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Influence of the electric field on changes of absorption and refractive index in optical beam

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In this paper the results of examination concerning the influence of electric field on the changes of absorption and refractive indices in optical glass are presented and the interpretation of the observed effects are given.

1. Introduction

This paper is a continuation of earlier publications and is intended as an attempt to explain some phenomena occurring in the glass exposed to electromagnetic waves. As stated in papers [1-4] the glass exposed to interaction with the UV radiation changes its absorption and refractive index, the changes of linear sizes of the samples and their birefringence being also observed. All these changes being of isotropic character occur in the irradiated part of the samples but also, though to a lesser degree, in the nonirradiated part.

It was supposed that the observed changes resulted from the creation and displacement of electric changes inside the glass during its irradiation. In this work an experimental verification of the above hypotheses is attempted.

2. Experimental part

All the experiments described below were perf ormed for the BaK 102 optica glass of the composition presented in the Table, and produced by Jelenia Góra Optical Works (Poland).

Composition of the glass	SiO_2	B_2O_3	Na_2O	K_2O	ZnO	BaO	As_2O_3
Percentage by weight	58.7	2.95	3.46	9.9	4.74	19.65	0.6

2.1. Relaxation of the electric polarization

The changes in the relaxation curves were examined in the glass samples irradiated and nonirradiated with UV radiation.

The glass plates of sizes $20 \times 30 \times 0.15$ mm were divided into two parts (Fig. 1). The right-hand part was irradiated with UV radiation and then two pairs of electrodes were applied to both sides of the plates. To both pairs of electrodes a steady electric field was applied at definite time moments. The relaxation curves were measured for the samples prepared in this way. A typical run of the relaxation curve for one of the samples examined is shown in Fig. 2.

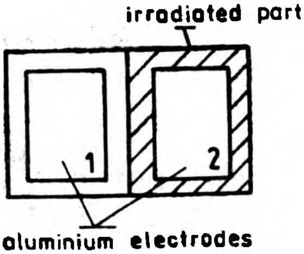

Fig. 1. Preparation of the sample

The following electric fields were applied successively to the plates:

i) $+500$ V/d during 30 min.,

ii) -500 V/d during 30 min.

(where d is the thickness of plates).

In the irradiated part a change in position of the relaxation curve (broken line) was observed with respect to that corresponding to the nonirradiated part (continuous line). On the base of the relaxation curves it may be stated that the charge in the irradiated part differs from that in the nonirradiated part.

2.2. Examination of the current flow in glass during its irradiation

Of two electrodes deposited on the glass sample 0.25 mm thick was transparent to the UV radiation. The sample was connected in series with an electrometer and a resistor $R = 10^{12}\ \Omega$ (Fig. 3) and irradiated by using the HBO 200 lamp from the 10 cm distance. The measurement was repeated for a glycerine electrode. A change of electrometer indication was observed for aluminium and glycerine electrodes at the moments when the UV radiation was switched on and switched off. The differences are illustrated in Fig. 4. The effect observed is connected with the release and displacement of the current carriers.

2.3. Influence of the electric field on the absorption changes of the glass

The absorption changes after the irradiation and next after the application of the electric field were examined in the glass plates of sizes 20×30 mm and thickness ranging from 0.15 to 0.20 mm. Two pairs of aluminium electrodes were evaporated on the examined glass plates (Fig. 1) after one part of the sample had been irradiated and transmission of both parts measured. Next, to each pair the electric voltage was for some time applied. The electrodes were removed in a diluted KOH and next the transmission was measured again. It has been stated that the evaporation and the removal of the electrodes do not change the glass transmission. The voltage of 500 V applied several times for 20 min. each time to each pair of electrodes resulted in the appearance of an electric field between the electrodes. The direction of this field was changed alternatively. After the electrodes had been washed out and the transmittivity of glass measured, it was

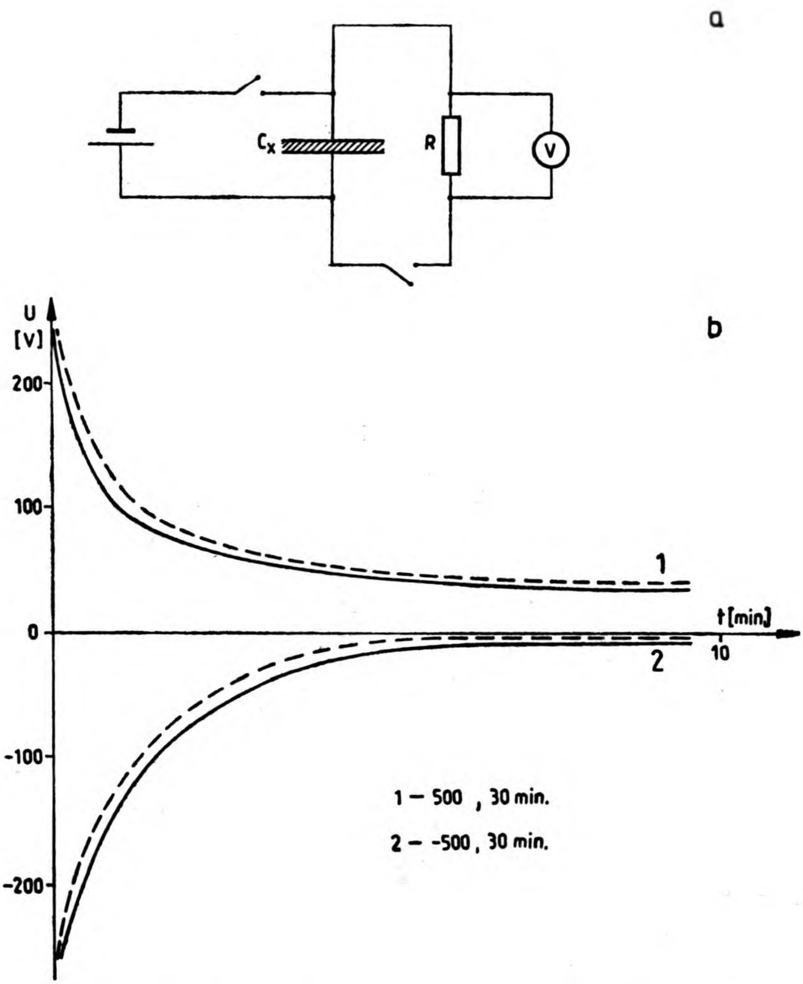

Fig. 2. Determination of the relaxation curves: a – measuring set-up, b – relaxation curves describing the irradiated (continuous line) and nonirradiated (broken line) parts (C_x – investigated sample, R – resistor, V – voltmeter)

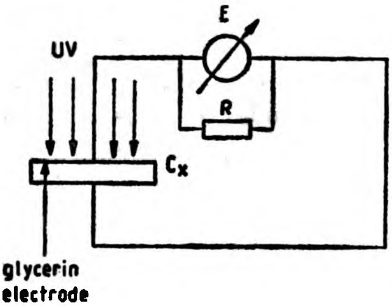

Fig. 3. Measuring setup for current flow (C_x — investigated sample, E — electrometer, R — resistor)

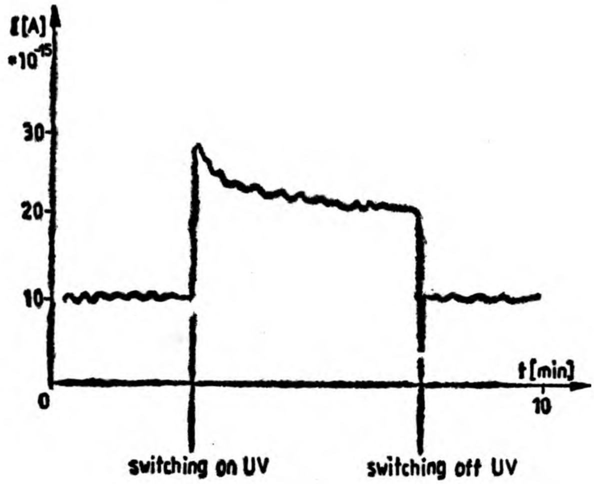

Fig. 4. Current flow observed in the glass sample during the irradiation by UV radiation

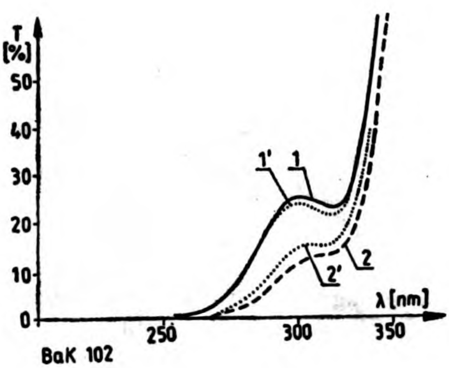

Fig. 5. Transmittivity of glass: before irradiation (1), and after irradiation (2). 1′ and 2′ denote transmittivity of the plate after application of the steady electric field to the nonirradiated and irradiated parts, respectively

stated that the changes appeared in both the irradiated and nonirradiated parts of the plates. The results of the measurement are shown in Fig. 5. The application of the alternating field resulted in no changes in transmittivity.

2.4. Influence of the electric field on the distribution of the refractive index changes

The aim of examination was to determine the influence of the electric field on the distribution of changes in the refractive index in the sample prepared in the following way: two parts of the sample of BaK 102 glass of sizes $15 \times 15 \times 30$ mm were irradiated at the room temperature for one hour (Fig. 6). To the irradiated parts a constant voltage was applied, as it was shown in Fig. 7.

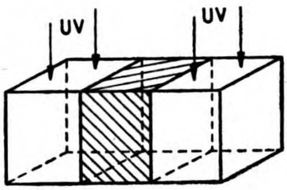

Fig. 6. Sample orientation during the irradiation

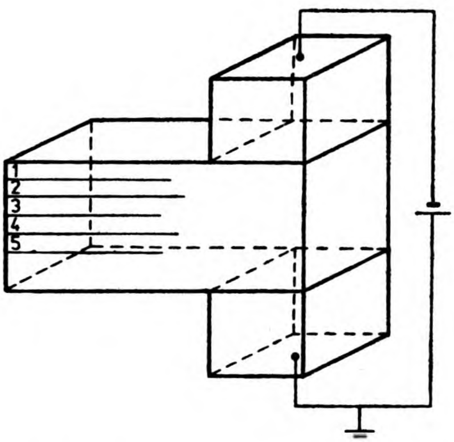

Fig. 7. Sample orientation at the presence of the external electric field (1–5 — scanning lines)

The distribution of the changes in refractive index and the thickness of the investigated glass sample were examined along the scanning lines perpendicular to the field (as shown in figure) in the Twyman-Green interferometer by using the Kowalik method [5]. Before irradiation the distribution of both the refractive index and the thickness in the sample were measured. Next, the differences between the initial distributions and those formed after UV irradiation in the presence of the electric field (similarly as in [4]) were measured. The subsequent experiments were performed and the due results in the form of the changes in refractive index distribution and in linear sizes of the samples are shown in Figs. 8 and 9, respectively. Here, the figures a correspond to the

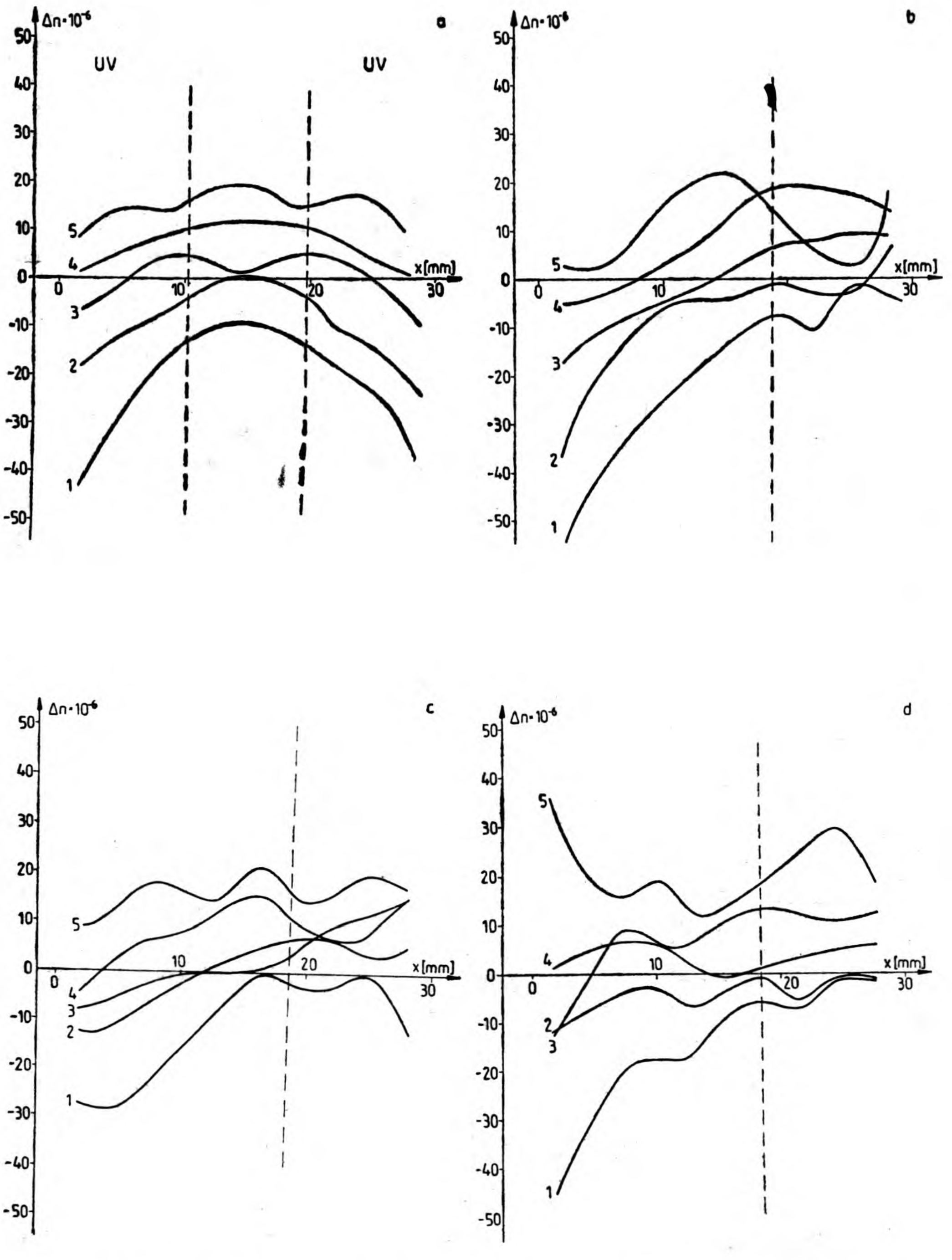

Fig. 8. Changes of refractive index in the glass sample after its irradiation and application of the steady electric field. The numbers denote the successive scanning lines: **a** — after irradiation without applied field, **b** — after application of the +12 kV voltage during 1 h, **c** — after application of the −12 kV voltage during 1 h, **d** — permanent change

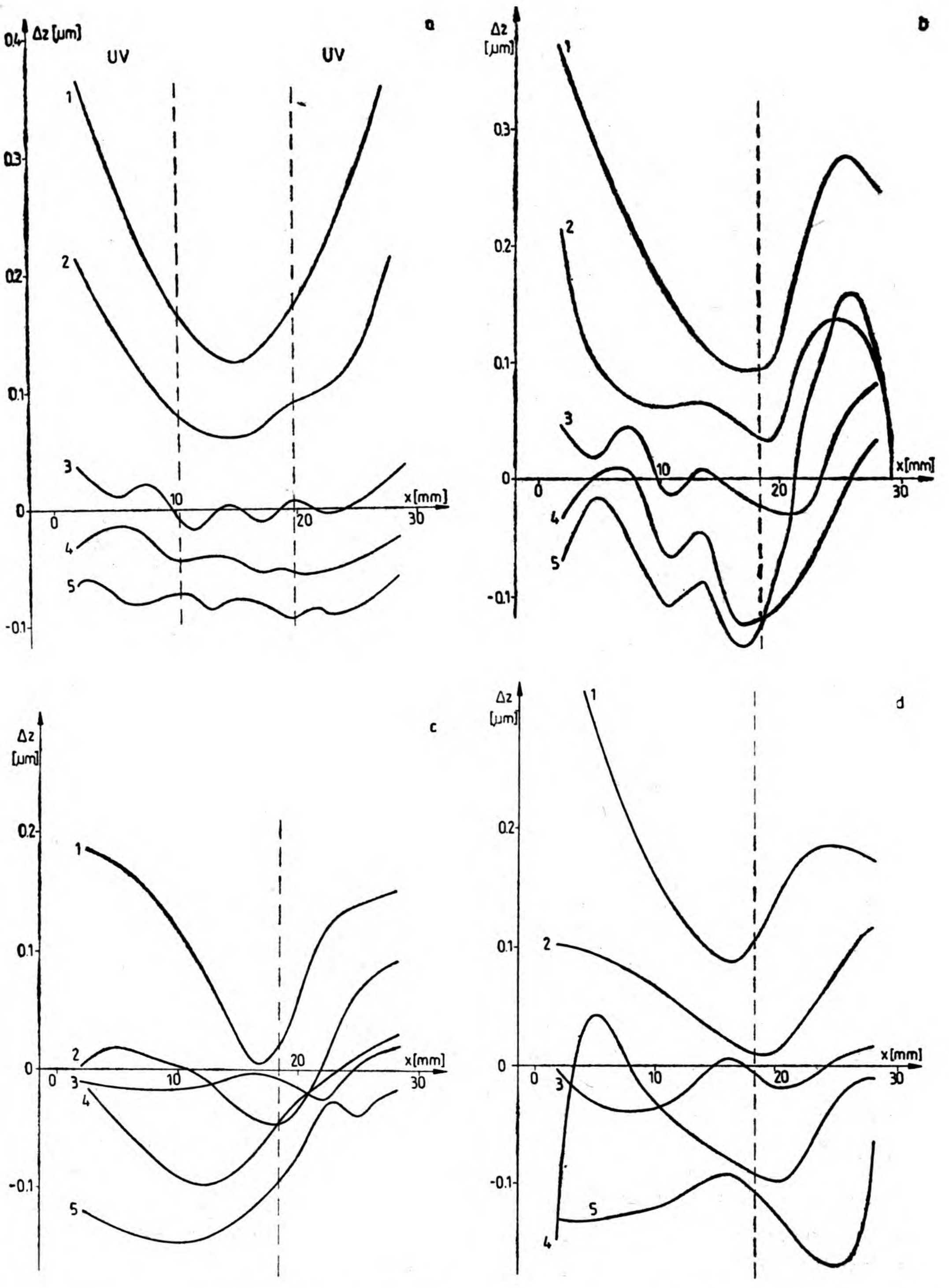

Fig. 9. Changes of the linear sizes of the glass sample after irradiation and application of the steady electric field. The numbers denote the successive scanning lines: **a** — after irradiation without the applied field, **b** — after application of the +12 kV voltage during 1 h, **c** — after application of the −12 kV voltage during 1 h, **d** — permanent changes

situation after irradiation but without electric field, the figures **b** to that after the application of the voltage equal to +12 kV for one hour to one of the irradiated parts of the samples, the figures **c** present the situation after the application of the —12 kV voltage for one hour to the same part of the sample and, finally, the figures **d** represent the permanent changes which occurred due to previous action of the field.

3. Concluding remarks

The observed changes in the refractive index and the associated effects are due to the existence of the local changes in the dielectric current and mechanical strains caused by the dislocation of carriers generated during the irradiation and the creation of the space charge and the related polarization of the micro-regions in glass. This polarization which results also in changes of refractive index and the associated effects may be obtained by application of the steady electric field to the glass samples.

The relations connecting the known changes in polarizability and the packing density of the molecules with the changes in absorption and the refractive index in dielectrics are known from the theory of dispersion. There exist relations allowing us to calculate the changes in refractive index from the known changes in absorption and vice versa.

The alkali-silicon glasses, being the subject of the examinations in this work, are characterized by a liquation and nonuniform structures. Nonuniform structure is a cause of some polar and nonpolar regions which appear in the glass.

In the glass subjected to UV radiation the following processes may occur:

— release of trapped electrons,

— generation of new electrons (for instance, in the BaK 102 glass containing cerium by ionization of Ce^{3+} ($Ce^{3+} + h\nu \rightarrow Ce^{3++} + e$)).

The release of the photoelectrons during the irradiation may fill the oxygen vacances. A part of them may be captured by electron traps, i.e., the ion centres of varying valency. They may be also captured by the defects located on the surfaces limiting the regions of liquation. The charge may be also gathered on the surfaces of microcracks. Due to trapping of the electrons a macroscopic charge may appear in the dielectric. The appearing space charge generates an internal field in the dielectrics and contributes to the glass polarization. The nonuniformities in the glass (in the form of local changes in the dielectric constant) have an influence on the formation of the space charge.

In the nonuniform structures the charge is gathered on the surfaces separating the regions of different properties. In the glasses, the surfaces involve those separating regions of liquation from the matrix, the amorphic regions from the crystalline ones, and the glass regions from the air or gas slits.

In glasses the role of electric charge carriers may be performed by electrons but mainly by cations, anions and ionized defects of the structure. If a steady electric field is applied to the glass, a displacement of the charge is observed. This displacement may cause a polarization of the microregions in glass. The external electric field causes migration of the sodium and potassium ions inside the liquation region [6]. Due to this migration an excess of concentration of K^+ and Na^+ ions that occurs at the boundary of the liquation regions from the cathode side, results in polarization of those regions. Some contribution to the polarization of the microregions is also introduced by some space charge due to displacement of electrons in the direction of the anode.

The existing polarization is a cause of observed changes of refractive index, linear sizes and absorption in the glass samples examined. The magnitude of the obtained effects changes essentially when changing the strength of the field applied.

The fact of permanent changes in the refractive index (i.e., such which remain after removal of the electric field) is an interesting result. This may offer one more way to produce the gradient glass media.

References

[1] Gębala S., Pawlik E., Optica Applicata **8** (1978), 89.
[2] Pawlik E., Gębala S., Optica Applicata **8** (1978), 125.
[3] Pawlik E., Gębala S., Optica Applicata **9** (1979), 115.
[4] Pawlik E., Kowalik W., ibidem.
[5] Kowalik W., Appl. Opt. **17** (1978), 2956.
[6] Rysiakiewicz E., Doctor's Thesis, Institute of Physics, Technical University of Wrocław, Wrocław 1981 (unpublished).

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Влияние электрического поля на изменения абсорбции и когффициента преломления оптических стекол

Представлены результаты исследований влияния электрического поля на изменения коэффициента преломления и абсорбции оптических стекол, а также обсуждены наблюдаемые явления.