Curso de introduccion a la Investigacion en Optica. Abril 09

Óptica Visual y Biofotónica

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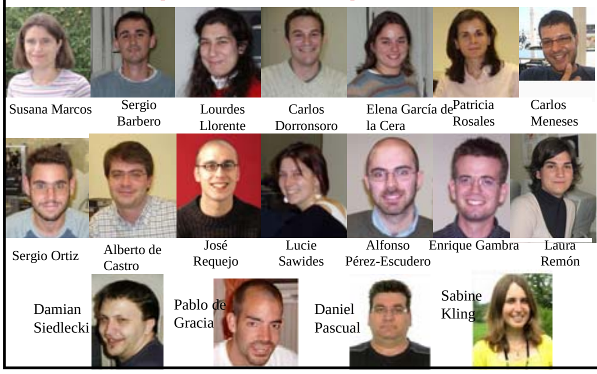
Visual Optics and Biophotonics Lab



Susana Marcos, Sergio Barbero, Lourdes Llorente, Carlos Dorronsoro, Elena García de la Cera, Patricia Rosales, Carlos Meneses

Sergio Ortiz, Alberto de Castro, José Requejo, Lucie Sawides, Alfonso Pérez-Escudero, Enrique Gambra, Laura Remón

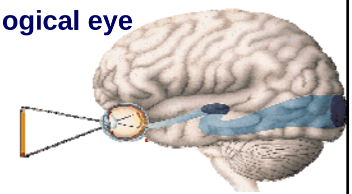
Damian Siedlecki, Pablo de Gracia, Daniel Pascual, Sabine Kling

Colaboran

- Instituto de Oftalmobiologia Aplicada, U. Valladolid
- Fundación Jiménez Díaz, IQFRS, CIB, IQO,
- Schepens Eye Research Institute- Harvard, USA
- New England College of Optometry, USA
- University of Tuebingen, Germany
- University of Houston, USA
- De Vrije University, The Netherlands
- University of Miami, USA ; State Univerity of New York USA
- University of Nevada, USA ; Copernicus University, Poland

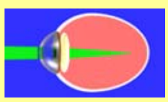
Goal

Development of optical and photonic technologies in biomedicine, in particular for the non-invasive assessment of the normal and pathological eye



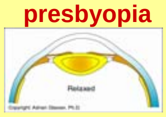
Relevance

myopia



- Affects 50% of the population

presbyopia

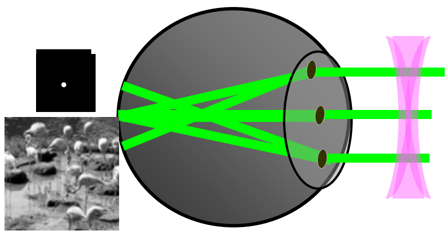


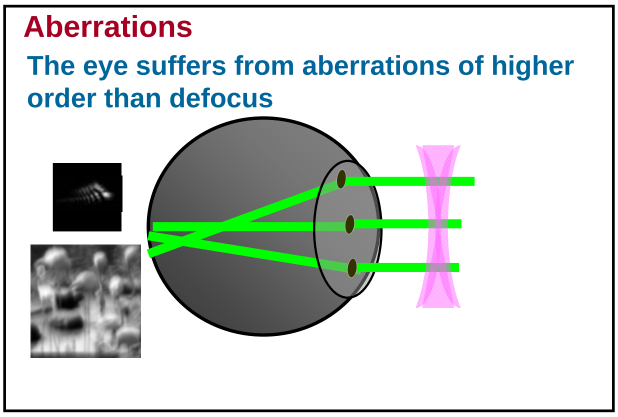
- Affects 100% of the population older than 50

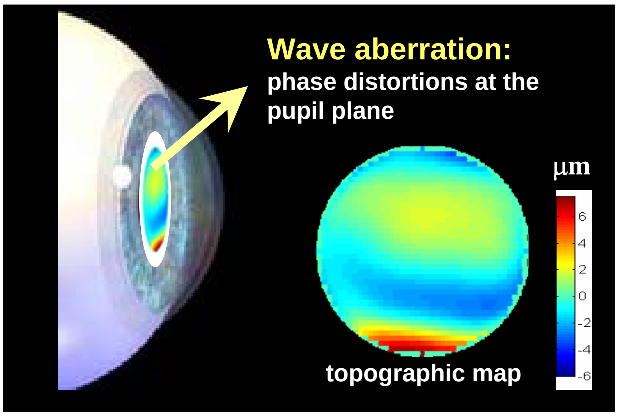
- Causes for their development not well understood
- No treatment available
- New alternatives for correction

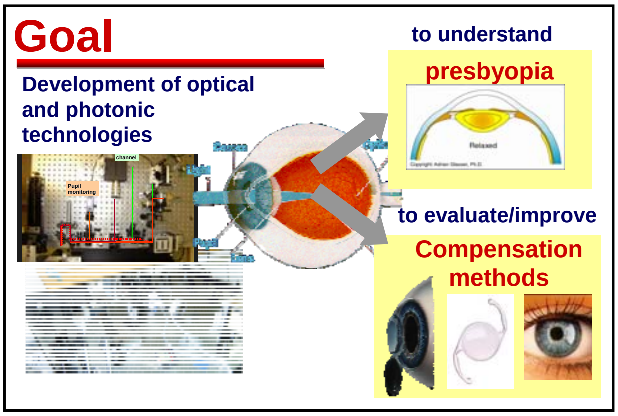
Aberrations

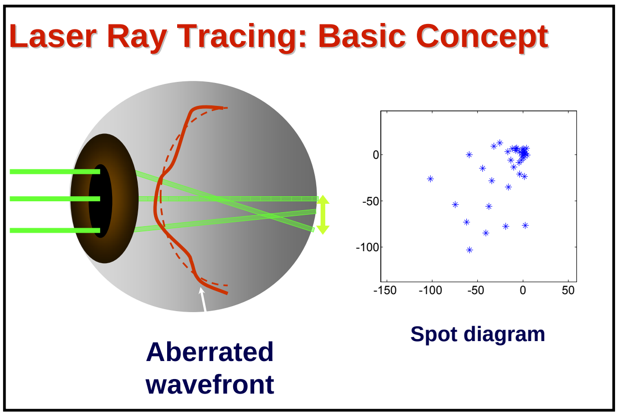
Simpler case: defocus (myopia)

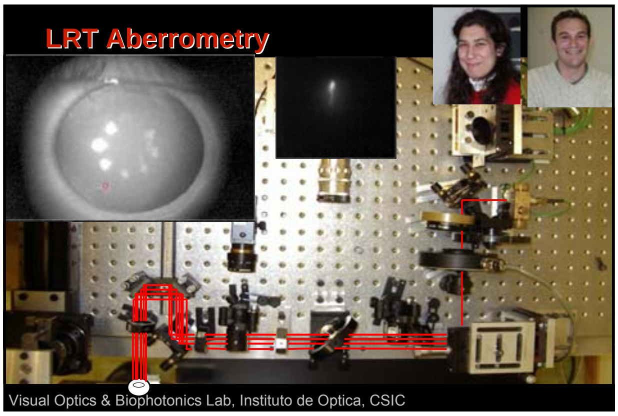


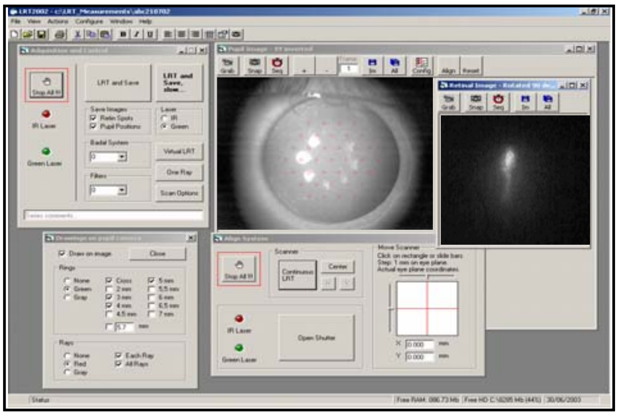

Aberrations
The eye suffers from aberrations of higher order than defocus

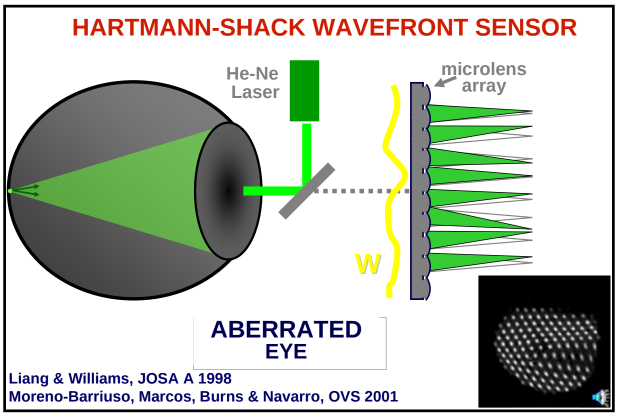

Wave aberration:
phase distortions at the pupil plane
µm
6
4
2
0
-2
-4
-6
topographic map

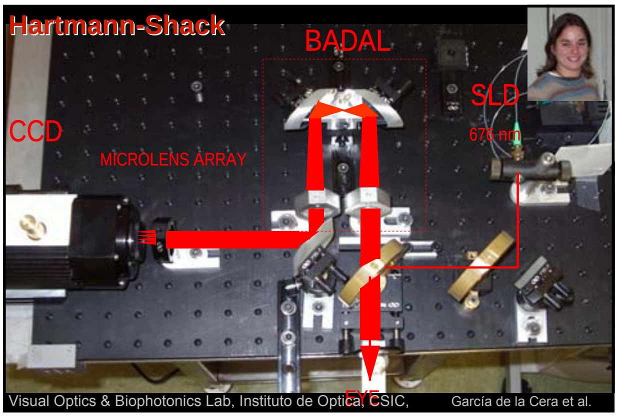

Goal
Development of optical and photonic technologies
to understand
presbyopia
to evaluate/improve
Compensation methods

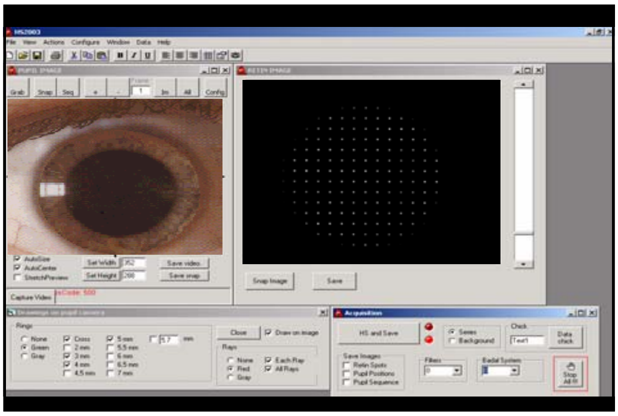

Laser Ray Tracing: Basic Concept
0
-50
-100
-150
-100
-50
0
50
Aberrated wavefront
Spot diagram

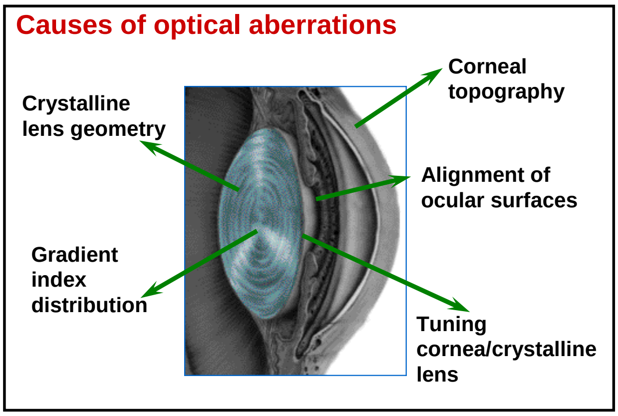

LRT Aberrometry
Visual Optics & Biophotonics Lab, Instituto de Optica, CSIC

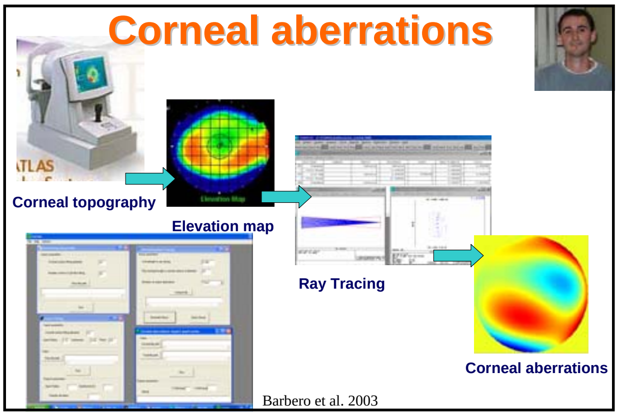


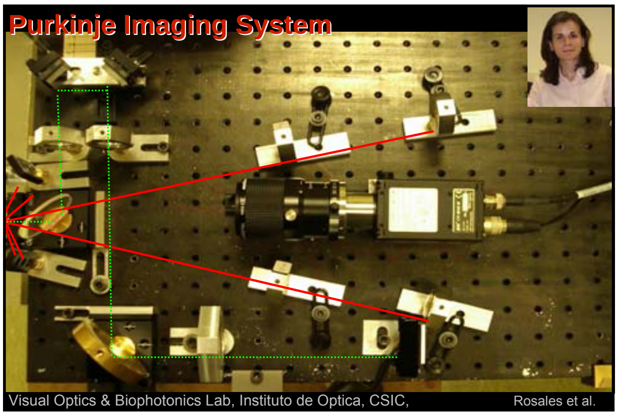

HARTMANN-SHACK WAVEFRONT SENSOR
He-Ne
Laser
microlens
array
W
ABERRATED
EYE
Liang & Williams, JOSA A 1998
Moreno-Barriuso, Marcos, Burns & Navarro, OVS 2001

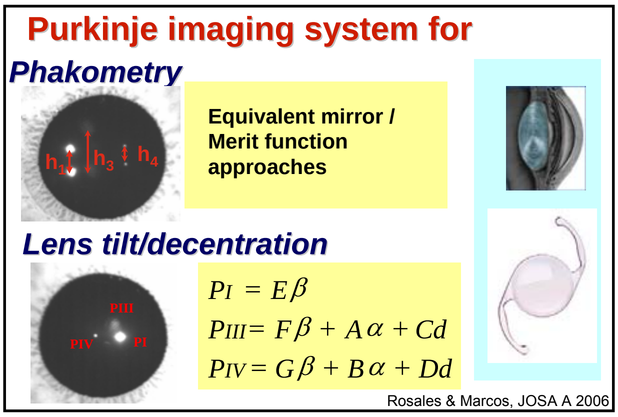

Hartmann-Shack
BADAL
SLD
676 nm
CCD
MICROLENS ARRAY
EYE
Visual Optics & Biophotonics Lab, Instituto de Optica, CSIC,
García de la Cera et al.

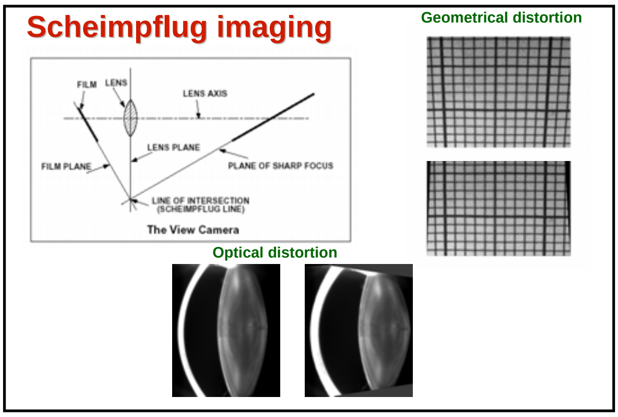


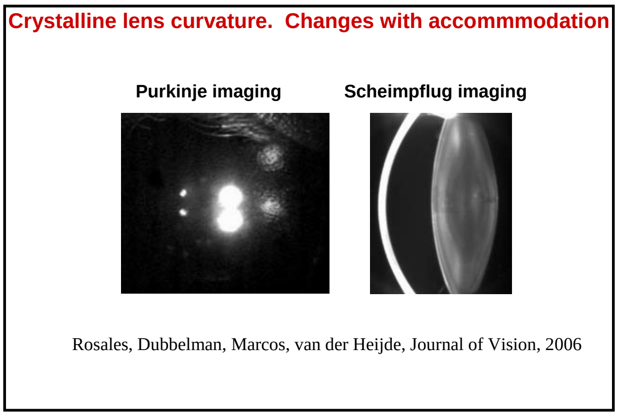

Causes of optical aberrations
Crystalline
lens geometry
Corneal
topography
Alignment of
ocular surfaces
Gradient
index
distribution
Tuning
cornea/crystalline
lens


Corneal aberrations
Corneal topography
Elevation map
Ray Tracing
Corneal aberrations
Barbero et al. 2003

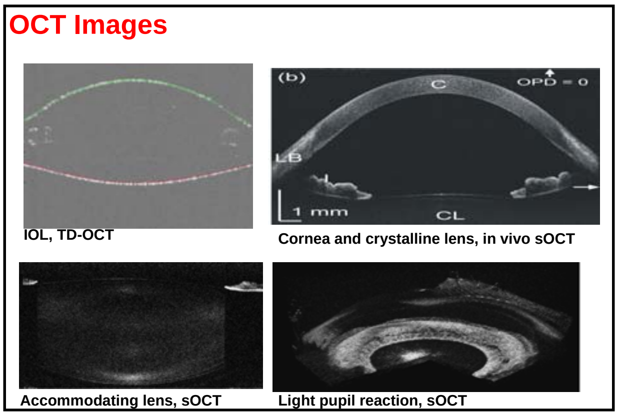

Purkinje Imaging System
Visual Optics & Biophotonics Lab, Instituto de Optica, CSIC,
Rosales et al.


Purkinje imaging system for
Phakometry
Equivalent mirror / Merit function approaches
Lens tilt/decentration
PIII
PIV
PI
$P_I = E\beta$
$P_{III} = F\beta + A\alpha + Cd$
$P_{IV} = G\beta + B\alpha + Dd$
Rosales & Marcos, JOSA A 2006

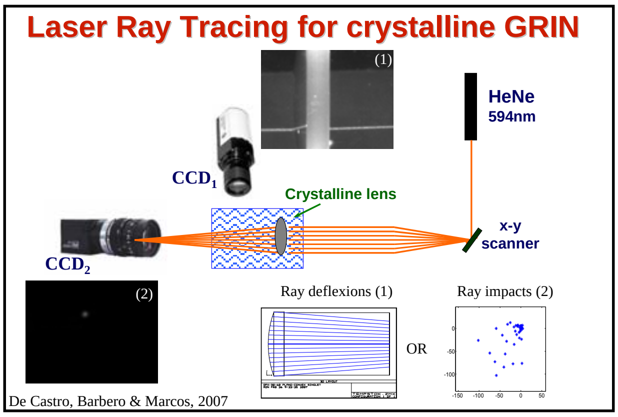

Scheimpflug imaging
Geometrical distortion
FILM
LENS
LENS AXIS
LENS PLANE
FILM PLANE
PLANE OF SHARP FOCUS
LINE OF INTERSECTION (SCHEIMPFLUG LINE)
The View Camera
Optical distortion

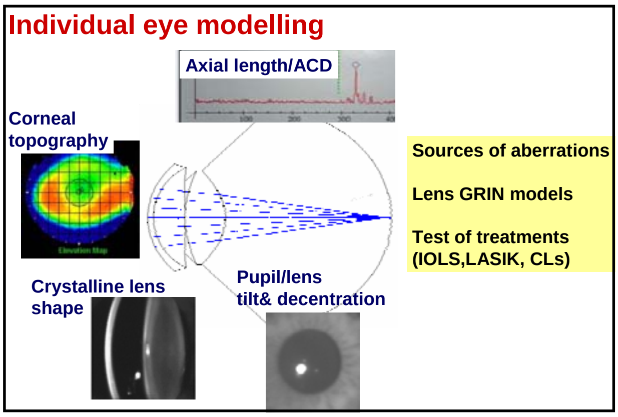

Crystalline lens curvature. Changes with accommmodation
Purkinje imaging
Scheimpflug imaging
Rosales, Dubbelman, Marcos, van der Heijde, Journal of Vision, 2006

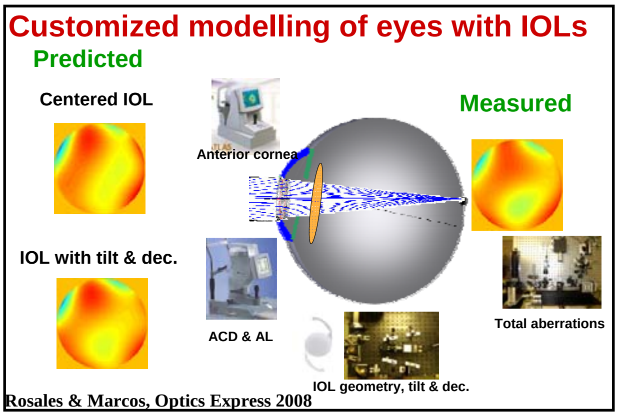

Optical Coherence Tomography
CSIC
Visual Optics & Biophotonics Lab, Instituto de Optica, CSIC,
Ortiz et al.

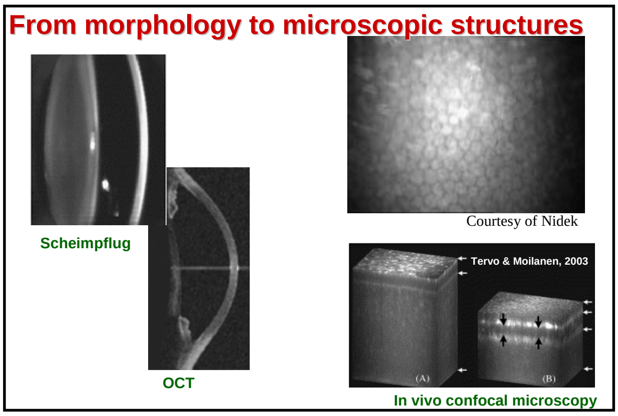

OCT Images
IOL, TD-OCT
(b)
C
OPD = 0
LB
1 mm
CL
Cornea and crystalline lens, in vivo sOCT
Accommodating lens, sOCT
Light pupil reaction, sOCT

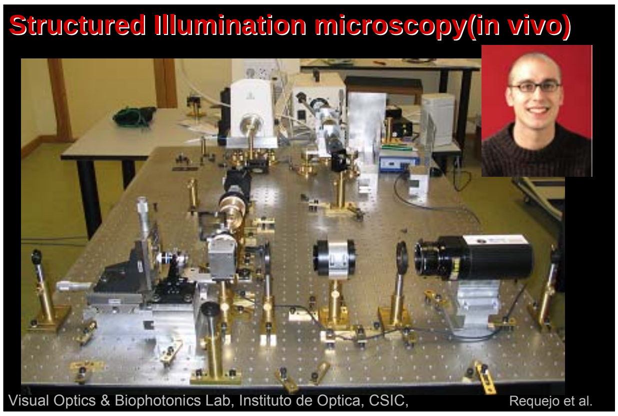

GRIN-LRT
Institute of Optics.- Madrid
CSIC

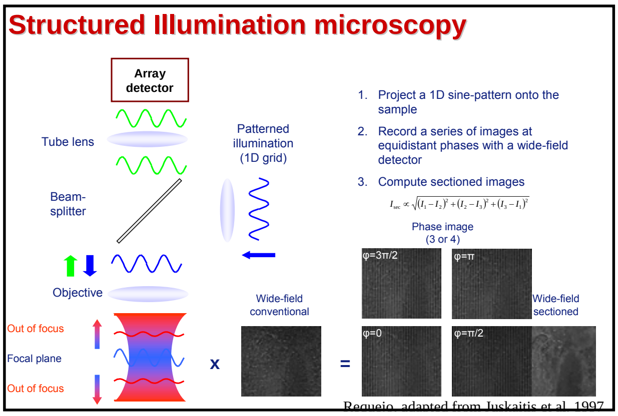

Laser Ray Tracing for crystalline GRIN
(1)
HeNe
594nm
CCD1
Crystalline lens
x-y
scanner
CCD2
(2)
Ray deflexions (1)
Ray impacts (2)
OR
De Castro, Barbero & Marcos, 2007


Individual eye modelling
Axial length/ACD
Corneal
topography
Sources of aberrations
Lens GRIN models
Test of treatments
(IOLS,LASIK, CLs)
Crystalline lens
shape
Pupil/lens
tilt& decentration


Customized modelling of eyes with IOLs
Predicted
Centered IOL
Anterior cornea
Measured
IOL with tilt & dec.
ACD & AL
Total aberrations
IOL geometry, tilt & dec.
Rosales & Marcos, Optics Express 2008

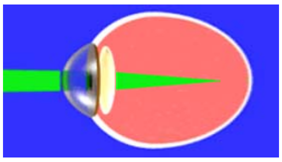

From morphology to microscopic structures
Courtesy of Nidek
Scheimpflug
Tervo & Moilanen, 2003
OCT
In vivo confocal microscopy


Structured Illumination microscopy(in vivo)
Visual Optics & Biophotonics Lab, Instituto de Optica, CSIC,
Requejo et al.


Structured Illumination microscopy
Array
detector
Tube lens
Patterned
illumination
(1D grid)
Beam-
splitter
Objective
Wide-field
conventional
Out of focus
Focal plane
Out of focus
x
=
1. Project a 1D sine-pattern onto the sample
2. Record a series of images at equidistant phases with a wide-field detector
3. Compute sectioned images
Phase image
(3 or 4)
φ=3π/2
φ=π
φ=0
φ=π/2
Wide-field
sectioned
Requejo, adapted from Juskaitis et al. 1997

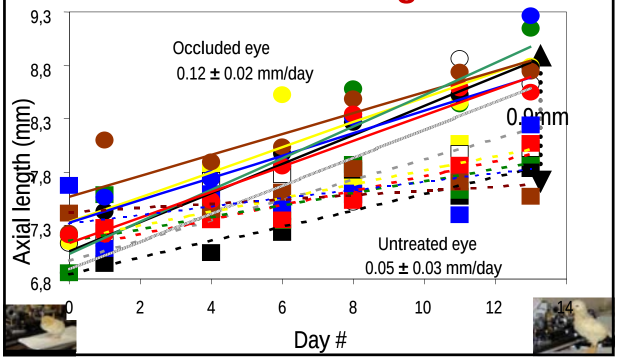
Some sample questions

Question 1.- What triggers myopia development? What is the role of ocular aberrations in myopia?



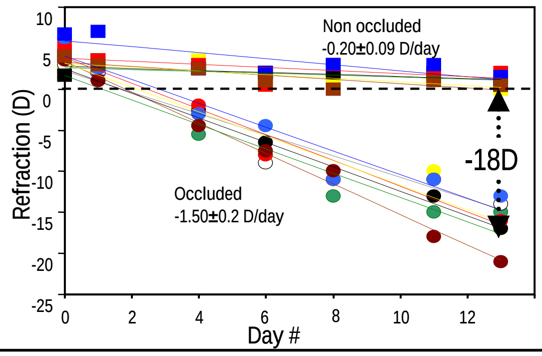
Garcia de la Cera, Rodríguez & Marcos, Vision Res. (2006)

Chick model: Axial length



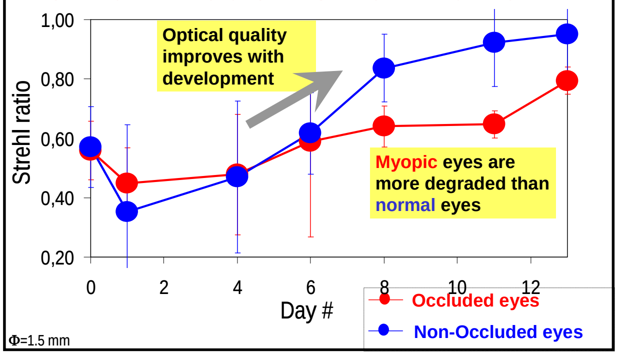
Garcia de la Cera, Rodríguez & Marcos, Vision Res. (2006)

Chick model: Refraction



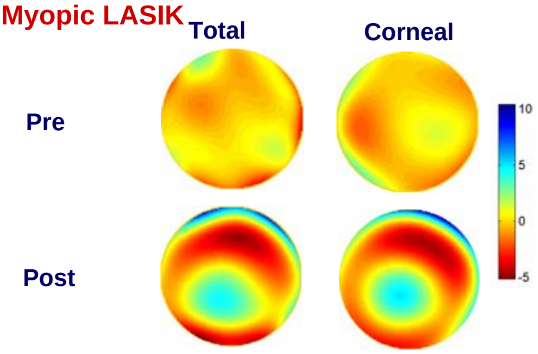
Garcia de la Cera, Rodríguez & Marcos, Vision Res. (2006)

Chick model: Strehl ratio



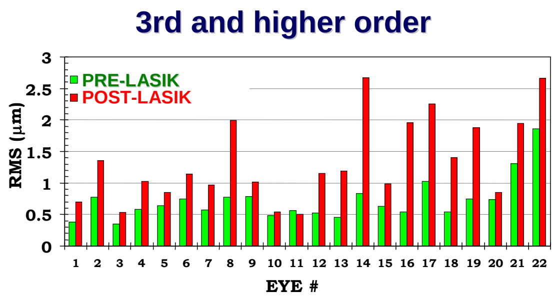
Question 2.- What is the optical response of the cornea after refractive surgery? Can we improve the laser ablation algoritms?

Myopic LASIK



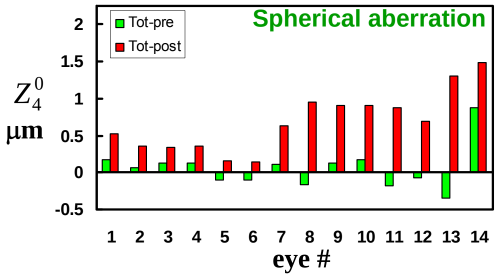
Marcos et al., IOVS (2001)

TOTAL aberrations



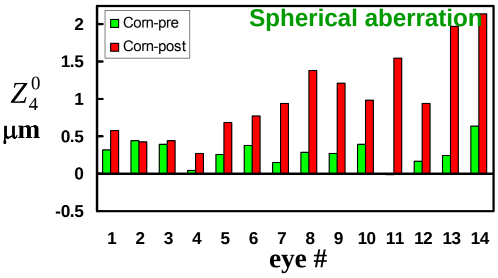
Moreno-Barriuso et al. IOVS (2001)

Increase of TOTAL Spherical Aberration with LASIK



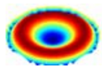
Marcos et al. IOVS (2001)

Increase of CORNEAL Spherical Aberration with LASIK



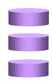
Marcos et al. IOVS (2001)

Why corneal spherical aberration / asphericity increases after standard LASIK?



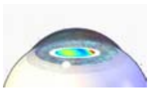
✓Due to the design of the profile?

Marcos et al. J. Refract. Surg 2003



✓Due to discrepancies in the laser energy delivery?

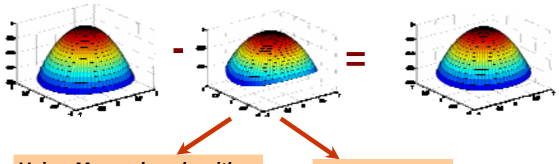
Cano, Barbero & Marcos. JOSA 2004



✓Due to corneal biomechanical effects?

Dorronsoro, Cano, Merayo & Marcos, Opt. Express 2006

"Computational surgery"



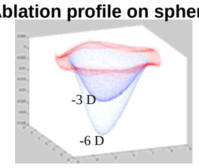
Using *Munnerlyn algorithm* and a *Parabolic approximation* of the Munnerlyn algorithm

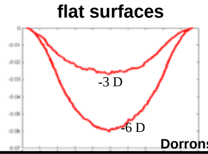
Using actual data of R1, R2, D, and S for each subject

Marcos, Cano & Barbero, J.Refract Surg (2003)

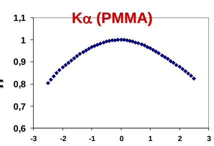
Experimental Kα (PMMA)

$$K\alpha = \frac{\text{Ablation profile on spheres}}{\text{Ablation profile on flat surfaces}} =$$



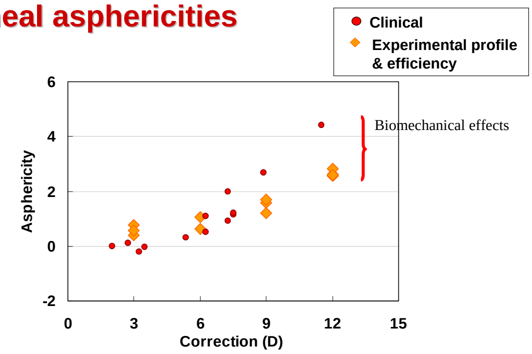


Laser efficiency effects (experimental)



Dorronsoro, Cano, Merayo, Marcos, Opt Express 2006

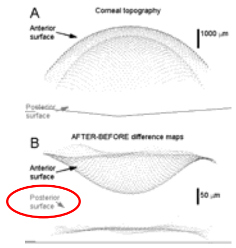
Corneal asphericities



Dorronsoro, Cano, Merayo & Marcos, 2006. Optics Express 2006

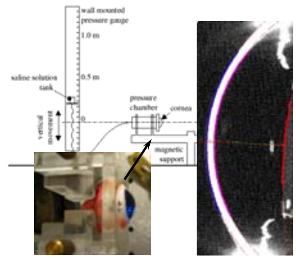
Corneal biomechanical properties

LASIK-induced changes in the posterior corneal surface



Pérez-Escudero, Sawides, Dorronsoro, Merayo, Marcos, IOVS 2009

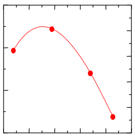
Corneal deformation with increasing Intraocular Pressure



Pérez-Escudero et al. 2008; Kling et al 2009

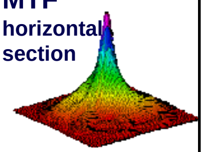
Comparison with visual performance

Contrast sensitivity

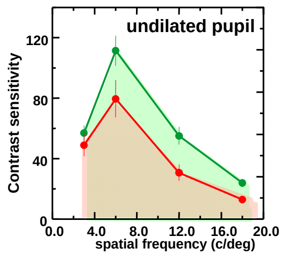


PRE & POST LASIK

MTF horizontal section

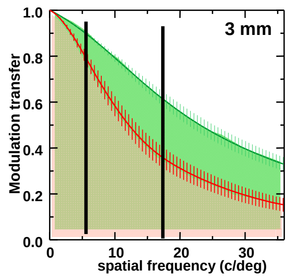


CSF



Area $\frac{\text{PRE}}{\text{POST}}$ = 1.51

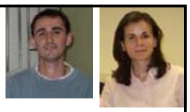
MTF



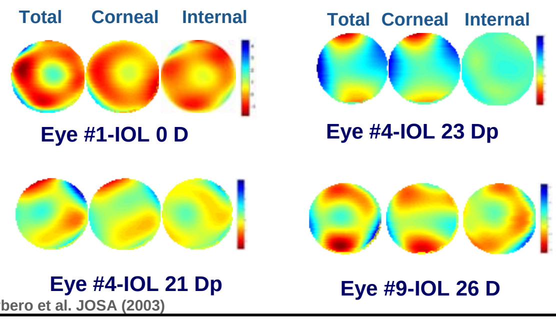
Area $\frac{\text{PRE}}{\text{POST}}$ = 1.38

Marcos. J. Refract. Surg. (2001)

Question 3. Can we improve optical quality of patients after cataract surgery with new intraocular lens designs?

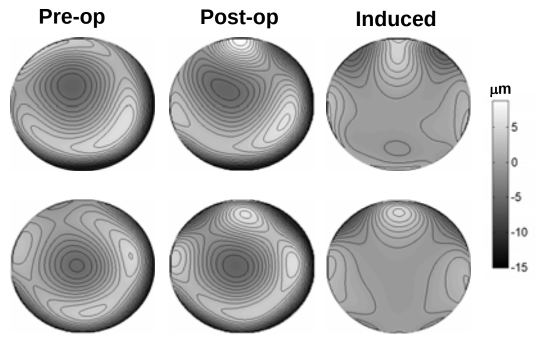


Total, corneal & internal aberrations POST CATARACT surgery



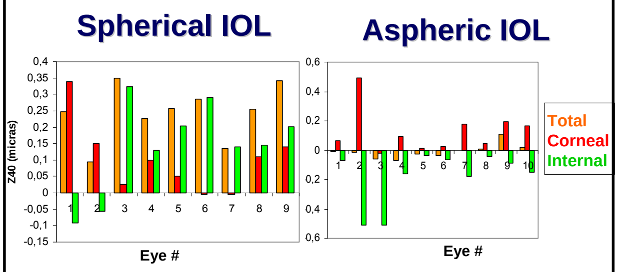
Barbero et al. JOSA (2003)

Corneal aberrations



Marcos et al. JCRS 2006 Φ=10 mm, centered at corneal reflex

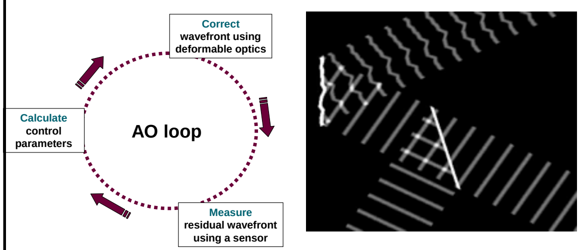
Spherical aberration. Spherical/Aspheric



Barbero et al. JOSA (2003)

Marcos et al. J. Refract Surg (2005)

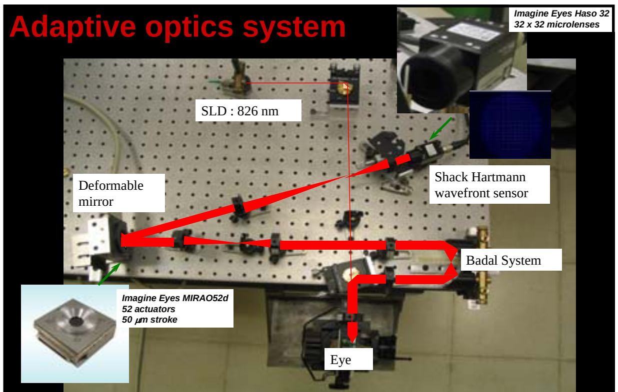
Close loop adaptive optics correction



Courtesy of Nicolas Chateau, Imagine eyes

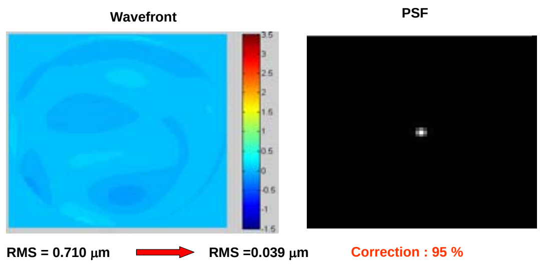
Question 4. Can we improve vision by correcting ocular aberrations?

Adaptive optics system



Sawides, Gambra & Marcos, 2007

AO-correction of ocular aberrations

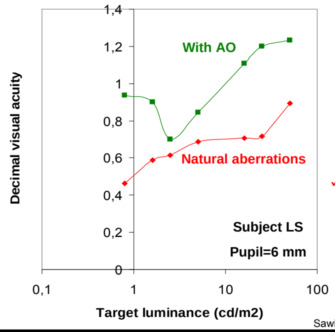


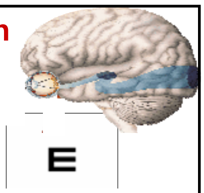
RMS = 0.710 µm → RMS =0.039 µm Correction : 95 %

Pupil diameter: 6.6 mm

Gambra, Sawides & Marcos, 2007 *The 6th International Workshop on* Adaptive Optics, Galway, Ireland

Visual acuity after correction of ocular aberrations



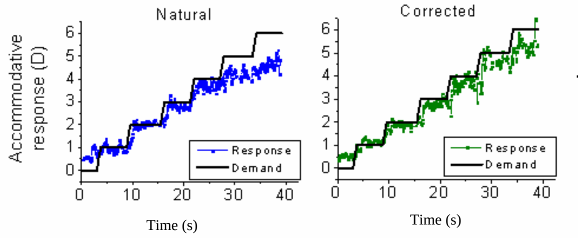


✓Improvement at all luminances

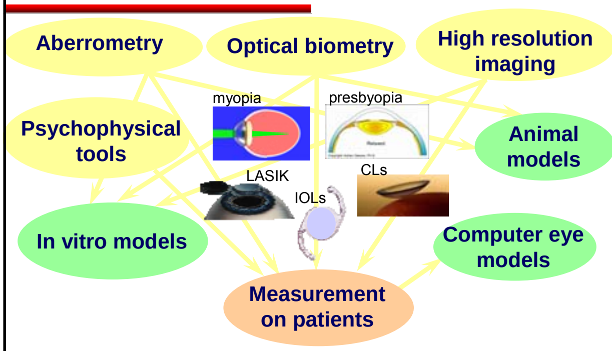
✓Increase of VA with luminance is primarily neural

Sawides, Dorronsoro, Gambra & Marcos, JOV 2008

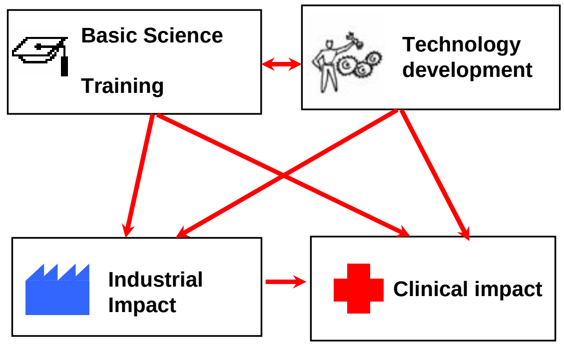
Influence of the ocular aberrations on accommodation



Overview



Outreach



Oportunidades de Becas/Contratos

- Opciones de solicitud de becas (FPU, FPI, JAEpre)
- Contratos con cargo a proyecto

http://www.vision.csic.es