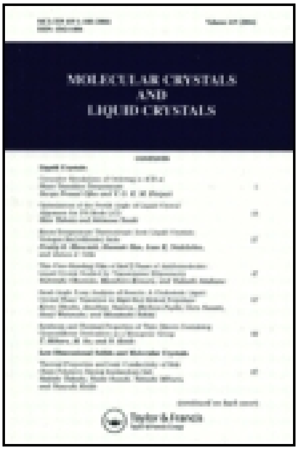

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New PDLC Thermosensitive Systems in Teaching Physics

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New PDLC Thermosensitive Systems in Teaching Physics

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An application of thermosensitive PDLCs in physics curriculum is described. Several examples of students' exercises and lecture demonstrations concerning heat effects are presented.

Keywords: Liquid crystals; chiral nematics; polymer-dispersed liquid crystals; thermosensitive foils; thermography

1. INTRODUCTION

An application of the selective light reflection, observed in cholesterol esters, to study the temperature and its distribution on a surface of different objects has a long history [1]. In particular, those liquid crystals have been applied by J. L. Fergason to visualise thermal phenomena in teaching physics [2], allowing students to "see the invisible" and better understand discussed subjects. A possibility of thermal imaging by liquid crystals has been improved due to an application of chiral nematics which are more durable against UV light, have wider useful temperature range, higher spatial resolution and intensity of selective reflected light. Moreover, a polymer composites containing those substances exhibit better useful properties in comparison with thin film of the same liquid crystal, e.g. lower angle dependence of the maximum of selective reflected wavelength. In practice, multiple-use and dustproof materials should be applied, what can be obtained by advanced methods of embedding liquid crystal into polymer matrix. Such structures can be reckoned among polymer-dispersed liquid crystals (PDLC) [3]. They are promising for applications due to their simple technology, low cost and a possibility to use in form of foils or paints [4]. In this contribution the results of an application of thermosensitive PDLCs in teaching physics are presented. They include modified classic Fergason experiments [2] and several new ones. Presented experiments have been used in the students' laboratory for general physics course, in advanced labs for applied physics students, moreover as lecture presentations.

2. EXPERIMENTAL

Chiral nematic liquid crystal mixtures described in details elsewhere [4] have been embedded into poly(vinyl acetate) matrix by solvent-induced phase separation. Systems containing 20 per cent by weight of a polymer in ethyl/butyl acetate mixture and 30 per cent by weight of liquid crystal with respect to the dry polymer have been chosen for further studies [4]. Those systems have been used in form of paint deposited onto blackened objects or foils of sandwich structure containing supporting foil of poly (ethylene terephthalate) with black absorbing layer and adhesive layer. Thermal effects have been observed visually. In some cases temporary images have been registered by video camera.

3. DEMONSTRATIONS AND EXERCISES

3.1. Visualisation of heat diffusion in different materials and measurements of their heat conductivity

Rods made of different materials (glass, polymethylmethacrylate, copper, iron, brass and aluminium) have been blackened by acrylic lacquer and then painted by a solution of liquid crystal and polymer. Then those rods have been placed in a special heating stage and heated from one end. Heat transport has been visualised as a movement of colours along the rod (see Figure 1a). By measuring time and a distance between heat source and e.g. green colour at the rod, student can calculate heat conductivity of studied materials.

The effect of heat transport has been also shown by heating pin introduced into a plate made from another material and covered by PDLC film (see Figure 1b).

3.2. Visualisation and measurements of heat capacity and coefficient of heat transfer

Bodies made of studied materials (some of them with special holes and inclusions) have been prepared and then painted by black laquer and PDLC paint (see Figure 2). Students have observed temperature and its distribution on a body surface and could conclude that holes or inclusions of another material affect heat transport through the body (see Figure 3). In an advanced course students can calculate heat capacity of the body placed in thermal insulation by measuring time of heating to different temperatures.

a) b)

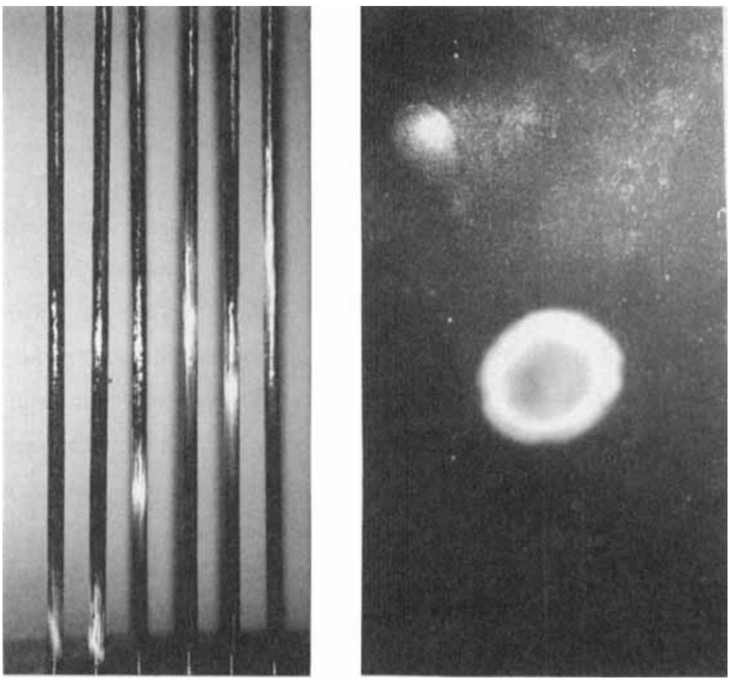

FIGURE 1. a) Thermal image of heat transport in rods made of different materials, b) temperature distribution on a surface of a body in which heated pin was introduced.

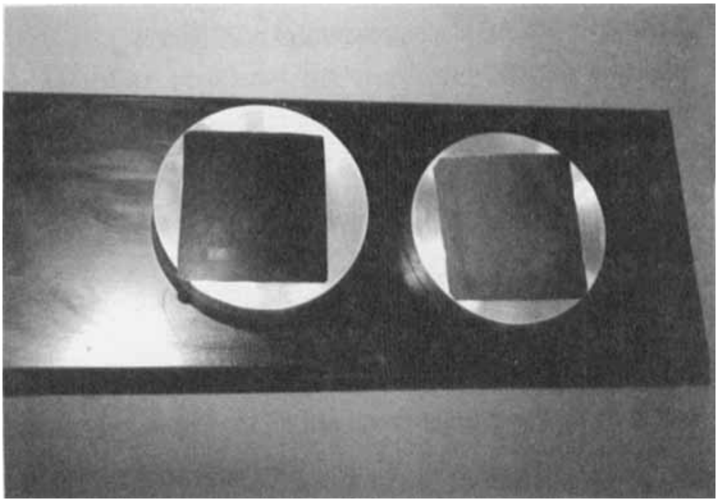

FIGURE 2. The effect of heating of thick rods made of different material.

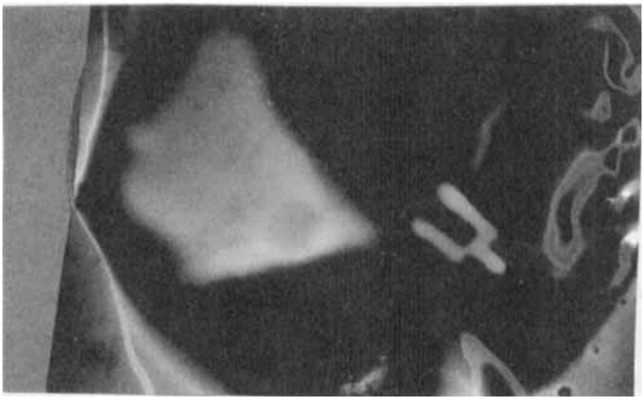

FIGURE 3. Thermal image of a surface of inhomogeneous body containing holes and inclusions of another material.

3.3. Measurement of radiation intensity of point sources

Bulbs of different power have been adopted as models of point radiation sources. Using thermographic foil students can measure the temperature at a given distance from the bulb and calculate the intensity of its radiation.

3.4. Visualisation and measurements of intensity of infrared and microwave radiation

Thermosensitive foil has been placed in some distance from electric heater or microvawe lamp. A change of foil colour suggested the presence of invisible radiation, what has been used during a lecture. The measurements of radiation intensity are also possible.

3.5. Visualisation and measurements of Joule-Lenz heat

Electric circuits and devices (e.g. power supply) have been painted by PDLC paint. Students could see thermal effect of a current and conclude that they are a source of temperature changes during experiments what can disturb measurements. In advanced course

3.6. Visualisation and measurements of friction heat effects

The classic experiment for measurement of friction coefficient includes a block sliding down on an inclined plane due to movement of a weight connected with the block by a thin cord thrown through a pulley. The block has been painted by PDLC paint. After several experiments student can observe colour at the block wall. This experiment can be especially used as a lecture demonstration for different block and plane materials.

3.7. Visualisation of temperature changes in ideal gas transformations

In our students' laboratory the exponent $\kappa = \frac{c_p}{c_v}$ for air is studied by classic Clement-Desormes method. In this method isochoric and adiabatic transformations are performed in glass balloon containing air giving points belonging for the same isotherm. Certain time should go by between the transformation (pumping or and the measurement of pressure to allow the system to reach thermal equilibrium with an environment. To show students those thermal effects, thermosensitive foils with different temperature of coloured response have been stuck to the baloon. Student can see temperature changes of the balloon, i.e. air, independently on environment temperature.

3.8. Visualisation of mode structure of laser beam

A beam of He-Ne laser has been directed at thermosensitive foil. Obtained thermal image has been registered visually or by video camera (see Figure 4) during lecture presentation.

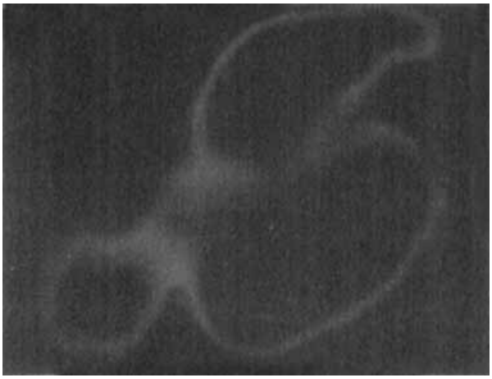

FIGURE 4. Thermal image of mode structure of laser beam.

DISCUSSION

All presented experiments should take into account uncontrolled heat effects, i.e. heaters, light sources and air movements. On the other hand, PDLC films should be properly lighted up to secure high intensity of selective reflected light. It is especially important when experiments are performed as lecture demonstrations.

In many cases thermosensitive PDLC can be used as an additional element of exercise to make student aware of thermal effects connected with an experiment.

It is useful to use two or three foils with slightly different temperature of colour response to make the experiment independent on ambient temperature.

CONCLUSIONS

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