Optica Applicata, Vol. XIV, No. 3, 1984

Presentations

Institute of Design of Precise and Optical Instruments, Warsaw Technical University

The activity of the group working in optics and optical instruments design dates from 1953. At that time, when the war-destroyed industry, including the optical industry and optical research institutes, was under fast reconstruction, the necessity of teaching engineers in precision mechanics was clearly seen. The demand for unique measuring devices and control equipment was increasing. To this end the Chair of Optical Instruments was organized by its Chairman Professor Jan Matysiak, who was a person of great industrial experience and educational achievements. The Chair of Optical Instruments has been since 1970 one of the four scientific-educational groups constituting the Institute of Design of Precise and Optical Instruments. After Prof. Jan Matysik retired in 1975 the Group of Optical Instruments Design has been guided by Professor Romuald Jóźwicki.

The main aim of this Group is to educate the engineering staff for the work in optical industry. Since the group of this kind is unique in Poland, the education given to the students must enable them an easy adaptation to their future work in design and technological offices as well as in scientific laboratories. The basic education comprises mechanics and electronics. The students follow special programmes in mathematics and physics, and study geometrical optics, diffraction theory of optical imaging, physical optics, instrumental optics, holography, principles of the laser technique and its applications, optical materials technology, assembly technology, design of optical instruments and mechanical design of optical instruments. During the 5-year study comprising altogether 4000 hours, 660 hours are devoted to specialized studies, 50% of which is of basic general character, 20% – of design profile, and 20% concerns the technology. Each student has four, one-month lasting, industrial training. The last year is devoted to the graduate work, its purpose is to prove that the student is ready to start the work as an engineer in the industry. Every year about 15 persons are graduated. Since 5 years one-year courses have been organized for engineers in order to make them acquainted with the achievements in optics and optical metrology.

During the thirty years history of the Group the research topics have been changing because of the changing demands of industry and research institutes, growing capabilities of the research staff, and of progress in world optics (especially because of the development of lasers). During the first 15 years the main activity, except for teaching, was the design and construction of various instruments ordered from outside. Next, with the development of computer techniques in this country, our Group was engaged in the aberration correction of optical systems. For about the recent 10 years we have been designing unique optical equipment and studying various optical phenomena, especially the diffraction problem related to optical system quality, performing also the technological research for the industry.

In the last 3 years (being the subject of this presentation) the following main research topics deserve a special emphasis.

1. The imaging theory

The theory of optical imaging has been rigorously presented in geometrical optics. In analysis of the diffraction phenomena the geometrical nomenclature is used, but its meaning changes in wave optics. For example, the term *geometrical focus* has no meaning in apodized systems, its equivalent for the non-truncated Gaussian beam being the beam-waist. Since more and more problems in instrumental optics require the wave-optics approach, the future goal is to present the unifield diffraction theory of optical imaging. For that purpose the imaging has been analysed by an aberration-free and non-limited optical system (paper 3) and the analogy with geometrical optics approach established. The general principles of reference sphere transformation for the object and Fourier spaces have been formulated in paper 3. The imaging process has been divided into two independent parts:

1. Ideal imaging by the system composed of square phase correctors, which corresponds to aberration-free imaging in geomtrical optics.
2. Imaging by the system of distorters describing the influence of diaphragms, apodizers and aberrations (paper 7).

The advantage of the distorter approach is a generalization of the analysis; it concerns all the systems that can be represented by a distorter. The theory of Gaussian beam transformation through the composed optical system has been presented in paper 1, and the synthesis of field changes of a truncated beam has been proposed in paper 5. The analyses of vignetting (paper 6) and parallactic phenomenon (paper 4) are conducted. The book on the theory of optical imaging is under preparation.

The leading person — Professor Romuald Jóźwicki.

2. Periodic elements in optics and acousto-optics

The main research interests concern the theory and applications of periodic structures under coherent and incoherent illumination. The general theory of Fresnel field of the complex amplitude transmittance diffraction grating has been formulated in papers 9, 10, and 12. The intensity distribution has been used, as giving the information on phase modulation introduced by photographic emulsions (papers 9, 10, 13). The new interpretation of the Talbot effect using the Fourier spectrum properties of periodic objects has been given in paper 19. A universal model for analysis of optical and acousto-optical systems using two diffraction gratings separated in space has been proposed in papers 14, 22, 41, 45–47, 49. The analysis concerns the Fraunhofer as well as Fresnel diffraction field. Few interferometric configurations using diffraction gratings under coherent and incoherent illumination and employed for the same operations in optical information processing have been described in papers 10, 11, 25, aberrations in optical systems and phase objects are studied in papers 16, 28, 30 and optical differentiation of displacement patterns — in papers 24–26. The method of multi-exposure computer generated holograms of many phase objects has been worked out; the product and sum-type holograms have been analysed in paper 18. The analysis models for studying the intensity distribution in the Fourier plane given in paper 24 are used for optimum design of multi-exposure holograms. The last research activities concern the coherent and incoherent superposition of self-imaging phenomenon (papers 20, 31) and the analyses of selected topics of light diffraction on acoustical waves and tilted optical gratings (papers 32, 47–50).

The leading person — Professor Krzysztof Patorski.

3. Image quality analysis

Research work conducted in this area includes the following topics: generalizations of Maréchal intensity formula that take into account apodization as well as the focal shift phenomenon (papers 51, 54), aberration-balancing techniques, both for apodized systems (papers 53, 55), and for the systems suffering from parallactic errors (paper 56), as well as sampling theorems for rotationally- symmetric problems (paper 52). Special attention has been paid to the optical systems for the use with Gaussian laser beams (papers 53–55).

The recent, unpublished contributions, deal with rapid methods of computing aberrational diffraction patterns (papers 57, 58), Dini sampling theorems for nonrotationally-symmetric systems (paper 60), colour correction in visual optical systems based on colorimetric approach (paper 59), aberration-balancing methods in the case of partially-coherent illumination, and — finally — efficient mathematical methods for decoding wavefronts from interferograms. Some results of the above investigations are being implemented in domestic optical industry.

The leading person — Dr. Stanisław Szapiel

4. Unique equipment and instrumentation design

The instrumentation is designed and produced on the demand of industry and scientific institutes.

The modular laser acousto-optic laboratory system (papers 33–40)

The system has been designed to provide a precise instrumentation for advanced academic teaching, selected industrial measurements and scientific research. The main areas of the system applications are coherent optics, nondestructive testing, acoustic imaging and laser metrology. From the educational point of view the laboratory system consists of 12 laboratory stands that represent 3 basic topics: visualization of acoustic fields, acousto-optical phenomena (principles and applications), and laser acousto-optic accessories.

Optical flat testing interferometer

The interferometer (see the Figure), based on Fizeau scheme, is equipped with a reference pattern plate made of high-quality glass or fused quartz with flatness inaccuracy $< \lambda/20$ over ϕ 180 working surface. Two standard light sources can be employed alternatively: mercury spectral lamp ($\lambda = 546$ nm) and He-Ne laser ($\lambda = 633$ nm). Interferogram may be observed with an optical eye piece or on the TV monitor. TV camera transmits the interferogram onto the monitor with a special electronic equipment for contouring interference fringes with equal density curves.

The instrumentation for the satellite orientation in space

The principles of the equipment performance are based on the electronic read-out of the information about angular localization and magnitude of the star. The measurement is performed by comparison with internal reference image generated by the instrument. The work done in cooperation with the Institute of Electronics Fundamentals of the Warsaw Technical University has been performed for the Space Research Center. The instrumentation is presently under operational tests.

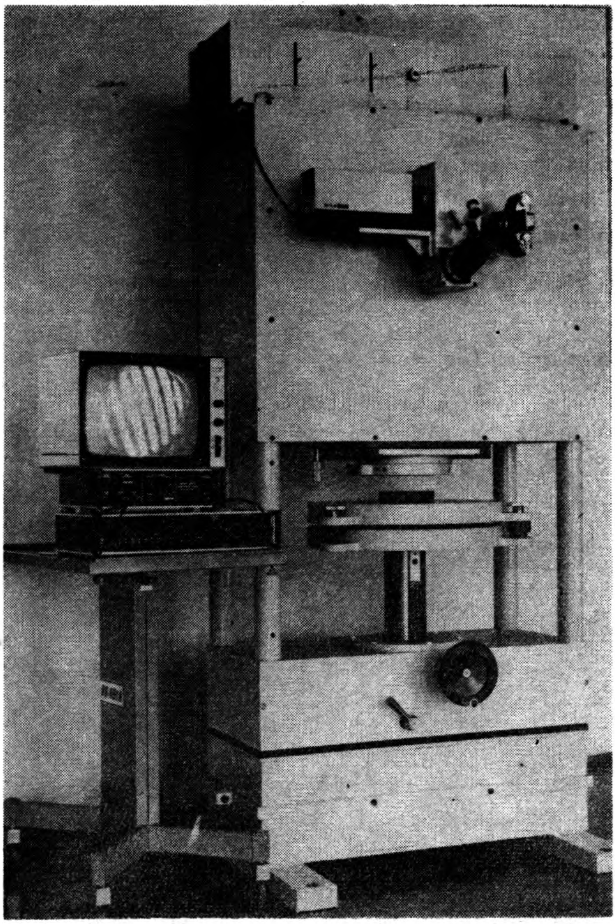
5. Technological studies

The main research effort in this field is devoted to the technological studies concerning the production of optical elements made of crystals and used in infrared, especially in high power, CO_2 lasers. The technology-oriented works on acousto-optical transducers and modulators are conducted, as well. The processes of adhesive and thermocompressive contact are investigated.

Staff members

The group consists of 8 persons responsible for the scientific and educational activity (their names and fields of research are listed below), as well as of 8 persons of technical staff (designers, technicians):

Professor Romuald Jóźwicki: instrumental optics, imaging theory, design of optical instruments,



General view of the interferometer with the special electronic equipment to display interferometric fringes

Professor Krzysztof Patorski: diffraction, interference, acousto-optics,
Dr. Małgorzata Kujawińska: holography, optical information processing,
Dr. Marcin Leśniewski: instrumental optics, design and assembly of optical instruments,
Dr. Maciej Rafałowski: instrumental optics, design and assembly of optical instruments,
Dr. Stanisław Szapiel: diffraction, image quality analysis, numerical methods in diffraction,
M. Sc. Eng. Andrzej Szwedowski: technology of optical elements,
M. Sc. Eng. Andrzej Wojtaszewski: design of optical instruments.

List of publications 1980–1983

Imaging theory

1. Jóźwicki R., *Laser optics* (in Polish), Wydawnictwa Naukowo-Techniczne, Warszawa 1981, pp. 234.

2. Jóźwicki R., *The application of the vector analysis in the quasi-spherical wave scalar diffraction*, Optik **62** (1982), 231–247.

3. Jóźwicki R., *Transformation of reference spheres by an aberration free and infinitely large optical system in the Fresnel approximation*, Optica Acta **29** (1982), 1383–1393.

4. Spik A., *Parallactic phenomenon in a composed optical system*, Optyka **1–4** (1982), 41–47 (in Polish).

5. Jóźwicki R., *Parametric analysis of truncated Gaussian beams*, Optica Acta **30** (1983), 73–84.

6. Rataj M., *Image vignetting of the harmonic amplitude object*, Optik **65** (1983), 253–261.

7. Jóźwicki R., *Imaging synthesis in the Fresnel approximation*, Optica Acta (in press).

Periodic elements in optics

8. Patorski K., Bokus A., *Studies of the single sideband Fresnel diffraction patterns of periodic objects*, Optica Applicata **10** (1980), 29–39.

9. Patorski K., *Fresnel diffraction patterns of a sinusoidal complex object with a small phase modulation*, Optik **55** (1980), 39–46.

10. Patorski K., *Three beam interference images of a single-frequency complex object with a small phase modulation*, Optik **55** (1980), 107–118.

11. Patorski K., *Production of binary amplitude gratings with arbitrary opening ratio and variable period*, Opt. Laser Technol. **12**, (1980), 267–270.

12. Kujawińska M., *Coding of many phase objects using multi-exposure synthetic hologram*, Doctor's thesis, Warsaw Technical University, 1981 (in Polish).

13. Patorski K., Parfjanowicz G., *Self-imaging phenomenon of a sinusoidal compexl object*, Optica Acta **28** (1981), 357–367.

14. Patorski K., *Theory and applications of Fresnel diffraction field of linear periodic objects*, Habilitation thesis, Warsaw Technical University, Mechanics V (1981), 73 (in Polish).

15. Kujawińska M., *Coding of many phase objects using computer generated binary holograms*, Optica Acta **28** (1981), 843–855.

16. Patorski K., *Periodic source Ronchi-Talbot shearing interferometer*, Optik **62** (1982), 207–210.

17. Patorski K., Wronkowski L., Dobosz M., *Some properties of Fresnel images of a square wave amplitude grating*, Optica Acta 29 (1982), 565–567.

18. Kujawińska M., *The analysis of the product and sum-type multi-exposure synthetic holograms*, Opt. Commun. **44** (1982), 565–567.

19. Jóźwicki R., *The Talbot effect as a sequence of quadratic phase corrections of the object Fourier transform*, Optica Acta **30** (1983), 73–84.

20. Patorski K., *Incoherent superposition of multiple self-imaging. Lau effect and Moiré fringe explanation*, Optica Acta **30** (1983), 745–758.

21. Patorski K., *Fraunhofer diffraction patterns of tilted planar objects*, Optica Acta **30** (1983), 673–679.

22. Patorski K., *Theory and applications of optical systems using periodic structures.* Proceedings of the 1983 European Optical Conference, Rydzyna, Poland (in press).

23. Patorski K., *Self-imaging phenomenon. Lateral shift of Fresnel images*, Optica Acta **30** (1983), 1255–1258.

24. Kujawińska M., *Fourier spectrum analysis of multi-exposure synthetic holograms*, Optica Acta **30** (1983), 1319–1329.

25. Patorski K., Szwaykowski P., *Producing and testing of binary amplitude gratings using self-imaging and double exposure technique*, Optics and Laser Techn. **15** (1983), 316–320.

26. Patorski K., Szwaykowski P., *Optical differentiation of quasi-periodic patterns using Talbot interferometry*, Optica Acta (in press).

27. Patorski K., *Optical differentiation of displacement patterns using double diffraction and spatial filtering*, Optics and Laser Technol. (in press).

28. Patorski K., *Heuristic explanation of the grating shearing interferomatry using incoherent illumination,* Optica Acta (in press).

29. Patorski K., *Modified double grating shearing interferometer,* Optica Applicata **13** (1984).

30. Patorski K., *Reversed path Ronchi test,* Optica Applicata (in press).

31. Patorski K., *Some experiments in the Fresnel region of double diffraction systems* (submitted to Optica Acta).

32. Patorski K., *Fresnel diffraction field (self-imaging) of obliquely illuminated linear diffraction grating* (submitted to Optica Acta).

Acousto-optics

33. Szwedowski A., Szapiel S., *Laser acousto-optics laboratory,* AND **VI**, 1 (1980), 4–6 (in Polish).

34. Piwoński A., *Visualization of ultrasonic fields,* AND **VI**, 1 (1980) 6–14 (in Polish).

35. Kozłowski J., *Triangular-path (Sagnac) interferometer,* AND **VI**, 1 (1980), 14–21 (in Polish).

36. Szapiel S., *Glass-plate lateral shearing interferometer,* AND **VI**, 1 (1980), 22–26 (in Polish).

37. Szapiel S., *Acousto-optical heterodyne interferometer,* AND **VI**, 1 (1980), 26–30 (in Polish).

38. Szapiel S., Kozłowski J., *Acousto-optic intercavity modulator,* AND **VI**, 1 (1980), 30–34 (in Polish).

39. Piwoński A., *Measurement of elastic constants of materials using Shaefer-Bergman* method, AND **VI**, 1 (1980), 39–42 (in Polish).

40. Szwedowski A., Szapiel S., *Laser acousto-optics laboratory, the recent developments in science and technology,* AND **VI**, 1 (1980), 42–48 (in Polish).

41. Patorski K., *Theory and applications of the far field double diffraction on the progressive spatial phase modulation and stationary amplitude grating,* Optica Applicata **11** (1981), 71–83.

42. Patorski K., *Diffraction testing of ultrasonically-produced phase gratings using a double beam illumination method,* Ultrasonics **19** (1981), 120–124.

43. Patorski K., *Optical testing of ultrasonic phase gratings using Fresnel diffraction method,* Ultrasonics **19** (1981), 169–172.

44. Patorski K., Szwaykowski P., *Light intensity distribution in the Fresnel diffraction region of a non-sinusoidal phase diffraction grating,* Optica Applicata **11** (1981), 627–631.

45. Patorski K., *Fourier series for the irradiance of light modulated by an ultrasonic progressive wave associated with an optical amplitude grating,* Acustica **52** (1983), 246–256.

46. Patorski K., *Fourier series analysis of the irradiance of light modulated by an ultrasonic progressive wave associated with an optical phase grating on an anti-parallel sound beam,* Acustica **53** (1983), 1–10.

47. Patorski K., *Optical harmonic analysis of ultrasonic phase gratings. Selected topics.* Proceedings of 2nd Spring School: *Acousto-optics and its Applications,* May 24–29, 1983, Wieżyca, Poland (in press).

48. Kozłowski J., Szapiel S., *The self-stroboscopic interferometric method for visualization of travelling acoustic wave,* Proceedings of 2nd Spring School: *Acousto-optics and its Applications,* May 24–29, 1983, Wieżyca, Poland (in press).

49. Patorski K., *Stationary Fresnel diffraction field of an ultrasonic progressive wave associated with an optical grating,* Parts I, II, III, Acoustic Letters **7** (1983), 27–30, 39–42.

50. Patorski K., *Fresnel diffraction field of ultrasonic phase gratings under double beam illumination* (submitted to Ultrasonics).

Image quality

51. Szapiel S., *Generalization of Maréchal intensity criteria for apodized systems,* Doctor's thesis, Warsaw Technical University, 1980 (in Polish).

52. Szapiel S., *Sampling theorem for rotationally-symmetrical systems based on Dini expansion,* Opt. Lett. **6** (1981), 604–606.

53. Szapiel S., *Aberration-balancing technique for radially-symmetric amplitude distributions: a generalization of the Maréchal approach,* J. Opt. Soc. Am. **72** (1982), 947–956.

54. Szapiel S., *Maréchal intensity formula for small-Fresnel-number systems,* Opt. Lett. **8** (1983), 327–329.

55. Szapiel S., *Aberration-balancing: conventional versus unconventional problems and techniques,* Proceedings of the 1983 European Optical Conference, Rydzyna, Poland (in the press).

56. Spik A., *The influence of wave aberrations on the parallactic phenomenon* (submitted to Optik).

57. Szapiel S., *Point-spread function calculation: a quasi-digital method* (submitted to J. Opt. Soc. Am.).

58. Szapiel S., Spik A., *Fast computation of the three-dimensional field distributions in focal region of aberrated systems: the merry-go-round method* (in preparation).

59. Szapiel S., *Color correction in visual optical systems using uniform-color-space-based image quality criteria* (submitted to J. Opt. Soc. Am.).

60. Szapiel S., *Sampling theorems for nonrotationally-symmetric systems* (submitted to J. Opt. Soc. Am.).

Others

61. Leśniewski M., *Theoretical foundations of a new method of determination of technological tolerances of optical elements,* Optyka **3–4** (1981), 37–45.

62. Chen H., Kujawińska M., *Astigmatic one step technique of rainbow hologram process,* Opt. Commun. **30** (1982), 169–174.

63. Rafałowski M., *Zentrierung einer Punktquelle auf die Achse eines sphärischen konfokalen Fabry-Pérot-Interferometers. Theorie,* Optik **60** (1982), 113–127.

64. Rafałowski M., *Zentrierung von Punktbildern auf die Achse eines quasikonfokalen Fabry-Pérot-Interferometers. Realisierung, Experimente und Anwendung,* Optik **61** (1982), 293–306.

65. Patorski K., Szapiel S., *The guide to coherent light students laboratory,* Warsaw Technical University 1982.

Romuald Jóźwicki