

CONTENTS

LIST OF TABLES	13
LIST OF ILLUSTRATIONS	13
ACKNOWLEDGEMENTS	19
DECLARATION	21
ABSTRACT.....	23
KEY FOR SYMBOLS.....	25
CHAPTER 1 INTRODUCTION.....	27
1.1.- THE HUMAN EYE	28
1.1.1.- CORNEA.....	29
1.1.2.- CRYSTALLINE LENS	32
1.1.3.-CHAMBERS OF THE EYE.....	34
1.1.4.- UVEA.....	34
1.1.5.- RETINA.....	35
1.1.6.- AXIS OF THE EYE.....	36
1.2.- ABERROMETRY	37
1.2.1.- OPTICAL ABERRATIONS	37
1.2.2.- ESTIMATION OF ABERRATIONS	42
1.2.3.- HISTORY AND TYPES OF ABERROMETERS.....	45
1.2.4.- OPTICAL ABERRATIONS OF THE HUMAN EYE	49
1.2.4.1.- Ocular Aberrations	49
1.2.4.2.- Corneal Aberrations	52
1.2.4.3.- Internal Aberrations: interaction between total and corneal aberrations.....	53
1.2.5.- ABERRATION MEASUREMENT IN PATIENTS: INFLUENCE OF THE MEASUREMENT LIGHT AND SAMPLING PATTERN	55
1.2.5.1.- Polarisation State of the measurement light	55
1.2.5.2.- Measurement Light Wavelength	59
1.2.5.3.- Pupil Sampling Pattern	61
1.2.6.- APPLICATIONS	64
1.3.- AMETROPIA AND EMMETROPISATION.....	66
1.3.1.- AMETROPIA AND OPTICAL ABERRATIONS.....	70
1.4.- LASIK AS A CORRECTION OF REFRACTIVE ERRORS	70
1.4.1.- REFRACTIVE SURGERY AND OPTICAL ABERRATIONS	74
1.5.- THESIS SYNOPSIS.....	76
CHAPTER 2 METHODS	79
2.1.- MEASUREMENT OF OCULAR ABERRATIONS: THE LASER RAY TRACING TECHNIQUE.	80

2.2.- THE LASER RAY TRACING DEVICE.....	83
2.2.1.- EXPERIMENTAL SETUP	84
2.2.2.- SOFTWARE.....	90
2.2.2.1.- System Control Software	90
2.2.2.2.- Processing Software for retinal images (ocular aberrations)...	91
2.2.2.3.- Processing software for pupil images (passive eyetracking)...	93
2.3.- SYSTEM CALIBRATION.....	97
2.3.1.- RETINAL CAMERA.....	97
2.3.2.- PUPIL CAMERA.....	99
(a) Offset	100
(b) Scale (equivalence between pixels and millimetres)	100
2.3.3.- ASTIGMATISM CORRECTION AND SCANNER CALIBRATION...	101
(a) Astigmatism compensation	102
(b) Scanner calibration.....	102
2.3.4.- SAMPLING PATTERN VERIFICATION.....	103
2.3.5.- FOCUSING BLOCK SCALE CALCULATION	106
2.3.6.- COMPENSATION OF DEFOCUS BY THE FOCUSING BLOCK (FB)..	109
2.3.7.- OPTICAL ABERRATIONS INTRODUCED BY THE SYSTEM	111
(a) Geometrical aberrations	111
(b) Chromatic aberrations	112
2.3.8.- HIGH ORDER ABERRATIONS IN HUMAN EYES.....	112
2.3.8.1.- LRT1 vs LRT2.....	113
(a) Phase Plate.....	113
(b) Human Eyes	115
2.4.- PROTOCOL FOR MEASUREMENTS IN SUBJECTS.....	118
CHAPTER 3.- INFLUENCE OF POLARISATION ON OCULAR	
ABERRATIONS.....	121
3.1.- ABSTRACT	121
3.2.- INTRODUCTION	122
3.3.- METHODS.....	124
3.3.1.- LASER RAY TRACING.....	124
3.3.1.1.- Set up and procedures.....	124
3.3.1.2.- Experiments.....	124
3.3.1.3.- Subjects	126
3.3.2.- HARTMANN-SHACK.....	126
3.3.2.1.- Set up and procedures.....	126
3.3.2.2.- Experiments.....	127
3.3.2.3.- Subjects	128
3.3.3.- COMPARISON OF HS AND LRT SETUPS.....	128
3.3.4.- STATISTICAL ANALYSIS.....	130
3.4.- RESULTS.....	130
3.4.1.- RAW DATA	130
3.4.2.- INTENSITY PATTERNS.....	132
3.4.3.- WAVE ABERRATION PATTERNS.....	134
3.4.4.- ZERNIKE COEFFICIENTS	136
3.5.- DISCUSSION.....	138

CHAPTER 4 ABERRATIONS OF THE HUMAN EYE IN VISIBLE AND NEAR INFRARED ILLUMINATION	141
4.1.- ABSTRACT	141
4.2.- INTRODUCTION	142
4.3.- METHODS	144
4.3.1.- LASER RAY TRACING.....	144
4.3.1.1.- Set up and procedures.....	144
4.3.1.2.- Setting and control experiment.....	144
4.3.1.3.- Subjects.....	145
4.3.1.4.- Measurements	146
4.3.2.- HARTMANN-SHACK.....	146
4.3.2.1.- Set up and procedures.	145
4.3.2.2.- Setting and control experiment	145
4.3.2.3.- Subjects.....	147
4.3.2.4.- Measurements	148
4.4.- RESULTS	148
4.4.1.- RAW DATA	148
4.4.2.- WAVE ABERRATION MAPS.....	150
4.4.3.- ZERNIKE COEFFICIENTS AND RMS.....	151
4.5.- DISCUSSION	154
4.5.1.- DIFFERENCES IN IMAGE INTENSITY PROFILES.....	156
4.5.2.- CHROMATIC DIFFERENCE OF FOCUS.....	158
4.5.3.- CONCLUSION.....	160
CHAPTER 5.- EFFECT OF SAMPLING ON REAL OCULAR ABERRATION MEASUREMENTS	163
5.1.- ABSTRACT	163
5.2.- INTRODUCTION	165
5.3.- METHODS	169
5.3.1.- LASER RAY TRACING.....	169
5.3.2.- EYES	170
5.3.3.- EXPERIMENTAL PROCEDURE.....	170
5.3.3.1.- Artificial Eyes	170
5.3.3.2.- Human Eyes	171
5.3.4.- DATA PROCESSING	171
5.3.4.1.- Wave aberration estimates	171
5.3.4.2.- Wave aberration variability metrics.....	172
5.3.4.3.- Statistical analysis	174
5.3.4.4.- Numerical Simulations.....	175
5.4.- RESULTS	177
5.4.1.- ARTIFICIAL EYES.....	177
5.4.1.1.- Wave Aberrations	177
5.4.1.2.- Difference Metrics.....	178
5.4.1.3.- Statistical Tests	179
5.4.2.- HUMAN EYES.....	181

5.4.2.1.- Wave Aberrations	181
5.4.2.2.- Difference Metrics.....	182
5.4.2.3.- Statistical Tests	185
5.4.3.- NUMERICAL SIMULATIONS.....	186
5.5.- DISCUSSION.....	188
5.5.1.- ARTIFICIAL AND HUMAN EYES.....	188
5.5.2.- NUMERICAL SIMULATIONS	191
5.5.3.- COMPARISON TO PREVIOUS LITERATURE	193
5.5.4.- CONCLUSIONS	194
CHAPTER 6.- OPTICAL ABERRATIONS IN MYOPIC AND	
HYPEROPIC EYES.....	197
6.1.- ABSTRACT	197
6.2.- INTRODUCTION	198
6.3.- METHODS.....	201
6.3.1.- SUBJECTS	201
6.3.2.- AXIAL LENGTH AND CORNEAL SHAPE	202
6.3.3.- OCULAR ABERRATIONS.....	202
6.3.4.- CORNEAL TOPOGRAPHY: ESTIMATION OF CORNEAL AND INTERNAL ABERRATIONS.	202
6.3.5.- REFRACTION.....	203
6.3.6.-STATISTICAL ANALYSIS.....	204
6.4.- RESULTS	205
6.4.1.- AXIAL LENGTH AND CORNEAL SHAPE	205
6.4.2.- OPTICAL ABERRATIONS	207
6.5.- DISCUSSION.....	212
6.5.1.- CORNEAL SHAPE IN MYOPES AND HYPEROPES	212
6.5.2.- AGE RELATED ABERRATION DIFFERENCES IN MYOPES AND HYPEROPES.....	213
6.5.3.- ABERRATIONS AND DEVELOPMENT OF MYOPIA AND HYPEROPIA.....	217
6.5.4.- CONCLUSIONS	218
CHAPTER 7.- CHANGE IN OPTICAL ABERRATIONS OF THE EYE	
WITH LASIK.....	219
7.1.- ABSTRACT.....	219
7.2.- INTRODUCTION	221
7.3.- METHODS.....	224
7.3.1.- SUBJECTS	224
7.3.2.- LASIK SURGERY	224
7.3.3.- MEASUREMENTS AND STATISTICAL ANALYSIS.....	226
7.4.- RESULTS	226
7.4.1.- TOTAL AND CORNEAL WAVE ABERRATION PATTERNS.....	226
7.4.2.- CHANGE IN TOTAL AND CORNEAL ABERRATIONS WITH MYOPIC LASIK.....	230
7.4.3.- CHANGE IN OCULAR AND CORNEAL ABERRATIONS WITH HYPEROPIC LASIK.....	232
7.4.4.- COMPARISON BETWEEN THE RESULTS AFTER MYOPIC AND AFTER HYPEROPIC LASIK.....	235
7.4.5.- CHANGE OF INTERNAL ABERRATIONS WITH LASIK	238

7.5.- DISCUSSION.....	239
7.5.1.- CHANGE IN ABERRATIONS WITH MYOPIC AND HYPEROPIC LASIK.....	239
7.5.2.- ROLE OF PREOPERATIVE INTERNAL OPTICS	242
7.5.3.- CHANGES IN INTERNAL ABERRATIONS AND BIOMECHANICAL RESPONSE	246
7.5.4.- COMPARISON WITH OTHER STUDIES	248
7.5.5.- IMPLICATIONS.....	251
7.5.6.- CONCLUSIONS	252
CHAPTER 8.- CONCLUSIONS	255
Appendix A.- JACOBI, LEGENDRE AND ALBRECHT SAMPLING COORDENATES.....	261
REFERENCES AND BIBLIOGRAPHY.....	259

LIST OF TABLES

Table 1.1:	Comparison of the features of the different techniques to estimate ocular aberrations from transverse aberrations.	48
Table 2.1:	RMS values for different orders for the two wavelengths of the set-up.....	112
Table 7.1	Refractive surgery data for hyperopic eyes	225
Table A.1	Coordinates of the 49 samples of the Albrecht, Jacobi and Legendre patterns.....	261

LIST OF ILLUSTRATIONS

Figure 1.1:	Cross-section of the eye (side view)	28
Figure 1.2:	Histological section of the cornea.....	30
Figure 1.3:	Diagram showing the shape of cross-sections of a prolate and an oblate ellipsoids compared to a sphere, according to their asphericity (Q) value.....	31
Figure 1.4:	Diagram showing a cross-section of the crystalline lens.....	33
Figure 1.5:	Diagram showing the different layers of the vertebrate retina.	36
Figure 1.6:	Schematic representation of the wave aberration.....	39
Figure 1.7:	Illustration of three Seidel aberrations: astigmatism (A), spherical aberration (B) and coma (C).	41
Figure 1.8:	Representation of the Zernike base functions.	43
Figure 1.9:	Schematic diagram of the working principle of Hartmann-Shack sensor.	47
Figure1.10:	Schematic diagram of the working principle of Laser Ray Tracing	48
Figure 1.11:	Diagrams showing different states of polarisation.....	56
Figure 1.12:	Polarisation effects in the eye.....	59
Figure 1.13:	Cross-section of ametropic eyes.	66
Figure 1.14:	Prevalence rates of myopia around the world as a function of age.	68

Figure 1.15:	Illustration showing the different steps in the LASIK surgical procedure.	72
Figure 1.16:	Representation of the ablation patterns for myopic and hyperopic correction.	73
Figure 2.1:	Schematic diagram of the working principle of Laser Ray Tracing Technique.....	82
Figure 2.2:	Diagram of the LRT2 setup.....	85
Figure 2.3:	Snapshot of the control program for LRT2.....	88
Figure 2.4:	Frame of a movie showing a typical run with LRT2.....	88
Figure 2.5:	Snapshot of the processing software interface.....	93
Figure 2.6:	Illustration of the steps performed by the pupil processing software.....	95
Figure 2.7:	Example of output figures from the pupil processing.....	96
Figure 2.8:	Wave aberration maps for one human eye computed using nominal and actual entry pupil coordinates, and corresponding difference maps.....	91
Figure 2.9:	Illustration of the Retinal Camera Calibration.....	99
Figure 2.10:	Illustration of the Pupil Camera Calibration.....	101
Figure 2.11:	Verification of the pupil sampling pattern.....	105
Figure 2.12:	Spot diagram from LRT corresponding to an artificial eye with positive defocus.....	106
Figure 2.13:	Different configurations of the Badal system for correction of refractive error.....	108
Figure 2.14:	Spherical error correction by the Focusing Block versus the nominal value of the trial lens.....	110
Figure 2.15:	Aberrations of the phase plate measured with LRT1 and LRT2.....	114
Figure 2.16:	Aberrations of Eye #1 measured with LRT1 and LRT2.....	116
Figure 2.17:	Aberrations of Eye #2 measured with LRT1 and LRT2.....	117
Figure 3.1:	Schematic diagram of the configuration of LRT1 used in this study.....	124
Figure 3.2:	Configurations of the set-ups to obtain the different polarising conditions.....	125

Figure 3.3:	Schematic diagrams showing the configuration of the Hartmann-Shack sensor used in this study.....	127
Figure 3.4:	Wave aberration contour for control eyes measured in both the LRT setup and the SH system.....	129
Figure 3.5:	Raw data as captured by LRT and HS.....	131
Figure 3.6:	Pupillary intensity maps from LRT aerial images.....	133
Figure 3.7:	Pupillary intensity maps from LRT for right and left eyes of the same subject.....	133
Figure 3.8:	Hartmann-Shack spot images for different polarisation conditions.....	134
Figure 3.9:	Wave aberration contour maps for some of the eyes measured with LRT and HS.....	135
Figure 3.10:	Zernike coefficients comparing different combinations of polarization conditions.....	136
Figure 3.11:	Zernike coefficients Z_2^0 , Z_2^{-2} , Z_3^1 and Z_4^0 for all eyes of this study, comparing at least two different polarization states.....	137
Figure 4.1:	Schematic diagram of the LRT1 configuration used in this study.....	145
Figure 4.2:	Schematic diagram of the HS wavefront sensor used in this study.....	147
Figure 4.1:	Raw data as obtained from LRT and HS wavefront sensor.....	149
Figure 4.4:	Wave aberration maps from LRT and HS for green and infrared light.....	150
Figure 4.5:	Plots of sets of the Zernike coefficients for green and IR light for the same eyes as in Figure 4.4.....	152
Figure 4.6:	Defocus for infrared vs. green wavelength for all subjects.....	153
Figure 4.7:	Bar diagrams comparing astigmatism, spherical aberration, and RMS for HOA with green and infrared for all subjects.....	155
Figure 4.8:	Experimental and simulated aerial images for green and infrared light.....	157
Figure 5.1:	Pupil sampling patterns used in the measurement of the ocular aberrations for this work.....	169

Figure 5.2:	Wave aberration, difference, probability, and significance maps obtained for the artificial eye A3, using the different sampling patterns.....	178
Figure 5.3:	RMS_Diff values and dendrograms from the hierarchical cluster analysis obtained for the artificial eyes.....	180
Figure 5.4:	Wave aberration, difference, probability, and significance maps obtained for the human eye R12, using the different sampling patterns.....	181
Figure 5.5:	Ranking values for RMS_Diff and W%, and dendrograms corresponding to the hierarchical cluster analysis for the measured and simulated human eyes.....	184
Figure 5.6:	Comparison between the classification from the global and eye by eye hierarchical cluster analysis on the 12 human eyes.....	185
Figure 5.7:	Results obtained for the keratoconic, post-LASIK, and post RK eyes for RMS_Diff and W, and dendrograms from the hierarchical cluster analysis (HCA).....	187
Figure 6.1:	Axial length (A), corneal apical radius of curvature (B), corneal asphericity (C), total, corneal, and internal spherical aberration (D), third-order RMS (E), and third and higher order RMS (F), averaged across hyperopes and myopes.....	206
Figure 6.2:	Total, corneal, and internal third and higher order aberration maps for three of the hyperopic and three of the myopic eyes.....	208
Figure 6.3:	Corneal, total, and Internal spherical aberration for myopic and hyperopic eyes sorted by increasing age.....	211
Figure 6.4:	Spherical aberration of the hyperopic and myopic eyes included in this study as a function of age in comparison with spherical aberration of eyes from aging studies.....	214
Figure 7.1:	Wave aberration maps for HOA, before and after myopic LASIK surgery.....	228
Figure 7.2:	Wave aberration maps for HOA, before and after hyperopic LASIK surgery.....	229
Figure 7.3:	Total and Corneal HOA RMS and SA before and after LASIK for myopia.....	230

Figure 7.4:	Pre- and post-operative RMS, averaged across all myopic eyes, for HOA, 3rd order aberrations, 4th order aberrations and 5th and higher order aberrations, for a 6.5-mm pupil.....	231
Figure 7.5:	Total and Corneal HOA RMS (A) and SA before and after LASIK for hyperopia.....	233
Figure 7.6:	Pre- and post-operative RMS, averaged across all hyperopic eyes, for HOA, 3rd order aberrations, 4th order aberrations and 5th and higher order aberrations, for a 6.5-mm pupil.....	234
Figure 7.7:	Total, corneal and internal SA induced by myopic and hyperopic LASIK as a function of absolute spherical correction, for a 6.5-mm pupil.....	237
Figure 7.8:	Diagrams showing the transition points of the cornea after ablation for correction of myopia or myopic astigmatism on the steepest meridian (A), myopic astigmatism on the flattest meridian (B), hyperopia or hyperopic astigmatism (C).....	241
Figure 7.9:	Total, corneal and internal HOA maps before (top) and after (bottom) myopic LASIK for eye M6.....	244

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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
C _n	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
H _n	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
°	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