Last Ten Years of Scientific Activity

Maksymilian Pluta

Central Optical Laboratory in Warsaw was founded after World War II. This is a scientific institution possessing the status of a research institute. Its activity includes different fields in applied optics with emphasis on

- geometrical optics and the theory of imaging,
- microscopy,
- physical optics,
- optical instruments design,
- photoelectronics,
- photographic science and engineering,
- technology of optical elements making and thin film technique,
- crystal growing,
- optical measurements and quality examination of optical systems.

So far as geometrical optics in C.O.L. is concerned the research work was concentrated mainly on different problems dealing with automatizing the optical system calculation. A number of basic theoretical works have been performed as well as tens of computer programs (both of universal and specialistic character) elaborated for optical systems calculation on various computers (as Elliot 803B, ICT 1904, ZAM 41, Odra 1304, Odra 1204, and others). They were employed for design of objectives (projection objectives, enlarger objectives, and others) and different optical systems (such as microscopic, interferometric, and xerographic systems) for the Polish optical industry. Special attention was paid to the theory and design of microscopic systems of zoom type. A number of different systems of various magnification factors have been designed, the latters ranging between 2 and 10. Independently, some guard aspects of the optical system design were thoroughly studied. Investigations have been also carried out concerning methods of theoretical analysis of the working tolerances for optical elements with special emphasis on the influence of non-centricity. Some effords have been devoted to successfully solve the problem of optimizing the technological parameters of spectacle lens making in mass production, i.e., to minimize the number of both the operations and tools. Also the problem of constructing toric spectacle lenses of large diameter has been worked out. An illustration — though incomplete — of these activities may be found in the papers [1–10] quoted in References.

In the same time the research work in the field of physical optics was concentrated on the following phenomena: phase contrast, interference, polarization, fluorescence, and others. Most of the work was intended for practical reasons in microscopy and micro-interferometry. The most important publications dealing with these questions are listed as [11–26]. In 1967 the experimental work in holography was initiated in C.O.L. The first holographic setup for transparent objects was built, and successful holograms, as the first ones in Poland [27], were performed by help of a He–Ne laser. Next year, holograms of spatial objects (both of reflecting and scattering type) were produced. Simultaneously, experimental works were originated which aimed at constructing a holographic microscope. Soon magnified "lens-less" holographic images of reflecting objects were produced, while the obtained of magnification of several times, and of good quality. A considerable success was achieved in 1969, when an original method of producing of holograms in convergent object beams was elaborated by applying a magnifying lens between the object to be examined and the holographic plate ("image holography"). By applying this technique one of the first holograms of light-reflecting micro-objects was obtained [28]. This method of hologram producing in convergent object beams became a fundamental technique in holographic microscopy of high magnification for transmitted light. An experimental model of such a microscope to be used mainly for micro-interferometric examination was built in the year 1970. At the same time two other original methods were developed [29, 30], which enabled a holographic examination of the object by use of shearing interferometry, as well as some experiments in the holographic Fourier spectroscopy were originated. The latters, being continued during next years, resulted in designing an original device, which enables the holographic subtraction of spectral lines to be performed [31, 32]. In the year 1971 a prototype of a holographic microscope was constructed, affording an interferometric examination of the specimens in both the transmitted and reflected light. Moreover, an universal holographic kit was designed and directed to the Polish Optical Works for commercial manufacturing. Simultaneously, some theoretical and experimental research work on holographic imaging in the higher diffraction orders [33, 34] was continued as well as some experiments in spatial frequency filtering [35, 36] and holographic imaging of birefringent objects [37] were performed. Also, some research was carried out, which concerned the registration of the quickly changing objects by help of pulse holography and holographic analysis of mechanical vibrations [38]. Finaly, an original and efficient method of coherent noice suppression in coherent systems and especially in interferometric systems with laser illumination was elaborated [39, 40]. This method was next applied to the both speckle suppression and coherent noice elimination in the holographic microscopy [41, 42]. A number of experiments with "volume" (thick) holograms of the Denisyuk type and white-light image reconstruction were also made [43].

Parallelly to the holographic investigation a series of experimental works were performed on application of the laser light to the instrumental optics. In one of the earlier works [44] a possibility of laser light application for testing the mounting centricity of multi-lens systems by using multi-beam interference method was examined. This idea was then exploited in a later developed procedure of central cementing the multi-lens systems, and in designing an arrangement suitable for mass centricity control as required in industry [45]. Another series of experiments, aiming at designing a Fabry-Perot microinterferometer with laser illumination for transparent objects examination were undertaken to meet the requirements of biological specimens investigation [46]. At first, these investigations did not lead to any satisfactory results because of too strong coherent noise. While applying the new method of coherent noise suppression [39] the improvement in quality was so substantial that the construction of several different types of interferometers became only the matter of time. In fact, many different interferometers were designed with laser illumination, among which a multi-pass interferometer for the surface roughness examination with the accuracy $\lambda/100$ is particularly worth mentioning.

In the years 1971–1972 a series of experiments dealing with application of the speckle effect to the examination and measurement of the transversal displacements and flows [47, 48] were performed.

A number of unique measuring and control devices as well as various technological equipments were designed and produced in C.O.L. for numerous institutes and factories in Poland. Among others, the following are worth mentioning: a measuring microscope to control the width of the milling slot in paper machines, measuring microscope for determining the ship hull model displacements caused by vibrations, device to control the exactness of the meter rules within the range 0–630 mm with the accuracy of 0.005 mm, projection-microscope arrangement to control the slide-caliper scales, device for Pittler die chaser control, mining interferometer for measuring both methane and dioxide concentration in mines, special type projector for drawing the sheet metals for ship hulls, arrangement for the research work in the acoustic holography and a number of industrial view-finders [49].

So far as the photoelectronics are concerned, research and experimental studies were carried out in order to develop new optoelectronic devices as, e.g., photoelectronic industrial refractometers [50–53], photoelectronic control and measuring devices for optical industry [54, 55], and electro-optical instruments for measuring various electrical magnitudes [56]. Several types of photoelectronic refractometers to be applied in sugar, fruit and vegetable processing industry were designed and performed. They were subjected to careful trial exploitations both in Poland and abroad. Some of them were submitted to commercial manufacturing. Among the photoelectronic and measuring instruments for determining different optical magnitudes, the focal-length tolerator as well as a digital focometer deserve some attention [55]. The last arrangement is supposed to measure the absolute value of the focal length of both single converging lenses and composite converging systems with the accuracy equal to about 0.001 f within the focal length range $f = +10$ mm to $f = +640$ mm. The measurement is almost fully automatized and lasts about 20 s. Besides, a photoelectric microscopic photometer with an original optical system supplied with an interference-polarizing beam splitter was constructed. The minimum measuring field of this photometer is equal to 0.5 μm (when using $a \times 100$ microscopic immersion objective).

Investigations dealing with photographic engineering were also carried out in C.O.L. Special emphasis is to be placed, among others, on experimental and technological works concerning the photographic multiplication of the optical images as well as the production of different microimages on the glass substrate using photoresists [57].

Experimental and research works dealing with technology of optical elements processing were performed in two fields. One of them consists in modernization and amelioration of the existing methods of manufacturing of optical elements to improve the quality of the products and to lower the production costs. The purpose of the other one is to elaborate new methods and develop a new technology to be applied in production of those new optical elements which are appearing parallelly to the progress in optical design. The most important research carried out in C.O.L. in this field during last ten years may be listed as follows:

— examination of the processes of diamond milling, grinding and polishing for different sorts of optical glass in order to determine the optimal parameters for processing technology;

— examination of the processing materials (i.e. diamond, milling cutters, substrates for polishing tools, polishing powders, and others) with an emphasis on application of some plastics for grinding and polishing tools;

— examination of the processing technology of optical crystals and elaboration of the processing procedures for different optical elements (e.g. birefringent prisms and plates, polarizing prisms) and electro-optical elements (light modulators) including the problem of corrosion resistance of the hydrophilic crystals;

— elaboration of technological procedures for laser elements production (laser rods of different shapes of windows made of ruby and neodymium glass);

— elaboration of mass production technology of lenses of extremely small radius (balls) used in microscope objectives and condensers as front lenses;

— examination of technology of aspherical elements (both of rotational symmetry and cylindrically shaped) for projection systems and movie projectors;

— examination of the ways of performing the super-smooth and extremely accurate surfaces o the optical elements for laser resonators.

Another important research including elaboration of experimental and technological procedures was carried out in the field of optical thin films. Among others, the following processing technologies were worked out: a procedure for the dielectric mirrors with selective reflection and variable transmission factor, procedure for antireflecting coating for different wavelengths, and narrow-band interference filters for various wavelengths. Also, a procedure for cold mirrors performence for the movie projectors, and a procedure for anticorrosive coatings on optical elements have been elaborated [58].

In the field of crystal growing an original procedure has been invented for the growth of large KDP (potassium dihydrogen phosphate) crystals production of weight amounting up to 2 kg. The pilot production of those large crystal pieces is now being realized and simultaneously the processing procedure is elaborated for making optical elements of these materials to be applied next to light modulation and harmonics generation.

The optical measurement methodology and the imaging quality evaluation were represented by a number of works, where some attention was paid to define different criteria and quality measures for all the basic products of the Polish optical industry. Special attention was paid to microscopes and their basic accessories (objectives, eye-pieces, fine and rough focussing mechanisms, stage cross-movement mechanisms, etc.). Independently, a lot of time was devoted to careful and versatile examination of photographic enlargers, photographic objectives, optical measuring devices and others. Some of the results of these examinations may be found in [59, 60]. One of the papers [61] treating on similar subject contains a discription of a simple and efficient method concerning the determination of coloration degree for optical glasses and suggests their classification due to the value of this parameter. An interesting instrument for check of internal defects in spectacle glass mouldings has been elaboroted and constructed as well. This instrument is based on the Schlieren effect. The element to be checked is placed in an immersion bath and its shadow image is projected onto a ground glass screen. The device has been highly automized and therefore enables a quick segregation of the elements under test into two groups: of good and defected pieces.

The results of the research, design and experimental works carried out in C.O.L. are usually described in form of detailed final reports. Some of them have been published in the C.O.L. informational bulletin "Optyka".

References

[1] WAGNEROWSKI T., *Über eine Konstruktion einflacher Projektions-Okulare mit einem hohem Kompensationsvermögen der Seidelfeldwölbung des Mikroskopobiektives*, Proc. of the 2nd Conference for Optics, Budapest 1963.

[2] BARTKOWSKA J., *Principal Points, Cardinal Axes and Focal Planes of a Slightly Decentred Optical System*, Jap. J. Appl. Phys. **4**, Suppl. I, 39–45 (1965).

[3] WAGNEROWSKI T., *Théorie élémentaire du triplet pancratique symétrique dont les lentilles extrêmes sont déplacées solidairement*. Rev. Opt. théor. appl. **45**, 245–248 (1966).

[4] BARTKOWSKA J., *Differrentiale der Seidelschen Aberrationen nach Linsendicken und Luftabstanden und Anwendung bei Untersuchung eines symmetrischen pankratischen Dreilinsers*, Acta Phys. Pol. **31**, 41–49 (1967).

[5] BARTKOWSKA J. and BARTKOWSKI Z., *Seidel Aberrations of a Slightly Decentred Optical System*, Optica Applicata **1**, 3–22 (1971).

[6] KRYSZCZYŃSKI T., *On a Semiautomatic Method of Aberrations Correction of Optical Systems*, Optica Applicata **1**, 23–38 (1971).

[7] KRYSZCZYŃSKI T., *A Method of Preliminary Optimizing the Optical Systems*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).

[8] BARTKOWSKA J., *Some Remarks Concerning the Aberration Correction in Pancratic Systems*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).

[9] PŁUŻAŃSKI M., *A Method of Tolerance Evaluation for Optical System Parameters*, 1st Polish Conference on Applied Optics, 1971, September 20–27, Bierutowice (Poland).

[10] CHOJNACKA A., *Imaging of the Microscope Objective Pupils into a Fixed Position by Applying a Movable Single-lens Component with Practically Stable Object-image Distance*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).

[11] PLUTA M., *Dispositif à contrast de phase ayant des anneaux de phase positifs préparés à partir du noir de fumée et de substance diélectrique*, Microskopie **22**, 326–336 (1967).

[12] PLUTA M., *Stereoscopic Phase-contrast Microscope*, Microscope **16**, 32–36 (1968).

[13] PLUTA M., *Properties of the Amplitude-contrast Microscope with Soot Amplitude Rings*, Microscope **16**, 211–226 (1968).

[14] PLUTA M., *Optical Properties and Applications of Thin Soot Layers in Phase-contrast and Amplitude-contrast Microscopy*, Proc. of the 2nd Colloquium on Thin Films, Akadémiai Kiado, Budapest 1967, 257–266.

[15] PLUTA M., *A Phase-contrast Device with Positive and Negative Image Contrast*, J. Microscopy **89**, 205–216 (1969).

[16] PLUTA M., *A Double Refracting Interference Microscope with Variable Image Duplication and Half-shade Eye-piece*. J. Phys. E (Sci. Instrum.) **2**, 685–690 (1969).

[17] PLUTA M., *A Highly Sensitive Phase-contrast Device*, Microscope **17**, 235–248 (1969).

[18] PLUTA M., *A New Polarization Interference Microscope*, Microscope **18**, 113–122 (1970).

[19] PLUTA M., *On the Accuracy of Microinterferometric Measurements of Optical-path Differences by Means of the Half-shade Method*, J. Microscopy **93**, 83–100 (1971).

[20] PLUTA M., *Kombination des Phasenkontrastverfahrens mit der Fluoreszenzmikroskopie mittels aus dünnen Interferenzschichten ausgeführter Kondensor-Ringblenden*, Mikroskopie **27**, 121–128 (1971).

[21] PLUTA M., *Messung der Doppelbrechung und der Brechzahlen von Mikrokristallen mittels eines Interferenz-Polarisationsmikroskops mit variabler Bildverdoppelung*, Microscopica Acta **71**, 3–21 (1971).

[22] PLUTA M., *Double Refracting Interference Microscope with Continuously Variable Amount and Direction of Wavefront Shear*, Optica Acta **18**, 661–675 (1971).

[23] PLUTA M., *Differential Interference Contrast Microscope with Continuously Variable Waverfront Shear and Pupilar Compensation*, Optica Acta **19**, 1015–1026 (1972).

[24] PLUTA M., *Interference Microscopy of Polymer Fibres*, J. Microscopy, **96**, 309–332 (1972).

[25] POPIELAS M., *A Phase and Amplitude Contrast Investigation of Reflecting Materials*, Microscope **20**, 101–110 (1972).

[26] PLUTA M., *Incident-light Double Refracting Interference Microscope with Variable Wavefront Shear.*, Optica Acta **20**, 625–639 (1973).

[27] DASZKIEWICZ M., PAWLUCZYK R. and PLUTA M., *Holographic Experiments in Central Optical Laboratory*, XXth Congress of Polish Physicists, Lublin 1967.

[28] DASZKIEWICZ M., PAWLUCZYK R. and PLUTA M., *A Microholographic System Enabling to obtain Holograms with no Pseudoscopic Real Image*, Acta Phys. Polon. **36**, 27–31 (1969).

[29] PAWLUCZYK R., *Interférométrie différentielle holographique au moyen d'un hologramme de Gabor réalisé à partir d'un hologramme de Leith-Upatnieks*, Symposium international sur les applications de l'holographie, Besançon (France), juillet 1970.

[30] DASZKIEWICZ M., *Observation of Differential Interference Patterns by a Hologram Illuminated with Partially Sheared Coherent Beam*, Symposium international sur les applications de l'holographie, Besançon (France), juillet 1970.

[31] DASZKIEWICZ M., PAWLUCZYK R. and PLUTA M., *Holographic Fourier Spectroscopy by Using Birefringent Prisms*, 4th Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1970.

[32] DASZKIEWICZ M., *Holographic Fourier Spectroscopy*, Winter School on Holography, Novosybirsk (U.S.S.R.) 1973.

[33] PAWLUCZYK R., *Holographic Imaging of a Point Object in Higher Diffraction Orders*, Optica Acta **10**, 291–305 (1972).

[34] CHABROS W., *Dzialanie hologramu jako filtru korelacyjnego w wyższych rzędach ugięciowych*, 5th Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1972.

[35] CHABROS W., *Application of the Holography in Dactyloscopy*, 5th Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1972.

[36] CHABROS W., *Linear and Crossed Gratings Realized by the Use of the Holographic Techniques*, 1st Czechoslovak and Polish Conference on Optics, 1972, September 4–8, Rusava (Czechoslovakia).

[37] DASZKIEWICZ M., *Simultaneous Holographic Reconstruction of Two Independent Polarizing Components of the Object Beam*, 5th Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1972.

[38] CHABROS W. and PAWLUCZYK R., *Holographic Examination of Vibrations of a Metallic Plate*, 5th Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1972.

[39] Mróz E., Pawluczyk R. and Pluta M., *A Method for Coherent Noise Elimination in Optical Systems with Laser Illumination*, Optica Applicata **1**, 2, 9–15 (1972).

[40] Pawluczyk R. and Mróz E., *Unidirectional Optical Coherent Noise Elimination by the Time Averaging Method*, Optica Acta, **20**, 379–386 (1973).

[41] Pawluczyk R., *Holographic Microscope with Elimination of the Coherent Noise*, 1st Czechoslovak and Polish Conference on Optics, 1972, September 4–8, (Czechoslovakia).

[42] Pawluczyk R., *Coherent Noise Elimination in Holographic Microscope*, Opt. Commun. **7**, 366–370 (1973).

[43] Pawluczyk R., *White Light Reconstruction of Holograms Recorded on 10E70 Photographic Plates*, Optica Applicata **3**, 1, 42–42 (1973).

[44] Pawluczyk R. and Pluta M., *Application of Laser Light for Examination of the Quality of Miscroscope Objectives*, XXth Congress of Polish Physicists, Lublin (Poland) 1967.

[45] Fuszara M., *Interferometr do centralnego sklejania soczewek*, Biul. Inform. Optyka, **4** (1972), 169–172.

[46] Pawluczyk R. and Pluta M., *Multi-beam Interferometry with Laser Illumination*, 3rd Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1968.

[47] Mróz E., Pawluczyk R. and Pluta M., *Preliminary Experiments with Speckle Effect Applied to Investigation of Small Vibrations, Displacements and Streams*, 5th Conference on Radiospectroscopy and Quantum Electronics, Poznań (Poland) 1972.

[48] Mróz E., *In-plane Strains Study by Laser Speckle Photography*, 2. Internationale Tagung „Laser und ihre Anwendungen", 4–9 Juni 1973, Dresden.

[49] Pracki S., *Zagadnienie konstrukcji przemysłowych wzierników optycznych i ich zastosowania*, 1st Czechoslovak and Polish Conference on Optics, 1972, September 4–8, Rusava (Czechoslovakia).

[50] Szukalski J. and Jasny J., *Polish Research Work in the Field of Industrial Refractometry*, Acta IMEKO V, Versailles 1970.

[51] Szukalski J. and Jasny J., *Impulsowy analizator refraktometryczny*, Pomiary-Automatyka-Kontrola **16**, 1, 9–11 (1970).

[52] Szukalski J. and Gadoś J., *Fotoelektryczny analizator refraktometryczny o budowie nurnikowej*, Pomiary-Automatyka-Kontrola **16**, 2, 57–60 (1970).

[53] Kotecki A., *Refraktometry przemysłowe*, Pomiary-Automatyka-Kontrola **10**, 8, 347–356 (1964).

[54] Jasny J. and Płocharski S., *Photoelectric Tolerator of Focal-length*, Optica Applicata **3**, 1, 22–23 (1973).

[55] Jasny J., *Focal-length Digital Meter*, Optica Applicata **3**, 1, 27–28 (1973).

[56] Szukalski J., *An Alectro-optical Device for Measurement of Pulsing Electromagnetic Fields and Current Surges*, Optica Applicata **3**, 1, 26–27 (1973).

[57] Bielski J., *A Possibility of Producing Microimages on a Glass Substrate with the Help of Photoresist*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).

[58] Stefaniak T., *Anti-corroding Coatings for Optical Glass Elements*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).

[59] Kozłowski T., *Criteria and Quality Assessment Methods for Microscope Objectives and Eye-pieces*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).

[60] Bielski J. and Zarzycka M., *Kryteria oceny jakości powiększalników i obiektywów powiększalnikowych*, 1st Czechoslovak and Polish Conference on Optics, 1972, September 4–8, Rusava (Czechoslovakia).

[61] Sokołowski S., *Determination of the Colourless Degree for Optical-Glasses*, 1st Polish Conference on Applied Optics, 1971, September 20–25, Bierutowice (Poland).