FACULTY OF ENGINEERING AND ARCHITECTURE

ELECTRONICS AND INFORMATION SYSTEMS DEPARTMENT
LIQUID CRYSTALS AND PHOTONICS RESEARCH GROUP

LIQUID CRYSTALS AND LIGHT EMITTING MATERIALS FOR PHOTONIC APPLICATIONS

Kristiaan Neyts April 2018 Lecture series at WAT in Warsaw

GHENT UNIVERSITY

WAT

nb-photonics
Center for Nano- and Biophotonics
Ghent University

Liquid Crystals and Photonics

OVERVIEW

Photonic applications (6h)

- Liquid crystal beam steering
- Liquid crystal tunable lenses
- Liquid crystal smart windows
- Spatial light modulator
- Liquid crystal flat optics
- Wave guide modulation
- Liquid crystal lasing

Liquid Crystals and Photonics

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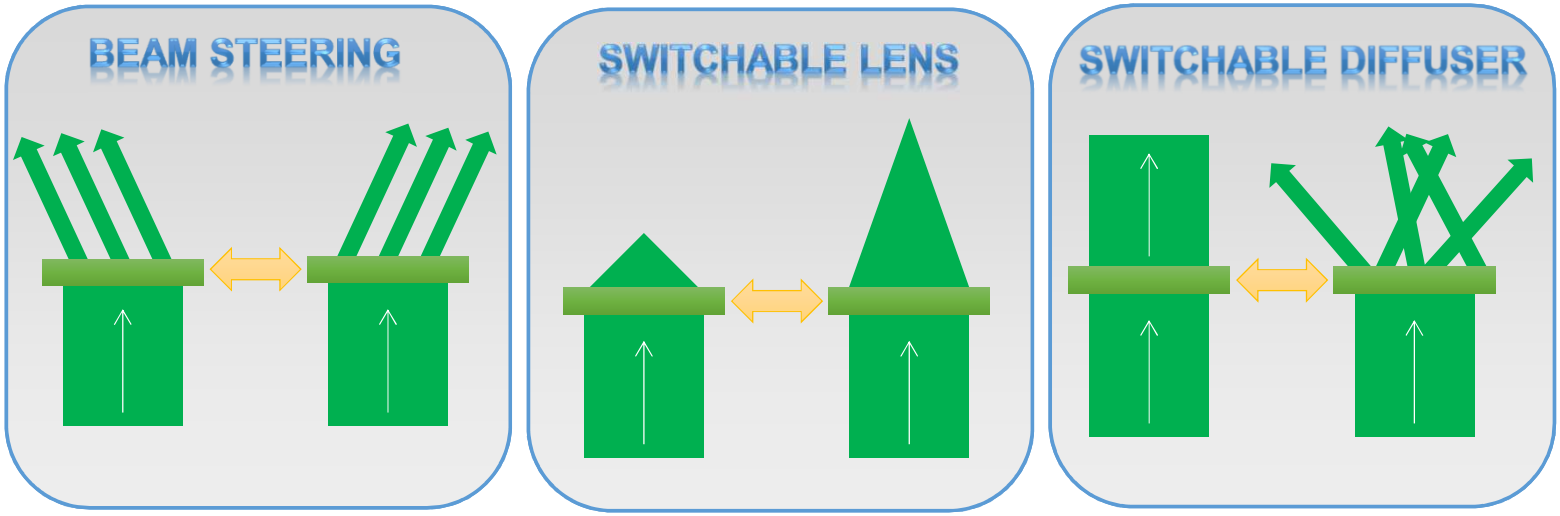

Liquid Crystals and Photonics

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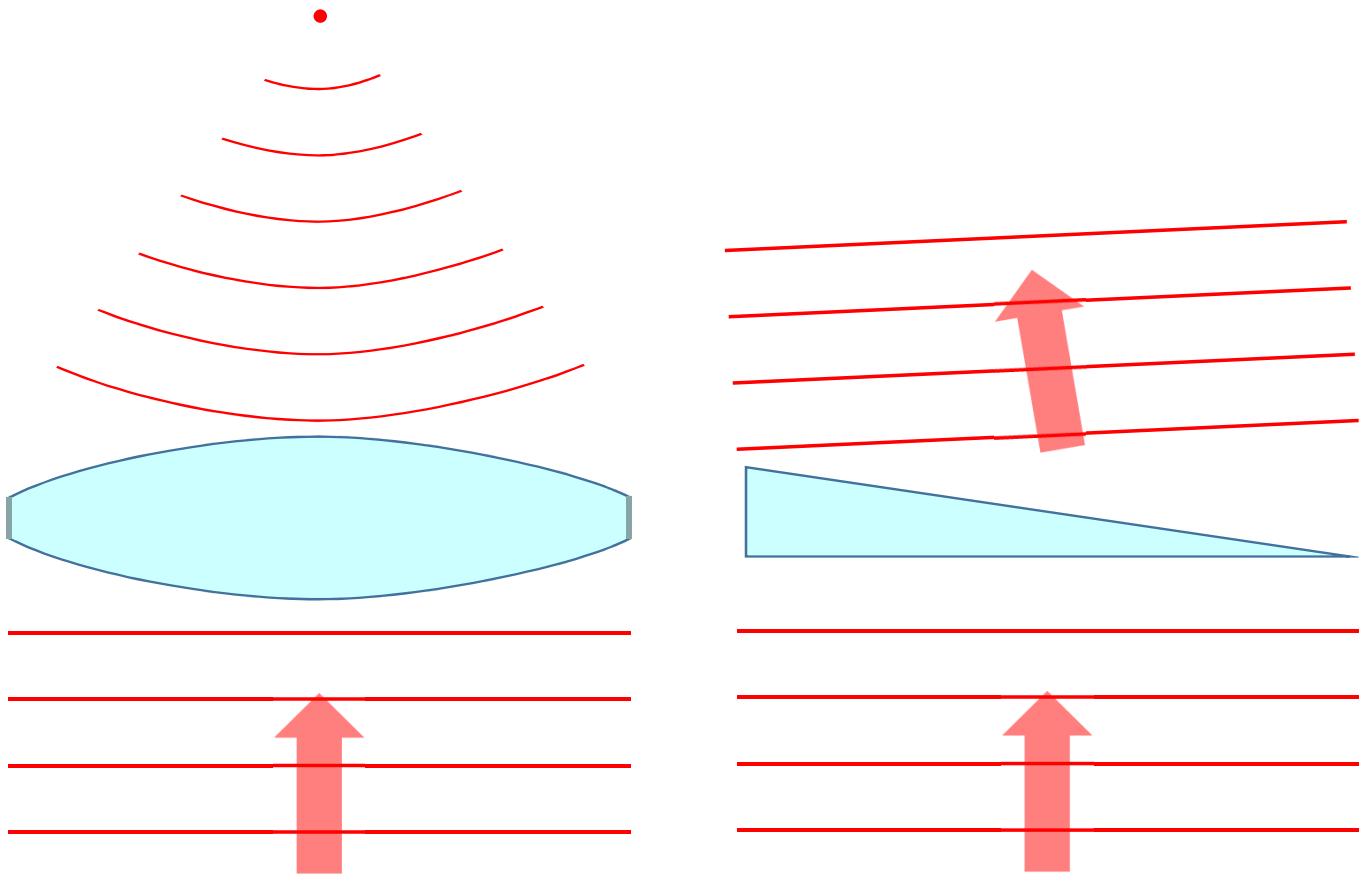
BEAM STEERING & TUNABLE LENSES



Liquid Crystals and Photonics

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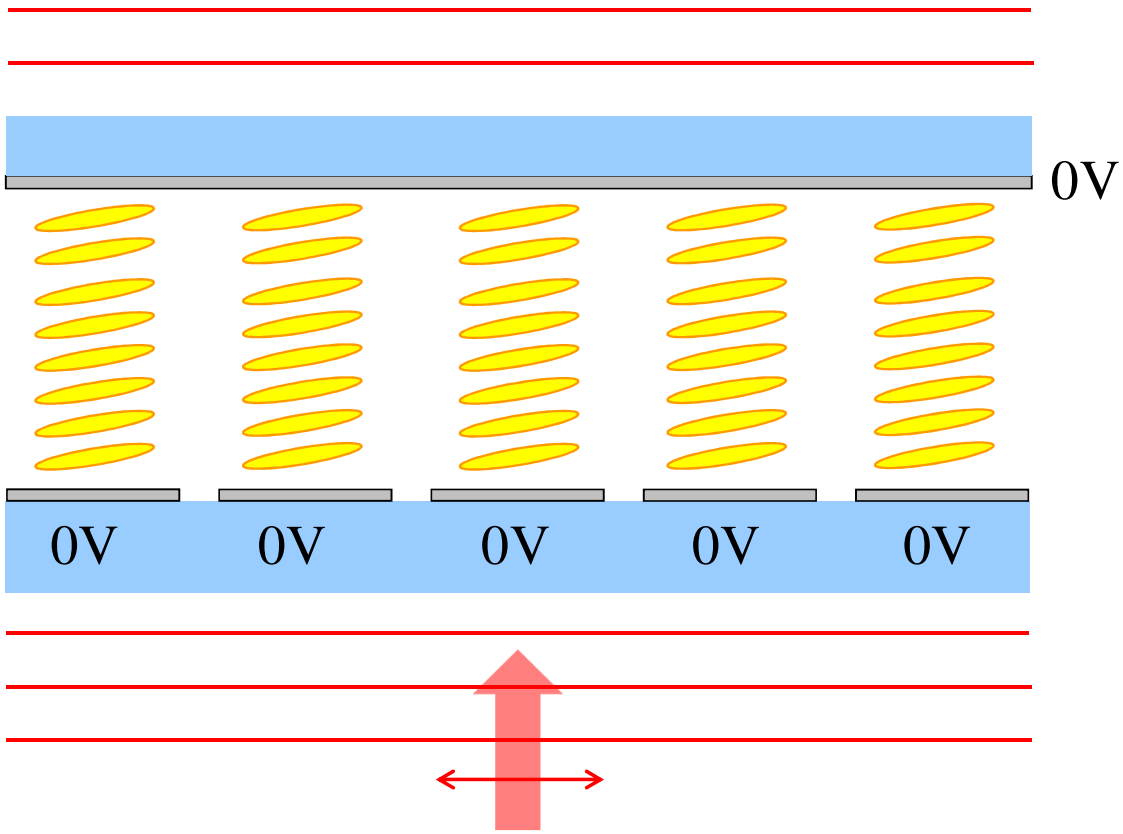
BEAM STEERING & TUNABLE LENSES



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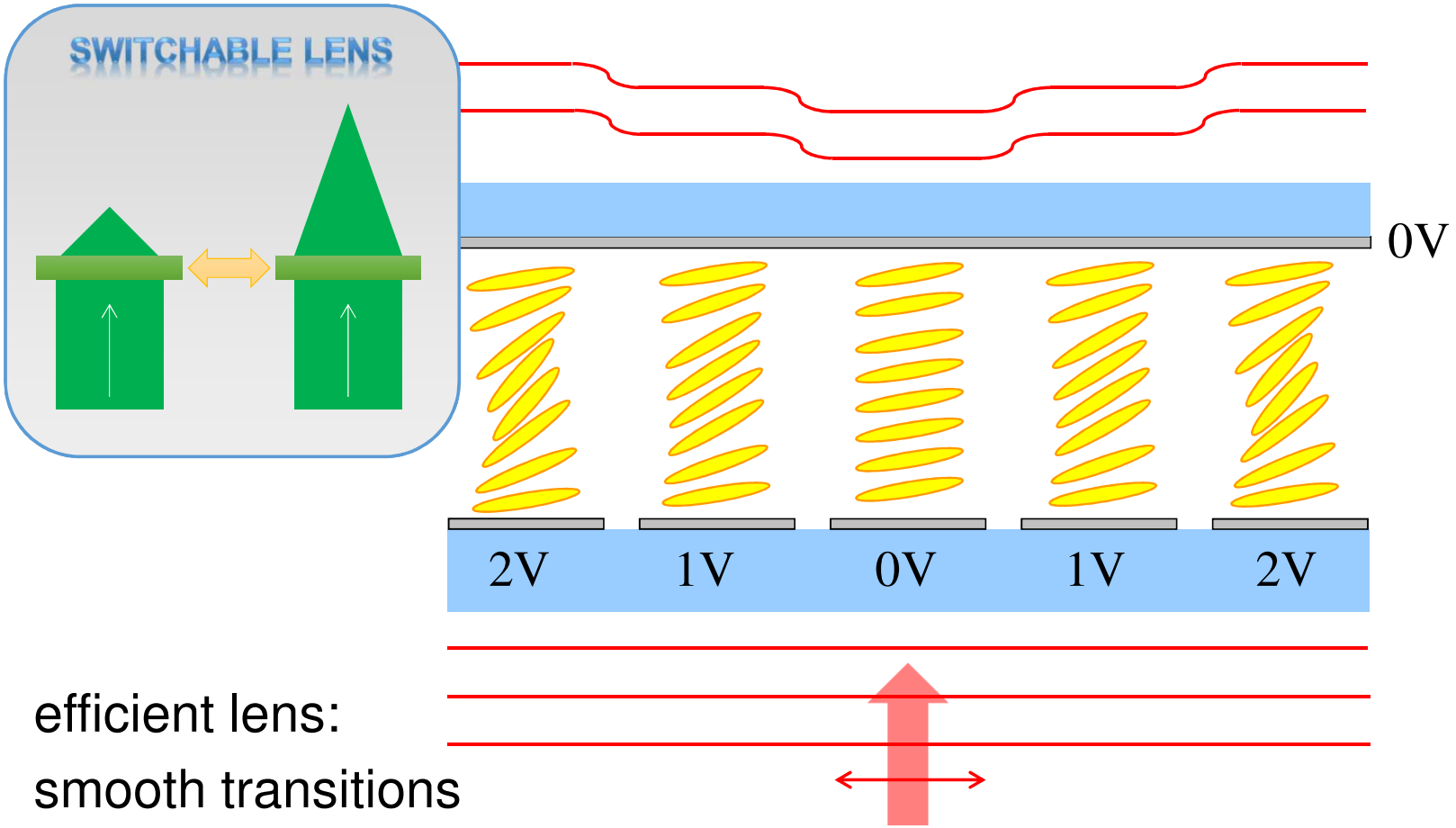
TUNABLE LENS

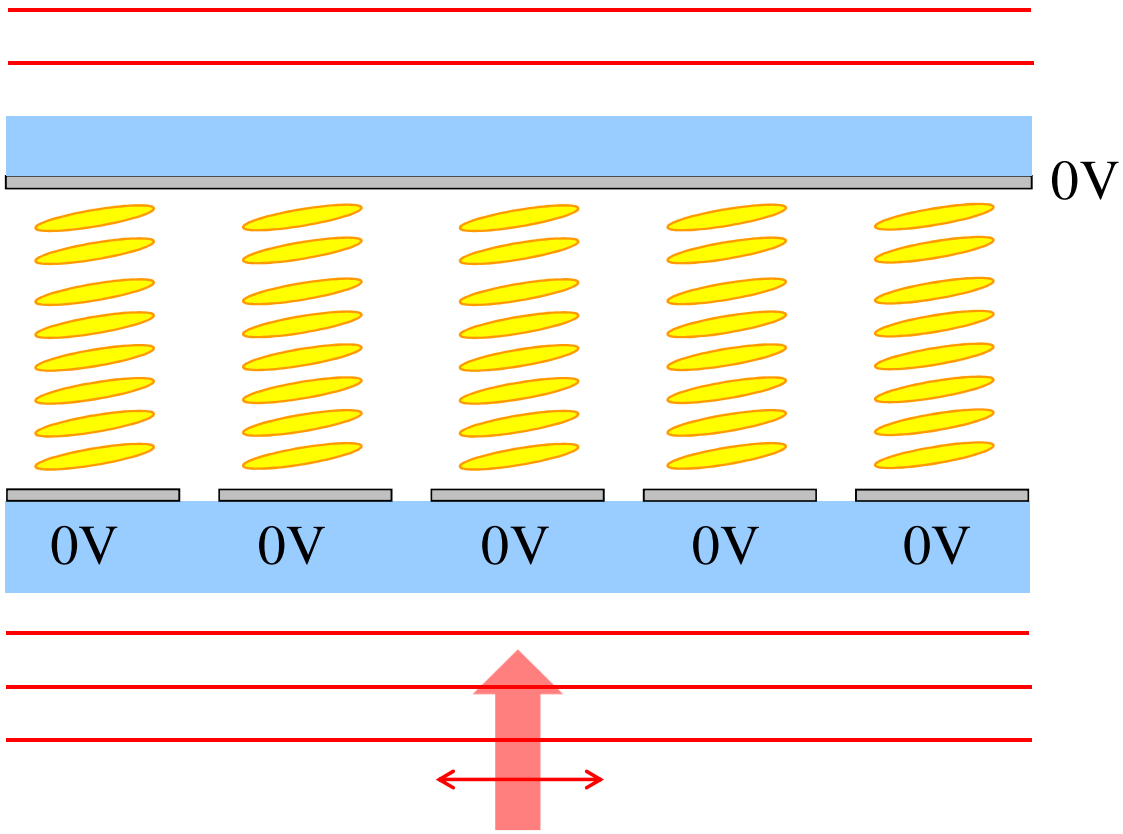


efficient lens:

smooth transitions

(no fringe field effects)

BEAM STEERING & TUNABLE LENSES



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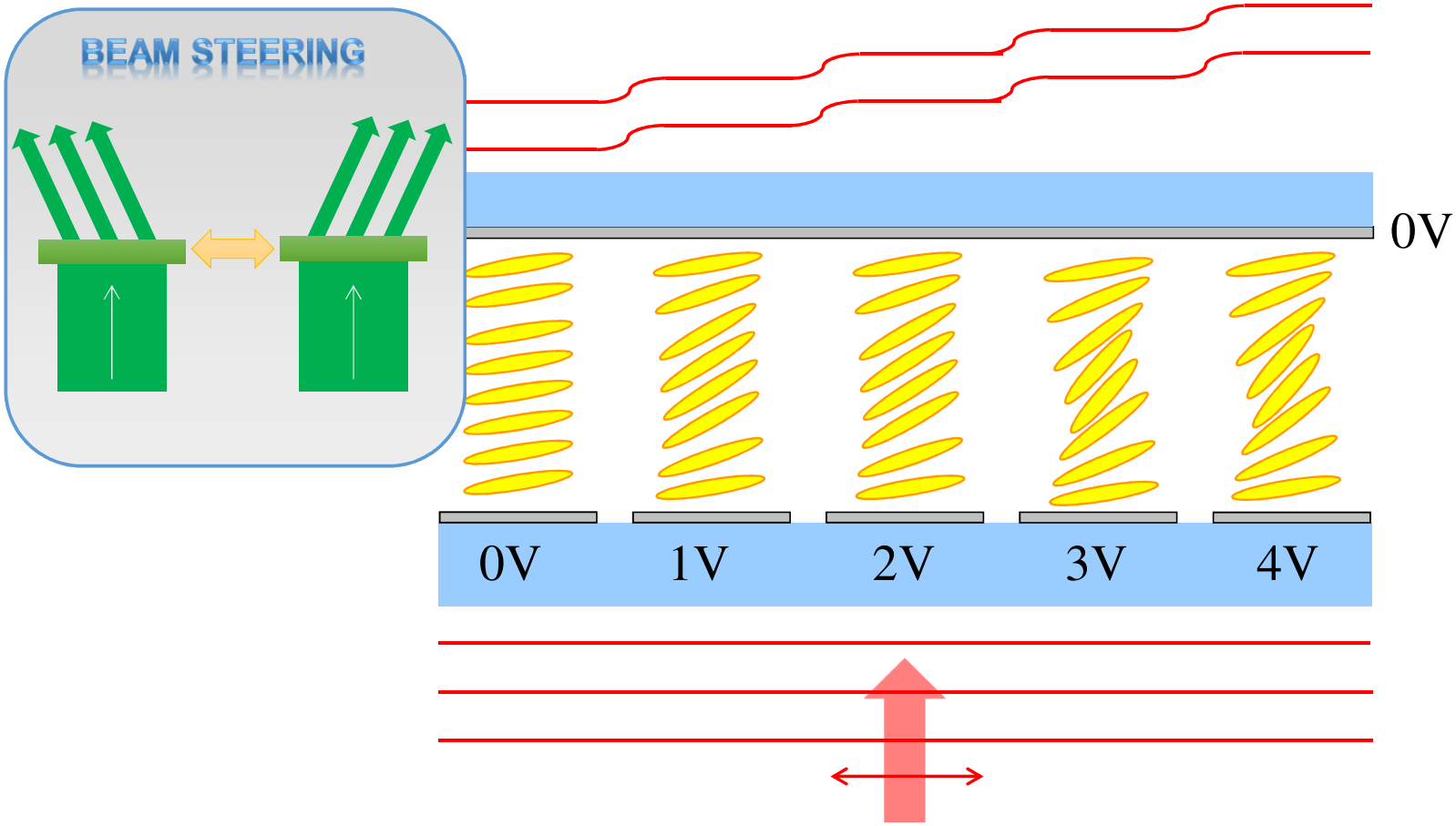
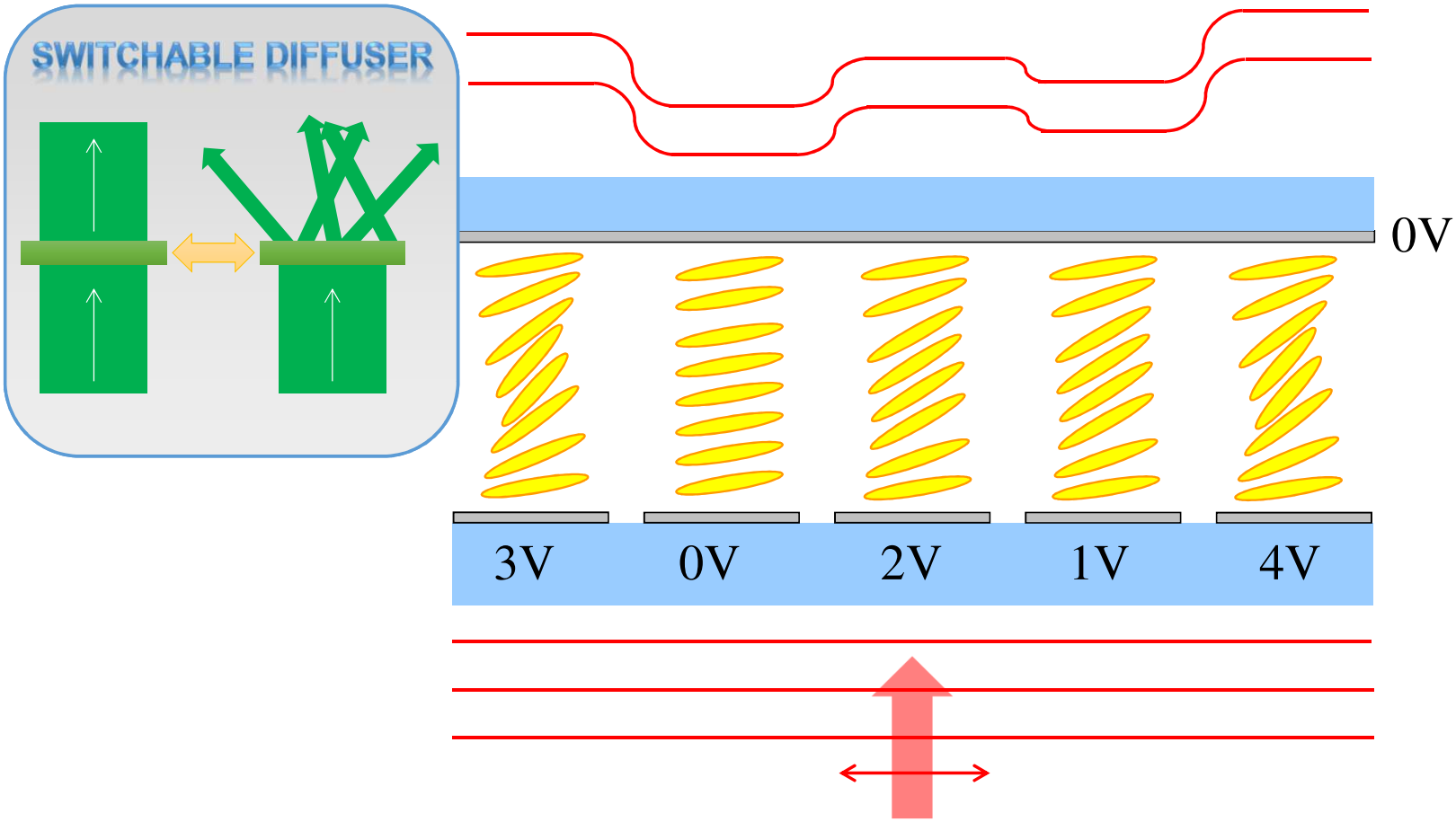
BEAM STEERING



SWITCHABLE DIFFUSER



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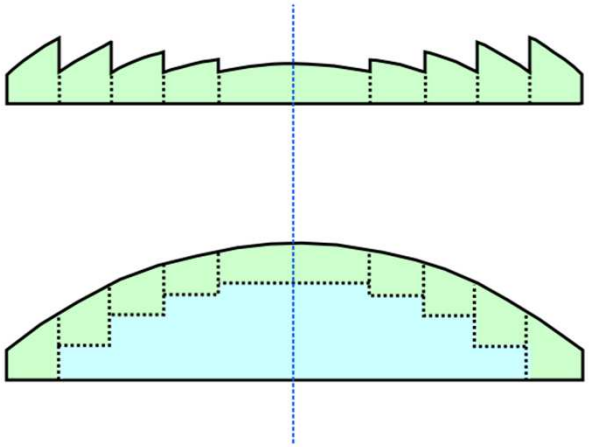
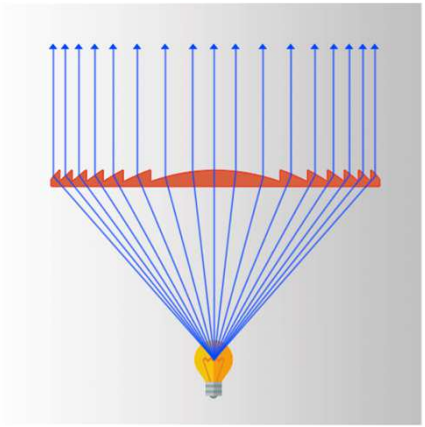
LENS AND FRESNEL LENS

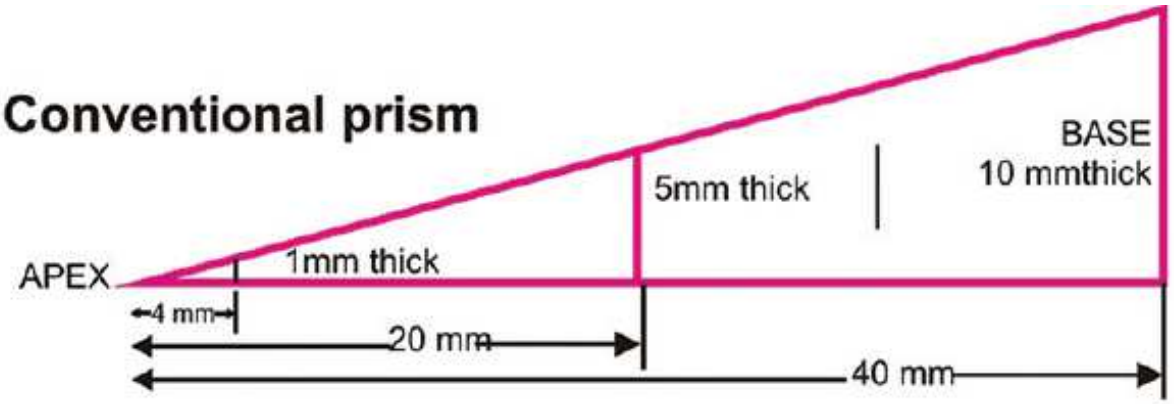


lens with reduced thickness: each sector with the same focal length

original lens, with sections



PRISM AND FRESNEL PRISM



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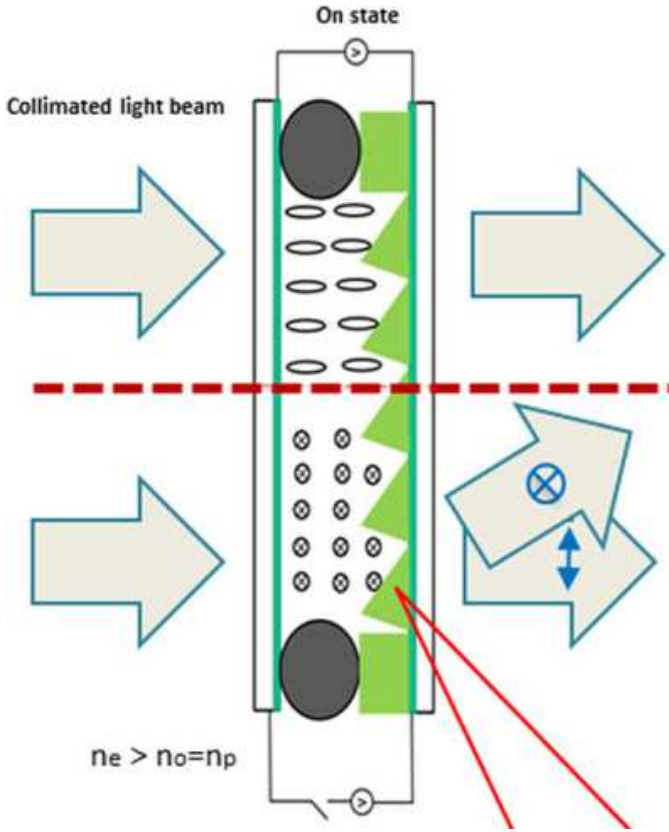
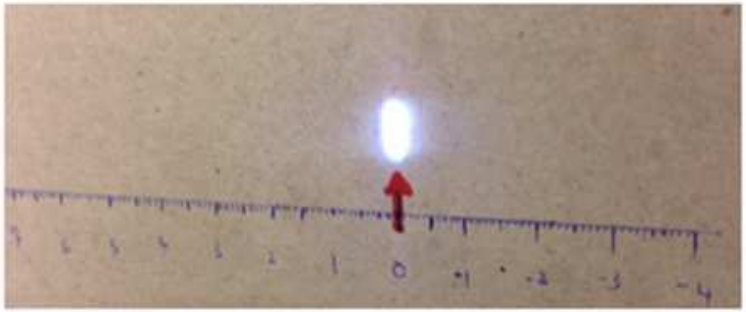
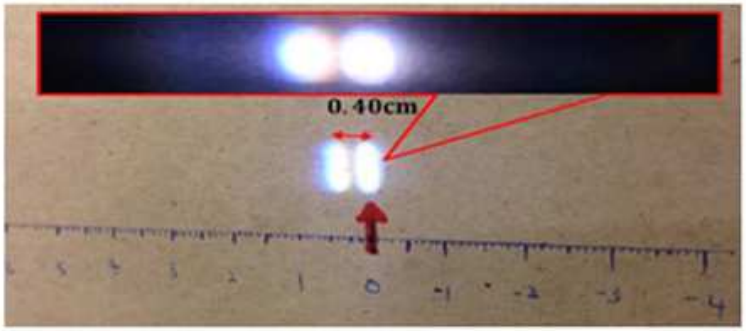
LC BEAM STEERING

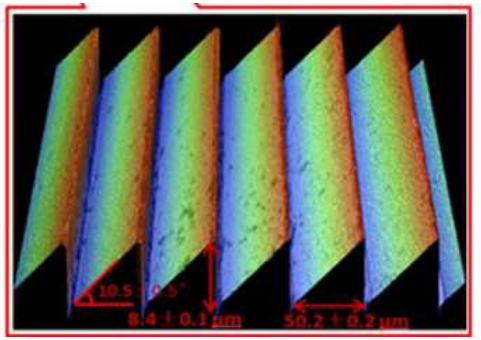




$n_o = n_{polymer}$



$n_e > n_{polymer}$

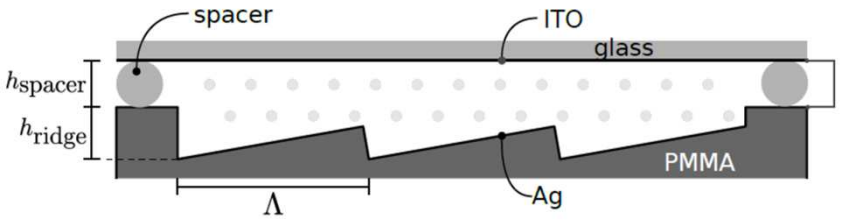


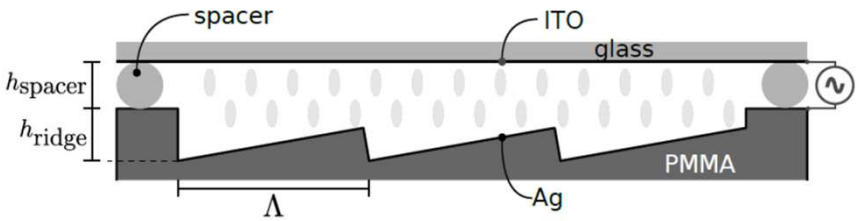
*X. Shang et al., IEEE Photonics Journal **7** (2015)*

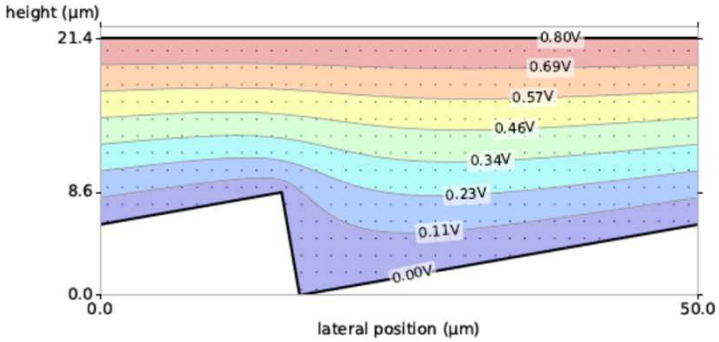
LC BEAM STEERING

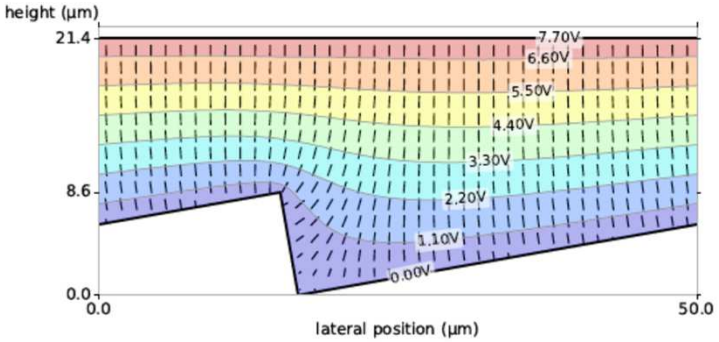
reflective beam steering

variable thickness LC
variable electrode
one voltage









Willekens et al

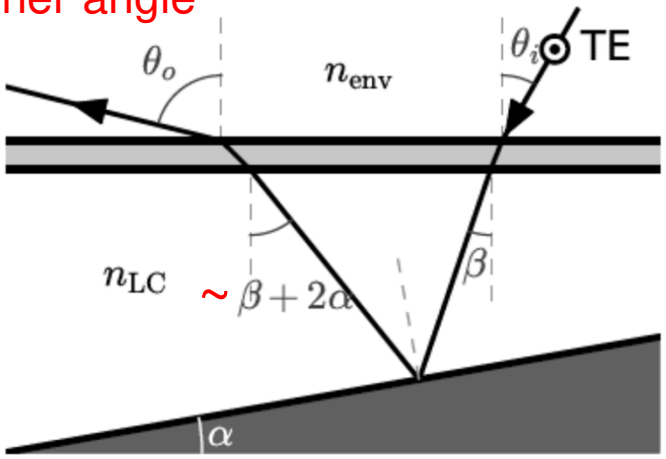
LC BEAM STEERING

variable thickness

one voltage

higher n

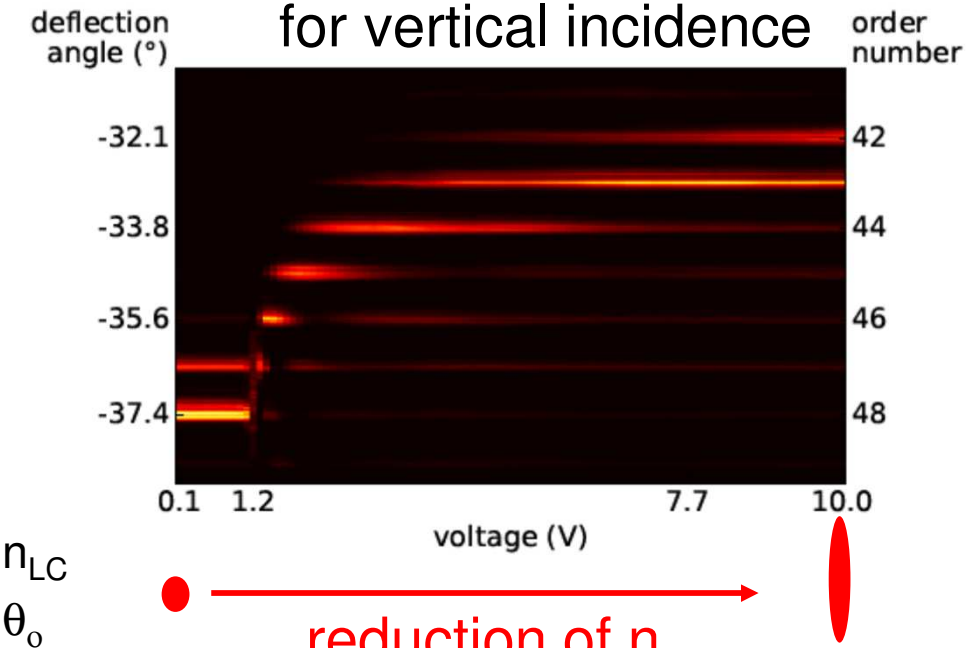
higher angle



10°

reflective prism

for vertical incidence



variation of n_{LC}

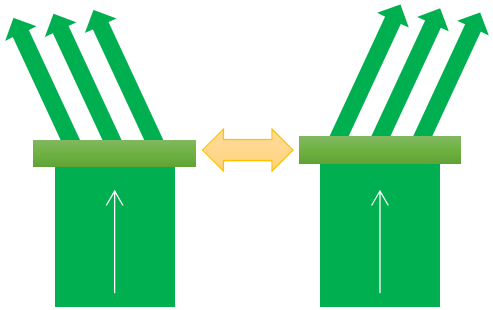
variation of θ_o

reduction of n

Willekens et al

BEAM STEERING

Applications

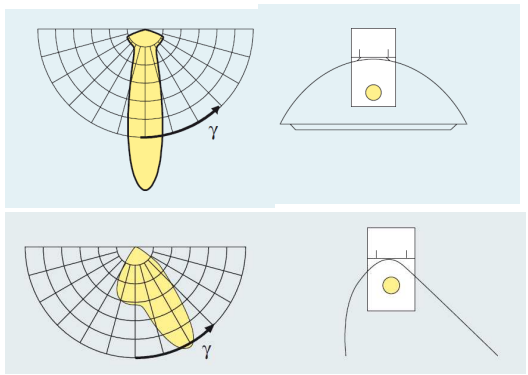


SECONDOS

3D displays with eye tracking

Solar tracking

Switchable lighting



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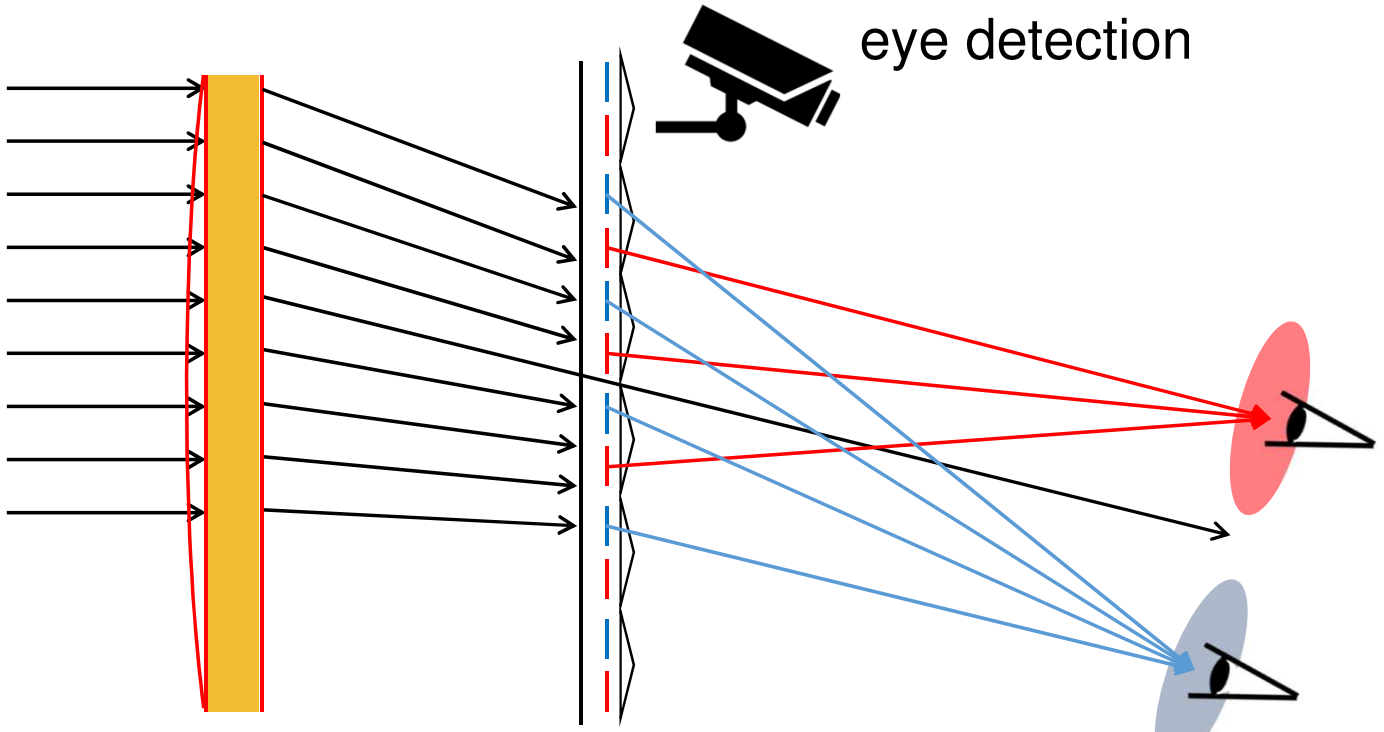
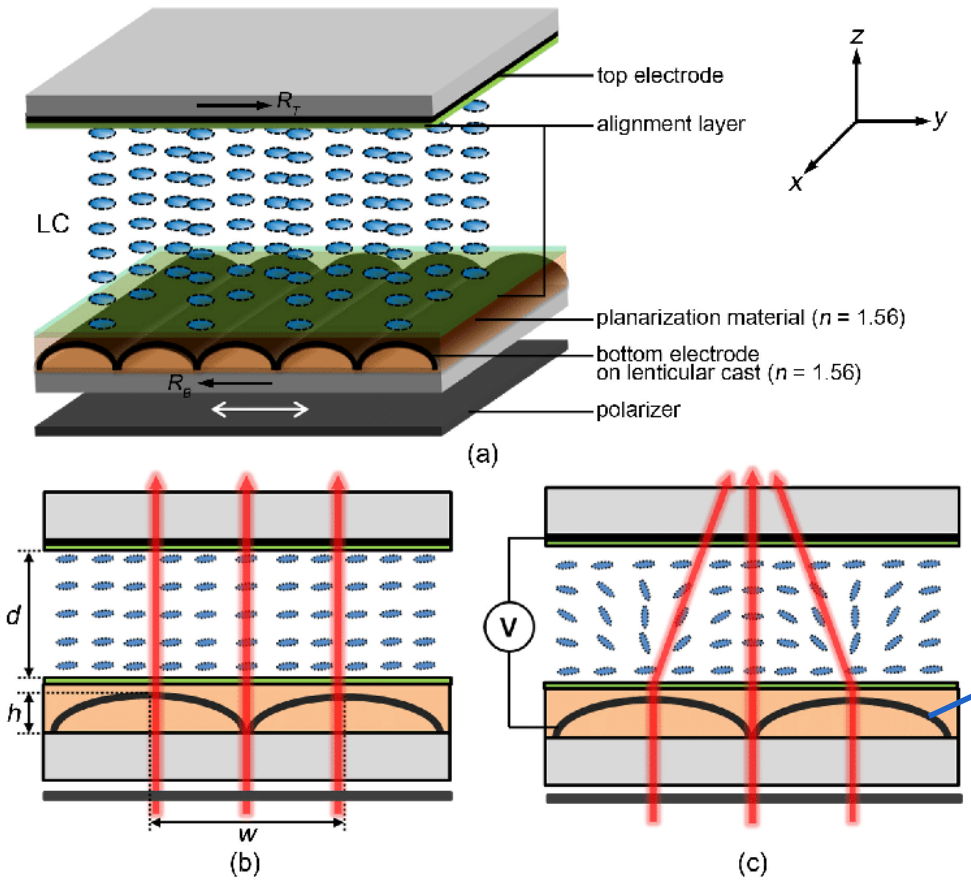
BEAM STEERING

Outlook: 3D TV with eye tracking, low power

- pixels direct light to the eyes of the observer by beam steering



LC LENS



flat LC

curved electrodes

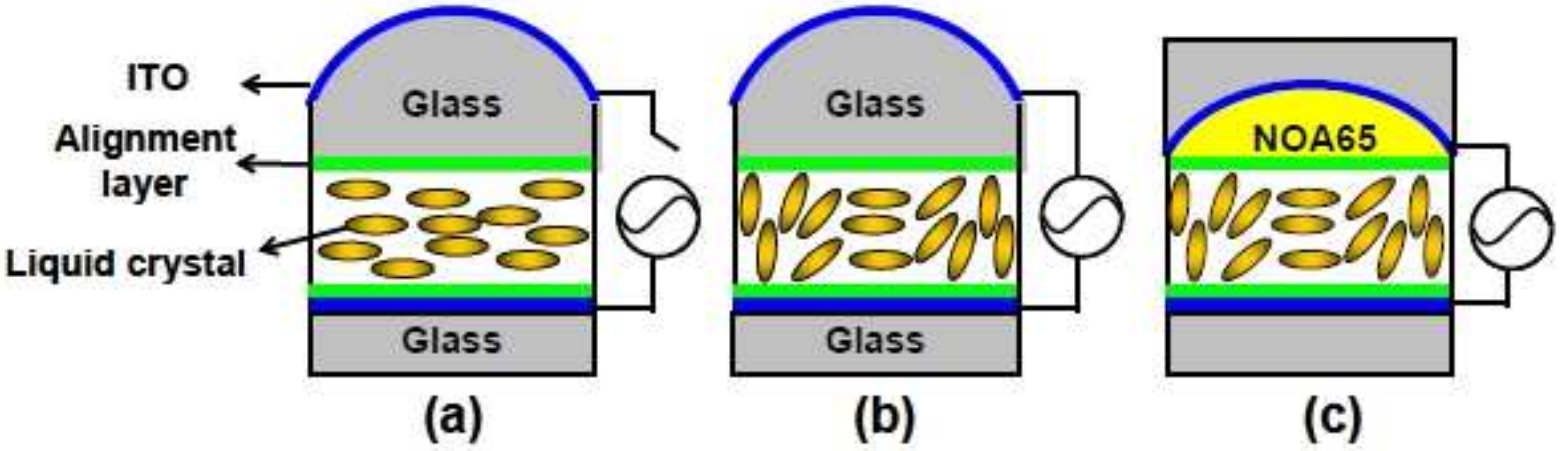
one voltage

electrodes with different distance

Sin Doo Lee

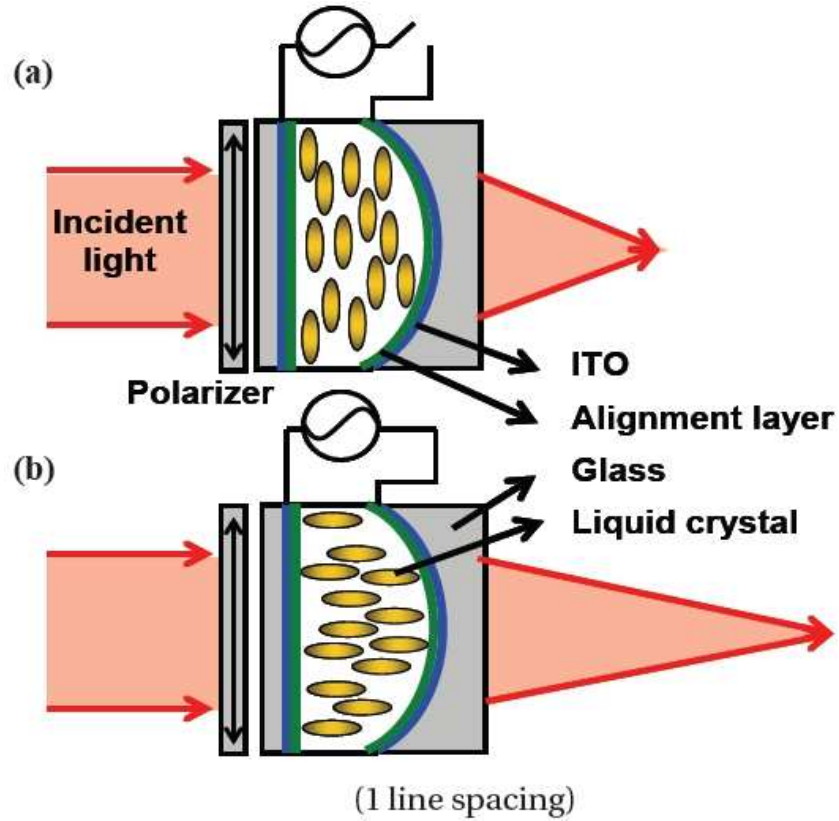
LC LENS

flat LC
curved electrodes
one voltage



Lin Yi-Hsin

LC LENS



curved LC
curved electrodes
one voltage

thick lens
large thickness, slow

Liquid Crystals and Photonics

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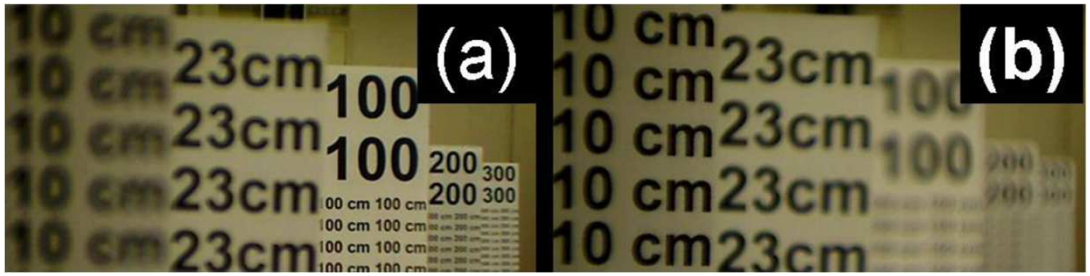
Lin Yi-Hsin

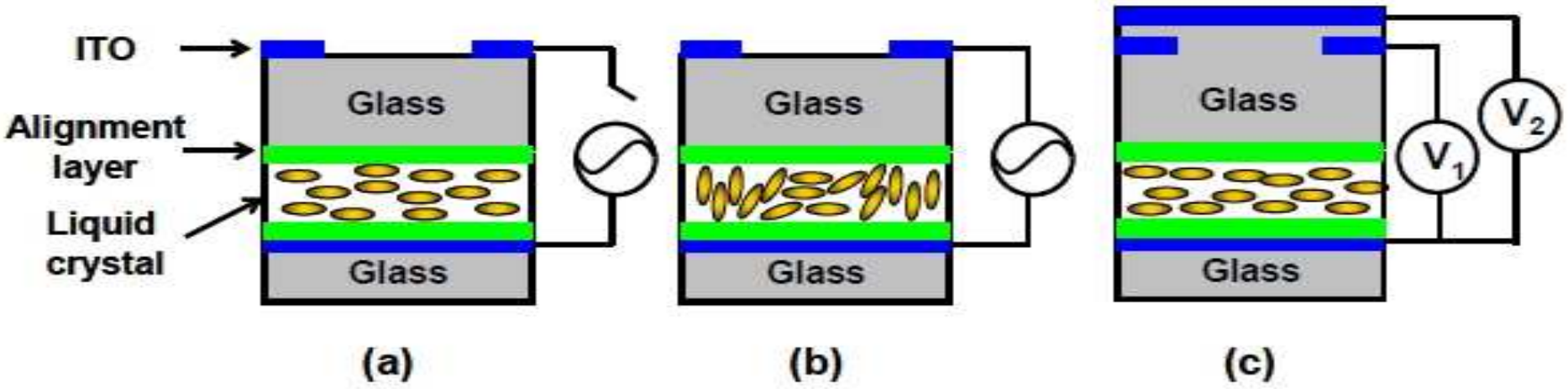
LC LENS



flat LC

flat electrodes

two voltages



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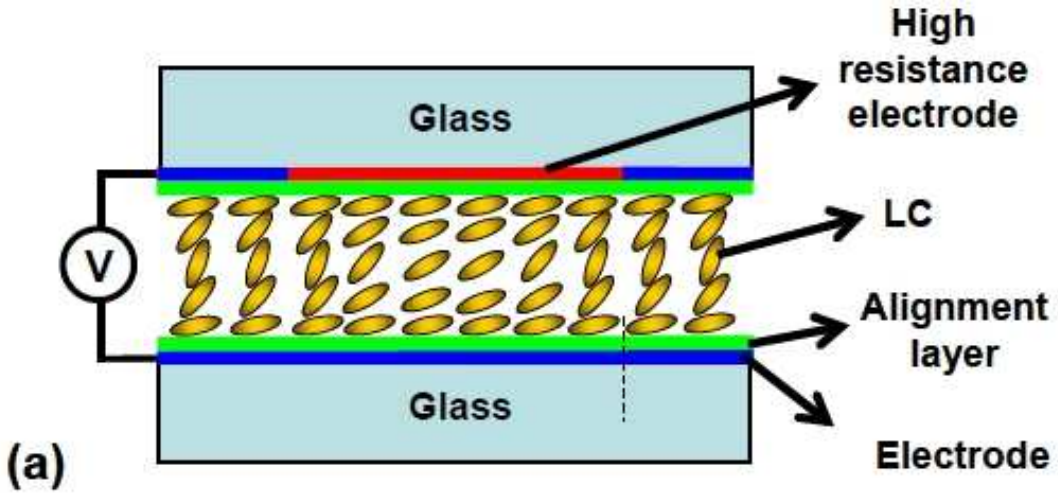
LC LENS



flat LC

flat electrodes

variable voltage

Liquid Crystals and Photonics

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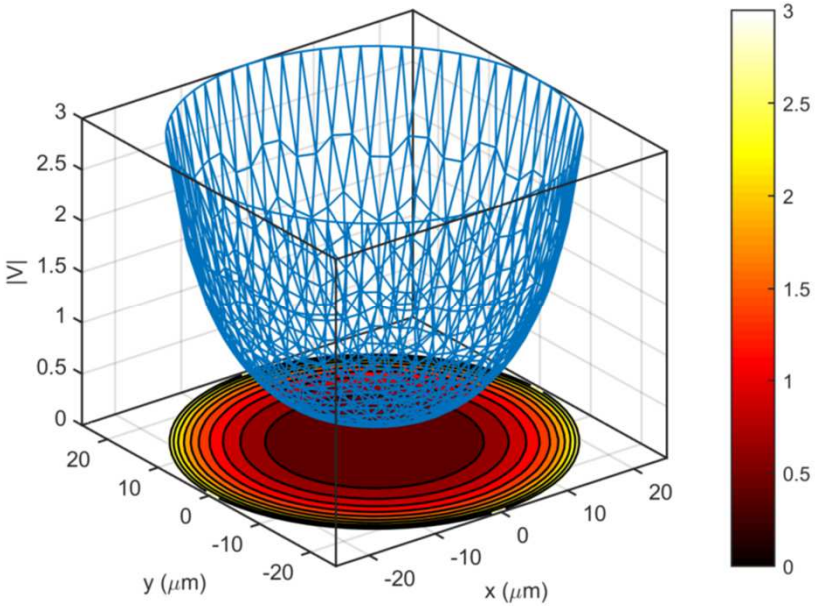
Lin Yi-Hsin

LC LENS

simulation of voltage distribution:

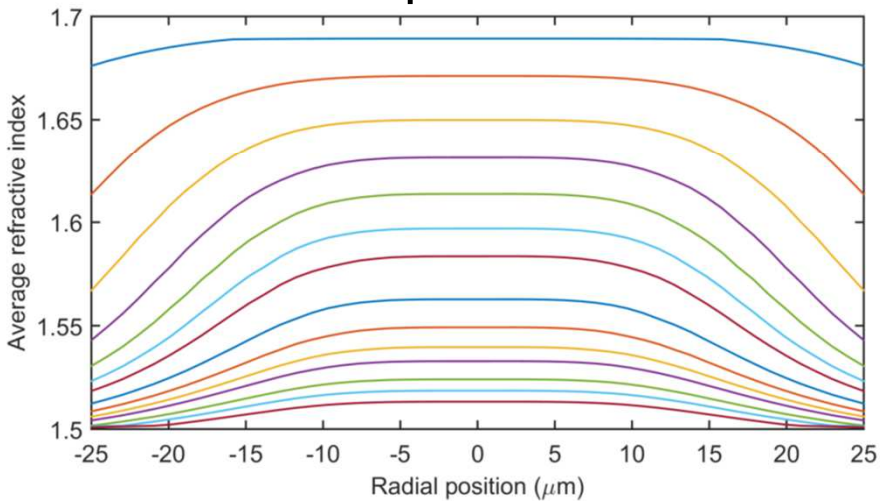
ring metal with high resistance electrode



voltage V(r)

refractive index n(r)

… not parabolic…



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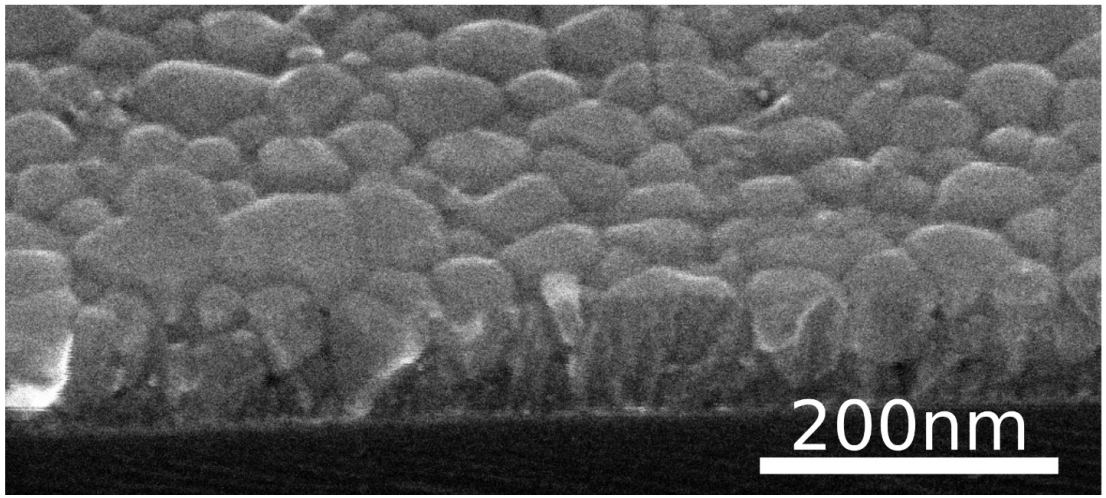
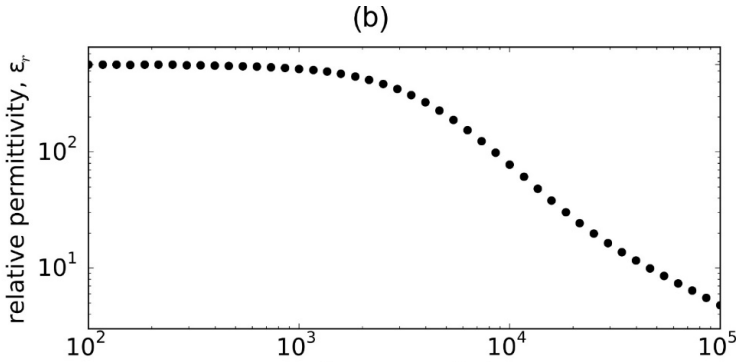
LC LENS

lens with high dielectric constant: PZT layer

by spin coating+heating: well-oriented ferro-electric material

on glass (epsilon 500)





Liquid Crystals and Photonics

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LC LENS

lens with high dielectric constant: PZT layer

ring electrodes + PZT to homogenize the voltage

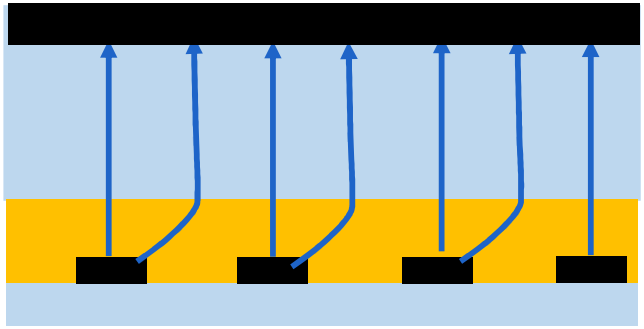
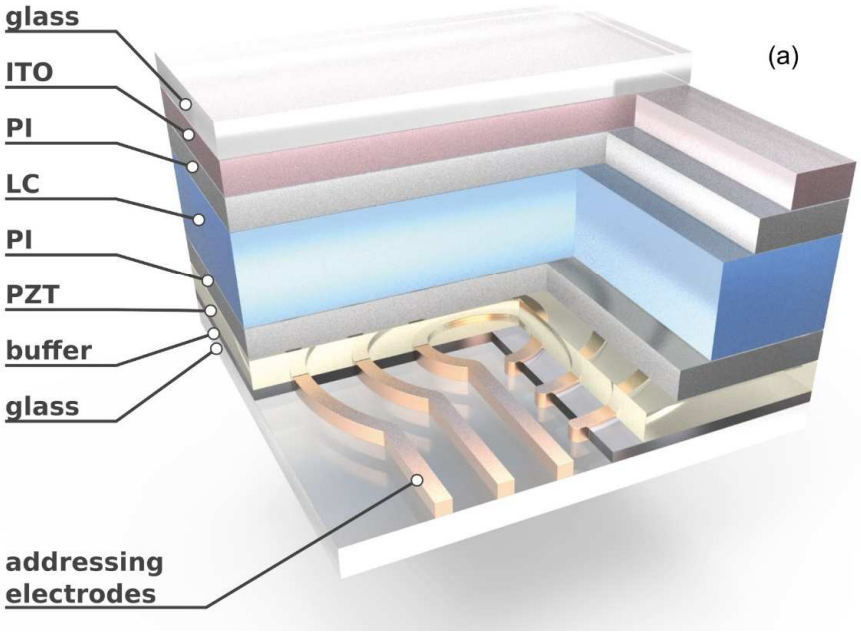
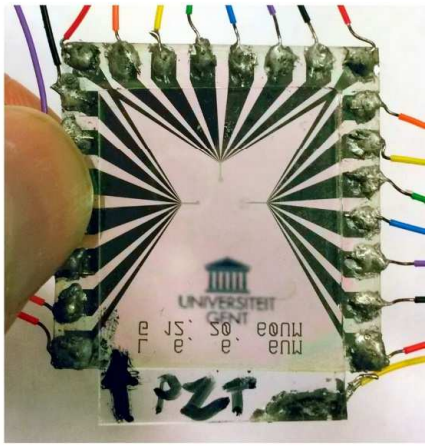


Figure 1





Liquid Crystals and Photonics

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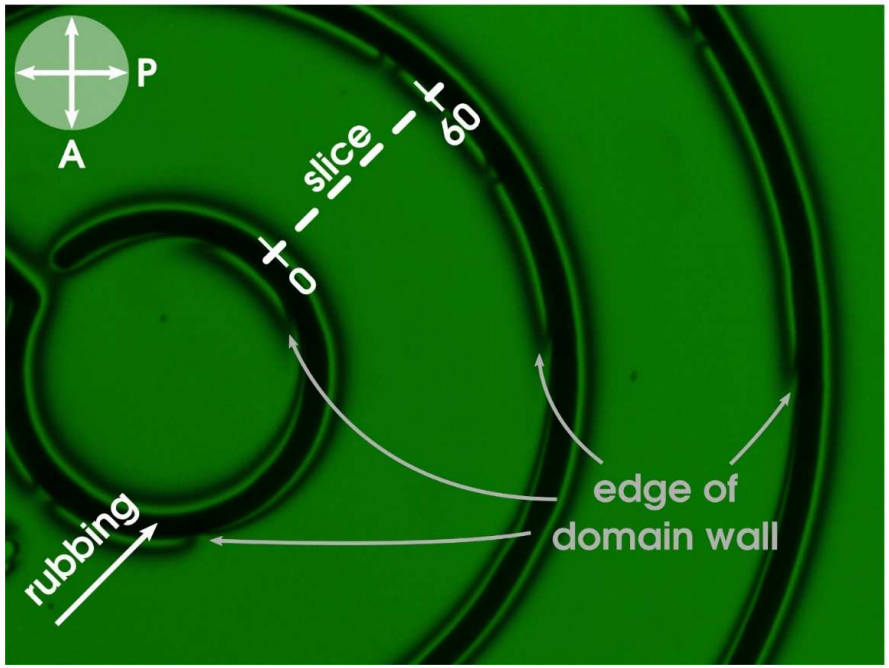
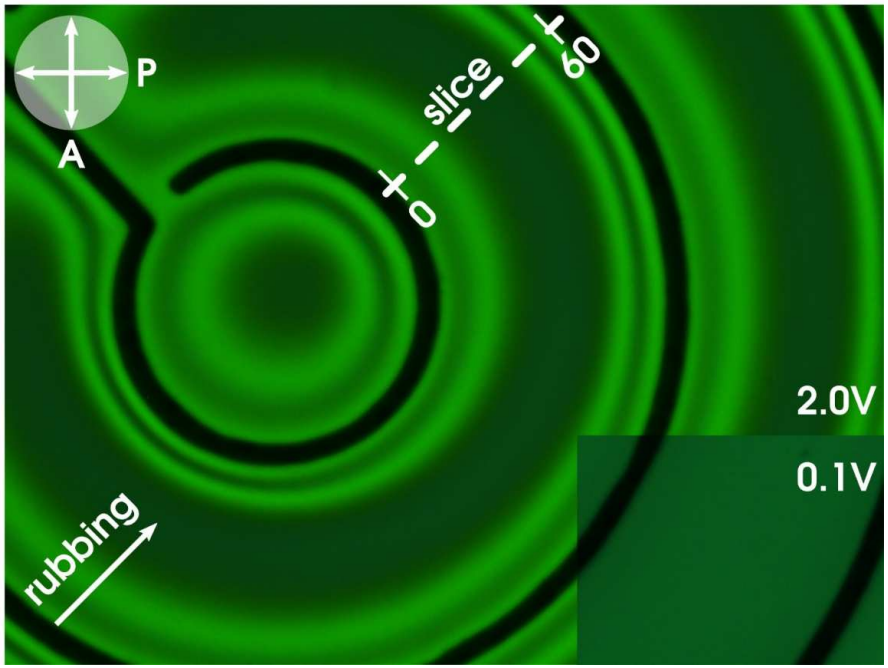
LC LENS

lens with high dielectric constant: PZT layer

with pzt



without pzt



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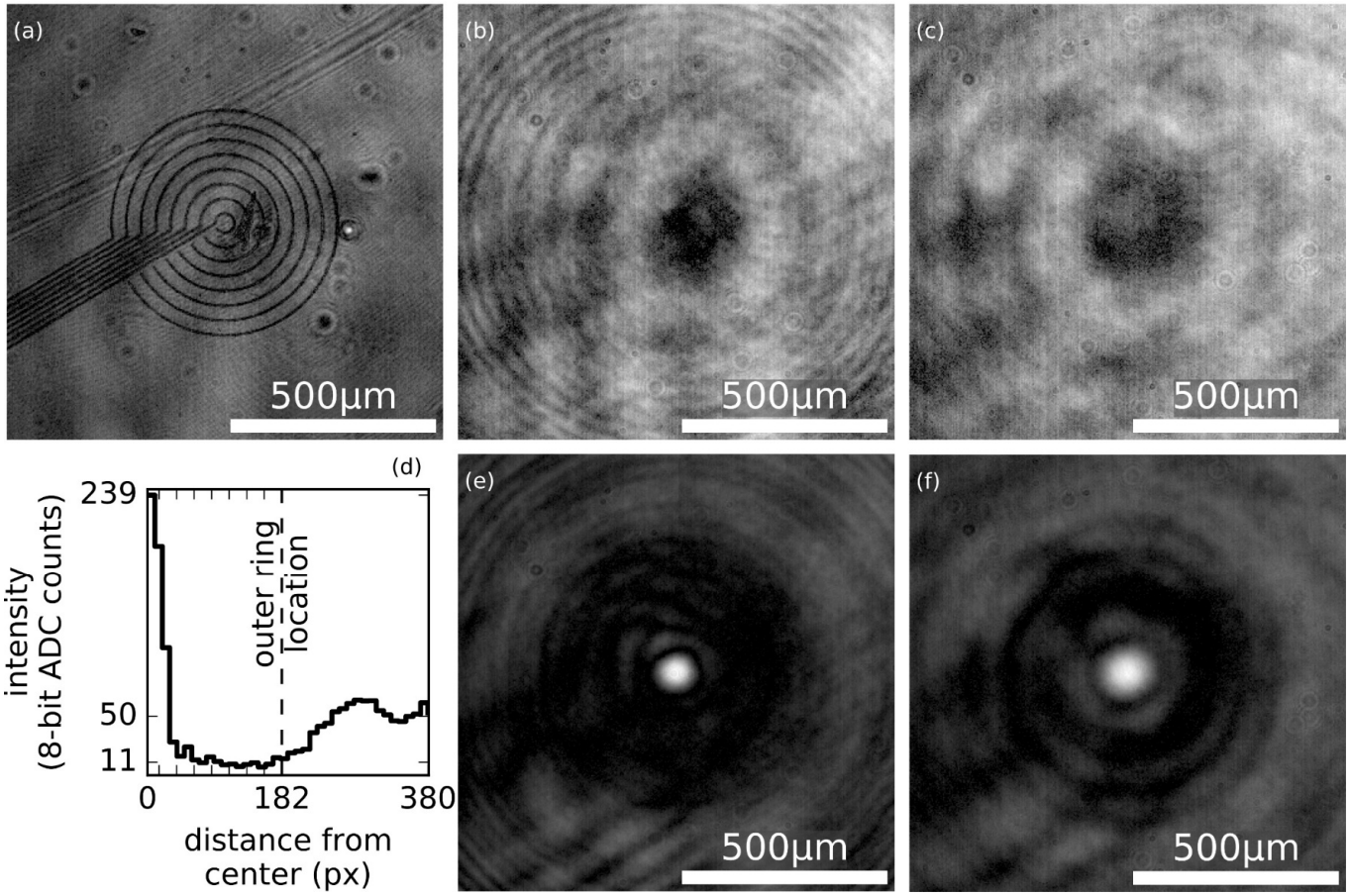
LC LENS

focus on lens

at 44 mm distance

at 74 mm distance



no voltage

with voltages

Liquid Crystals and Photonics

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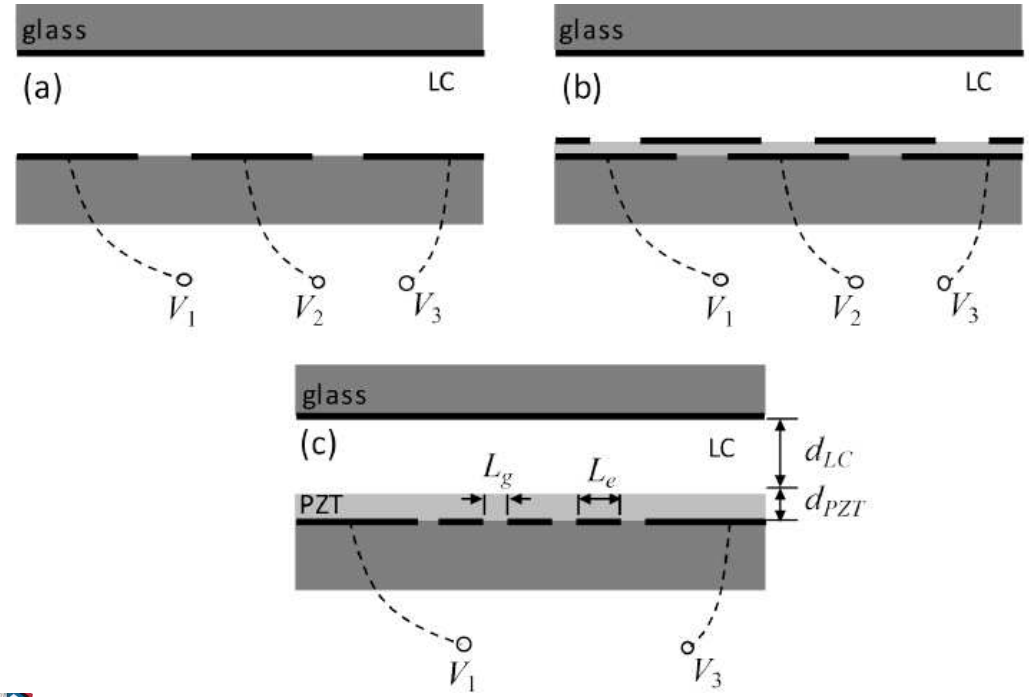
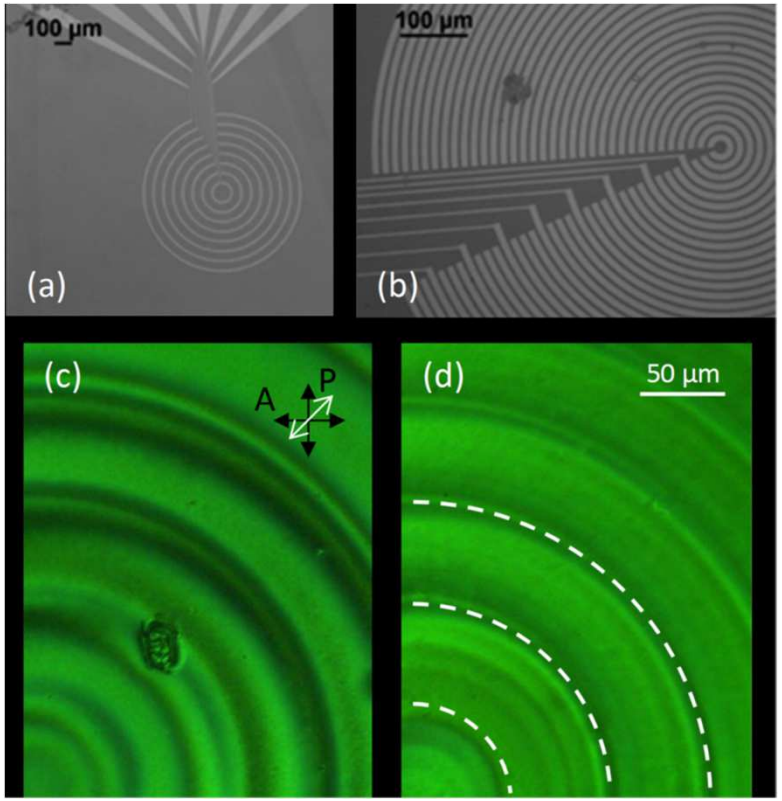
LC LENS



ring electrodes

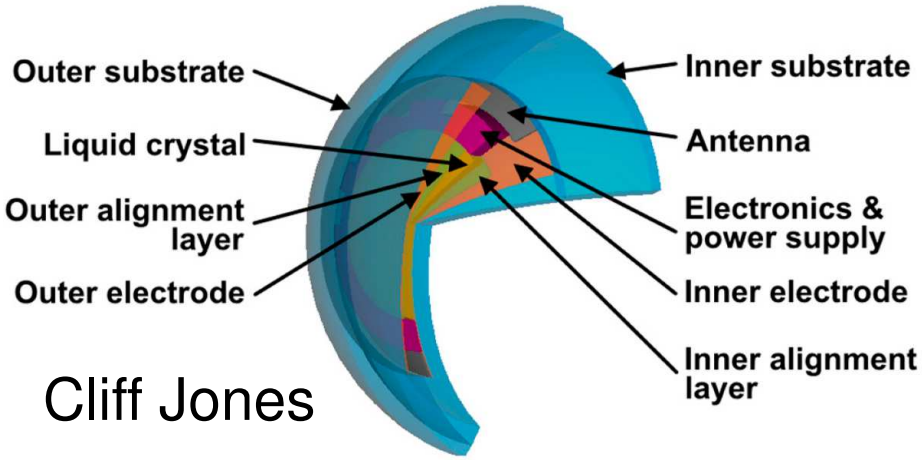
+intermediate electrodes

+PZT high ε

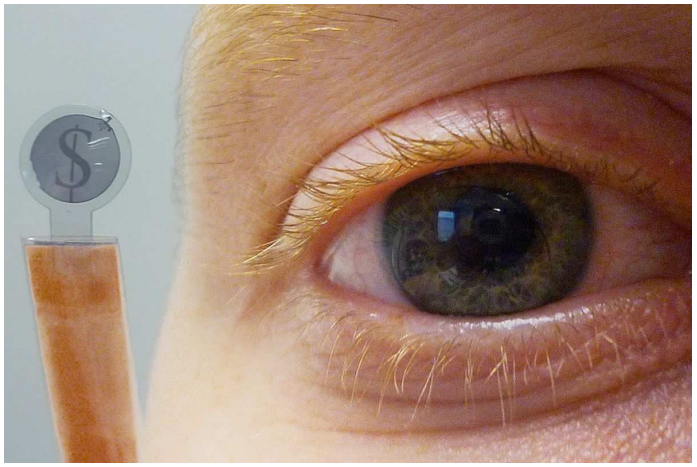


smooth rotation

LC LENS

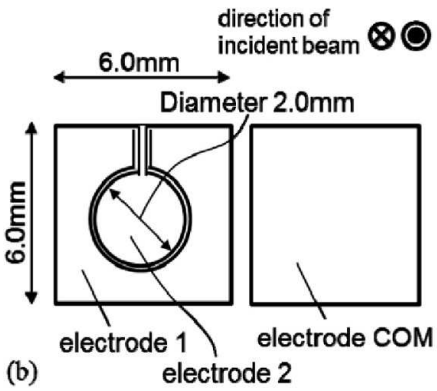


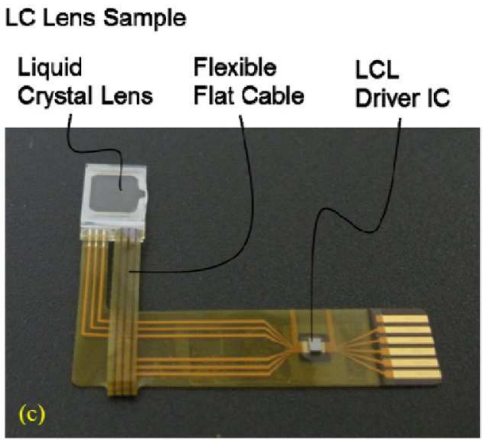
Cliff Jones



Jelle Desmet

Liquid Crystals and Photonics





TouchFocus™

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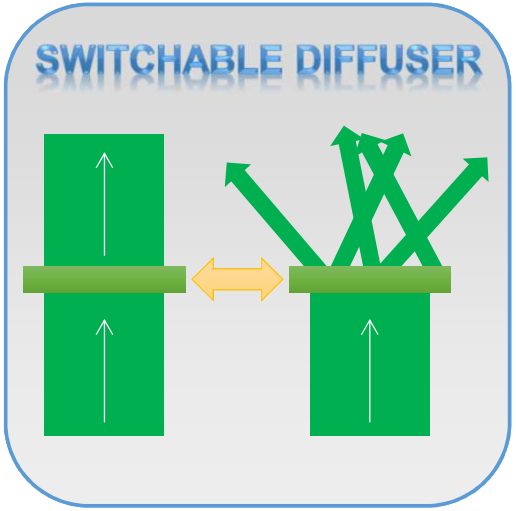
Ozaki: camera lens

SWITCHABLE DIFFUSER

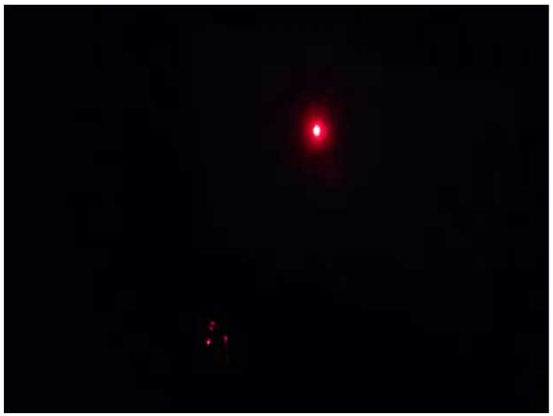


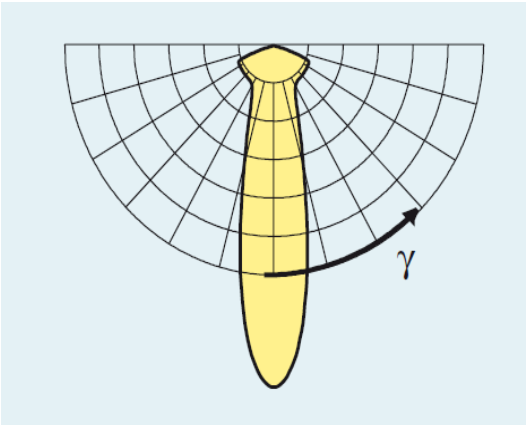
Applications

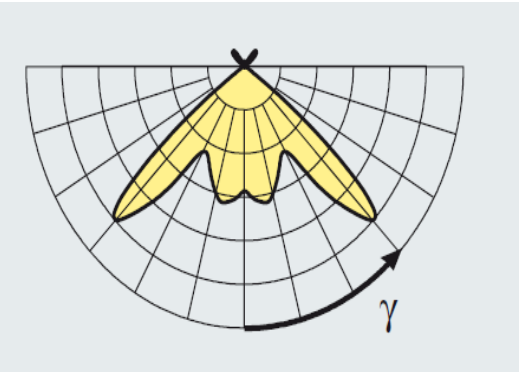
Privacy windows

Image: www.smarttint.com

Switchable lighting







SPATIAL LIGHT MODULATOR

modulating the phase pixel by pixel

Liquid Crystals and Photonics

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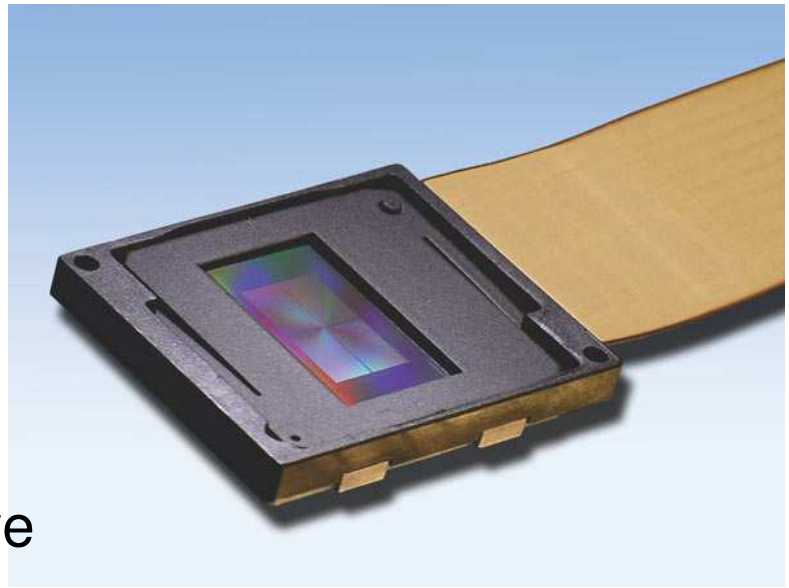
SPATIAL LIGHT MODULATOR

PLUTO-2 Spatial Light Modulator – Microdisplay Features

Display Type:	**Reflective LCOS (Phase Only)**
Resolution:	1920 x 1080
Pixel Pitch:	**8.0 µm**
Fill Factor:	93 % (dependent on version)
Active Area	15.36 x 8.64 mm (0.7″ Diagonal)
Addressing	8 Bit (256 Grey Levels)
Signal Formats	DVI – HDTV Resolution
Input Frame Rate	60 Hz



holoeye

Liquid Crystals and Photonics

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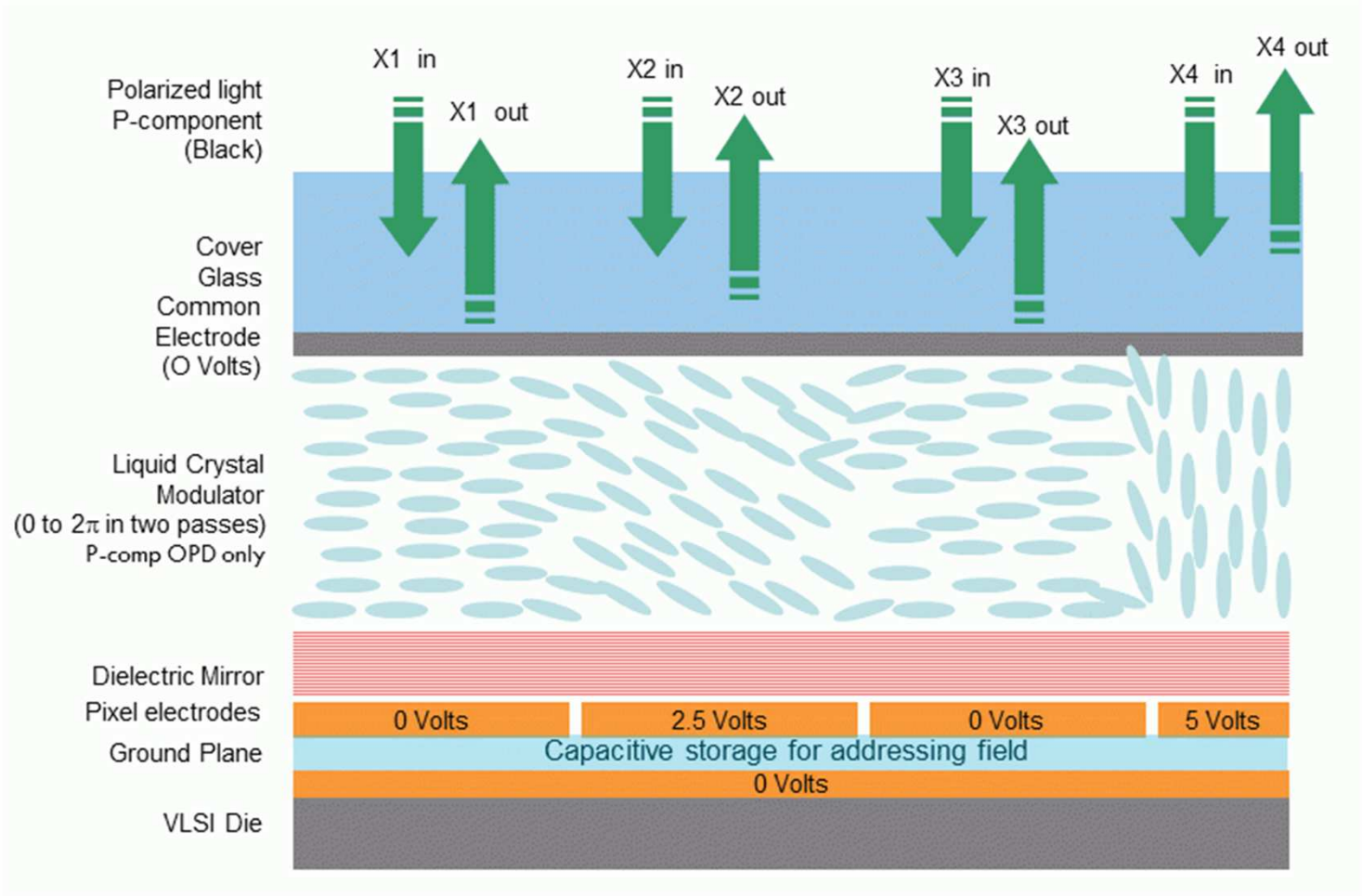
SPATIAL LIGHT MODULATOR



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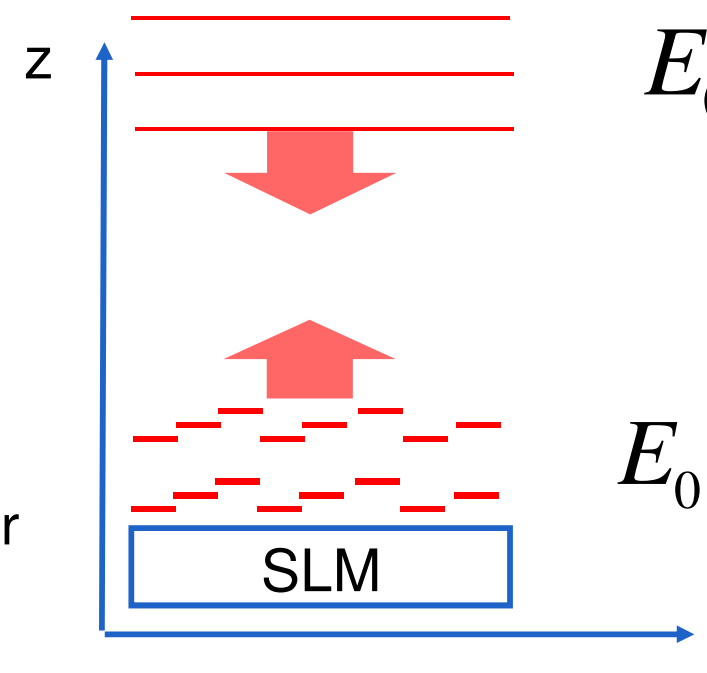
meadowlark

SPATIAL LIGHT MODULATOR

plane wave on an SLM

the wavefront is deformed, by a phase delay $\phi(x, y)$



$$E_0 \cdot e^{i(\omega t + kz)}$$

$$E_0 \cdot e^{i(\omega t - kz - \phi(x,y))}$$

spatial light modulator
pixels of a few µm

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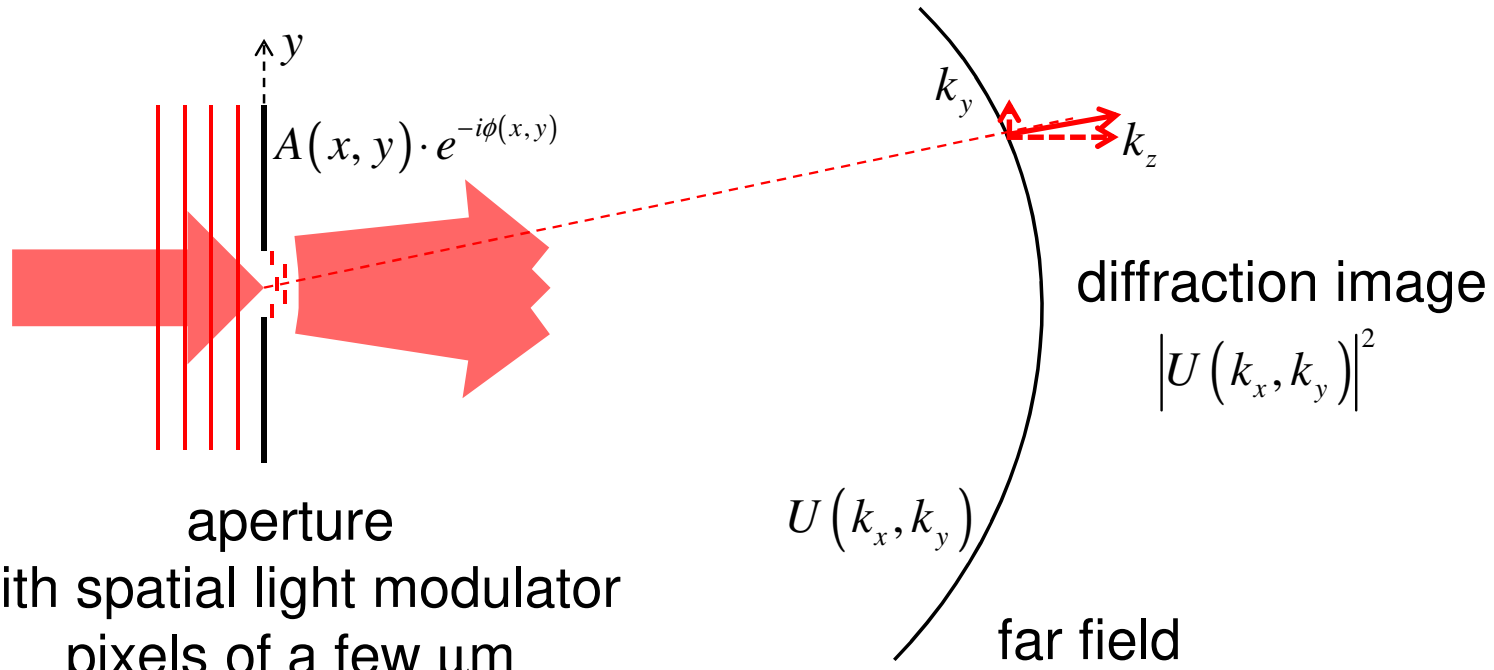
SPATIAL LIGHT MODULATOR

Fraunhofer **diffraction**: a Fourier transform in the far field

$$U\left(k_x, k_y\right) = \int_{aperture} A(x,y)\cdot e^{-i\phi(x,y)} \cdot e^{-i\left(k_x x + k_y y\right)} dxdy$$



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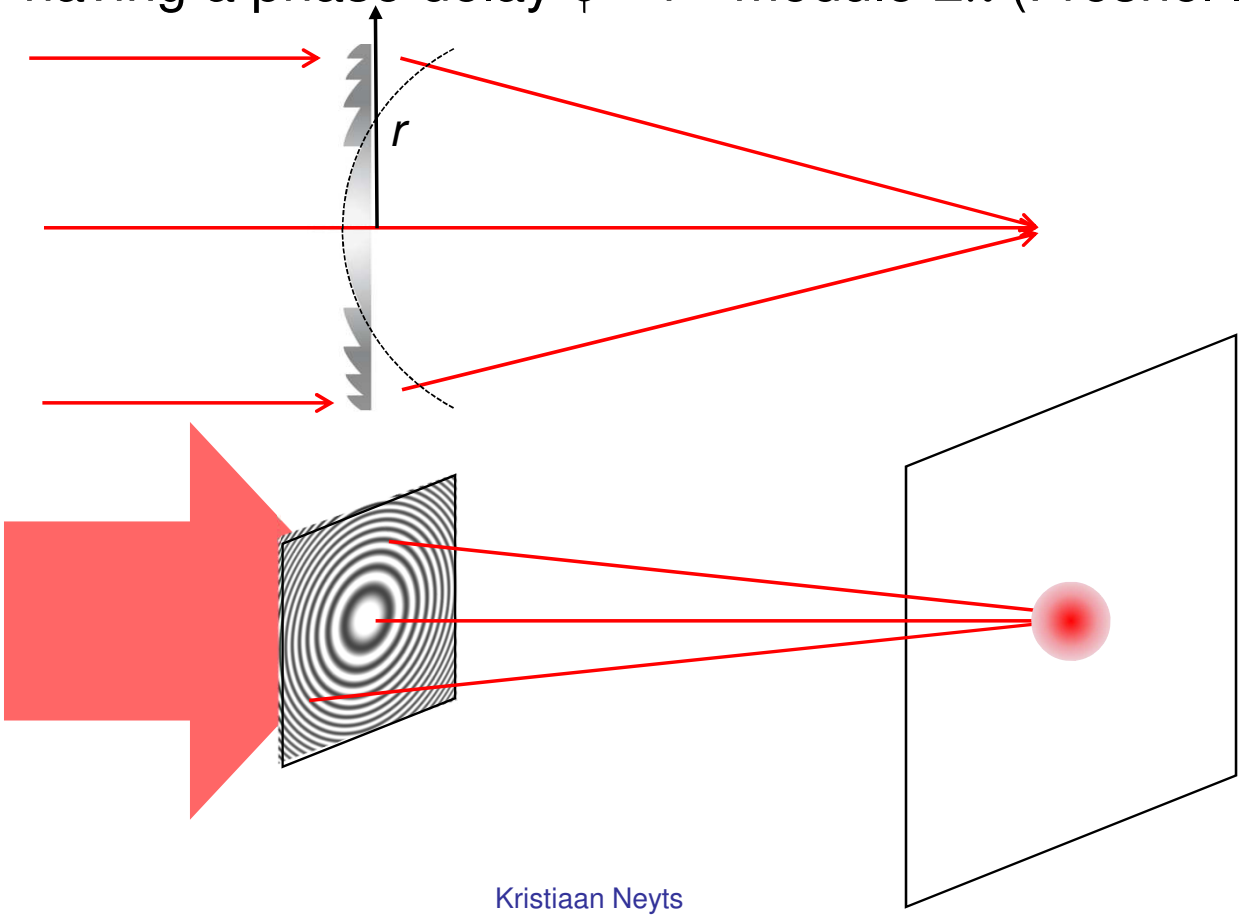
HOLOGRAPHIC PROJECTION: SLM

An SLM with phase modulation can realize lensing
by having a phase delay $\phi \sim r^2$ modulo 2π (Fresnel lens)



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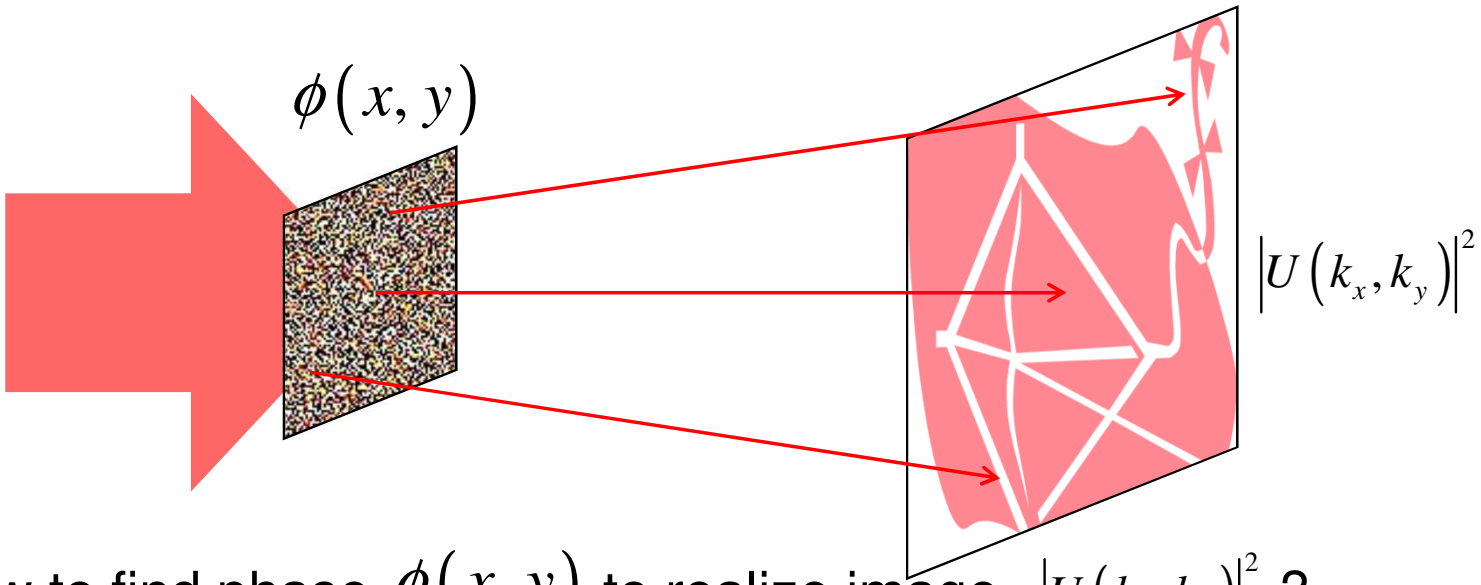
SPATIAL LIGHT MODULATOR

nematic LC SLM, only **phase modulation** (modulo 2π): $\phi(x, y)$



how to find phase $\phi(x, y)$ to realize image $|U(k_x, k_y)|^2$?

complex numerical algorithms...

can be used in many fields: beam shaping, lithography

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