Optics in general physics for high engineering education

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ABSTRACT

Optics in general physics courses is intended for optical mentality formation providing for the army of engineers to understand and realize the modern optics possibilities. Optics education improvement depends on deep modernization of the experimental basis of physics courses. To protect these courses from superfluous theorizing experimental lectures could be inculcated in teaching. For example a cycle of demonstration experiments on polarization properties of birefringent plates is briefly described in the paper. The experimental device for the fundamentals of holography demonstration is also presented in the paper showing the ways of contemporary optical techniques teaching and training.

1. INTRODUCTION

The coherent epoch in optics which began three decades ago became a powerful accelerator of science and engineering. Nowadays contemporary optical devices and techniques are intensively inculcated in industry including non-conventional applications. At the same time rapid development in optics demands the corresponding optical mentality formation providing for the army of engineers to understand and realize the modern optics possibilities. For many students the first and often the last acquaintance with fundamentals of optics takes place at the general physics lectures, so optics presentation in physics courses is of great importance for the progress in optics itself.

Unfortunately the convectional optics formed before the coherent revolution is still preserved in general physics for high school. First of all it is typical for demonstration experiments and training laboratories which are often based on ancient equipment more suitable for museums. As the result students receive wrong impression about the contemporary optics level, and many of them are "frightened out" after acquaintance with old optical techniques. It explains why optical engineering prestige is now lower than that of popular specialities as electronics and mechanics.

Therefore optics education improvement essentially depends on deep modernization of the experimental basis of the general physics course. The most important purposes of this modernization are

1) "specific gravity of experimental information" increasing both for primary phenomena observation and for theoretical and experimental results comparison;

2) acquaintance with modern optics applications in science and engineering;

3) "experimental culture" of optical measurements improvement;

4) new optical phenomena and objects inclusion into general physics courses.

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It is not a secret that modern general physics courses become more and more theoretical pushing away both students and administration of engineering departments. That is why new kinds of lectures must be found to safe general physics in high engineering school. We suppose that experimental lectures could help to solve this problem. The main idea is the supremacy of experiment and the subordinate role of theory, however it is very difficult to find the golden mean between these sides of the course. As the examples of the activity in this direction a cycle of demonstration experiments on polarization and a demonstration device on holographic interferometry are presented in this paper.

2. POLARIZATION PROPERTIES OF BIREFRINGENT PLATES

Polarization of light and media anisotropy are among the most difficult subjects for studying in general physics. The difficulties are multiplied by the absence of effective visual aids. Keeping in mind that our students are not professional opticians and that they are interested particulary in polarization effects applications we exclude from the physics course almost all theoretical questions connected with crystallooptics and concentrate the attention on polarization states transformation by linear and circular birefringent plates.

To demonstrate these phenomena, a very convenient and simple carrier is used (Fig.1,a) which consists of two organic glass holders settled on the object plane of an overhead projector. Two large polarizers based on dichroic films are mounted on these holders. Rotating the upper polarizer (analyser) we can demonstrate the Malus law. If we settle a quarter-wave glimmer plate between these polarizers arranging the plate axis to be parallel to the lower polarizer axes of transmittance no effects will be noticed at the screen. Rotating the plate by 45 degrees we shall observe that the light intensity passed the plate doesn't change under the analyser rotation (Fig.1,b). Combining this plate with a similar one we shall obtain a half-wave plate which rotates the azimuth of linear polarization: the plane image at the screen is dark when the field surrounding the plate is bright and vice versa.

For thick plates chromatic effects appear, and the colour of a plate depends on the analyser axis position. It is worth demonstrating a very important element of polarization devices, that is a phase compensator, or Babinet compensator. It consists of two single-wedge compensators which create a beautiful inhomogeneously coloured pictures being arranged between crossed polarizers.

As for induced linear birefringence it is easy to prepare a small isotropic bar from organic glass and mount it into a press arranged between crossed polarizers. Increasing pressure we observe the bar lightening and colouring due to photoellasticity. This experiment demonstrates a very powerful technique used for media strain investigation. For example several tempered glass samples could be observed between crossed polarizers imaging the picture of stress distribution.

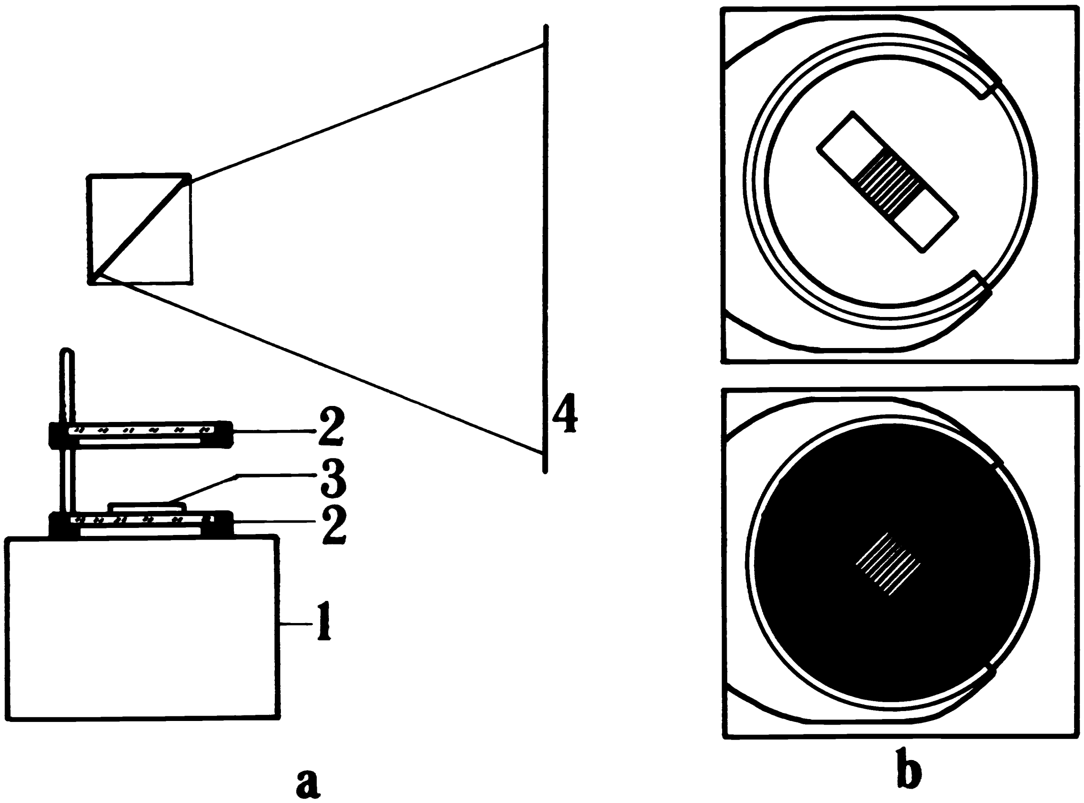


Fig.1. Polarization phenomena demonstration
a) schematic of experimental setup: 1- overhead projector, 2- polarizer holders. 3- anisotropic plate, 4- screen;
b) images at the screen corresponding to a quarter-wave plate under analyser different positions.

Optical active crystals could be demonstrated under similar conditions, e.g. plates of right and left rotating quartz. But the most impressive demonstration on circular birefringence is Faraday rotation by ferroelectric crystals. e.g. gadolinium orthoaluminate. This very simple experimental device shown in Fig.2,a contains a microscope and a miniature TV-camera and allows students to observe magnetic domains and their transformation under magnetization (Fig.2,b).

We consider that being acquainted with this cycle of experiments students could be able to carry out polarization measurements independently.

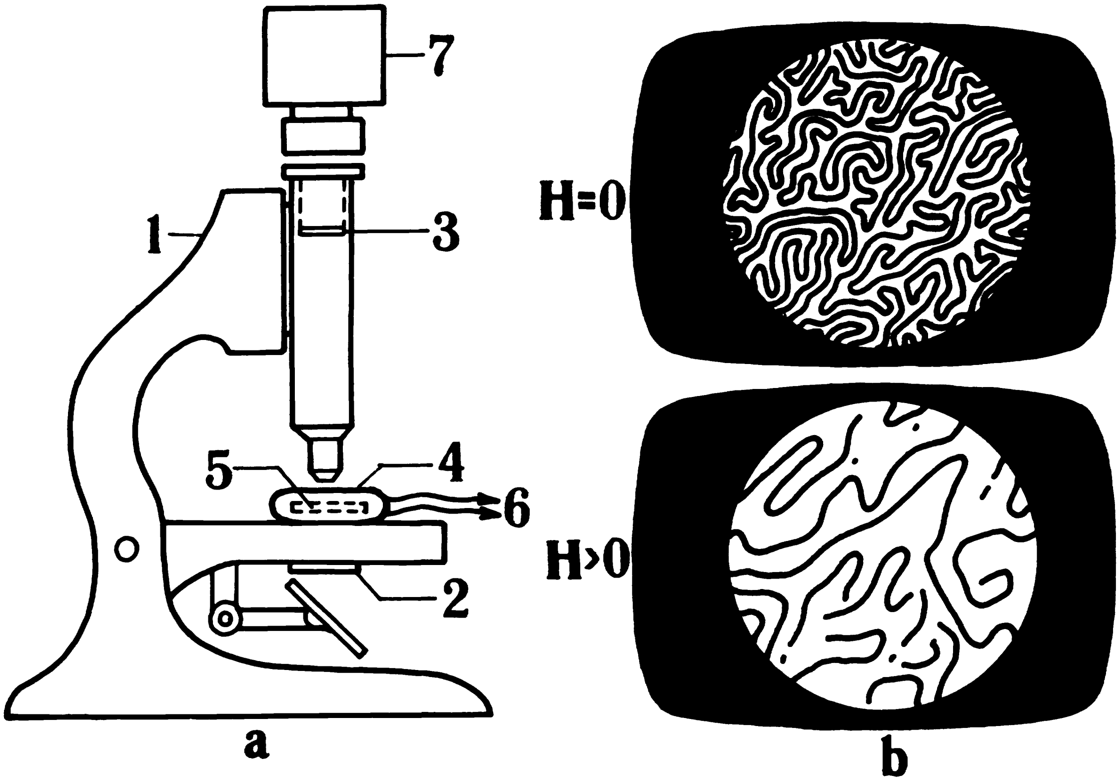
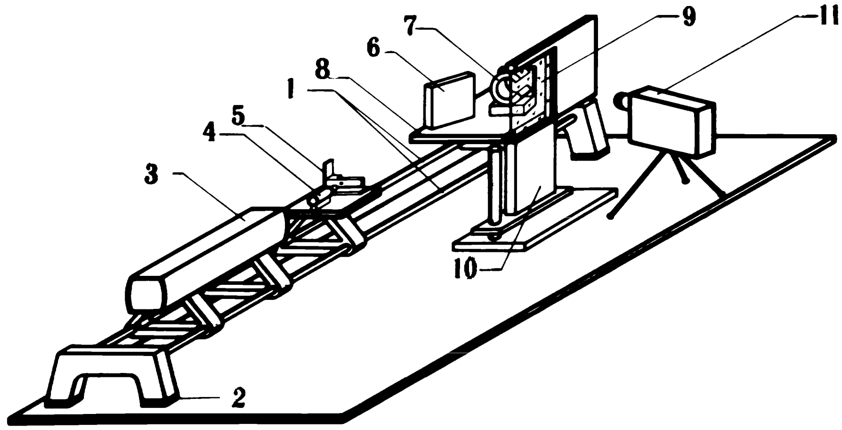


Fig.2. Experimental device for Faraday effect and magnetic domains demonstration
a) schematic drawing: 1- microscope, 2- polarizer, 3- analyser, 4- gadolinium orthoaluminate crystal, 5- coil, 6- dc source, 7- TV-camera;
b) crystal images under magnetization.

3. DEMONSTRATION EXPERIMENTS ON HOLOGRAPHIC INTERFEROMETRY

The fundamentals and applications of holography are presently included in every general physics course. To improve teaching of these subjects it is necessary to provide the complete holographic process experimental demonstration. A universal device for holograms recording, reading and objects microdistortions or microvibrations interferograms observations developed for lectures demonstrations and laboratory experiments is described in this section.



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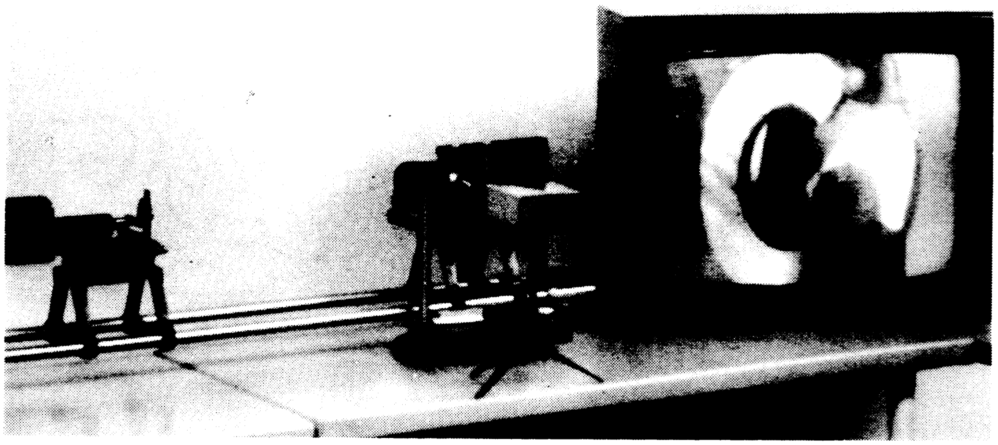

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Fig.3. Experimental device for holograms recording demonstration
a) schematic drawing: 1-tracks, 2-vibroprotecting layings, 3-He-Ne laser, 4-short-focus objective, 5-pin-hole diaphragm, 6-reference mirror, 7-object, 8-massive base, 9-photoplate (hologram), 10-opaque vessel, 11-TV-camera;
b) photo of the experimental arrangement with a holographic interferogram picture at the monitor.

The experimental setup shown in Fig.3 is settled on the demonstration table directly in the class-room. The optical carriers are arranged on the vibroprotected tracks. A single-mode He-Ne laser (wavelength 628 nm, power 10 mW) output beam is spatially filtered by a short-focus objective and a pin-hole diaphragm (diameter 50 - 70 μm). After filtering the homogeneous beam illuminates a mirror and an object both arranged on massive base with Γ-wall as a photoplate carrier. The beams reflected by the mirror and the object create the interference pattern which is imaged by a photoplate LOI-2 (spatial resolution 5000 lines/mm, sensitivity 0.05 units of the USSR standard). Chemical development is carried out without the plate displacement. The opaque vessels with chemical solutions are successively lifted without touching the plate. After the hologram production it is possible to observe the object holographic image and the holographic interferograms under the object distortion. The complete holographic process beginning from the interference pattern recording passing through the plate chemical development to the object image and interferograms observation is visualized by a TV-system.

During the demonstration the mirror and the object are kept under observation at the TV-monitors. The class-room is soft darkened for about a minute while the photoplate is mounted at the Γ-wall and exposed (15 s). After development in the opaque vessel (3 - 5 min) the plate is processed in the lightened class-room. Several minutes are enough for fixing and drying in alcohol. If the object is shut the holographic image could be observed at the TV-monitors. Changing the TV-camera position it is easy to demonstrate volume properties of holographic images. If the object is opened and slightly distorted the interference fringes appear demonstrating the principles of real-time holographic interferometry (Fig.3). To obtain a double-exposure interferogram the plate should be twice exposed before and after distortion. The experimental device described here was produced in 1985 and since that time became one of the most popular physical demonstrations.

4.CONCLUSION

The paper illustrates possible ways of improving optical education in high engineering school. Opposite to professional opticians teaching general optical education ignores complicated theoretical problems and experimental details concerned optical designing. At the same time conventional and modern optical techniques and devices as well as the fundamentals of light propagation should be clearly and effectively presented in general physics courses to arouse future engineers interest in optics applications. To realize this task under limited time available thorough selection of the studied subjects and effective visual aids should be used as it has been shown in the paper. A few other examples of demonstration experiments cycles could be mentioned which have been developed at our department.

Diffraction:
- Fresnel diffraction by simple obstacles (aperture, disk, knife-edge, slit, etc.);
- Fraunhofer diffraction by a slit (indeterminacy principle);
- Chaos multiple disk diffraction (non-coherent addition of elementary diffraction patterns);
- diffraction gratings (elementary diffraction patterns interference);
- Fraunhofer spectrum spatial filtering (image processing);

Interference:
- Michelson interferometer;
- coherence of light beams;
- beams interference in thin films;
- Fabry-Perot interferometer;
- holographic interferometry;

Fiber-optics:
- total reflection;
- polarization properties under total reflection;
- power leakage through the boundary under total reflection;
- optical waveguide model;
- image transmission through optical fibers;
- optical fibers for communication links.