Lecture demonstrations for general physics course using television

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Usp. Fiz. Nauk **121**, 345–348 (February 1977)

The note contains a description of some demonstrations used in the course of general physics but are difficult to demonstrate in a large hall because of the small dimensions of the phenomena and the weak illumination. The PTU-106 television system is used for such demonstrations.

PACS numbers: 01.50.My, 01.50.Fr

There are several desciptions in the literature[1] of lecture demonstrations using television, but extensive applications of this progressive method are only just beginning. Television has a number of undoubted advantages and can be used to demonstrate the dynamics of phenomena at low illumination and high magnification. For more than two years, the Physics Department of Leningrad State University has been arranging demonstrations of experiments in a large lecture theater. Some of these demonstrations are described below. The demonstrations make use of the standard PTU-106 television system. Six television sets are placed at strategic points, and this is quite enough for viewing from any point in the theater.

1. ANOMALOUS DISPERSION IN VAPORS (THE METHOD OF HOOKS)

The main part of the demonstration equipment (Fig. 1) is the Rozhdestvenskiĭ interferometer,[2] built in the workshops of the Physics Laboratory. The white-light source is the slide projector 6. Horizontal interference bands are projected onto the entrance slit of the UM-2 monochromator. The exit slit of the monochromator is removed, and the focal plane lies on the photocathode of the orticon 8. Glass cells 3 are placed in both arms of the interferometer. A piece of sodium metal is placed in a special recess in one of these cells. Cleaning is achieved by intensive heating and by pumping with a backing pump. A buffer gas (neon) is introduced in order to reduce the deposition of sodium on the windows. The electrical heater 4 ensures the necessary sodium vapor pressure. This experiment is quite difficult to demonstrate and requires the suppression of vibrations. The interferometer is therefore mounted on two rigidly coupled optical benches 2 which are mounted on a heavy demonstration table 9 supported by rubber rings.

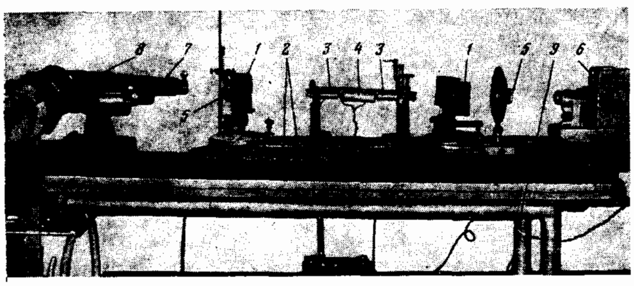

FIG. 1. Apparatus for demonstrating anomalous dispersion in sodium vapor. 1—Interferometer head, 2—optical bench, 3—glass cells, 4—electrical heater, 5—beam shaping lenses, 6—slide projector, 7—monochromator, 8—transmitting tube, 9—demonstration table.

The experiment can be demonstrated in two ways. In the first variant, a narrow dark absorption line appears on the television screen as the vapor pressure is increased, and the variation in curvature of the interference bands in the neighborhood of this line reproduces the variation in the refractive index near the absorption line (this is the Puccianti method). In the second variant, a thin piece of mica is introduced into the arm of the interferometer containing the "empty" cell, and this produces an additional path difference. The Rozhdestvenskiĭ "hooks" are then found to appear near the absorption line (Fig. 2).

2. BROWNIAN MOTION

The specimen is an emulsion of milk in water (in the ratio of about 1:100), placed between cover slips on the horizontal table of a microscope. It is illuminated by a source of light which is weak enough to prevent heating. The actual image of the specimen is projected onto the photocathode of the camera. In order to be able to

FIG. 2. Rozhdestvenskiĭ hooks near the absorption line of sodium.

FIG. 3. Instantaneous photograph of Brownian particles shown against a measuring grid.

estimate the mean square displacement due to the random motion of the particles in a period of about 1 min, the microscope-orticon-TV screen system must produce sufficient magnification. In our case, the magnification is about 20 000. Before the demonstration, the scale of length is determined by comparing a given distance with the scale in the eyepiece of a microscope.

Figure 3 shows a photograph of Brownian particles together with a reference grid (side length of the square is 10 μ). A transparent sheet placed on the television screen is used to mark the position of a given Brownian particle at intervals of 5 sec. This method can be used to estimate $\overline{\Delta r^2}$ and the magnitude of the Boltzmann constant. Thus, for example, from Fig. 4 with $r \sim 0.5\ \mu$, $\eta = 0.01\ P$, $\Delta t = 5$ sec, $T \sim 300\,^{\circ}\mathrm{K}$, we find, using the Einstein–Smoluchowski formula,[3] that $k \sim 10^{-16}$ erg/deg.

3. IMAGE FOCUSING DURING DIFFRACTION OF LIGHT ON A SMALL SCREEN

Figure 5 shows the image of the symbol $h\nu$ on the television screen. The object was inscribed with a sharp needle on a blackened glass plate and was illuminated by the DRSh-250 lamp equipped with a condenser. The distance between the object and the orticon cathode was about 12 m.

Lectures on the diffraction of light are sometimes illustrated with photographs of the diffracted image.[4] The television method of demonstrating this is better than the conventional demonstration because the students

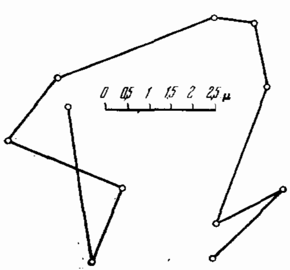

FIG. 4. Positions of Brownian particles at intervals of Δt = 5 sec.

FIG. 5. Diffraction image of the symbol $h\nu$.

can see the apparatus and the lecturer can vary the experimental conditions.

4. MAGNETIC DOMAINS

A thin (0.1 mm) single-crystal plate of orthoferrite ($DyFeO_3$)[5] is placed on the stage of a polarizing microscope. The real image of the surface of the plate is projected onto the photocathode of the receiving tube. When the microscope magnification is about 100 and a particular orientation of the optic axis of the crystal is used, it is possible to see dark and bright regions (domains) with relatively sharp boundaries. This is a manifestation of the Faraday effect due to the strong magnetic field within the domains. When a horseshoe magnet is brought close to the ferromagnetic plate, so that there is a magnetic field component perpendicular to the specimen surface, the domain picture is modified and the energetically inconvenient domains are squeezed out. The total area of bright or dark domains depends on the field direction. As the field is increased still further, the domain boundaries disappear altogether (a single domain state is produced). This state is stable and remagnetization in a highly inhomogeneous field is necessary if the multidomain structure is to be reestablished (this can be done with the aid of a magnetic needle). Figure 6 shows a photograph taken from the television screen of the domains in the absence of the external field (a) and in the weak field of a permanent magnet (b).

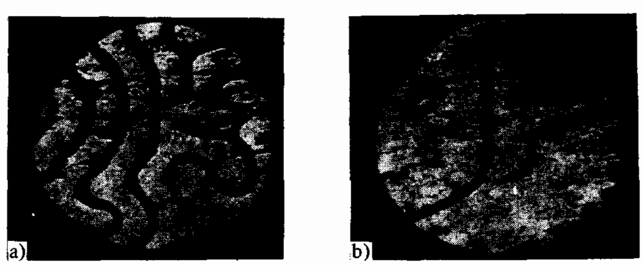

FIG. 6. Domain structure of orthoferrite: a) without magnetic field; (b) in the field of a permanent magnet.

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[2]D. S. Rozhdestvenskiĭ, Izv. Akad. Nauk SSSR Ser. Fiz. No. 6, 1119 (1934).
[3]A. Einstein and M. Smoluchowski, Brownian Motion (Transl. from German, ONTI, M.–L., 1956, pp. 22–27).
[4]R. V. Pohl, Introduction to Optics (Transl. from German, Nauka, 1966, p. 146.
[5]Fizicheskie i fiziko-khimicheskie svoĭstva ferritov (Physical and Physicochemical Properties of Ferrites), Nauka i Tekhnika, Minsk, 1975, pp. 153–156.

Translated by S. Chomet

Model of deformed crystalline structure

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Usp. Fiz. Nauk **121**, 348–349 (February 1977)

PACS numbers: 61.70.Yq

When plastic deformation of crystalline solids is investigated, it is useful to have models that simulate the formation and motion of the different structural defects. This is usually done with two-dimensional ball bearing or bubble models. The ball bearing model consists of a single layer of ball bearings of the same diameter, located between two parallel transparent plates. The packing symmetry of the model is modified by shaking, and the resulting local change in density simulates the structural defects in the medium. In this type of model, the defects are fixed irregularities that appear as a result of uncontrolled interaction between the ball bearings. Bragg's model[1] consists of inflated bubbles held in position by surface tension, and clusters of such bubbles simulate the crystal structure of real solids. Bubble models are more satisfactory because they involve attractive forces between bubbles, due to surface tension, and repulsion forces due to the excess pressure in each bubble. A disadvantage of both models is the uncontrollable change in shape, size, and position of the defects. Both models are difficult to make.

The relatively simple two-dimensional model proposed here is an improvement on both the conventional ball bearing and the bubble models. It produces mobile structural defects, and the interaction which involves both attractive and repulsive forces can be controlled. The model (Fig. 1) consists of steel ball bearings 1 held in a stretched rubber ring 2 and placed between transparent plates 3. Six screws 5 with plungers 6 are arranged on a rigid ring 4 and are used to produce the loading on the model. Displacement of any one of the plungers deforms the rubber ring and displaces the ball bearings. This is opposed by the reaction due to the rubber ring which simulates elastic bonding forces between the ball bearings. Departures from symmetry simulate the development of dislocations, vacancies, pores, slip processes, formation of boundaries between grains, and other phenomena that are typical of deformed crystalline structures. Slip is produced by displacing ball bearings in one row relative to a neighboring row. Unequal displacement of ball bearings along a row simulates dislocational breaking of symmetry. Grain boundaries appear as a broken line along which there is an appreciable linear variation in density. When the land is removed, there is a partial re-establishment of density due to the compressive reaction of the rubber ring. The points of intersection of shearing displacements are occupied by clusters of defects which do not disappear when the load is removed. Rapid application of a force to a plunger leads to a discontinuous shift of the ball bearings and even to a rearrangement in the region adjacent to the plunger. By using ball bearings of two different diameters, it is possible to observe distortions that are characteristic of the influence of impurities (the smaller ball bearings can move in the voids between the larger ball bearings). The possibilities of the model can be extended by using groups of ball bearings of different color.

Figure 2 shows a similar model in which steel ball bearings are replaced by rings made from a photoelastic material. When the plungers are pushed-in in the radial direction, the rings are displaced and elastically deformed, so that one can observe in transmitted polarized light the characteristic dark and bright regions representing the stresses on the contacts and their distribution within the medium. The rubber (black) rings simu-

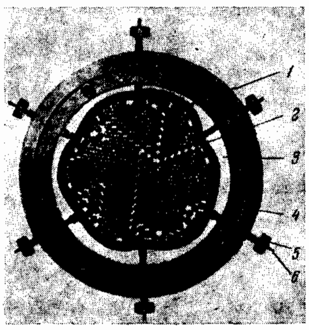

FIG. 1. Ball bearing model of a crystalline structure.