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II EOS Topical Meeting on Physiological Optics

Abstract Booklet

September, 20th-23rd
Granada (Spain)

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Facultad de Ciencias
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Welcome to the II EOS Topical Meeting on Physiological Optics.

The II EOS TOPICAL MEETING ON PHYSIOLOGICAL OPTICS will be held in the *Palacio de Congresos y Exposiciones* de Granada (Spain), from 20 to 23 September 2004. The meeting is organized by the Departamento de Óptica of the Univerisidad de Granada, in collaboration with the European Society of Optics and the SEDO (Sociedad Española de Optica). The first meeting was held in Wroclaw (Poland) in 1999 and was extremely successful within the European community of Physiological Optics. This meeting in Granada builds on the II EOS Topical Meeting, but it is open to all worldwide researchers. These conferences support research in Physiological Optics, encouraging the exchange of new ideas as well as the establishment of new contacts and cooperation within this area of research.

Topics of the conference will include: *cornea, crystalline lens and accommodation, retinal-image quality, refraction and eye aberrations, adaptive optics in the human eye, contact and intraocular-lens design, refractive surgery, new ophthalmic technologies applied to vision*, and all related topics on physiological and visual optics.

The scientific and local committees invite your participation in this meeting. We hope that Granada, with a long university tradition and a superb historical and artistic heritage, will provide the setting for a pleasant stay during the congress.

José Ramon Jiménez Cuesta
Meeting Chairman

Organising Committee.

- José Ramón Jiménez Cuesta, Ph. D. (Chairman)
- Antonio García-Beltrán, Ph. D. (Secretary)
- Carlos María Salas Hita, Ph. D. (Treasurer)
- José Antonio Díaz Navas, Ph. D.
- Rosario González Anera, Ph. D.
- Enrique F. Hita Villaverde, Ph. D.
- Luis M. Jiménez del Barco Jaldo, Ph. D.
- Raimundo Jiménez Rodríguez, Ph. D.
- Juan Antonio Martínez Ferrer, Ph. D.
- María del Mar Pérez Gómez, Ph. D.
- Francisco Pérez Ocón, Ph. D. (webmaster)
- A. Manuel Rubiño López, Ph. D.
- Eva M. Valero Benito, Ph. D.
- Ana M. Yebra Rodríguez, Ph. D.

Scientific Committee.

Submitted research contributions have been reviewed by an International Scientific Committee, consisting of experts in the various disciplines of physiological optics. The organisers gratefully acknowledge the scientific help and the valuable suggestions of the members of this committee.

- David A. Atchison, Ph. D.
  (School of Optometry, Queensland University of Technology, Australia)
- Scott M. MacRae, M. D.
  (Department of Ophthalmology, University of Rochester, New York, USA.)
- Henryk Kasprzak, Ph. D.
  (Institute of Physics, Wroclaw University of Technology, Wroclaw, Poland)
- Susana Marcos, Ph. D.
  (Instituto de Óptica "Daza de Valdes", C.S.I.C. Madrid, Spain)

- Pablo Artal, Ph. D.
  (Laboratorio de Óptica, Departamento de Física, Universidad de Murcia, Spain)
- José Ramón Jiménez Cuesta, Ph. D.
  (Departamento de Óptica, Universidad de Granada, Spain)

Sponsors.

The organising committee is very grateful for the meeting support from the following Institutions and Companies:

- Ministerio de Ciencia y Tecnología.
- Junta de Andalucía.
- Universidad de Granada.
- Colegio Nacional de Ópticos-Optometristas.
- Sociedad Andaluza de Optometría y Contactología.
- Winter Group.
- TOPCON España.
- ZEISS.
- INDO.
- ESSILOR.

Instructions to authors.

Oral presentations.

Speakers will have 12 minutes for their presentations, plus 3 minutes for discussion. They are asked to keep the programme in order to avoid annoying delays. During the breaks and before the sessions begin, speakers must set up their presentations contacting the audiovisual technician in the meeting room.

Standard audioviual equipment.

We gratefully acknowledge Palacio de Congresos y Exposiciones for providing the following audiovisual equipment: LCD proyector, overhead and slide proyector, screen, and lapel microphone. There will be a laptop operating *only* with Windows XP Professional and providing Office 2003 Pro Suite: thus authors using this system *do not have to bring* their own laptop.

Poster presentations.

Poster authors will be able to set up starting at 9:30 on Wednesday. Authors are asked to pick up their assigned poster numbers, and received board assignments at the poster desk. Presenters will be at their posters to answer questions from 17:15 to 19:15. It is author's responsability to remove their posters at the end of the session. Organisers assumes no responsability for posters left up after the end of the poster session. Panels will be 190cm high and 90cm wide.

Special Issue in Journal Of Optics.

All participants in the meeting interested in submitting a paper to Journal of Optics A: Pure and Applied, can follow the submission guidelines at the URL http://www.iop.org/EJ/authors/ before November 30th 2004, indicating that the work was presented at the II EOS Topical Meeting on Physiological Optics, Granada (Spain), September 2004.

Lunches.

The organising committee recall that during the Meeting, lunches will be held in the Palacio de Congresos y Exposiciones.

Programme

MONDAY, 20TH

18:00 Registration. Palacio de Exposiciones y Congresos.

20:30 Wellcome Cocktail. Carmen de la Victoria (Albayzin).

TUESDAY, 21ST

08:00 Registration. Palacio de Exposiciones y Congresos.

09:00 Opening Remarks.

Session 1

Advanced instrumentation
Chair: **Stephen Burns.**
Schepens Eye Research Institute.

09:15 **Invited Paper:** ***Applications of adaptative optics for vision correction and retinal imaging***. David Williams. Center for Visual Science. University of Rochester. Rochester, NY. USA. . . . . [**IP1**]

10:00 ***High speed full-field optical coherence tomography (OCT)***. Kate Grieve, Arnaud Dubois and Claude Boccara. Laboratoire d'Optique Physique, Ecole Suprieure de Physique et Chimie Industrielles. CNRS. France. . . . . [**AIO1**]

10:15 ***Eccentric correction in subjects with large central visual field loss***. Jörgen Gustafsson, Linda Lundström and Peter Unsbo. Certec, Division of Rehabilitation Engineering Research, Department of Design Sciences. Lund University. Sweden. Biomedical and X-ray Physics, Royal Institute of Technology. Stockholm. Sweden. . . . . [**AIO2**]

10:30 **Coffee Break.**

11:00 ***Simulating vision with adaptive optics using a LC-SLM***. Silvestre Manzanera, Pedro M. Prieto, Enrique J. Fernández and Pablo Artal. Laboratorio de Optica. Universidad de Murcia. Murcia. Spain. . . . . [**AIO3**]

11:15 ***Comparison of a red and green laser in adaptive optics imaging of parafoveal capillaries and leukocyte movement***. Joy A. Martin and Austin Roorda. College of Optometry. University of Houston. Houston, TX. USA. . . . . [**AIO4**]

11:30 ***Imaging the retinal photoreceptor mosaic with directional light***. Brian Vohnsen, Ignacio Iglesias, and Pablo Artal. Laboratorio de Optica. Universidad de Murcia. Murcia. Spain. . . . . [**AIO5**]

11:45 ***Deconvolution of retinal images***. V. Nourrit, B. Vohnsen, I. Iglesias and P. Artal. Laboratorio de Optica. Universidad de Murcia. Murcia. Spain. ..... [**AIO6**]

12:00 **Break.**

Session 2

Ocular Scattering

Chair: **David Atchison.**
School of Optometry, Queensland University of Technology.

12:15 ***Impact of ocular scattering on visual performance***. Esther Berrio, Juan M. Bueno, Maris Ozolinsh and Pablo Artal. Laboratorio de Optica. Universidad de Murcia. Murcia. Spain. ..... [**OSO1**]

12:30 ***Estimation of corneal scattering by analysis of Tscherning aberrometer images***. Dirk De Brouwere and Harilaos Ginis. Vardoyannian Eye Institute Crete. University of Crete. Greece. ..... [**OSO2**]

12:45 ***Colour stimuli perception in adverse viewing conditions***. Maris Ozolinsh, Michle Colomb and Gatis Ikaunieks. Department of Optometry and Vision Science, University of Latvia. Laboratoire Règional des Ponts et Chaussèes de Clermont-Ferrand. France. . [**OSO3**]

13:00 ***A clinical instrument to measure intraocular scattering***. S.O. Luque, J.M. Bueno, F. Díaz, M. Arjona, J. Pujol and P. Artal. Centre per al Desenvolupament de Sensors, Instrumentació i Sistemes. Universidad Politécnica de Cataluña. Terrassa (Barcelona). Spain. Laboratorio de Óptica. Universidad de Murcia. Murcia. Spain. ..... [**OSO4**]

13:15 **Discussion sessions 1 and 2.** Discussants: David Atchison and Stephen Burns.

13:30 **Lunch Break (Palacio de Congresos y Exposiciones).**

Session 3

Animal models

Chair: **Frank Schaeffel.**
University Eye Hospital. Tübingen.

15:00 **Invited Paper:** ***Wavefront sensing and retinal image in the mouse***. Stephen Burns. Schepens Eye Research Institute. ..... [**IP2**]

15:45 ***Monochromatic aberrations and changes in eye size in growing and myopic chick eyes***. M. C. W. Campbell, M. L. Kisilak, J. J. Hunter, L. Huang and E. L. Irving. Guelph-Waterloo Physics Institute and School of Optometry. Waterloo. Austalia. . . . [**AMO1**]

16:00 ***Longitudinal changes of ocular aberrations during development in normal and myopic chick eyes***. E. García de la Cera, S. Marcos, G. Rodriguez and J. Merayo. Instituto de Óptica, CSIC. Madrid. Spain. Instituto Universitario de Oftalmobiología Aplicada. Universidad de Valladolid. Valladolid. Spain. ..... [**AMO2**]

16:15 ***A battery of optical tests to measure visual function and myopia in alert mice***. Christine Schmucker and Frank Schaeffel. Section of Neurobiology of the Eye. University Eye Hospital. Tübingen, Germany. ..... [AMO3]

16:30 **Coffee Break.**

Session 4

Crystalline lens and IOLs

Chair: **Pablo Artal.**
Universidad de Murcia.

17:00 ***Refractive power of the whole crystalline lens for a GRIN model***. M.A. Rama, M.T. Flores-Arias, C. Bao, M.V. Pérez and C. Gómez-Reino. Universidade de Santiago de Compostela. Santiago de Compostela. Spain..... [CIO1]

17:15 ***A purkinje imaging system for phakometry and for lens tilt and decentration measurements: development, validation, and test on crystalline and intraocular lenses***. P. Rosales, S. Marcos and S. Barbero. Instituto de Optica, CSIC. Madrid. Spain. School of Optometry. Indiana University. Bloomington, IN. USA..... [CIO2]

17:30 ***The optical structure of the crystalline lens and its aberrations***. G. Smith. Department of Optometry. University of Melbourne. Parkville. Australia. ..... [CIO3]

17:45 ***Effect of misalignments in IOLs correcting spherical aberration***. J. Tabernero, A. Benito, P. Piers, V. Nourrit, M. Redondo and P. Artal. Laboratorio de Optica. Universidad de Murcia. Murcia, Spain. Pfizer Ophthalmology. Groningen. Netherlands. Clinica Ircovision. Cartagena (Murcia). Spain..... [CIO4]

18:00 ***Visual axial PSF of diffractive multifocal lens***. Pedro J. Valle, Manuel P. Cagigal, Vidal F. Canales and José E. Oti. Deparatmento de Física Aplicada. Univ. de Cantabria. Santander. Spain..... [CIO5]

18:15 ***Experimental limitations to the tomographic retrieval of the gradient index of a crystalline lens***. D. Vazquez and E. Acosta. Universidade de Santiago de Compostela. Santiago de Compostela. Spain..... [CIO6]

18:30 **Discussion sessions 3 and 4.** Discussants: Frank Schaeffel and Pablo Artal.

21:00 **Night visit to Alhambra (Buses will leave from the Palacio de Congresos y Exposiciones).**

WEDNESDAY, 22ND

Session 5

Ocular aberrations properties

Chair: **David Williams.**
Center for Visual Science. University of Rochester.

09:00 **Invited Paper:** ***Eye shape in myopia***. David Atchison. School of Optometry. Queensland University of Technology. Australia. ..... **[IP3]**

09:45 ***Distribution of critical pupil diameter and depth-of-focus in an emmetropic population***. Ginis H.S., Plainis S., Pallikaris A., Aslanides I.M. and Pallikaris I.G.. University of Crete. VEIC. Greece. ..... [**OAO1**]

10:00 ***Dynamical changes of corneal topography and its influence on psf of the eye***. D. Siedlecki, H. Kasprzak and B. K. Pierscionek. Institute of Physics. Wroclaw University of Technology. Wroclaw. Poland. Biomedical Sciences. University of Ulster. UK. ..... [**OAO2**]

10:15 ***Temporal changes in optical quality of air-tear film interface at anterior cornea after blink***. Robert Montés-Micó, W. Neil Charman and Jorge L. Alió. Research, Development and Innovation Department. Ophthalmologic Institute of Alicante. Alicante. Spain. Department of Optometry and Neuroscience. University of Manchester. Institute of Science and Technology (UMIST). Manchester. UK. ..... [**OAO3**]

10:30 **Coffee Break.**

11:00 ***Compensation of corneal aberrations by the internal optics is better in eyes with a larger angle kappa***. Antonio Benito and Pablo Artal. Laboratorio de Óptica. Universidad de Murcia. Murcia. Spain. ..... [**OAO4**]

11:15 ***Dynamics of ocular aberrations: a theoretical model***. Luis Diaz-Santana. Applied Vision Research Centre. The Henry Wellcome Laboratories for Vision Sciences. City University. London. UK. ..... [**OAO5**]

11:30 ***Development of an experimental model on artificial corneas for the study of adaptation and optical quality of contact lenses***. C. Dorronsoro, R. G. Anera, M.J. Gonzalez, L. Llorente and S. Marcos. Instituto de Óptica, CSIC. Madrid. Spain. Departamento de Óptica. Universidad de Granada. Granada. Spain. Instituto Universitario de Oftalmobiología Aplicada. Universidad de Valladolid. Valladolid. Spain. ..... [**OAO6**]

Session 6

Wavefront-sensing techniques

Chair: **M.C.W. Campbell.**
Guelph-Waterloo Physics Institute and School of Optometry.

11:45 ***Point diffraction interferometer for characterization of soft contact lenses***. E. Acosta, S. Chamadoira and R. Blendowske. Universidad de Santiago de Compostela. Santiago de Compostela. Spain. Fachochschule, Darmstadt. Germany. ..... [**WSO1**]

12:00 ***Robust zernike polynomial representation of ophthalmic surfaces***. D. R. Iskander. School of Optometry. Queensland University of Technology. Australia. . . . . [**WSO2**]

12:15 **Break.**

12:30 ***Influence of pupil sampling pattern and density on ocular wave aberration measurements***. L. Llorente, C. Dorronsoro, S.A. Burns and S. Marcos. Instituto de Óptica (CSIC). Madrid. Spain. . . . . [**WSO3**]

12:45 ***Design of a curvature-based wave-front sensor for the human eye***. Cristiano Torti and Luis Diaz-Santana. Applied Vision Research Centre. The Henry Wellcome Laboratories for Vision Sciences Centre. Department of Optometry and Visual Science. City University. London. UK. . . . . [**WSO4**]

13:00 ***Manufacture and testing of a calibration set for ocular aberrometers***. Pablo Rodríguez, Rafael Navarro, Justiniano Aporta, Justo Arines, Salvador Bará and Jorge Ares. Instituto de Óptica "Daza de Valdés", CSIC. Madrid. Spain. Departamento de Física Aplicada. Universidad de Zaragoza. Zaragoza. Spain. Área de Óptica. Universidad de Santiago de Compostela. Santoago de Compostela. Spain. . . . . [**WSO5**]

13:15 **Discussion sessions 5 and 6.** Discussants: David Williams and M.C.W Campbell.

13:30 **Lunch Break (Palacio de Congresos y Exposiciones).**

Session 7

Accommodation and presbiopia

Chair: **José R. Jiménez.**
Departamento de Óptica. Universidad de Granada.

15:00 **Invited Paper:** ***Accommodation in the aging eye***. W. Neil Charman. Department of Optometry and Neuroscience. Institute of Science and Technology (UMIST). University of Manchester. Manchester. UK. . . . . [**IP4**]

15:45 ***Assessment of accommodation and pseudoaccommodation using dynamic aberrometry***. N. Chateau, F. Harms, R. Legras, N. Lopez-Gil and J. Nguyen-Khoa. Imagine Eyes. Orsay. France. CNRS. laboratoire Aime Cotton. Orsay. France. Universidad Murcia. Grupo de Ciencias de la Vision. Murcia. Spain. Clinique de la Vision. Paris. France. . . . . [**APO1**]

16:00 ***Optical aberrations in current designs of progressive-power lenses***. Eloy A. Villegas and Pablo Artal. Lab. de Óptica. Universidad de Murcia. Murcia. Spain. . . . . [**APO2**]

16:15 ***Optimal design of axicons for presbyopia compensation***. Jorge Ares, Ramon Flores, Zbigniew Jaroszewicz and Salvador Bará. (1) Departamento de Física Aplicada. Universidade de Santiago de Compostela. Santiago de Compostela. Spain. Instituto de Óptica Aplicada (IOS). Varsovia. Poland. . . . . [**APO3**]

16:30 **Discussion and Business Meeting.**

16:50 **Coffee Break.**

Session 8

Poster Session

17:15 **Two-hours poster discussion session.**

Transverse chromatic aberration after corneal refractive surgery. R.G. Anera, J.R. Jiménez, L. Jiménez del Barco and E. Hita. Departamento de Óptica. Universidad de Granada. Granada. Spain. ..... [**P1**]

Chroma memory and age. V.J. Camps and J. Pérez-Carpinell. Depto. de Óptica. E.U.O. Universidad de Alicante. Alicante. Spain. Depto de Óptica. Universitat de Valencia. Burjassot. Spain. ..... [**P2**]

Imaging retinal disease with adaptive optics. J. Carroll, S. Choi, J. Wolfing, H. Hofer and David R. Williams. University of Rochester. Center for Visual Science. Rochester. NY. USA. ..... [**P3**]

Permissible lateral misalignments in corneal ablation for myopic eyes. J. A. Díaz, J. A. Martínez, R. G. Anera and J. R. Jiménez. Departamento de Óptica. Universidad de Granada. Granada. Spain. ..... [**P4**]

On the ability of retinoscopy to detect ocular aberrations. Walter D. Furlan, Maria Teresa Caballero, Amparo Pons, Genaro Saavedra and Manuel Martínez Corral. Departamento de Óptica. Universitat de Valencia. 4100–Burjassot. Spain. Departamento de Óptica. Universitat de Alicante. 03080–Alicante. Spain. ..... [**P5**]

Objective polarimetry for ophthalmologic diagnosis. José Jorge Gil Pérez. ICE Universidad de Zaragoza. Zaragoza. Spain. ..... [**P6**]

Determination of the optical axis of the cornea from its elevation topography. L. González, R. Navarro and J. L. Hdez-Matamoros. Instituto Nacional de Técnica Aeroespacial. Madrid. Spain. Instituto de Óptica Daza de Valdés. CSIC. Madrid. Spain. Clínica RealVisión. Madrid. Spain. ..... [**P7**]

Alterations of the corneal endothelium with the use of spherical hydrogel contact lenses. O. Holgado Navarro, J. Velasco Cabrera and F.J. Bermúdez Rodríguez. Depto. de Óptica. Ftad de Ciencias. Universidad de Granada. ..... [**P8**]

A hybrid lens to achromatise the human eye. M. Irlbauer, J. A. Díaz and J. A. Martínez. Departamento de Óptica. Universidad de Granada. Granada. Spain. ..... [**P9**]

Measurement and testing of visual acuity with MULTISPOT 250 Aberrometer. N. Iroshnikov, A. Larichev. Medical Physics Department. Faculty of physics., MSU. ..... [**P10**]

The influence of external effects on stereothreshold. Gunta Krumina, Ivars Lacis, Maris Ozolinsh. Department of Optometry and Vision science. University of Latvia. .. [**P11**]

Corneal asphericity after myopic correction with excimer lasers. A. Larichev, N. Iroshnikov, V. Maniahin, M. Yablokov and V. Sugrobov. Medical Physics Department. Faculty of Physics. MSU. S.N. Fyodorov Eye Microsurgery State Institution. ..... [**P12**]

- ***Ocular monochromatic aberration statistics in a large emmetropic population***. S. Plainis, I.M. Aslanides, D. Tsatsaronis and I.G. Pallikaris. VEIC School of Medicine. University of Crete. Heraklion. Greece. ..... [**P25**]

- ***Video processing based on reconfigurable logic for low vision aids***. F. Vargas-Martin, M.D. Peláez-Coca, E. Ros, J. Díaz and S. Mota. Dept. de Física. Universidad de Murcia. Murcia. Spain. Depto. de Arquitectura y Tecnología de Computadores. Universidad de Granada. Granada. Spain. ..... [**P26**]

- ***Effects of optic nerve section on growth and refraction of chick eyes raised under 12/12 and constant light***. T. Li and H. Howland. Neurobiology and Behavior. Cornell University. Ithaca, N.Y. USA. ..... [**P27**]

- ***Intraocular image design***. I. Lipshitz. The Lipshitz Eye Center. Tel Aviv. Israel. ... [**P28**]

20:30 **Meeting Dinner (Buses will leave from the Palacio de Congresos y Exposiciones).**

THURSDAY, 23ST

Session 9

Refractive surgery

Chair: **Susana Marcos.**
Instituto de Óptica, CSIC.

08:45 **Invited Paper:** ***The causes of higher order aberration with LASIK vs surface ablation***. Scott MacRae. Department of Ophthalmology, University of Rochester. Rochester. New York. USA. ..... [**IP5**]

09:30 ***Scattering decrease during wound healing post-lasik: role of myofibroblast***. Blanco-Mezquita J.T., Martínez-García M.C., Mar S. and Nájera S.. IOBA. University of Valladolid. Valladolid. Spain. Cell Biology Department. University of Valladolid. Spain. Optics & Physics Applied Department. University of Valladolid. Valladolid. Spain. ..... [**RSO1**]

09:45 ***A polarimetric method to evaluate changes in corneal biomechanics after refractive surgery***. Juan M. Bueno, Esther Berrio, José M. Marín and Pablo Artal. Laboratorio de Óptica. Universidad de Murcia. Murcia. Spain. ..... [**RSO2**]

10:00 ***Theoretical elastic response of the cornea to refractive surgery: risk factors for keratectasia***. Antonio Guirao. Departamento de Física., Universidad de Murcia. Murcia. Spain. ..... [**RSO3**]

10:15 ***Static and dynamic pupil decentrations in laser refractive surgery***. J. Porter, G. Yoon, S. MacRae, G. Pan, T. Tweitmeyer, I. G. Cox and D. R. Williams. Center for Visual Science. University of Rochester. Rochester, NY. USA. Department of Ophthalmology. University of Rochester. Rochester, NY. USA. Lens Eye Research. Bausch & Lomb. Rochester, NY. USA. ..... [**RSO4**]

10:30 **Coffee Break.**

11:00 ***Differences between real and expected corneal shape after aspherical corneal ablation***. J.R. Jiménez, C. Villa, R. Gutiérrez, R.G. Anera and L Jiménez del Barco. Departamento de Optica. Universidad de Granada. Spain. Clínica Novovision. Madrid. Spain. Departamento de Oftalmología. Universidad de Murcia. Spain. ..... [**RSO5**]

11:15 ***Customized eye model development to evaluate the visual quality evolution after LASIK surgery***. Dolores Ortiz, Jose M. Saiz, Fernando Moreno and Francisco González. Grupo de Óptica. Universidad de Cantabria. Santander. Spain. ..... [**RSO6**]

11:30 ***Comparison of the mesopic CSF after Lasik with standard and aspheric profile***. César Villa Collar, Ramón Gutiérrez Ortega, Antonio Uceda Montañés, José Ramón Jiménez Cuesta and Jesús Conejero Arroyo. Clínica Novovisión. Madrid. Spain. ..... [**RSO7**]

Session 10

Computer-Eye Models

Chair: **Henryk Kasprzak.**
Institute of Physics, Wroclaw University of Technology.

11:45 ***Eye modelisation through a diffractive hybrid technique.*** D. Mas, J. J. Miret, J. Pérez, C. Vázquez, C. Hernández and C. Illueca. Dept. Optica. Universidad de Alicante. Alicante. Spain. ..... [**CEO1**]

12:00 ***Prediction of optical aberrations by personalized eye models.*** Rafael Navarro, Luis González, José L. Hernández. Instituto de Óptica "Daza de Valdés". CSIC. Madrid. Spain. Depto. de Física Aplicada. Universidad de Zaragoza. Zaragoza. Spain. Instituto Nacional de Técnica Aeroespacial. INTA. Madrid. Spain. Clínica Realvisión. Madrid. Spain. ..... [**CEO2**]

12:15 ***Influence of IOP on the geometrical and biomechanical properties of the linear and nonlinear model of the eye globe-effect of the optical self-adjustment.*** M. Asejczyk-Widlicka, W. ródka and H. Kasprzak. Institute of Physics. Wroclaw University of Technology and Institute of Mechanical Engineering. Faculty Deformable Bodies Mechanics Division. Wroclaw University of Technology. Wroclaw. Poland..... [**CEO3**]

12:30 **Discussion sessions 9 and 10.** Discussants: Susana Marcos and Henryk Kasprzak.

12:45 **End of Meeting.**

Abstracts-Oral Sessions

High speed full-field optical coherence tomography (OCT) AIO1

Kate Grieve, Arnaud Dubois and Claude Boccara

✉ *Laboratoire d'Optique Physique, Ecole Suprieure de Physique et Chimie Industrielles, CNRS, France*

We have previously reported the use of a technique called full-field optical coherence tomography, using a white light source, for imaging of biological tissues including ex vivo ocular animal tissues, mouse and frog embryos, human oesophagus and plant cell-death studies. Here we present a new version of this full-field OCT system with rapid acquisition speed, offering for the first time the possibility of in vivo biological imaging. The instrument is based on the Linnik interferometer, i.e. with identical microscope objectives placed in each arm. The numerical aperture of the microscope objectives governs the transverse resolution; we achieve 0.9 microns. A Xenon arc source is employed giving an axial resolution of 1 micron. Sensitivity of 80 dB is achieved through oversampling. A quarter wave plate is placed in one ofthe interferometer arms in order to introduce a phase difference of $\lambda/2$ between the two arms. A glass plate of thickness equal to the quarter wave plate is included in the other arm to balance dispersion mismatch. The signal is sent to a polarising beam splitter where it is separated into its two phase opposed components to be captured simultaneously by a pair of CCD cameras. By calculating the difference of these two images we extract the interference signal from the background intensity. The acquisition speed is limited only by the minimum exposure time of the CCD cameras, in this case 5 ms. A full two-dimensional en face image is captured in this time period. Preliminary results of imaging in animal tissues will be presented.

Keywords: Interference microscopy, optical coherence tomography, medical and biomedical imaging.

Eccentric correction in subjects with large central visual field loss AIO2

Jörgen Gustafsson, Linda Lundström and Peter Unsbo

✉ *Certec, Division of Rehabilitation Engineering Research, Department of Design Sciences, Lund University, Sweden. Biomedical and X-ray Physics, Royal Institute of Technology, Stockholm, Sweden*

PURPOSE: Subjects with central visual field loss (CFL) have to rely on their remaining peripheral vision. In large angles, eccentric vision is limited by the poor image quality due to large optical aberrations and by the resolution capacity of the peripheral retina. The aim of this project is to improve the visual function in subjects with CFL by correcting the peripheral optics of the eye. METHOD: The eccentric optical errors have been measured with the PowerRefractor instrument and with a Hartmann-Shack wavefront sensor. To evaluate the visual improvement, psychophysical procedures for detection and resolution at high

and low contrasts have been used. RESULTS: As a first step, the lower order peripheral aberrations, corresponding to the eccentric refractive error, have been corrected and compared to the subject's earlier foveal correction. In practical use, the eccentric correction gave a subjective improvement of visual performance in nine out of twelve selected subjects with large CFL. CONCLUSIONS: Correction of the large off-axis optical errors can improve eccentric vision in subjects with CFL. It is often difficult to find the best eccentric correction due to the large aberrations and the poor fixation. However, wavefront sensing is a fast and easy method for eccentric refraction. The wavefront data can also be used to better understand the large individual variations in peripheral vision.

Keywords: central visual field loss (CFL), peripheral vision, aberrations, eccentric correction, Hartmann-Shack wavefront sensor.

AIO3 Simulating vision with adaptive optics using a LC-SLM

Silvestre Manzanera, Pedro M. Prieto, Enrique J. Fernández and Pablo Artal

✉ *Laboratorio de Optica, Universidad de Murcia*

By means of adaptive optics we are able to control the wavefront aberrations in real-time. This can be used in vision research in two applications: to obtain high-resolution images of the retina and to induce aberrations patterns of any kind in the eye to simulate vision. There are two main types of devices to modify the wavefront: deformable mirrors and liquid crystal spatial light modulators (LC-SLM). We were interested in a device of the last type: the X7550 from Hamamatsu, optically addressed trough a standard XGA output. We built an adaptive optics prototype specially designed to be used in vision research with this device. The system consists of three channels: a real time Hartmann-Shack sensor to measure the eye's aberrations, the LC-SLM to control the wavefront shape, and a channel allowing subjects to perform visual tasks through the adaptive optics system. We calibrated and tested the device, including temporal response, aberration generation and correction (first in artificial eye, and then in different living eyes). This modulator has advantages in terms of high spatial resolution, high effective stroke (by means of phase wrapping) and mode independence allowing production and compensation of a larger range of aberrations than with other correcting devices. However, there are some drawbacks for particular applications, mainly the low temporal response and the diffraction effects. Examples of the performance of the system and a discussion of its limitations and potential for performing visual optics experiments will be presented.

Keywords: eye SLM adaptive optics.

Comparison of a red and green laser in adaptive optics imaging of parafoveal capillaries and leukocyte movement AIO4

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PURPOSE: The recent application of adaptive optics in a scanning laser ophthalmoscope (AOSLO) with a red wavelength laser has made long-term imaging of parafoveal capillaries and leukocyte movement possible without contrast dyes. However, the use of red light for imaging capillaries and bloodflow is not optimal since the absorption of hemoglobin is over an order of magnitude lower for red vs. green light. Using an AOSLO, we investigated the benefits of applying a green versus red wavelength laser in imaging retinal parafoveal capillaries and leukocyte movement. METHODS: Three normal subjects, 26-36 years, were dilated and imaged using an AOSLO. Imaging wavelengths of 660 nm and 532 nm with a frame rate of 30 Hz and 1.4x1.5 deg. field of view were used in each imaging session that lasted 1.5 hours. The subject's parafoveal capillaries were imaged in their best focal plane with both wavelengths and equal retinal light exposure levels. Varying diameter capillaries were selected from the same retinal location per red and green wavelength for Michelson contrast calculations. RESULTS: Equal Michelson contrast measurements were found with red and green wavelength for larger diameter capillaries. Smaller diameter capillaries had a contrast gain that ranged from 34-137% with the green vs. red wavelength. CONCLUSIONS: There is an improvement in contrast when imaging the smallest diameter parafoveal capillaries with a 532nm vs. 660nm laser in the AOSLO. The green wavelength laser should be useful in further studies of retinal parafoveal capillaries and leukocyte movement.

Keywords: adaptive optics;retinal imaging, blood flow.

Imaging the retinal photoreceptor mosaic with directional light AIO5

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The retinal photoreceptors have long been known to be sensitive to the direction of the incoming light. This sensitivity manifests itself in the Stiles-Crawford effect, i.e., a reduced visibility of rays that are incident off axis on the eye, and the related Optical Stiles-Crawford effect that produce a peak of the reflected light intensity in the plane of the pupil. We have recently explored this effect to obtain high-resolution images of the mosaic of cone photoreceptors away from the foveal centre. In this contribution, we present and discuss results on imaging of the photoreceptor mosaic with directional light, and we compare the outcome of experiments with numerical simulations.

Keywords: Retinal imaging, photoreceptors, Optical Stiles-Crawford effect.

AIO6 Deconvolution of retinal images

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Scanning Laser Ophthalmoscopes (SLO) can provide high resolution images of the retina, but limited by the eye's wave-aberration. Among the techniques that can be used to improve the image quality of an SLO, adaptive optics (AO) has been found highly suited, although involved more experimental complexity and higher costs. As an alternative or complement to AO, we investigate here the possibilities of using image deconvolution. We recorded retinal images with our own research SLO subtending 1 to 5 degrees with pixel size of 256x256 at 30 Hz frame rate and 512x512 at 15 Hz respectively. After assessing the image formation process, and in order to use standard deconvolution techniques, we assume that the image formation process is linear and incoherent. Two algorithms were implemented: a one-step method and an iterative method. Since it is difficult to measure the Point Spread Function with enough accuracy, both algorithms are 'blind', i.e., they restore both image and PSF. We found that standard deconvolution methods can be applied successfully to improve image quality. The main limiting factors are the low signal-to-noise ratio and random eye motions.

Keywords: retinal imaging.

OSO1 Impact of ocular scattering on visual performance

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Beyond aberrations, scattered light is another factor that produces a reduction on visual performance. The contribution of intra-ocular scattering is low in normal young eyes but increases significantly with age and, perhaps, after some types of refractive surgery. However, there is not a simple way to evaluate the impact of ocular scattering increase on the visual performance in vivo (separately from the effects of aberrations). An indirect approach is proposed here. We used the degree of polarization (DOP) as a parameter to objectively estimate the contribution of the ocular scattering (Bueno et al., J. Opt. Soc. Am. A, 21, 2004). On the other hand, we used a thin plate of a polymer dispersed liquid crystal (PDLC) material to induce controlled amounts of light scattering without altering ocular aberrations. The behaviour of the PDLC plate was first tested in an artificial eye. In a group of normal young subjects, with moderate to low aberrations, we measured the DOP and visual acuity for the naked eye and for the eye plus the PDLC plate, for different scattering levels. This approach allowed us to measure the effect of scattering on visual performance, while keeping constant ocular aberrations.

Keywords: ocular scattering, depolarization, visual performance, aberrations.

Estimation of corneal scattering by analysis of tscherning aberrometer images OSO2

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PURPOSE: Corneal scattering is assumed to be a consideral drawback of refractive surgery. At present, only subjective methods are available to estimate haze development. The purpose of this study is to get a quantitive relation between corneal scattering and the broadening of peaks in Tscherning images after refractive surgery. METHODS: Images of the Wavelight aberrometer were analysed. They can be seen as the result of a double pass experiment in which light gets scattered twice at the corneal plane, once localised (way-in) and once non-localised (way-out). This scattering causes broadening of the incoming laser profile. The spot profiles were measured before refractive surgery, 1 day, 2 days and 1 week after surgery. In the scattering model, only anomalous scattering is taken into account due to the similar optical properties of the keratocyte's nuclei. Analysis was performed in Matlab. RESULTS: Eyes have been examined before Lasik, one day post-op, 2 days post-op and one week post-op. All spots of the Tscherning images have been compared. All spots tend to be most broad one day after surgery, and tend to go back to the pre-op profile one week after refractive surgery. CONCLUSIONS: In this study we investigated the peak broadening of tscherning images of eyes following refractive surgery. This study suspects that a more profound study of more eyes, in correlation with confocal microscopy can result in an objective quantification of small angle scattering after refractive surgery.

Keywords: corneal scattering, keratocytes, LASIK.

Colour stimuli perception in adverse viewing conditions OSO3

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We report on vision perception in adverse viewing conditions of stimuli with varying colour and luminance contrast considering: the difference of different colour stimuli transfer through light scattering environment (and in case of eye pathologies also in the eye); variance in retinal images blur and contrast; and physiological variation in structure and distribution density of three retinal S, M and L cone photoreceptor systems. Parallel to the basic knowledge the topic is of great interest in applied vision research, particularly for safe driving in adverse weather, in mesoscopic conditions, presence of glare etc. We have measured visual acuity using greyscale and different colour contrast Landolt-C optotypes exposed on computer screen. Experiments were performed indoors simulating artificial cataract (likely similar also to foggy weather conditions) with special PDLC polymer dispersed liquid crystal eye occluders. Applying alternate low

voltage to the occluder allowed to obtain simultaneous changes of light scattering and diminishing of visibility. Other measurements were carried out in artificial fog chamber producing different fog conditions within 6-10 m viewing distance. Besides mentioned before the contrast sensitivity for colour contrast (in L*a*b* coordinates) Gabor gratings was investigated for white(grey)-red white-green, white-red comparing with same brightness achromatic gratings. Applying of white-yellow stimuli allowed to change the stimuli blue channel content (subtracting the blue primary within the yellow details) most scattered in fog. The highest degree of diminishing of colour contrast stimuli perception due to induced light scattering was detected for white-yellow (subtraction of blue) Landolt-C and Gabor gratings and white-green information stimuli.

Keywords: colour vision, adverse conditions, fog, scattering, glare, cataract.

OSO4 A clinical instrument to measure intraocular scattering

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A commercially available device (OQASTM, Visiometrics S.L.) based on the double pass technique has recently been developed. Although this instrument is quite useful to estimate the retinal image quality, the effect of the intraocular scattering cannot be quantified. Since depolarization is a useful parameter to characterize the level of scattered light (Bueno et al., J. Opt. Soc. Am. A, 21, 2004), we incorporated a polarimeter in the OQAS instrument to objectively measure the amount of scattering. This includes a fixed linear polarizer in the incoming pathway and an analyzer unit composed of a rotatory quarter-wave plate and another fixed linear polarizer in the recording stage. The modified OQAS system permits the use in clinical environments. We have performed a set of preliminary measurements in a group of normal young eyes (used as control), a group of normal older eyes and in patients after LASIK refractive surgery.

Keywords: Double pass, retinal image quality, intraocular scattering, depolarization.

AMO1 Monochromatic aberrations and changes in eye size in growing and myopic chick eyes

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Emmetropization is the normal process of eye growth to produce a clear in-focus image; refractive error variability decreases and the mean moves from hyperopia (farsightedness) towards an accurate focus on the retina. We have shown

that for a constant pupil size, aberrations in the growing chick eye decrease exponentially with age over a period of 14 days from hatching. Through optical modelling, we show that an exponential decrease in aberrations is consistent with scaling of the optics of the eye. Chickens, a common myopia model, emmetropize to compensate for -15D lenses, predominately through axial growth. We show that the decrease in aberrations observed during normal growth is interrupted by myopia induced by negative lenses. This suggests that the normal decrease in aberrations, like the decrease in refractive error, is an active emmetropization process. Thus, the fine structure of the optics of the chick eye is influenced by visual experience. We show that the time course of aberration changes is not the same as that of refractive error change in lens-induced myopia. Understanding the mechanisms which control emmetropization may lead to prevention of myopia (nearsightedness), a leading cause of blindness in the world today.

Keywords: emmetropization, lens-induced myopia, monochromatic aberrations, chick model.

Longitudinal changes of ocular aberrations during development in normal and myopic chick eyes

AMO1

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PURPOSE: The chick is a well-known myopia model, where degraded retinal image-quality causes ocular elongation. Our purpose was to 1) describe longitudinal changes of aberrations in normal and myopic chick eyes, 2) compare optical quality in emetropic and myopic eyes 3) investigate interactions between myopia and aberrations. METHODS: Seven White-Leghorn one-day old chicks were occluded monolaterally with diffusers for two weeks. Aberrations, refraction and axial-length were measured in occluded and contralateral eyes of awake chicks, prior to treatment (day 0) and on days 1, 4, 6, 8, 11,13. Aberrations were measured with a custom-built Hartmann-Shack; refraction with retinoscopy; and axial-length with adapted ultrasound biometry. RESULTS: Occluded eyes developed axial myopia (on average 17.43 D higher, and 1.13 mm longer than the untreated eye). All eyes were hyperopic on day-0, and myopia increased at 0.2 ± 0.09D/day and 0.05 ± 0.03mm/day (untreated eye) and 1.50 ± 0.2D/day and 0.12 ± 0.02mm/day (occluded eye). Pupil size increased with age (from 2.01 to 2.6mm), although differences untreated/occluded were significant (p=0.006) at day-13. Average RMS (excluding defocus, and for actual pupil diameters) decreased from 0.44 ± 0.14 at day-0 to 0.24 ± 0.1 microns (day-13), and from 0.6 ± 0.3 to 0.34 ± 0.14 microns, for untreated/occluded eyes. Spherical aberration was 0 in untreated eyes, and significantly <0 during days 4-11 in occluded eyes. Average ratio (across chicks and days) RMS(occluded)/RMS(untreated) During the treat-

ment period was 1.42. Differences between untreated/occluded eyes decreased by day-13. Strehl(untreated)/Strehl(occluded)=1.17 (diameter=2.5mm) at day-13. CONCLUSIONS: 1) Aberrations tended to decrease with age in both untreated/occluded eyes. 2) Myopic eyes tended to be more aberrated than untreated eyes (not significant at day-13), but their contribution to image-degradation was minimal compared to defocus. 3) In this model, aberrations seem to be an effect rather than cause of axial-elongation.

Keywords: emetropization, experimental myopia, refractive error, axial elongation, aberrations, optical quality.

AMO3 A battery of optical tests to measure visual function and myopia in alert mice

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The mouse is becoming an important model to study the genetic and environmental influences on refractive development, because its genome has been extensively studied, many genetic knock-out models are available and because it can be easily bred. However, its eyes are small (about 3 mm axial length), their optical quality is not very good and spatial acuity is not very high. Still, we and others have found that visual experience has significant effects on refractive development also in mice. To study myopia and visual function, we have established a battery of new techniques. Automated infrared photorefraction was adapted for mice and can resolve refractive changes of 2-3 diopters. Optical low coherence interferometry is used to measure ocular dimensions with a with a standard deviation of only about $15\mu m$. Visual acuity is determined in unrestrained mice by a self-programmed video tracking technique, in which both angular speed and body orientation of mice are tracked in an optomotor task. It gave a grating acuity of the mice of about 0.5 cyc/deg, with reduced acuity when the ambient illuminance declines. Retinal function is determined by automated pupillography. In this technique, the mouse is slightly restrained by grabbing its neck, while a green LED attached to the video camera of the photorefractor is flashed with adjustable intensity and duration. Pupil size, refraction and stimulus trace are all recorded to a file. Using these techniques, it is possible to study the effects of defined knock-out of genes on myopia development and to determine the effects of pharmacological intervention on both myopia development and retinal function.

Keywords: myopia, mouse, interferometry, pupillography, grating acuity, photorefraction.

CIO1 Refractive power of the whole crystalline lens for a GRIN model

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Gradient-index (GRIN) models of human lens have received wide attention in optometry and vision sciences for considering the effect of inhomogeneity of

the refractive index on the optical properties of the crystalline lens. Within the framework of the continuous asymmetric bi-elliptical model , we present analytical expresion for the refractive power of the crystalline lens of the human eye with a transverse parabolic refractive index distribution in sagital section modulated by a longitudinal refractive index along the z optical axis containing up to 6th order in z. The refractive power of the lens as a whole has three components: two surface power components and a power that is due to the gradient in the refractive index. GRIN power is characterized by the axial and field rays, two linearly independent solutions of the paraxial ray equation, that they describe the light propagation in the crystalline lens. Dependence of the refractive power of the whole lens on the thickness and equatorial radius is shown.

Keywords: Crystalline lens, GRIN model, GRIN optics.

A purkinje imaging system for phakometry and for lens tilt and decentration measurements: development, validation, and test on crystalline and intraocular lenses

CIO2

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PURPOSE : 1) To develop a compact, fast and reliable system to measure radii of curvature, tilts and decentrations of crystalline and intraocular lenses in vivo, based on recordings of Purkinje images I, III and IV. 2) To validate the technique. 3) To obtain measurements in normal eyes and patients with IOLs. METHOD: The system has two illuminating channels (890-nm LEDs); an imaging channel with an IR-enhanced CCD with a telecentric lens; and a fixation channel with a Badal system. The heights of double PIII and PIV relative to PI were used to estimate lens radii of curvature, using both equivalent mirror and iterative methods. Lens tilt and decentration were estimated assuming linear relationships between the positions of PI, PIII, PIV and eye rotation, lens tilt and decentration. The procedures and assumptions were tested using eye models in Zemax, and nominal IOL parameters. Keratometry, and anterior-chamber-depth were also measured. We tested 10 normal eyes (age:29.62.3), and 9 eyes with IOLs (age:75.4 3). RESULTS: The iterative method provided better phakometry estimates than the equivalent mirror (by 4%). Computer models using radii, tilt and decentration estimates, and ACD reproduced the Purkinje experimental locations within 0.04 mm. We measured anterior and posterior crystalline lens radii ranging from 8.11-11.41 and -6.82-5.29 mm, respectively, tilts of 2.51-+4.3 horizontally, -6.17-4.78 deg vertically, and decentrations of -0.14-0.1 horizontally, 0.01-0.17 mm vertically. IOL tilts were -9.03-+7.59 horizontally-10.35-+9.68 deg vertically, and decentrations -0.75-+0.34 horizontally, -0.26-+0.82mm vertically.

Keywords: crystalline lens, intraocular lens, optical biometry, curvature, tilt, decentration, cataract surgery.

CIO3 The optical structure of the crystalline lens and its aberrations

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There is much interest in correcting the aberrations of the eye by changing the shape of the anterior corneal surface. However, ocular aberrations also arise at the crystalline lens and there is evidence that the level of crystalline lens aberration is about the same at that of the cornea. At least for "spherical aberration" the cornea has positive aberration and lens has an almost equal amount of negative aberration, so the aberrations are finally balanced. Since the lenticular aberration changes with accommodation, becoming more negative with accommodation, a modified eye with aberration free distance vision will have more negative aberration when accommodating and therefore reduced retinal image quality. Furthermore, the ocular (spherical) aberration also changes with age, becoming more positive, which is probably due to the aberration of the lens becoming less negative. So the long-term advantage of correcting ocular aberrations may be limited. Therefore to fully understand the wider advantages and disadvantages of correcting ocular aberrations by corneal surgery, we need to know more about the aberration properties of the lens and how they change with accommodation and age. At the moment, we do not accurately know the structure of the lens, but using data available to date from various sources (e.g. magnetic resonance imaging), models of the lens have been constructed to examine the shape and gradient refractive index structure and standard aberration theory used to examine the levels of the various aberrations and the component parts (surface and bulk gradient index contributions) and finally predict the expected retinal image quality of the whole eye.

Keywords: aberrations, crystalline lens, retinal image quality.

CIO4 Effect of misalignments in IOLs correcting spherical aberration

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A new generation of intraocular lenses (IOLs), Tecnis Z9000, is designed to correct the corneal spherical aberration. A potential problem of these new IOLs could be the effects of the misalignments. We performed an study to determine the impact of misalignments in these lenses compared with the conventional IOLs. We measured corneal and ocular aberrations with a corneal topographer and with our own built Hartmann-Shack wavefront sensor in seven eyes implanted with two types of IOL. Also we used a new instrument we developed, based on the recording of Purkinje images, to estimate ocular misalignments (IOL tilt and decentration and ocular angle (kappa) in these seven eyes. A computer modelling useful to study the effects of misalignments was performed for each eye using the experimental data. Results showed that eyes implanted with

the correcting IOL had very little spherical aberration while those implanted with the conventional one did showed a much more important amount of this defect. Predictions from the computer model were well correlated with the measurements. The correcting IOLs are more sensitive to decentrations than the conventional ones, but there is still a range of decentrations in which it gives a better image quality than the non correcting lens. Our mean range of measured decentrations (0.5 Nasal to 0.2 Temporal and 0.5 Inferior to 0.3 Superior (mm)) were within the improvement range. This supports the benefit of correcting corneal spherical aberration with intraocular lenses.

Keywords: refractive surgery, phakic IOL, optical properties, cataract.

Visual axial PSF of diffractive multifocal lens CIO5

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During the past few years, a number of diffractive multifocal lenses have been proposed for ophthalmic applications. The analysis of visual system performance is often made by means of the transverse point spread function (PSF) or the modulated transfer function. Any of these functions completely characterizes the transverse ocular system behaviour. In the case of multifocal lenses the axial behaviour of the eye should also be taken into account. Both the transverse and the axial PSF can be obtained from the ocular wave aberration function. We have calculated the axial PSFs of real eyes from experimental data of the ocular wave aberration function measured with a Hartmann-Shack wavefront sensor. Then, we have simulated the optical performance of the real eyes with diffractive multifocal lenses. This simulation can be useful for the design and analysis of both diffractive multifocal contact lenses and diffractive multifocal intraocular lenses.

Keywords: multifocal lenses, contact lenses, intraocular lenses, presbyopia, ocular aberrations.

Experimental limitations to the tomographic retrieval of the gradient index of a crystalline lens CIO6

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In a series of previous works we have presented a new tomographic algorithm for the retrieval of the refractive index distribution in optical structures such as crystalline lenses. Firstly, the research has been focused on the fish lenses due to the simplicity of its spherical symmetry. Once tested the performance of the tomographic algorithm under this condition we have considered more generalized symmetries, such as the one of the mammalian lenses. In this case the gradient index can be assumed to be rotationally symmetric around the optical

axis but not along itself. Some initial results of the algorithm for this case have been already presented, using as a model the gradient index put forward by Gullstrand for the unaccommodated lens. Those results, based upon numerical simulations, have shown an accuracy in the fourth decimal digit of the gradient index but without taking into account any experimental error. The aim of the work here presented is to show a thorough study of the influence of the experimental errors on the retrieval of the gradient index of a lens using our tomographic algorithm. Several models of errors as well as their dependence on the used experimental technique are considered. Likewise, different approximations to how to tackle their effects and a realistic forecast of the accuracy of the retrieval are discussed, considering both the in vivo and in vitro possibilities.

Keywords: eye lens, gradient index measurement, tomography.

OAO1 Distribution of critical pupil diameter and depth-of-focus in an emmetropic population

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PURPOSE: Ocular monochromatic aberrations were measured in a large emmetropic population. We calculated the critical pupil diameter and we simulated the corresponding subjective depth of focus taking into account measured aberrations up to the sixth order. METHODS: A population of 393 healthy eyes of 218 nearly emmetropic subjects was tested. Total refractive error ranged between +0.50 and -1.25D (mean: -0.25 ± 0.47D), with the astigmatism being less than 0.75D. Uncorrected decimal VA ranged between 1.80 and 0.72 (mean: 1.12). Monochromatic wavefront aberration was obtained under natural pupil conditions using the Allegreto WaveFront Analyzer (WaveLight Laser Technologies, Erlangen, Germany). Wavefront aberration data were expanded to Zernike polynomials up to the 6th order. Off–line analysis was performed using MATLAB programs. The effect of higher order aberrations on retinal image quality was assessed using a number of image metrics (eg PSF, MTF). Stiles-Crawford effect was also accounted. RESULTS: Retinal image quality for each subject was evaluated as a function of pupil diameter. Critical pupil diameter was calculated as the largest pupil for which each eye can be considered diffraction-limited. Distribution of critical pupil diameter in our population was plotted. Moreover, the depth-of-field of the eye at natural daylight conditions is presented. CONCLUSIONS: The numerical values for depth-of-focus are derived by simulation and obviously depend upon the suitability of employed criterion. Although eyes with large amounts of aberrations were not enrolled in this study, the practical depth of focus is determined by the refractive error. As expected, the critical pupil diameter is generally smaller than the actual pupil diameter. For a small number of subjects however, the actual pupil diameter can be smaller than the critical under bright conditions.

Keywords: depth of focus, critical pupil diameter.

Dynamical changes of corneal topography and its influence on psf of the eye

OAO2

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Series of in vivo interferograms of the corneal surface with distinct astigmatism, registered each 40ms, using a Twyman-Green interferometer were used in analysis. Analysis of these interferograms indicates the shape of the living cornea and its changes in time. The resultant shapes were approximated with a set of 36 Zernike polynomials. The point spread function (PSF) of a refractive surface having the shape of each cornea was calculated. The results show that the PSF of the real cornea is dramatically small compared to the aberration free PSF. In spite of these aberrations, the acuity of vision of investigated patient was still high. Zernike analysis of variable in time corneal shape, shows that terms responsible for astigmatism are almost temporally steady, as might have been expected. However, the most varying terms are those responsible for trefoil and coma. Although the changes in corneal topography are relatively large, they do not have a significant influence on the PSF. Only small variations in PSF can be seen.

Keywords: gradient index, eye, eye schematic model, Point Spread Function, aberrations.

Temporal changes in optical quality of air-tear film interface at anterior cornea after blink

OAO3

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PURPOSE: The purpose of this study was to examine the temporal changes in the optical quality of the air-tear film interface at the anterior cornea following a blink. METHODS: Corneal aberrations were determined in 15 healthy subjects at 1 second time intervals after a blink, up to a total elapsed time of 15 seconds. Corneal aberrations were obtained from corneal elevation maps measured using a Tomey TMS-2N topographer and custom software. All data were decomposed using Zernike polynomials to yield the root mean square (RMS) wavefront deviations, in micrometers, for two pupil diameters (3 and 7-mm). RESULTS: Total wavefront aberration decreased slightly with time in the first few seconds after a blink for both pupil diameters, reaching a minimum after about 6 seconds. Thereafter aberrations increased steadily, exceeding the immediate post-blink level after about 10 seconds. CONCLUSIONS: In normal subjects, the contribution of the anterior cornea to the overall ocular aberration remains reasonably stable over the normal inter-blink interval (about 4 seconds) but rises to levels which could perceptibly degrade retinal image quality under circumstances

where the inter-blink interval is increased to exceed 10 seconds, as may occur during the use of visual display screens or when performing difficult tasks.

Keywords: air-tear film, eye aberrations.

OAO4 Compensation of corneal aberrations by the internal optics is better in eyes with a larger angle kappa

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Internal optics partially compensates for the corneal aberrations in young eyes. We explored the nature of this aberration compensation in a population of young eyes with myopia (n=57) and hyperopia (n=16), ranging from -8 to +7 D. We measured both ocular and corneal wave-front aberrations for a 6 mm pupil: the ocular aberrations using our own developed Hartmann-Shack wave-front sensor, and the corneal aberrations by ray–tracing from the elevation maps provided by a corneal topographer. The internal aberrations were obtained by subtracting the corneal from the ocular values. Both refractive groups showed a similar amount of ocular aberrations. However, the Compensation Factor (1-(RMSe/RMSc)) was higher in the hyperopic group (0.51) than in the myopic group (0.22), mainly due to a better compensation of the corneal lateral coma by the internal media. The higher compensation of the corneal lateral coma was well correlated with the distance from the corneal vertex to the pupil center. This distance was higher in the hyperopic eyes, because of larger angle κ. Tilted optical surfaces in the eye do not appear to produce a reduction of the overall ocular image quality. These results support a simple passive mechanism for the compensation of the aberrations.

Keywords: optics aberrations, angle–kappa.

OAO5 Dynamics of ocular aberrations: a theoretical model

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In this paper a model that simulates ocular aberration dynamics by incorporating tear film fluctuations is presented. The mechanics of he model show that the variability of ocular aberrations is a on-deterministic process driven mainly by fluctuations in the tear film. The model represents well experimental data and predicts that changes in tear film viscosity or an increase in tear film evaporation rate would alter the observed dynamics of ocular aberrations. It explains and predicts the statistical behavior observed in ocular aberration dynamics and also shows that outside crtain natural boundaries like viscosity and evaporation rate imposed by the tear film itself the wavefront RMS would tend to increase continuously with time. In contrast, when within those boundaries a self-regulatory mechanism tends to preserve the wavefront RMS. Additionally we show that the dynamics of ocular aberrations show evidence of self-organized criticality.

Keywords: aberrations, dynamics, tear-film, model.

Development of an experimental model on artificial corneas for the study of adaptation and optical quality of contact lenses OAO6

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PURPOSE: We developed an experimental model to study the optical properties of soft contact-lenses. Knowledge of the coupling between the optics of the eye and of the contact-lens, and how the lens flexes to conform the Cornea is essential to understand fitting of multifocal lenses, and why they do not work successfully in many patients. METHODS: Artificial eyes were manufactured on PMMA cylinders. The cornea was a polished spherical surface, and the retina was located in the corneal focal plane. Total and anterior surface aberrations were measured on naked artificial eyes and fitted with a monofocal soft contact-lens (-3.5D). Laser Ray Tracing and videkeratography were adapted to allow measurements in the vertical direction. A special holder was used to provide good centration and hydration of the lens, and uniform tear surface. A slight defocus was introduced in the videoketographer to avoid a secondary reflection appearing with the contact-lens. RESULTS: Consistent and repetitive corneal and total aberration measurements were possible on the artificial eye, with and without contact-lens. Control experiments without contact-lens show that neither the tear layer nor defocus of the the videokeratographer images affect corneal spherical aberration (-0.45, -0.46 and -0.47 microns respectively). Also, corneal is similar to total spherical aberration (-0.48 microns). Anterior surface spherical aberration decreases with the contact-lens on (-0.32 microns), indicating that the lens does not flex completely to the underlying cornea. Total spherical aberration with the contact-lens on decreases spherical aberration further (-0.09mm), suggesting a compensating effect of the tear lens. CONCLUSIONS: A new experimental model for the study of soft contact-lenses, based on aberrometry, has been developed which can be used to evaluate a priori the suitability of different lens designs to a patient's eye.

Keywords: contact lens, aberrations, optical quality.

Point diffraction interferometer for characterization of soft contact lenses WSO1

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In this work we will demonstrate the feasibility of a point diffraction interferometer (PDI) for comprehensive inspection and analysis of soft contact lenses

(spheric, toric and aspheric) providing information on the form and on aberrations as well. Oblique astigmatism can be easily induced and measured. The interferometer is easy to set up and has a wide dynamic range. It is very robust and not sensitive to vibrations. We measure soft contact lenses in saline but the procedure can be adapted to hard lenses to be measured in air. The setup may be transferred to other optical components as well.

Keywords: contact lens, interferometric testing, point diffraction interferometer, aberrations.

WSO2 Robust zernike polynomial representation of ophthalmic surfaces

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PURPOSE: The number of Zernike terms needed to accurately represent an ophthalmic surface is often disputed and arbitrarily chosen. The higher-the-order-the-better-the-fit approach does not consider the error associated with measurement, especially that of corneal elevation. In the era of customised refractive correction care is needed when modelling ophthalmic surfaces so the final corrective result is adequate. METHODS: Recently reported bootstrap methods have been viewed with some caution due to suspected tendency of underestimating the model order. We also found that they are not sufficiently robust and require huge amount of computations to lead sensible results. Classical model estimation techniques such as the Akaike Information Criterion or Minimum Distance Length greatly overestimate the model order. Thus, a new conditional model order estimator (CME) based on the theory of sufficient statistic has been used. Corneal elevation data from several videokeratoscopes was used. Noise of up to 0.5 microns was added to achieve simulated annealing. Data included normal corneas, keratoconics and post-LASIK corneas. RESULTS: CME is the most robust estimator of the Zernike model order. The estimated model order varied with corneal diameter. For normal corneas it ranged between 6 and 7 (28 to 36 terms). It was greater for irregular corneas and reached 14 (118 terms) for severe keratoconus for an 8 mm corneal diameter. CONCLUSIONS: CME is a simple and computationally inexpensive method of finding optimal number of Zernike terms for ophthalmic surface representation. The performance of CME is much more robust to the methods previously used in model order estimation.

Keywords: zernike polynomials, surface and wavefront modelling.

WSO1 Influence of pupil sampling pattern and density on ocular wave aberration measurements

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PURPOSE: To compare wave aberrations obtained using different sampling patterns and densities on the same eyes (artificial and human) in a configurable

wavefront sensor, and to assess the most appropriate sampling for measuring ocular aberrations. METHODS: We used a laser-ray-tracing system programmed with different sampling pattern configurations (hexagonal, rectangular and circular) and densities (19, 37, 49, 91 & 177 spots on a 6-mm pupil) on three artificial and two human eyes.Wave aberrations were fit by 7th-order Zernike polynomials. Differences across patterns were assessed by the RMS of the difference maps across sampling patterns, in both artificial and real eyes. Hexagonal-91 pattern was used as a reference. In real eyes probability maps were obtained by computing local p-values for repeated wave aberration estimates across different sampling patterns. The percentage of the significantly different regions within each wave aberration map was obtained for each sampling configuration. RESULTS: The standard-deviation (averaged across Zernike coefficients) across sampling patterns was <0.03mm in artificial eyes and <0.07mm in real eyes. The RMS standard-deviation was <0.07 mm and <0.1 mm respectively, and was reduced when the 19-sample patterns were excluded. The RMS difference across different samplings tended to be within RMS difference across similar sampling patterns, except for the 19-sample and the Jacobi and Legendre patterns. The percentage of pupil areas showing statistical aberration differences in real eyes ranged from 0.6% to 16%, to 24 % when Jacobi and Legendre were included and up to 36% when 19-sample patterns were included. CONCLUSIONS: Patterns with very small number of samples failed at reproducing the wave aberration. Sample distribution can be more relevant than sample density. Hexagonal-37 and Albrecht-49 show good compromise between reproducibility and sample efficiency.

Keywords: sampling, wavefront sensing, laser ray tracing, aberration.

Design of a curvature-based wave-front sensor for the human eye WSO4

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Curvature-based approaches to wave-front sensing offer distinct advantages to conventional Shack-Hartmann-based techniques - namely, increased flexibility in the sensor design and direct coupling to membrane and bimorph mirrors. A curvature sensor is being developed to explore alternative ways to optimize adaptive optics (AO) for the human eye. The design is based on the 'phase diversity'approach proposed in [1]. Both the geometry of the deformable mirror's actuators and the average characteristics of ocular aberrations will be taken into account during the sensor design. The latter will be determined through analysis of ocular wave-front data. It is expected that this sensor will help reduce error propagation in the control loop of an AO system by forming a bridge between the wave-front to be corrected and the device used to provide the correction. A preliminary curvature sensor has been constructed to investigate its ability to sense ocular wave-fronts. Accordingly, several diffraction gratings have

been produced as described in [1]. A pilot routine written in Matlab has been used to extract the defocused sub-images and calculate their intensity difference. A more robust algorithm is needed to more accurately detect the precise size and location of the sub-images in the presence of noise. The design of the sensor will be addressed in greater detail along with solutions to some of the problems mentioned above, results and recommendation for future work.[1] P.M. Blanchard, and A.H. Greenaway, 'Simultaneous multiplane imaging with a distorted diffraction grating,'Appl. Opt. 38, 6692-6699 (1999).

Keywords: wave-front sensor, curvature sensor, aberration, eye, diffraction, grating, Fresnel zone plate.

WSO5 Manufacture and testing of a calibration set for ocular aberrometers

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In the last decade there has been an extraordinary development of ocular aberrometry, with a variety of methods, Hartmann-Shack, Laser Ray Tracing, Tscherning, psychophysical, OPD scanner, which have given rise to many experimental and commercial devices. Different studies have shown that, when properly calibrated, aberrometers are highly reliable, even though the SNR they provide is modest. The correct calibration of aberrometers is essential in clinical applications, so that it should be an important part of the regular maintenance work of these devices. This has been typically made using an artificial eye adding trial lenses to introduce aberrations, but this method was restricted to second order aberrations. In order to calibrate the aberrometer response to higher order aberrations, here we present a set of phase plates, made by a grey-scale single-mask photosculpture in photoresist method. The set contains 3 subsets: (1) different pure modes to test the accuracy and linearity among different orders (from 3rd to 7th, about 0.3 - 0.4 microns); (2) plates having different amounts of the same mode, 3rd order coma ranging from 0.11 to 0.47 microns; and (3) a phase plate representing a real eye having a complex aberration pattern, including second order (RMS = 1.34 microns). Right after manufacturing the plates are tested using a Mach-Zehnder interferometer. Results obtained with two different types of aberrometers (H-S and LRT) are presented both showing a high linearity within the range covered by the calibration set.

Keywords: ocular aberrations, Hartmann-Shack, Laser Ray Tracing, phase plates.

Assessment of accommodation and pseudo-accommodation using dynamic aberrometry

APO1

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PURPOSE: Our purpose is to review several applications of ocular wavefront sensing, related to the accommodation function and to the correction of presbyopia. We illustrate these applications with experimental results from four clinical investigations. METHODS: All eyes under study were measured using an Imagine Eyes irx3 aberrometer with the following features : a) the displacements of an internal visual target can be programmed in order to stimulate accommodation at any distance; b) the wavefront range (20 ?m peak-to-valley) is large enough to measure the aberrations induced by presbyopic multifocal corrections : c) the device optically filters spurious reflections that originate from all interfaces in the eye, including intraocular implant surfaces. RESULTS: 1. Assessment of accommodation as a function of age : wavefront variations during accommodation stimulation showed significant changes with ageing, in particular for the spherical aberration. 2. Prediction of near addition : the objective addition calculated from aberrometer measurements was strongly correlated to the clinical subjective addition. 3. Investigation of intraocular implants : accurate measurements were possible despite higher levels of spurious reflected light. Monofocal, multifocal and new "accommodative" implants were evaluated. 4. Investigation of multifocal contact lenses : a specific algorithm could retrieve the on-eye position and power curve of progressive addition contact lenses. Calculations based on the wavefront measurements helped to predict visual performance at different distances. CONCLUSIONS: Dynamic aberrometry is a valuable technique to investigate accommodation and evaluate various presbyopic corrections modalities.

Keywords: accommodation, aberrometry.

Optical aberrations in current designs of progressive-power lenses

APO2

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Ophthalmic lenses with a progressive spherical power surface are a very common and suitable solution for compensating presbyopia. Peripheral astigmatism is the main problem of these lenses since their introduction in the 1950s. Nowadays, computer numerically controlled machines permit to fabricate designs of

progressive-power lenses (PPLs) with optimized astigmatism. However, the optical differences between the current designs have not been studied in detail yet. We have measured spatially resolved wave-front aberrations at relevant locations in three current PPLs with different designs using our own Hartmann-Shack wave-front sensor. In addition, we have also evaluated the effect of these aberrations on visual acuity. Although peripheral astigmatism is the main aberration in PPLs, small amounts of coma and trefoil are also present in all tested zones with a similar magnitude than in normal older eyes. Visual impact of the PPLs aberrations is small in the corridor and nearby zones. The overall amount of aberrations, calculated by adding values of each zone, is very similar in the three lenses, but their spatial distributions are different. Current designs of PPLs behave as a waterbed, where the aberrations can be moved but not reduced.

Keywords: progressive-power lenses, aberrations, Hartmann-Shack sensor, current designs, visual acuity.

APO3 Optimal design of axicons for presbyopia compensation

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Presbyopia is a physiological condition to which everybody arrives with the age. There are many different methods to compensate it but none of them is completely satisfactory to everybody. In a previous work we suggested the use of axicons to compensate presbyopia, as an extreme example of simultaneous vision element. Despite the fact that very promising results were obtained, it was also concluded that axicons, in its original form, are not suitable to provide the same quality of vision for all distances. Consequently further optimisation must be done. Starting from an phase axicon expressed as a linear combination of rotationally symmetric Zernike polynomials, in this work we have made use of optimisation techniques to design the optimal axicon profile for a particular presbyopic patient. Some retinal imaging simulations show that good vision quality (AV higher than 0.8) can be achieved with the designed elements for all distances. This good quality is obtained for equivalent additions lower or equal than 1 D, so they are suitable for young presbyopic people. Additionally, some new methods and rules are suggested to accomplish CAD (Computer Aided Design) searching solutions to compensate presbyopia in a more satisfactory way that the existent ones.

Keywords: presbyopia, axicons.

Scattering decrease during wound healing post-lasik: role of myofibroblast RSO1

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PURPOSE: Our aim was to study the corneal transparency during the wound healing process in a new animal model, the hen, after refractive surgery and to compare the most used techniques in nowdays, PRK and LASIK. METHODS: 25 adult hens were used divided into tree groups: 10 (20 eyes) were surgered with LASIK technique, 10 (20 eyes) with PRK and 5 (10 eyes) as a control. One month after surgery the animals were sacrificed under anesthesia and the corneas removed and carefully placed into a camera support, the transmittance and scattering was measure with and experimental device. The same corneas were fixed and included in suitable medium. After microscopy study, we used immunohistochemical techniques to demonstrated actin microfilaments. RESULTS: Transmittance and scattering measures shown significative differences between both techniques, Lasik similar than control and PRK very decrease transmittance. Lasik wound healing shown under microscopic examination a line with hipercelularity and PRK wound healing shown a strip hipercelularity. Most of these cells were actin positive and their morphology under electron microscopy shown intracitoplasmic condensations and stress fibers. CONCLUSIONS: We thought that in our results there are a direct relationship between transmittance and scattering and the number of cells. The majority of these cells are myofibroblast.

Keywords: refractive surgery, transmittance, scattering, myofibroblast.

A polarimetric method to evaluate changes in corneal biomechanics after refractive surgery RSO2

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Imaging polarimetry provides spatially resolved information on the polarization properties of an optical system. In particular, in the living human eye these are directly related to the biomechanical properties of the cornea, which could vary as a result of pathologies or surgery. We have used an aberro-polariscope, recently developed in our laboratory [Opt. Lett. 28, 1209 (2003)], to compare maps of polarization parameters obtained both in normal and post-LASIK eyes. The distribution of depolarization was not uniform across the pupil, with post-surgery eyes presenting larger levels of depolarization. The corneal retardation increases toward the edges of the pupil in normal eyes, however the pattern becomes irregular in eyes after LASIK refractive surgery. The maps of corneal slow axis also differ between both types of eyes, showing more locally noticeable

changes in the post-LASIK eyes. This type of instrument might be useful in a clinical environment to follow the biomechanical and optical changes of the cornea after refractive surgery or for the diagnosis of corneal pathologies.

Keywords: polarimetry, LASIK, depolarization, retardation, corneal axis.

RSO3 Theoretical elastic response of the cornea to refractive surgery: risk factors for keratectasia

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PURPOSE: To explore the role that pure mechanical elastic factors may have in post-refractive surgery corneal response, from mild curvature changes to keratectasia. METHODS: The central cornea near the apex was modelled as an elastic spherical thin shell loaded by the intraocular pressure (IOP). Equations for myopic LASIK were obtained to estimate shifts and curvature changes of the posterior corneal surface at the apex. The effect of every playing parameter was studied, identifying potential risk factors for ectasia. RESULTS: Theoretically, corneal thinning by ablation produces elastic deformation of the posterior surface that depends on the corneal parameters (curvature, Young's modulus, Poisson ratio, and thickness), the IOP, and the ablation profile. In particular, after myopic LASIK, we predict a forward shift and an increase in power of the posterior surface, in agreement with previous experimental findings. These changes rise non-linearly with the attempted correction, and are greater for thinner preoperative corneas, higher IOP, smaller Young's modulus, and thicker flaps. Corneas with Young's modulus half the average or less, or thickness less than 500 microns, may present high risk of ectasia, especially for high IOP and thick flaps. CONCLUSIONS: Some post-surgery phenomena may be explained in part by elasticity. Research efforts are needed to explain other biomechanical behaviours. The accepted criterion of 250 microns residual bed is insufficient for fine patient screening: it could be more restrictive depending on the individual ocular parameters. Technological advances are desirable to make possible a pre-surgery examination including 2-D maps of: topography, pachymetry and Young's modulus.

Keywords: refractive surgery, elastic model, keratectasia, corneal elastic response.

RSO4 Static and dynamic pupil decentrations in laser refractive surgery

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Static and dynamic pupil decentrations during laser ablations induce postoperative higher order aberrations. We measured the surgeon's accuracy in aligning

the pupil center with the laser center axis when engaging the eye-tracker in 17 eyes receiving conventional LASIK (Technolas 217z). A pupil camera operating at 50 Hz measured eye movements during the treatment in 10 eyes. The average ablation offset by the surgeon at the beginning of the procedure was 206.1 ± 80.99 microns, and was typically inferior and right of the patient's pupil center. Small amounts of cyclotorsion were observed during the ablation. The average magnitude of pupil decentration from the laser center was 227.02 ± 44.069 microns. The average standard deviation of eye movements was 65.70 ± 25.638 microns. Temporal power spectra calculated from the horizontal and vertical changes in eye position during the ablation were similar. 95% of the total power of the eye movements was contained in temporal frequencies up to 1 Hz, on average, in both directions. The mean higher order rms wavefront error that could theoretically result from eye movements alone was 0.76 ± 0.382 microns (6-mm pupil). There was a positive correlation (R = 0.774) between the theoretically induced higher order rms error and the standard deviation of the eye movements. Methods referencing the aberration measurement and treatment with respect to fixed features on the eye will reduce the potential for inducing higher order aberrations. An eye-tracker with a 2-Hz closed-loop bandwidth could compensate for most eye movements in conventional or customized ablations.

Keywords: LASIK, pupil decentrations.

Differences between real and expected corneal shape after aspherical corneal ablation

RSO5

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An important question that arises after refractive surgery is the difference between real and expected corneal profiles. This point influences the visual quality after refractive surgery and avoids a possible aberration correction of the eye. The study of this phenomenon is masked mainly because ablation algorithms are proprietary and the exact ablation profile is unknown. Most studies assume that the Munnerlyn formula or its paraxial approximation is used. We have studied corneal shape after LASIK with the CIPTA software. This ablation profile fixed expected corneal asphericity of a subject, and therefore it is possible to study differences between expected and real data. The programme selects a final asphericity value of Q=-0.46 in the majority of cases, optimizing the spherical aberration and visual performance. In our analysis, we have included reflection losses and non-normal laser incidence on the cornea. Results show a deviation between theoretical and real corneal shape showing the necessity of considering new variables that could explain these deviations; otherwise, improvement of refractive surgery, such as, eye- aberrations correction could not be effective.

Keywords: refractive surgery, corneal asphericity, customized ablation.

RSO6 Customized eye model development to evaluate the visual quality evolution after LASIK surgery

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In this work, we have developed a personalized eye model to explain the evolution of the visual acuity and the contrast sensitivity after a LASIK surgery. The eye model was based in the Kooijman theoretical eye in which the measured values of radii and thickness between different surfaces were introduced [1]. The possible alterations (inhomogeneities) induced by the laser ablation in the corneal stroma were implemented in the form of Gaussian-distributed refractive index variations of given correlation length [2]. The contrast sensitivity and visual acuity evolution were evaluated in terms of the Modulation Transfer Function (MTF) and the Point-Spread Function (PSF) calculated by ray tracing. The personalized eye model, including local inhomogeneities, have allowed: i) to obtain a MTF evolution similar to that observed for the contrast sensitivity for 18 real eyes, as well as an estimate of the characteristic size of the local effects; ii) to establish a relation between the visual acuity for 37 real eyes and the size of the retinal point image and the magnification, and iii) to explain the evolution of the visual acuity after LASIK surgery. The main conclusion is that LASIK surgery not only modifies the corneal curvature but may also induce a decrease of quality in the system caused by the regeneration of corneal tissue following the flap cut and laser ablation. [1] J.N.Fernández del Cotero, F.Moreno, D.Ortiz, E.Vélez, F.González, J.M.Saiz, J.I.Velarde, L.De Valentín-Gamazo, P.García-Antón. J. Refract. Surg 17:305-309 (2001) [2] D.Ortiz, J.M Saiz, F.González. Opt. Lett. 29(7): 739-741 (2004).

Keywords: visual quality, eye model, LASIK.

RSO7 Comparison of the mesopic CSF after Lasik with standard and aspheric profile

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PURPOSE: To compare the refracting results and the contrast sensitivity function (for the frequencies of 6, 12 and 18 cycles by degree) in obtained mesopics conditions by means of Lasik conventional of standard profile (Munnerlyn) and customized with aspheric profile. METHODS: 32 patients with refracting defect bilateral similar in both eyes (difference smaller to 1 diopter in sphere and/or cylinder and to 0.1 in Q factor) to which practices of randomized way Lasik with standard ablation in an eye and aspheric in the other. The interventions were made by the same surgeon who used laser excimer Sight model Astracan

(LaserSight, Orlando, Fl) and software CIPTA (Corneal Interactive Programmed Topographic Ablation - Ligi, Taranto, Italy -) to obtain the aspheric profile. For the obtaining of the mesopic CSF was used VCTS 6500 (Vistech, Dayton, OH) when the light reflected in the test was of 3 candles/m2 according to a digital luxometer. RESULTS: To the 6 months of the surgery, the refracting results (efficacy, predictability, safety and stability) were similar. The mesopic CSF showed better values in all the analyzed frequencies being statistically significant ($p<0.1$) for 12 and 18 cycles per degree. CONLUSIONS: The aspheric ablation, in Lasik, make better the visual quality in mesopics conditions respect to the traditional spherical ablation.

Keywords: mesopic CSF, LASIK, standard and aspheric profile.

Eye modelisation through a diffractive hybrid technique CEO1

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PURPOSE: The purpose of this paper is to present a new modelisation technique of the human eye based on the calculation of light distributions inside the eye and statistically validate our results through comparison with experimental studies in the bibliography. METHODS: We obtain corneal surface data and axial lengths for real eyes. With these data, we construct a diffractive model of a human eye. Through an angular spectrum propagation method, we calculate propagated light distributions at any distance inside the eye. From these calculated patterns, we obtain the Strehl ratio and the Modulation Transfer Functions (MTF) of 44 eyes, divided in two groups according to the age. We compare our results with those in the bibliography. Finally, we check the performance of the method through individual comparison of the calculated image positions with respect to the retina with the refractive data for the each subject. RESULTS: Strehl ratio values and variation of the MTF curves with age and pupil size that we obtain with our method result similar to those obtained experimentally. We are also capable of reproducing analytical MTF expressions that are proposed in the bibliography. CONCLUSIONS: Observed agreement between our method and results from other authors allow statistical validation of our model. We also find a good correlation between calculated refraction and subjective exams. The method allow simulation of light patterns at any plane of interest inside the eye and even reconstruction of retinal images.

Keywords: retinal image, fresnel diffraction, numerical algorithms.

CEO2 Prediction of optical aberrations by personalized eye models

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There is an urgent need to develop methods to simulate, design and predict the outcome of personalized ocular treatments, especially when there may be irreversible changes such as in cataracts and refractive surgery. The key to achieve this goal is to have realistic and accurate models of the eye to be treated, reproducing both anatomy and functionality with high fidelity. Our approach to solve this problem consists of the following stages: (1) To depart from a generic schematic eye model which predicts population average aberrations; (2) anatomical customisation consisting of substituting generic parameters of that model by real available data taken on the specific eye to be modelled. Here we use the standard measurements commonly available in clinics, namely elevation topography, pupil axis and ultrasound biometry; (3) first & second order optical customisation that is achieved by modifying the curvature radii of the lens to reproduce the manifest refraction (sphere and astigmatism); (4) Innovative optical optimisation technique to find the shape and position of the lens that best predicts the measured ocular aberrations. This procedure permits us to reproduce with a high accuracy the wave aberration of all eyes studied: The RMS difference between measured and predicted aberration was of the order 0.03 microns, that is below the measurement errors. It is important to note that the optical optimisation (step 4) was always necessary; otherwise the RMS difference between model and measurement remains similar to the RMS aberration. Some remaining problems and open issues will be discussed.

Keywords: custom eye models, aberrations.

CEO3 Influence of IOP on the geometrical and biomechanical properties of the linear and nonlinear model of the eye globe-effect of the optical self-adjustment

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PURPOSE: Deformations of the cornea due to the variation in IOP (observed in humans) change its dioptric power and its distance to the retina to such a degree, that acuity of vision should be affected. In order to find the eyeball's mechanism of compensation (self-adjustment) for optical disturbances caused by changes in IOP, a specific biomechanical model of eyeball with a limbus ring is proposed. METHODS: The proposed property of the eyeglobe model was

tested on a physically linear and nonlinear model of the eyeball. The computing models were set up into COSMOS system, using finite elements method. The structure comprises geometrical dimensions and linear and nonlinear material properties of the cornea and sclera. We tested different approximations of both surfaces of the cornea, and an equivalent tensile stiffness of the limbus ring-segment of the eyeball. The limus ring limits deformations of the cornea due to variations in IOP. So far the biomechanical models of the eyeball without limbus ring have exclude self-adjustment effect. CONCLUSIONS: Each of investigated parameters of the model affect the self-adjustment ability, especially elastic parameters of material of the eyeglobe tissue. Both liner and nonlinear models give different results. The linear model exhibits its self-adjustment ability for the wider range of the Young moduli of the eyeball tissue than the nonlinear one.

Keywords: intraocular presure, eye globe, model of the eye, Young's moduli.

Abstracts-Poster Session

Transverse chromatic aberration after corneal refractive surgery P1

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From a schematic-eye model, we have theoretically deduced an expression for the transverse or lateral chromatic aberration (TCA) after refractive surgery. Our aim is to investigate analytically how the chromatic aberration varies after the emmetropization process. We have characterized these changes in the TCA from changes in corneal asphericity. The results indicate that TCA after refractive surgery diminish as the degree of myopia increases, a trend contrary to that occurring with monochromatic aberrations such as spherical or coma. These results can explain the fact that the real deterioration of the visual function under photopic conditions detected in those operated on for myopia is less than expected when only the monochromatic aberrations are taken into account.

Keywords: refractive surgery, transverse chromatic aberration, myopia.

Chroma memory and age P2

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PURPOSE: The aim is to study the effect of age changes on chroma of 5 reference tests, using the methods of simultaneous and successive color matching. METHODS: We use 5 grey cardboard circle panels on which are arranged 20 comparative chips, chosen round 5 reference tests (violet 10PB 5/4, bluish green 10G 5/8, yellow green 5GY 5/6, orange 5YR 5/8, and pink 10RP 5/6) respectively), from Munsell Color Atlas. 75 normal trichromat men [25 preadolescents (mean age = 10.1 years), 25 young adults (mean age = 24.3), and 25 old adults (mean age = 69.5)], take part in the experiment. For simultaneous matching the observer chooses from among the comparative chips the one which most resembles the reference test, putting the reference test near to the comparison ones. By memory, the observer looks at the reference test for 5 sec in order to memorise it; after that time the observer is asked to recognize the comparison test equal to the memorized one, 15 sec, 15 min, and 24 hrs later. RESULTS and CONCLUSIONS: 1) By simultaneous matching, original chroma is matched well independent of age for violet and pink. For both greens and orange the elderly matched worst than the rest of age groups. 2) By memory, if we consider the average of all delay times, we find that all groups remember original chroma of violet and yellow green well. For pink and bluish green young adults remember it better than the rest of groups. Finally, preadolescents remember orange chroma worse.

Keywords: color vision, color memory, chroma memory, aging.

P3 Imaging retinal disease with adaptive optics

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Adaptive optics corrects the eye's aberrations, enabling imaging of cone photoreceptors with unprecedented resolution. This offers an enormous advantage over conventional ophthalmoscopy in that for the first time it is possible to directly examine cellular losses in the retina. Recent work in our lab has focused on using this technology to elucidate disease mechanisms in the human retina. For example, adaptive optics retinal imaging has revealed a new form of red-green color blindness. Red-green color blindness results from the functional loss of one cone class, however it has not been clear whether these individuals have lost one population of cones or whether they have normal numbers of cones filled with either of two instead of the normal three pigment types. Evidence has accumulated in favor of the latter view in which the photopigment in one class of cone is replaced but the issue has not been resolved directly. We found in one subject a patchy loss of approximately 1/3 of his cone photoreceptors, providing the first direct demonstration that color blindness can arise from the loss of an entire class of photoreceptor. We anticipate that for other visual disorders involving photoreceptor loss, adaptive optics imaging will enable much earlier detection and diagnosis and prove to be a valuable tool to detect retinal pathology that is otherwise invisible with current clinical methods.

Keywords: adaptive optics, retinal disease, color blindness.

P4 Permissible lateral misalignments in corneal ablation for myopic eyes

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PURPOSE: To compare the lateral misaligments errors allowable for refractive surgery of simulated myopic eyes using Munnerling-based algorithm and that published in works which takes into account the corneal asphericity. METHODS: We have used the tolerancing routines of an optical design program to obtain the limit values of the lateral decentrations in corneal ablation, as well as taking into account the error in the final corneal asphericity. Corneal radius and asphericity data of a published work for corrected myopic eyes ranging from -1 to -7D were used, and the calculations were made for 7 mm pupil and monochromatic illumination of 543 nm. We have established the tolerancing criterion based on root-mean-square (RMS) spot size. Given the retinal image quality provided by the two ablation algorithms used, the criterion was different in each case. Thus, a reduction no greater than a 10% in the RMS spot size for the Munnerling-based ablation algorithm and a value of the RMS spot size equal to that of the schematic eye for the other one, were adopted. RESULTS: In both cases, different values are permitted for lateral decentrations, being the vertical

misalignments greater than the horizontal ones, and they increase with the myopia degree. Furthermore, significant differences were found in the magnitude of the lateral misaligments using both corneal ablation algoritms. Though, the asphericty error were also considered, it had no significant influence. CONCLUSIONS: This work agrees with those that claim for better procedures to corneal ablation aligments, but also shows that the use of an aspherical corneal ablation algorithm, which increases the retinal image quality, has greater tolerance on ablation lateral misalignments.

Keywords: ablation algorithms, refractive surgery, ablation lateral decentrations.

On the ability of retinoscopy to detect ocular aberrations P5

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Retinoscopy is certainly the most common technique of measuring the refractive state of the eye. The influence of optical aberrations in retinoscopy is usually considered as a serious handicap in refraction because they make the point of neutralization imprecise. However, the retinoscopic reflex contain specific information about the optical aberrations of the tested eye. We have investigated the ability of retinoscopy to detect and quantify ocular aberrations. Simple models of the human eye have been used in which we have simulated aberrations of several orders and different amounts. The appearance of the retinoscopic reflex in aberrated eyes was calculated using a monochromatic light source. The results show that under certain conditions conventional retinoscopy could be used to detect eye aberrations. Several examples will be presented.

Keywords: retinoscopy, eye aberrations.

Objective polarimetry for ophthalmologic diagnosis P6

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Double pass polarimetry is a powerful tool for analyzing some important ocular characteristics. A complete polarimetric measurement involves the obtainment of the sixteen elements of the corresponding Mueller matrix. These parameters contain all information about the basic polarizing phenomena: birefringence, diattenuation and depolarization; which are related with several kinds of eye pathologies. In general this information appears combined and coupled so that, until now, does not exist a general method for separating the basic physical contributions and hence the polarimetric techniques can't be exploited properly. From the singular value decomposition of the Mueller matrix, an objective method for extracting separately the global birefringence, diattenuation and depolarization produced by the eye is presented.

Keywords: polarimetry, mueller matrix.

P7 Determination of the optical axis of the cornea from its elevation topography

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Corneal topography has shown to be an essential tool in ophthalmology, both in diagnosis and in custom treatments, also having a strong potential in optometry. The post processing and analysis of corneal elevation, or local curvature data, is a necessary step to refine the data and also to extract the optically relevant information. For this purpose, most parametric models describe the corneal surface as the sum of a regular basis surface (sphere, conic, etc.) and a polynomial expansion (Zernike, splines, etc.), which accounts for irregularities and departures from the geometry of the basis surface. Here we propose to use a general second order function, quadric in 3D, as the basis regular surface. In its canonical form, the quadric is described by only its 3 semiaxes, and the general expression accounts for arbitrary translations and rotations. The complete model uses the Zernike expansion to account for irregularities, and has been validated obtaining better adjustment of experimental data with respect to other proposed models. For normal corneas, where departures from the basis quadric surface are relatively small, this model provides a natural way to determine the position and orientation of the optical axis, by transforming the general quadric to its canonical form through simple linear algebra. This has been successfully applied to 3D registration of topographical maps. Other basic and clinical applications (such as the early detection of keratoconus or correct cornea positioning in more advanced optical models for the whole eye) are also explored.

Keywords: corneal topography, cornea model.

P8 Alterations of the corneal endothelium with the use of spherical hydrogel contact lenses

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The corneal endothelium is fundamental to impede the continuity between the aqueous humor and the underlying intercellular space. These cells cannot be regenerated and their loss causes edematization of the cornea. Contact lenses of negative contact spheres diminish oxygen to the cornea, giving rise to corneal alterations. In this context, the number, size, and shape of the endothelial cells in healthy myopic wearers of hydrogel contact lenses were studied over time. The contact lenses were negative, the central thickness being less than along

the periphery. The analysis was made with a non-contact specular microscope in the central, upper, lower, nasal and temporal zones of the cornea in subjects having worn hydrogel lenses for 3, 6, 9 and 14 years. The decrease in cell density proved more accentuated in the peripheral zones and less so in the central zones. These results indicate the greater loss in cell density in corneal zones in contact with the periphery of the contact lens, where thickness is greater and where oxygen restriction is also greater. The reduction in the cell endothelium appears to be related to the restriction of corneal oxygen, the reduction being greater in the peripheral corneal zones.

Keywords: corneal endothelium, spherical hydrogel contact lenses.

A hybrid lens to achromatise the human eye P9

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In this study, we examine the design feasibility of a simple system intended to achromatise the human eye while taking into account the capabilities of diffractive optical elements. Thus, a resulting hybrid diffractive/refractive doublet has been designed, composed of two materials: glass or polymer (the latter being used for ease in manufacturing). The design performance has been compared with conventional systems by calculating the MTF for the lens-eye system, and using two schematic eyes: the chromatic eye and that of Escudero–Sanz & Navarro. Finally, given the implication that a correct position in front of the eye has on the accuracy of the system, a tolerancing analysis has been performed to calculate allowed values for the misalignment errors both for the existing systems as well as for the design proposed. The proposed design has a better performance in the sagital plane compared to existing conventional systems and it is less sensible to tilts, but more tight to vertical misalignments.

Keywords: diffractive optics, hybrid optical design, eye chromatic aberration.

Measurement and testing of visual acuity with MULTISPOT 250 Aberrometer P10

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A novel Shack-Hartman wavefront sensor based real-time aberrometer with built-in controllable target projector was used for comparing data of subjective refraction and measured aberration. The MULTISPOT 250 aberrometer is used for automatic measuring of full aberrations of human eye. The unique feature of the instrument is scanning reference spot, which greatly improves measuring accuracy (below wavelength/20) and speed (up to 70 Hz). The reference picture for the sensor contains up to 300 spots (for 8 mm pupil). The aberrations are presented as Zernike polynomial coefficients up to 6-th order. One series of measurements can include up to 1000 samples that allows singling out

statistically important aberrations. The controllable target projector allows the patient to adjust the focus of the projector in order to obtain the best visual quality of the target. Then the data of measured aberrations and of subjectively found refraction have been compared. We tested several methods of calculation refraction of the eye from Zernike polynomial coefficients. We found that the well-known Seidel expression sometimes overestimated the optical power of the aberrations (up to 400% if higher order aberrations are great enough). A method based on the point spread function minimization leads to a poor OTF. Our experiments suggest that the optimal choice is the RMS difference with Gauss sphere.

Keywords: aberrometer, Shack-Hartman, visual acuity, zernike coefficients.

P11 The influence of external effects on stereothreshold

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The aim of the present work was studies of correlation between the stereothreshold and the quality of eye stimuli in different eyes. To achieve this aim the following tasks have been set: assessment and comparison the characteristic values of stereovision in cases of real and induced cataract, amblyopia and uncorrected anisometropia as well as the comparison of the estimated stereothreshold values in cases of induced uncorrected myopic and hypermetropic anisometropia; and the characterization of influence of external effects on stereovision using sensitivity coefficient. Two methods were applied. In the near changes in the quality of stereoacuity were determined by the standard TNO test applying monocular overcorrection of positive and negative lenses. In the distance maximal stereo angle with optical overcorrection was determined using four-line test separating the stereostimuli or by colour filters (red and green) or polaroid plates. Tests results for 125 subjects! of both methods display the changes in the stereovision acuity under the influence of the optical overcorrection in the near and distance stereovision. A sensitivity coefficient of stereovision was introduced that found to be different in the case of the dominant and non-dominant eye overcorrection. The results of studies show, that in the case of hypermetropic anisometropia the stereothreshold is higher in comparison with myopic anisometropia under the same vision conditions. The sensitivity of stereovision to monocular overcorrection depends from subject's minimal stereo angle. The sensitivity coefficient varied within limits of $0,34 \pm 0,18$log(stereo angle)/D for 125 subjects.

Keywords: Stereoacuity, monocular blurring, sensitivity coefficient of stereovision, dominant and non-dominant eye, anisometropia.

Corneal asphericity after myopic correction with excimer lasers P12

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We present a study of corneal asphericity changes after myopic LASIK correction with the help of Microscan-2000 excimer laser system. Microscan-2000 is a "flying spot" type of surgical lasers. The ablation profile is calculated by the Munnerlyn-type of formula with no paraxial approximation. The resulted profile was measured by the direct ablation of PMMA plates with subsequent inspection by Zygo T phase-shift interferometer. The ablation profiles of several commercially available lasers obtained by the similar technique are presented for comparison. A group of approximately 50 patients with myopia ranging from -2.5 to -11D without significant astigmatism and other pathologies was selected for study. All patients passed exams with Tomey TMS-3 corneal topographer prior and after surgery. The corneal height maps were processed for estimation of power and conic constants. The study shows the significant increase of conic constant after the surgery. The changes are higher than may be expected when Anera et.all formula is applied. The discrepancy may be attributed to post-operated biomechanical response of the cornea. Preliminary results of application of custom ablation profiles with aspherical correction are presented.

Keywords: myopic LASIK, asphericity changes, ablation profiles.

Influence of high-order aberrations on dynamic accommodation P13

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PURPOSE: Dynamic accommodation of the ocular system depends on several factors such us chromatic aberration and stimulus spatial frequencies, but the effects of high-order aberrations have not been studied. The purpose of this study is to investigate the possible influences of induced third-order aberrations (coma and trefoil) on the dynamic accommodative response. METHODS: Gain of the dynamic accommodation response to a sinusoidal change in vergence (1 3 D) of a monochromatic stimulus was obtained with a dynamic infrared optometer (100 Hz). Measurements were obtained in 10 young individuals with and without special contact lenses that induced higher-order aberrations. Defocus and astigmatism from the subject's naked eye and those induced by possible decentrations and rotations of the contact lens were corrected with spectacle

trial lenses. RESULTS: Despite variations between subjects, statistical changes in accommodative gain after induction of third-order aberration were observed in only four participants, and only in two of these did we find a decrease in gain with induced aberration. In some cases, the gain increased after inducing a small amount of higher-order aberration, but that was not the normal tendency. CONCLUSIONS: The presence of third-order aberration on the eye does not seem to play a crucial role in the dynamics of the accommodation response.

Keywords: accommodation, optical aberrations.

P14 Monocular depth of field of the eye: a geometrical formula

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Physiological Optics books spend few lines to the depth of field of eye. However, this effect is so important that there exist a neuronal connection between accomodation and reduction of the pupil diameter. The retinal illumination decreases when an object is nearer to the eye; than, the reduction of diameter is related with the depth of field. A simple formula based on geometrical optics is derived for the depth of field depending on the pupil diameter and the visual acuity. The result match the experimental values obtained in related papers.

Keywords: depth of field, accomodation.

P15 Rectified luminance detection mechanisms at suprathreshold conditions

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In the present work, I studied whether luminance mechanisms can be influenced by the polarity of the signal producing separate light and dark responses. I used visual latencies to determine whether this paradigm can be applied to post-receptoral mechanisms at suprathreshold conditions. Monocular simple visual-reaction times were measured at the fovea for 12 circular random stepwise stimuli presented on a colour monitor at a 2-deg field size. The stimuli were chosen along the luminance achromatic axis of the colour space with chromaticity coordinates equal to the equal-energy illuminant (x=0.333; y=0.333). Their luminance was randomly selected between 3 and 27 candela per square meter (cd/m2) in increments of 2 cd/m2. A 15 cd/m2 achromatic adapting stimulus was chosen to provide suprathreshold luminance variations, to produce transient cone responses, and to select the stimuli according with induced polarity (6 test pairs). Three human observers took part in the experiment. To examine the rate at which responses were produced in each instant following stimulus presentation (events per millisecond), I calculated normalized hazard

functions from VRT raw data for each experimental condition. In the comparison of these functions for each pair of stimuli, the results for all observers confirm the existence of asymmetries at high processing times due to the polarity of the signal. The results found suggest that the luminance system can be divided into separate rectified ON and OFF pathways at suprathreshold conditions.

Keywords: luminance mechanisms, simple visual reaction time, hazard function, ON and OFF pathways.

FDTD analysis of the light propagation in the cones of the human retina: an approach to the Stiles-Crawford effect of the first kind P16

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This work analyses the propagation of light in the cones of the human retina, using the method of finite differences in the time domain (FDTD) on cylindrical coordinates, for systems with axial symmetry (BOR). This work constitutes a preliminary approach for studying the Stiles-Crawford effect of the first kind (SCE I), as a cone has been simulated, while the SCE I is a consequence of a great number of photoreceptors.The FDTD method enables a numerical resolution of Maxwell's equations. Implementation of these equations in a computer has given, at the exit of the cone, the intensity patterns for different angles at which light strikes the entry side of the photoreceptor, and different wavelengths of the incident light. The results of the simulation were as expected for phenomena of propagation of wave guides. This validates the characteristics of fibre optics presented by the cones of the retina, and, furthermore, the goodness of the method and of the computational model of the cone that we have proposed. This work demonstrates the power and versatility of the BOR-FDTD algorithm for the analysis and understanding of light-propagation phenomena in the photoreceptors of the retina, and thus offers broad possibilities in the field of research on visual processes, serving to support analyses and interpretations of psychophysical measurements.

Keywords: Stiles-Crawford, FDTD method, model cone.

Influence of theoretical model used for the calculations of third-order aberrations of human eye P17

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In this work, we study the influence of theoretical model used for the calculations of third-order aberrations of Human eye. In this study we calculated and compared the third-order aberrations for 4 sampled eyes, one without refractive error and three with refractive error; -1 diopters, -6 diopters and +6 diopters.

For the eye without refractive error we use 3 theoretical models and for each eye with refractive error we expand each one in three sub-models. We obtain these three sub-models using, for each eye models, 3 different sources of refractive error; axial error, first surface corneal refractive error and last surface lens refractive error. Finally, for all the sub-models we perform the analysis in three different situations; the eye is not compensated, the eye is compensated with a contact lens or the eye is compensated with an spectacle lenses, so in total we analyze 84 differences configurations born from an unique eye, different modeled, different refracted and different compensated. To establish a common point in all the analysis process we use; The Zernike polynomials description to obtain the third-order aberrations, and the exact ray tracing method, do with commercially available software, to generate the primary wavefront information necessary to obtain the Zernike polynomials coefficients.

Keywords: aberration, zernike polynomials, refractive error, ray tracing, eye model.

P18 Optical characterization of ophthalmic lenses by means of MTF determination from a laser speckle pattern

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The MTF determination allows a full evaluation of the image quality given by an optical system. This work presents a method for measuring the MTF of ophthalmic lenses using the generation of laser speckle with an integrating sphere. The laser radiation at the output port of the sphere passes through an aperture, which determines the spatial-frequency content of the speckle pattern that falls on a CCD detector. The measurements are performed positioning a rectangular double-slit aperture at the output port of the integrating sphere. Then, images of laser speckle are captured moving the CCD in normal direction to the aperture plane. The distance between the lens and the detector determines the spatial frequency being tested, therefore high frequencies are tested close to the lens and low frequencies are tested far from the lens. An important advantage of the double-aperture method is that the greatest spatial frequency which can be measured is approximately twice the Nyquist frequency of the CCD. The main disadvantage of this method is the necessity to move the CCD in order to measure in a broad range of spatial frequencies. This disadvantage can be avoid using a single-aperture, but in this case the MTF measurements are limited to spatial frequencies somewhat below Nyquist frequency. However, using a single-aperture, is possible to determine the MTF of the lens in one measurement. We can conclude that the double-slit method can be a versatile technique in order to compare the optical quality of ophthalmic lenses from different makers.

Keywords: MTF measurement, laser speckle, ophthalmic lenses.

Accommodation amplitude objective measurements using a double-pass based instrument P19

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The double-pass technique is a quite useful tool for the study of the eye's optical performance, measuring the actual retinal image. We have developed a method for the objective determination of the accommodation amplitude (OAM), analysing the decrease in retinal image quality with stimulus vergence. In order to obtain the OAM, two different criteria were applied. The first consists of a visual acuity (VA) estimation for each accommodative estate. The OAM is obtained when VA decreases 0.1 logMAR, as in classical subjective measurements. The other method is based on studying the shape of the double-pass images, and the OAM is obtained when the image size becomes the double of the image for far vision. To validate the method we performed a set of measurements for both phakic and pseudophakic eyes, and we compared the OAM obtained with the subjective values of accommodation amplitude (SAM). OAM results with the two applied criteria are similar. For phakic eyes we obtain good agreement between the OAM and SAM, specially when the subject was a presbyope. For pseudophakic condition we measured eyes implanted with 3 different IOL types: an accommodative IOL (AT-45,C&C Vision), ThinOptx IOL (Abingdon,VA) and acrylic IOL from Alcon (Fort Worth,TX). We obtained good agreement between OAM and SAM and we didn't find any statistical difference between IOLs.

Keywords: accommodation, double-pass, visual acuity, pseudophakic eyes, presbyopia.

Ocular component data in schoolchildren: a longitudinal study P20

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PURPOSE: The purpose of this study was to determinate the changes of ocular components (corneal radius, anterior-chamber depth, lens thickness, vitreous-chamber depth and axial length with age, and their influences in the configuration of refractive state. METHODS: Ocular biometric data on 112 children (7-10 years aged) were collected over the period 1995 to 2000 with two optometric revisions in an interval period of five years. Measurements included cycloplegic retinoscopy, keratometry and A-scan ultrasonography. The subjects were divided into three groups, myopic (refractive error <-0.50 D.), hyperopic (>+0.50 D.) and emmetropic group (between both values). RESULTS: As would be expected, there was a significant effect of age on refractive error, toward less hyperopia and more myopia. The vitreous-chamber depth and the axial length were the ocular components that presented the greatest changes with the age, and thus were the determining elements in the configuration of the myopic refractive state. There were no significant differences in corneal

radius with age, although in the myopic group there was a slight tendency to flattening corneal with age. The behaviour of anterior chamber depth and lens was more irregular, and therefore they need to be analyzed more exhaustively. We are analyzing these results.

Keywords: Age, emmetropization, ocular components, refractive error.

P21 Effect of yellow filter on mesopic pupil size

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PURPOSE: It has been recently reported that pupil size is independent of the wavelength for adapting luminances from photopic to mesopic. Herein, we tried to determine whether blue-blocking filters really increase pupil size, as has been reported previously, in an effort to establish if this type of lens has any effect on vision at night when blue takes on much greater importance. METHODS: Mesopic pupil size was measured in 62 eyes of 31 healthy subjects (mean age 37 +/- 13 years) using the digital (Procyon 2000) infrared pupillometer for binocular simultaneous measurements of pupil diameter. Measurements were performed at a low mesopic illuminance level (0.40 lux) after 5 min of dark adaptation and while the observer viewed through a yellow coated filter (X-482 nm cut-off), through a neutral density (ND) filter, or no filter. RESULTS: For right eyes, mean mesopic pupil diameter was 6.05 +/- 1.41 mm (range 3.05-8.17 mm) with the yellow filter, 5.97+/-1.37 mm (range 3.01-8.15 mm) with the ND filter, and 5.87+/-1.30 mm (range 3.02-8.28 mm) without a filter. No significant differences were shown between the pupil sizes of both eyes. No pupil size differences were detected whether a filter was used or not, nor when the population was divided into three age groups. CONCLUSIONS: The yellow filter had no effect on pupil size under mesopic luminance conditions. Accordingly, its use would not compromise visual quality at night.

Keywords: yellow filter, pupil size, mesopic.

P22 Influence of geometry of the anterior part of the eye on the image of the eye pupil

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Investigation of the pupil size and the time characteristics of its reaction on the light pulses stimulation plays more and more important role in modern ophthalmology, neurology and psychiatry. There exist different methods of fine pupil size measurement. However, in fact one measures a size of the virtual image of the pupil formed by the cornea, instead of the real pupil. The measured size and form of the image of the pupil depends on the corneal geometry, size of the real pupil and the distance between the corneal apex and the real pupil. The

observed image of the pupil is always greater than the real pupil and is located in front of the real pupil. We used the out of axis ray tracing method (5000 rays) to calculate the properties of the image of the pupil. This concerns the size of the pupil image and its position as a function of the central corneal curvature, eccentricity of the elliptic approximation of the corneal profile, Corneal astigmatism and the size of the real pupil. Results show that differences in magnification of the virtual image of the pupil can reach 15%.

Keywords: pupil size, corneal geometry.

Changes in refractive surgery in the last 5 years P23

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The field of Refractive Surgery (RS) had experienced great changes during the last five years, including the advances in the technological field (creation of new ablation software, development of aberrometers, etc.); the impulse of new surgical techniques (LASIK, Intraocular Lenses), going to the indications of each of these techniques. It is important not to forget that the subjetive aspects, such as the reasons and expectations that move the patient to undergo this type of surgery, had evolutioned along this time.

Keywords: refractive surgery, LASIK, surgery indication, motivation.

Focusing of near Ir laser beams by the eye's optics P24

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The main features of thermal action of near IR radiation onto eye appears to be the most significantly at the spectral regions where Bouguer absorption coefficients of ocular media have the order of few sm-1(approximately, 1200-1400 & 1550-1750 nm). In this case, while laser beam is propagating, the rising of energy concentration due to focusing accompanies by its decreasing because of optical absorption. The rates of the both processes are comparable. Their superimposition can generate a series of interesting effects that are of great importance for laser medical applications and laser safety. We explored these phenomena by using a two-dimensional (axial symmetric) phantom model and theory of propagation of Gaussian beams in a both scattering and absorbing medium. The radial distribution of radiation on retina estimated on the base of the modulation transfer function of the averaged statistical human eye. For some cases underestimation of danger of laser radiation has been shown. On the other hand a number of effective regimes can be found for medical treating action onto local intraocular pathologies.

Keywords: eye, near IR, gaussian beam, MTF.

P25 Ocular monochromatic aberration statistics in a large emmetropic population

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PURPOSE: Although there has been a considerable research concerning the statistics of ocular higher order aberrations, most studies have employed groups of uncorrected ametropic or optically-corrected eyes with high refractive error. This study explored distribution statistics of monochromatic aberrations in a nearly emmetropic population. METHODS: The wavefront aberration function was obtained using the Allegreto WaveFront Analyzer (WaveLight Laser Technologies). 393 healthy eyes of 218 subjects were tested. Mean age was 33.1 years (range: 21 to 43). Total refractive error ranged between +0.50 and -1.25D, with the astigmatism being < 0.75D. Analysis of the wavefront data was performed for both 6mm and full-size pupils. RESULTS: The results agreed with previous studies, showing a significant dispersion in all Zernike coefficients. Population average values of Zernike coefficients were almost zero, with the exemption of primary and secondary spherical aberration. However, mean spherical aberration was $0.037\mu m$, significantly lower than previously reported. The equivalent defocus of higher order aberrations was < 0.25 D. Bilateral symmetry was studied: even-symmetric modes were positively correlated, whereas odd-symmetric modes were negatively correlated. There was a tendency for an increase in higher order aberrations with age, which was cancelled out when full-size pupil analysis was performed. CONCLUSIONS: Ocular aberration statistics in an 'emmetropic' population confirmed previous research with Hartmann-Shack aberrometry. Mean Spherical aberration was positive, even though its magnitude was lower than cited before, probably due to the low refractive error of our population. Moreover, when studying higher order aberrations on older subjects, the pupil miotic effect of ageing should be taken into account.

Keywords: eye aberrations, aberrometry.

P26 Video processing based on reconfigurable logic for low vision aids

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Low vision patients are subjects with very restricted visual fields or low contrast. There are different pathologies affecting these kind of patients with different evolutions that an be classified in three categories: low contrast vision, tunnel vision and peripheral vision. This contribution describes simple real-time image processing schemes that can be used as core of optoelectronic visual aids. The presented approaches have been implemented in specific hardware (FPGA device) to achieve real-time processing in low cost portable systems. The inclusion

of a reconfigurable circuit FPGA allows real time video processing, the setting control by the user, and personalization for each individual person in a simple way, resulting in an unique platform. This represents a very valid alternative to optical aids that are widely used in this field.

Keywords: low vision, visual field expansion, visual aids, FPGA, Augmented View, opto-electronics, CCTV.

Effects of optic nerve section on growth and refraction of chick eyes raised under 12/12 and constant light P27

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PURPOSE: Raising chicks (Gallus Gallus domesticus) in constant light (CL) is known to alter their refractions, corneal radii and other ocular dimensions. These CL effects can be limited or reduced by diurnal occlusion of the eye(s) or pineal body while raising the chick in CL. We wished to assess if these changes in ocular development under CL are mediated by local or central mechanisms. METHODS: Four groups of 6 to 9 week old chicks had their right eye optic nerves severed. Sham operations were performed on left eyes as controls. One day after surgery, the first group of the chicks was raised in a normal light cycle (12/12); the second group was under CL; the third group had right eyes covered 12 hours per day in CL and the fourth group had left eyes covered 12 hours per day in CL. Two weeks after the experimental conditions were applied, the eyes were measured. RESULTS: Under 12L/12D conditions, optic nerve section (ONS) does not affect the refraction and ocular development. However, ONS eyes showed more CL effects. Covering the ONS eyes could not protect either the operated eye or opposite eye from CL effects. On the other hand, protection was afforded only the non-ONS eyes by covering those 12 hours daily. CONCLUSIONS: The central nervous system may be required for diurnal occlusion protection in CL.

Keywords: animal eyes, animal models.

Intraocular image design P28

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Normally light from any object that is placed in front of an eye goes through the optical system of the eye and is projected exactly on the Macula. We developed a new concept of optically re-designing the image of an object from inside the eye. The principle of this concept is to use intra-ocular reflecting mirrors in order to optically change the way in which the object is reflected as an image on the Retina. These mirrors are usually (but not necessarily) embedded inside an intra-ocular lens (IOL), which is inserted inside the eye after removal of the

crystalline lens (Cataract Surgery). By using these reflecting surfaces inside the eye we can re-design the image that the eye sees without changing the object. For instance if we want to have a larger image on the retina, we do not have to put an optical system between the object and the eye, we can change it by aligning the mirrors inside the eye as a Cassegren telescope with such a curvature and location that it will create a larger image on the retina (as for macular degeneration as an example). Having the possibility to design the image from inside the eye (behind the pupil, which usually prevents it to be done in the normal situation) enables us to change the image by using different optical measures such as : magnification, minification, moving the image to a certain location on the retina, increase or decrease the relative contrast between the central or peripheral vision, increase or decrease the visual field and many other optical possibilities that were impossible until now. We can actually design the size, location and contrast of the image that we want to project on the retina in order to help patients with their different medical problems.

Keywords: intraocular, mirrors, retina.

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