LETTER TO THE EDITOR

STRESS-INDUCED BIREFRINGENCE IN AN ISOLATED
AND A SHORTCIRCUITED KH₂PO₄ CRYSTAL

It is known [1, 2] that at the phase transition of KDP a dense domain structure (DS) occurs which is identical for an isolated or shortcircuited crystal. This DS prevents the determination of the spontaneous value of birefringence $\Delta n_{12}$ below $T_c$, measured when viewing along the c-axis. The DS can be removed by an applied stress $\sigma_6$ which, of course, induces an additional birefringence in both phases.

![Fig. 1. Geometry of the KDP samples. Semitransparent electrode is represented by shadowed area.](image)

Plate-like samples have been prepared whose geometry is shown in Fig. 1. Two teflon cubes pressed against the side surfaces by a spring produce nonzero $\sigma_6$ inside the sample; its magnitude has not been measured. To maintain defined electrical boundary conditions, one half of the sample was covered by gold-evaporated semitransparent electrodes (so that $E = 0$) while the other half was left isolated ($D = 0$). The sample was placed on the cold finger of an optical cryostat with controlled temperature.

When the crystal is cooled through $T_c = 122.6$ K a DS arises which is identical in both halves. Applying $\sigma_6$ below $T_m$, we have repeatedly found that first the domains in the shortcircuited part disappear at some critical stress $\sigma^{*}_6 (E = 0)$ but to remove the domains from the isolated part a higher stress $\sigma^{*}_6 (D = 0)$ is required. The boundary of the single-domain region at intermediate stresses $\sigma^{*}_6 (E = 0) < \sigma_6 < \sigma^{*}_6 (D = 0)$ is quite sharp and coincides with the edge of the electrode. Diminishing $\sigma_6$ to zero leads to immediate reoccurrence of DS in both parts of the sample.

The attempts to remove the DS were successful only in the region $T_c$ to $T_c - 4$ K; at lower temperatures, the crystal breaks before the DS starts to disappear. After
the crystal is made uniformly polarized at $T_c - 4$ K, the birefringence values $\Delta n_{12} (D = 0)$ and $\Delta n_{12} (E = 0)$ can be measured by a Berek compensator as a function of increasing $T$. At $T_c - 4$ K and $\sigma_6 \approx \sigma_6^* (D = 0)$, we found $\Delta n_{12} (D = 0) \approx \approx 8 \times 10^{-4}$ and it remains nearly constant with increasing $T$, while $\Delta n_{12} (E = 0) \approx \approx 11 \times 10^{-3}$ at $T_c - 4$ K and decreases significantly in the vicinity of $T_{tr}$. At $T_{tr} + 15$ K both values of $\Delta n_{12}$ become almost identical. Figure 2 shows the ratio $\Delta n_{12} (E = 0)/\Delta n_{12} (D = 0)$ vs. temperature. It should be mentioned that $\Delta n_{12} (D = 0)$ does not change in time within the period of about 20 minutes.

![Graph showing the ratio $\Delta n_{12} (E = 0)/\Delta n_{12} (D = 0)$ vs. temperature.](image)

Several comments may be added to these observations. The difference between $\sigma_6 (D = 0)$ and $\sigma_6 (E = 0)$ is obviously due to the energy of the depolarizing field. To remove the domains at $E = 0$ it only requires to apply a coercive stress. Removing the domains at $D = 0$, however, involves vanishing of the ferroelectric state at the given temperature since the depolarizing field of a single domain crystal shifts its transition point to lower temperatures [3]. Therefore an energetical barrier has to be overcome at $D = 0$, corresponding to the energy gain due to the previous transition into the ferroelectric state. This is, of course, an oversimplified picture since the presence of $\sigma_6$ itself removes the difference between the paraelectric and ferroelectric phase. A more detailed analysis would require the knowledge of the thermodynamic potential of KDP.

According to the model of Bjorkstam and Oettel [2], a low permittivity surface layer of KDP samples is responsible for the insensitivity of DS to shortcircuiting. The depolarizing field exists within the layer so that the bulk does not “see” the shortcircuiting electrodes. Contrary to the experiment, this model would give $\sigma_6 (E = 0) =$