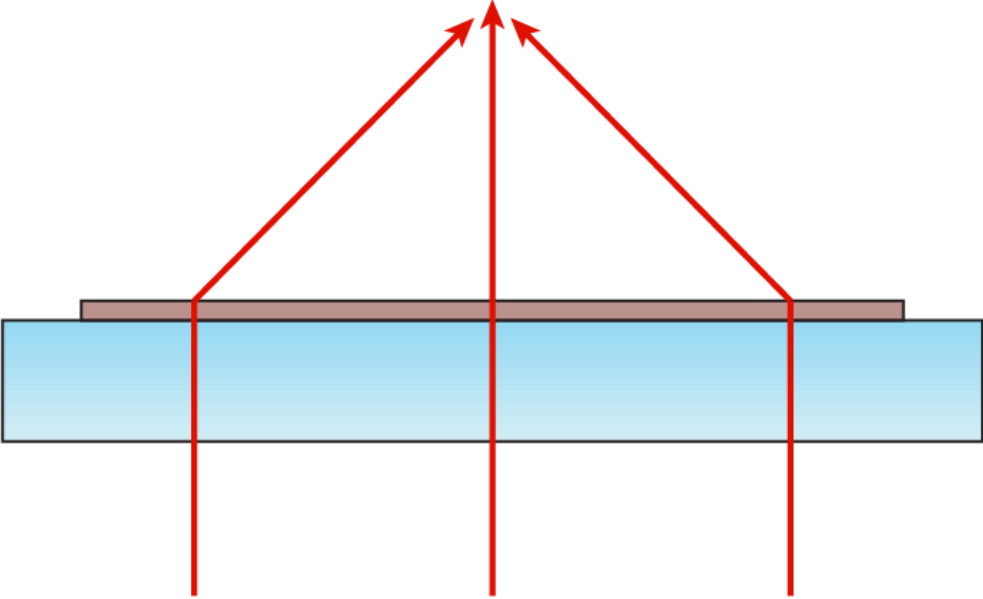


0.000,000,000,1 m
(0.1 nm)

Van macroschaal naar nanoschaal



~ 1 cm



< 1 nm

Van macroschaal naar nanoschaal



Ingrediënten:

1) Zeer sterke interactie met licht

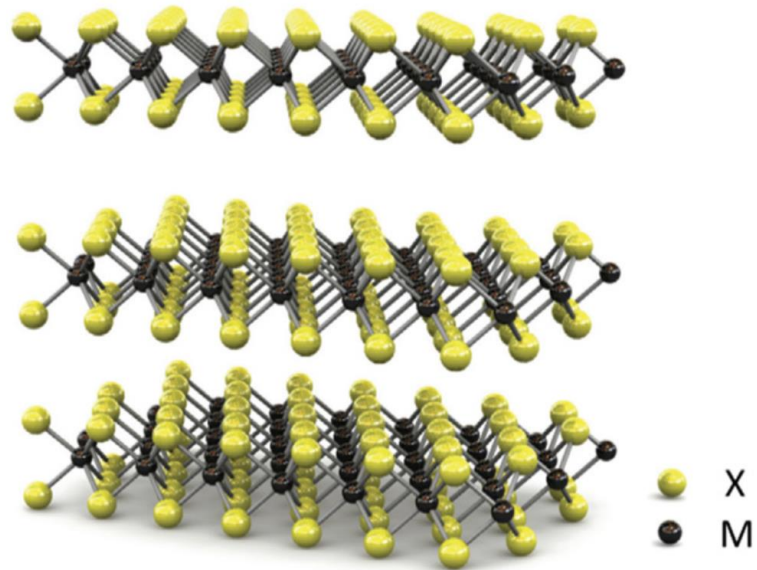
2) Ontwerp voor “vlakke” lens

$\sim 1 \text{ cm}$

$< 1 \text{ nm}$

Nieuwe 2D quantummaterialen

- Gelaagde atoomstructuur

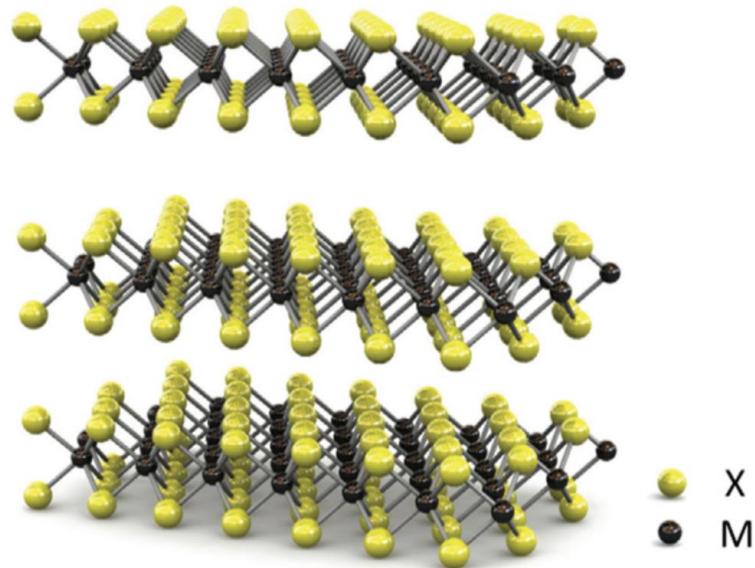


M = Mo, W

X = Se, S

Nieuwe 2D quantummaterialen

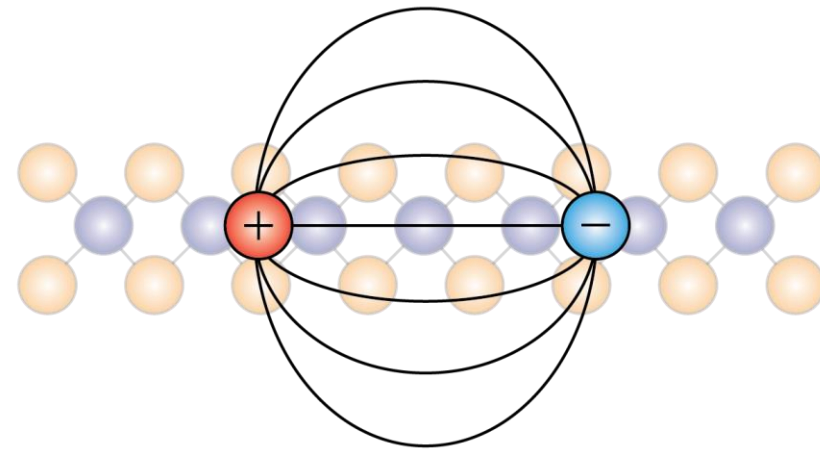
- Gelaagde atoomstructuur



M = Mo, W
X = Se, S

Nature Nano. 6, 147 (2011)

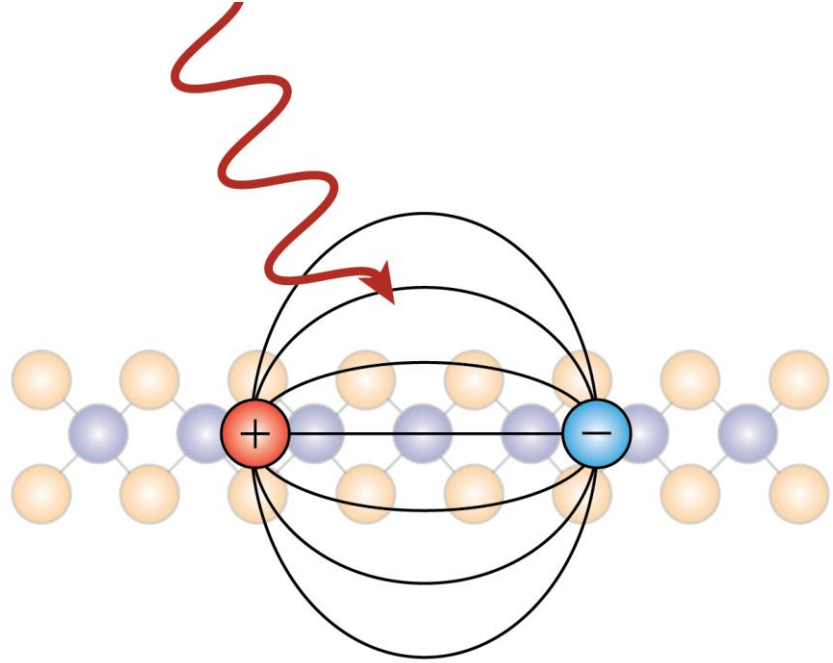
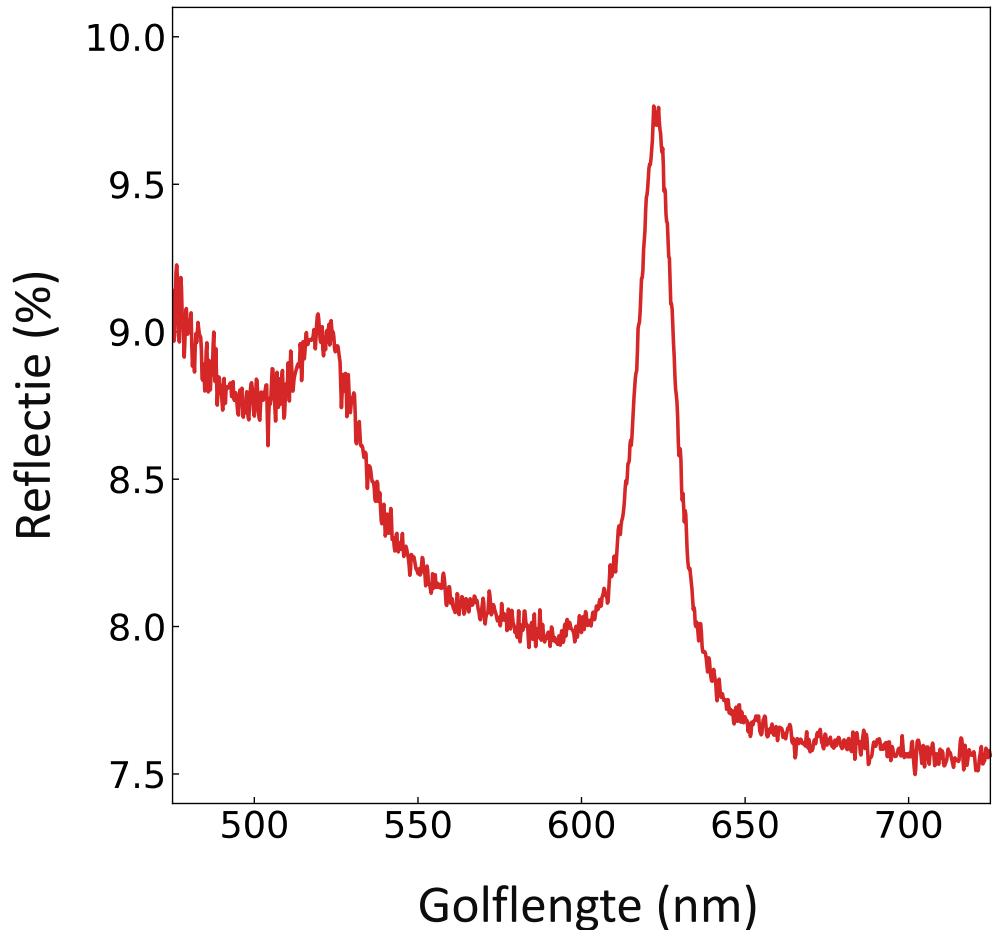
- Monolaag: 0.6 nm dik



- Exciton: elektron gebonden aan “gat”

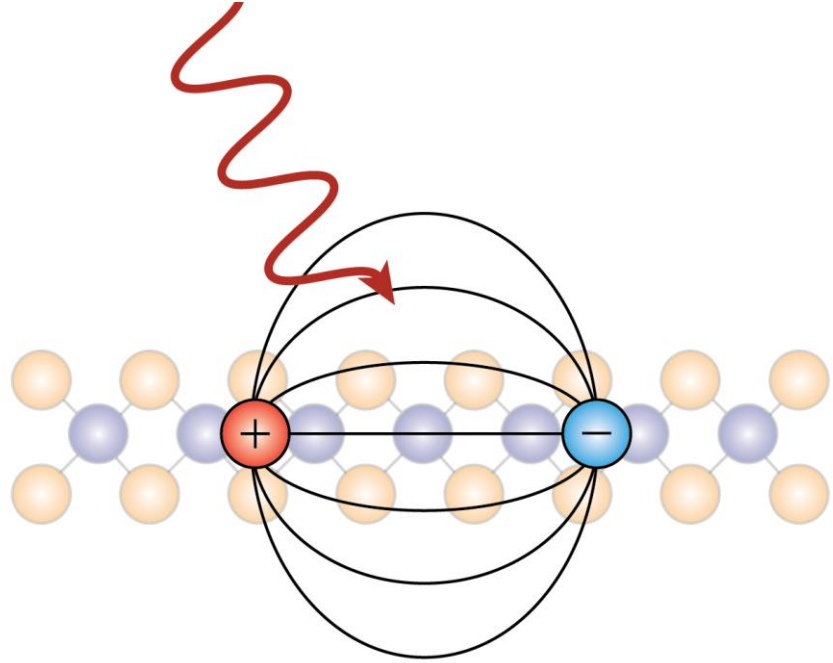
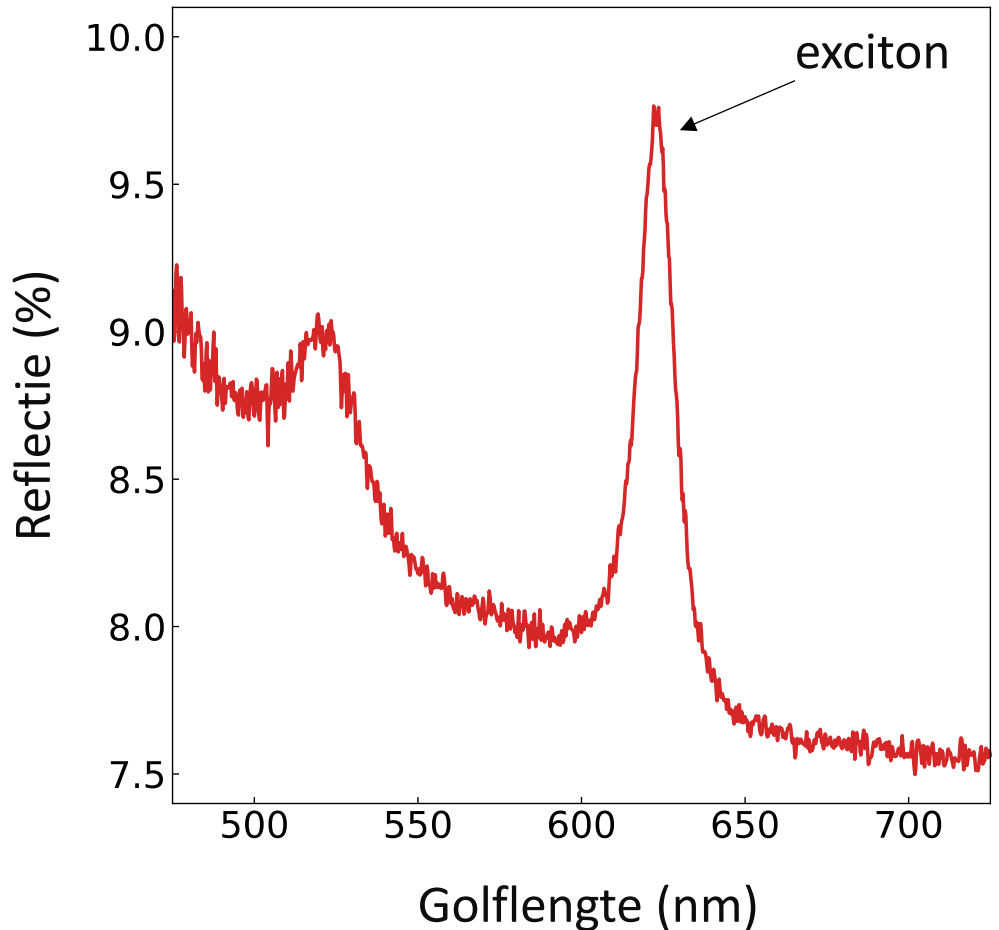
Nieuwe 2D quantummaterialen

- Sterke interactie met licht



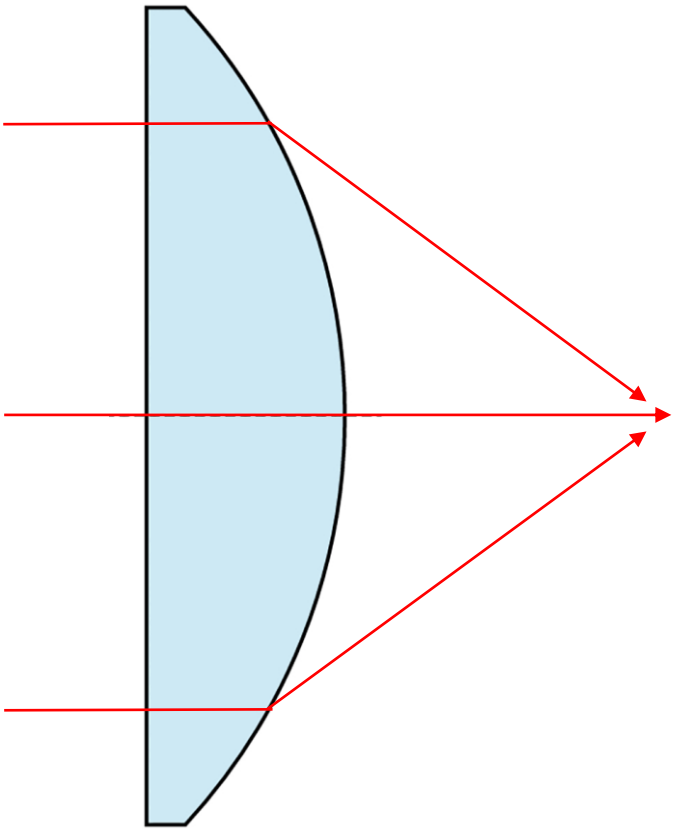
Nieuwe 2D quantummaterialen

- Sterke interactie met licht

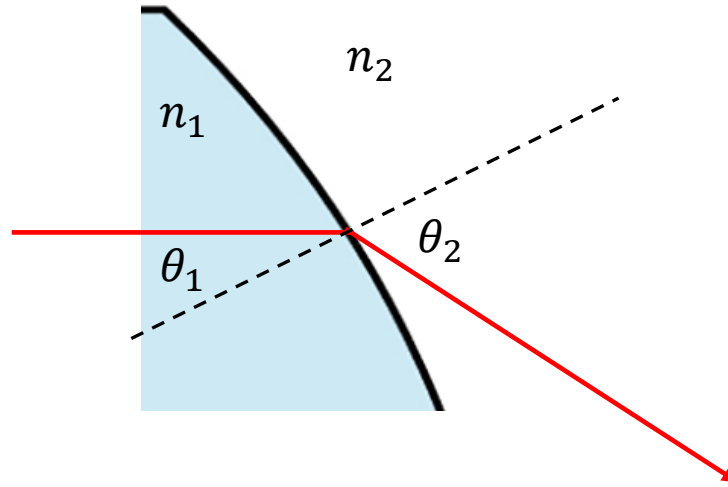


Van 3D lens...

- Refractie



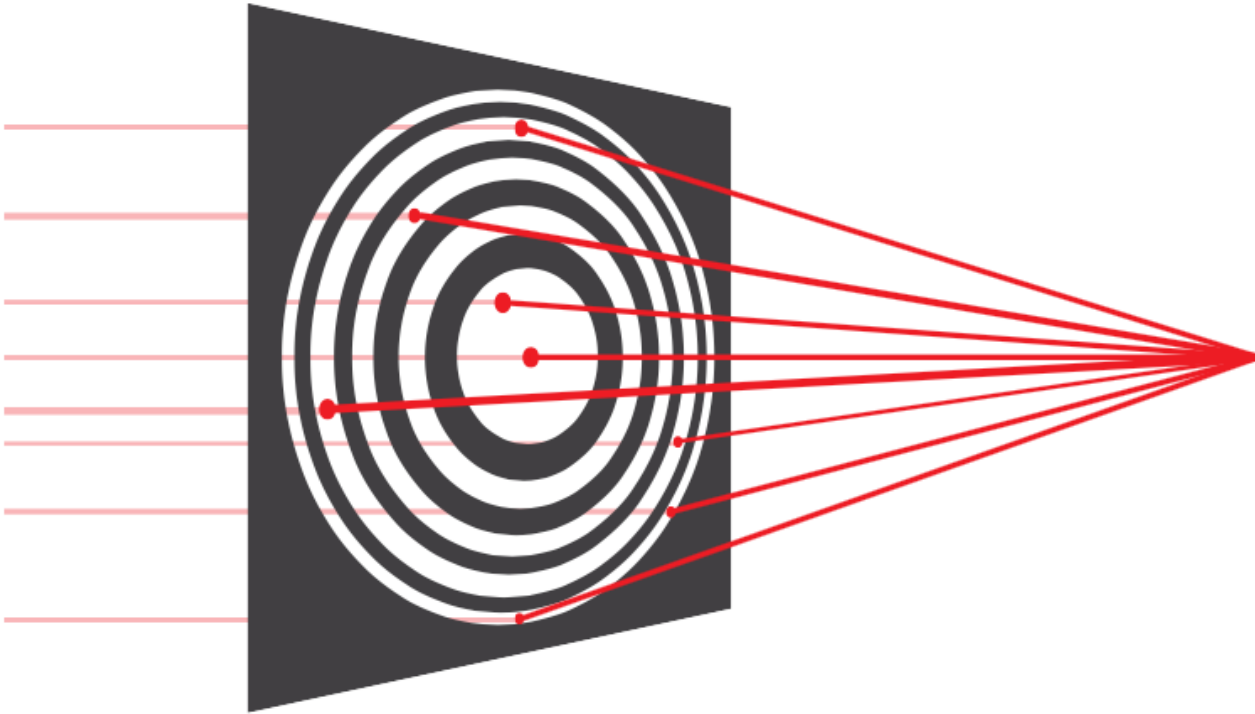
- Wet van Snellius



$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

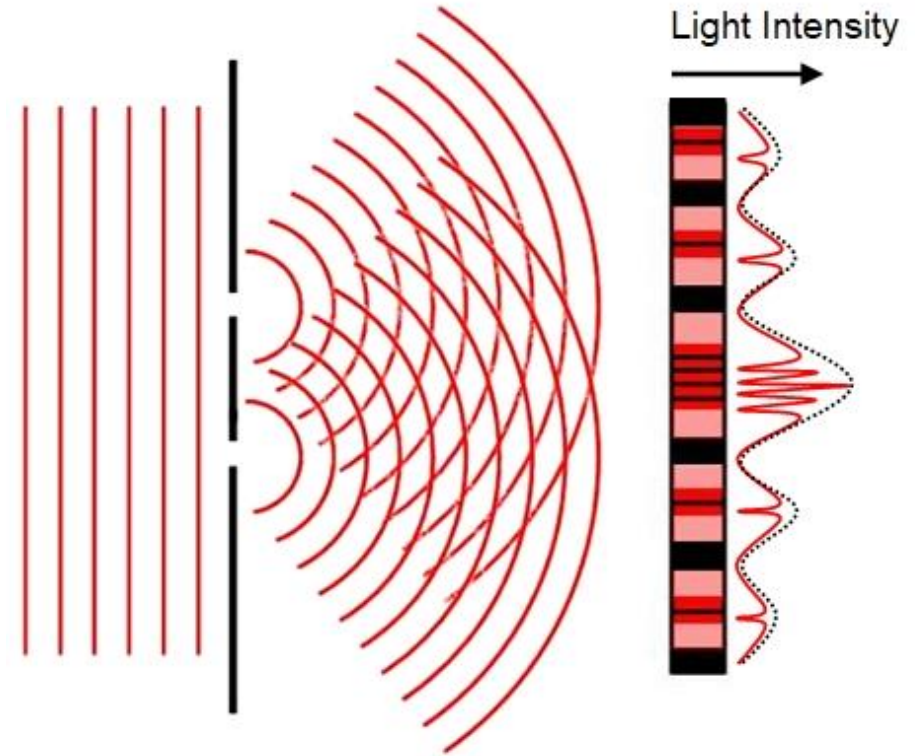
...naar 2D lens

- Zone plate lens



zoneplate.lbl.gov

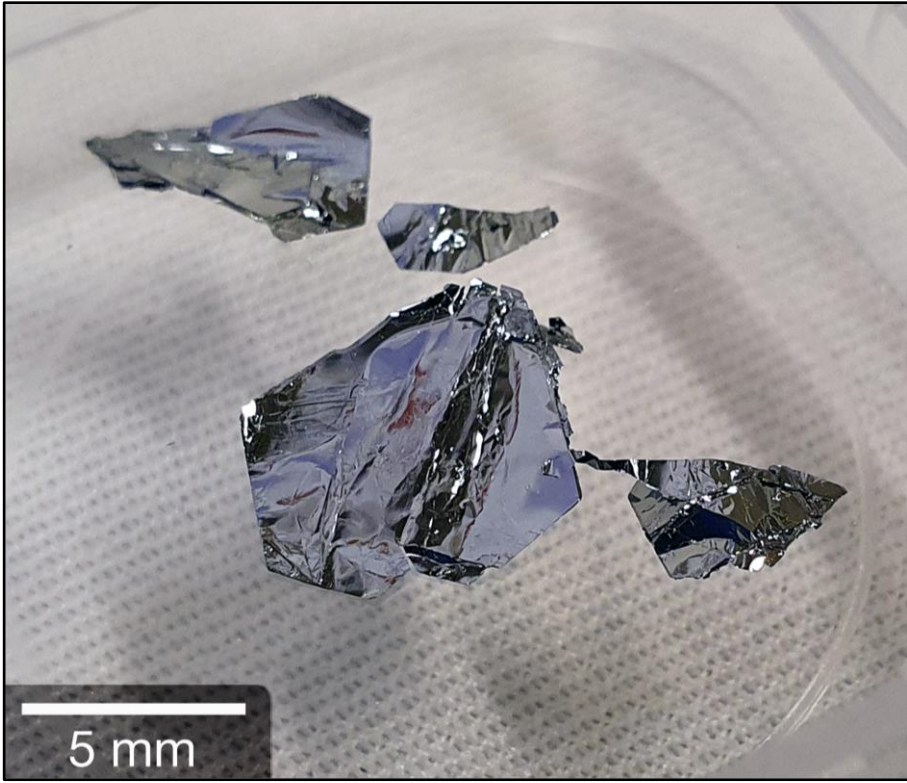
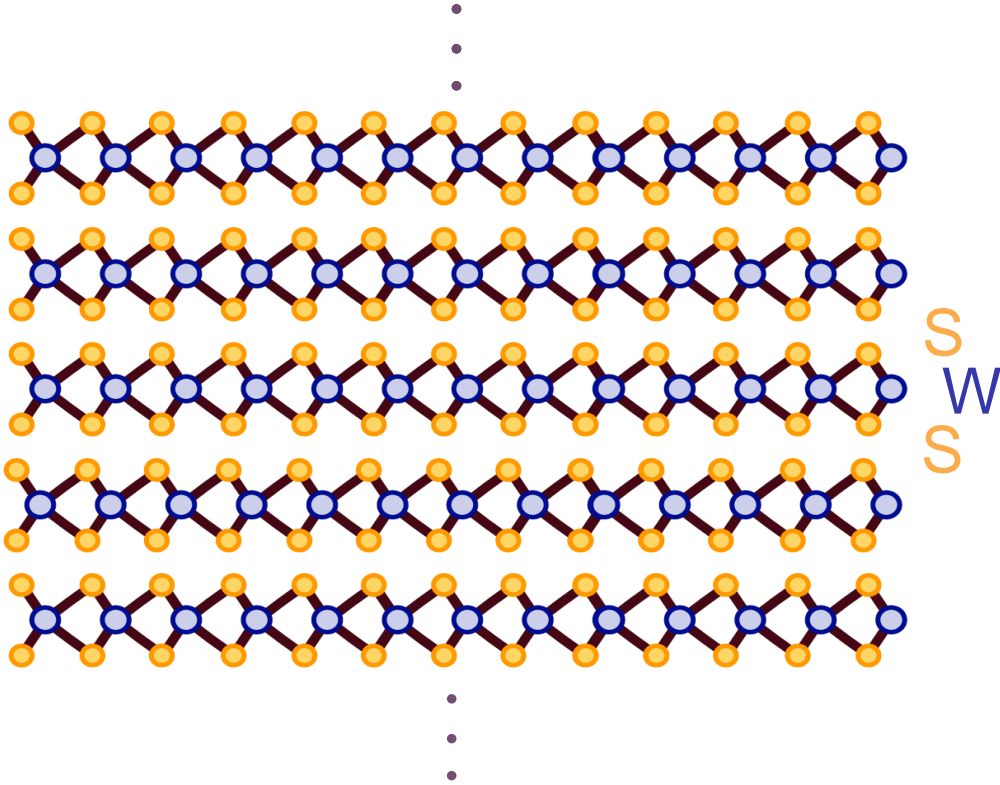
- Diffractie



cronodon.com

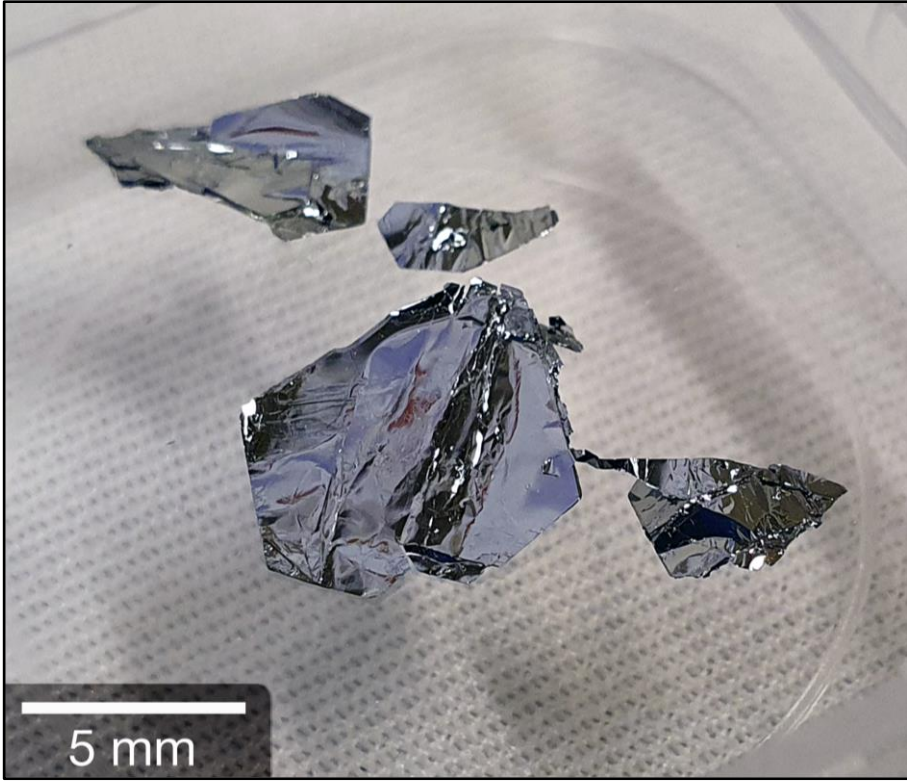
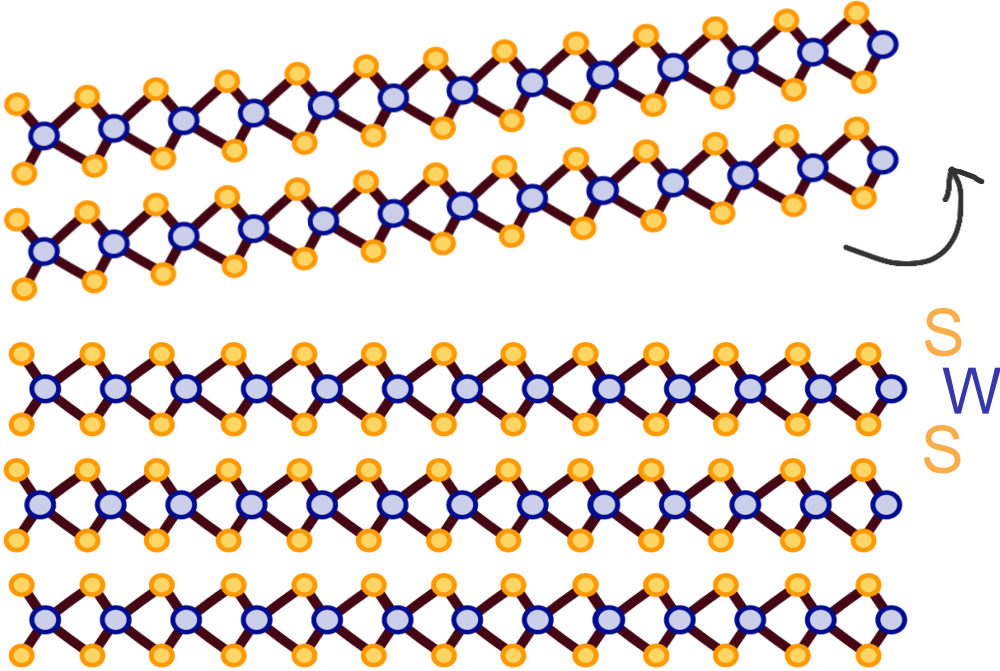
2D materiaal exfoliatie

- Bulk WS_2



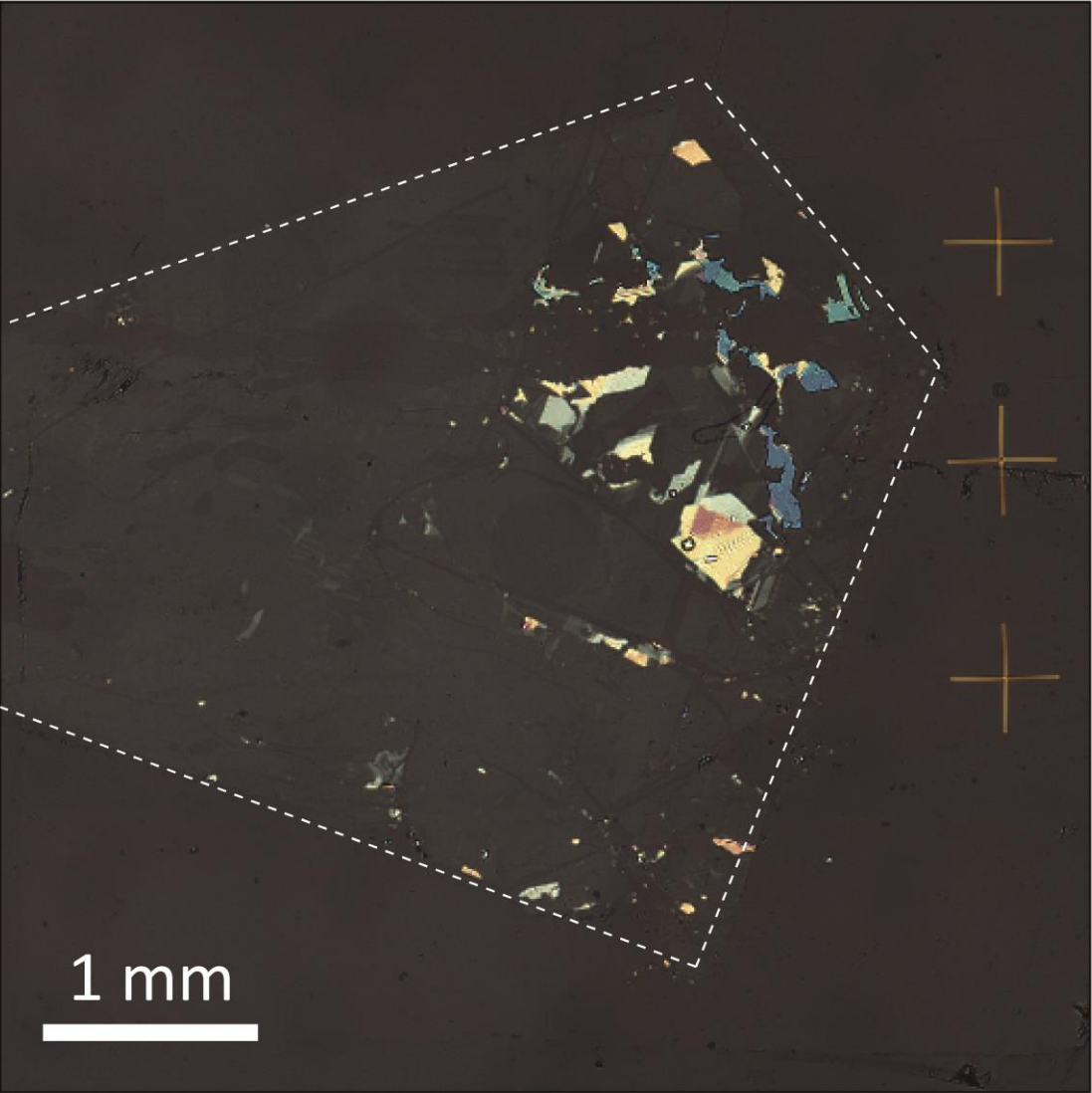
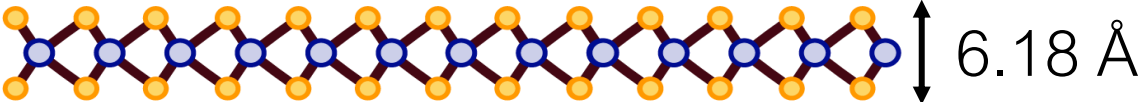
2D materiaal exfoliatie

- Bulk WS_2

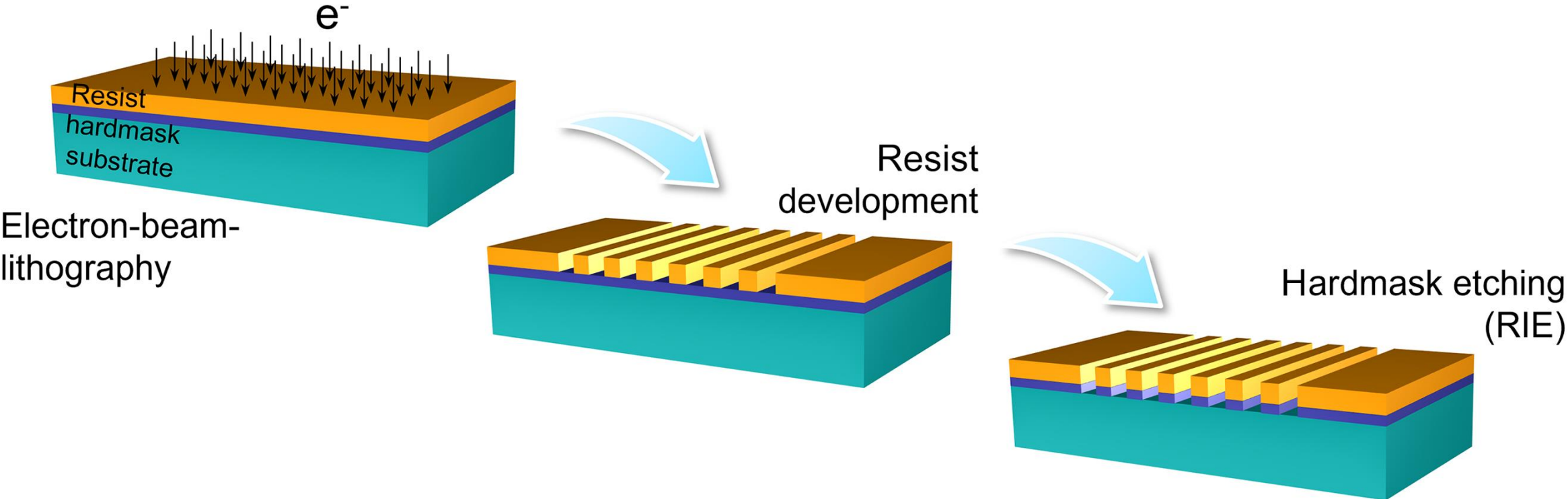


2D materiaal exfoliatie

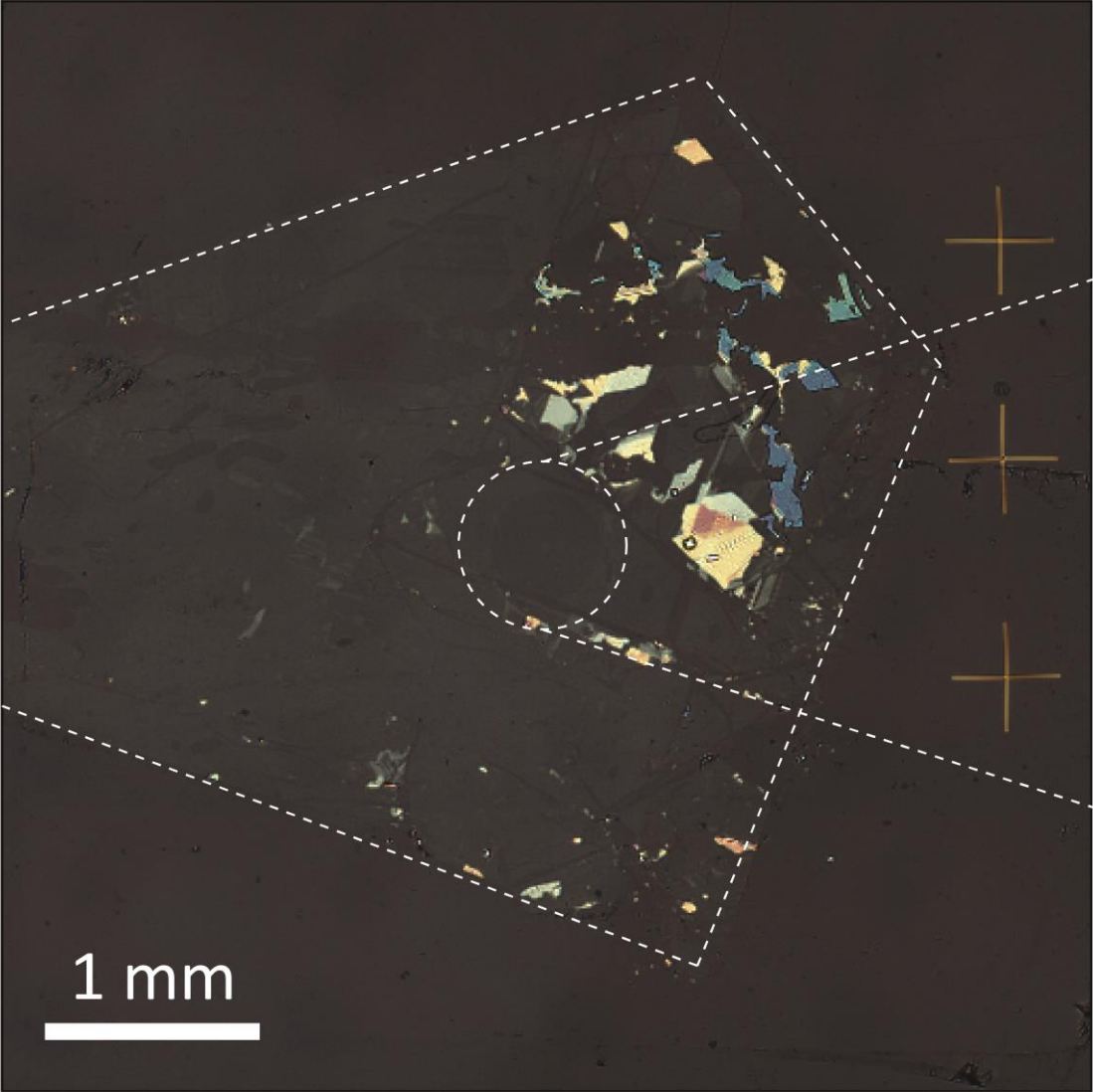
- Monolaag WS₂



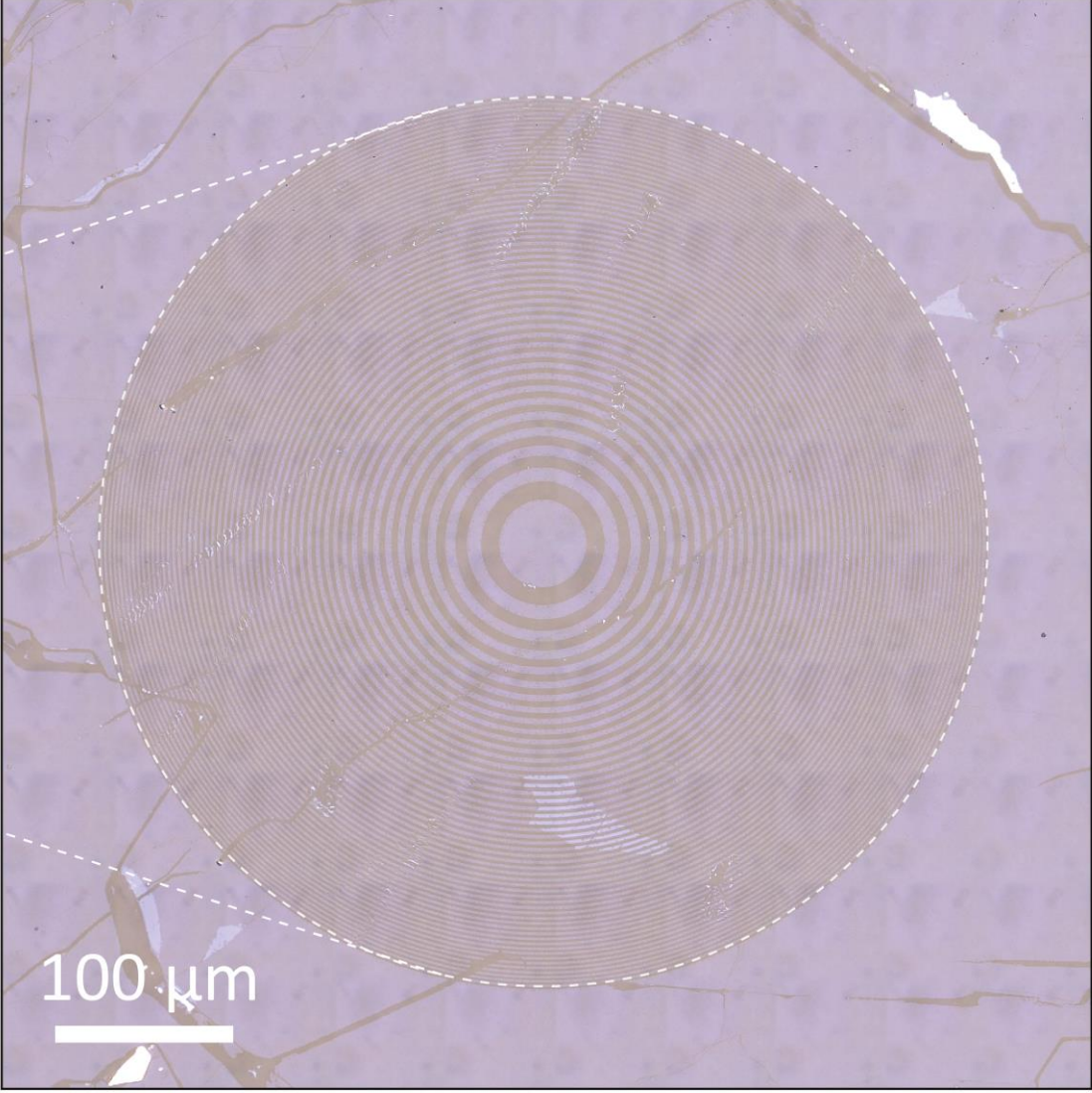
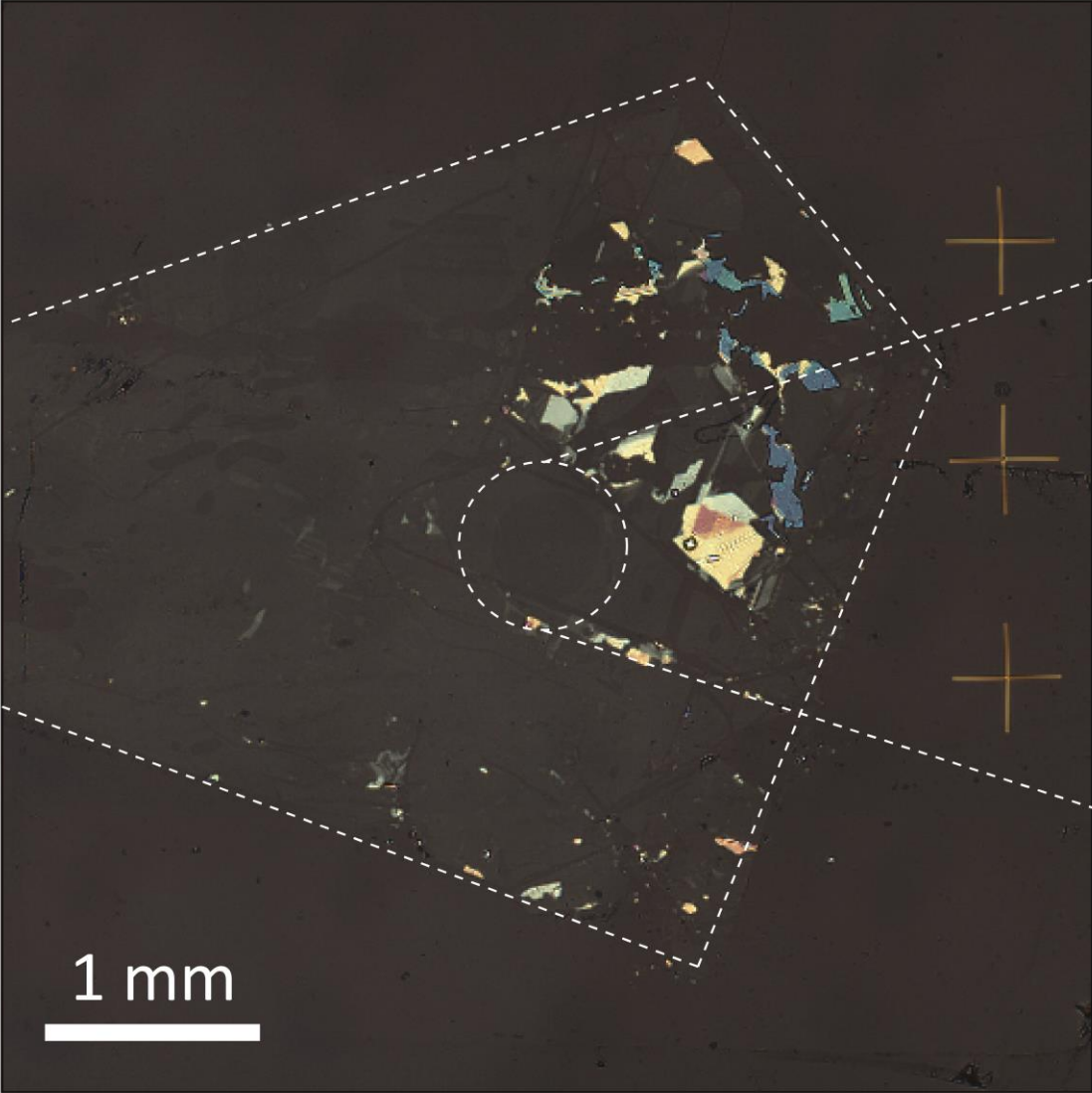
Nanolithografie



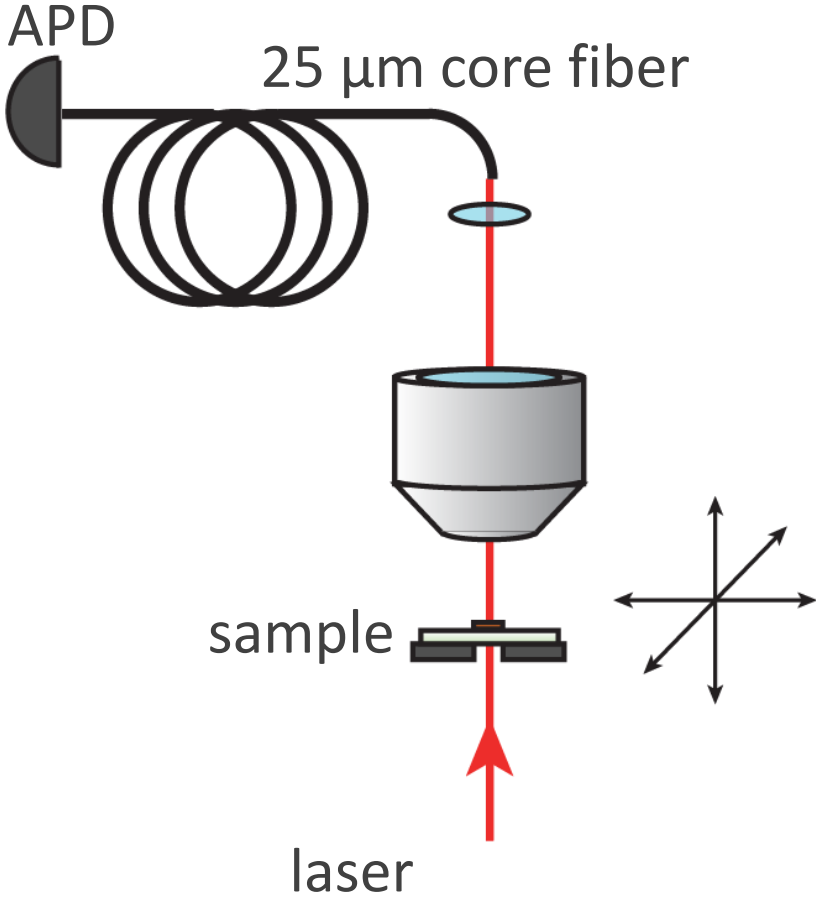
Een lens met dikte van 1 atoomlaag



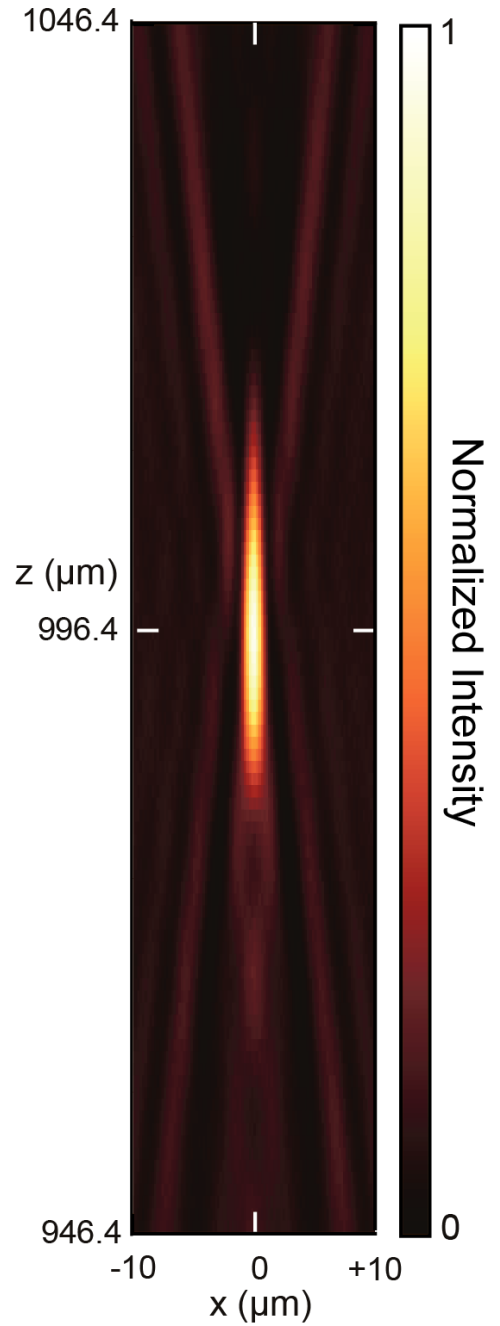
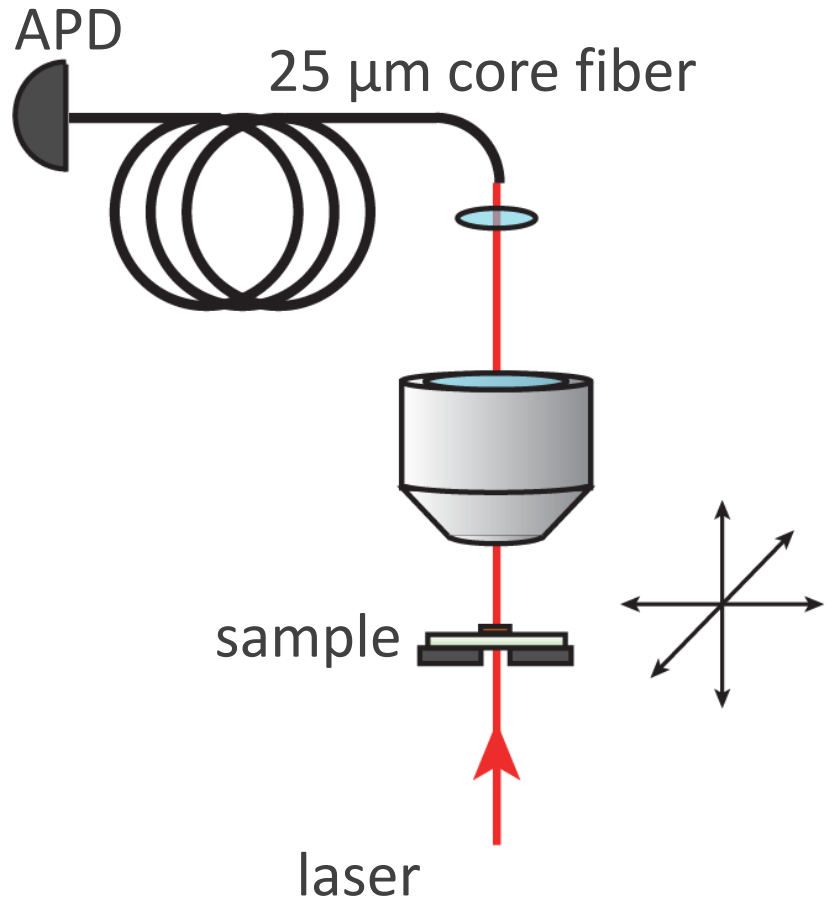
Een lens met dikte van 1 atoomlaag



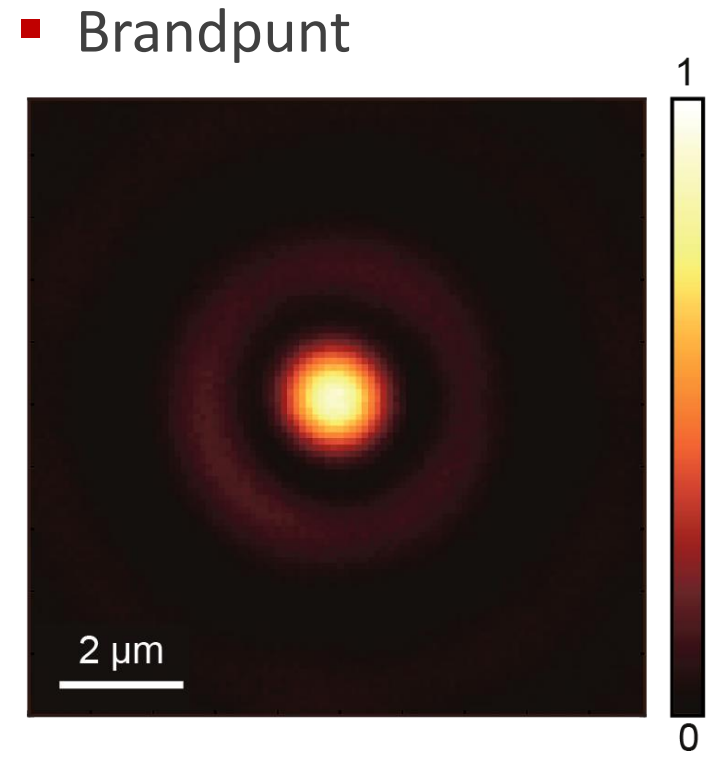
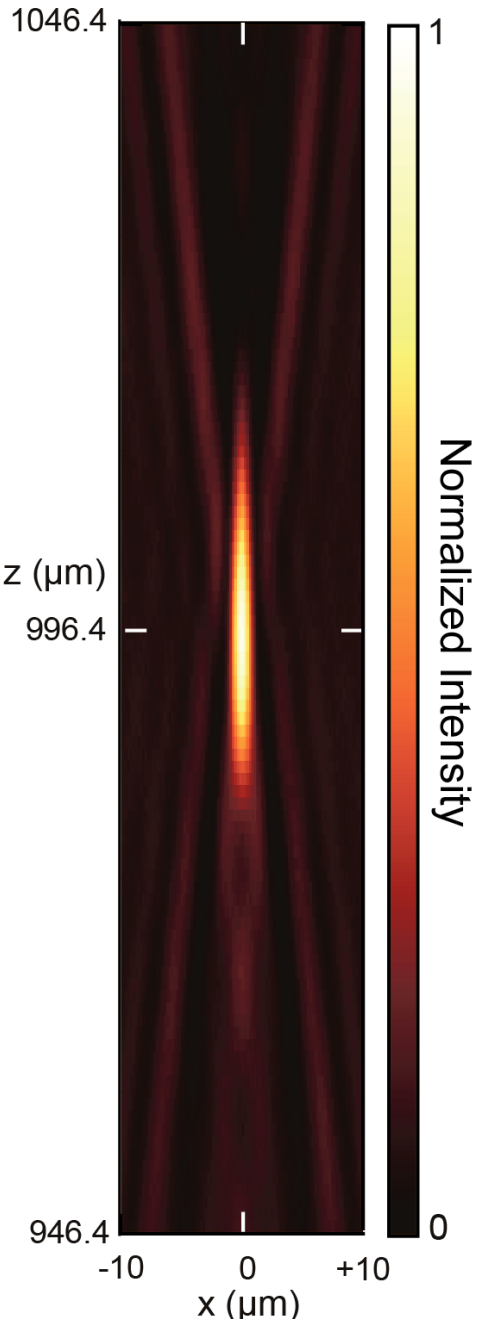
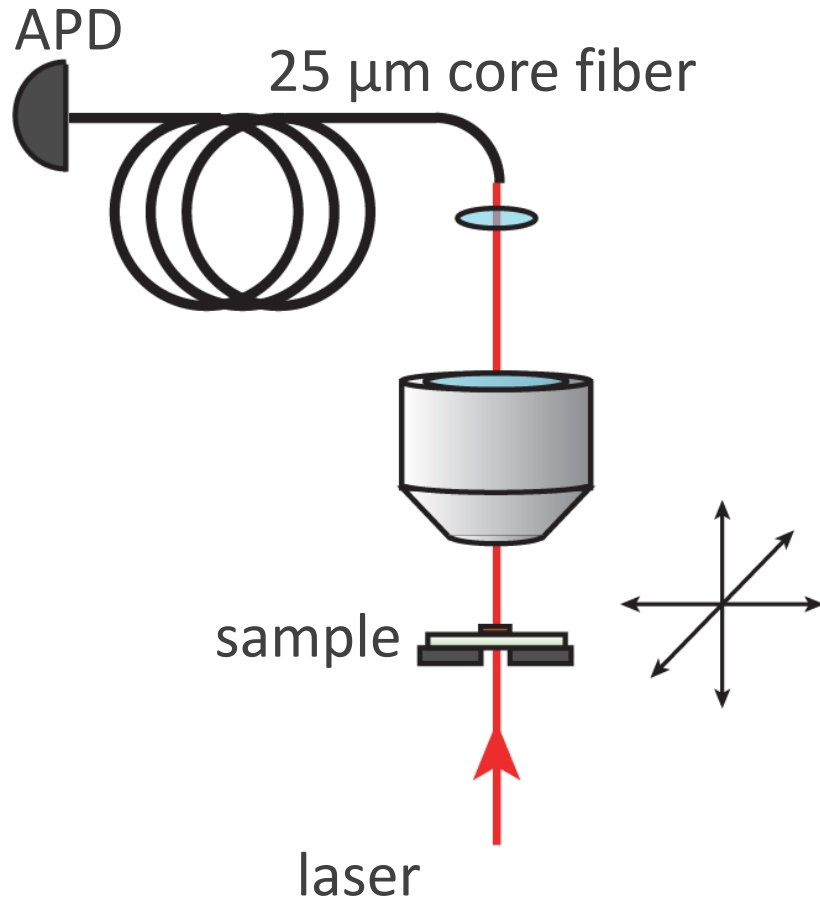
Werking van de lens



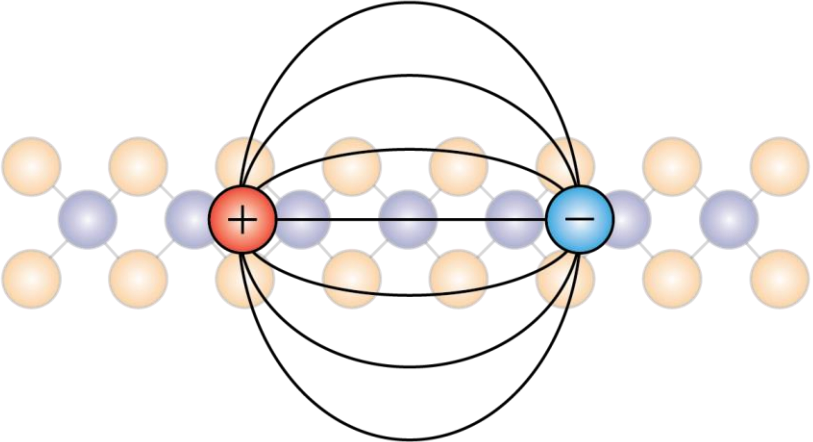
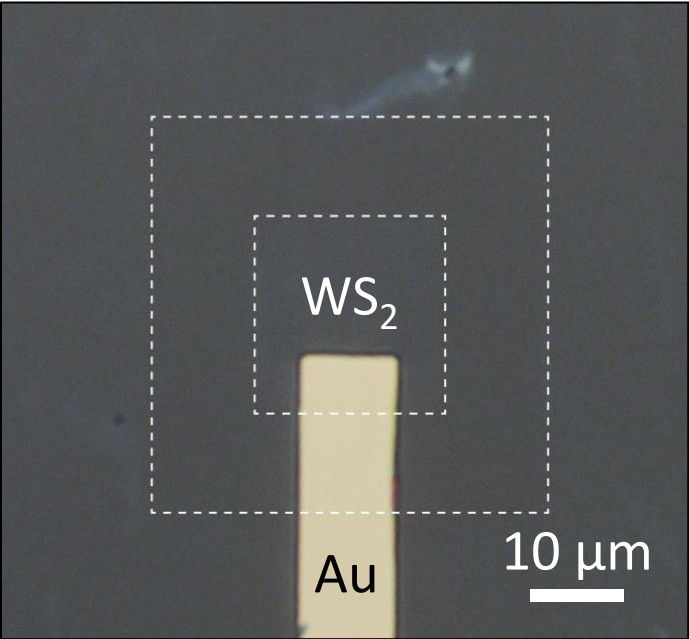
Werking van de lens



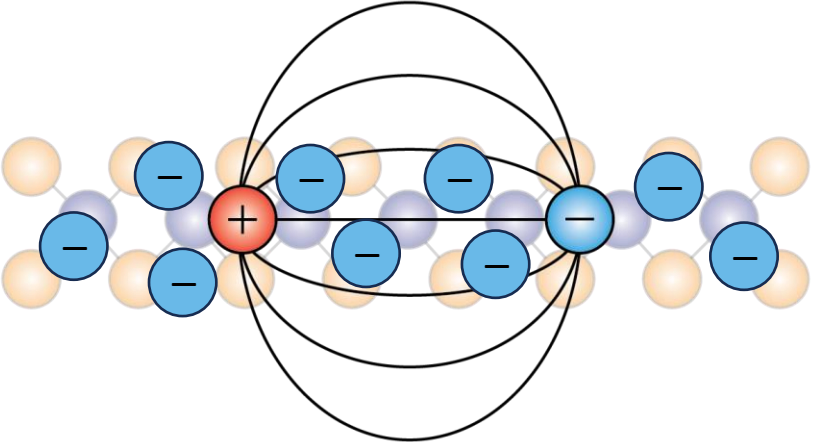
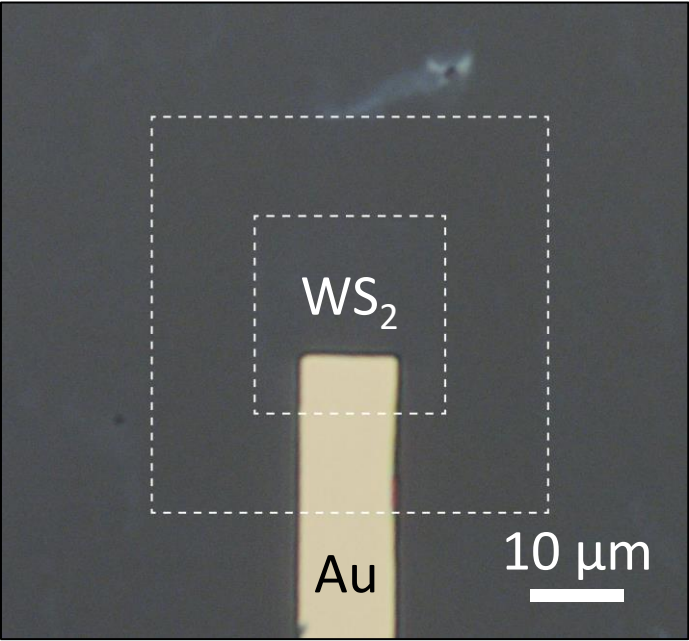
Werking van de lens



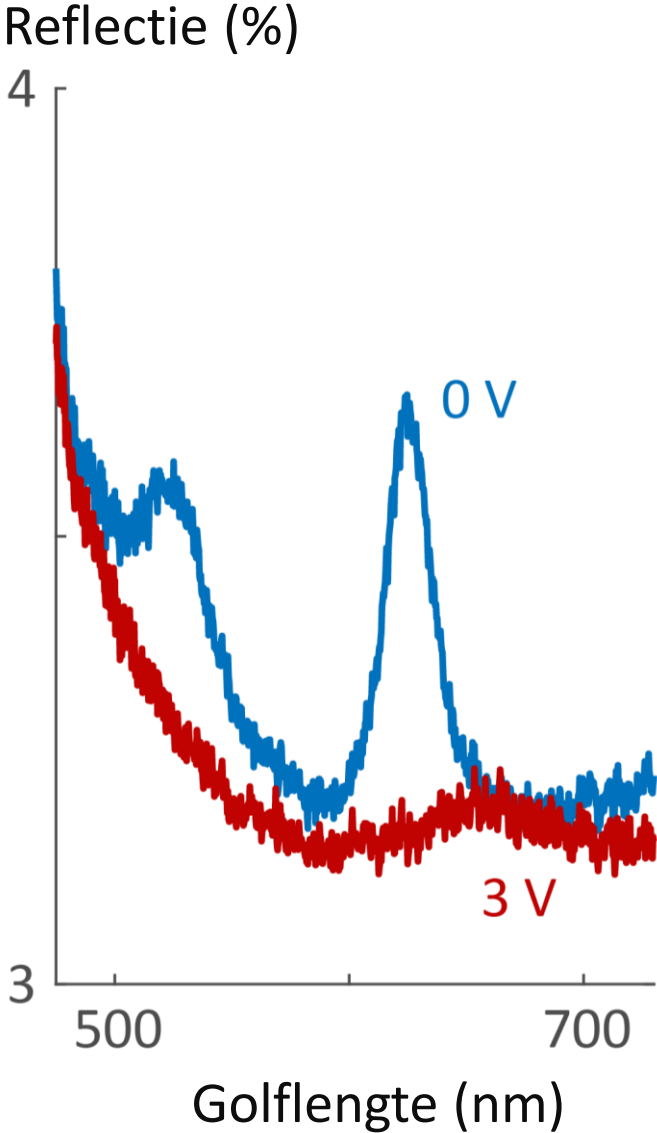
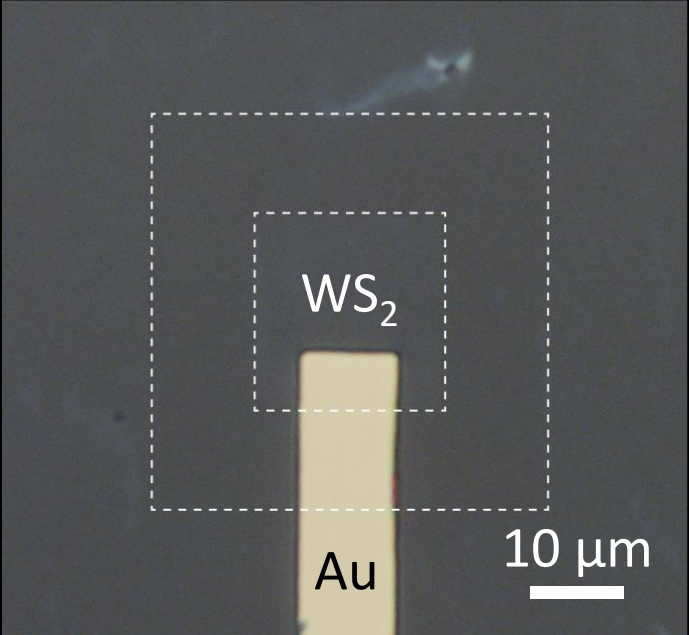
Elektrisch verstellbare brekingsindex



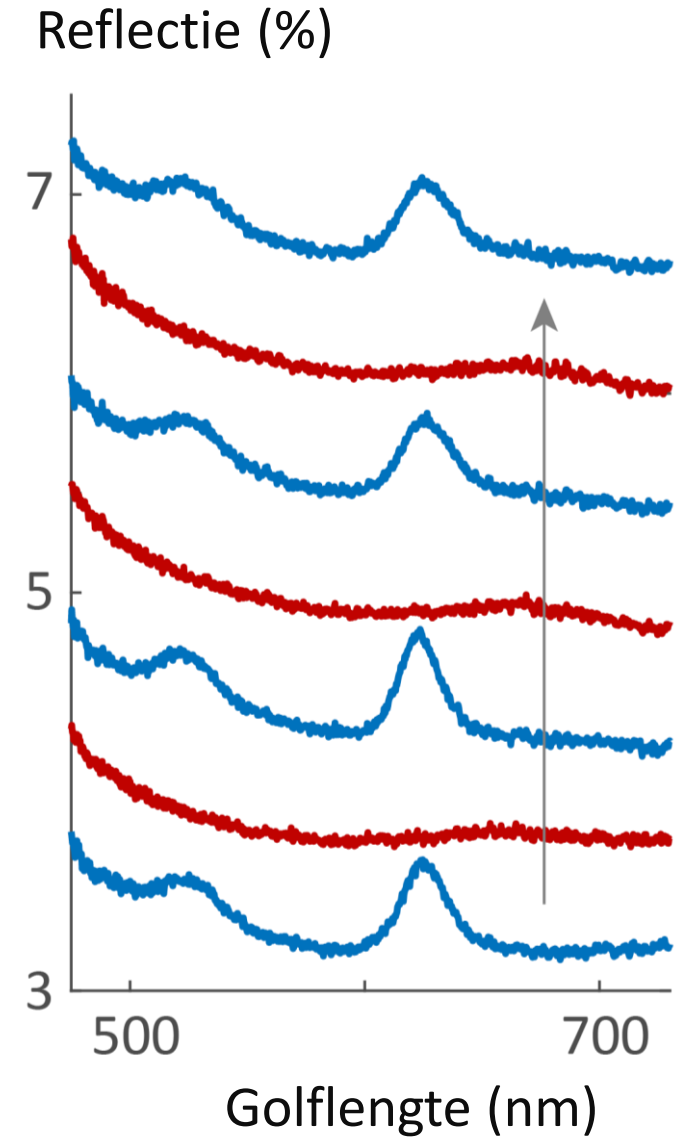
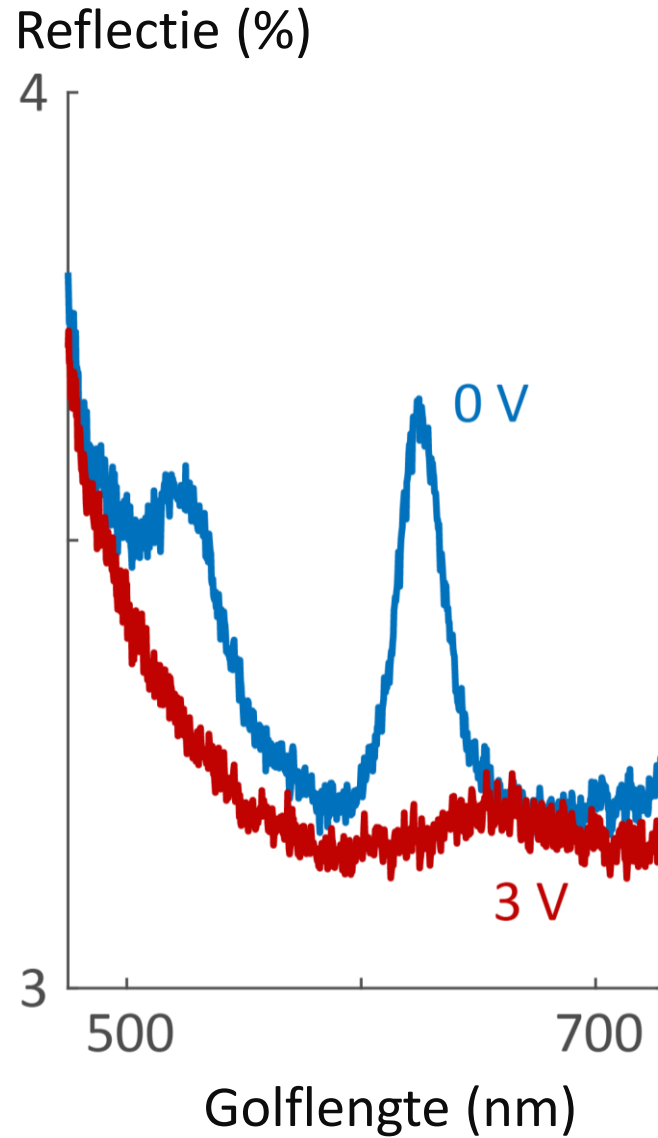
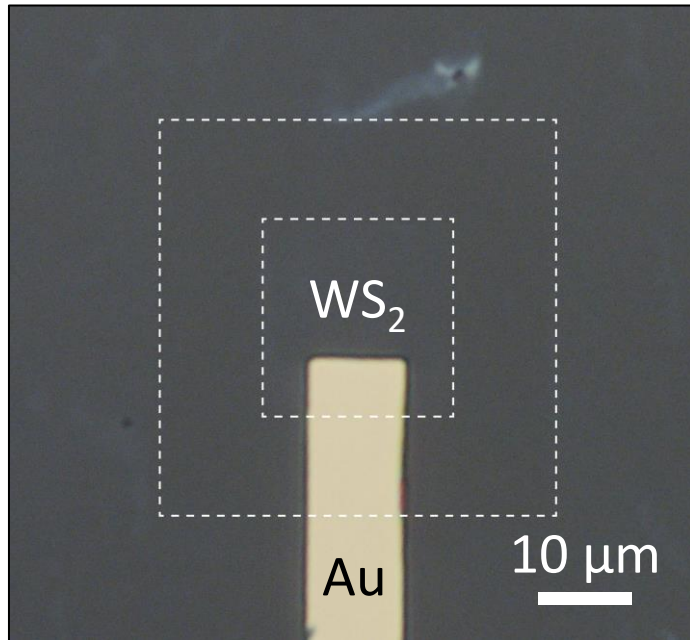
Elektrisch verstellbare brekingsindex



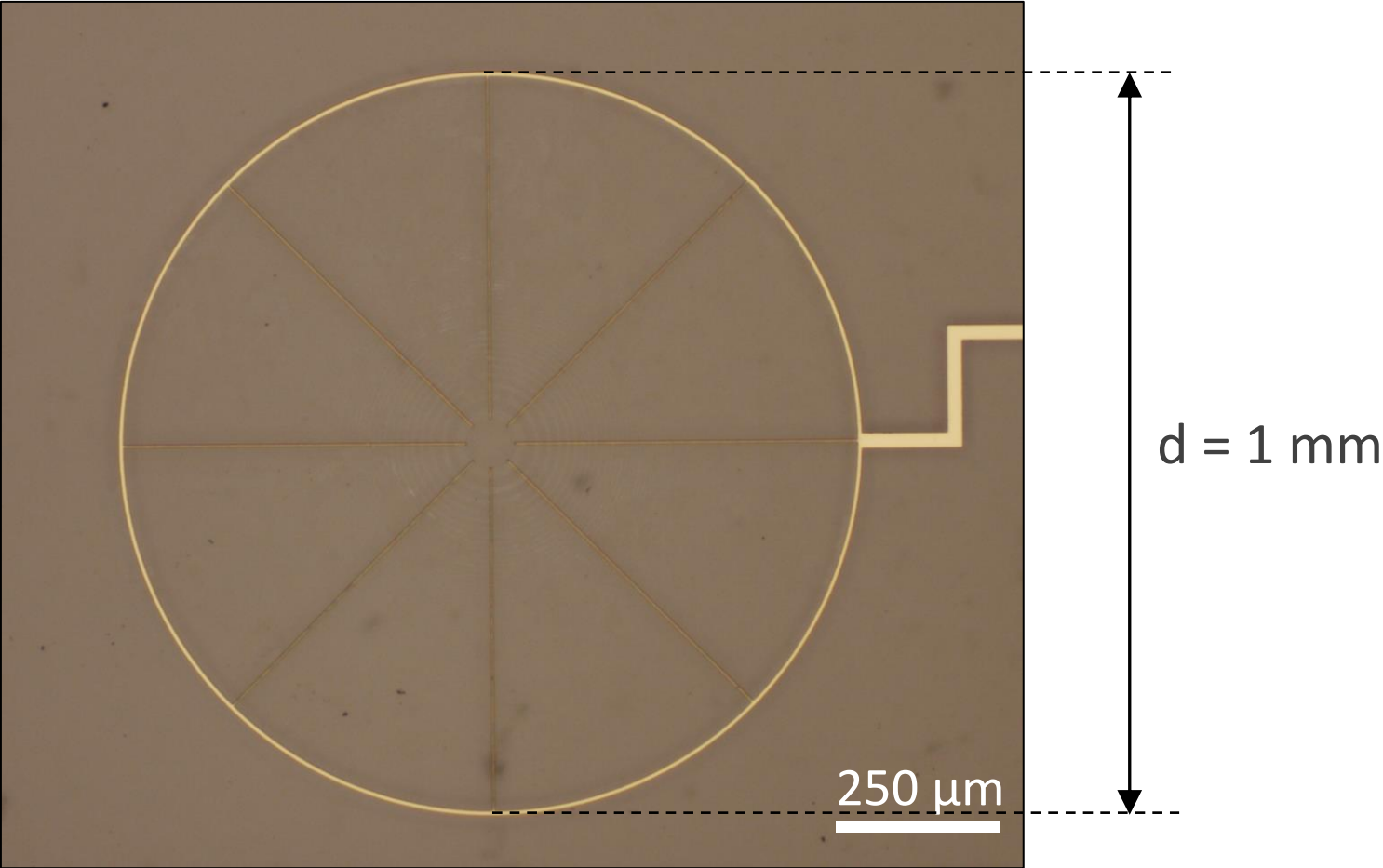
Elektrisch verstelbare brekingsindex



Elektrisch verstelbare brekingsindex

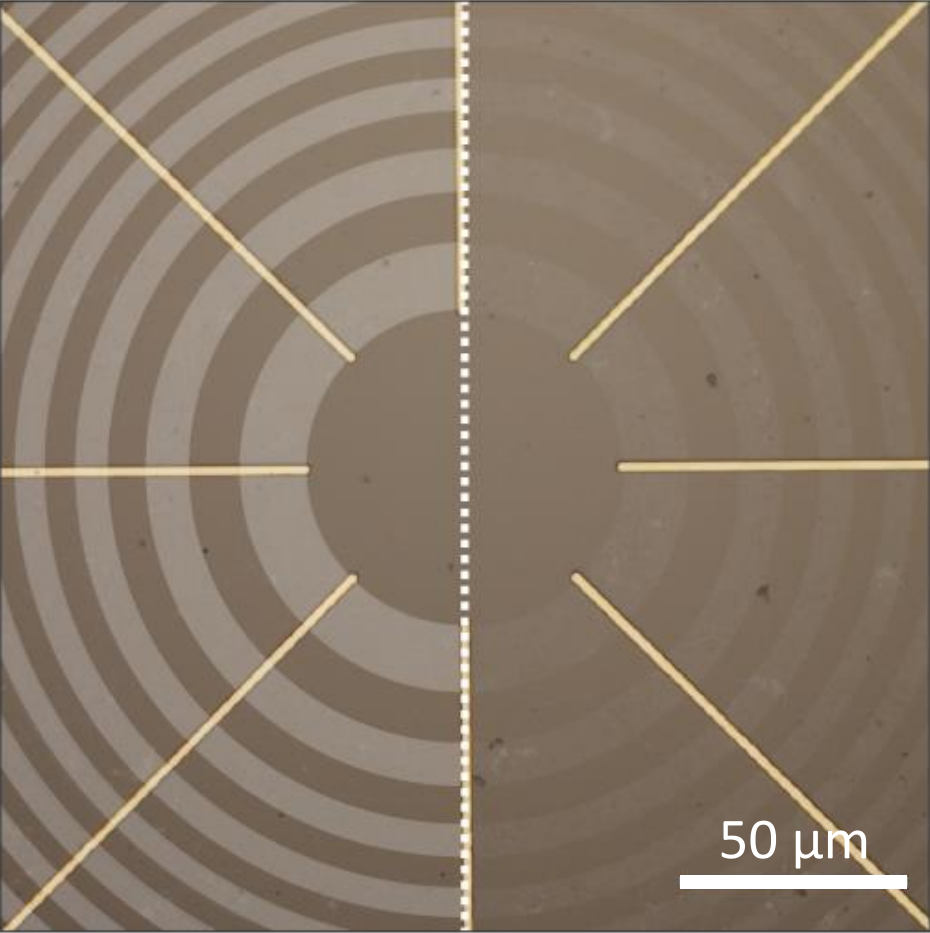
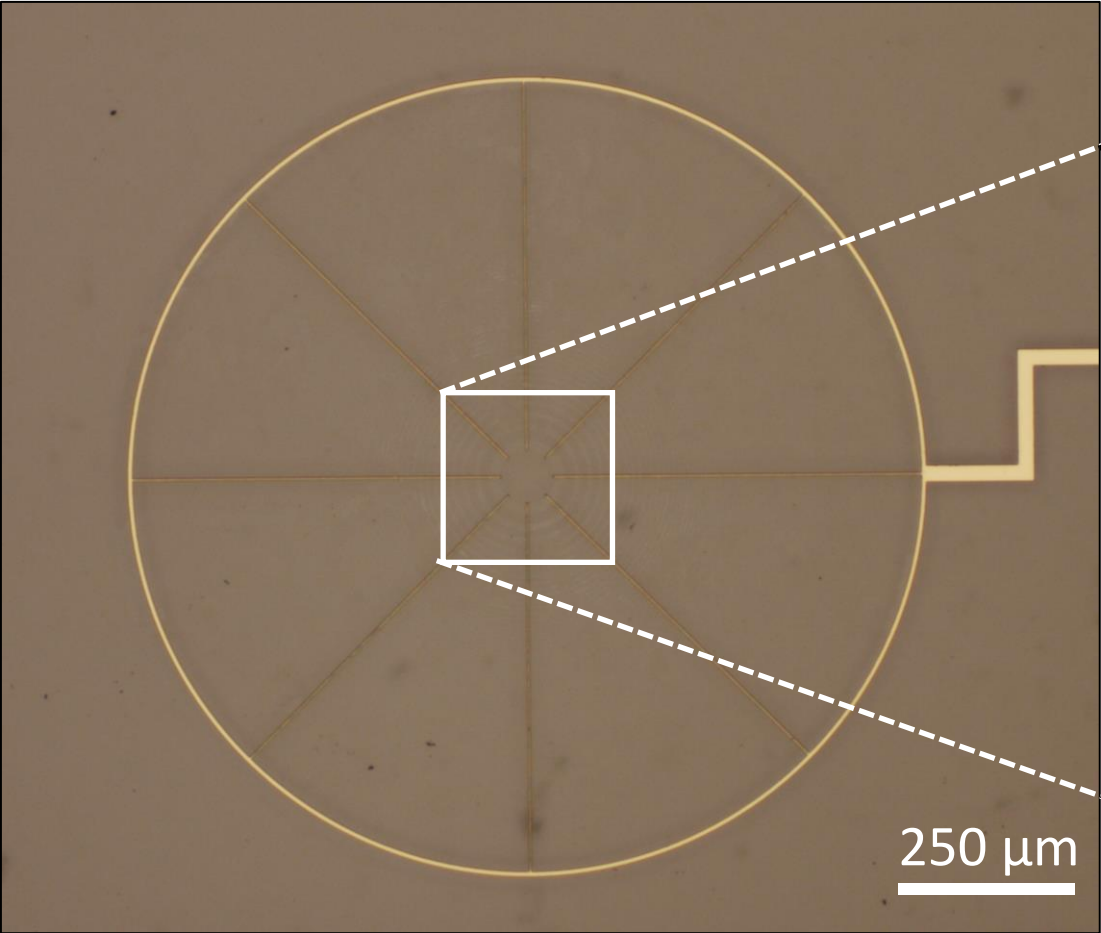


Fabricage elektrische lens



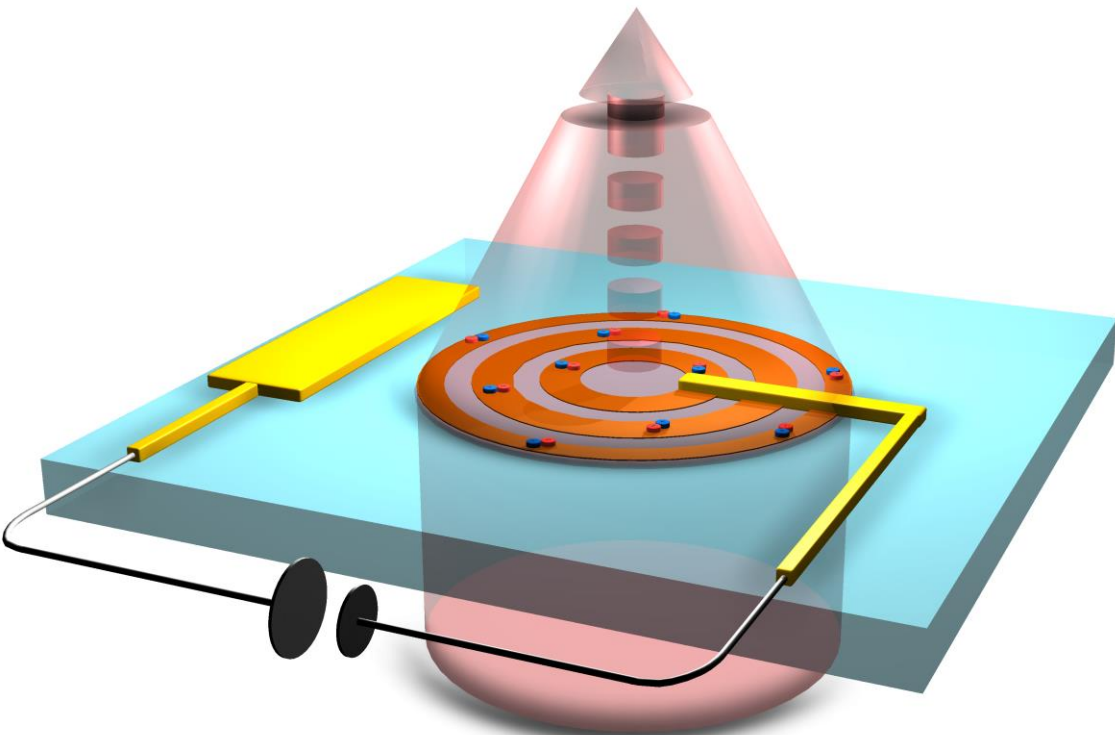
■ $f = 2 \text{ mm}$

Fabricage elektrische lens

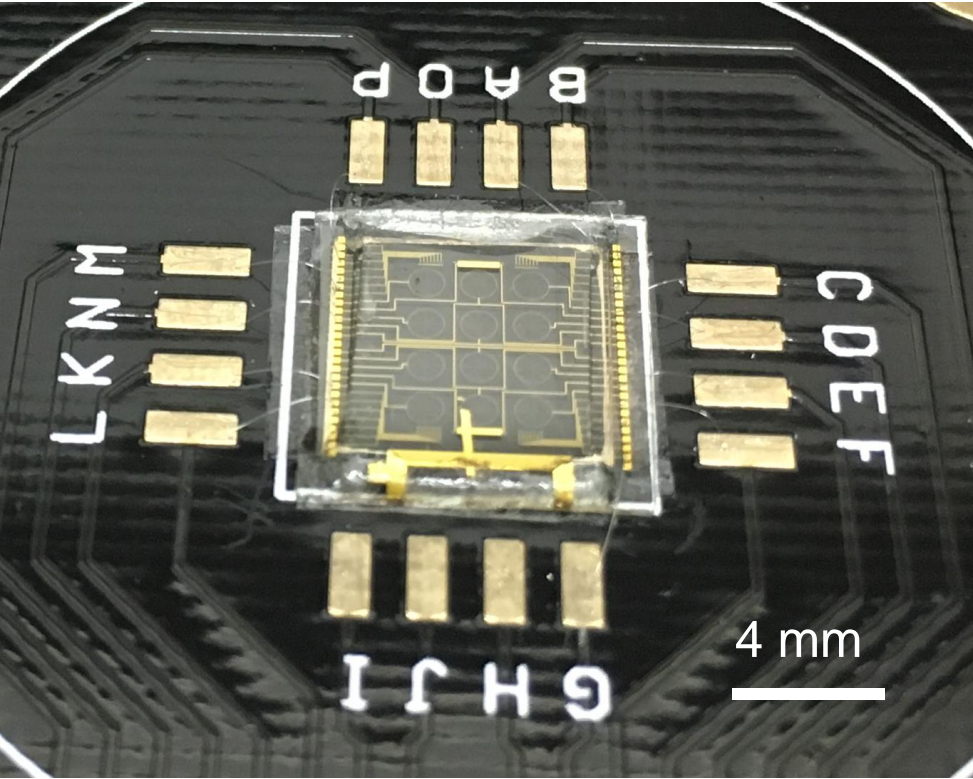
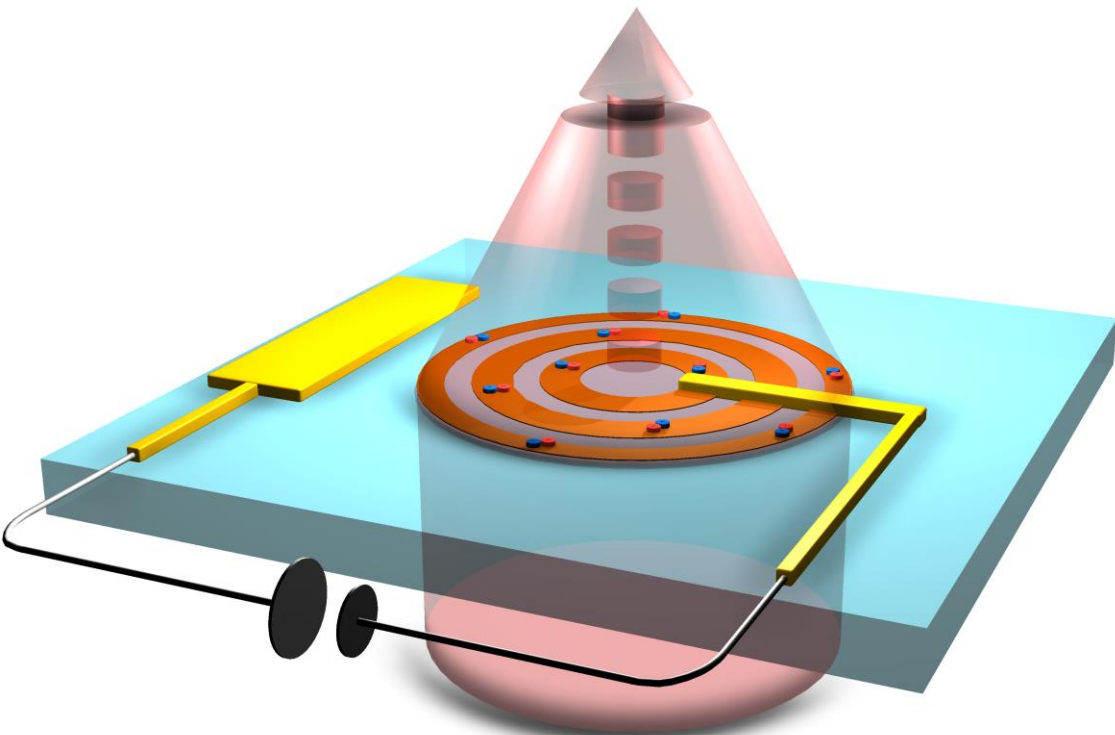


■ $f = 2 \text{ mm}$

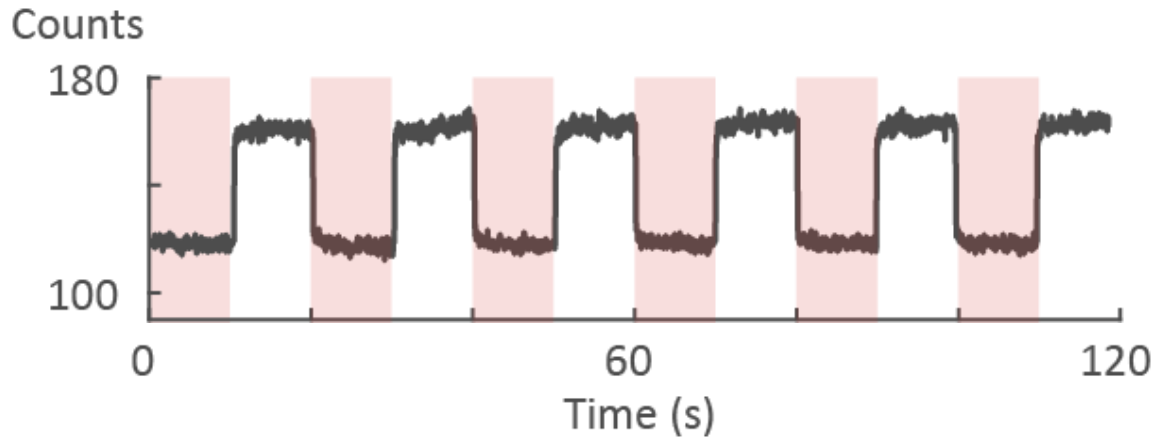
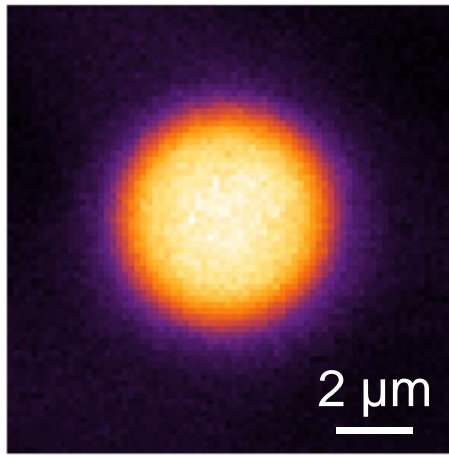
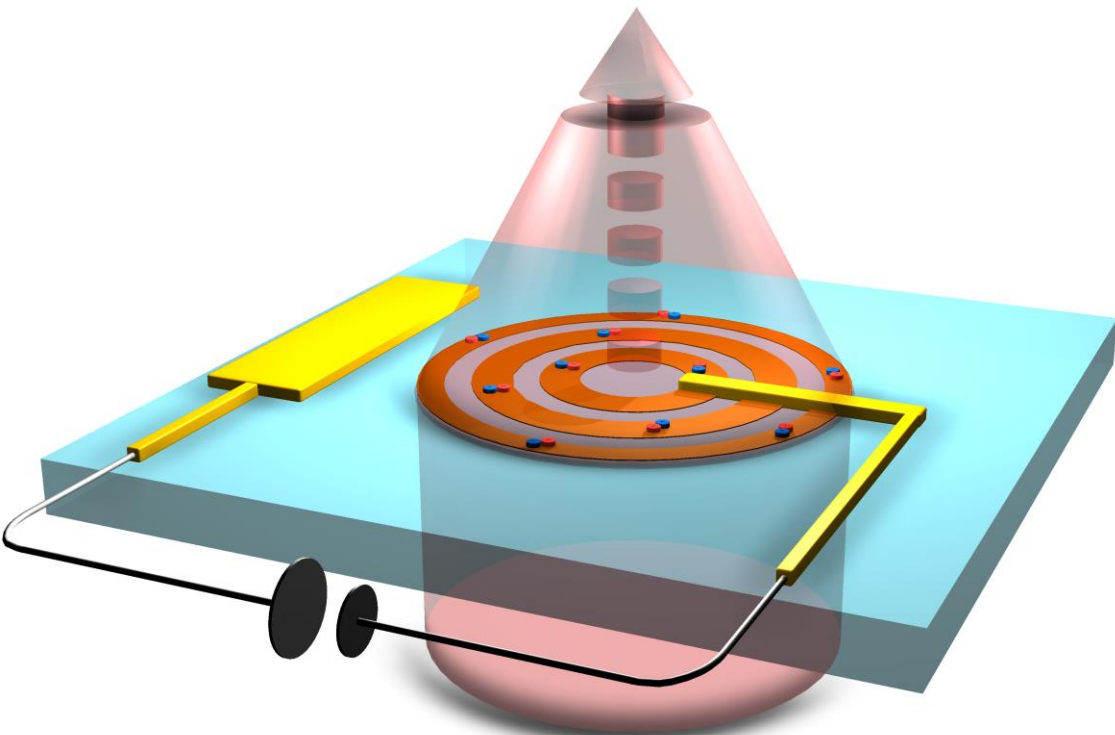
Lens met aan/uit schakelaar



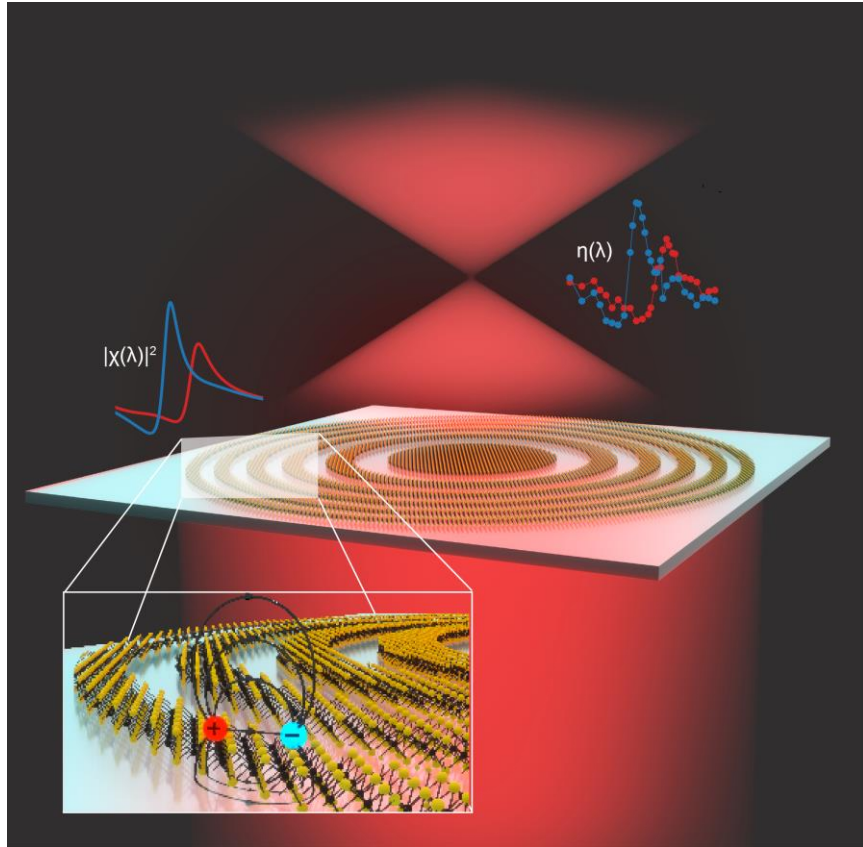
Lens met aan/uit schakelaar



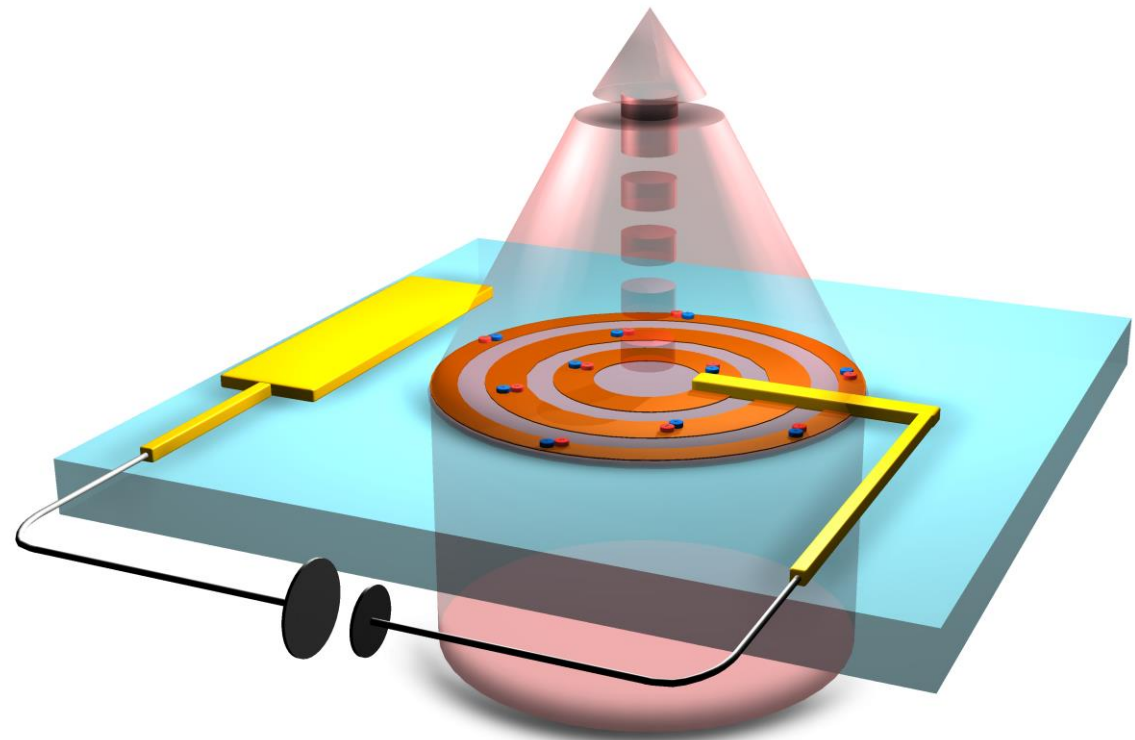
Lens met aan/uit schakelaar



De dunste lens op aarde met een aan/uit schakelaar



Nano Letters 24, 6240 (2024)



Nature Photonics 14, 426 (2020)

Met dank aan...

Ludovica Guarneri

Tom Hoekstra

Thomas Bauer

Johanna Grönqvist

Freek van Gorp

Alex Lambertz

Bernardo Dias

Anne Claude

Mehmet Atif Durmus

Eva Almeida



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Eva Almeida



Stanford University (USA)

Qitong Li

Jung-Hwan Song

Mark Brongersma

Fang Liu

