Micro-retardadores ópticos: óptica reprogramable y óptica difractiva de nueva generación

XLV Simposium Nacional de Alumbrado 2019

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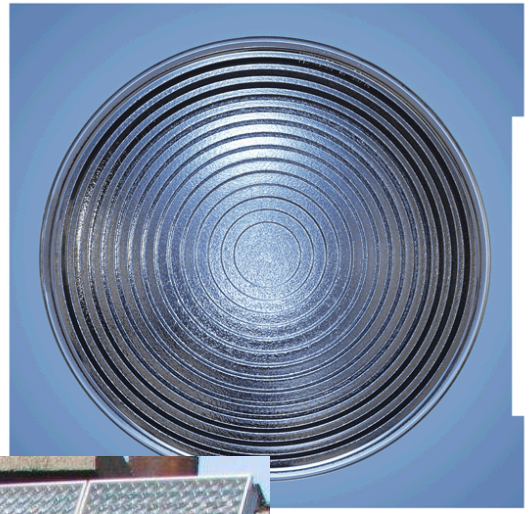
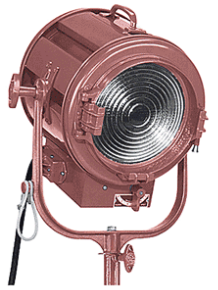
Twitter: @tecnopto

Fresnel lenses

The first Fresnel lens was installed in 1823 in the **Cordouan lighthouse**, where its beam was visible for 32 km.

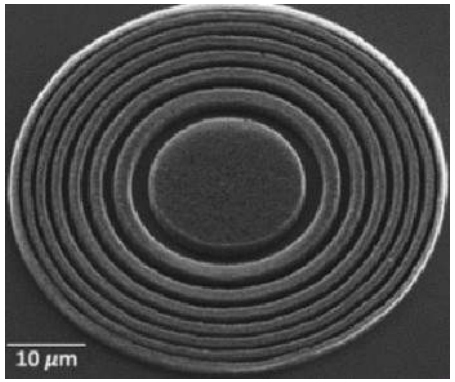
Since then they have been used in a myriad of applications





http://www.luximprint.com/portfolio/ioffe-institute-cpv-fresnel-lenses/

en.wikipedia.org/wiki/Fresnel_lens



https://theophthalmologist.com/subspecialties/why-apodized-diffractive-refractive-is-attractive

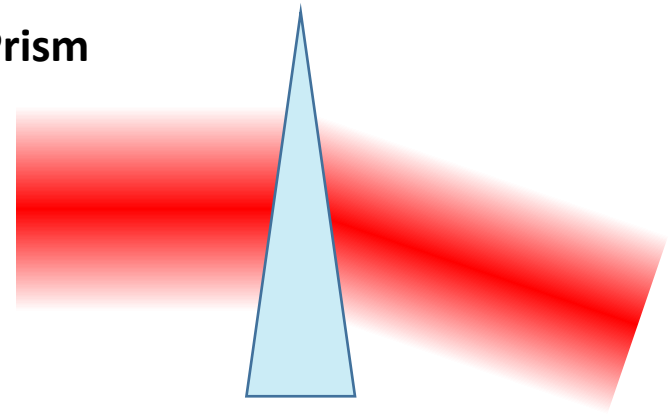
http://commons.wikimedia.org/wiki/File:Cordouan.jpg

http://www.eng.cam.ac.uk/news/bright-idea-carbon-nanotube-fresnel-lenses

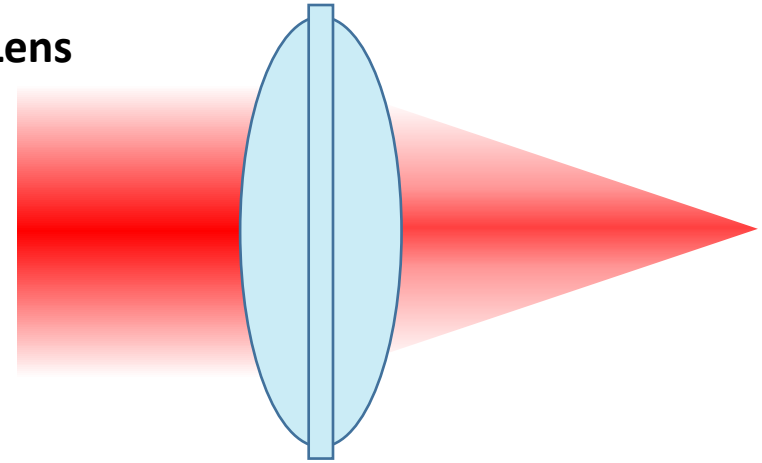
Diffractive Optics versus Refractive Optics

Diffractive Optical Elements (DOE) replicate the behaviour of other refractive optical elements by expliting the diffraction property of light.

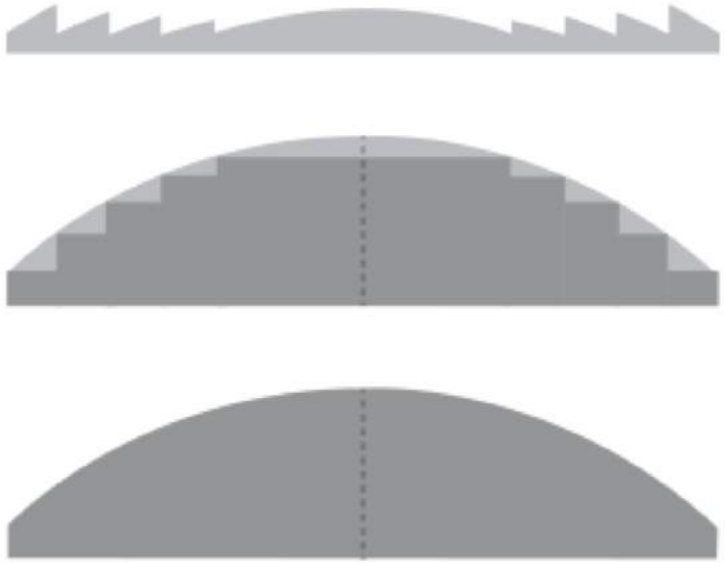
Prism



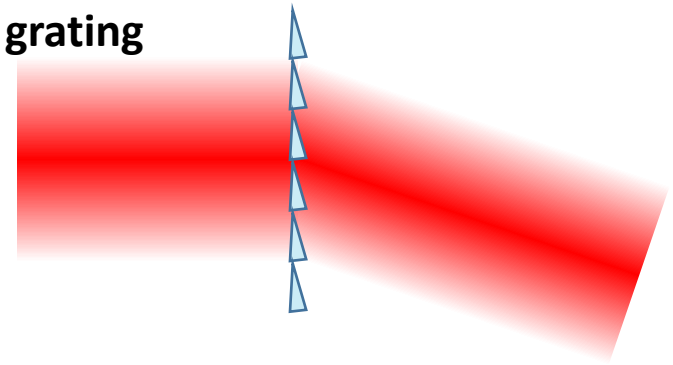
Lens



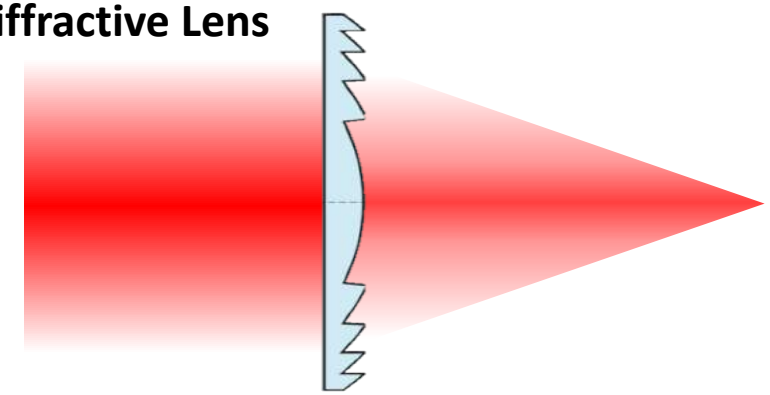
Dispersion is oppossite in refractive and diffractive elements, so they can be combined to chieve compensated elements



Blazed linear phase grating



Diffractive Lens

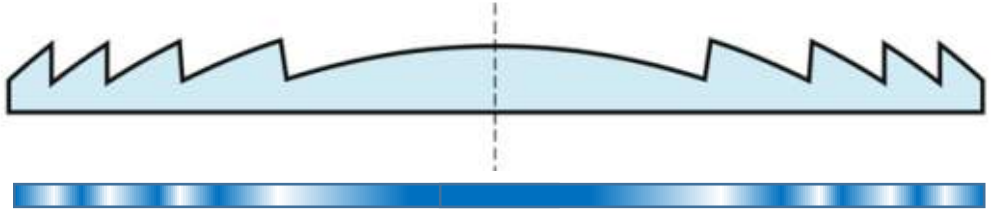


Four Generations of Diffractive Optics

The difractive effect is generated by a phase variation along the section of the light beam.

We can differentiate among **four different mechanisms** to develop **Diffractive Optical Elements**

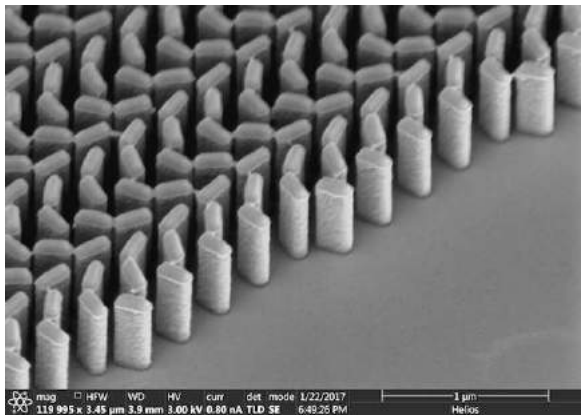
DOE 1G – Thickness variation

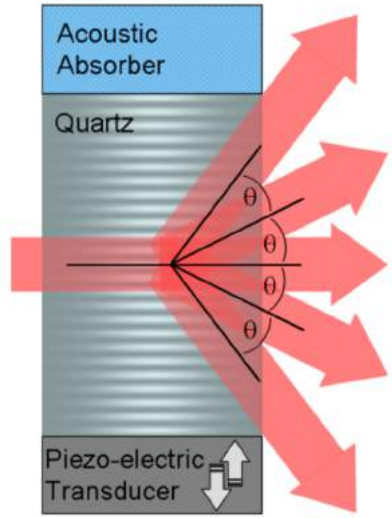


DOE 2G – Refractive Index Variation

DOE 3G – Optical Birefringence Variation

DOE 4G – Geometric Phase Variation





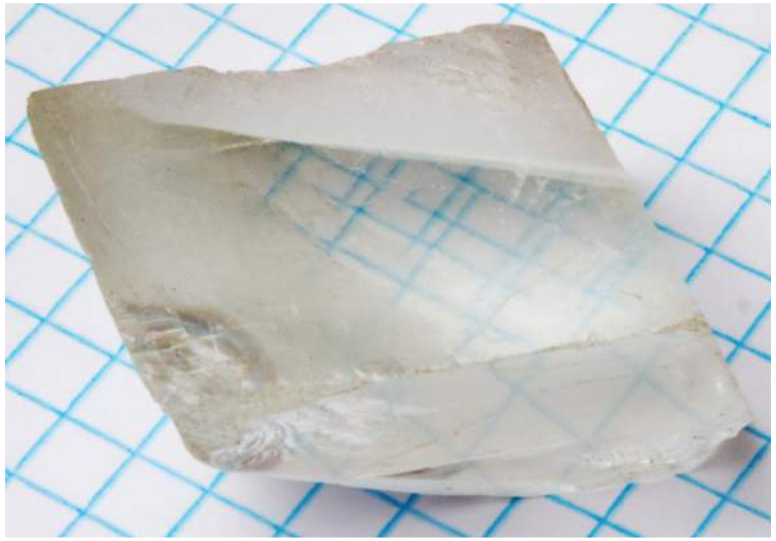
Birefringence and photoelasticity

Birefringence is the optical property of a material having a **refractive index that depends on the polarization and propagation direction of light**.

In general, light is split in one **ordinary ray**, that travels with the same velocity in every direction through the crystal, and one **extraordinary ray** that travels with a velocity that is dependent upon the propagation direction within the crystal.

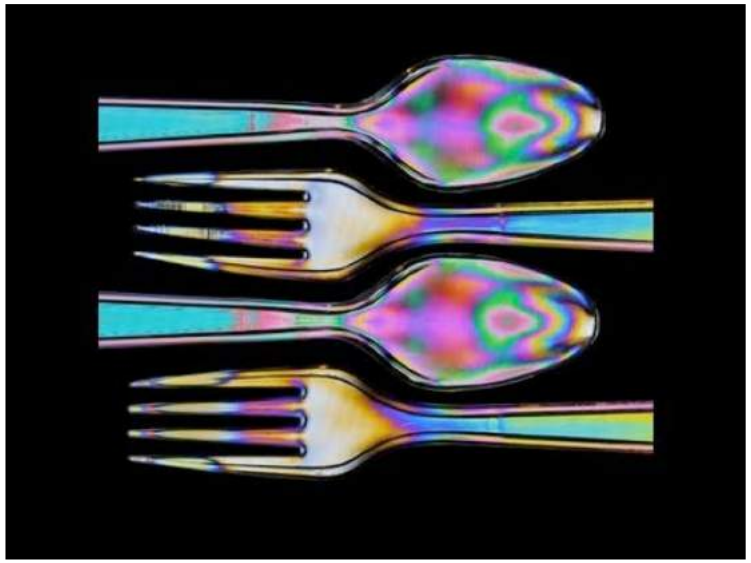
Examples are calcite and quartz crystals, as well as many polymers.

Double refraction on a quartz crystal



http://upload.wikimedia.org/wikipedia/commons/0/09/Crystal_on_graph_paper.jpg

Photoelasticity in plastic pieces



http://en.wikipedia.org/wiki/Waveplate#mediaviewer/File:Waveplate.png

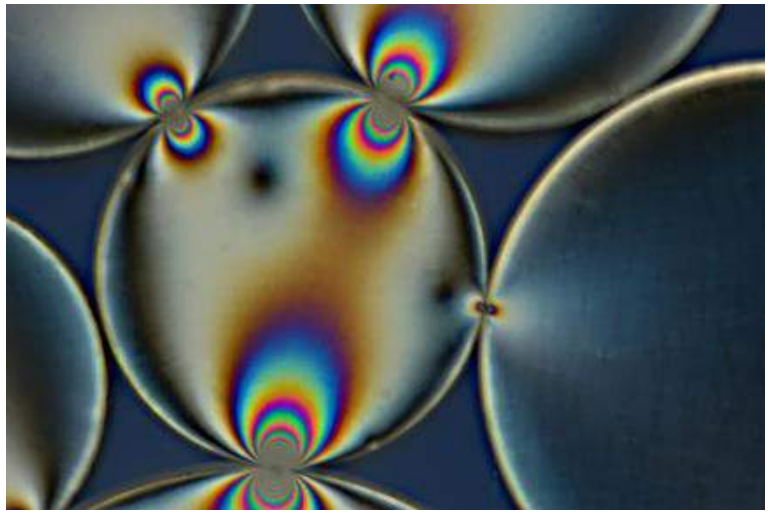
Some of birefringence

Iceland spar
Espato de Islandia

https://en.wikipedia.org/wiki/Sunstone_(medieval)

El cristal que guió a los vikingos hasta Groenlandia
http://www.elmundo.es/ciencia-y-salud/ciencia/2018/04/13/5ac7b1f2468aebac4f8b4681.html

Photoelasticity to meassure stress



http://dutcgeo.ct.tudelft.nl/allersma/diskSc.jpg

Electro-optic modulators for communications

http://www.directindustry.com/prod/bookham/product-55037-592288.html

Early cancer detection

http://dermlite.com

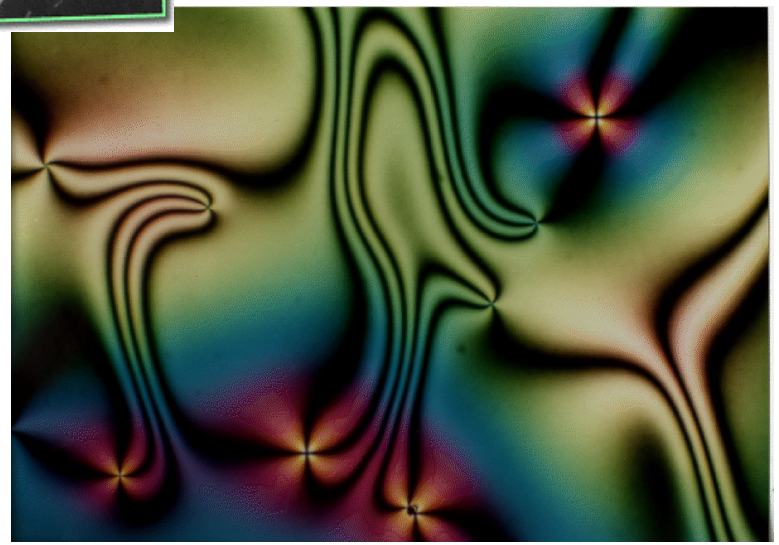
Friedrich Reinitzer. 1888 is credited for the first systematic description of the liquid crystal phase when he prepared cholesteryl benzoate.

Liquid-Crystal Displays - LCDs

Devices that use the **birefringence** of liquid crystal materials.

These properties change upon application of a small electric field, thus producing **optical modulation**.

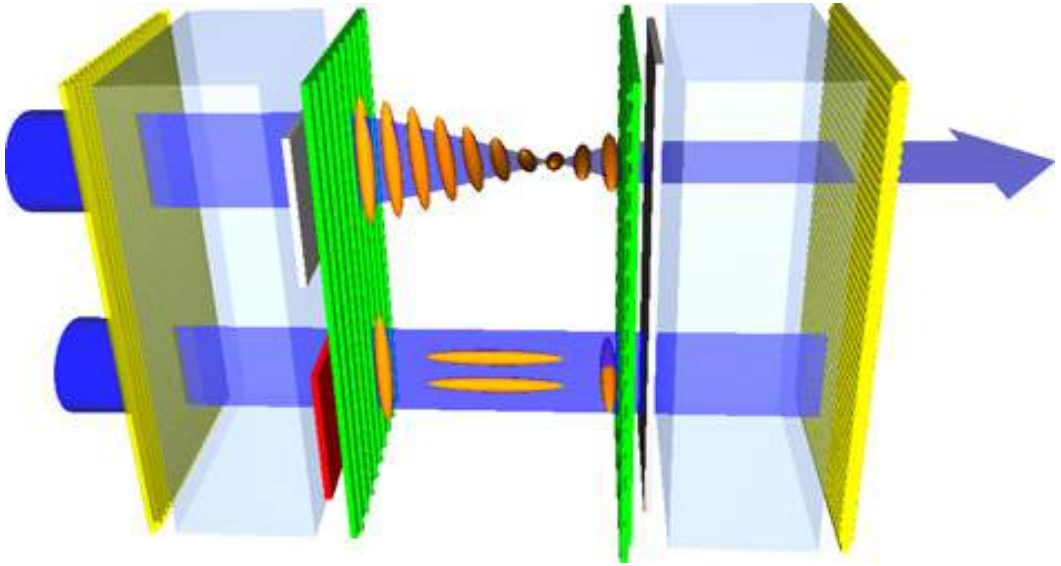
LCD is a mature technology employed in a variety of applications for visualization.

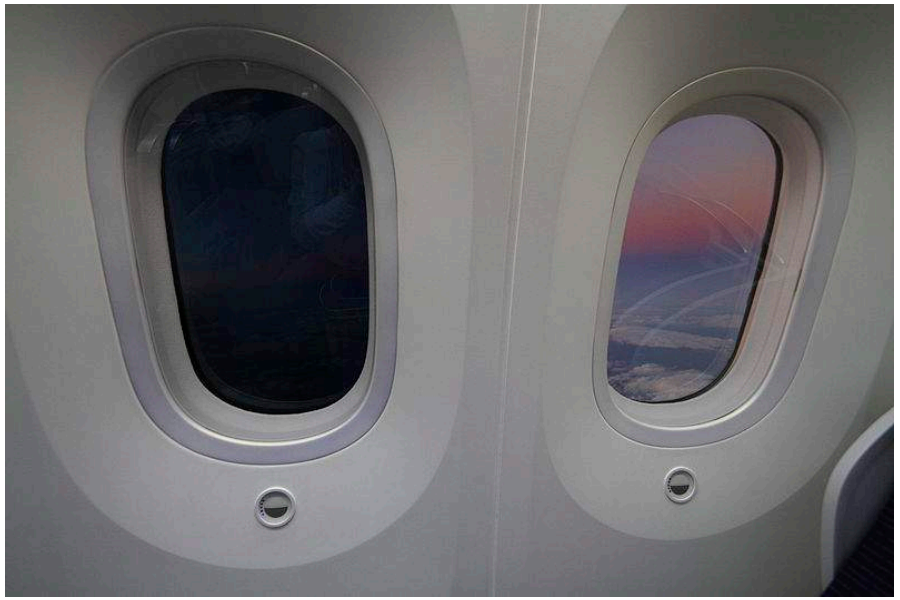


http://www.sussex.ac.uk/Users/az73/Qtensor.html

The twisted nematic LCD

It is the most common LC configuration. The require the use of **POLARIZED LIGHT** to create transparent / opaque windows





Polymer dispersed liquid-crystals (PDLC) can be used to create transparent / difuser windows

http://www.benqmaterials.com/

Spatial Light Modulators - SLMs

SPATIAL LIGHT MODULATORS – Pixelated devices that impose a spatially varying modulation on a light beam

Two main current SLM mature technologies are basically:

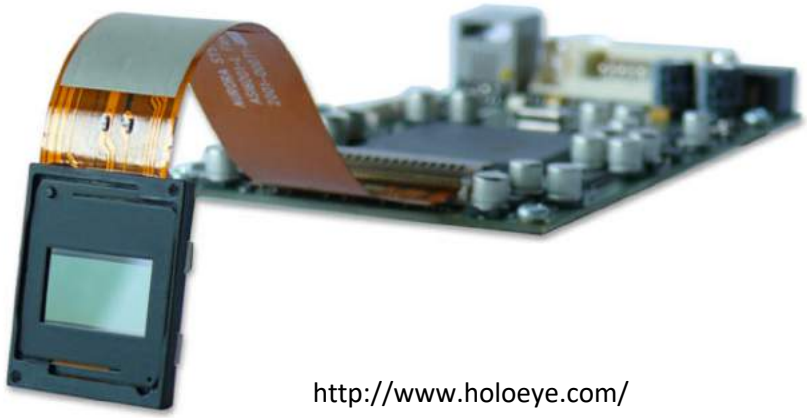
DLP – Digital Light Processors displays

- Based on micromirror MEMs technology.
- Fast refleshing rates.
- Only binary-intensity modulation.
- Phase modulation can be encoded with digital holography.
- Wavelength insensitive.

LCD – Liquid Crystal Displays

- Based on the optical anisotropy of LC materials.
- Require polarized light.
- Slow rates.
- Wavelength sensitive.
- Direct modulation of the intensity, the phase, or the state of polarization.

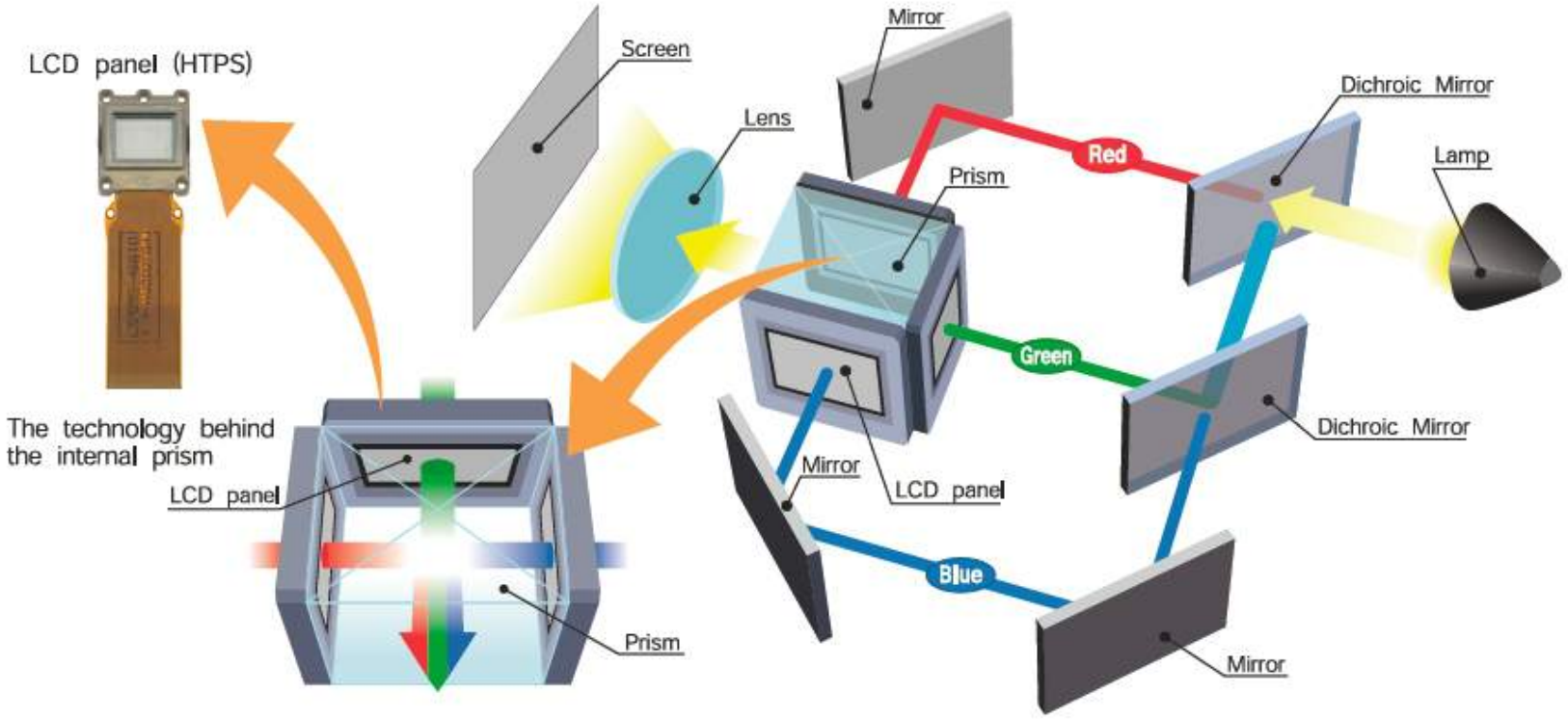
http://www.ti.com/



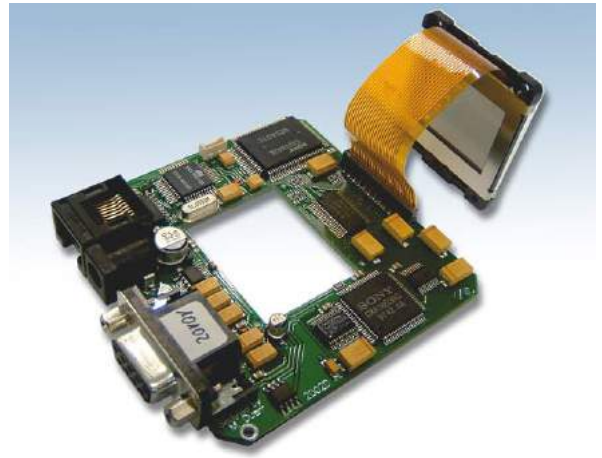
http://www.holoeye.com/

Projection Displays

The primary use of SLMs is as **microdisplays** in **imaging projection systems**.
Here they are usually twisted nematic LCOS or DLP devices.



http://en.wikipedia.org/wiki/File:3LCD_illustration_diagram.jpg

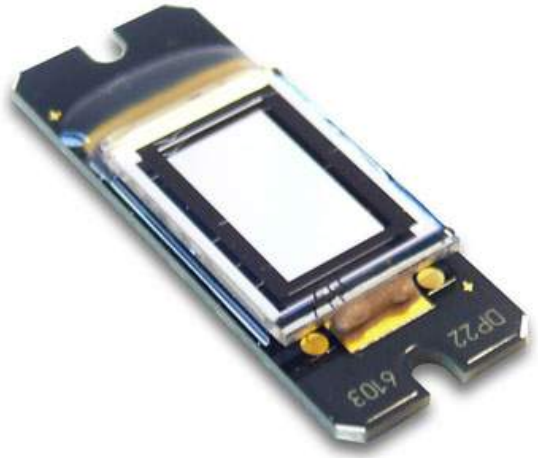


http://www.holoeye.com/

Liquid Crystal on Silicon (LCoS) Displays

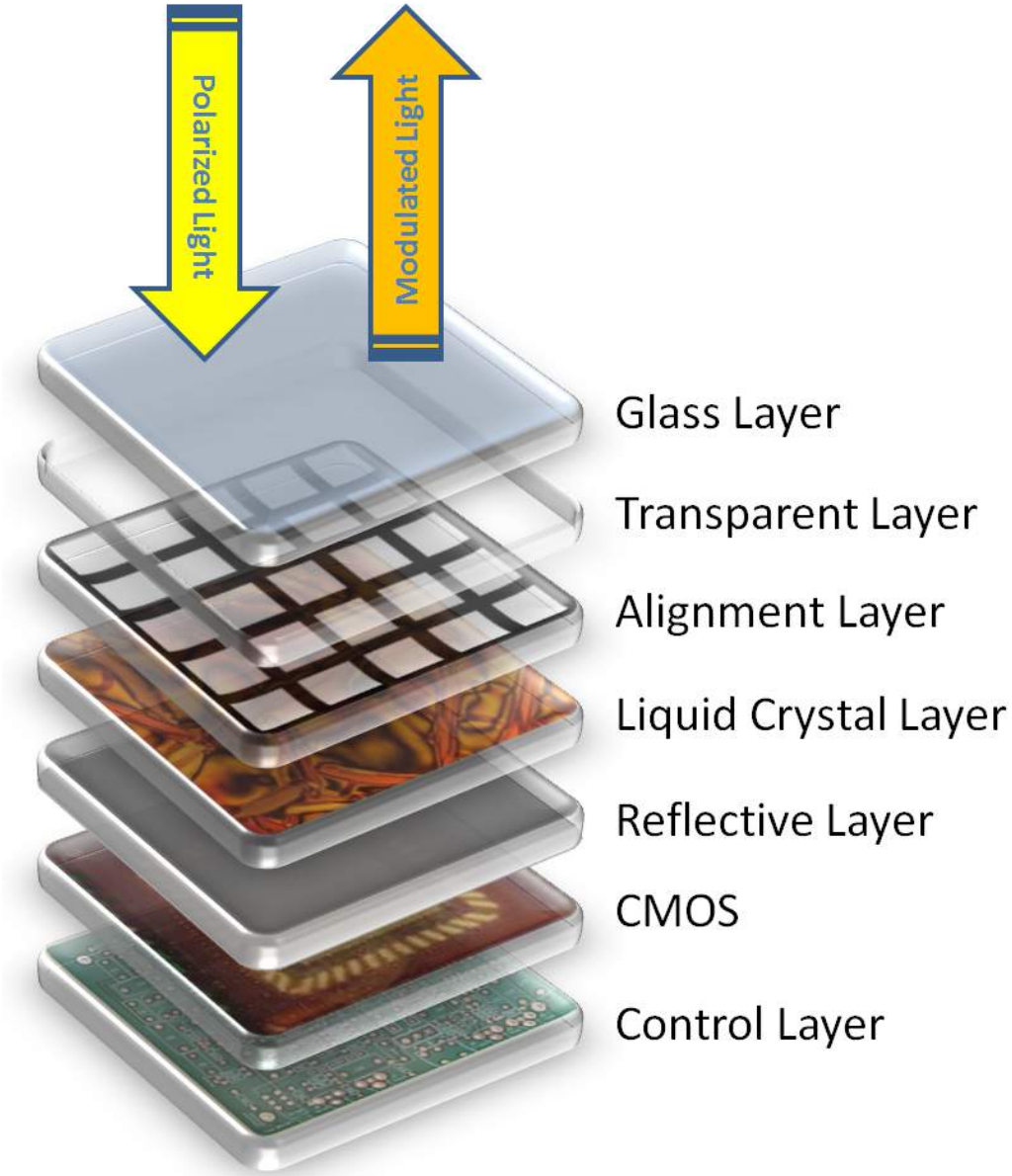
Reflective displays

Advantages:
- Better fill factor,
- Reduced pixel size;
- Better resolution.



https://holoeye.com/lcos-microdisplays/hed-7200-color-lcos/

Optics for virtual & augmented reality



http://rvlab.icg.tugraz.at/project_page/project_microsense/images/lcos.png

Pixelated Optical Retarders – DOE 3G

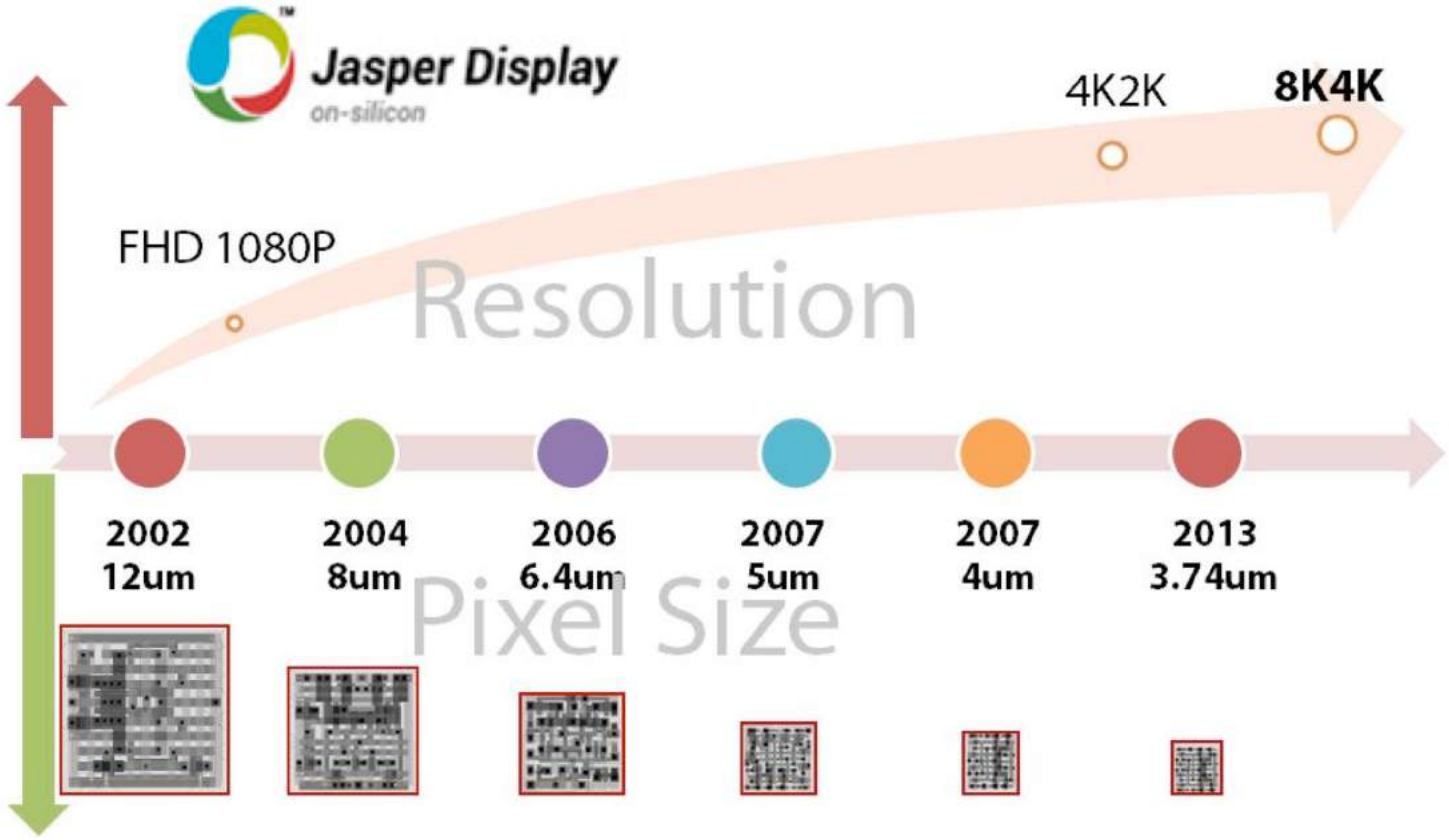
Nematic parallel aligned liquid-crystal SLMs act as a matrices of programable linear retarders.

They can be used to **control and shape the phase and state of polarization** of a light beam

http://www.meadowlark.com

http://www.hamamatsu.com/

http://www.holoeye.com/

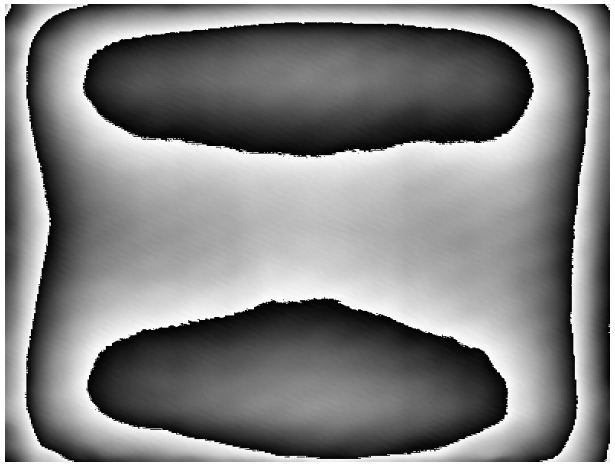


http://www.jasperdisplay.com/

Remaining aspects:

1 – **Uniformity - Aberration**;

LCoS displays suffer from backplane deformation. Some companies give images to compensate the related aberration



2 - **Flicker**

Digital addressing exploits signal temporal fluctuation and eye integration. However, when applied in diffractive optics, it reduces efficiency

3 – **Fringing**

Reduced size of pixels produce the effect that signal in one pixel affects the surrounding pixels. Effective reduced spatial resolution.

Applications beyond displays

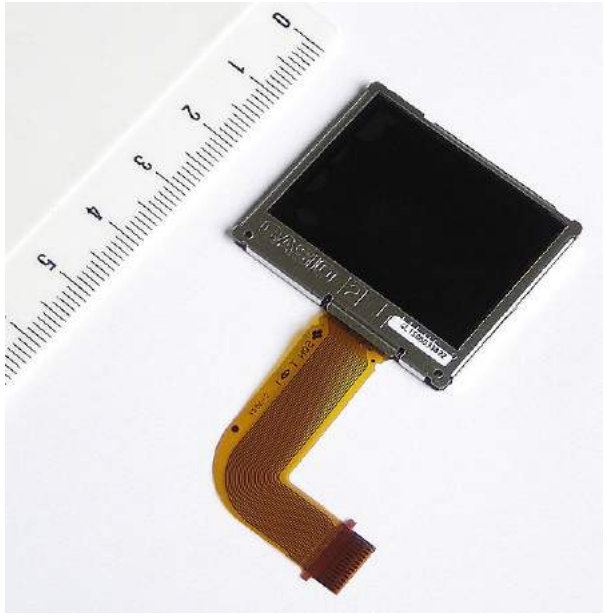
Current spatial resolution allow the realization of diffractive patterns.

Phase-only modulation can be achieved for certain state of polarization.

They can be used as **programmable optical elements, with applications in:**

- **Wavefront sensing and adaptive optics**
- **Customized light beam shaping**
- **Pulse shaping**
- **Optical metrology techniques**
- **Reconfigurable interconnects**
- **Wavelength selective switches**
- **Beam-steering devices**
- **Optical communications**
- **Quantum information processing**
- **Quantum optical computing;**
- **Holographic displays**
- **Displays for augmented and virtual reality**
- **Holographic microscopy**
- **Optical trapping and tweezing**
- **Computational imaging**
- **Holographic material laser fabrication**
- **Massless lithography and 3-D printing**

http://www.holoeye.com/



Some examples – Device selection and operation

https://www.hamamatsu.com/

HAMAMATSU – LCOS-SLM series

Wavelength range:	355 nm - 1550 nm
Spatial Resolution:	1272 x 1064 pixels
Panel Active Area:	9.9 mm x 7.7 mm
Pixel Pitch:	12.5 µm

https://www.thorlabs.com/

THORLABS Exulus

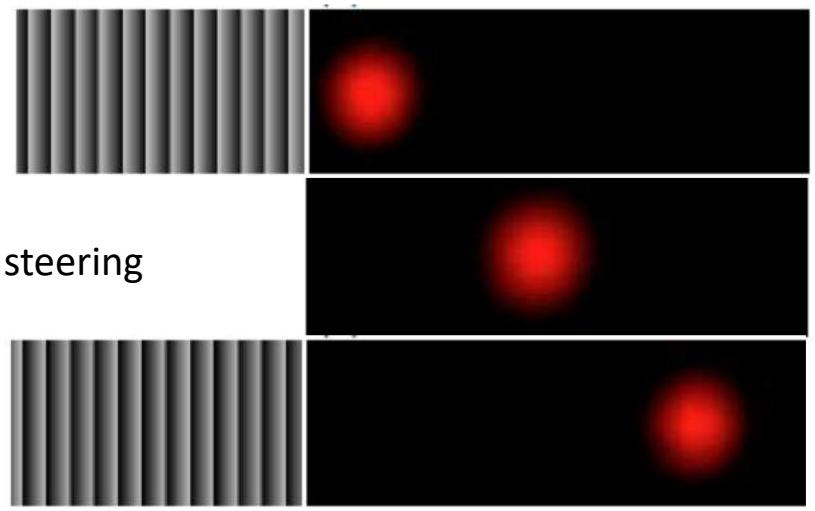
Wavelength range:	400 nm - 850 nm
Spatial Resolution:	3840 x 2160 pixels (4K UHD)
Panel Active Area:	15.6 mm x 9.2 mm
Pixel Pitch:	3.74 µm
Damage threshold:	CW - 5 W/cm

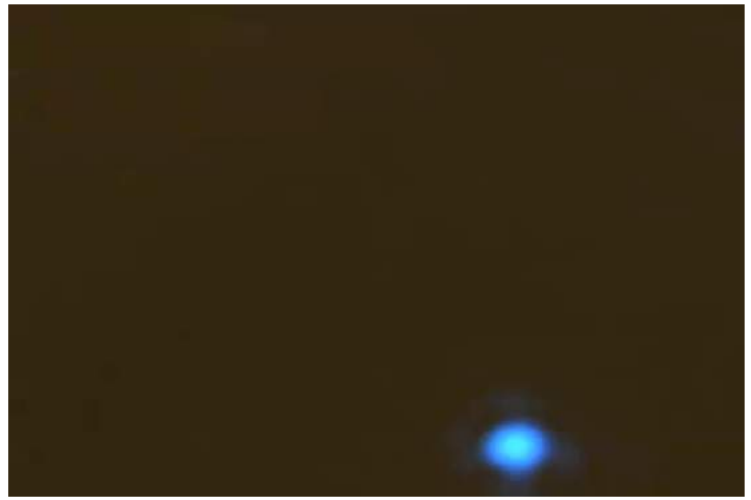
Transmissive TN displays offer a much lower cost alternative.

But they require a precise in a selective polarization configuration, achieved with our systematic procedure.

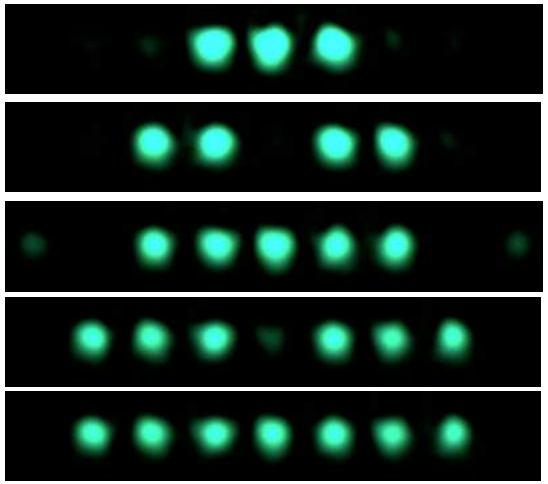
Laser beam control

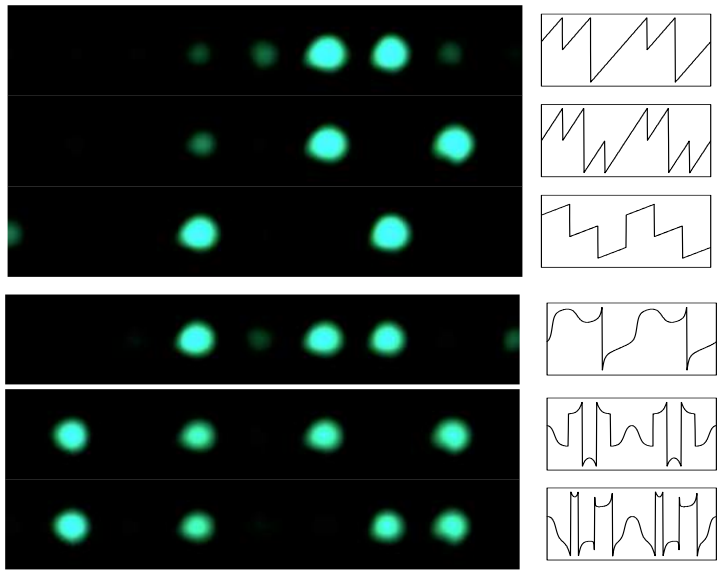
1. Laser beam steering



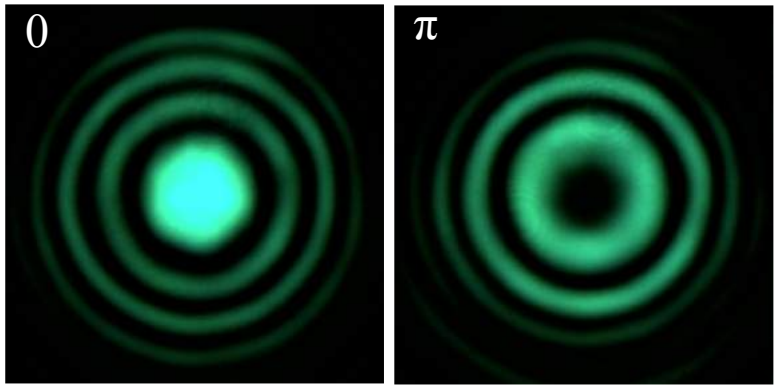


2. Laser beam splitting



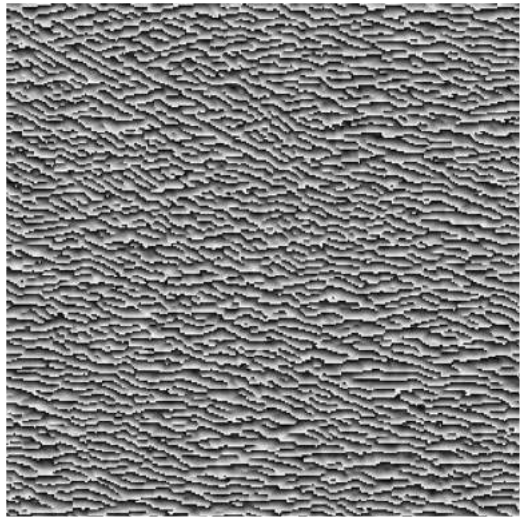


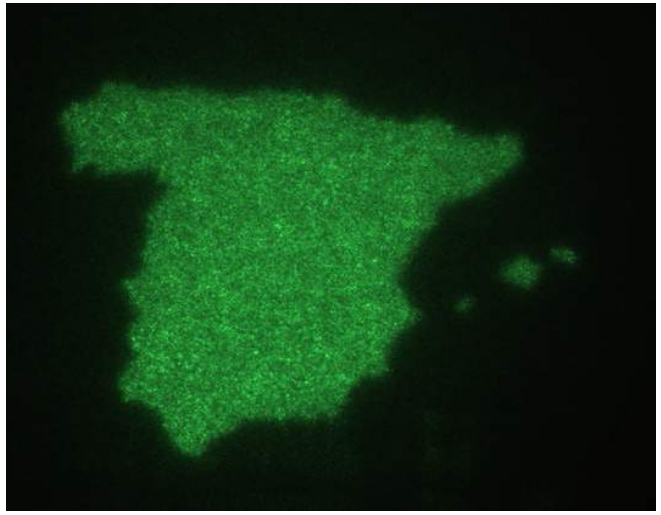
3. Phase shifting interferometers



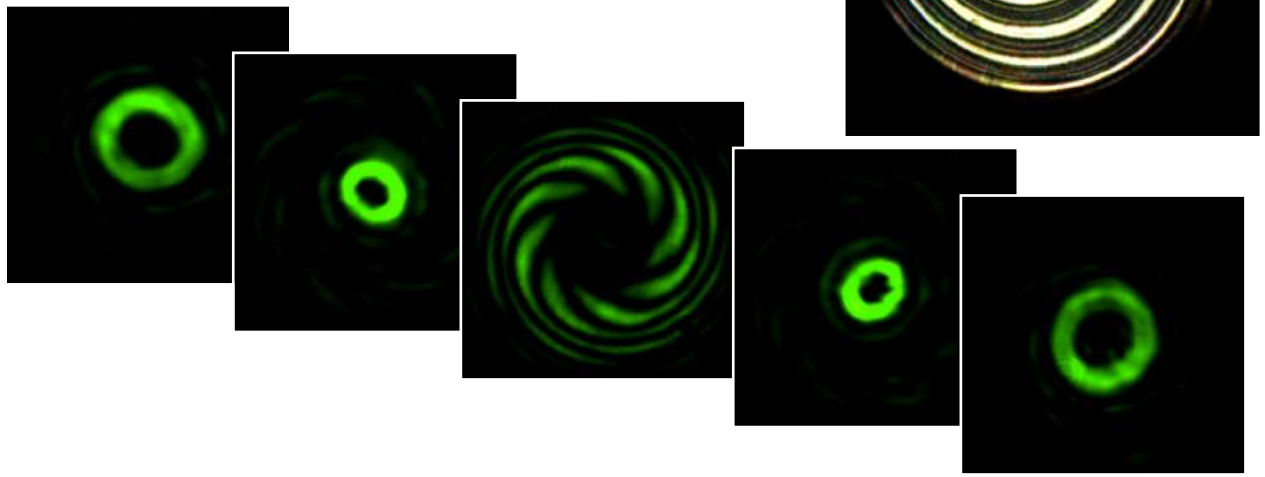
Laser beam control

4. Holographic laser projection



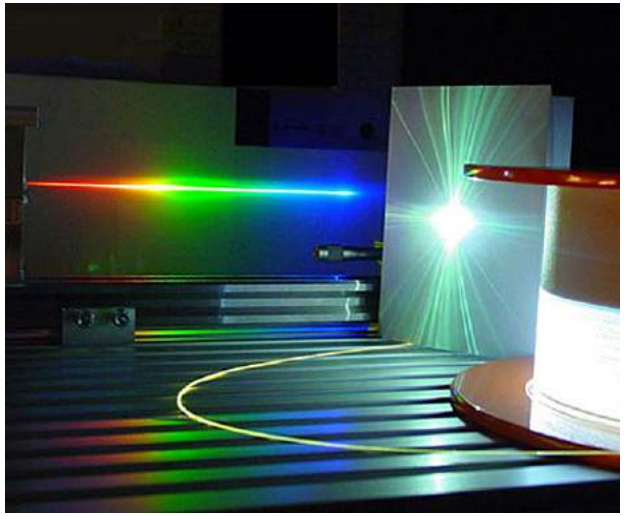


5. Customized LC multifocal vortex lens for OAM based detection

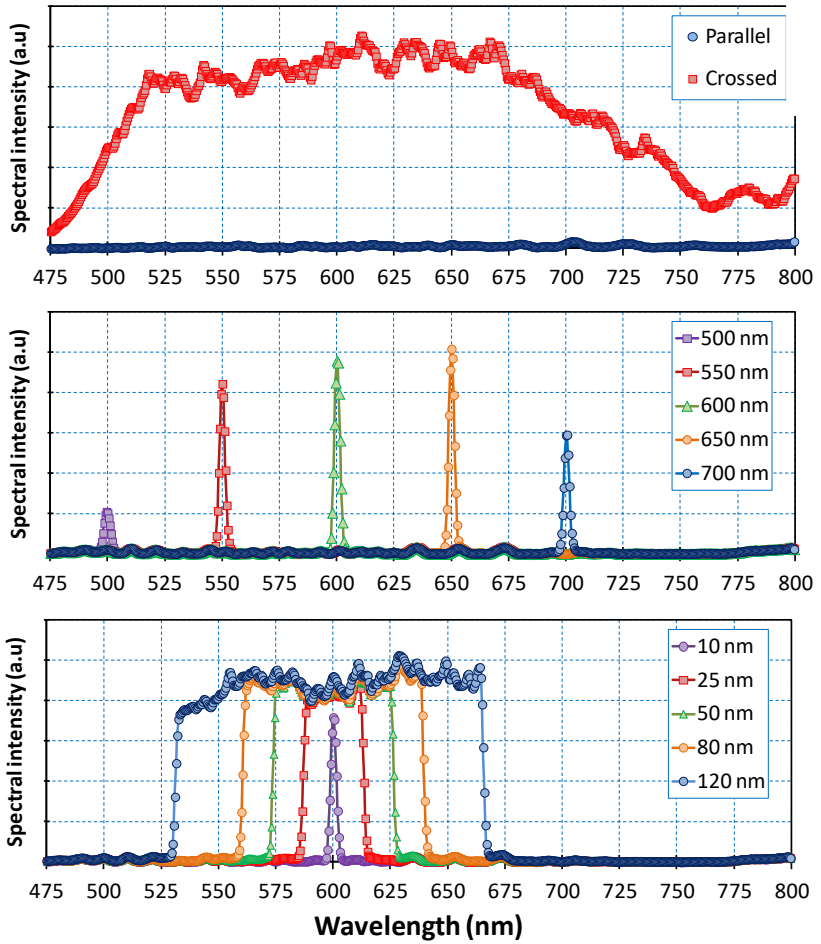


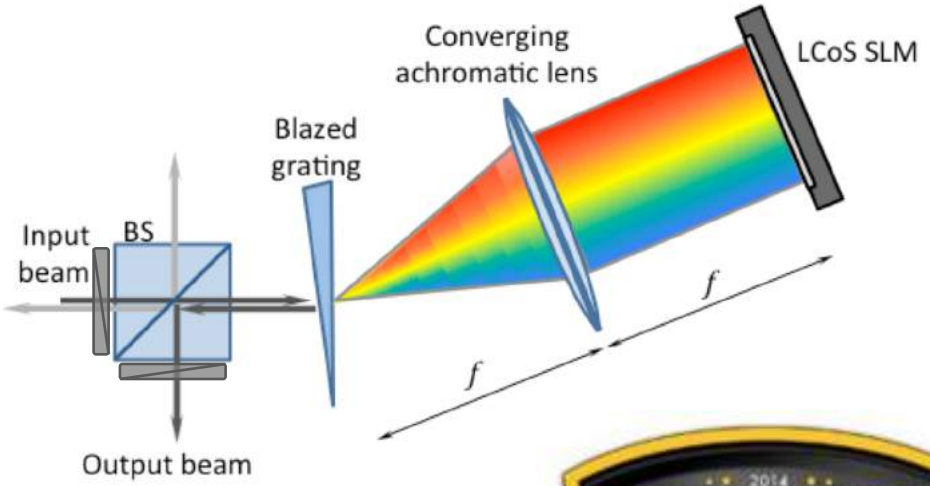
Hyperspectral digital laser source

Supercontinuum laser source



Broadband half-wave retarder



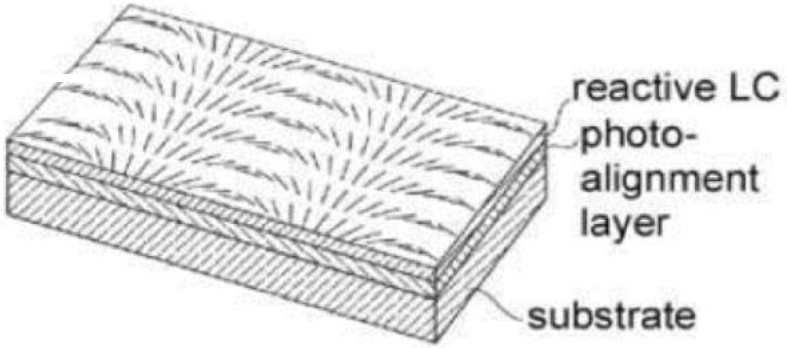


Opt. Lett. **39**, 5483 (2014)

Edmund Optics Educational Award 2014

santec The Photonics Pioneer

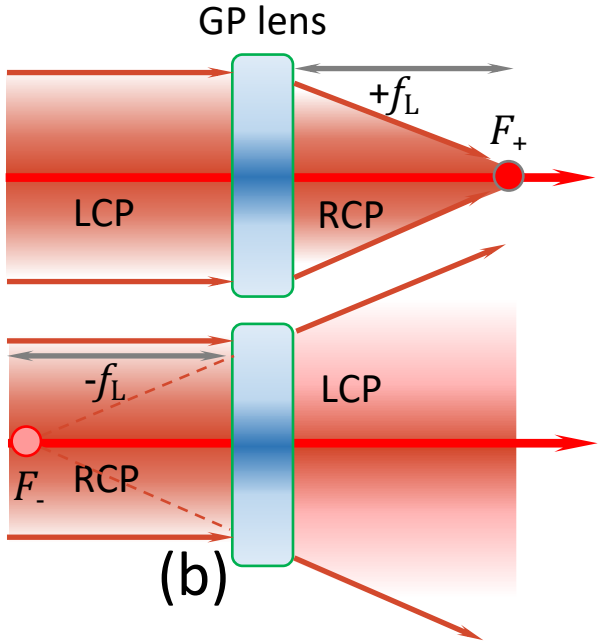
http://www.santec.com/en/products/instruments/tunablefilter?gclid=CL_ogILFs8sCFdUW0wodtDIBYQ

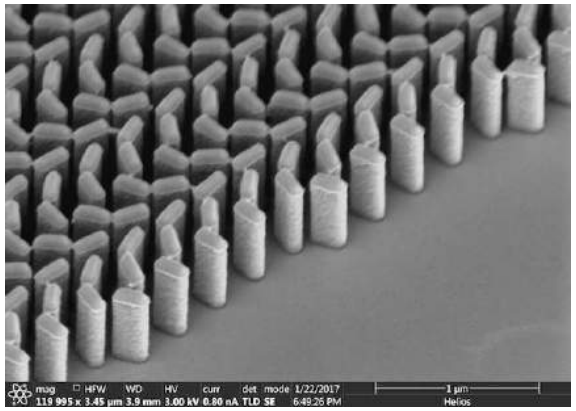


Geometric Phase – DOE 4G

- Linear half-wave retarders with spatial variation of the principal axis;
- They can be made of liquid-crystal (LC), LC polymers, or metamaterials;
- Geometric-phase lenses, polarization diffraction gratings or q-plates are commercially available.

THEY REQUIRE USING CIRCULARLY POLARIZED LIGHT



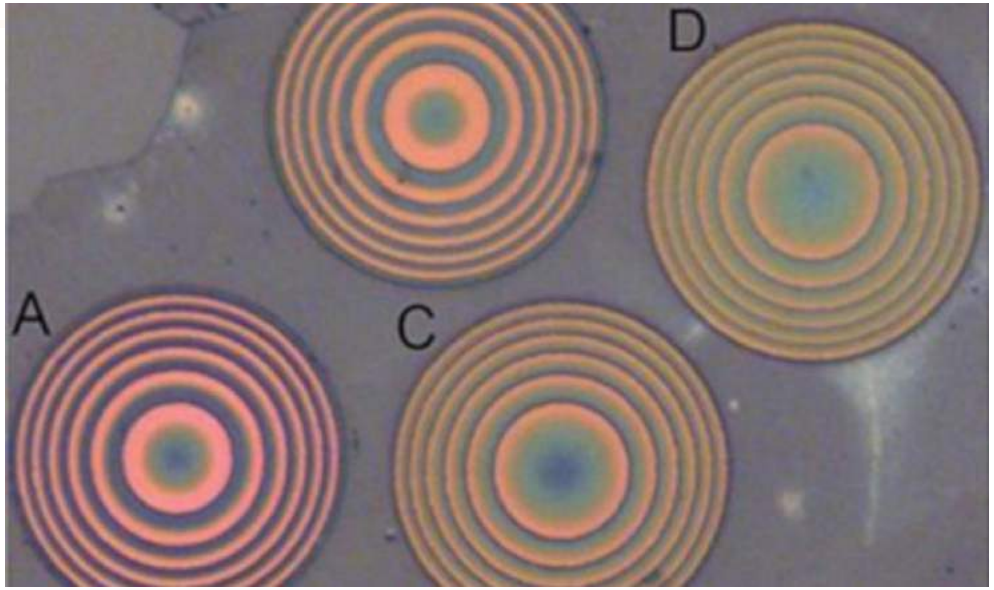


Capasso Labs

Edmund Optics

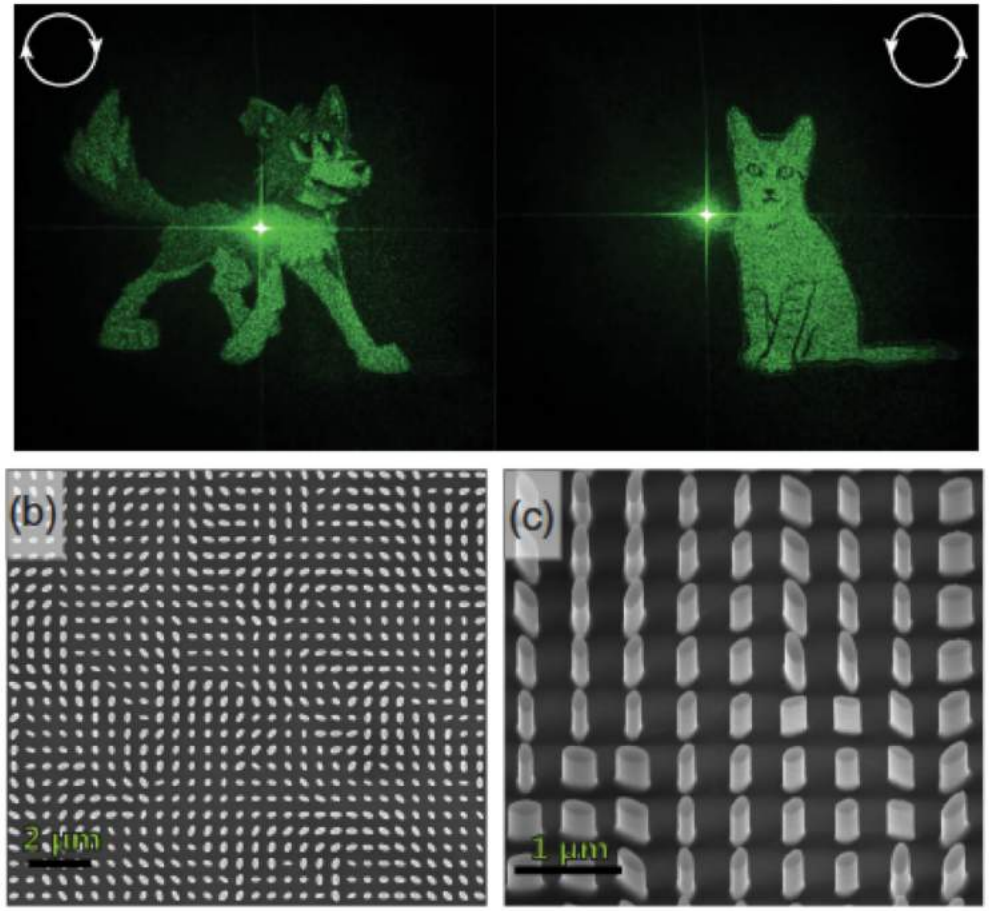
Some Applications

Ultra-thin lenses

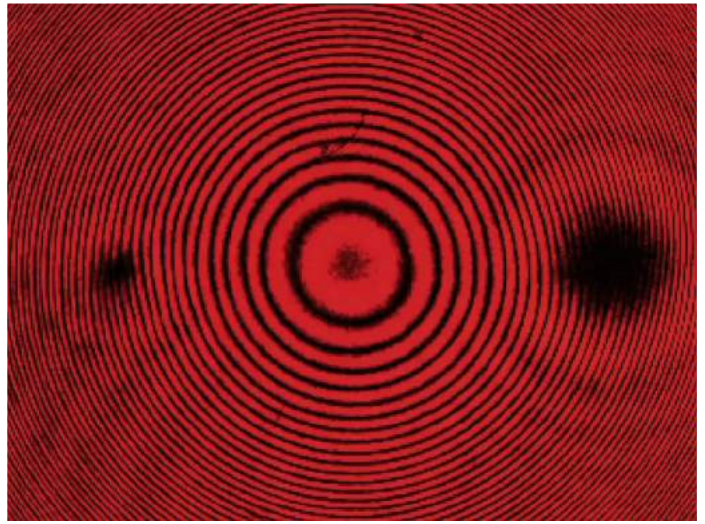


https://www.asianscientist.com/2018/11/in-the-lab/metalens-2d-material-nanophotonics/

Polarization sensitive holograms



Common-path interferometers



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