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Interferometric measurements of aberrations in isolated porcine lenses

Eva Acosta[1], Christina Schwarz[2], Juan M. Bueno[2] and Pablo Artal[2]
[1]*Facultad de Física, Universidad de Santiago de Compostela, SPAIN*
[2]*Laboratorio de Óptica, Universidad de Murcia, SPAIN*

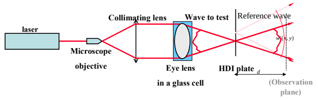
eva.acosta@usc.es

INTRODUCTION

We study the nature of optical aberrations present in isolated pig crystalline lenses by means of interferometric measurements. We analyze the deviation of the results from a symmetric model and the possible systematic presence of dominant aberrations.

METHODS

Wave aberrations (WA's) in twelve ex-vivo crystalline lenses were measured by using point-diffraction interferometry [1-3]. The principle behind this technique is the interference produced between a reference spherical beam generated by diffraction through a clear pinhole placed in a semitransparent plate and the beam under test focusing in the vicinity of the pinhole (see figures below).

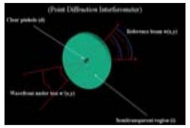


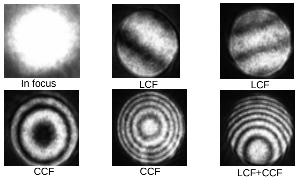
$$I(x,y)\propto\sin^2\left[w(x,y)-\frac{x^2+y^2}{2d}-\alpha x-\beta y-\gamma(x^2+y^2)\right]$$

Linear carrier fringes

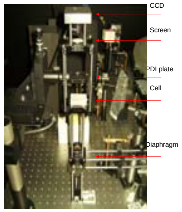
Circular carrier fringes

"A point object (pinhole) diffracts light into a perfect spherical wave"





Different pictures of carrier fringes for a diffraction limited lens. They are obtained by moving the pinhole along the optical axis (circular fringes) and/or in a transversal plane (linear fringes)

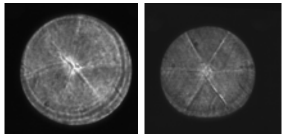


Picture of the experimental set-up

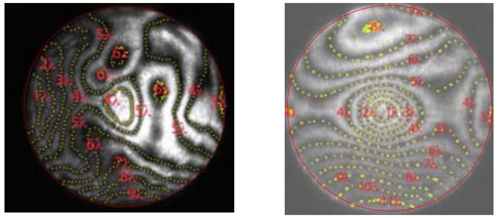
Experimental procedure

Lenses were analyzed within just a few hours post-mortem and kept inside the globe at room temperature until measurement. The pupil diameter analyzed was 5.5 mm.

The lenses were inserted in a glass cell with plane-parallel faces filled with BSS plus solution. The anterior face of lenses was illuminated with a monochromatic (633nm) plane wave.

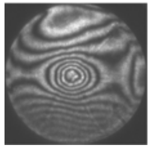


All lenses were measured under the same alignment conditions with respect to the axis of the interferometer by checking the alignment of the sutures of the eye lens.

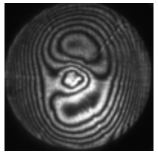


-The dark fringes of the recorded interferograms (above) were tracked semi-automatically for fitting (yellow points in the figure). In order not to soften phase details when fitting, many points can be tracked over some fringes or regions of fringes optically relevant, like the central fringe of the figure in the left. Accuracy of experimental measurements is about λ/10 (limited by the biological noise). Fringe data is used to fit the phase aberrations of the lenses to a chosen set of Zernike polynomials.

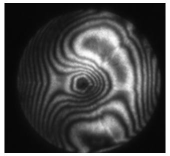
- Several interferograms of the same lens with different amounts of circular and linear carrier fringes can be fitted together in order to have a complete sampling of the phase and this leads to a more robust fit (although loosing some accuracy).



Pinhole in focus (CLS)



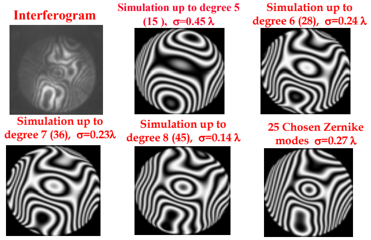
Circular carrier fringes added



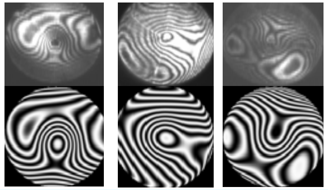
Linear & circular carrier fringes added

Data processing & analysis

Interferograms and simulated interferograms after fit with different number of Zernike polynomials



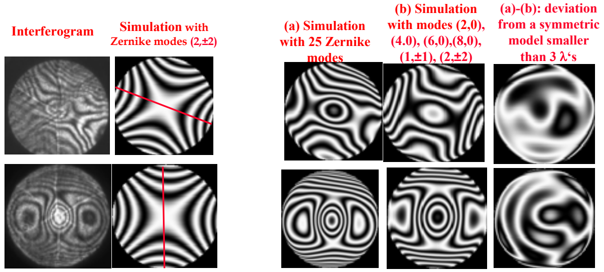
Interferograms and simulated interferograms after fit with 25 chosen Zernike polynomials



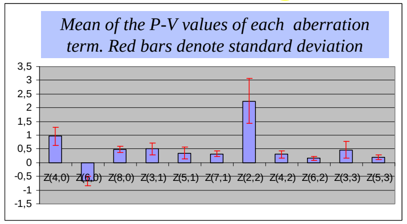
Direct fit to the phase allows for the visual inspection of the goodnes of the fit, *"Chi by eye"* test. We found as significative aberrations:

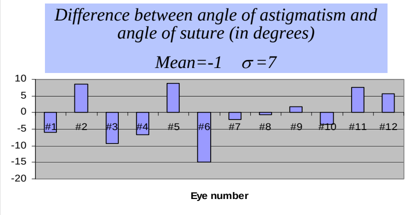
Azimuthal frequency 0	Azimuthal frequency 1	Azimuthal frequency 2	Azimuthal frequency 3	Azimuthal frequency 4
(2,0) defocus	(1,±1) tilts	(2, ± 2) primary astigmatism	(3, ± 3) trifoil	(4, ± 4) tetrafoil
(4,0) spherical aberration	(3, ±1) primary coma	(4, ± 2) secondary astigmatism	(5, ± 3) trifoil	
(6,0) spherical aberration	(5, ± 1) secondary coma	(6, ± 2) tertiary astigmatism		
(8,0) spherical aberration	(7, ± 1) tertiary coma			

Only 25 Zernike polynomials are significative: those such that **radial index (n) +azimuthal index (m) ≤ 8**
mean rms error of fits= 0.2 λ
We also found a **high correlation** betwen one **suture direction** and the axis of the primmary **astigmatism**



Average aberrations in the lenses





CONCLUSIONS

- WA's of isolated porcine crystalline lenses were measured with a point-diffraction interferometer.
- The method allowed for a greater insight into the aberration structure of porcine crystalline lenses showing a systematic astigmatism in all lenses, the axis of which was closely correlated with the direction of one of the sutures of the lenses.
- In ruling order astigmatism, together with spherical aberration, comas and trefoil, are the main aberrations present in all lenses.

REFERENCES

1.-*C. Koliopoulos et al., Opt. Lett.* **3**, *118 (1978)*
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3.-*E. Acosta et al., Ophthal. Physiol. Opt.* **29**, *235 (2009)*

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