

TEMPERATURE ANOMALIES OF OPTICAL PROPERTIES IN CADMIUM DIPHOSPHIDE CRYSTAL

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The temperature dependence of refractive indices of ordinary and extraordinary rays (n_o , n_e) in the temperature region 20-110°C for different directions in cadmium diphosphide crystal are presented in the given work. It is obtained that n_o and n_e increase with temperature growth. It is shown the thermo-optical coefficient for n_e depends on direction of laser beam relatively optical axis of the crystal and for n_o it doesn't depend. Several anomalies in the form of steps and bends are revealed on the curves of the temperature dependence of refractive indices. The detected features are connected with the transitions between commensurate and incommensurate phases.

Crystals of the tetragonal modification cadmium diphosphide belong to the A^2B^5 group and are a promising material to be used in the quantum electronics and laser techniques. Owing to large value of birefringence CdP_2 can be used as active elements in optoelectronics. Strong dependence of refractive indices on temperature and low heat conduction allow to produce deflectors of laser beam on the basis of CdP_2 single crystal. Placing a plate from the CdP_2 crystal into resonator of the ruby or neodymium laser, it can be possible to change smoothly length of impulse from 20-25 ns to 150-300 ns with keeping of the impulse shape [1].

CdP_2 crystals have complex structure [2] and thus possess interesting optical properties. The crystal is of a dark red color, transparent in a limited range of wave's lengths in the visible spectrum part, optically negative and optically active.

The work aimed at determining temperature dependence differences of the refractive indices depending on the crystal orientation.

The temperature dependence of the ordinary and extraordinary ray refractive indices [3] in the region of 20-110°C for the red laser line is presented in the given work. The measurements were carried out by means of the least deviation method using five prisms of the same size but different orientation as the samples. The prisms with sizes of 10x10x5x3 mm were cut from the transparent crystal of high quality. Refractive angle of each of them was equal to 18°.

Laser beam propagates through investigated prisms under next angles to the optical axis of the crystal: ~90° (prisms 1 and 2, for vertical and horizontal plains), ~16°, ~28° and 50° (prisms 3, 4 and 5).

The prisms were placed into the optical furnace with two windows for the falling and refracted rays. Temperature measurements were carried out in regime of continuous heating or cooling which rate can be varied.

It is established that the refractive indices increase along with the temperature growth both for the ordinary and extraordinary rays. Beginning with 70°C the crystal gets darker and then it becomes black and nontransparent by the temperature of 100-110°C owing to the shift of the absorption line. Temperature dependence of refractive indices of ordinary and

extraordinary rays in direction perpendicular to the optical axis for the red laser line with wavelength 632,8 nm is shown in Fig.1.

Values n_o , n_e и Δn are equal to 3,4225; 3,2814 and -0,14 at room temperature in this direction. Temperature dependence n_o and n_e for the direction of laser beam in the crystal under the angle $\sim 16^\circ$ to the optical axis is presented in Fig.2. As one can see both curves are almost parallel. It means that thermo-optical coefficients of both refractive indices are practically the same at comparatively small deflection of laser beam of the optical axis.

The temperature dependence of the ordinary ray is the same for all directions of the laser beam propagation within the crystal, and its thermo-optical coefficient, dn_o/dt , is constant value.

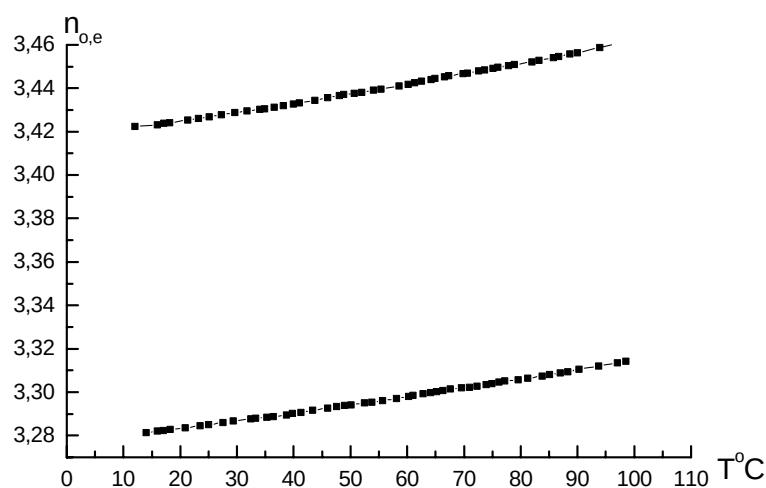


Fig.1. Temperature dependence of ordinary and extraordinary rays refractive indices measured in direction perpendicular to the optical axis.

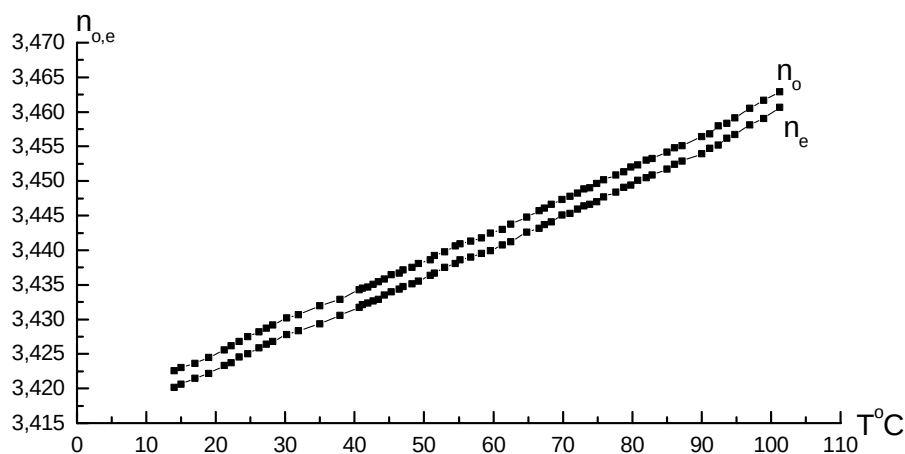


Fig.2. Temperature dependence of ordinary and extraordinary refractive indices measured under the angle 16° to the optical axis of CdP_2 crystal

The temperature dependence of extraordinary refractive index is not usual. It is revealed that not only the value of the extraordinary refractive index depends on the direction of light propagation within the crystal but also its thermo-optical coefficient also depends on the direction. Therefore thermo-optical coefficient dn_o/dt is constant and does not depend on direction of laser beam in the crystal and dn_e/dt is variable and depends on direction of laser beam in the crystal.

The increasing of deviation of laser beam of the optical axis results in decreasing of dn_e/dt . Two waves ordinary and extraordinary with reciprocally orthogonal polarization propagate along the optical axis with rate of ordinary wave, i.e. $n_o = n_e$ in the temperature region 20-110°C, and their thermo-optical coefficients are equal in this direction too. These two waves have not only different refractive indices in direction perpendicular to the optical axis, but also different thermo-optical coefficients.

Fig. 3 shows dependence of thermo-optical coefficient of extraordinary beam dn_e/dt on the angle between the optical axis of the crystal and direction of laser beam. It is seen that increasing of laser beam deflection of the optical axis results in decreasing dn_e/dt .

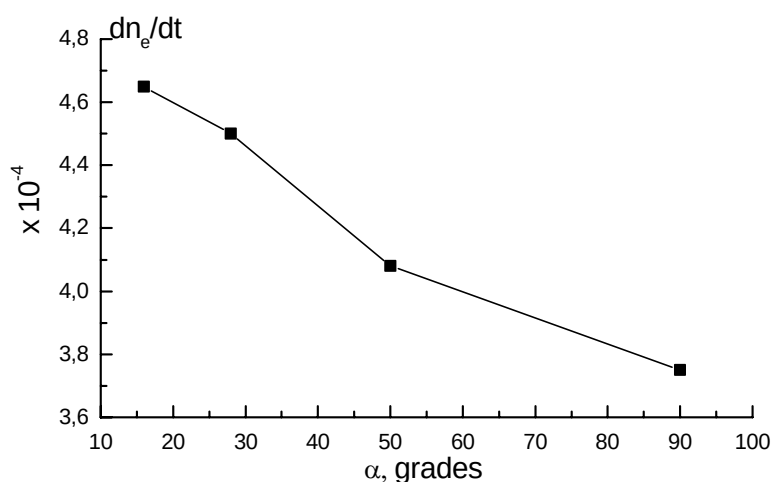


Fig.3. Dependence of thermo-optical coefficient of extraordinary ray refractive index on the angle between direction of laser beam and optica axis.

From the Fig.3 it follows also that the smaller angle of deflection of laser beam of optical axis the nearer value dn_e/dt to dn_o/dt .

It means that thermo-optical coefficients of both ordinary and extraordinary rays along the optical axis of CdP₂ crystal are equal in the whole temperature region 20-110°C, $dn_e/dt = dn_o/dt \approx 4,7 \cdot 10^{-4}$.

At small "steps" of temperature measurements equal to 2-3°, there is a succession of anomalies on all curves $n_{o,e} = f(t)$. Sections of the curves between the anomalies are rectilinear. The revealed anomalies take place nearly at the same temperatures for all investigated samples: 20°C, 35°C, 50°- 55°C°, 70°- 75°C, 85°- 90°C.

The temperature dependence of the extraordinary ray refractive index for two samples (1,2) in direction perpendicular to the optical axis, but in reciprocally perpendicular planes, is presented in Fig.4.

At the same time temperature behavior of refractive indices for each direction in CdP₂ crystal is specific.

The bend point at 20° is clearly seen in the graphs obtained at measuring of refractive indices of prisms 1,2 and 3. The bend point at 35-37°C is observed on every curve $n_{o,e} = f(t)$, but it reveals especially distinctly in shape of “step” at propagation of light through the prism

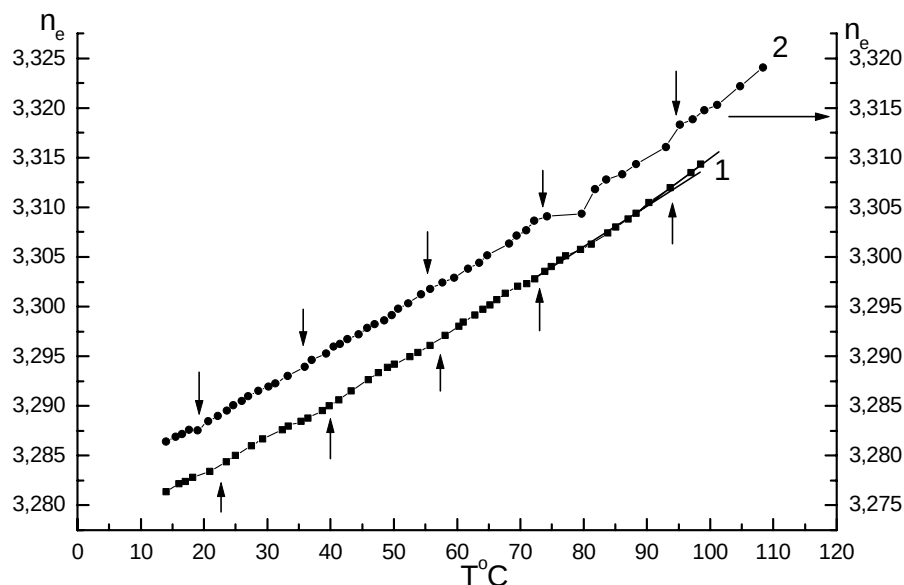


Fig.4. Temperature dependence of refractive index of extraordinary ray for the prisms 1 and 2 measured in direction perpendicular to the optical axis but in two perpendicular planes. Arrows show bend points on the curves.

4 under the angle 28° to the optical axis. The bend at 50°C is good seen at the measurements of the prisms 2 and 3, and for the other ones it is smoothed. Transition in the temperature region 85-87°C is revealed on every curve, and for the prisms 2 and 5 it presents in the shape of “step”. At frequent measurements the steps can be smoothed, but the bends and change of the slope angle of the rectilinear sections are kept.

We suggest that pointed anomalies are connected with phase transitions between incommensurate phases of type of “devils staircase” [4].

References

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