THE ELECTRIC FIELD INDUCED LIGHT BIREFRIGENCE $HoAl_3(BO_3)_4$

V.A. Bedarev, D.N. Merenkov, S.M. Poperezhai

B.Verkin Institute for Low Temperature Physics and Engineering of NAS of Ukraine, 47 Nauky Ave., 61103 Kharkiv, Ukraine

Introduction

$RAl_3(BO_3)_4$ crystallize in the noncentrosymmetric structure, space group *R*32. Due to their noncentrosymmetric structure these materials possess also interesting optical properties which makes them potential candidates for applications based on their good luminescent and nonlinear optical response. The magnitude of the magnetoelectric effect strongly depends on the type of rare earth ion in these compounds. Holmium aluminum borate demonstrates the greatest magnitude of electric polarization *P* reached 3.600 μC/m^2 (at a magnetic field of 70 kOe) [1]. Previously, the electro-optical Pockels effect (EOPE) was discovered in rare-earth borate $TmAl_3(BO_3)_4$ (P_{max} ≈ 300 μC/m^2) at room temperature [2]. The EOPE is associated with a changing in the dispersion law for the dielectric constant of the crystal. The change is caused by a Stark shift in the energy levels of rare earth ions under the influence of an external electric field. It is obvious that the structure of the energy levels of rare earth ions in $HoAl_3(BO_3)_4$ and $TmAl_3(BO_3)_4$ crystals is different, and the magnitude of the electro-optical effect, like the magnetoelectric one, depends on the type of rare earth ion. Therefore, we investigated the Pockels effect in holmium aluminum borate.

If the electric field E reduces the optical class of crystal from the uniaxial to biaxial, the symmetric part of the dielectric impermeability will $\Delta \boldsymbol{a_{ij}} = \boldsymbol{r_{ij}E_k} + \boldsymbol{p_{ijlm}U_{lm}}$. Here Δa_{ij} are additives of the symmetric part of the dielectric impermeability a_{ij}; E_k is the projection of the electric field vector on the coordinate axes; r_{ijk} is the tensor of electro-optic coefficients and describes the primary Pockels effect; U_{lm} is a deformation of crystal; p_{ijlm} is the photoelastic coefficient tensor and describes the secondary Pockels effect. For *R*32 the general birefringence induced by the electric field is $\Delta \boldsymbol{n} = \boldsymbol{n_a^3}(\boldsymbol{r} + (\boldsymbol{p_1} + \boldsymbol{p_2})\boldsymbol{d})\boldsymbol{E_x} = \boldsymbol{n_a^3}(\boldsymbol{r} + \boldsymbol{r_d})\boldsymbol{E_x} = \boldsymbol{n_a^3 r_g E_x}$, where r_d is the electro-optical coefficient corresponding to the secondary electrooptical effect; r_g is the general electro-optical coefficient, depending both on primary and on secondary electro-optical effects.

Electro-optic experiment details

The single crystal plate of $HoAl_3(BO_3)_4$ with dimensions 4x4 mm^2 and thickness *d* = 230 μm was investigated. The light beam of He-Ne laser (wavelength λ= 633 μm) was directed along the C_3 axis, and the electric field E was directed along the C_2 axis of crystal . Experiments were carried out at room temperature. The birefrigence δ/2(*E*) induced by electric field was measured by using a modulation technique with modulation of the polarization plane and synchronous detection.

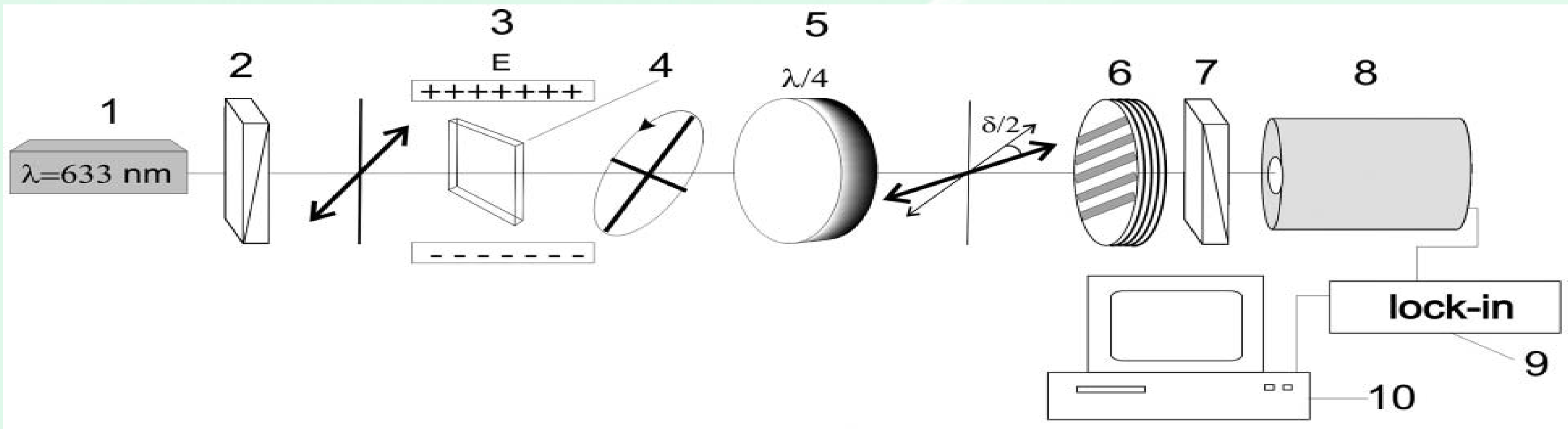
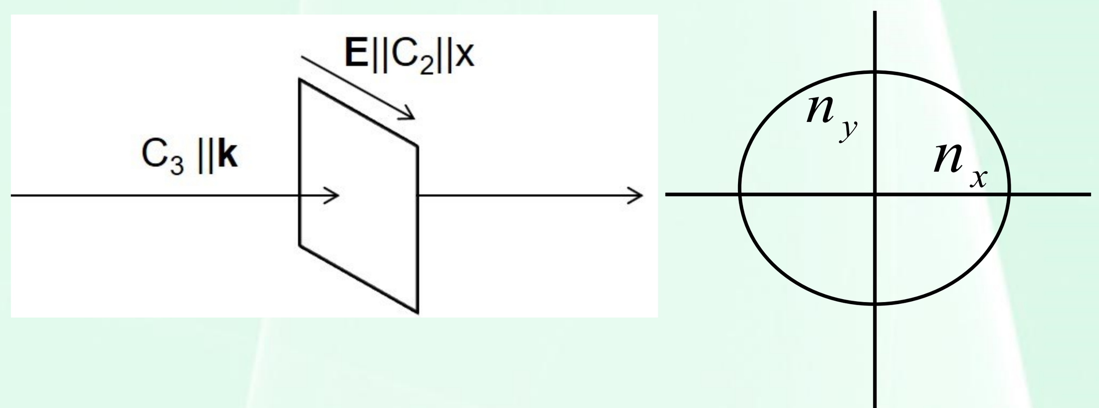


Diagram of experimental setup: (1) laser with λ = 632.8 nm, (2) polarizer, (3) capacitor, (4) sample, (5) λ/4-plate, (6) modulator, (7) analyzer, (8) photoelectronic multiplier, (9) amplifier, (10) personal computer.

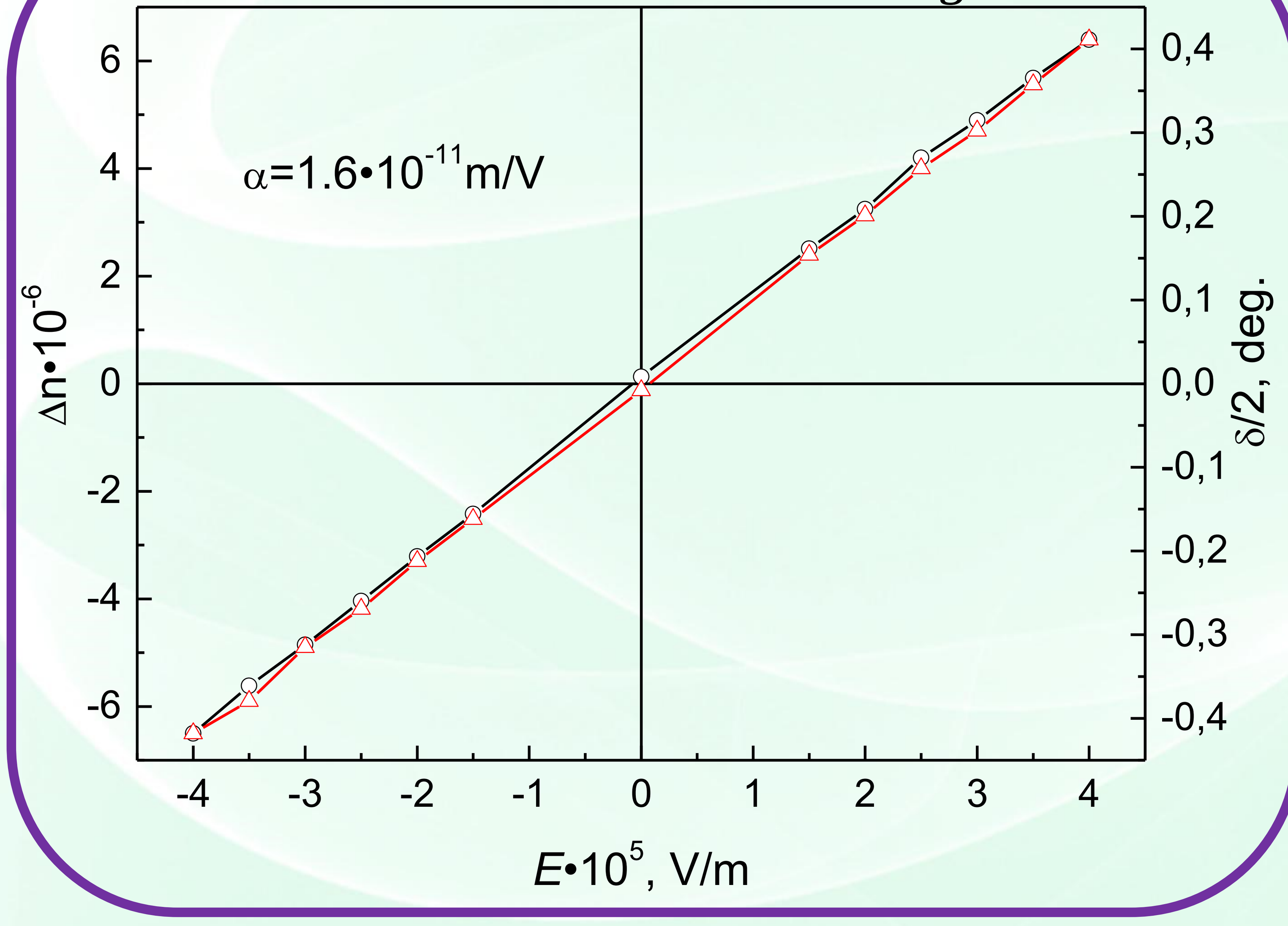


$$n_x = n_y = n_0$$
$$\Delta n = 0$$

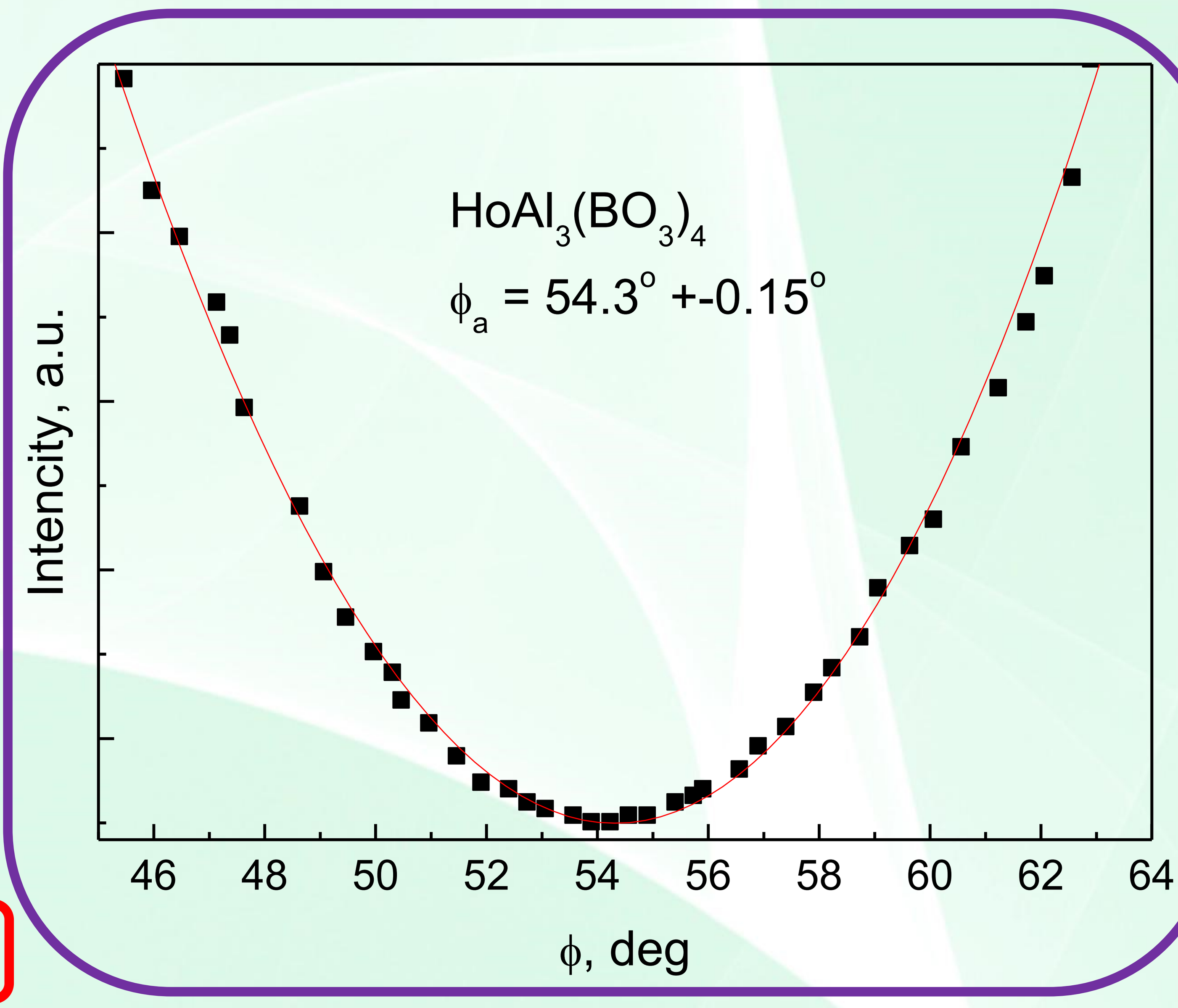
$$\Delta n(E) = \delta/2(E)\lambda/\pi d$$

λ is the light wavelength, *d* is thickness of sample.

$$\Delta n = \alpha E_x \quad \Rightarrow \quad \alpha = n_a^3 r_g$$



$$n_a = tan\varphi_{B_a} = 1.39$$



r_g= 5.9 • 10^{-12} m/V

Conclusions:

- ✓ By measuring the angular dependences of the intensity of light reflected from the sample surface the Brewster angles was determined and the value of the main refractive index crystal was obtained.
- ✓ The general electro-optic coefficient of $HoAl_3(BO_3)_4$ was established.

[1] K.-C. Liang, R.P. Chaudhury, B. Lorenz, Y.Y. Sun, L.N. Bezmaternykh, V.L. Temerov, and C.W. Chu, Phys. Rev B. 83(R), 180417 (2011). http://dx.doi.org/10.1103/PhysRevB.83.180417.

[2] R.P. Chaudhury, B. Lorenz, Y.Y. Sun, L.N. Bezmaternikh, V.L. Temerov and C.W. Chu, Phys. Rev B. 81(R), 220402 (2010). http://dx.doi.org/10.1103/PhysRevB.81.220402.

[3] M.I. Pashchenko, V.A. Bedarev, D.N. Merenkov, S.L. Gnatchenko, L.N. Bezmaternykh, A.L. Sukhachev and V.L. Temerov, Appl. Opt. 55, B11 (2016). http://dx.doi.org/10.1364/AO.55.000B11.