

Concept of Modern Optical Training Labs for Optical Engineering Students

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ABSTRACT

This contribution is the extension of our communications on conferences EDUCATION IN OPTICS in RUSSIA 1991 & HUNGARY 1993 [1-3]. The aim of this report is to present general principles and detailed program of training labs in Geometrical, Wave and Quantum optics on the General Physics level (for second year students). In recent years this concept has been employed in St.Petersburg Institute of Fine Mechanics & Optics.

INTRODUCTION

The statements of this report are dedicated to organization of process, software and hardware for laboratory course in Optics in the course of general Physics for students of Universities and Polytechnical Institutes in Russia, who are specialized in Optics, optical Mechanics and Electronics. The total amount of training hours is from 18 (9 two-hours classes) to 48 (12 four-hours classes) in one term. The main advantages of proposed Teaching Technique are the module construction, high flexibility, good consolidation of the lecture material and wide range of optical test-objects. It allows students to study not only traditional phenomena, but also the modern applications of wave and quantum optics. The examples of students curriculum and labs are also discussed.

GENERAL PRINCIPLES

Rapid development of optical technologies demands the change of the conception of study Optics. We consider the students, who study General Physics, now have to understand the main modern optical phenomena and can operate new equipment such as diffraction, gradient and holographic elements, laser technics, nonlinear effects, biomedical and ecology application, optical computers and information systems, image processing etc. In the teaching laboratory or lecture courses all those mean:

- connection between traditional parts (interference, diffraction, polarization etc.) and modern optical phenomena in the same period of time;
- teaching the classic optical phenomena by using modern objects of study - film and photolithographic structures, semiconductor materials, fiber-optics or liquid-crystal elements;
- using the examples of digital image analysis, CCD - devices and computer simulation.

The deep teaching of modern Physics usually demands the deep knowledge of Mathematics. At the same time, the study of the theoretical material beside real physical phenomena is not effective. That is why, Purposes of deep laboratory course in Optics are illustration and good motivation of application of matrix in geometry optics and polarization, correlation analysis in study coherence, elements of Fourier transform in diffraction, spatial filters etc.

It is important to inoculate in students the skills to make experiments by using laser and diode sources of light, systems of forming spectral and spatial properties, fiber optical systems, various receivers of radiation. The equipment has to make possible the realization of various interference schemes, phase methods, demonstration of properties of diffraction and holographic elements.

MODULAR EQUIPMENT

The laboratory course should make possible the realization not less than 3-4 labs per one tutorial, and each lab should be supported by the number of objects. Variance of the methods and objects allows to change the study program, depending on level of students and their specialization. We consider, the provision of variance can be made by module principle of the laboratory equipment. An optical module educational laboratory (OMEL) enable to provide the studies by frontal manner in accordance with the lecture matter (see Table.1). The OMEL covers main sections of the course, namely: laws of geometrical optics, photometry, interference of coherent and partial coherent light sources, simple apertures diffraction (see Table 2, A - general level, B - deep level, C - high level), diffraction on the regular and irregular structures, polarization, dispersion, reflection and absorption of light, atomic and molecular spectra, solid emission spectra. The OMEL equipment is formed by referred module principle [2]. With the aid of module equipment (optical constructor) the students may realize various optical sets in different versions (from usual "manual" to automatized installations under IBM PC control). The modification of optical sets needs a minimum time.

Table 1. Contents of the lecture course "Wave & Quantum Optics" with topics of module labs.

1	2	3	4
	Minimum course	Enhanced course	Labs (3...4 h)
1	Introduction. Optotechnics - key to modern high technology.	Temporal & Spatial Fourier Transform: Properties. Examples.	
2	Electromagnetic nature of light. Plane & Spherical Waves, Wave Groups Dispersion. Phase & Group Velocity.		Acquaintance with Hard- & SoftWare
3	Ray Optics. Principal Laws. Lenses & Mirrors. Optical Devices Classification.	Gradient Mediums. Normal Modes. Principles of Fiber Optics.	
4	Energy of Light. Photometry. Real Light Sources. Radiation Spectrum. Broadening.		Ray Optics & Photometry.
5	Interference of monochromatic & nonmonochromatic Waves. Coherence of Light. Coherence Time & Length.	Coherence & Correlation. Complex Degree of Coherence. Convolution. Autocorrelation.	
6	Young's Double Slit. Fresnel's Biprism. Lloyd's Mirror. Stellar Interferometer. Source Size & Coherence		Interference I.
7	Division of Amplitude. Newton's Rings. Thin Films. Equal Thickness Stripes. Twin-Beam Interferometers Classification.	Temporal Coherence. Contour of Spectral Line. Fourier Transform Spectroscopy.	
8	Multiple Beam Interference. Fabry-Perot Interferometer. Resolution in Wavelength. Interference Filters.		Interference II.
9	Interference of secondary Waves. Huygens Fresnel Principle. Half-Period Zones. Phasor Diagram. Poisson's Spot. Zone Plate. General Aperture.	Kirchhoff's Diffraction Theory. Diffraction & Spatial Fourier Transform. Properties of Zone Plates.	
10	Fresnel's & Fraunhofer Diffraction. Cornu's Spiral. Rayleigh Distance. Single Slit. Rectangular & Round Aperture.		Diffraction I.
11	Diffraction Patterns of the N Slits. Diffraction Gratings. The Effect of Slit Width & Shape. X-Ray Diffraction.	Diffraction at a Ring Aperture. Babinet principle. Fourier Transforms in Grating Theory. Fractal Diffraction.	
12	Diffraction Theory of Imaging. Abbe-Porter Experiment. Resolving Power. Rayleigh Criteria. Coherent Illumination.		Diffraction II.
13	Sin-Gratings. Sound Waves Diffraction. Holography. Holograms of Plane & Spherical Waves. Thick Holograms.	Spatial Filtering. Basics of Fourier Optics. Phase-Contrast Microscopy. Computer Generated Holograms.	

1	2	3	4
14	Isotropic Propagation. Refractive Index & Wave Impedance. Fresnel's Formulas. Lorentz Dispersion Theory. Absorption.		Dispersion & Absorption.
15	Polarization of Light. Elliptical, Circular & Plane Polarizations. Devices & Measurements. Natural & Induced Birefringence. Optical Activity.	Formal Description. Stokes Parameters. Poincare's Sphere. Coherence & Polarization. Basics of Crystal Optics. Polarized Rays Interference.	
16	Elastic & Nonelastic Scattering. Classical & Quantum Description. Thermal Radiation. Photons. Plank's Formula.		Polarization & Scattering
17	Spontaneous & Stimulated Emission. Light Amplification. Classification of Lasers. Basics of Nonlinear & Fiber Optics.	Optical Cavities. Modes. Gaussian Beam Optics. Ultra Short Pulses. Solitons. Optical Bistability.	
18	Photoeffect. Pressure of Light. Thomson & Compton Scattering. Necessity for Quantum-Mechanical Approach.		Lasers & Fibers.

Table 2. Laboratory occupation N 4 - Diffraction I (diffraction on the single objects)

<input type="checkbox"/>	Experimental investigations	Results
A1	Measurements of Diffraction at a Single Slit with different Widths	Dependence on the Slits Width, Check-Up the Condition of the Fraunhofer Diffraction
A2	Measurements of Diffraction at a Circular Apertures (Holes, Discus & Rings)	Calibration of the Ary's Spot, Size Determination, Features of the Ring's Diffraction.
A3	Study of the Fresnel Diffraction, Changing the Quantity of Half-Period Zones.	Check-Up the Rayleigh Criterion, Observation of the Poisson Spot.
B1	Study of the Resolution Limits, Coherent & Non-coherent Illumination.	Determination of the Resolving Power.
B2	Testing the Amplitude & Phase Zone Plates.	Measurements of the Main & Multiple Focus Lengths, Intensity Comparison.
C1	Study of the Diffraction at the Phase Objects, Phase-Contrast Microscopy.	Determination of the Phase Shifts, Choice of the Most Effective Procedure.
C2	Spatial Filtering: Application of Different Binary Masks .	Observation of the Images, Calculation of the Spatial Frequences.
C3	Study of Gaussian Beam Diffraction and Diffraction at a Apodise Aperture.	Input Amplitude Distribution Dependence of the Resolving Power.

The basic elements of OMEL are the modules (manual or controllable by PC) for fine turnings of optical elements, test-objects, photosensors etc. The View of the Optical Laboratory with Modular Equipment can be seen in Fig.1. This Equipment is supported by Windows Interactive Software (see Fig.2 and [4]). Modules were produced uniformly, have the same contact ware and so they can be composed in various combinations for realization of different measuriments schemes, which are shown in Fig.3. Modules in common use are: axes and vertical turning module, spectral selection module, photosensor pinhole or matrix module, shutter module. Exept this, there are auxiliary modules: sources of light (coherent and incoherent), photodetectors, support elements, screens etc.

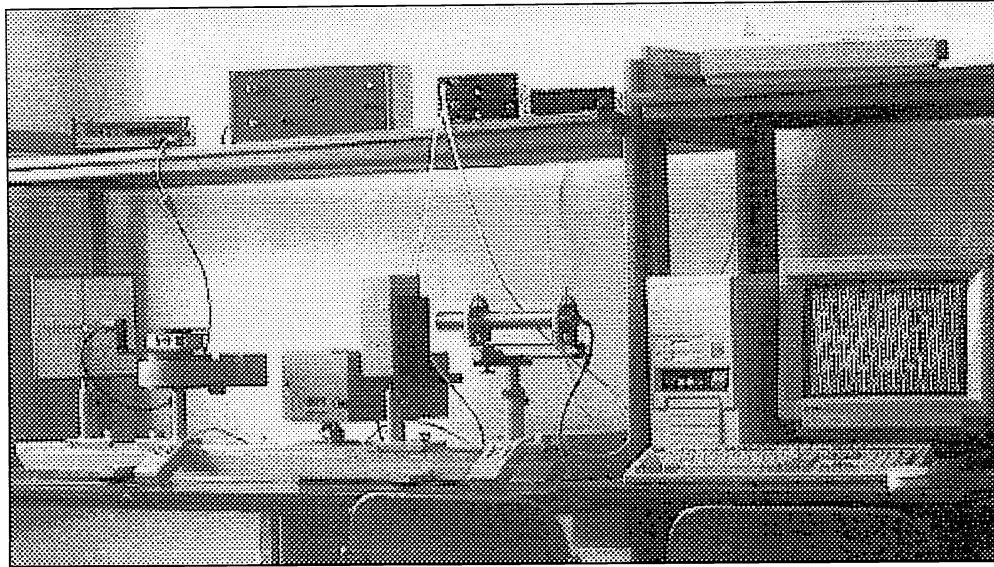


Fig.1 View of the Optical Laboratory with Modular Equipment.

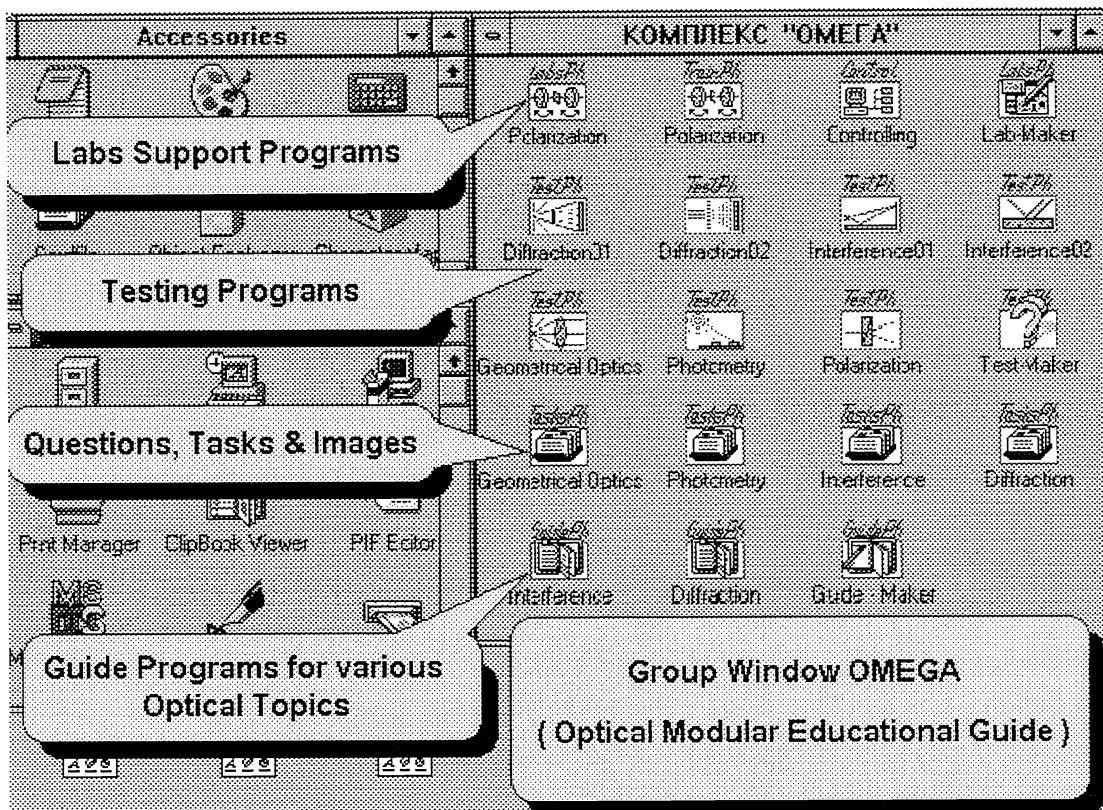
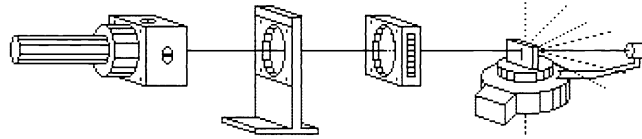
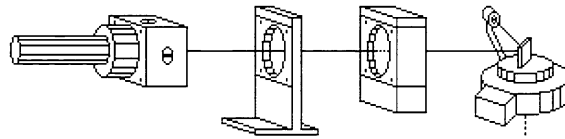


Fig.2 Group Window of Interactive Software for Enhanced Study of Optics.

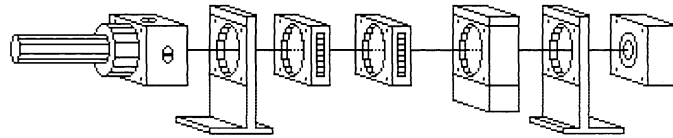
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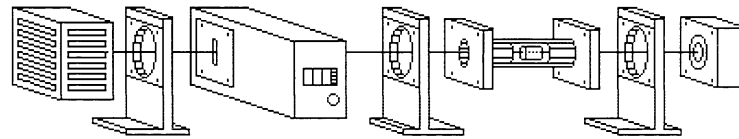
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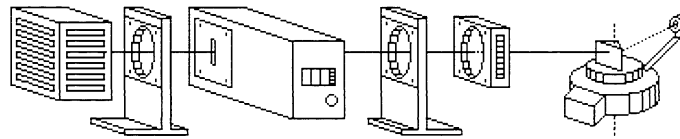
C.



D.



E.



F.

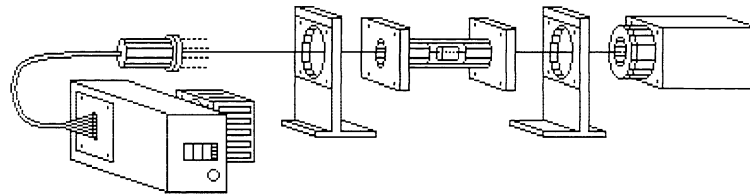


Fig.3 Examples of Modular Setup for Optical Training Labs:

- A - STUDY OF DIFFRACTION, INTERFERENCE & DISPERSION OF LIGHT
- B - STUDY OF REFLECTION FROM VOLUME MATERIALS & FILM STRUCTURES
- C - MEASUREMENTS OF POLARIZATION PARAMETERS
- D - THE INVESTIGATION OF ABSORPTION, EMISSION & FLUORESCENCE SPECTRA
- E - THE DETERMINATION OF REFRACTIVE INDEX & WAVE IMPEDANCE
- F - THE STUDY OF INTERFERENCE & POLARIZATION IMAGES

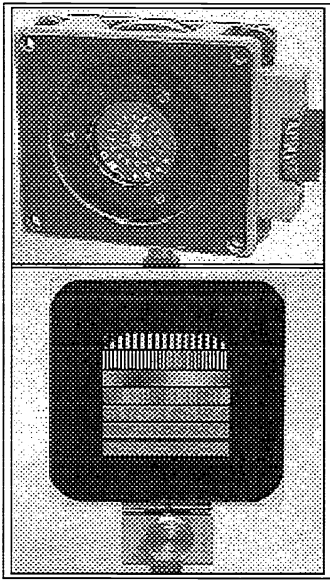


Fig.4 Manual modul with test-objects for laboratory experiments (top) and photolithographic gratings for lecture demonstrations.

PHYSICAL TEST-OBJECTS

There are several physics test-object: both the traditional optical elements (e.g. lenses, prisms, biprisms, mirrors, visual observation screens etc.) and the special optical objects to be made by a photolithography technology (e.g. differents slits, apertures, disks, one- and two-dimensional regular and irregular structures, objects with light reflection and light absorption dielectric films etc.). In addition, some cuvette collections with liquid solutions of different composition and radiation sources (e.g. spectral lamps, continuous spectrum imitator-lamps etc.) are made use. This object collection may be considerably extended in case of new optical materials application, for example, liquid crystals, microporous mediums, photosensitivity and structures of light radiation.

Examples of test-objects for labs and lecture demonstrations are shown in Fig.4 and 5. Because of uniform sizes one can use the same manual modules to support all test-objects. Diffraction and Interference Patterns from this objects are presented in Digital Image Files Collection, which formed by means of CCD-camera [3].

CONCLUSIONS

The samples of usage of the laboratory make possible to come to a conclusion about the good perspectives of OMEL devices for training in wave optics. The physical test objects, which were made by advantage technologies: submicron photolithography, film structures on isolator and semiconductor basis, flat reflectional optics, phototropic, microporous and liquid crystal matrixes and so on, have an interest, too. We think, such methods of education teach

students to use PC, not only for calculation and vision, but as a control element in high-technology systems. Another OMEL possibilites (Optoelectronics training, Optical Methods in Ecology, etc.) discuss in reports [1-2].

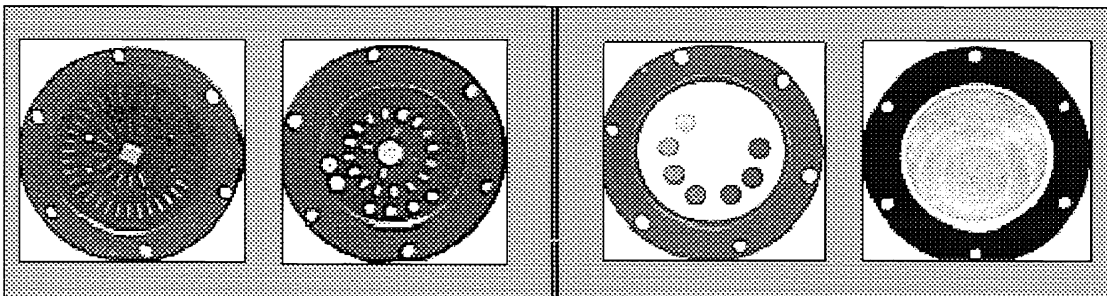


Fig.5 Examples of test-objects for diffraction and interference investigations: two amplitude photolithographic structures (left) with more than 100 different masks (slits, holes, disks, rings, zone plates, 1D&2D simple gratings, 1D Fourier-gratings, 2D periodic and random structures, etc.) and two film structures (right) with absorbtion and dielectric layers on the glass basis.

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- 4.S.C.Stafeev, V.Y.Michnovetz and others, *Windows Software for enhanced studying and testing knowlege in optics*, same volume.