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Declaration

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Abstract

In this thesis the laser ray tracing (LRT) technique for measurement of ocular aberrations has been implemented, validated and applied, in conjunction with complementary techniques, to the study of ocular aberrations in human eyes. In particular, we studied optical aberrations in myopic and hyperopic eyes and the optical changes induced by refractive surgery for myopia and hyperopia.

We have studied the impact of the optimisation of some experimental parameters on the estimation of the wave aberration. We demonstrated that although the polarisation state and wavelength of the illumination light affected the intensity patterns of the images obtained using reflectometric aberrometry (LRT and Hartmann Shack sensor), these changes did not affect the estimation of aberrations. We also showed that the difference in the defocus term (focus shift) due to the use of different wavelengths is in agreement with the Longitudinal Chromatic Aberration of the Indiana Chromatic Eye Model for average normal eyes, although intersubject variability is not negligible. In addition, we studied experimentally the influence of the geometrical distribution and density of the pupil sampling on the estimation of aberrations using artificial and normal human eyes, and performed numerical simulations to extend our results to "abnormal"eyes. We found that the spatial distribution of the samples can be more important than the number of samples, for both our measured as well as our simulated "abnormal" eyes. Experimentally, we did not find large differences across patterns except, as expected, for undersampled patterns.

We found that hyperopic eyes tended to have more positive asphericity and greater total and corneal spherical aberration than myopic eyes, as well as greater 3rd and higher order aberrations. Although we found no significant differences between groups in terms of internal aberrations, internal spherical aberration showed a significant age-related shift toward less negative values in the hyperopic group. We also assessed the impact of the LASIK corneal surgery, a popular surgical technique for correction of refractive errors, on the optical quality for both myopic and hyperopic standard techniques. Third and higher order ocular and anterior corneal aberrations increased with the surgery. Ocular and corneal spherical aberration changed towards more positive values with myopic LASIK, and towards more negative values with hyperopic LASIK. Changes in internal spherical aberration were of opposite sign than those induced in corneal spherical aberration. Changes induced by hyperopic LASIK were larger than those induced by myopic LASIK for a similar attempted correction.

KEY FOR SYMBOLS AND ABBREVIATIONS

2D	two dimensional
3D	three dimensional
A49	Albrecht pattern with 49 samples
AL	Axial Length
AL/CR	Axial Length to Corneal Radius ratio
ANOVA	Analysis of Variance
CCD	Coupled Charge Device
Cn	Circular pattern with n samples
CPP	Conjugate Pupil Plane
CR	Corneal Radius
CRT	Cathode Ray Tube
CSF	Contrast Sensitivity Function
D	Dioptres
DF	Dichroic Filter
FA	Field Aperture
FB	Focusing Block
GRIN	Gradient Index
HCA	Hierarchical cluster analysis
He-Ne	Helium Neon
Hn	Hexagonal pattern with n samples
HOA	3^{rd} and Higher Order Aberrations (excluding piston, tilts, defocus and astigmatism)
HS	Hartmann-Shack
i.e.	id est, this is
IR	Infrared
J49	Jacobi pattern with 49 samples
λ	Wavelength
L	lens
L49	Legendre pattern with 49 samples

LASIK	Laser Assisted In situ Keratomileusis
LCA	Longitudinal Chromatic Aberration
LED	Light Emitting Diode
LP	Linear Polariser
LRT	Laser Ray Tracing
LRT1	1st generation laser ray tracing device
LRT2	2nd generation laser ray tracing device
μm	microns
MPE	Maximum Permitted Exposure
mrad	milliradians
MTF	Modulation Transfer Function
nm	nanometres
^{o}	degrees
OCT	Optical Coherence Tomography
PCBS	Polarising Cubic Beam Splitter
PRK	PhotoRefractive Keratectomy
PSF	Point-Spread Function
Q	Asphericity
QWP	Quarter Wave Plate
R	Radius of curvature
RMS	Root Mean Square wavefront error
Rn	Rectangular pattern with n samples
RPE	Retinal Pigment Epithelium
SA	Spherical Aberration
SE	Refractive error Spherical Equivalent
SF	Spatial Filter
SRR	Spatially Resolved Refractometre
std	standard deviation
TCA	Transverse Chromatic Aberration
vs	Versus, compared to