Wrocław University of Science and Technology
Department of Optics and Photonics

Author's summary of professional accomplishments

Experimental investigations and numerical modeling of optical and geometrical properties of the anterior segment of the eye

Damian Siedlecki, PhD

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1. Personal and contact details

Personal details

Name: Damian Siedlecki
Date of birth: 24 Feb 1978
Place of birth: Dzierżoniów
Marital status: married, two children

Contact details

Visual Optics Group
Department of Optics and Photonics
Wrocław University of Science and Technology
Wybrzeże Wyspiańskiego 27
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Education and degrees

2005 PhD in Physics,
Institute of Physics, Wrocław University of Technology (currently: Wrocław University of Science and Technology). Dissertation title: “*Development and analysis of a simplified model of the optical system of the eye with regard to the aberrations of a real eye*”.
Supervisor: Prof. Henryk Kasprzak;

2001 MSc in Biomedical Engineering,
Faculty of Fundamental Problems of Technology, Wrocław University of Technology (currently: Wrocław University of Science and Technology). Dissertation title: *“Development of the corneal topography system”*.
Supervisor: Prof. Henryk Kasprzak;

1996 baccalaureate - I Liceum Ogólnokształcące in Dzierżoniów, class of maths and physics.

Employment information

2008 - now	research associate at Wrocław University of Technology (currently: Wrocław University of Science and Technology), Faculty of Fundamental Problems of Technology, Department of Optics and Photonics (earlier: Institute of Physics), Visual Optics Group, headed by Prof. Henryk Kasprzak;
May 2008 – September 2009	post-doc fellow at Instituto de Óptica „Daza de Valdés”, Consejo Superior de Investigaciones Cientificas (CSIC), Madrid, Spain;
July – September 2006	post-doc fellow at the Institute of Vision and Optics, University of Crete, Heraklion, Greece;
2005 – 2008	research assistant at Wrocław University of Technology (currently: Wrocław University of Science and Technology), Faculty of Fundamental Problems of Technology, Institute of Physics.

Languages

English:	fluent written and spoken
Spanish:	basic
German:	basic

Foreign internships

May 2008 – September 2009	post-doc internship at Instituto de Óptica „Daza de Valdés”, Consejo Superior de Investigaciones Cientificas (CSIC), Madrid, Spain, funded in the framework of Spanish government's programme JAE-DOC;
July – September 2006	post-doc internship at the Institute of Vision and Optics, University of Crete, Heraklion, Greece, organized and funded by the Research Training Network "SHARP-EYE: Adaptive Optics for Retinal Imaging and Improved Vision";
18 October – 1 November 2003 2 – 13 February 2004	two short-term internships at the Department of Biomedical Sciences, Bradford University, Bradford, United Kingdom, funded by The British-Polish Young Scientists Programme (YSP) organized by British Council Poland and Polish Scientific Committee.

2. Description of the scientific research within the framework of the habilitation application

2.1. List of publications constituting the basis of the application, with the personal contribution of the author

Bibliometrics

Number of scientific publications:	**12**
Total *Impact Factor*:	**23,056**[a]
Number of citations:	**213**[b]
Number of citations excluding the auto-citations:	**184**[b]
Number of patents:	**1**

[a] according to the Web of Science database, in agreement with the year of issue.
[b] according to the Journal Citation Report database (last update on 4.05.2016).

2.1.1. Scientific publications

H1. Optical coherence tomography for quantitative surface topography,
S. Ortiz, D. Siedlecki, L. Remon, S. Marcos
Applied Optics 2009;48(35):6708-6715.

IF = 1,410[a] Number of citations: 38[b]

Personal contribution: co-authorship of the idea of the investigations aimed to obtain the quantitative topographical data from 3-D OCT measurements; co-authorship

of the methodology of the investigations; co-development of the time domain OCT system; co-development of the procedure of OCT system calibration and the field distortion correction algorithm; collection of the OCT topographical measurements of the surfaces described in the publication; comparative analysis of the topographical data obtained in the experiment; discussion and analysis of the results; manuscript preparation: bibliographical study, graphics and text edition.
Estimated personal contribution: 40%

H2. Corneal topography from spectral optical coherence tomography (sOCT),
S. Ortiz, D. Siedlecki, P. Perez-Merino, N. Chia, A. de Castro, M. Szkulmowski, M. Wojtkowski, S. Marcos
Biomedical Optics Express 2011;2(12):3232-3247.

IF = 2,333[a]   Number of citations: 28[b]

Personal contribution: co-authorship of the idea of the investigations aimed to develop the numerical method of the corneal topography estimation from the 3-D OCT imaging; calibration of the instrument, with use of field distortion correction methodology, described in the previous paper; discussion and analysis of the results; manuscript preparation: bibliographical study, authorship of 4 figures, text edition.
Estimated personal contribution: 40%

H3. Three-dimensional ray tracing on Delaunay-based reconstructed surfaces,
S. Ortiz, D. Siedlecki, L. Remon, S. Marcos
Applied Optics 2009;48(20):3886-3893.

IF = 1,410[a]   Number of citations: 12[b]

Personal contribution: co-authorship of the idea of the investigations aimed to develop the ray tracing algorithm through the optical surfaces given as discrete data (points); co-development of the numerical algorithms; numerical simulations on the examples described in the paper; comparative analysis of the results of the algorithm being the basis of the publication; discussion and analysis of the results; manuscript preparation: bibliographical study, text and graphics edition.
Estimated personal contribution: 35%

H4. Optical distortion correction in Optical Coherence Tomography for quantitative ocular anterior segment by three-dimensional imaging,
S. Ortiz, D. Siedlecki, I. Grulkowski, L. Remon, D. Pascual, M. Wojtkowski, S. Marcos
Optics Express 2010;18(3):2782-2796.

IF = 3,753[a]   Number of citations: 61[b]

Personal contribution: co-design of the methodology used in the study; co-development of the time domain OCT system; calibration of the SOCT instrument; co-development of the numerical algorithms for optical distortion correction; collection of the OCT measurements described in the publication; comparative analysis of the experimental data; discussion and analysis of the results; manuscript preparation: bibliographical study, authorship of 3 figures included in the publication, edition of the text.
Estimated personal contribution: 35%

H5. Distortions of the posterior surface in optical coherence tomography images of the isolated crystalline lens: effect of the lens index gradient,
D. Borja, D. Siedlecki, A. de Castro, S. Uhlhorn, S. Ortiz, E. Arrieta, J.-M. Parel, S. Marcos, F. Manns
Biomedical Optics Express 2010;1(5):1331-1340.

IF = 2,333[a] Number of citations: 18[b]

Personal contribution: authorship of the idea of the study aimed to estimate the influence of the gradient index distribution in the crystalline lens medium on the shape of the OCT profile of the posterior lens surface, distorted by the presence of the optical distortion; design of the methodology of the investigations; development of the numerical procedures, performing the numerical simulations of the OCT data of a crystalline lens with use of ray tracing algorithms through the gradient index media; comparative analysis of the simulations results and the OCT images captured in the experimental part of the study; discussion and analysis of the results; manuscript preparation: literature study, authorship of 2 figures, edition of the text.
Estimated personal contribution: 45%

H6. Age-dependent variation of the gradient index profile in human crystalline lenses,
A. de Castro, D. Siedlecki, D. Borja, S. Uhlhorn, J.-M. Parel, F. Manns, S. Marcos
Journal of Modern Optics 2011;58(19-20):1781-1787.

IF = 1,170[a] Number of citations: 17[b]

Personal contribution: authorship of the idea of the study aimed to reconstruct the parameters of the gradient index distribution for the crystalline lenses of different ages, on the basis of the OCT images containing the distorted profile of the posterior surface of the lens, affected by the presence of optical distortion and estimation of the trend of these parameters with age; design of the experiment and methodology of the investigations; co-development of the numerical algorithm for retrieval of the optimal values of the gradient index parameters; analysis and discussion of the results; manuscript preparation: edition of the text.
Estimated personal contribution: 30%

H7. Distortion correction of OCT images of the crystalline lens: gradient index approach,
D. Siedlecki, A. de Castro, E. Gambra, S. Ortiz, D. Borja, S. Uhlhorn, F. Manns, S. Marcos, J.-M. Parel
Optometry and Vision Science 2012;89(5):E709-E718.

IF = 1,895[a] Number of citations: 8[b]

Personal contribution: authorship of the idea of the study aimed to develop a numerical algorithm for the optical distortion correction of the OCT data of a gradient index crystalline lens; development of the algorithm; numerical simulations and statistical analysis for the estimation of the effectiveness of the correction algorithm; manuscript preparation: literature study, authorship of the figures, edition of the text.
Estimated personal contribution: 70%

H8. Placement of a crystalline lens and intraocular lens: retinal image quality,
D. Siedlecki, J. Nowak, M. Zając
Journal of Biomedical Optics 2006;11(5):054012.

IF = 2,870[a] Number of citations: 11[b]

Personal contribution: development of a numerical model of a pseudophakic eye, taking into account various geometries and various optical materials of lens artificial implants (IOLs); implementation of the model to the environment that enabled optical simulations and performance analysis; numerical simulations on the influence of crystalline lens and IOL localization on the optical performance of the model; discussion and analysis of the results; manuscript preparation: bibliographical study, authorship of graphics and text.
Estimated personal contribution: 65%

H9. Retinal images in a model of a pseudophakic eye with classic and hybrid intraocular lenses,
D. Siedlecki, M. Zając, J. Nowak
Journal of Modern Optics 2008;55(4-5):653-669.

IF = 1,062[a] Number of citations: 7[b]

Personal contribution: full literature study on the chromatic properties of the materials used for fabrication of lens artificial implants (IOLs); preparing various numerical models of a pseudophakic eye, taking into account various geometries and various optical materials of the implants; implementation of the model to the environment that enabled optical simulations and performance analysis; numerical simulations aiming to search for the optimal parameters of the hybrid IOL model, which could decrease the total longitudinal chromatic aberration (LCA) of the whole model to the level of a healthy eye; consultation and analysis of the results; manuscript preparation: authorship of graphics and text.
Estimated personal contribution: 70%

H10. On the longitudinal chromatic aberration of the intraocular lenses,
D. Siedlecki, H. Ginis
Optometry and Vision Science 2007;84(10):984-989.

IF = 1,638[a] Number of citations: 10[b]

Personal contribution: authorship of the idea of the investigations aiming to estimate the chromatic properties of IOLs (IOL materials); design of the experimental methodology;. construction of the optical setup and collection of the experimental data on the focal lengths of different intraocular lenses in air, for different wavelengths; statistical analysis; estimation of the chromatic dispersion of the IOL materials used in the study; estimation of the obtained chromatic properties on the magnitude of the longitudinal chromatic aberration of a pseudophakic eye; manuscript preparation: bibliographical study, authorship of graphics and text.
Estimated personal contribution: 90%

H11. In vivo longitudinal chromatic aberration of pseudophakic eyes,
D. Siedlecki, A. Jóźwik, M. Zając, A. Hill-Bator, A. Turno-Kręcicka
Optometry and Vision Science 2014;91(2):240-246.

IF = 1,603[a] Number of citations: 3[b]

Personal contribution: authorship of the idea of the study aiming to estimate the longitudinal chromatic aberration of pseudophakic eyes *in vivo*; design of the methodology of the experiment; authorship of the design of the clinical refractometer adaptation to the measurements in monochromatic light for 3 different wavelengths (modification of the illuminator of the instrument); consultations to the personnel of the Department and Clinic of Ophthalmology, Wrocław Medical University about the planned *in vivo* measurements; preparation of the informed consent to be signed by patients; performing the measurements on the patients; statistical analysis and discussion of the results; manuscript preparation: literature study, authorship ofgraphics and text.
Estimated personal contribution: 80%

H12. Optical coherence tomography as a tool for ocular dynamics estimation,
D. Siedlecki, W. Kowalik, H. Kasprzak
BioMed Research International 2015;Article ID 293693

IF = 1,579[a] Number of citations: 0[b]

Personal contribution: design of the methodology of the experiment; performing the *in vivo* measurements; capturing the OCT image sequences; numerical analysis of the collected sequences; consultations on the image processing tools and algorithms to be used in the study; consultations and analysis of the results; manuscript preparation: literature study, authorship of graphics and text.
Estimated personal contribution: 65%

2.1.2. Patent

H13. Ortiz Egea Sergio, Marcos Celestino Susana, Siedlecki Damian, Dorronsoro Diaz Carlos: Patent numbers: WO2012146811-A1; ES2391510-A1; ES2391510-B1; EP2704095-A1; US2014107960-A1; JP2014512242-W; EP2704095-B1; ES2546076-T3. **Method for calibrating and correcting the scanning distortion of an optical coherence tomography system**.
Patent details:
WO2012146811-A1, published on: 01 Nov 2012, IPC: G06T-005/00, language: Spanish
ES2391510-A1, published on: 27 Nov 2012, IPC: G06T-005/00, language: Spanish
ES2391510-B1, published on: 27 Nov 2012, IPC: G06T-005/00, language: Spanish
EP2704095-A1, published on: 05 Mar 2014, IPC: G06T-005/00, language: English
US2014107960-A1, published on:17 Apr 2014, IPC: G01B-009/02, language: English
JP2014512242-W, published on: 22 May 2014, IPC: A61B-003/10, language: Japanese
EP2704095-B1, published on: 01 Jul 2015, IPC: G06T-005/00, language: English
ES2546076-T3, published on: 18 Sep 2015, IPC: G06T-005/00, language: Spanish.

This patent is a result of the research project realized under the leadership of Susana Marcos at Instituto de Óptica, Consejo Superior de Investigaciones Cientificas in Madrid.

The aim of the project was to develop a method of retrieval of quantitative data on the anterior segment geometry from the optical coherence tomography data. My contribution was: co-authorship of the idea; design of the methodology of the investigations; development of the calibration procedure of the OCT instrument and its implementation; consultation, analysis and interpretation of the results. Estimated personal contribution: 30%

[a] according to Web of Science database, in agreement with the year of issue.
[b] according to Journal Citation Report database (last update on 8.04.2016).

2.2. Description of the scientific goal and obtained results

The scientific goal of the series of works being the basis of the habilitation application was to use the available methods and measurement techniques and to develop novel tools and numerical algorithms for retrieval of reliable information on the geometrical (shape, surface topography, thickness) and optical (refractive index, chromatic dispersion) properties of several structures of the anterior segment of the eye, having an essential importance in the optical performance of the eye.

2.2.1. Introduction

An eye is a very rich source of information on a condition of a human visual system. There are several techniques used for the purposes of the investigations into the properties of its elements. Among all the available diagnostic techniques, the optical ones are the most popular, as the least invasive.

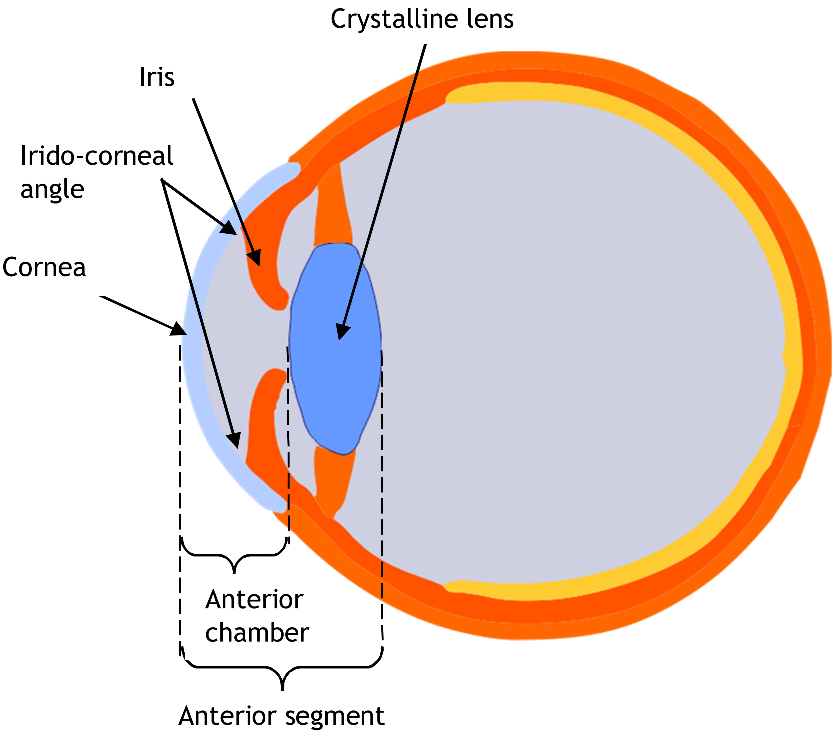

Figure 1 The structure of the eye globe. The scheme indicates the elements of the eye being the subject of the investigations described in the publications **[H1-H13]**.

From the physical (optical) point of view, the most important part of an eye is its anterior part called the anterior segment. The anterior segment consists of all the anatomical structures of the eye, between the anterior surface of the cornea and the posterior surface of the crystalline lens (Figure 1). The reason of its importance is that within the anterior segment, on the surfaces being the borders of several optical media, the incoming rays are refracted and make the form of a converging beam that reaches the posterior part of the eye and creates the retinal image. The aberrations of the eye's optical system depend essentially on the condition of the surfaces within the anterior segment. Finally, the aberrations have a significant influence on the broadly-understood quality of vision.

For this reason, the precise estimation of the parameters: both geometrical (shape, surface topography) and optical (refractive index, chromaticity) properties of several structures within the anterior segment of the eye is of critical importance and is the goal of many studies and scientific elaborations. Development of both reliable diagnostic methods of this part of the eye and physically-justified numerical procedures of the processing of the data being the result of these diagnostic methods is the source of the knowledge on the eye and the whole visual system.

In my investigations, described in works **[H1-H13]**, constituting the basis of the application for habilitation, I was involved both in measurements and simulations of the optical and geometrical parameters of the anterior segment of the eye, and in development of physically-justified numerical analysis methods, aimed to retrieve the quantitative information on the elements of the anterior segment of the human eye.

2.2.2. Corneal topography [H1, H2, H13]

As the most external element of the optical system of the eye, being covered by a thin film of tears, the cornea is an element of essential importance in the retinal image formation. The refractive power of its anterior surface is about 70% of the total refractive power of the eye. That is the reason, why the total aberrations of the eye and the retinal image quality depend mostly on the shape (topography) of the anterior surface of the cornea.

Recent development of still more and more precise and reliable methods of corneal topography measurements is closely related to the progression in the contact lens technology and surgical methods of refraction correction. Most of currently available instruments used for corneal topography measurements (corneal topographers, videokeratometers) is based on a method described first in XIX century, where the concentric rings pattern (called Placido rings) is projected onto the cornea and the images of the rings reflected on the anterior surface of the cornea (or rather on the tear film) are observed. Another technique, that is being used in the ophthalmic diagnostics, is the technique based on Scheimpflug imaging. This imaging method relates to the situation, when the object plane is tilted in relation to the plane, where its geometric image is formed. The Scheimpflug images of the anterior segment of the eye are being captured in different meridional sections of the cornea. These images are the source of the information on the shape of the cornea in a particular section. Finally, the data from different meridians are collected together in a form of a map, containing the topographical data on the anterior surface of the cornea.

An alternative to the methods of the corneal topography measurements mentioned above, can be the optical coherence tomography (OCT). This interferometric technique, described for the first time in 1992 [L1,L2], is the imaging method currently experiencing probably the most rapid development in medical imaging. Its continuous development - strictly related to the development of instrumentation [L3,L4,L5,L6], enables data acquisition with still increasing speed, still better resolution and still longer axial range. All these, together with development of sophisticated techniques of tomographic image processing [L7,L8,L9,L10], result in continuous findings of brand new applications of the OCT technique.

As the interest in OCT technique increased, I together with the members of Visual & Biophotonics Lab at Consejo Superior de Investigaciones Cientificas in Madrid decided to use the optical coherence tomography instrument for the purposes of acquiring the topographical maps of the anterior surface of the cornea. It was related to development of a method of retrieval of quantitative data from the anterior segment 3-D OCT data. Such quantitative data, acquired from the OCT instruments commonly used in ophthalmology, was typically – up to 2008 – limited to axial distances between consecutive layers (i.e. corneal thickness [L11,L12], anterior chamber depth [L13,L14]) or irido-corneal angle [L15] within the accuracy provided by axial resolution and exact knowledge of the refractive index of the tissue. Although the use of OCT in pachymetric examinations [L16,L17] and ocular biometry [L18,L19] was widespread, its capability to be used in corneal topography estimation had been only limitedly exploited [L20].

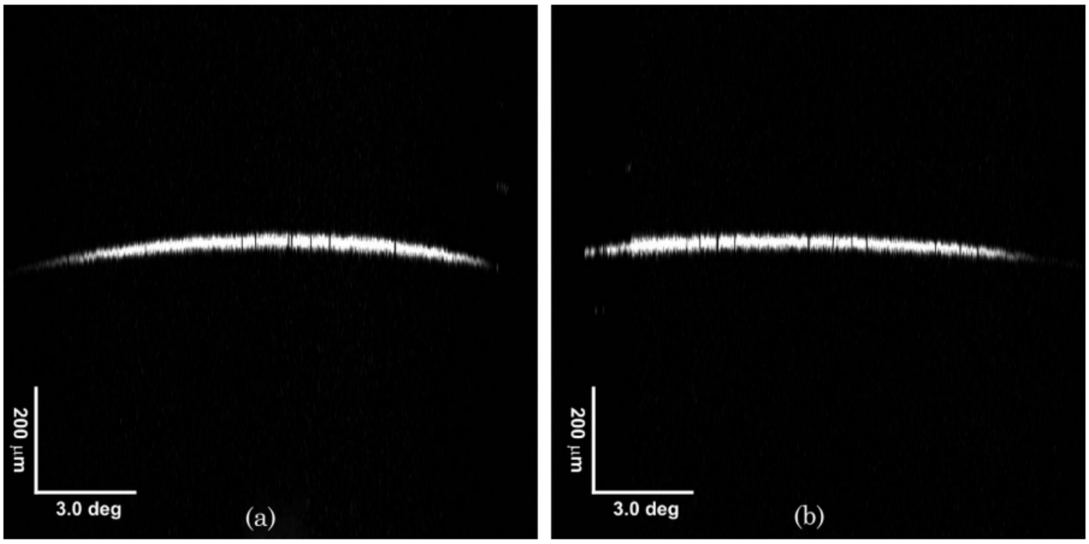

Figure 2 OCT images of a flat optical surface, captured in two mutually perpendicular directions: (a) vertical and (b) horizontal. In these figures, the effect of fan (field) distortion can be clearly observed, because the flat surface appears curved. These images are the empirical prove that the magnitude of fan distortion is different in different cross-sections. This figure was published in **[H1]**.

This situation was caused by the presence of so-called fan distortion or field distortion. This phenomenon is related to malformation of the most external structures of the samples imaged by means of optical coherence tomography: the imaged external surface appears misshaped and the information about its geometry cannot be retrieved directly from the tomograms (Figure 1). The explanation of this phenomenon could be found in a) the architecture of the scanning system [L22,L23] used in optical tomographers, where the two scanning mirrors, that deflect the scanning beam in vertical and horizontal directions, are spatially separated by some distance; b) design, position and alignment of the collimating lens in relation to the mirrors of the scanner.

The numerical simulations performed in the study **[H1]** confirmed our suppositions and showed that for a given collimating lens of a given focal length, the magnitude of field distortion depends mainly on the axial separation between the mirrors in the scanner and the distance between the lens and the scanning system. We have proved that for a given separation between the mirrors in the scanner, an optimal position of the collimating lens can be found, assuring the least magnitude of field distortion. However the field distortion cannot be totally eliminated by means of hardware modification. It was shown that the OCT images of a sample cannot be considered as its representation in the Cartesian coordinates (x, y, z), but rather in the system of coordinates (θ, φ, L), where L denotes the optical path along a ray and (θ, φ) are angles (horizontal and vertical, respectively) of the mirrors of the scanner, which can be explicitly related to the angular coordinates of a ray that reaches the imaged sample in the object space.

Such an approach became the basis of development of a numerical method of calibration of the OCT instrument, consisting of two stages: 1) experimental estimation of the magnitude of field distortion and 2) numerical correction of this distortion. This method was first described in **[H1]**. The OCT data to be corrected in this work was captured with use of a custom-developed time domain OCT system (TdOCT). This system had the capability to capture confocal images of the sample, which enabled the optimal alignment of the sample in relation to the optical setup (signal-to-noise ratio optimization). Capturing the confocal images of a 2-D periodic mesh and their precise analysis was one of the most crucial actions for the calibration of the instrument. The efficiency of the proposed method was tested on the example of spherical optical elements, made of plastic material of a known radii of curvatures. The method of the OCT instrument calibration and correction of the field distortion as an effective method of acquiring the topographical maps was granted with an international patent protection **[H13]**.

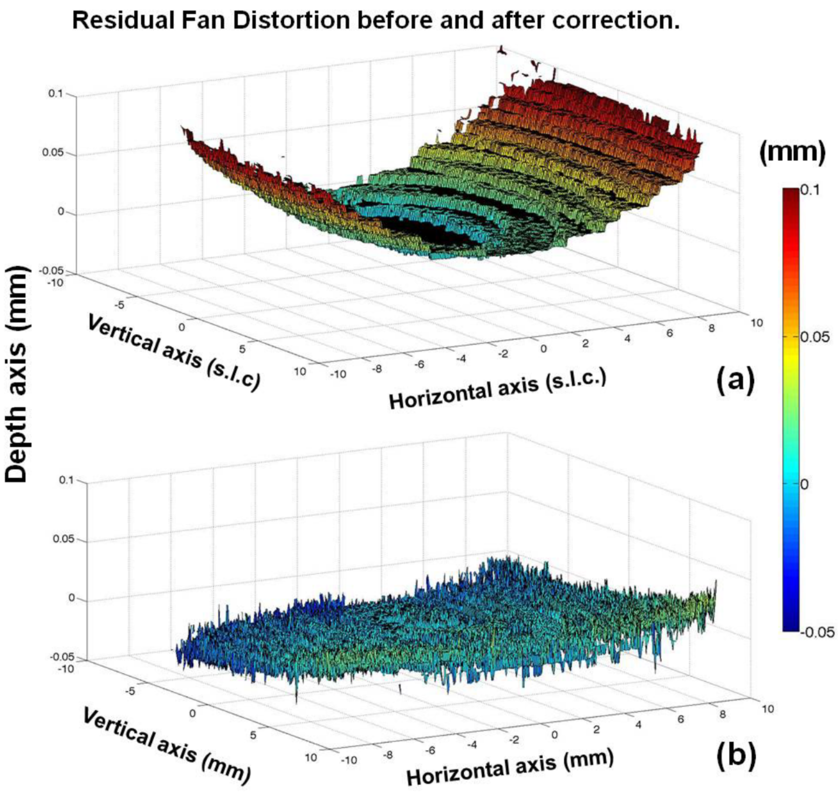

Figure 3 (a) Map of field distortion captured with use of a spectral OCT system for a flat optical surface. This surface is represented in local coordinates of the OCT instrument (system local coordinates, s.l.c.). (b) residual field distortion after field distortion correction, represented in Cartesian coordinates. This figure was published in **[H2]**.

In the next publication **[H2]**, the calibration procedure developed with my significant contribution, was successfully implemented to a spectral OCT system (SOCT), constructed in a cooperation with the Optical Biomedical Imaging Group at Nicolaus Copernicus University in Toruń. As the confocal channel was impossible to be implemented in the instrument of that type of OCT technique, for the purposes of the imaged surface representation in Cartesian coordinates, I used 2-D *en face* images of a grid of a well-determined period. Each of such *en face* images was a result of the axial integration of the 3-D OCT data of the grid. It enabled me to determine the shape and magnitude of the field distortion of the SOCT system (Figure 3) and estimate the topographies of test elements made of plastic materials.

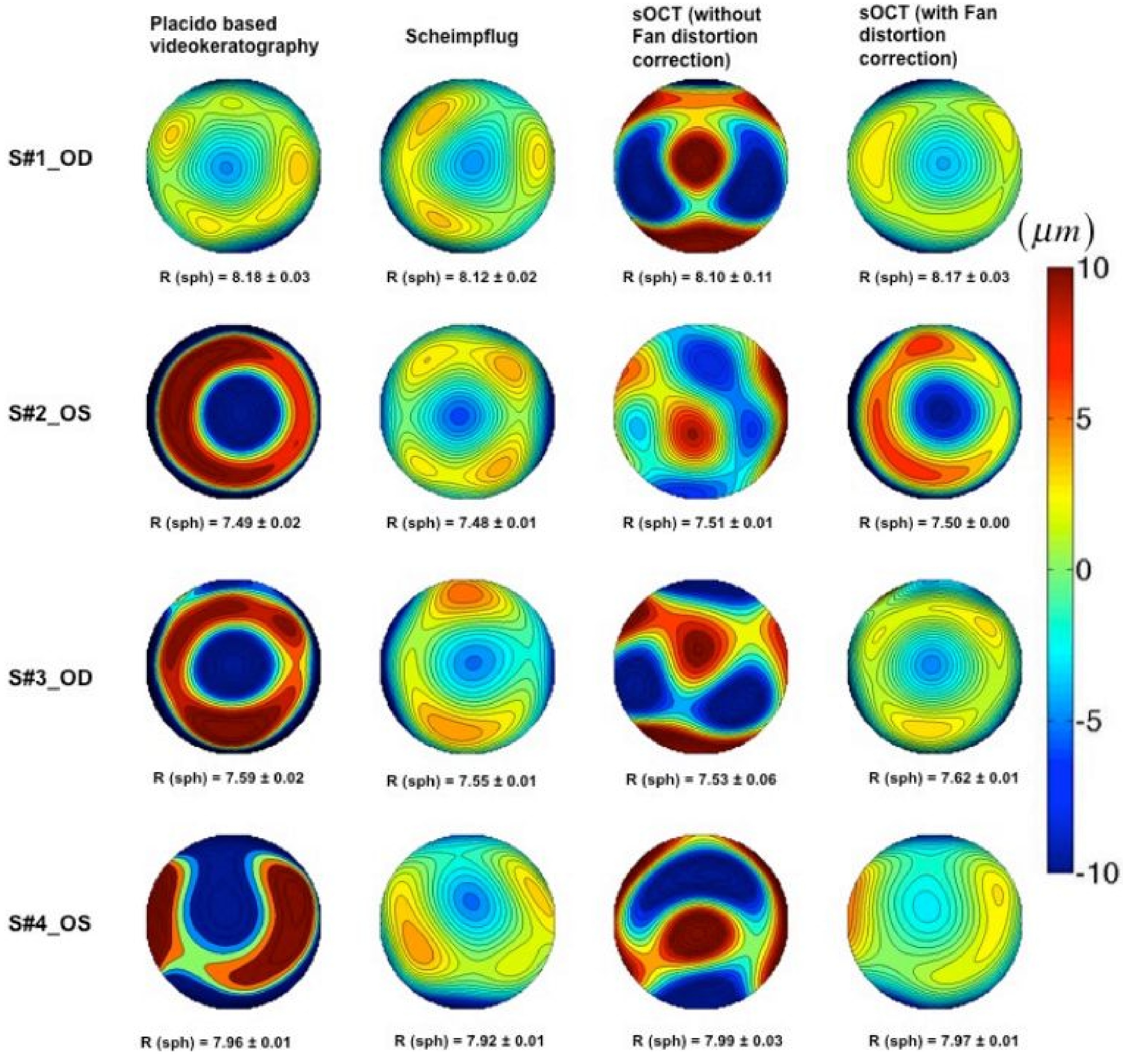

Figure 4 Comparison of maps of differences between the real topography (elevation) of the anterior surface of the cornea and the best fitting sphere, estimated for four different *in vivo* subjects by means of various techniques and ophthalmic instruments. From left to right: Placido based videokeratography, Scheimpflug imaging, SOCT before field distortion correction, SOCT after instrument calibration and field distortion correction. *R* denotes the radii of curvature of the best fitting sphere. This figure was published in **[H2]**.

Capability of using the same calibration procedure and elimination of the field distortion from the 3-D OCT data from spectral OCT device has enabled to use the optical coherence tomography in corneal topography measurements *in vivo*. In case of time domain OCT it was impossible, because of extremely long data acquisition time, when compared to the movability of the eye globe. For the purposes of the study described in **[H1]** the acquisition of the full 3-D information about the imaged surface – by means of TdOCT instrument – took even up to 1 minute. While with use of the instrument based on the spectral OCT technique, the acquisition time of the whole 3-D information was less than 0,8 seconds. Such a short acquisition time was a compromise between the lateral sampling density and the eventual presence of undesired motion artifacts of the eye globe. The comparison of the results of the corneal topography measurements by means of calibrated SOCT shows a significant similarity to the results obtained by means of commercial instruments used in ophthalmic practice (Figure 4).

The method of OCT device calibration and field distortion correction – developed and described in the studies **[H1,H2,H13]** - appeared to be an essential step in the investigations aimed to retrieve not only qualitative, but also quantitative information about the geometries of the imaged elements from the OCT data. Although it is natural that the field distortion itself concerns the most external surfaces – such as the anterior surface of the cornea – but its correction was an essential and very necessary stage while estimating the shapes of deeper parts of the eye, such as the posterior surface of the cornea and the anterior surface of the crystalline lens.

2.2.3. Anterior chamber [H3, H4]

An intrinsic feature of optical coherence tomography, just similar to any other interferometric techniques, is that the raw data captured with its use, contain information on the optical path inside the imaged sample. It means that all the raw, unprocessed OCT images are the representation of the optical path – rather than geometrical one– of a ray within the imaged structure. As it was shown in **[H1]**, each particular A-scan in OCT data, corresponding to a single line in an OCT image (B-scan) or in a 3-D scan, contains the information on the “history” of the scanning beam. This “history” incorporates the information about the refractive/reflection/scattering indices changes along the ray path, while the spatial information on where do these changes take place is given indirectly. In practice it means that the OCT images of the anterior chamber of the eye do not take into account the refraction of rays on the surfaces of cornea and crystalline lens. They are just a graphical representation of optical paths of rays comprising the scanning fan. That is why a very significant distortion of geometrical dimensions of the imaged elements can be observed on raw OCT images. In bibliography this phenomenon is called an **optical distortion** and it needs to be emphasized that its characteristics and magnitude are not accidental at all.

In the case of investigations aimed to reveal the quantitative information on shapes of anatomical elements of the eye globe, such as the posterior surface of the cornea and the anterior surface of the crystalline lens, the optical distortion becomes an undesired effect resulting in counterfeiting the real data. The OCT data need to be processed in order to correct this unwanted effect.

The first stage of the optical distortion procedure was to develop an accurate ray tracing algorithm through the optical surfaces given in a form of discrete points **[H3]**. This algorithm was developed together with the members of Visual & Biophotonics Lab at Consejo Superior de Investigaciones Cientificas in Madrid. By means of the Delaunay triangulation method, any surface of any geometry can be approximated with a set of flat triangles, as it is usually done in the finite-element method (FEM). Each of these triangles can be described with use of a characteristic vector, normal to the triangle. In this notation, the problem of refracted/reflected ray calculation comes down to finding the exact triangle that is intersected by an incident ray. Thus the vectorial Snell’s law can be calculated, based on the knowledge of the directional cosines of the incident ray and the normal vector, characteristic to the exact triangle of incidence and the refractive indices of the media. Effectivity of the proposed algorithm was tested, with regard to its accuracy and time consumption. The results obtained in the study showed that the described method – due to its flexibility and applicability to the surfaces given in a form of discrete data points (i.e. obtained from the OCT imaging) – could be successfully applied as a tool for further development of the optical distortion correction procedure from the OCT images.

Naturally, the next step was to develop the numerical procedure of optical distortion correction to be used for the purposes of reconstruction of geometry of the eye's internal structures. In the next study **[H4]** we have presented such a procedure. It consisted of several smaller algorithms: a) calibration of the OCT instrument and field distortion correction **[H1,H2,H13]**, b) OCT data denoising, c) segmentation of the OCT data and distorted surface reconstruction, d) ray tracing through the surfaces given as a set of discrete points **[H3]**. The proposed method assumed *a priori* knowledge of the group refractive indices of cornea and aqueous humor for the wavelength used for OCT data recording. These data – influenced by both the field and optical distortions – after initial denoising and contrast enhancement, underwent the segmentation in order to identify the consecutive surfaces and to calculate of the optical paths between them. The topography of the most external surface (namely: the anterior cornea) was obtained after correction of the field distortion of the OCT instrument. The proper calibration of the device is also a source of information on directional cosines of rays forming the scanning fan. The detailed corneal topography and directional cosines of the rays reaching the cornea were the input data for numerical ray tracing algorithm through the anterior corneal surface. The output were the directional cosines of rays refracted on this surface. If one calculates the lengths which are equal to the optical paths divided by the refractive index and puts them along the corresponding directional cosines, the resulting endpoints of these lengths assembled together give the information on the shape of the next imaged surface, ready for further interpretation and analysis.

The proposed method was tested on an opto-mechanical eye model of known geometrical parameters, on a porcine eye *in vitro* and on human eye *in vivo*. The results were compared to the nominal data (for the eye model) and to the data from commercial Scheimpflug camera (for the eyes *in vitro* and *in vivo*). The comparative analysis of the posterior corneal surface reconstruction showed high efficiency of the method proposed in the study. The discrepancies between the results obtained from the commercial instrument and the corrected OCT data were estimated to be about 1%. This way it was proved that the 3-D optical distortion correction plays a significant role in quantitative analysis of the OCT data of the anterior segment of the eye and enables a plausible reconstruction of the geometry of inner structures of the eye. These conclusions were confirmed also for the anterior surface of the crystalline lens in further investigations [L24,L25].

2.2.4. Crystalline lens [H5, H6, H7]

In the case of investigations aimed to reconstruct the geometry of the anterior segment of the eye, the optical distortion is an undesired phenomenon, resulting in significant counterfeiting the real information on the inner structures of the eye. However a completely different approach to the problem is possible, as well. Since the optical coherence tomography is a way to visualize the information on the optical path, in the case of OCT data of an inhomogeneous medium – i.e. gradient index medium – the profile of the surface distorted by the presence of a gradient should contain the encoded information on the gradient index distribution within such an inhomogeneous sample. The shape of such profile obtained for a homogenous medium should be remarkably different from the shape obtained for a gradient index medium. Such a breakthrough would be particularly valuable for the case of a crystalline lens – still not fully elucidated due to its location inside the eye globe, its inaccessibility and intersubject variability.

The observation mentioned above was the starting point to the series of investigations of another element of the anterior segment of the eye: a crystalline lens. The goal of these studies was to develop a numerical method aimed to obtain the information on the gradient index distribution inside the crystalline lens. The studies were performed in cooperation with a group of researchers from Bascom Palmer Eye Institute in Miami, who captured and provided the OCT images of a number of human crystalline lenses *in vitro*.

In the first approach it was required to verify the validity of this postulate **[H5]**. For this purpose I developed the data collection methodology, required for numerical OCT images simulations. OCT images of human lenses *in vitro* were captured in two different configurations: a) “Anterior-up” configuration with the anterior surface facing the OCT beam and the posterior surface was distorted by the presence of gradient index in the lens medium; b) “Posterior-up” configuration where the lens was carefully rotated around its horizontal axis and the posterior surface faced the OCT beam (*Figure 5*). This methodology was adopted by the group from Bascom Palmer Eye Institute.

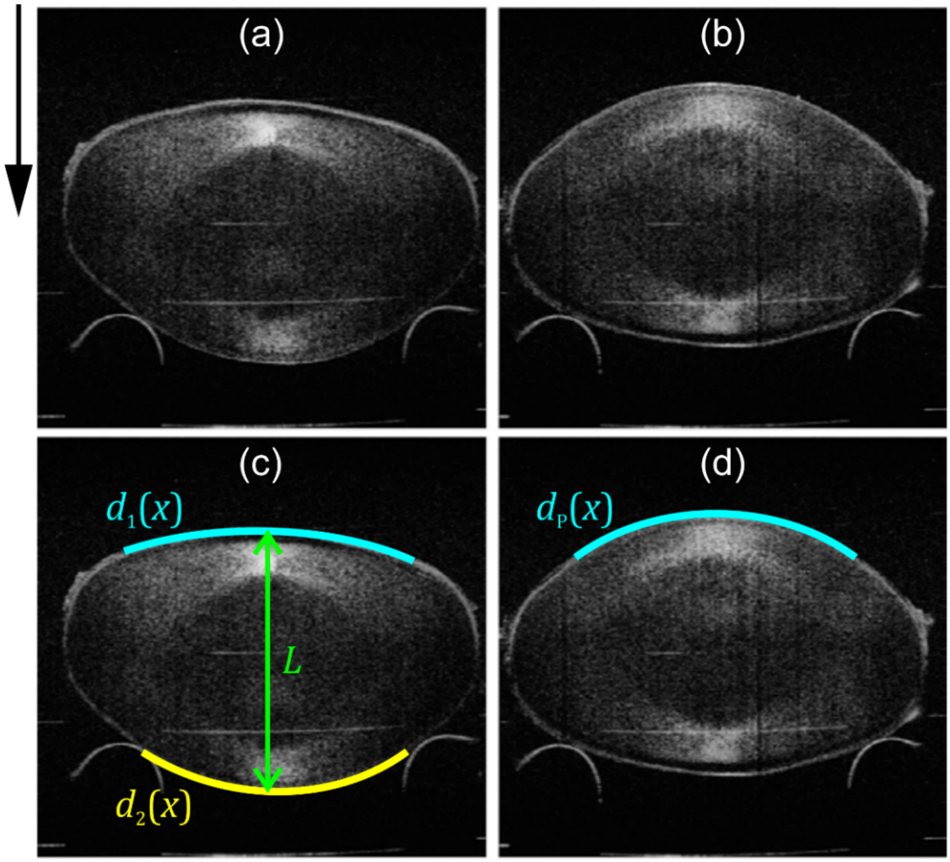

Figure 5 OCT images of a single crystalline lens *in vitro*, captured in „Anterior-up” configuration (a and c) and in “Posterior-up” configuration (b and d). The black arrow on the left side shows the incidence direction of the scanning beam. Blue solid lines represent the profiles $d_1(x)$ and $d_P(x)$ distorted only by the homogenous preservative medium ($n = 1{,}345$ for $\lambda = 825$ nm). The green arrow depicts the optical path L along the axis of the sample. The yellow solid line represents the profile $d_2(x)$ of the posterior lens surface in configuration “Anterior-up”. This profile is distorted by the presence of gradient index distribution within the lens preceding the posterior lens surface. In numerical simulations the shape of this profile was used as a reference profile.

Field-distortion-free tomograms of human lenses *in vitro* underwent numerical processing in order to retrieve the following data:

- profiles of the anterior and posterior lens surface (respectively: $d_1(x)$ and $d_P(x)$), optically distorted by the homogenous refractive index of the preservation fluid, in which the crystalline lens was immersed;
- profile $d_2(x)$ of the posterior lens surface in the “Anterior-up” configuration, optically distorted as a result of transition of the scanning rays through the gradient index medium of the crystalline lens;
- optical path L on the axis of the crystalline lens.

Moreover, from the provided shadowphotographs of the same lens it was possible to obtain the actual axial thickness t of the crystalline lens. The knowledge of this parameter enabled calculation of the average value n_L of the refractive index along the axis of the lens.

Having the distorted profiles $d_1(x)$ and $d_P(x)$ it was possible to estimate the actual profiles $z_1(x)$ and $z_P(x)$ of the anterior and posterior surface, respectively. $z_1(x)$ and $z_P(x)$ together with the axial thickness t were the data on the real geometry of the crystalline lens. The actual profiles $z_1(x)$ and $z_P(x)$, the distorted profile $d_2(x)$, the axial thickness t and the average refractive index along the axis n_L comprised the full set of input data of OCT data simulations of the gradient index crystalline lens. In order to perform the numerical simulations, it was required to assume the type of an analytical function that would describe the gradient index distribution within the lens. For this purpose I assumed one of the functions for which the shape of isoindical contours followed the external shape of the lens [L26].

The goal of numerical simulations performed in the study described in **[H5]** was to prove that it is possible to find such parameters of gradient index distribution, which would result in the deformation of the posterior lens surface, similar in shape to $d_2(x)$ profile, obtained in the experiment. My simulations showed that for each of 12 human crystalline lenses used in the study (aged from 6 to 90 years) it was possible to estimate the optimal values of the gradient index distribution given in an analytical form. What is particularly important, the simulations proved that the discrepancies between the distorted profile for the gradient index of optimal values of refractive index distribution parameters and the distorted profile from the experiment are significantly smaller than for simulations performed for homogenous medium. It turned out that the central radius of curvature of the profile distorted by the presence of the inhomogeneity of the refractive index within the lens is not significantly different from the radius of curvature obtained for a constant refractive index. But unlike the radius of curvature of the distorted surface, its asphericity is remarkably different for GRIN and homogenous media. This way the postulate that the profile of the surface optically distorted by the gradient index inside the lens contains the information on the distribution of the gradient has been proved.

Thereafter, the methodology presented in **[H5]** was the basis for development of a numerical method of estimation of values of refractive indices in the core and cortex of human crystalline lens *in vitro* [AP6] from OCT images and with an *a priori* assumption of a general formula used for analytical description of gradient index distribution. An essential element of this method was proper definition of a merit function, taking into account the discrepancies between the experimental optical path within the crystalline lens obtained from OCT data and the simulated path estimated by means of numerical ray tracing through gradient index medium. The procedure – based on heuristic routine of genetic algorithms – searched for the optimal values of gradient index distribution parameters, corresponding to the minimum of the merit function.

The goal of the study presented in **[H6]** was to verify the developed method and to validate its capabilities in the reconstruction of gradient index distribution of isolated human crystalline lenses of different ages. The reason of the importance of this study is that the human crystalline lens – with its functions and abilities – plays an essential role in the optical system of the eye; but because of its location inside the eye globe, its complex anatomy, its age and intersubject variability, the crystalline lens still has not been fully discovered.

The OCT images of nine cadaver lenses were analyzed in the study. The donor age ranged from 6 to 72 years. The results of this analysis showed that for seven lenses the values of their average refractive index $n_{śr}$ along the axis were between 1,409 and 1,423. For two lenses the estimated values of average refractive index were out of this range. The apparent discrepancies could be due to small positioning errors in the measurement setup. The analytical model of gradient index distribution used for the purpose of this study was the model proposed by Manns et al. [L27]. This model is described by the following parameters: n_0 – refractive index at the surface of the lens, $n_{\max}$ – refractive index in the nucleus and p – power coefficient describing the steepness of the gradient. The optimal values of $n_{\max}$ ranged from 1,399 to 1,434 for all the lenses under consideration, while the optimal values of n_0 ranged from 1,351 to 1,388. These values did not present any systematic variation with age (p-value = 0,39 and 0,37, respectively) and because of relatively high dispersion of the data, no trend with age could be found. However the values of power coefficient p increased significantly with age (p-value = 0,039). Although the study was conducted on a relatively small statistical sample, the obtained results confirmed the results of earlier studies achieved by means of other experimental techniques [L28,L29,L30,L31]. The investigations presented in **[H6]** showed that the accuracy of estimation of gradient index distribution parameters is mainly limited by experimental errors (i.e. centration of the sample) and experimental setup (the axial resolution of the setup used in the study was around 10μm). The profile of the distorted posterior lens surface obtained from the simulations performed for the optimal values of GRIN distribution parameters was compared to the values obtained from the OCT images and the magnitude of the discrepancies (not larger than 15μm) was comparable to the axial resolution of the OCT instrument used in the study.

Next challenge in the investigations into quantitative information retrieval from OCT data of a crystalline lens was the GRIN optical distortion correction so that the actual shape of its posterior surface and axial thickness for lens could be reconstructed. Described in **[H4]** the optical distortion correction method was designed for a homogenous medium and appeared to be not effective enough if applied for gradient index media, such as crystalline lens. Therefore, for the purposes of the study described in **[H7]** I developed the algorithm of the OCT data correction, appropriate for application to inhomogeneous refractive index distribution. The starting point in the investigations on this algorithm were, again, the OCT images of the isolated crystalline lens. An element of a crucial importance to the proposed algorithm [Figure 6] is a proper selection of an analytical model of the gradient index distribution in the lens medium, so that the shape of isoindical contours would follow the external geometry of the crystalline lens. These parameters of the model, which are independent of the lens geometry (for the Manns model [L27] such parameters are: n_0 – refractive index at the surface of the lens, $n_{\max}$ – refractive index in the nucleus and p – power coefficient) could be presumed from the literature data, taking into account the age of the lens under consideration. The correction algorithm requires also the initial knowledge of the anterior lens surface geometry (namely: its radius of curvature R_a and conic constant k_a), which can be estimated basically from the same OCT images, already corrected from the optical distortion for homogenous media. The rest of the input: the initial values of the parameters related to the posterior surface – its radius of curvature R_p, its conic constant k_p and axial thickness of the lens t could be acquired from the initial estimation, i.e. based on preliminary distortion correction performed as if the lens was a homogenous medium. The raytracing algorithm and optical path calculation is repeated iteratively until the distorted posterior surface profile in simulations will be as similar to the profile from the OCT experiment as possible. Each single iteration is related to the modification of current values of the posterior surface parameters R_p and $k_p$and the current lens thickness t, what would result in revision of the gradient of the index distribution and the overall shape of the isoindical contours.

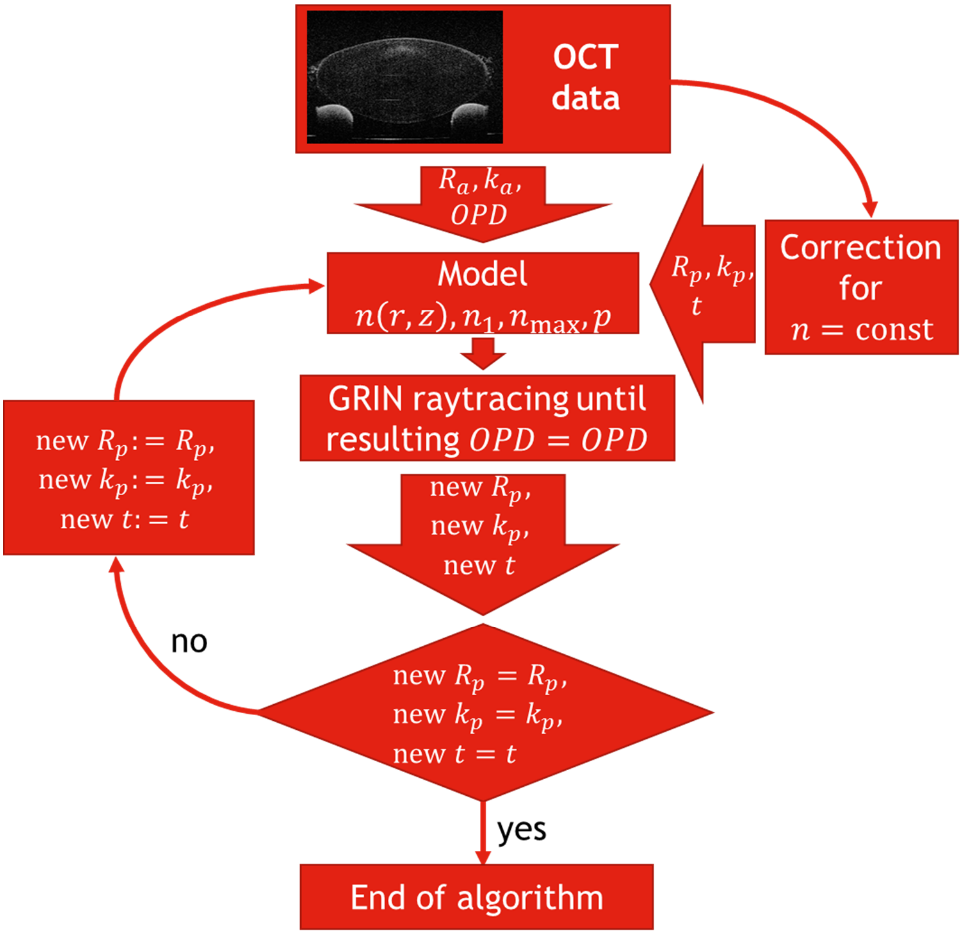

Figure 6 The block diagram of the algorithm for the correction of optical distortion of a gradient index lens. R_a denotes the axial radius of curvature of the anterior lens surface. k_a denotes the conic constant of the anterior lens surface. R_p denotes the axial radius of the posteriori lens surface. k_p denotes the conic constant of the posteriori lens surface. t denotes the axial thickness of the lens.; OPD denotes the optical path along the optical axis of the lens.

In the same study **[H7]** the GRIN distortion correction algorithm was tested for the accuracy of the reconstruction of the actual geometry of the crystalline lens. For this purpose the optimal values of the posterior surface parameters, being the result of the proposed algorithm, were compared to their actual values obtained from the OCT measurements in the “Posterior-up” configuration. The reconstructed values of R_p and k_p manifested only a slight improvement as compared to standard methods of correction for homogenous media. However the reconstruction of the axial lens thickness by means of GRIN distortion correction was apparently improved.

Taking into account that the reconstruction of the posterior lens surface is based solely on the input data of: a) the actual shape of the anterior surface of the lens and b) the distorted profile of the posterior lens surface, affected by the presence of the gradient refractive index, the proposed algorithm is the very first step of essential importance for retrieval of the quantitative information on the crystalline lens geometry from its OCT images captured *in vivo*. In work **[H7]** a discussion was included on the elasticity of the proposed algorithm, related to i.e. incorporating any of existing procedures of raytracing or any other analytical models for description of the gradient index distribution. This brings perspectives of further development of the described method.

2.2.5. Intraocular lenses (pseudophakia) [H8, H9, H10, H11]

In some pathological conditions, i.e. when the crystalline lens becomes opaque (cataract) or its mechanical damage, the only effective method of therapy is a surgical intervention of removal of pathologically altered natural lens and its replacement with an artificial implant – so called intraocular lens (IOL). In the eye with implanted IOL – called hereafter a pseudophakic eye – the artificial implant takes over all the optical functions of the removed crystalline lens. Such an implant becomes a very significant element of the anterior segment of the eye and the whole optical system of the eye. The quality of vision and visual comfort of a patient depends essentially on the optical parameters of the IOL implanted in his eye. From the optical point of view it means that the design parameters (to be more precise: geometrical and optical ones) of such an implant should ensure the optical performance as high as possible. For this reason it is crucial to have the pseudophakic eye numerically modelled and to have its optical performance numerically quantified.

In the work **[H8]** I used such a numerical model of a pseudophakic eye for the purposes of estimation of the influence of the natural lens and the IOL localization inside the eye on the optical performance. While the natural lens displacement could be caused only by a strong strike, the localization of an IOL inside the eye is rather random and depends mainly on surgeon's personal experience. In this work I estimated the influence of a) lens and IOL tilt, b) their decentration and c) their horizontal dislocation on the optical performance quality in both the monochromatic and polychromatic light conditions. For this purpose I used the numerical model of the eye described for the first time by Liou and Bennan [L32], at that time widely considered as a gold standard. The pseudophakic eye model was constructed from the same model by replacing the gradient crystalline lens from the original with a model of an intraocular implant made of polymethyl methacrylate (PMMA). The IOL power and its initial axial placement inside the model were calculated from the empirical formulas normally used in ophthalmological practice [L33,L34]. The results of simulations showed that the optical performance of the pseudophakic eye model is significantly lower – in terms of optical quality metrics – than the optical performance of the original model – both in mono- and polychromatic light. However, the decrease in the optical performance quality for the increasing tilt and decentration are relatively lower for IOL than for "natural" gradient lens. It would suggest a lesser "sensitivity" and better tolerance of the retinal image parameters on the changes of IOL localization: the same magnitude of tilt/decentration/displacement results in relatively smaller decrease of the optical performance quality for the artificial implant than for the gradient lens. The increased tolerance of the image quality to the axial, vertical and angular localization of the implant inside the eye is particularly important in the case of a real surgical intervention, when the perfect precision of IOL placement is barely possible.

During the investigations conducted for the purposes of the work described above, for the first time in my career I focused my attention on the chromatic aberrations of a pseudophakic eye. This topic seemed to be interesting, novel and still not many studies had been performed in this area. The literature studies I have made showed that only a few sources presented the chromatic dispersion properties of the materials used for fabrication of IOL implants. Their full review – as for 2008 – is presented in the paper **[H9]**. In works **[H8]** and **[H9]** I used these data for the purpose of the polychromatic optical performance analysis of the numerical models of a pseudophakic eye. The simulations performed in these studies manifested that the magnitude of the longitudinal chromatic aberration of these models is essentially larger than its "physiological" value obtained for a model of a healthy eye. It is particularly important, because the physiological amount of the longitudinal chromatic aberration on the level of 2 diopters is a significant impulse for accommodation [L35,L36] and its excess may lead to visual discomfort [L37]. This thesis was the basis for the development of an idea of a new, hybrid – refractive-diffractive – intraocular lens, which would decrease the total longitudinal chromatic aberration of a whole pseudophakic eye to the physiological level, typical for healthy eyes. Diffractive IOLs already exist, they are used in so called multifocal intraocular lenses: an artificial substitute of accommodation, enabling both far and near vision. In case of the proposed hybrid IOL, the new approach stands for the particular role of the diffractive structure: it is meant to partially correct the longitudinal chromatic aberration of the whole pseudophakic eye to the level of the chromatic aberration of a healthy eye.

In the work **[H9]** I proposed that such an IOL could be fabricated with use of any of optical materials currently used for their production and the diffractive pattern could have the form of a kinoform in order to ensure the highest possible diffractive efficiency. The simulations of the optical performance performed in the study showed that both the polychromatic Point Spread Function (PSF) and the polychromatic Modulation Transfer Function (MTF) obtained for pseudophakic model eye with hybrid IOL would have similar (or even slightly better) characteristics when compared to the model of a healthy eye with physiological chromatic aberration.

The next two papers: **[H10]** and **[H11]** present experimental studies, aimed to complement the scientific knowledge on the actual polychromatic features of intraocular implants. In the work **[H10]** I used a simple optical setup in Bessel configuration for measurements of the *in vitro* focal lengths of several IOLs and its chromatic aberration (in the air). The accuracy of focal length estimation, estimated to be at the level of ±0,1mm was obtained due to high quality interference filters, precise measurement of the lens axial movement and a CCD array used for capturing the sharp images formed by the lens under investigation. Having the focal lengths measured in air for different wavelengths, it was possible to assess the chromatic dispersion curves of the materials used for these IOLs and, in result, to estimate the longitudinal chromatic aberration of a pseudophakic eye. The obtained results validated my earlier suppositions, that the longitudinal chromatic aberration of an eye with IOL is significantly larger than in the case of a healthy eye.

The paper **[H11]** presents the results of the chromatic aberration of pseudophakic eyes *in vivo*. The measurements were performed with use of a custom-modified refractometer. The modification was done to its illuminator, where the original one was replaced by a custom-designed illuminator, equipped with a single RGB diode of a well-estimated, sharp spectral characteristics for each of its color. The *in vivo* measurements were performed in a cooperation with the group of physicians from the Department and Clinic of Ophthalmology, Wrocław Medical University. The pseudophakic subjects were classified into two groups, taking into account the types of implanted IOLs. The control group of healthy subjects were measured as a reference. The intraocular lenses being measured in this study were fabricated by the same manufacturer of the same material, but their spectral transmission characteristics were different due to the presence of additions: the material of one type of IOL contained a color filter aimed to block the blue light; the other group of IOLs did not contain such a filter. The refractive error was measured for three wavelengths: red 660 nm, green 525 nm and blue 470 nm. The obtained results showed that the longitudinal chromatic aberration measured for subjects implanted with IOL without the blue-blocking-filter was significantly larger than for the control group. Whereas the chromatic aberration for subjects implanted with IOL with the filter had essentially the same magnitude as the control group. This suggests that the presence of additions (i.e., chromatic blockers) in the IOL material may significantly decrease the magnitude of the pseudophakic eye's chromatic refractive error shift and, in result, its optical performance in polychromatic light. It is rather unlikely that the blue-light blockers simply decrease the magnitude of the total longitudinal chromatic aberration of the pseudophakic eye. However, they may diminish its visual effect by dimming the short wavelengths and, therefore, weighing the polychromatic sensitivity function.

The obtained results confirmed the other investigations [L38,L39] performed on the same types of intraocular lenses, but with the use of other experimental techniques.

Taking into account still not a large number of bibliographic positions presenting the empirical data of dispersive properties of intraocular lenses in polychromatic light, both papers **[H10]** and **[H11]** make a significant contribution to the state of scientific knowledge in this topic.

2.2.6. Dynamics of the geometry changes of the irido-corneal angle [H12]

Under the influence of these subtle changes of the intraocular pressure and a pulsatile blood flow through the retinal arteries, aiming to supply the anatomical structures of the eye in oxygen and nutrients, the whole eyeball undergoes some rhythmical changes of its volume [L40,L41]. As a result, some periodical dislocations and sine changes in the shape of the cornea and sclera can be observed [L42,L43]. Also the internal structures of the eye globe, such as irido-corneal angle, are subject to these kind of changes.

A noticeable continuous development of optical coherence tomography and improvements of its instrumentation has made this imaging method one of the most versatile and universal diagnostic techniques not only in ophthalmology. As a source of reliable and detailed data on the internal structures, that cannot be imaged by means of other techniques, the optical coherence tomography still finds new applications. Taking into account the axial resolution of the tomographic images and the acquisition rate still being improved by using the cutting-edge instrumentation, the optical coherence tomography seems to be a perfect tool to investigate the dynamics of the changes in the anterior part of the eye [L44] induced by the pulsatile variability of the intraocular pressure. To the best knowledge, the only one study related to the ocular pulse estimation by means of OCT was the study performed by Dion et al. [L45], but the analytical method proposed by the authors was limited only to single A-scans of the OCT data.

In the work **[H12]** I proposed a new method of temporal and spectral analysis of the sequences of 2-dimensional OCT images of the irido-corneal angle, captured with the acquisition rate of 22,7 Hz (Figure 7). I also presented preliminary results of the investigations into the dynamics estimation of the changes in the irido-corneal angle geometry captured with use of a commercial anterior chamber OCT instrument. The sequences of OCT B-scans captured for glaucomatous subjects (aged from 65 to 70 years old) manifested subtle, but – from a scientific point of view – substantial changes in the geometry of the irido-corneal angle. The results of spectral analysis of the angle geometry fluctuations obtained for different subjects featured specific peaks at different frequencies related to different activities, including breathing, involuntary head movements and, what is most interesting, blood pulsation in the ocular vessels. The frequencies of peaks related to the latter activity manifested intersubject variability. It was a prove that the OCT technique has a potential for the investigations into ocular dynamics. However the nature and the origin of changes in the anterior chamber geometry captured by means of OCT and eventual usability of this imaging method in early diagnostics of glaucoma are still to be discovered in studies conducted on a larger population sample, taking into account various types of glaucoma disease.

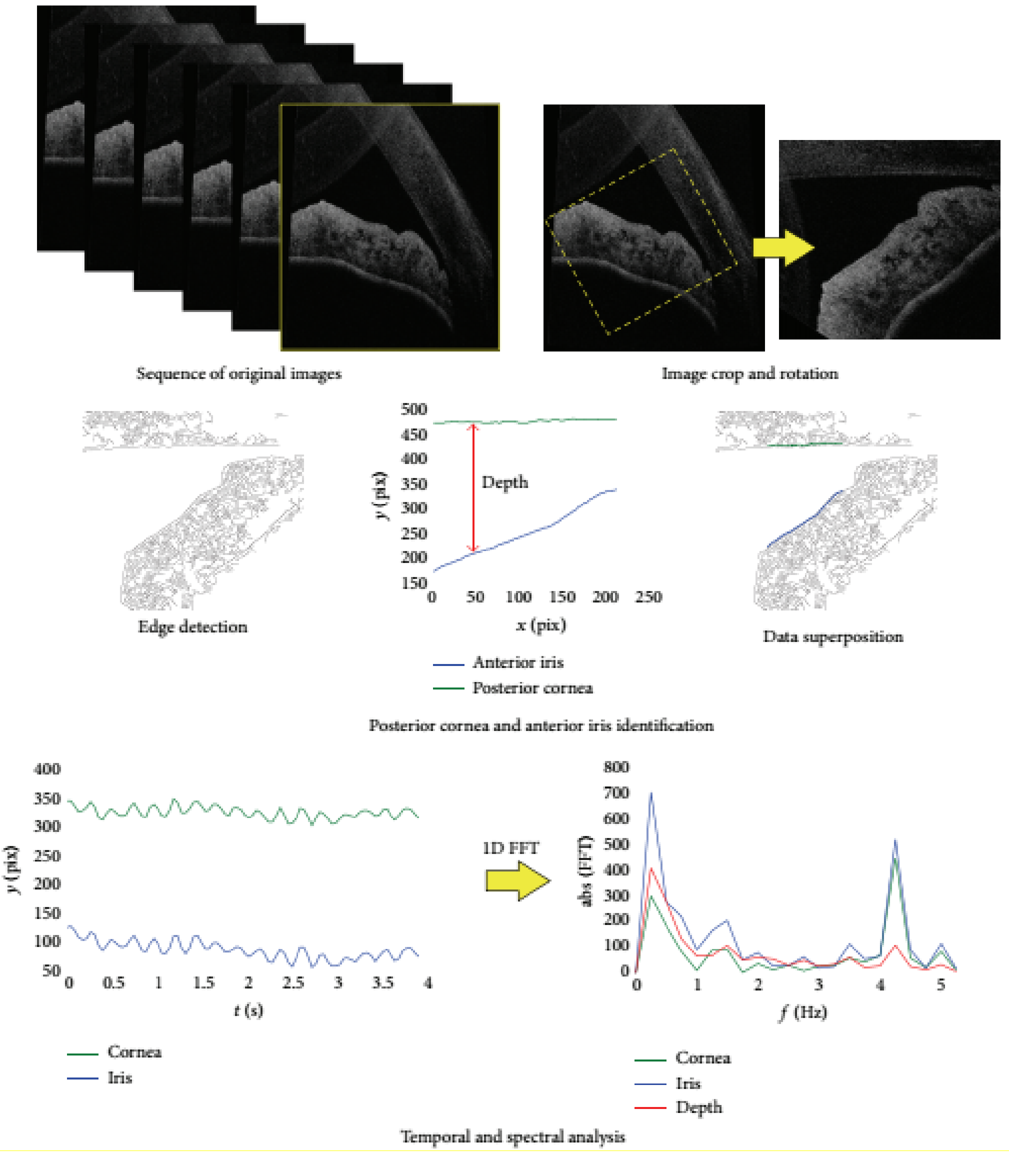

Figure 7 Several stages of the analysis procedure of the sequences of the OCT images of the irido-corneal angle aimed to estimate the dynamics of its geometry changes. This figure was published in **[H12]**.

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L38. Nagata T, Kubota S, Watanabe I, Aoshima S, "Chromatic aberration in pseudophakic eyes," *Nihon Ganka Gakkai Zasshi* 1999;103:237-242.

L39. Perez-Merino P, Dorronsoro C, Llorente L, Duran S, Jimenez-Alfaro I, Marcos S, "In vivo chromatic aberration in eyes implanted with intraocular lenses," *Invest Ophthalmol Vis Sci* 2013;54:2654-2661.

L40. Northrop RB, Nilakhe SS, „A no-touch ocular pulse measurement system for the diagnosis of carotid occlusions," *IEEE Trans Biomed Eng* 1977;24:139−148.

L41. Silver DM, Farrell RA, Langham ME, O'Brien V, Schilder P, „Estimation of pulsatile ocular blood flow from intraocular pressure," *Acta Ophthalmol Suppl* 1989;191:25−29.

L42. Kowalska MA, Kasprzak H, Iskander DR, Danielewska M, Mas D, „Ultrasonic in vivo measurement of ocular surface expansion," *IEEE Trans Bio-Med Eng* 2011;58:675-680.

L43. Danielewska M, Iskander DR, Kowalska MA, Kasprzak H, „Phase dependencies between longitudinal corneal apex displacement and cardiovascular signals: is the ocular pulse influenced by the electrical activity of the heart?," *Clin Exp Optom* 2012;95:631-637.

L44. Gambra E, Ortiz S, Perez-Merino P, Góra M, Wojtkowski M, Marcos S, „Static and dynamic crystalline lens accommodation evaluated using quantitative 3-D OCT," *Biomedical Optics Express* 2013;4(9):1595-1609.

L45. Dion C, Singh K, Ozaki T, Lesk MR, Costantino S, „Analysis of pulsatile retinal movements by spectral-domain low-coherence interferometry: influence of age and glaucoma on the pulse wave," *PLoS One* 2013;8:e54207.

3. Scientific activity

3.1. List of scientific papers and conference presentations before obtaining the doctoral degree

3.1.1. Scientific papers

AB1. D. Siedlecki, H. Kasprzak, B.K. Pierscionek, "Schematic eye with a gradient-index lens and aspheric surfaces," *Optics Letters* 2004;29(11):1197-1199.

IF: 3,882[a] Number of citations: 30[b]

This paper presents the results of investigations performed in the framework of my doctoral thesis. My personal contribution to this paper was: co-authorship of the idea of the research aimed to develop a numerical model of the optical system of the eye with a radial gradient distribution within the lens. This distribution was meant to minimize the total spherical aberration of the model; implementation of the numerical algorithms of tracing rays through the gradient index medium; performing the simulations aimed to estimate the optimal values of the gradient index distribution parameters in the lens; discussion and analysis of the obtained results; manuscript preparation: bibliographical study, graphics and text edition.
Estimated personal contribution: 75%

AB2. D. Siedlecki, H. Kasprzak, "New shape of a videokeratometric illuminator," *Optica Applicata*, 2002;32(4):665-672.

IF: 0,291[a] Number of citations: 0[b]

This paper presents the results of investigations performed in the framework of my master thesis. My personal contribution to this paper was: implementation of the numerical algorithms of the reverse tracing rays reflected from the anterior surface of the cornea; performing the numerical simulations aimed to estimate the optimal shape of the videokeratometric illuminator with regard the initially assumed values of the corneal profile geometry; estimation of the image surface shape; discussion and analysis of the obtained results; manuscript preparation: bibliographical study, graphics and text edition.
Estimated personal contribution: 85%

3.1.2. Conference communicates published in conference proceedings indexed in Journal Citation Reports (JCR) database

The presenter of the communicate during the conference is marked with bold font.

CB1. **D. Siedlecki**, H. Kasprzak, "New shape of a videokeratometric illuminator – comparison with a cylindrical one" poster presented at: Light and Optics in Biomedicine, 20-22 October 2002, Warszawa, Poland. Conference proceedings: *Systems of Optical*

Security 2003, Book Series: PROCEEDINGS OF SPIE Eds.: Z. Jaroszewicz, E. Powichrowska, M. Szyjer, 2004;5566:95-99.

IF: none Number of citations: 0[b]

3.1.3. Other communicates and conference presentations

The presenter of the communicate during the conference is marked with bold font.

KB1. **D. Siedlecki**, H. Kasprzak, “Novel eye schematic model and its application in radial gradient index intraocular lens design,” poster presented at: The Joint Conference of The German Society of Applied Optics (DGaO) and Section of Optics of the Polish Physical Society (PTF), 17-20 May 2005, Wrocław, Poland. Conference proceedings: *Joint Conference of the German Society of Applied Optics (DGaO) and the Section of Optics of the Polish Physical Society. 106th Conference of the DGaO,* Erlangen: Deutsche Gesellschaft für Angewandte Optik, 2005.

KB2. **D. Siedlecki**, H. Kasprzak, B.K. Pierscionek, “Dynamical changes of corneal topography and its influence on PSF of the eye,” oral presentation at: II Topical Meeting on Physiological Meeting, 20-23 September 2004, Granada, Spain.

3.1.4. Description of the scientific activity before obtaining the doctoral degree

I am a graduate of the Faculty of Fundamental Problems of Technology at the Wrocław University of Science and Technology (formerly: Wrocław University of Technology). I finished Master’s degree in Technical Physics with a major in Biomedical Engineering – Biomedical Optics in 2001. Under Prof. Henryk Kasprzak’s supervision I accomplished my Master’s thesis entitled: “*Development of the corneal topography system*”. At that time I familiarized myself with physiological optics and diagnostics techniques used for measurements of the optical properties of the eye.

Immediately after finishing Master’s degree studies, I started doctoral studies under supervision of prof. Henryk Kasprzak. The investigations I conducted within the scope of my doctoral dissertation were related to numerical modeling the geometrical and optical properties of the optical system of the eye. In the framework of my doctoral thesis, I developed a gradient model of a crystalline lens, which – due to a specific – radial – gradient index distribution, significantly decreased the total spherical aberration of the eye. In order to obtain the results and to optimize the radial gradient index distribution parameters, I used custom-developed software (authored by me), containing the implemented algorithms of ray tracing through gradient index media. With use of this software I managed to develop almost diffraction-limited (for objects located at infinity) model of the optical system of the eye [AB1]. Finally, I used this model for the purposes of estimation of the influence of the dynamic changes in corneal topography on the retinal image parameters.

During my doctoral studies I started cooperation with Prof. Barbara K. Pierscionek. This cooperation was possible due to two short term internships at the Bradford University in UK which took place in 2003, funded by British Council Poland and State Committee for Scientific Research in the framework of The British-Polish Young Scientists Programme (YST). In the next few years this cooperation has resulted in three common publications in international scientific journals.

On 26 September 2005 I successfully defended my doctoral dissertation entitled: "*Development and analysis of a simplified model of the optical system of the eye with regard to the aberrations of a real eye*".

3.2. List of scientific papers and conference presentation after obtaining the doctoral degree

3.2.1. Scientific papers published in the journals indexed in the Web of Science database

AP1. R. Koprowski, D. Siedlecki, H. Kasprzak, Z. Wróbel, "Rapid dynamic changes of the geometry of the anterior segment of the eye: A method of automatic spatial correction of a temporal sequence of OCT images," *Computers in Biology and Medicine* 2016;72:132-137.

IF: 1,24[a] Number of citations: 0

My personal contribution to this paper was: co-authorship of the idea of research aimed to develop the numerical method of the spatial correction of the bitmaps being a part of temporal sequences of the OCT images of the irido-corneal angle; capturing the sequences presented in the paper; discussion and analysis of the obtained results; manuscript preparation: bibliographical study, graphics and text edition.
Estimated personal contribution: 35%

AP2. A. Jozwik, D. Siedlecki, M. Zajac, "Analysis of Purkinje images as an effective method for estimation of intraocular lens implant location in the eyeball," *Optik* 2014;125(20):6021-6025.

IF: 0,667[a] Number of citations: 1[b]

My personal contribution to this paper was: co-authorship of the idea of the research aimed to analyze the experimental Purkinje images captured with use of the opto-mechanical model of the eye; authorship of the design of the LED illuminator used in the experiment; discussion and analysis of the obtained results; manuscript preparation: bibliographical study, authorship of 2 illustrations and manuscript revision.
Estimated personal contribution: 25%

AP3. A. Jozwik, D. Siedlecki, M. Zajac, "Verification of numerical algorithm for crystalline lens location in the eyeball basing on Purkinje images," *Optik* 2013;124(13):1581-1584.

IF: 0,769[a] Number of citations: 2[b]

My personal contribution to this paper was: co-authorship of the idea of the research aimed to analyze the simulated Purkinje images obtained with use of the optical modelling software (Zemax). I also contributed to: implementation of the pseudophakic eye model to the Zemax environment, discussion of the obtained results and manuscript preparation: bibliographical study, authorship of 1 illustration and manuscript revision.
Estimated personal contribution: 25%

AP4. A. Jozwik, J. Nowak, D. Siedlecki, M. Zając, J. Zarówny, “Retinal images in optomechanical eye model with monofocal intraocular lens,” *Optica Applicata* 2011;41(3):593-605.

IF: 0,398[a] Number of citations: 2[b]

My personal contribution to this paper was: co-authorship of the idea of the research aimed to estimate the influence of the intraocular lens localization on the optical performance of the pseudophakic eye with use of the opto-mechanical model of the eye. I also contributed to: design of the opto-mechanical model of the eye, discussion of the obtained results and manuscript preparation: bibliographical study and manuscript revision.
Estimated personal contribution: 10%

AP5. A. Barcik, D. Siedlecki, “Optical performance of the eye with progressive addition lens correction,” *Optik* 2010;121(21):1937-1940.

IF: 0,454[a] Number of citations: 1[b]

This paper presents the results of investigations performed by Agnieszka Barcik in the framework of her MSc thesis. My personal contribution to this paper was: authorship of the idea of investigations on the numerical estimation of the optical performance of the eye with progressive addition lens correction for far and near vision; topographical measurements of the complex shapes of the progressive addition lens surface; help in implementation of the eye models with spectacle lens correction to the Zemax environment; discussion and analysis of the obtained results; help in text edition.
Estimated personal contribution: 25%

AP6. A. de Castro, S. Ortiz, E. Gambra, D. Siedlecki, S. Marcos, “Three-dimensional reconstruction of the crystalline lens gradient index distribution from OCT imaging,” *Optics Express* 2010;18(21):21905-21917.

IF: 3,753[a] Number of citations: 36[b]

My personal contribution to this paper was: authorship of the idea of the study aimed to reconstruct the parameters of the gradient index distribution of human crystalline lenses on the basis of their OCT images containing the distorted profile of the posterior surface of the lens, affected by the presence of optical distortion; design of the experiment and methodology of the investigations; co-development of the numerical algorithm for retrieval of the optimal values of the gradient index parameters; analysis and discussion of the results; manuscript preparation: edition of the text.
Estimated personal contribution: 25%

AP7. D. Siedlecki, H. Kasprzak, B. Pierscionek, “Radial gradient index intraocular lens: a theoretical model,” *Journal of Modern Optics* 2008;55(4-5):639-647.

IF = 1,062[a] Number of citations: 3[b]

This paper presents the results of investigations performed in the framework of my doctoral thesis, partially expanded by the research I performed during the first years of my employment at the Wrocław University of Science and Technology. My personal contribution to this paper was: co-authorship of the idea of design of the intraocular lens with the radial gradient index distribution aimed to minimization of the total spherical aberration of the eye; implementation of the numerical algorithms of tracing rays through the gradient index medium; performing the simulations aimed to estimate the optimal values of the gradient index distribution parameters in the intraocular lens in relation to the axial eye length and estimation of the image formed as a corneal reflection; discussion and analysis of the obtained results; manuscript preparation: bibliographical study, graphics and text edition.
Estimated personal contribution: 75%

AP8. D. Siedlecki, H. Kasprzak, B.K. Pierscionek, “Dynamic changes in corneal topography and its influence on the point-spread function of the eye,” *Applied Optics* 2007;46(8):1361-1366.

IF = 1,701[a] Number of citations: 3[b]

This paper presents the results of investigations performed in the framework of my doctoral thesis, partially expanded by the research I performed during the first years of my employment at the Wrocław University of Science and Technology. My personal contribution to this paper was: analysis of the interferograms presented in the paper in order to estimation of the corneal topography changes; performing the numerical simulations aimed to estimate to influence of these images on the retinal image quality; discussion and analysis of the obtained results; manuscript preparation: bibliographical study, graphics and text edition.
Estimated personal contribution: 70%

3.2.2. Scientific papers published in other journals

BP1. M. Lewandowska, W. Jasińska-Kwaśnik, A. Jóźwik, D. Siedlecki, “Measurement of oxygen permeability of contact lenses based on analysis of porosity,” *Interdisciplinary Journal of Engineering Sciences* 2015;3(1):1-5.

IF: none Number of citations: 0

This paper presents the results of investigations performed by Wanda Jasińska in the framework of her MSc thesis. My personal contribution to this paper was: authorship of the idea of investigations discussion and analysis of the obtained results; manuscript revision.
Estimated personal contribution: 15%

3.2.3. Conference communicates published in conference proceedings indexed in Journal Citation Reports (JCR) database

The presenter of the communicate during the conference is marked with bold font.

CP1. **A. Jozwik**, D. Siedlecki, M. Zajac, “Evaluation of intraocular lens implant location in the eyeball basing on the Purkinje images,” poster presented at: 18th Czech-Polish-Slovak Optical Conference on Wave and Quantum Aspects of Contemporary Optics, 3-7 September 2012, Ostravice, Czech Republic. Conference proceedings: *18th Czech-Polish-Slovak Optical Conference on Wave and Quantum Aspects of Contemporary Optics, Book Series: PROCEEDINGS OF SPIE.* Eds.: J. Peřina Jr, L. Nozka, M. Hrabovsky, *et al.* 2012;8697:86970O.

IF: none Number of citations: 1[b]

CP2. **A. Barcik**, J. Nowak, D. Siedlecki, M. Zając, J. Zarówny, “Physical model of human eye with implantable intraocular lenses,” poster presented at: 16th Polish-Slovak-Czech Optical Conference on Wave and Quantum Aspects of Contemporary Optics, 8-12 September 2008, Polanica Zdrój, Poland. Conference proceedings: *16th Polish-Slovak-Czech Optical Conference on Wave and Quantum Aspects of Contemporary Optics, Book Series: PROCEEDINGS OF SPIE*, Eds.: A. Popiolek-Masajada, E. Jankowska, W. Urbanczyk, 2008;7141:71411A.

IF: none Number of citations: 2[b]

CP3. **D. Siedlecki**, M. Zajac, J. Nowak, “Characteristics of the retinal images of the eye optical systems with implanted intraocular lenses,” oral presentation at: 15th Czech-Polish-Slovak Conference on Wave and Quantum Aspects of Contemporary Optics, 11-15 September 2006, Liberec, Czech Republic. Conference proceedings: *15th Czech-Polish-Slovak Conference on Wave and Quantum Aspects of Contemporary Optics, Book Series: PROCEEDINGS OF SPIE* Eds.: M. Miler, D. Senderakova, M. Hrabovsky, 2007;6609:66091C.

IF: none Number of citations: 0[b]

CP4. M. Zajac, **D. Siedlecki**, J. Nowak, “Retinal images in the human eye with implanted intraocular lens,” poster presented at: 15th Czech-Polish-Slovak Conference on Wave and Quantum Aspects of Contemporary Optics, 11-15 September 2006, Liberec, Czech Republic. Conference proceedings: *15th Czech-Polish-Slovak Conference on Wave and Quantum Aspects of Contemporary Optics Book Series: PROCEEDINGS OF SPIE* Eds.: M. Miler, D. Senderakova, M. Hrabovsky, 2007;6609:66091D.

IF: none Number of citations: 0[b]

CP5. **D. Siedlecki**, M. Zajac, J. Nowak, “Retinal image quality with the different types of intraocular lenses including new idea of the hybrid IOLs,” poster presented at: Biophotonics 2007: Optics in Life Science, 18-20 June 2007, Munich, Germany. Conference proceedings: *BIOPHOTONICS 2007: Optics in Life Science, Book Series: PROCEEDINGS OF SPIE* Ed.: J. Popp, G. von Bally, 2007;6633:63329-63329.

IF: none Number of citations: 0[b]

3.2.4. Other communicates and conference presentations

The presenter of the communicate during the conference is marked with bold font.

KP1. **D. Siedlecki**, R. Koprowski, W. Kowalik, H. Kasprzak, „Koherentna tomografia optyczna w pomiarach dynamiki kąta tęczówkowo-rogówkowego," oral presentation at: Konferencja OPTYKA 2014, 7 November 2014, Poznań, Poland;

KP2. A. Jóźwik, **D. Siedlecki**, M. Zając, „Podłużna aberracja chromatyczna oka pseudofakicznego mierzona in vivo," poster presented at: Konferencja OPTYKA 2014, 7 November 2014, Poznań, Poland;

KP3. **A. Juszczyk**, D. Siedlecki, „Obliczenia obrazów Purkinjego dla modelu oka pseudofakicznego," poster presented at: Konferencja OPTYKA 2014, 7 November 2014, Poznań, Poland;

KP4. **D. Siedlecki**, W. Kowalik, R. Koprowski, H. Kasprzak, Z. Wróbel, "Optical coherence tomography as a tool to estimate dynamics of the irido-corneal angle," poster presented at: VII European/I World Meeting in Visual and Physiological Optics, 25-27 August 2014, Wrocław, Poland. Confefence proceedings: *Proceedings of the VII European / I World Meeting in Visual and Physiological Optics VPOptics 2014*, Eds.: D. Robert Iskander, Henryk T. Kasprzak. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, p. 313-316, 2014;

KP5. **D. Siedlecki**, A. Hill-Bator, A. Jóźwik, "In vivo chromatic aberration of pseudophakic eyes," oral presentation at: Spring Workshop on Eye Research, 5-6 April 2013, Wrocław, Poland.

KP6. **A. Jóźwik**, D. Siedlecki, M. Zając, "Measurements of intraocular lens location in the eyeball based on purkinje images," oral presentation at: Spring Workshop on Eye Research, 5-6 April 2013, Wrocław, Poland;

KP7. **D. Siedlecki**, A. Jóźwik, A. Hill-Bator, A. Turno-Kręcicka, M. Zając, „Longitudinal chromatic aberration in eyes with intraocular lens implanted: preliminary report," poster presented at: The 17th ESCRS Winter Meeting, 15-17 February 2013, Warszawa, Poland;

KP8. **A. Jóźwik**, M. Lewandowska, M. Mulak, D. Siedlecki, M. Zając, „Model research of the retinal image quality in the eye with artificial intraocular lens," poster presented at: The 17th ESCRS Winter Meeting, 15-17 February 2013, Warszawa, Poland;

KP9. **A. Jóźwik**, D. Siedlecki, M. Zając, "Ocena położenia soczewki wewnątrzgałkowej w oku oparta na analizie położenia odbić Purkiniego," poster presented at: Konferencja Optyka 2012, 9-10 November 2012, Poznań, Poland;

KP10. **D. Siedlecki**, S. Ortiz, S. Marcos, "Calibration of a commercial anterior segment OCT instrument for accurate corneal topography," oral presentation at: 6th EOS Topical Meeting on Visual and Physiological Optics (EMVPO 2012), 20-22 August 2012, Dublin, Ireland. Conference proceedings: *6th EOS Topical Meeting on Visual and Physiological Optics (EMVPO 2012): Final Programme*. European Optical Society, p. 40-41, 2012;

KP11. **M. Lewandowska**, D. Siedlecki, G.J. Ziółkowski, "Różne techniki pomiaru kształtu powierzchni soczewki wewnątrzgałkowej," oral presentation at: Współczesna myśl techniczna w naukach medycznych i biologicznych: III sympozjum, 25-26 May 2012, Wrocław, Poland. Conference proceedings: *Współczesna myśl techniczna w naukach medycznych i biologicznych: III sympozjum, Wrocław, 25-26 maja 2012: materiały konferencyjne*. Wrocław: Oddział Polskiej Akademii Nauk we Wrocławiu, p. 95-96, 2012;

KP12. A. Jóźwik, M. Lewandowska, D. Siedlecki, **M. Zając**, „Lokalizacja wszczepialnej soczewki wewnątrzgałkowej a jakość obrazu siatkówkowego," oral presentation at: II Międzynarodowe Forum Chirurgii Okulistycznej, 13-14 April 2012, Katowice, Poland;

KP13. **A. Jóźwik**, D. Siedlecki, M. Zając, „Sposób wyznaczania lokalizacji soczewki wewnątrzgałkowej z wykorzystaniem odbić Purkiniego," poster presented at: II Polska Konferencja Optyczna, 27 June – 01 July 2011, Międzyzdroje, Poland;

KP14. **A. Jóźwik**, D. Siedlecki, M. Zając, „Możliwości oceny jakości obrazu siatkówkowego w oku ze wszczepioną soczewką wewnątrzgałkową," poster presented at: Interdyscyplinarna Konferencja „Ko-oper field 2011", 8-11 June 2011, Szklarska Poręba, Poland. Conference proceedings: *Interdyscyplinarność badań naukowych 2011*: Ed. Jarosław Szrek. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, p. 155-158, 2011.

KP15. **S. Ortiz**, D. Siedlecki, P. Perez-Merino, S. Marcos, „Anterior Segment Optical Coherence Tomography (OCT): From Nice Images to Accurate Topography," poster presented at: *Annual Meeting of the Association for Research in Vision and Ophthalmology (ARVO)*, 1-5 May 2011, Fort Lauderdale, USA. Conference proceedings: *Investigative Ophthalmology & Visual Science* 2011;52(14): E-abstract 3022.

KP16. **A. Jóźwik**, D. Siedlecki, M. Zając, "Modelowanie numeryczne obrazów Purkiniego," oral presentation at: Współczesna myśl techniczna w naukach medycznych i biologicznych: II sympozjum, 15-16 April 2011, Wrocław, Poland. Conference proceedings: *Współczesna myśl techniczna w naukach medycznych i biologicznych: II sympozjum, Wrocław, 15-16 kwietnia 2011: materiały konferencyjne*. Wrocław: Oddział Polskiej Akademii Nauk we Wrocławiu, p. 29-30, 2011;

KP17. **D. Siedlecki**, A. de Castro, S. Ortiz, D. Borja, S. Uhlhorn, F. Manns, S. Marcos, "Estimation of the contribution of the gradient index structure to the posterior surface optical distortion in excised human crystalline lenses imaged by Optical Coherence Tomography," oral presentation at: 5th European Meeting on Visual and Physiological Optics (EMPVO), 22-24 August 2010, Stockholm, Sweden. Conference proceedings: *EOS Topical Meeting: 5th European Meeting on Visual and Physiological Optics (EMVPO): Final Programme*. European Optical Society, p. 23, 2010;

KP18. **A. de Castro**, S. Ortiz, E. Gambra, D. Siedlecki, S. Marcos, "Three-dimensional reconstruction of the gradient refractive index of the crystalline lens in vitro from OCT images," oral presentation at: 5th European Meeting on Visual and Physiological Optics (EMPVO), 22-24 August 2010, Stockholm, Sweden. Conference proceedings: *EOS Topical*

Meeting: 5th European Meeting on Visual and Physiological Optics (EMVPO): Final Programme. European Optical Society, p. 24, 2010;

KP19. A. Jóźwik, **D. Siedlecki**, M. Zając, "Performance of multifocal intraocular lenses in the artificial eye model - preliminary results," poster presented at: 5th European Meeting on Visual and Physiological Optics (EMPVO), 22-24 August 2010, Stockholm, Sweden. Conference proceedings: *EOS Topical Meeting: 5th European Meeting on Visual and Physiological Optics (EMVPO): Final Programme*. European Optical Society, p. 51, 2010;

KP20. **A. Jóźwik**, D. Siedlecki, M. Zając, „Possibilities of measurements of intraocular lens performance in the artificial eye model," poster presented at: 8th International OSA Network of Students Conference IONS-8, 20-26 June 2010, Moscow, Russia;

KP21. **S. Ortiz**, D. Siedlecki, S. Marcos, „Quantitative OCT measurements of the anterior segment of the eye," oral presentation at: International Winter Workshop on Experimental Eye Research, 15-17 January 2010, Jugów, Poland;

KP22. **A. Jóźwik**, D. Siedlecki, M. Zając , "Measurement of intraocular lens performance in the artificial eye model," oral presentation at: International Winter Workshop on Experimental Eye Research, 15-17 January 2010, Jugów, Poland;

KP23. **S. Ortiz**, D. Siedlecki, L. Remon, D. Pascual, S. Marcos, "Correction of the optical distortion in optical coherence tomography systems," oral presentation at: IX Reunion Nacional de Optica, 14-17 September 2009, Ourense, Spain;

KP24. **A. Jóźwik**, D. Siedlecki, M. Zając, „Obraz siatkówkowy w modelu oka ze wszczepialną jednoogniskową soczewką wewnątrzgałkową," oral presentation at: I Polska Konferencja Optyczna, 27 June – 1 July 2009, Będlewo, Poland;

KP25. **S. Ortiz**, D. Siedlecki, L. Remon, S. Marcos, „ Three-dimensional Optical Distortion Correction for Quantitative Anterior Segment OCT," poster presented at: *Annual Meeting of the Association for Research in Vision and Ophthalmology (ARVO)*, 3-7 May 2009, Fort Lauderdale, USA. Conference proceedings: *Investigative Ophthalmology & Visual Science* 2009;50(13): E-abstract 5796.

KP26. **A. Jóźwik**, D. Siedlecki, M. Zając, „Charakterystyki optyczne modelowego oka ze sztuczną soczewką wewnątrzgałkową - analiza wybranych przypadków," oral presentation at: XVI Konferencja Inżynierii Akustycznej i Biomedycznej, 30 March – 3 April 2009, Zakopane, Poland;

KP27. **D. Siedlecki**, S. Ortiz, L. Remon, S. Marcos, "New imaging techniques to investigate optical properties of the crystalline and intraocular lenses," poster presented at: 5th International OSA Network of Students Conference IONS-5, 19-21 February 2009, Barcelona, Spain;

KP28. **A. Jóźwik**, D. Siedlecki, M. Zając, „Badanie jakości odwzorowania soczewek progresywnych," poster presented at: I Konferencja Optyczna, 21 November 2008, Poznań, Poland.

KP29. **D. Siedlecki**, H. Ginis, "The longitudinal chromatic aberration of pseudophakic eyes," oral presentation at: 4th European Meeting on Physiological Optics, 31 August – 2 September 2008, Heraklion, Greece;

KP30. A. Jóźwik, **D. Siedlecki**, "Optical performance of the eye with progressive addition lens correction," poster presented at: 4th European Meeting on Physiological Optics, 31 August – 2 September 2008, Heraklion, Greece;

KP31. **D. Siedlecki**, B.K. Pierscionek, "The Idea of Gradient Index Intraocular Lens (IOL)," oral presentation at: British Congress for Optometry and Vision Science, 4-5 September 2007, Coleraine, United Kingdom. Conference proceedings*: Ophthalmic and Physiological Optics* 2008;28(1):101 DOI: 10.1111/j.1475-1313.2007.00530_18.x;

KP32. **H.S. Ginis**, D, Kaltsa, D. Siedlecki, I. Pallikaris, „Longitudinal Chromatic Aberration in Eyes Implanted with Acrylic Intraocular Lenses," oral presentation at: *Annual Meeting of the Association for Research in Vision and Ophthalmology (ARVO)*, 27 April – 1 May 2008, Fort Lauderdale, USA. Conference proceedings: Invest. Ophthalmol. Vis. Sci. 2008;49(13): E-abstract 2423.

KP33. **D. Siedlecki**, "On the chromatic aberrations of IOLs," invited oral presentation at: 6th Aegean Summer School in Visual Optics, 26 June – 1 July 2005, Heraklion, Greece;

KP34. **D. Siedlecki**, "Alternative designs of IOLs," invited oral presentation at: 6th Aegean Summer School in Visual Optics, 26 June – 1 July 2005, Heraklion, Greece.

[a] according to the Web of Science database, in agreement with the year of issue.
[b] according to Journal Citation Report database, updated on 8 April 2016.

3.2.5. Description of the scientific activity after obtaining the doctoral degree, not related to the achievement being the basis of the application

After finishing doctoral studies I was employed as a research assistant at the Institute of Physics at the Faculty of Fundamental Problems of Technology, Wrocław University of Technology (currently: Wrocław University of Science and Technology). I continued my research work in the Physiological Optics Group (currently: Visual Optics Group). I was involved in upgrading the numerical model of the eye presented in my doctoral dissertation. I presented an idea of a gradient intraocular lens of a radial gradient index distribution [AP7]. In this work I also presented the algorithm of selection of the optimal values of the parameters of radial gradient index distribution. The numerical simulations performed in this study showed that these optimal values resulted in the optical performance practically free from aberrations. This way the diffraction limited model of a pseudophakic eye was obtained.

In 2007 I supplemented and extended my investigations on the influence of the corneal topography dynamics on the retinal image quality. This research was a continuation of the work presented in my doctoral dissertation and resulted in another publication [AP8].

The work [AP5] presents the results of numerical simulations of the optical performance of the progressive addition lens used for correction of presbyopia. These simulations were performed on the basis of the topographical data of the anterior surfaces of such ophthalmic lenses. Basically, the complex shape of these progressive surfaces results in both far and near correction. The simulations were performed by the first author of the publication, Agnieszka Barcik (Jóźwik) and presented in her Master’s thesis accomplished under my supervision.

The publications [AP2,AP3,AP4] comprise a part of a series of publications being the result of the research project “Badanie jakości obrazu w oku ze wszczepioną soczewką wewnątrzgałkową” (N518 414138), funded by the Ministry of Science and Higher Education in 2010-2013. These works present the results of experimental investigations on the method of estimation of the intraocular lens localization in the opto-mechanical model of the eye. This model was developed by the members of the Visual Optics Group.

3.3. Scientific papers: summary

A summary of personal scientific activity (updated on: 4 May 2016):

	Scientific works	**Before PhD**	**After PhD**	**Scientifics works resulting from Article 16, Paragraph 2 of the Act of 14 March 2003**
1.	Authorship and co-authorship of papers in scientific journals indexed in *Journal Citation Reports* (*JCR*) database	2	20	12
2.	Inventions, design and industrial patents presented during international or national exhibitions or fairs	-	-	-
3.	Authorship of realized original design, construction or technological achievement	-	-	-
4.	Granted international and national patents	-	1	1
5.	Authorship or co-authorship of monographs or scientific publications in journals not indexed in *Journal Citation Reports* (*JCR*) database	-	1	-
6.	Authorship or co-authorship of collective elaborations, catalogues, scientific work documentations or expert reports	-	-	-

7.	Leadership of international and national research projects or participation in such projects	-	2	-
8.	Number of lectures and oral presentations presented at international and national scientific conferences	1	9	-
9.	International and national awards for the scientific activity	-	-	-
10.	Total *impact factor* of scientific papers listed in the achievement resulting from Article 16 Paragraph 2 of the Act of 14 March 2003 on Academic Degrees and Academic Titles and on Degrees and Titles in Arts, according to the year of publication	X	X	23,056
11.	Total *impact factor* of scientific publications according to *Journal Citation Reports* (*JCR*), according to the year of publication;	4,173	33,100	X
12.	h-index according to *Web of Science* (*WoS*) database	X	10	X
13.	Number of citations according to *Web of Science* (*WoS*) database	total: 30, **without self-citations: 29**	total: 264, **without self-citations: 227**	total: 213, **without self-citations: 184**

3.4. Scientific papers summary: list of Impact Factor (IF) values

L.p.	**Scientific journal title**	**Total**		**Scientifics works resulting from Article 16, Paragraph 2 of the Act of 14 March 2003**	
		ΣIF*	**Number of papers**	**Number of papers**	**ΣIF***
1.	*Applied Optics*	4,521	3	2	2,820
2.	*BioMed Research International*[b]	1,579	1	1	1,579
3.	*Biomedical Optics Express*[c]	4,666	2	2	4,666
4.	*Computers in Biology and Medicine*	1,24	1	-	-
5.	*Interdisciplinary Journal of Engineering Sciences*	none	1	-	-
6.	*Journal of Biomedical Optics*	2,870	1	1	2,870
7.	*Journal of Modern Optics*	3,294	3	2	3,294
8.	*Optica Applicata*	0,689	2	-	-

9.	*Optics Express*	7,506	2	1	3,753
10.	*Optics Letters*	3,882	1	-	-
11.	*Optik*	1,890	3	-	-
12.	*Optometry and Vision Science*	5,136	3	3	5,136
13	*Proceedings of SPIE*	none	6	-	-
Sum:		37,273	29	12	23,056

* related to the year of publication.

[b] before 2013 the title of this scientific journal was: *Journal of Biomedicine and Biotechnology*. IF according to the 2014 JCR database.

[c] papers were published in 2010 – in the first volume of the journal. In 2011, the journal was included to the indexed journals list, therefore the related IF is given according to the 2011 JCR database.

4. International and national collaboration

1. Institute of Vision & Optics, University of Crete, Heraklion, Greece
   - Harilaos S. Ginis, PhD – co-author of 1 common publication
2. School of Biomedical Science, University of Ulster, Coleraine, United Kingdom
   - Prof. Barbara K. Pierscionek – co-author of 3 common publications
3. Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Miami, USA
   - Prof. Fabrice Manns – co-author of 3 common publications
   - Prof. Jean-Marie Parel – co-author of 3 common publications
   - Esdras Arrieta, PhD – co-author of 1 common publication
   - David Borja, PhD – co-author of 3 common publications
   - Stephen Uhlhorn, PhD – co-author of 3 common publications
4. Instituto de Óptica, Consejo Superior de Investigaciones Cientificas, Madrid, Spain
   - Susana Marcos, PhD – co-author of 8 common publications and 1 common international patent
   - Sergio Ortiz, PhD – co-author of 7 common publications and 1 common international patent
   - Alberto de Castro, PhD – co-author of 5 common publications
   - Laura Remon, PhD – co-author of 3 common publications
   - Enrique Gambra, PhD – co-author of 2 common publications
   - Pablo Perez-Merino, PhD – co-author of 1 common publication
   - Noelia Chia – co-author of 1 common publication
   - Daniel Pasqual – co-author of 1 common publication
   - Carlos Dorronsoro, PhD – co-author of 1 common international patent
5. Institute of Physics, Nicolaus Copernicus University, Toruń, Poland
   - Prof. Maciej Wojtkowski – co-author of 2 common publications
   - Prof. Maciej Szkulmowski – co-author of 1 common publication

- Ireneusz Grulkowski, PhD – co-author of 1 common publication

6. Department and Clinic of Ophthalmology, Wrocław Medical University, Wrocław, Poland
   - Aneta Hill-Bator, PhD – co-author of 1 common publication
   - Anna Turno-Kręcicka, PhD – co-author of 1 common publication

5. Scholarships and research grants

Research project: **„Badanie jakości obrazu w oku ze wszczepioną soczewką wewnątrzgałkową”** (N518 414138) funded by Ministry of Science and Higher Education in years 2010-2013 – co-investigator.

R&D project: **„Opracowanie nieinwazyjnej metody wczesnej diagnostyki jaskry w oparciu o badanie korelacji dynamiki przedniego odcinka oka i aktywności układu sercowo-naczyniowego”** (NR13-0012-10/2010) funded by the National Centre for Research and Development in years 2010-2013 – co-investigator.

Travel scholarship: **„Refractive properties and aberrations of model eyes determined using the method of double pass ray tracing,”** (WAR/342/14) in the framework of The British-Polish Young Scientists Programme (YSP) funded by British Council Poland and State Committee for Scientific Research in 2003.

6. Teaching activity, popularizing activity, organizational activity

6.1. Teaching activity

In years 2005-2016 I had – on average – about 330 teaching hours during each academic year including:

Basic Physics (lab)
Basics of Optical Information Processing (lab)
Computer-aided designing of the optical systems (computational lab)
Engineering Optics (lab)
Photometry and Colorimetry (lab)
Geometrical Optics (lecture, classes)
Geometrical Optics and Optical Devices (classes)
Geometrical Theory of Optical Imaging (computational lab)
Instrumental Optics (lecture, classes)
Introduction to Optics (classes)
Optical Measurements 1 (lecture)
Optical Measurements 2 (lab)
Optical Calculations (lecture, computational lab)
Optics for Optrometrists (classes)
Optometric Measurements (lab)
Theory of Optical Imaging (computational lab)
Wave Optics – Theory and Applications (classes)

Furthermore:

- co-authorship of manual instructions to the Basic Physics lab and Photometry and Colorimetry lab.

- faculty coordination of the *„Zemax Educational Programme"* offered by ZEMAX® software developer, being a tool for optical design, modeling and analysis and used for teaching purposes.

6.2. Supervision of BSc and MSc theses

Supervision of BSc and MSc theses in years 2005-2016:

2016	Patrycja Zwolenik	„Badania zmian topografii rogówki po pomiarach typu air-puff" *(BSc thesis)*
2016	Daria Bloch	„Porównanie wyników pomiarów centralnej grubości rogówki wykonanych za pomocą tomografu optycznego i tonometru" *(BSc thesis)*
2016	Dominik Halkowicz	„Korekcja aberracji sferycznej w numerycznym modelu oka pseudofakicznego" *(BSc thesis)*
2015	Agnieszka Duś	„Pomiary dynamiki w obrębie kąta tęczówkowo-rogówkowego z wykorzystaniem OCT" *(MSc thesis)*
2015	Natalia Małgorzata Idczak	„Symulacje jakości odwzorowania w modelach oka z gradientową soczewką oczną" *(BSc thesis)*
2015	Jolanta Lisowska	„Pomiar właściwości sprężystych soczewek wewnątrzgałkowych" *(BSc thesis)*
2015	Marta Kazimierska	„Wyznaczenie jakości odwzorowania w modelu oka z soczewką wewnątrzgałkową" *(BSc thesis)*
2014	Agnieszka Juszczyk	„Obliczenia obrazów Purkiniego dla modelu oka z wszczepioną soczewką wewnątrzgałkową" *(MSc thesis)*
2014	Anna Kowaluk	„Badania centralnej grubości rogówki wśród studentów Politechniki Wrocławskiej" *(MSc thesis)*
2014	Anna Szczepańska	„Wyznaczanie dystorsji polowej koherentnego tomografu optycznego" *(BSc thesis)*
2012	Marcin Szewczyk	„Analiza występowania wad refrakcji w społecznościach miejskich oraz wiejskich na podstawie przeprowadzonych badań" *(BSc thesis)*

2012	Agnieszka Duś	„Wykorzystanie techniki obrazów Purkiniego do pomiarów umiejscowienia soczewki wewnątrzgałkowej w modelu oka” *(BSc thesis)*
2010	Magdalena Urbaniak	„Ocena jakości widzenia po operacji usunięcia zaćmy i wszczepienia soczewki wewnątrzgałkowej” *(MSc thesis)*
2010	Dariusz Balcerek	„Pomiar aberracji chromatycznej oczu z wszczepioną soczewką wewnątrzgałkową” *(MSc thesis)*
2010	Wanda Jasińska	„Pomiar przepuszczalności tlenu w soczewkach kontaktowych” *(MSc thesis)*
2008	Agnieszka Barcik	„Badanie jakości odwzorowania soczewek progresywnych” *(MSc thesis)*
2008	Sylwia Giel	„Wpływ wieku i stopnia akomodacji na parametry układu optycznego oka ludzkiego” *(MSc thesis)*
2008	Wanda Jasińska	„Badanie ostrości wzroku u osób starczowzrocznych po korekcji soczewkami progresywnymi” *(BSc thesis)*
2008	Dariusz Balcerek	„Konstrukcja układu do subiektywnego pomiaru aberracji chromatycznej układu optycznego oka ludzkiego” *(BSc thesis)*

6.3. Popular-scientific activity

2014	Marketing promotion of the subject of Optics on the Day of Open Doors at ZS1 in Wrocław.
2013	Lecture in the framework of Science and Talent Festival at ILO in Oleśnica: *„Czy Dalton był daltonistą? Rzecz o widzeniu barwnym, ale nie tylko...”*
2013	Scientific workshop in the framework of Lower Silesian Science Festival in Wrocław: *1. „Tajniki widzenia przestrzennego”* *2. „Dlaczego widzimy w 3D?”*
2011	Two lectures and a scientific workshop in the framework of Lower Silesian Science Festival in Ząbkowice: 1. *„Tajniki widzenia przestrzennego”* (lecture); 2. *„Czy Dalton był daltonistą? Rzecz o widzeniu barwnym, ale nie tylko...”* (lecture); 3. *„Optyka na co dzień”* (workshop)
2011	Scientific workshop in the framework of Lower Silesian Science Festival in Wrocław: *„Tajniki widzenia przestrzennego”*
2010	Scientific workshop in the framework of Lower Silesian Science Festival in Wrocław: *„Tajniki widzenia przestrzennego”*
2006	Lecture from a series „XIII Series of Popularizing Physics Lectures”: *„Czy Dalton był daltonistą? Rzecz o widzeniu barwnym”*

6.4. Organizational activity

2014	*VII European/I World Meeting in Visual and Physiological Optics*, 25-27 August 2014, Wrocław: volunteer;
2013	*Spring Workshop on Eye Research* Wrocław 5-6 April 2013: member of the organizing committee;
2011	publication *„20 lat Seminarium Instytutu Fizyki: spis referatów"*, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław: editorship;
2010	*International Winter Workshop on Experimental Eye Research*, Jugów 15-17 January 2010: member of the organizing committee;
2006	publication *„15 lat Seminarium Instytutu Fizyki: spis referatów"*, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław: editorship;
2005-2008	Seminar of the Institute of Physics at Wrocław University of Science and Technology: secretary
2005	*The Joint Conference of the German Society of Applied Optics (DGaO) and Section of Optics of the Polish Physical Society (PTF)*, Wrocław 17-20 May 2005: member of the organizing committee;
2003-2005	Interdisciplinary Seminar for the doctoral students at the Institute of Physics, Wrocław University of Science and Technology: secretary.

6.5. Activity as a reviewer

In years 2005-2016 I have performed about 30 reviews of manuscripts for the following international scientific journals:

Applied Optics
BioMedical Engineering Online
Biomedical Optics Express
BMC Ophthalmology
Journal of Biomedical Optics
Journal of Cataract and Refractive Surgery
Journal of Modern Optics
Optica Applicata
Optics Express
Optics Letters
Optometry and Vision Science
Photonics Letters of Poland
The Open Optics Journal
Vision Research

Siedlecki