High resolution wavefront control with Photocontrolled deformable mirror

Laboratory for Ultravaiolet and X-Ray Optical Research
CNR-IFN, Via Trasea 7, Padova Italy

Stefano Bonora

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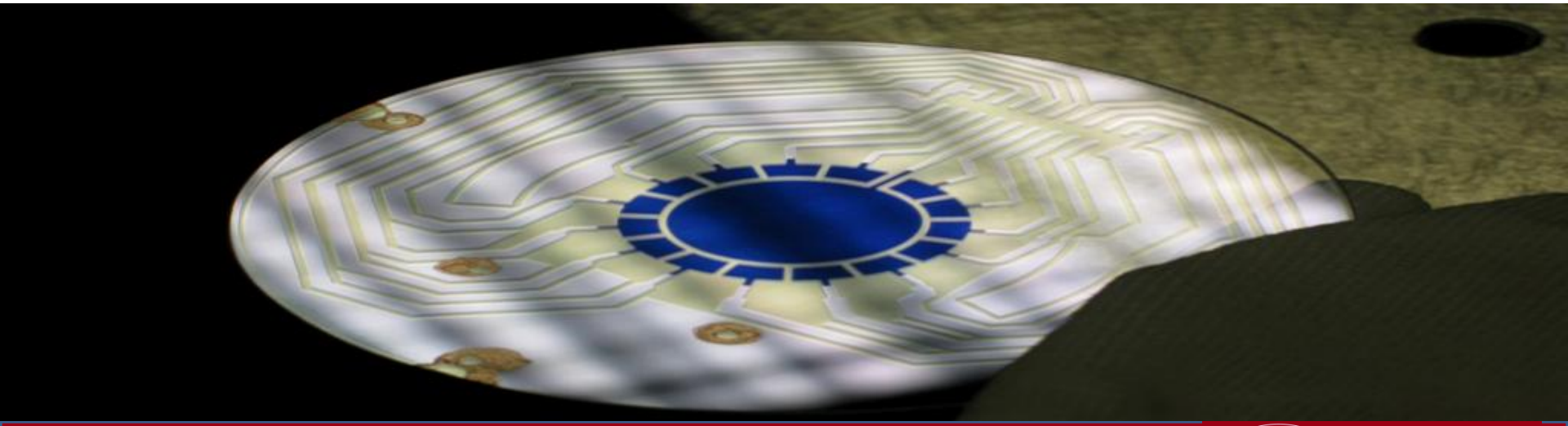


Lab: National Council of Research Institute of Photonics and Nanotechnology

- **10 researchers**
- **About 10 PhDs**
- **Graduate and undergraduate from UniPD**

Research:

Instruments for X-UV (spectrographs, monochromators)
for syncrotrons, FEL, spase missions, ultra high intense lasers

Adaptive optics devices development

Thin film coatings deposition

Industrial applications of optics → 6 spin off companies (2000-2012)

Adaptica srl manufactures Deformable Mirrors

Adaptive optics activity

Our deformable mirrors:

Electrostatic, bimorph (metallic or dielectric)

Research:

Application of DMs to pulse compression and shaping ultrashort lasers

UV, Vis, NIR and Mid-IR, High peak /High avg power lasers

S.Wall et al, Quantum interference between charge excitation paths in a solid-state Mott insulator, ***Nature Physics****, 114-118, Vol. 7, 2011*

REVIEW: D.Brida et al, Few-optical-cycle pulses tunable from the visible to the mid-infrared by optical parametric amplifiers ***J. Opt.*** *12 (2010) 013001*

DMs and Deformable diffraction grating for XUV ultrashort pulses

S. Bonora, et al. *Active diffraction gratings: Development and tests*, **Rev. Sci. Instrum**. 83, 123106 (2012);

High resolution wavefront control

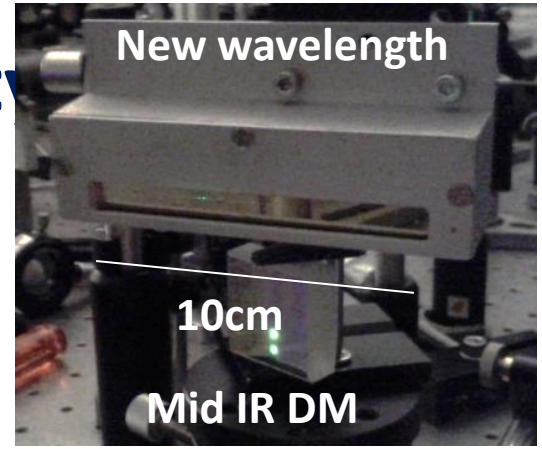
S.Bonora, et al. *High resolution wavefront correction with photocontrolled deformable mirror*, **Optics Express** Vol. 20, Issue 5, pp. 5178-5188 (2012)

Sensorless AO – Modal DM

S.Bonora, Distributed actuators deformable mirror for adaptive optics , **Optics Communications**, 284(13), 3467-3473 (2011)

S. Bonora et al, *Optimization of low-order harmonic generation by exploitation of a deformable mirror*, **Applied Physics B**, Vol. 106, Num. 4 (2012)

Adaptive optics activity



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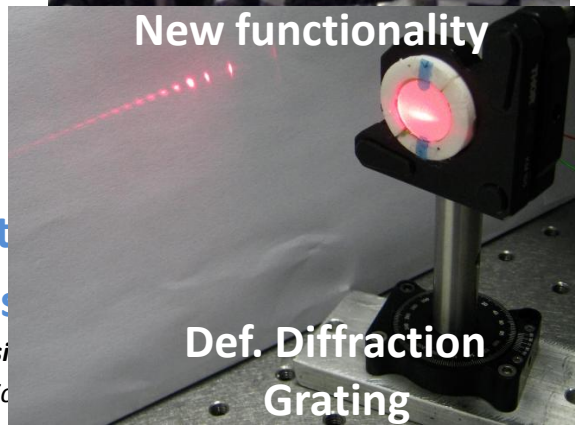

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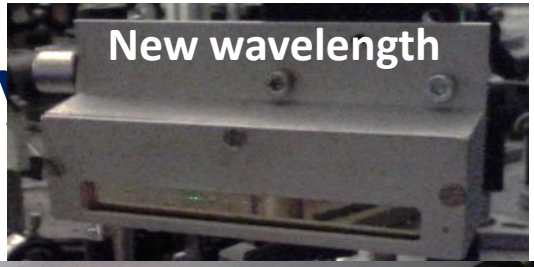

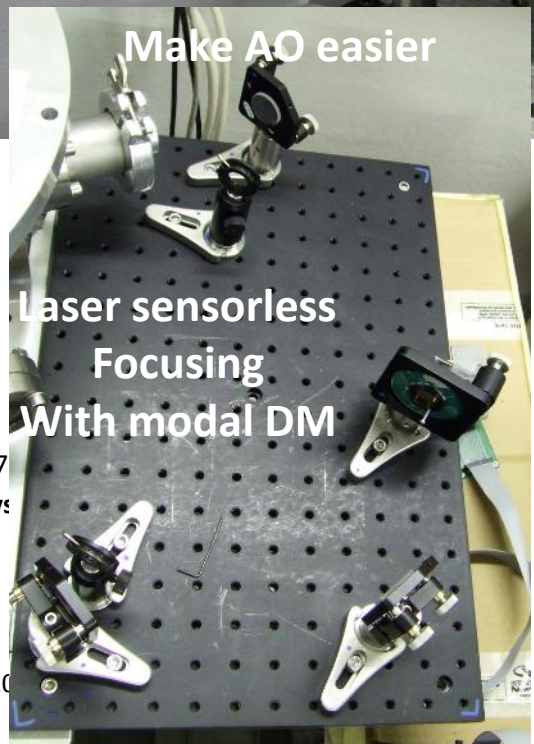

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Photo-controlled deformable membrane mirror

S. Bonora[1,4], U. Bortolozzo[2], J. P. Huignard[3] and S. Residori[2]

1_CNR-LUXOR Laboratory for UV and X-Ray Optical Research, Padova, Italy

2_INLN, Université de Nice Sophia-Antipolis, CNRS, France

3_Jphopto in Paris, France

4_Adaptica srl

AO devices limitation

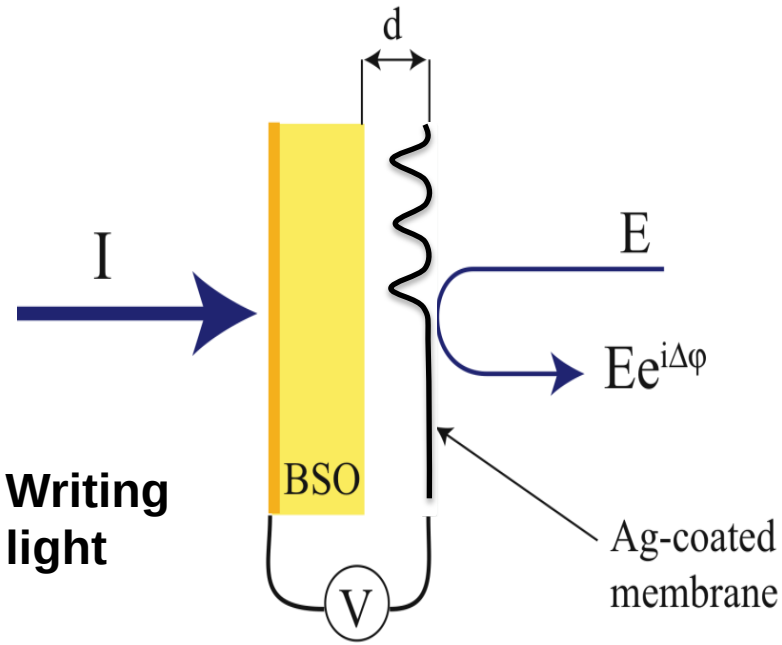
- Electronics parts complexity – driving
- Cabling
- High voltage – 300V
- Difficult to manufacture – optical quality

How to sort that limitations out?

Light driving

Light driven membrane mirror

The intensity I(x,y) determines the membrane deformation



Photoconductor: BSO

Membrane: nitrocellulose 5µm

Diameter: 19mm

d=50µm

V_{max}= 300Vpk-pk@2000Hz

Writing light Blue LED

DM Device for adaptive optics

Device is driven by a DLP projector

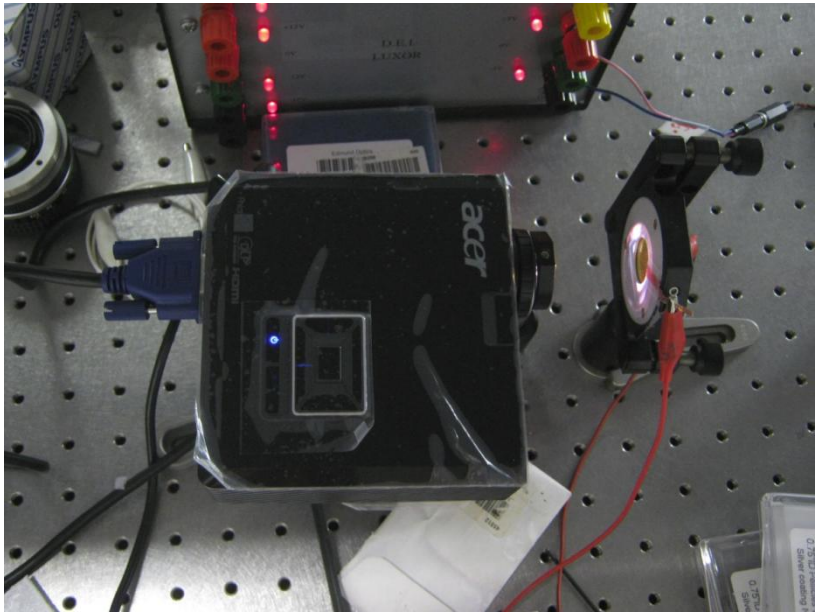
800 x 600 pixels, SVGA

VGA connected as second monitor

Just one power supply line

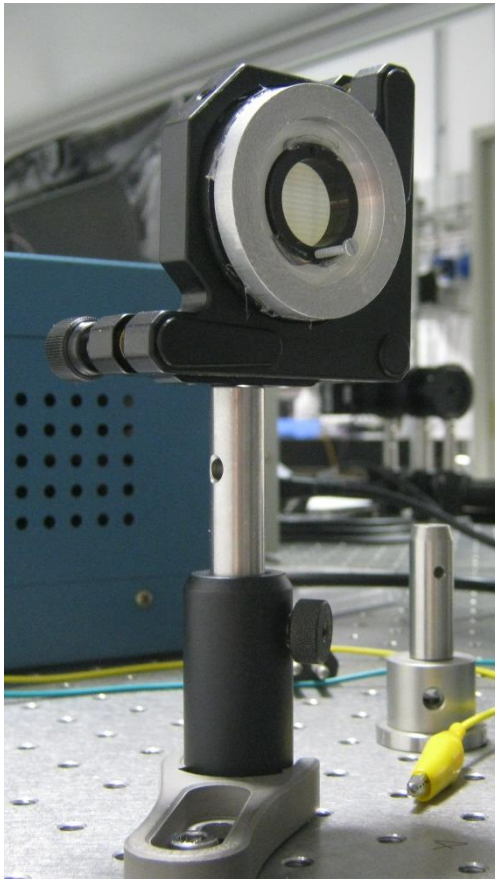
AC 300VPtV@500Hz

Membrane: nitrocellulose,
50μm spaced from BSO

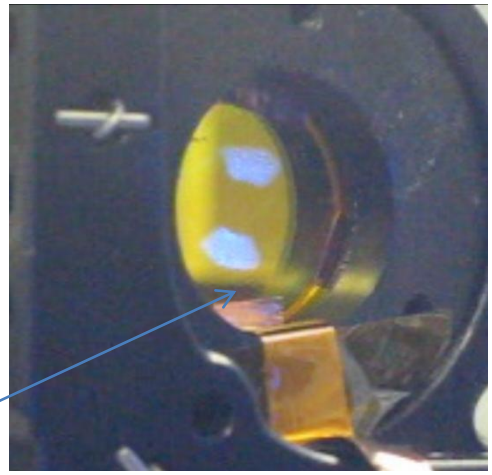


DM Device for adaptive optics

Front side

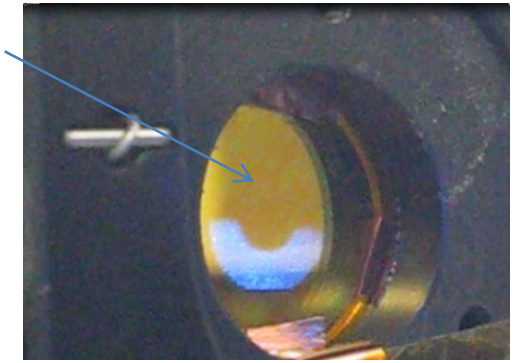


Back side



Blue:patter for astigmatism

Yellow:
BSO crystal

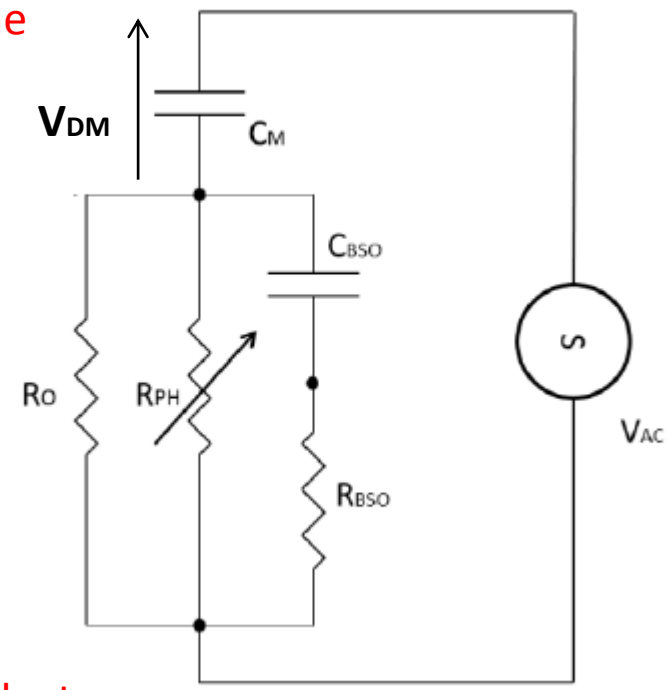


Blue:pattern for tilt

Prototype fits a 2’’ optical mount
No cables!

Electrical model

Membrane



Photoconductor

$$C_{DM} = \frac{\varepsilon_0 A}{t_{DM}} = 50\,pF$$

$$C_{BSO} = \frac{\varepsilon_0 \varepsilon_{BSO} A}{t_{BSO}} = 56\,pF$$

$$R_O = \frac{t_{BSO}}{\sigma_{BSO} A}$$

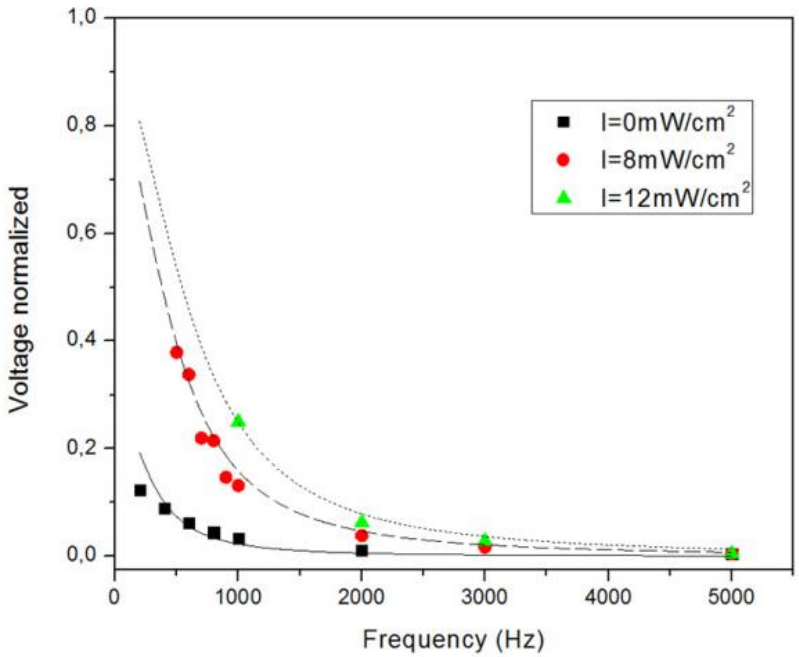
Hp: the resistivity changes linearly

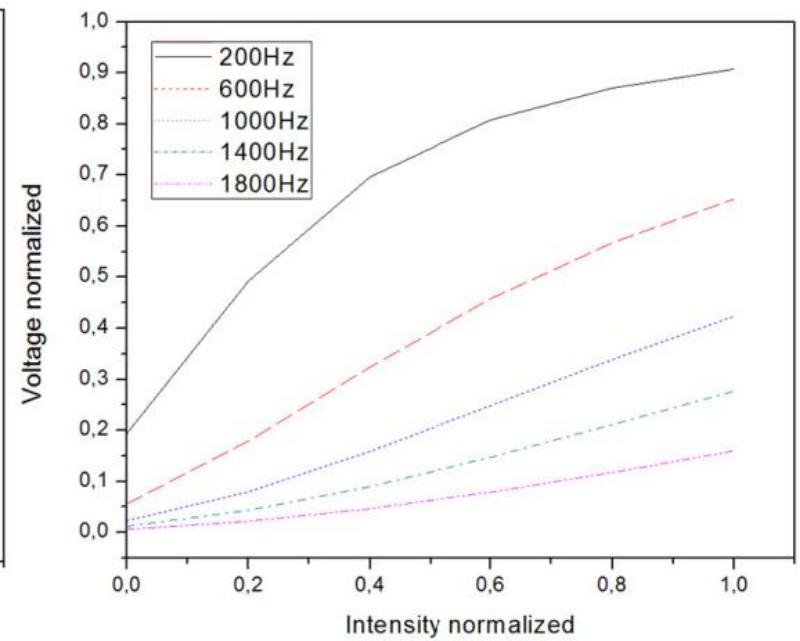
$$R_{PH} = \frac{t_{BSO}}{\sigma_{PH}(I) A} = \frac{t_{BSO}}{\underline{\alpha I \sigma_{BSO}} A}$$

Electrical model vs data

Voltage drop
on the membrane

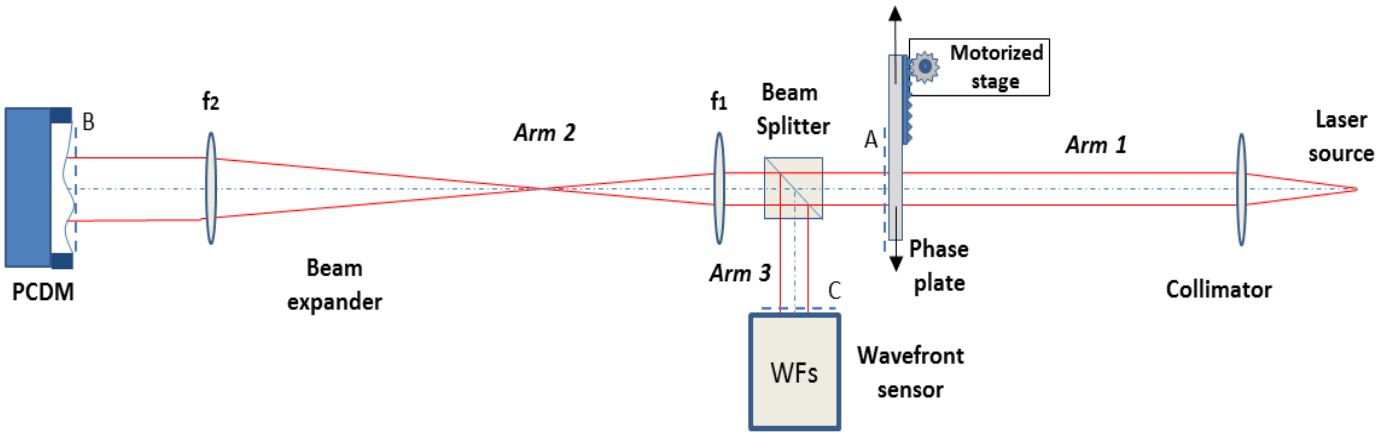
$$V_{DM} = V_{AC} \left[\left(\frac{1}{j\omega C_M} + R_{BSO} \right)^{-1} + \frac{1}{R_0} + \frac{1}{R_{PH}(I)} \right]^{-1} \Bigg/ \left\{ \frac{1}{j\omega C_M} + \left[\left(\frac{1}{j\omega C_M} + R_{BSO} \right)^{-1} + \frac{1}{R_0} + \frac{1}{R_{PH}(I)} \right]^{-1} \right\}$$

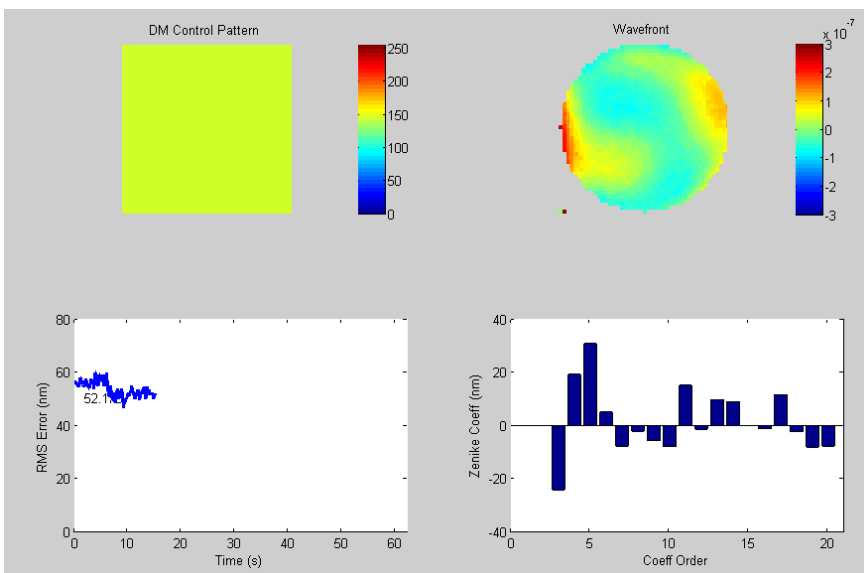


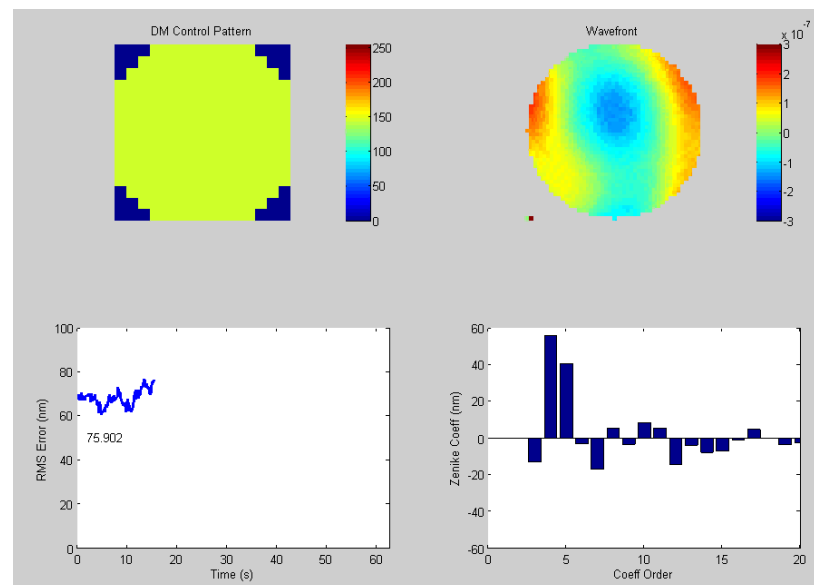


Closed loop correction

In collaboration with D.Coburn and C.Dainty, National University of Ireland, Galway

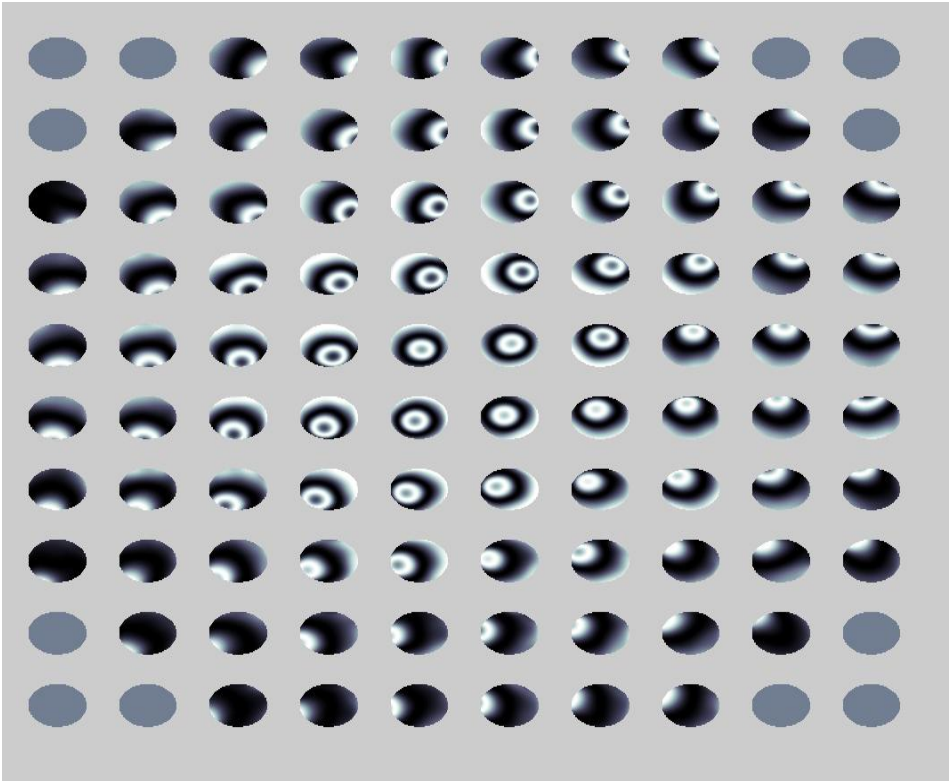


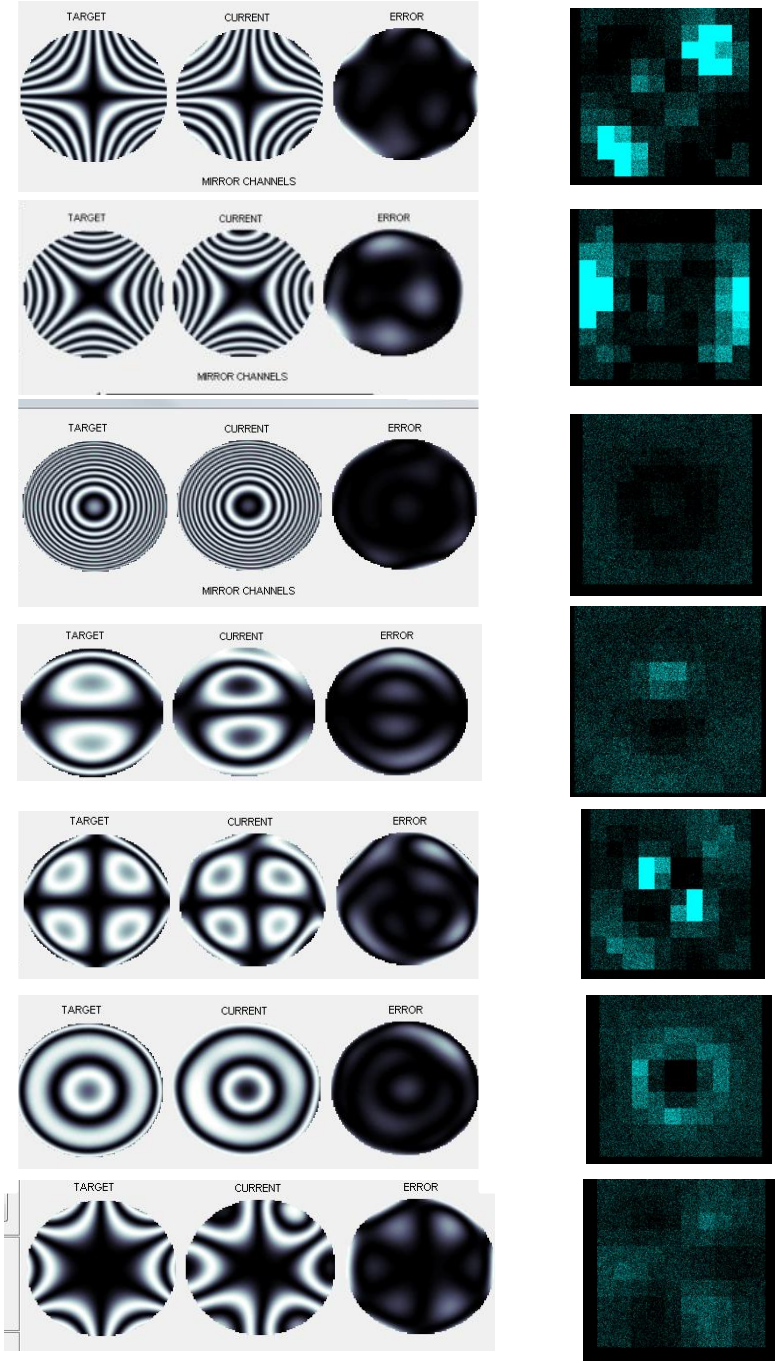




Zernike characterisation

12 x 12 poke matrix, 135 actuators

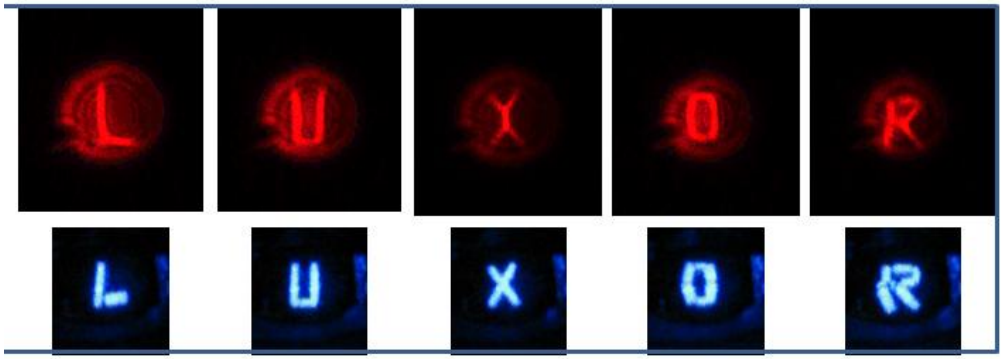




Future activities

Reading light

Driving light



Realization of:

1_astronomical turbolence simulator
2_thelmal lensing simulator setup
3_a large aperture mirror for astronomy
4_piezo photocontrolled DM

Optically adapting, **Editor's Choice, Science,** Vol 335, Issue 6075, pp. 1410, March 2012, by I.S. Osborne.

Continuous photocontrolled deformable membrane mirror U. Bortolozzo, S. Bonora, J. P. Huignard, and S. Residori, Appl. Phys. Lett. **96**, 251108 (2010); doi:10.1063/1.3457443

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Controlling a deformable mirror with light,
from **photonics.com**: 10/04/2010 http://www.photonics.com/Article.aspx?AID=44515

Light, instead of electrodes, could control deformable mirrors,
PHYSorg.com. 15 Jul 2010. www.physorg.com/news198389548.html

S.Bonora, U.Bortolozzo, S.Residori, Patent Pending

stefano.bonora@dei.unipd.it