New opportunities in optical testing given by photochromic materials

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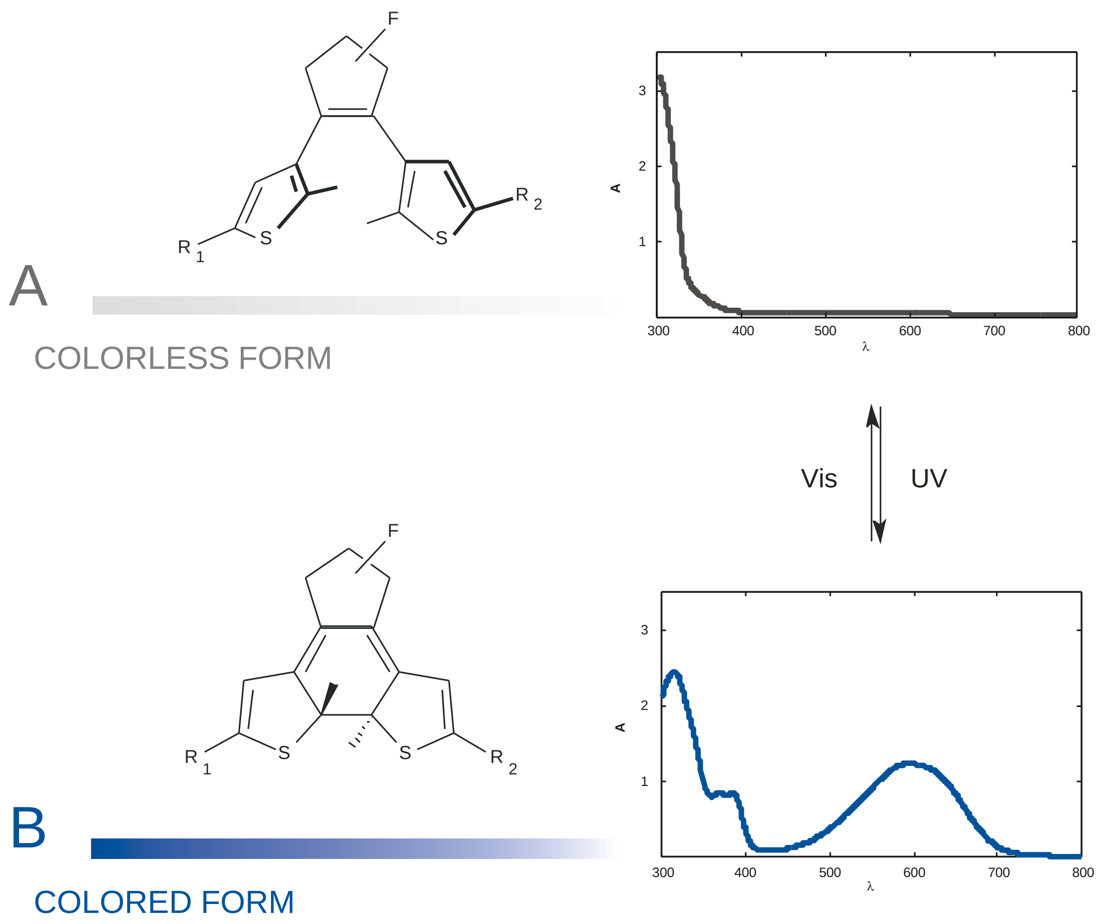
Photochromic materials

Change of:

- **UV-Vis absorption spectra**
- Luminescence
- Polarizability/Refractive indices
- Conductivity/charge mobility
- Dipole moment
- Redox potential.

And:

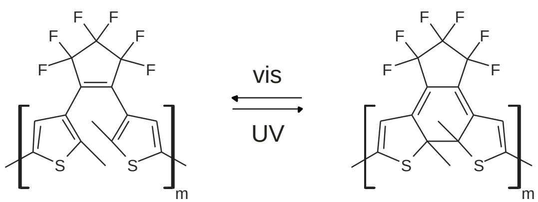
- No thermal switching
- Good fatigue resistance
- Fast responce



Bertarelli, C., Bianco, A., Castagna, R., Pariani, G., *J. Photochem. Photobiol. C: Photochemistry Reviews*, *12*(2), 106–125 (2011)

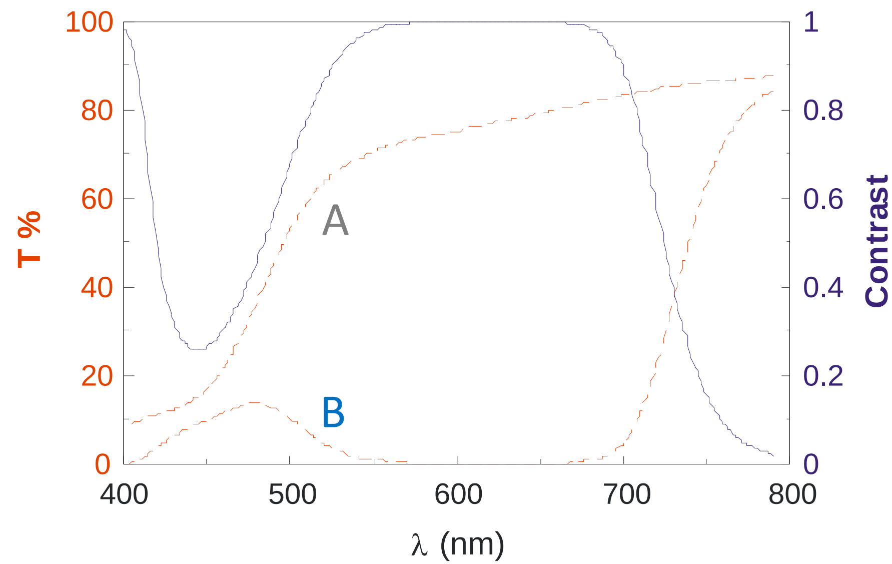
Photochromic Focal Plane Masks

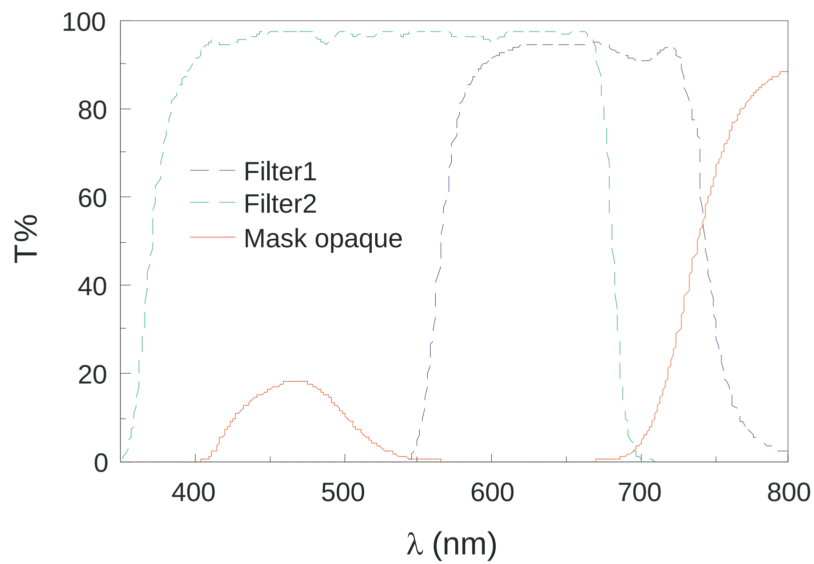
- Photochromic polymer (6%) in PMMA
- 70 μm thick film



A B

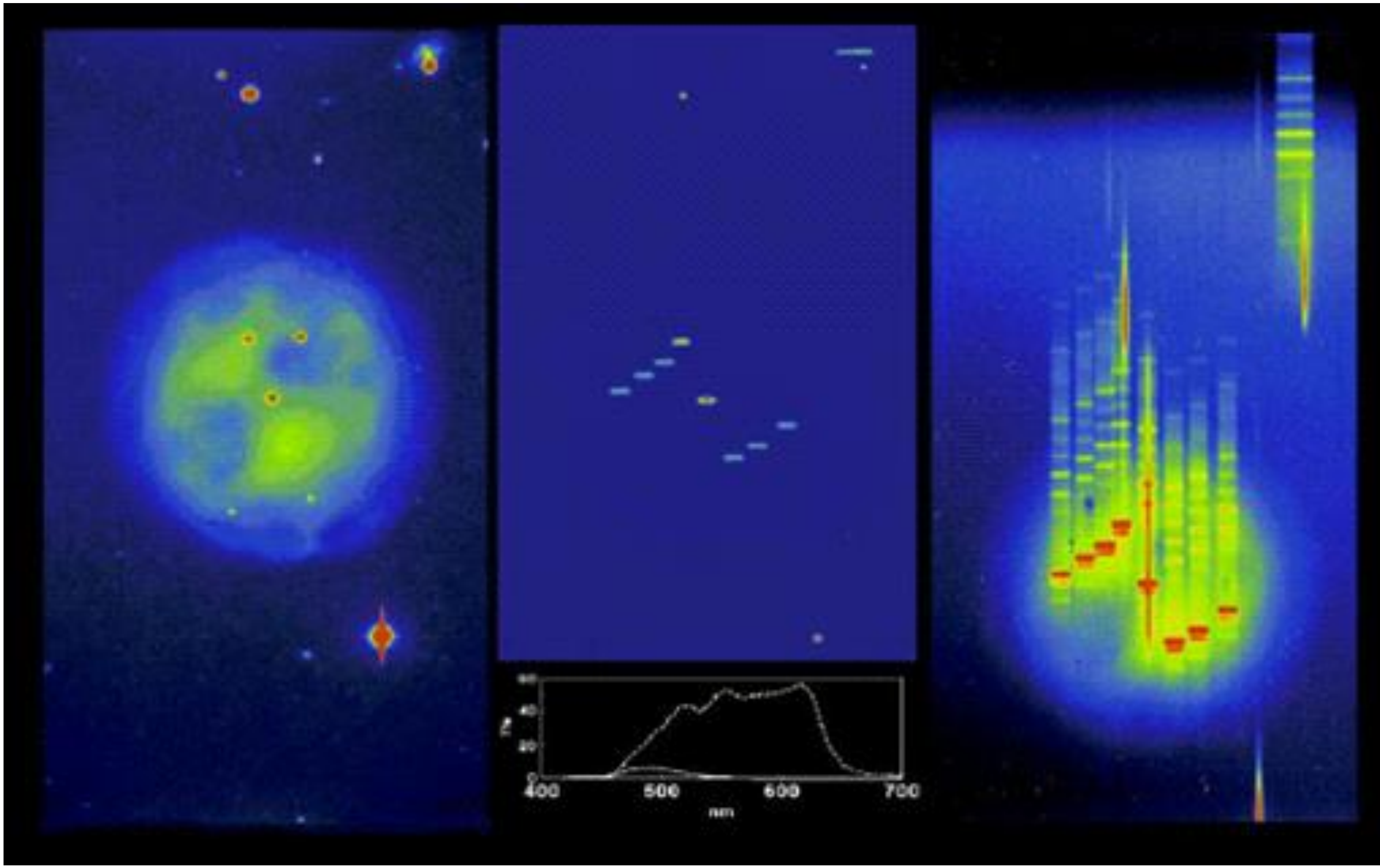
- large contrast in a specific spectral range of interest (Ha, Na,...)
- filters are needed to cover the entire spectral range
- easy to produce (with direct laser writing) and easy to use





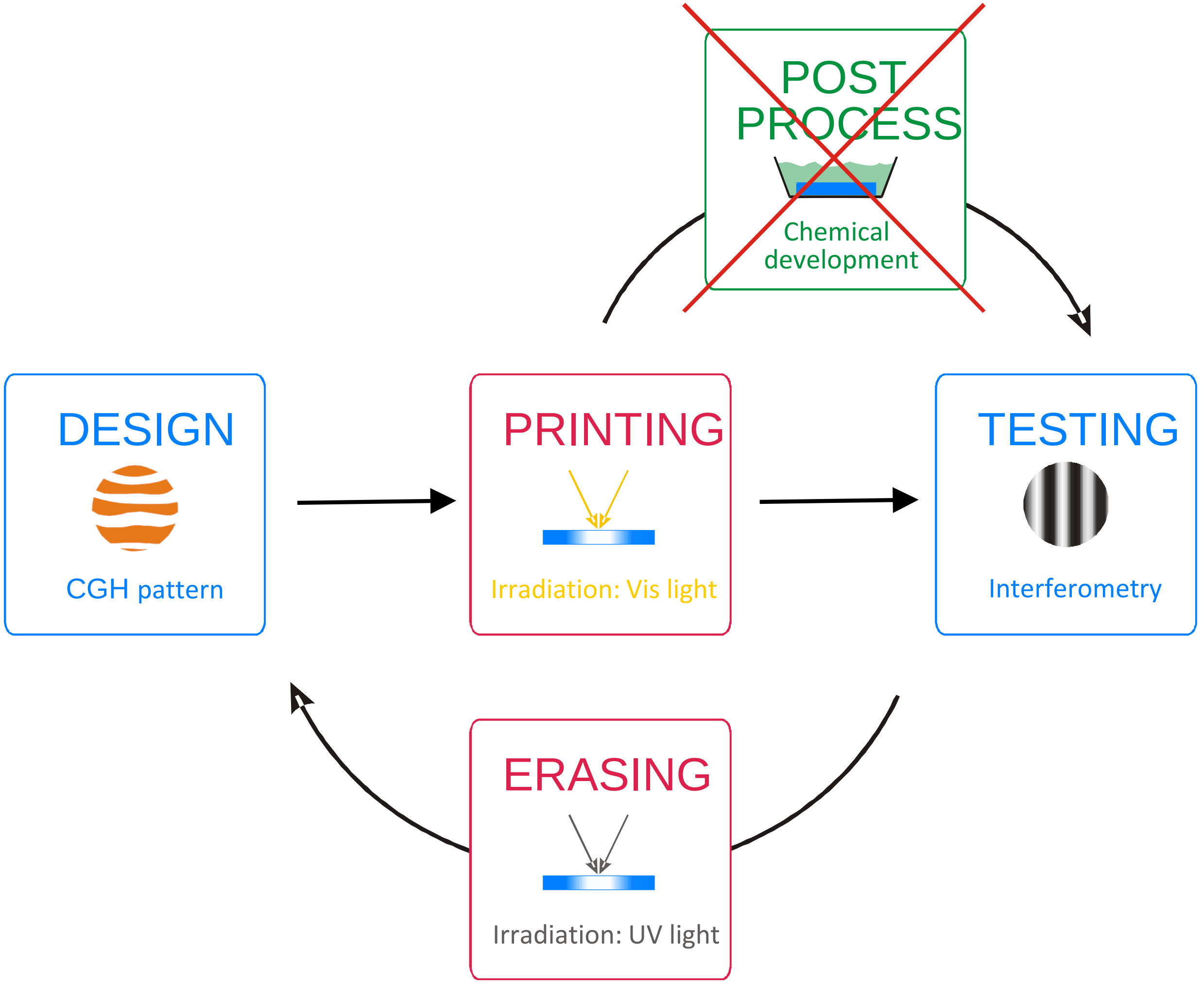
Bianco, A., et al., *Astron. Nachr., 326(5), 370-374 (2005)*

Photochromic FPM @ Asiago Telescope



Bianco, A., Bertarelli C., Gallazzi, M.C., Zerbi G., Giro, E., Molinari, E., *Astron. Nachr., 326(5), 370-374 (2005)*

Process



make the element re-writable: it is a reconfigurable platform

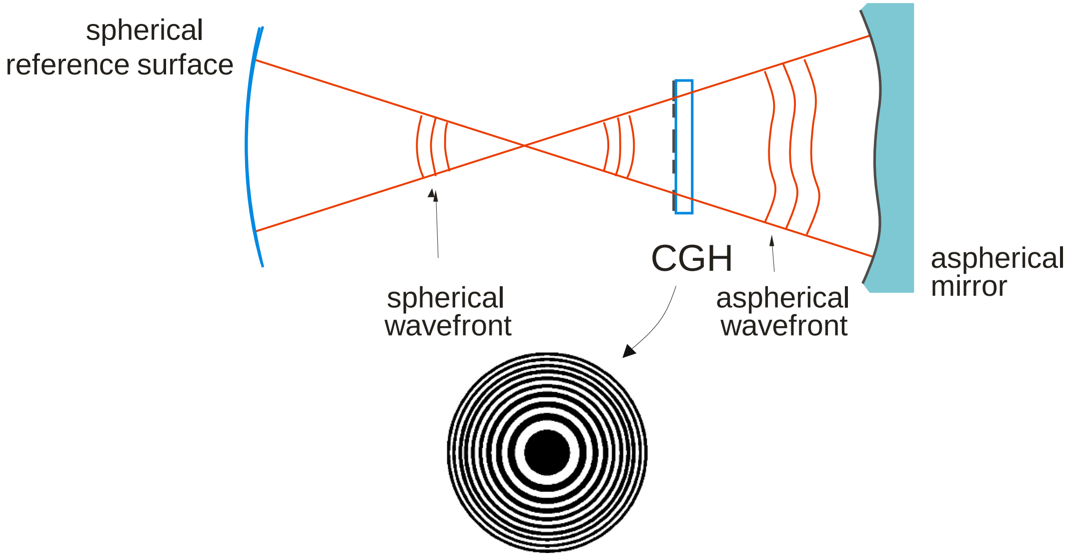
Interferometry

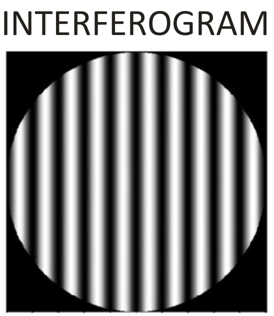
- Amplitude Computer Generated Holograms for optical testing
- Photochromic Point Diffraction Interferometer

Computer Generated Holograms

J. C. Wyant, **1971-72**

Null Test



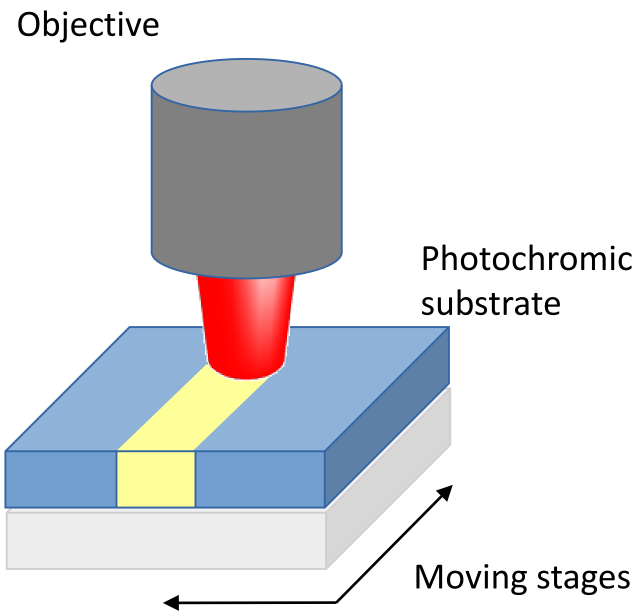


CGH: binary representation of the interferogram between the spherical and aspherical wavefront under test. Each line adds $m\lambda$ of OPD and changes the wavefront slope by $\sin(\theta) = m\lambda/\Lambda$, Λ is the local line spacing.

REQs:	Line period	Λ = down to 1 micron
	Accuracy	ε = 50 nm PV
	Size	D = 150 mm

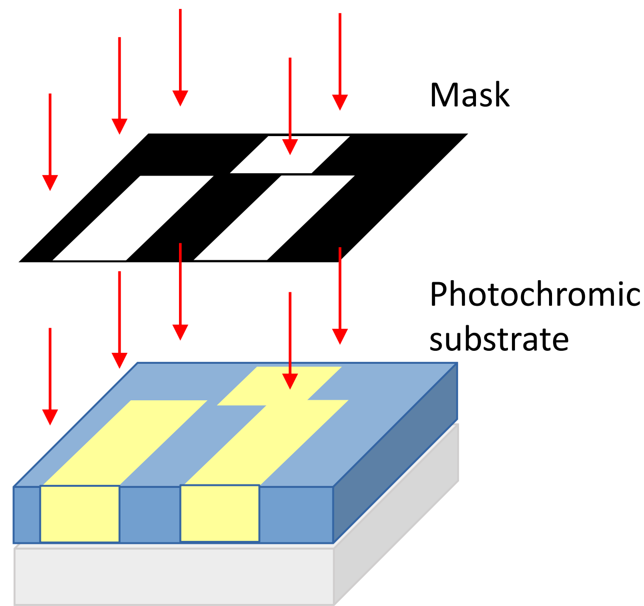
Writing strategies

Direct Laser Writing
scanning mode



- High pattern density/slow process
- High accuracy
- Compex system/very versatile

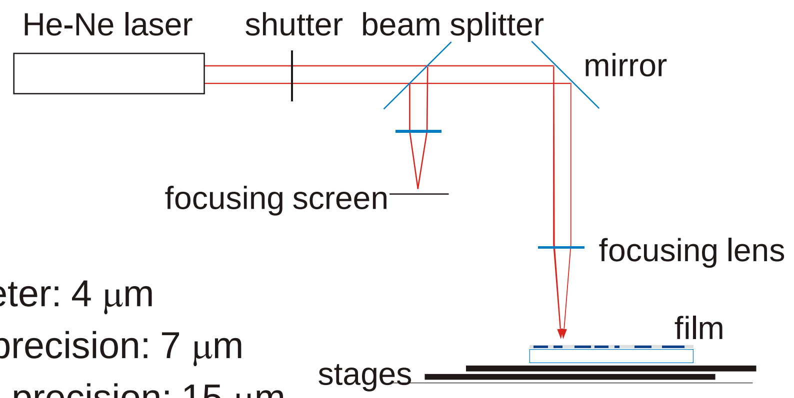
Mask projection
raster mode



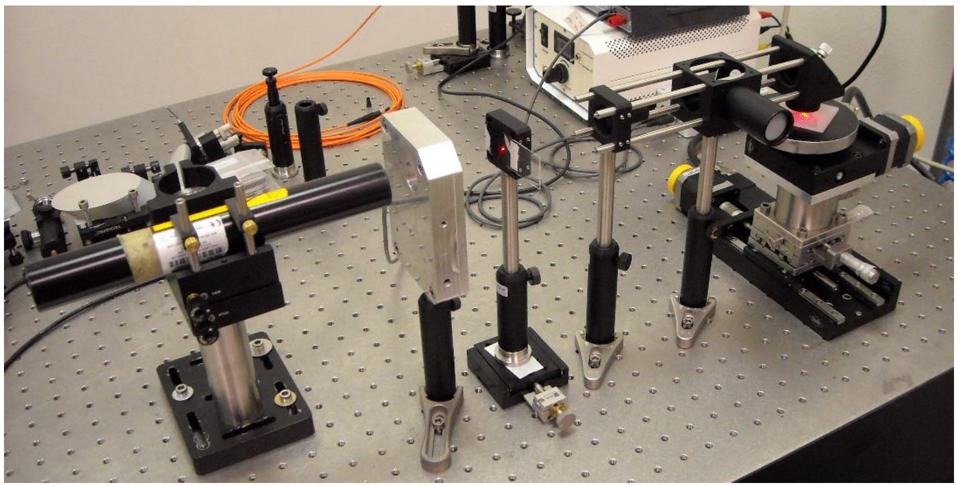
- Fast process/stitching for large areas
- Distorsions from projection
- Very versatile (according to the mask)

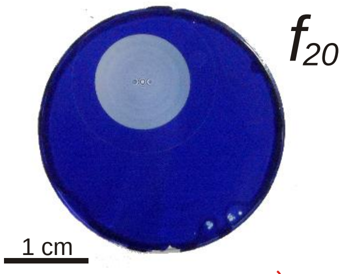
Amplitude Fresnel CGH – scanning mode

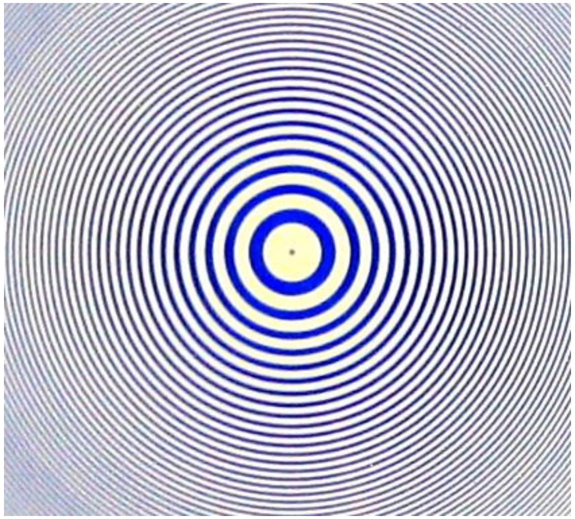
Laser Plotter



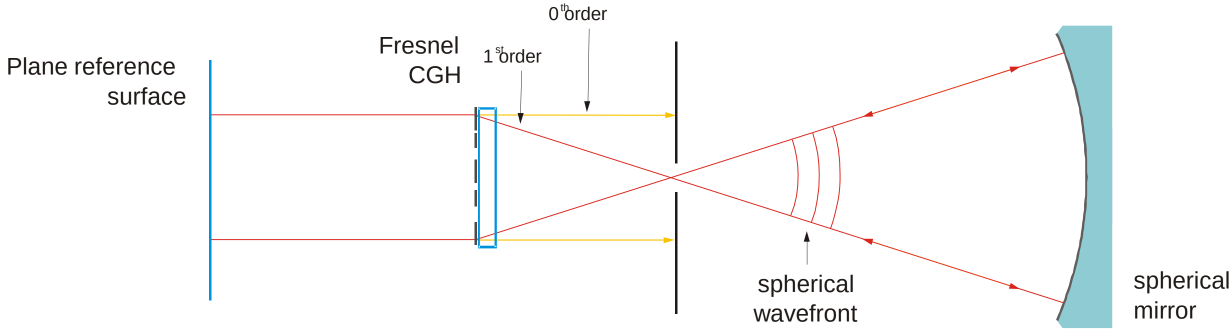
Spot diameter: 4 μm
Centering precision: 7 μm
Translation precision: 15 μm
Light density: 50 W/mm^2

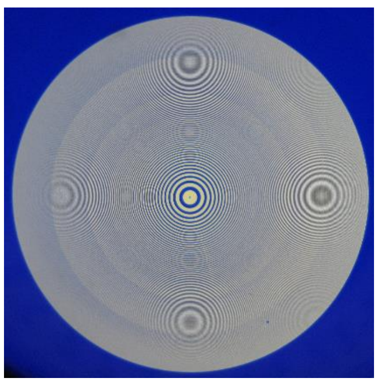




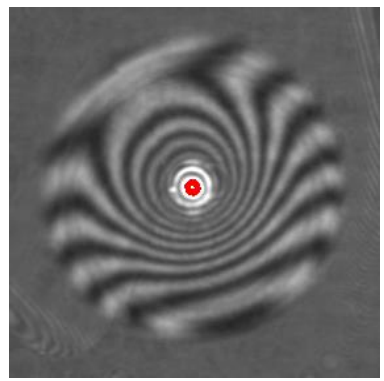


Test results

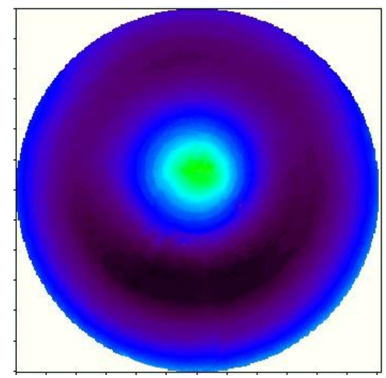




CGH



Interference fringes



Wavefront analysis

PV: 1680 nm
RMS: 238 nm

3λ PV,
λ/2 RMS

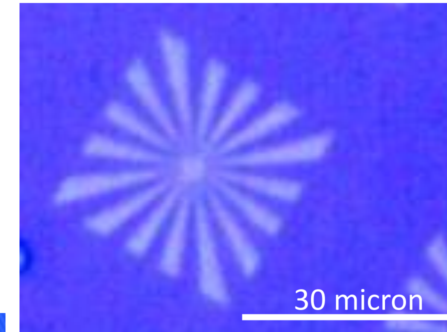
Fringes are well visible: the produced Fresnel CGH satisfies the basic requirements of optical quality and contrast

Other aberrations: some errors are introduced by the film surface and by the accuracy of the written pattern

Pariani, G., Bertarelli, C., Dassa, G., Bianco, A., Zerbi, G., *Optics Express*, *19*(5), 4536–4541 (2011)

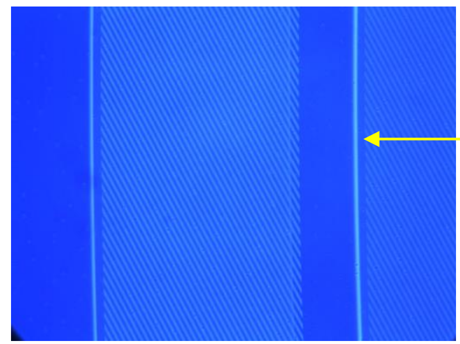
Production with standard DLW – scanning mode

Production of photochromic CGHs at the Institut für Technische Optik - Universität Stuttgart



CLWS300M (Production System)

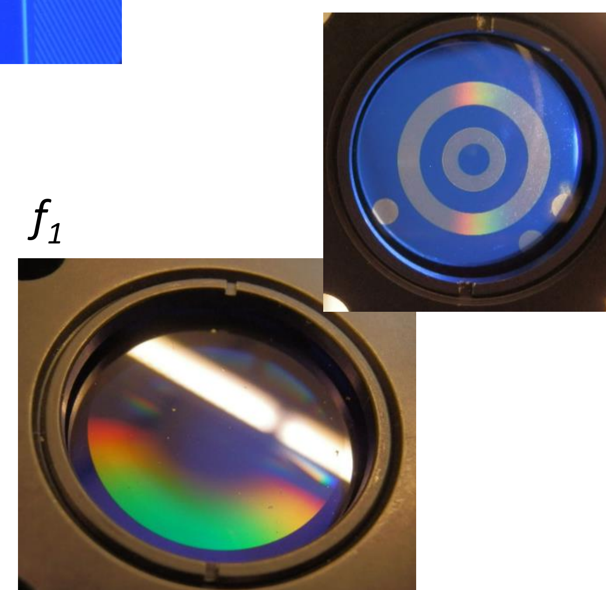
Smallest feature sizes:	< 1µm (binary)
Max. substrate size:	Ø 300 mm
Max. substrate thickn.:	25 mm
Write speed (typ.):	on-axis: 9 mm/h
	off-axis: 4 mm/h
Wavelength:	457-488-514 nm
Positioning increment:	radial: 0.6 nm
	azimuthal: 1'' @ 600 rpm



Autofocus beam in the visible

Results:

- High material resolution, up to the writing beam size
- High beam power may affect the surface
- Contrast low for the autofocus beam and wrong writing beam (at the limit of the material sensitivity)

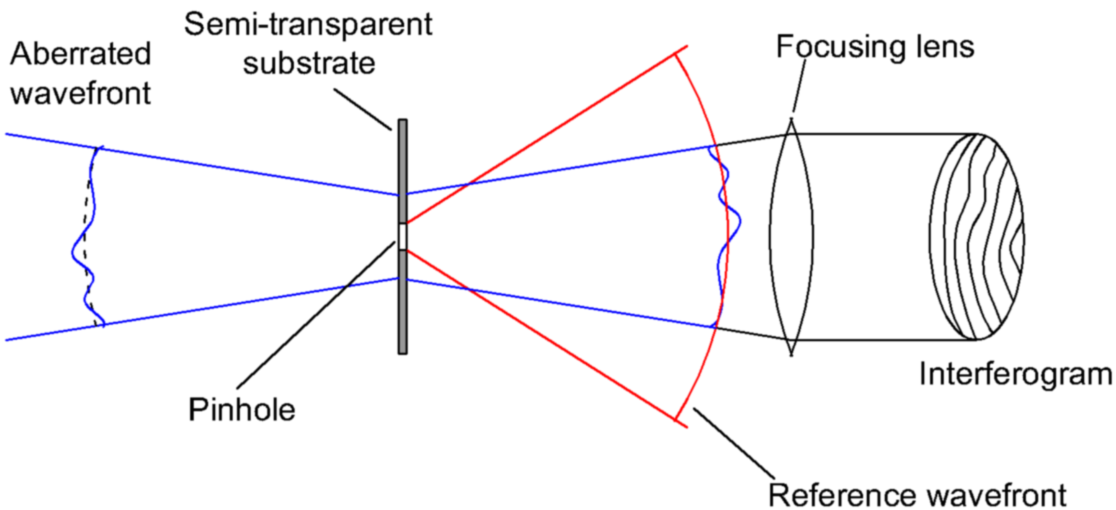


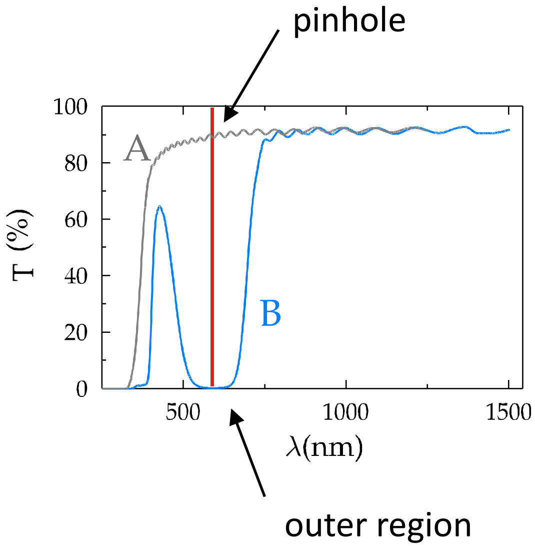
A custom DLW machine is required!

Pariani, G., Bertarelli, C., Bianco, A., Schaal, F., Pruss, C., *Proc. of SPIE*, *8450*(1), (2012).

Photochromic Point Diffraction Interferometer

Linnik 1933, Smartt 1972





Diffraction from a **pinhole** in a **semi-transparent film**

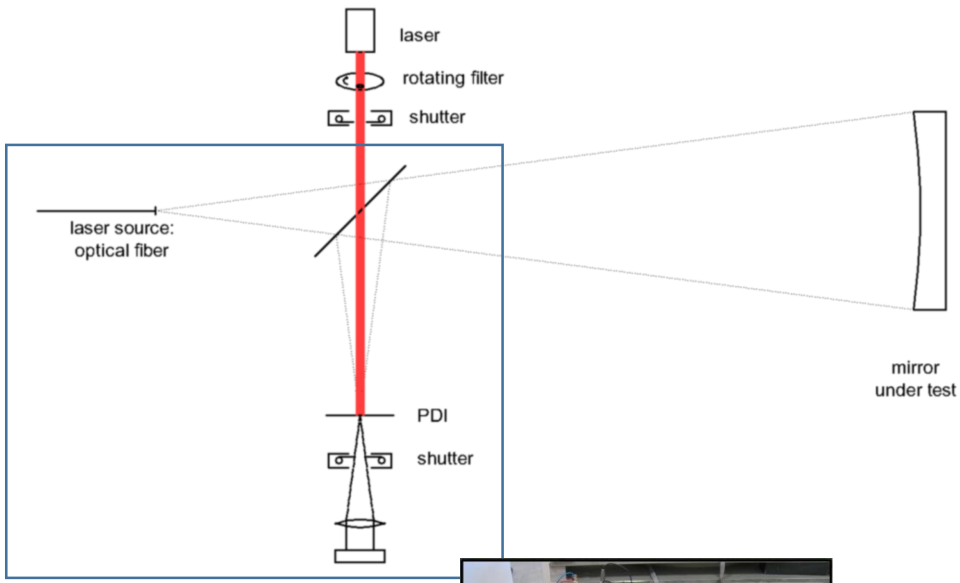
- Simple use: PDI is positioned in the focal plane of the optics under test
- Common path: very low sensitivity to vibrations and turbulence

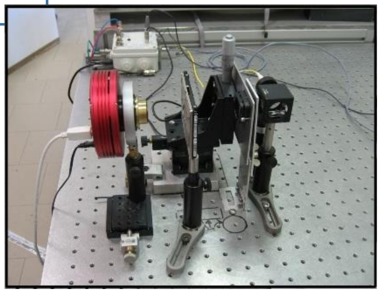
Quintavalla et al., *Opt. Laser Eng.* **2014**

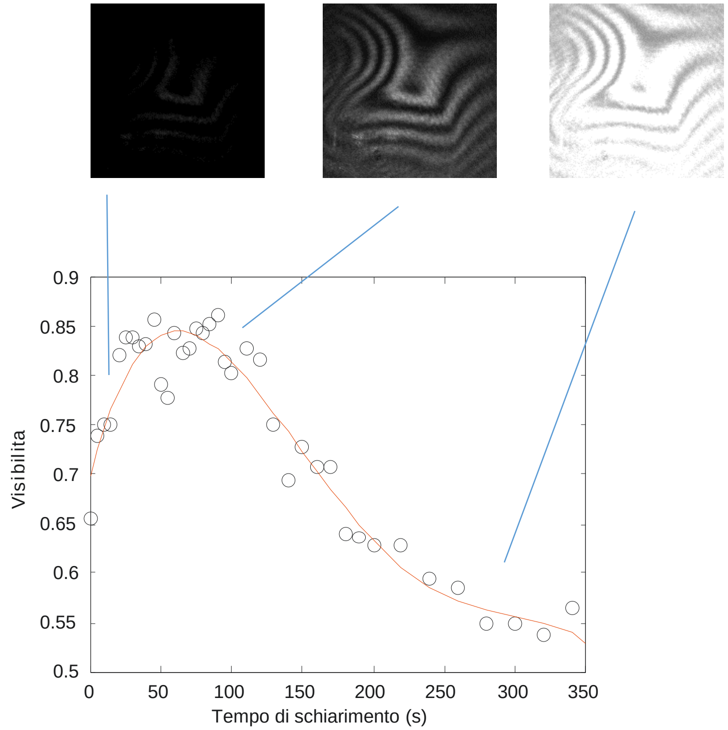
Why a photochromic PDI?

Optical writing of the substrate:

- single step process, no post process required
- tunable transparency with irradiation time to maximize the fringe visibility





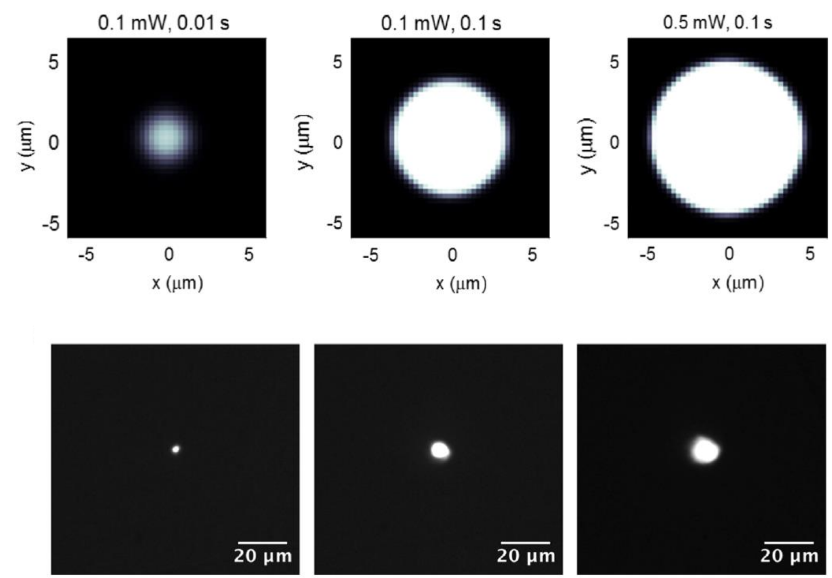


Why a photochromic PDI?

Optical writing of the substrate:

- single step process, no post process required
- tunable transparency with irradiation time to maximize the fringe visibility
- wide range of pinhole size to match the optics under test

  - Pinhole size tunable from 1 to 50 microns
  - The size depends on the photons dose
  - Auto-confinement of the beam inside the photochromic substrate



Why a photochromic PDI?

Optical writing of the substrate:

- single step process, no post process required
- tunable transparency with irradiation time to maximize the fringe visibility
- wide range of pinhole size to match the optics under test
- the pinhole may be written by the test optic!

  → no fine alignments required

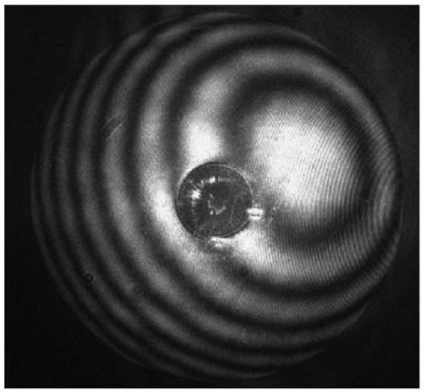
  → continous monitoring easily possible

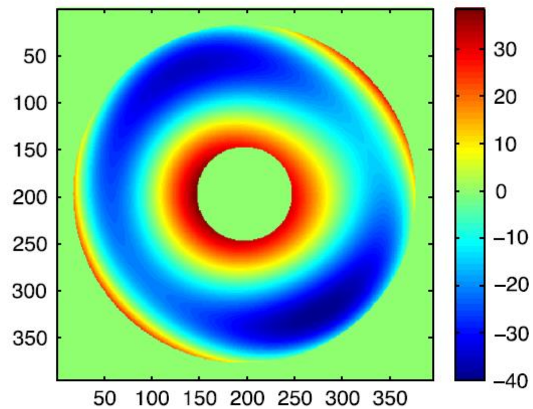
  → works properly for low aberrated optics

Results

self-referencing test

mirror at 0°

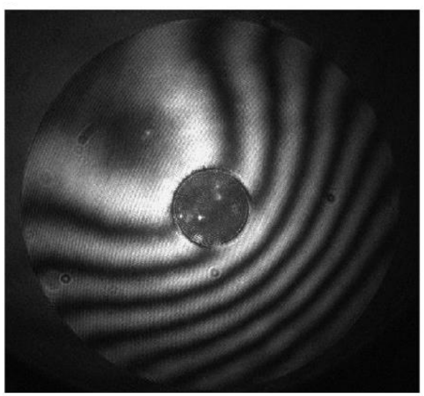


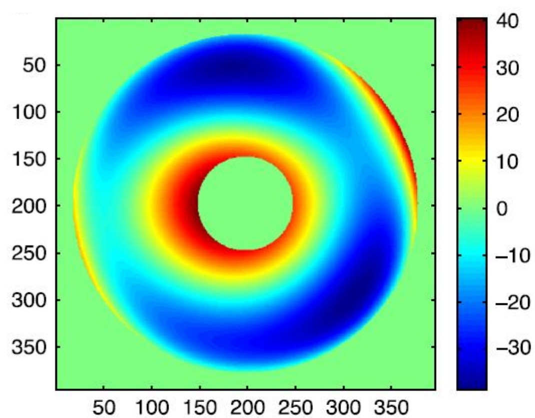


150mm dia., $f_{\#}$ 2 spherical mirror
2.5μm pinhole dia.

orientation (deg)	PtV (nm)	RMS (nm)
0	128±15	27±3
180	126±16	22±3

mirror at 180°

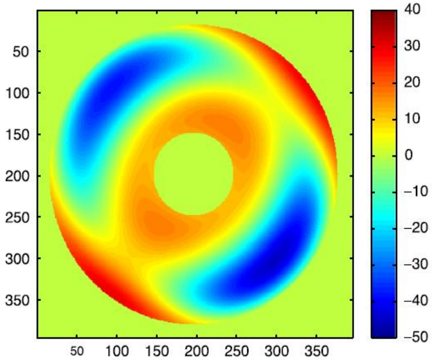




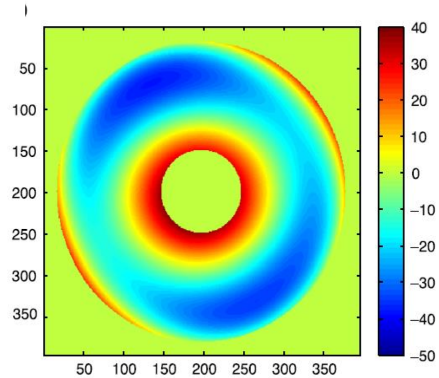
Results

comparison with a standard Fizeau inteferometer

Fizeau



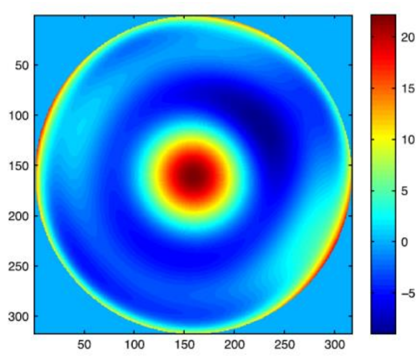
PDI



150mm dia., $f_\#$ 2 spherical mirror

INT	PtV (nm)	RMS (nm)
Fizeau	144±9	29±2
PDI	132±15	26±3

absolute accuracy



Certified 150mm dia., $f_\#$ 8, λ/8 PtV and λ/40 RMS spherical mirror

	PtV (nm)	RMS (nm)
SPEC	40	8
PDI	56±17	8.5±2