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# OBSERVATION OF ASYMMETRY OF THE DISTRIBUTION OF TURBULENT ELECTRIC FIELDS IN A DIRECT DISCHARGE PLASMA BY MEANS OF THE POLARIZATION IN THE STARK PROFILE OF THE Hα LINE

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Submitted 6 November 1970
ZhETF Pis. Red. 13, No. 1, 19 - 23 (5 January 1971)

As shown in earlier experiments [1, 2], the Stark broadening of hydrogen spectral lines makes it possible to measure the degree of turbulence of a plasma. However, the amplitude of the intensity of the electric microfields is not the only characteristic of the mechanism of turbulent heating. According to the theory of Rudakov and Korablev [3], the distribution of the ion-acoustic oscillations should have a rather sharp maximum in the direction of the current. Such an asymmetry in the distribution of the electric fields has not been observed experimentally so far. We have established the existence of anisotropy of the spectrum of ion-acoustic oscillations in a direct discharge, and measured its magnitude.

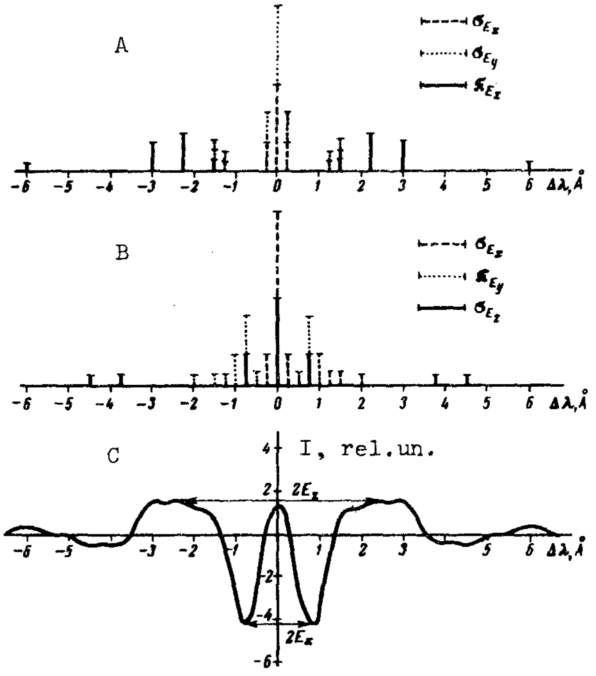

Fig. 1. Splitting of the Hα line in z-polarization (a) and in y-polarization (b); C - difference of the line contours of the z- and y-polarizations; each individual component is assumed to have a Gaussian shape with $\Delta\lambda_{1/2}$ = 0.8 Å.

To measure the degree of asymmetry, we used a new method based on the polarization in the Stark profile of the Hα line, which experiences quasistatic broadening in the electric fields of ion-acoustic oscillations [4].

1. Under straight-discharge conditions, the distribution function of the electric microfields has only axial symmetry. The presence of a maximum of the electric fields along the system axis will affect the profiles of the hydrogen spectral lines, depending on whether the polarization vector of the observed light is parallel or perpendicular to the system axis. Indeed, in a static electric field the splitting of the hydrogen spectral lines and the character of the polarization of the components depend strongly on the observation direction [5]. The σ components always lie near the center of the line, while the π components are farthest away from it. The expected character of the anisotropy effect can be visualized by considering the intensity distribution of light having different polarizations, radiated in the direction of the OX axis by hydrogen atoms, one-third of which are in the electric field

$E_x$ directed along the OX axis, one-third in the field $E_y$, and one-third in the field $E_z$. Figure 1 shows the corresponding picture of the Stark splitting at two directions of the light-wave polarization vector: A - parallel to the OZ axis (z-polarization) and B - parallel to the OY axis (y-polarization). It was assumed here that $E_x = E_y = (1/3)E_z$, and, in accordance with [2], the intensity $E_z$ was chosen equal to 30 kV/cm. As seen from the figure, for y-polarized radiation, the $\pi$ components are due only to the field $E_y$, and are therefore $E_z/E_y$ times closer to the line center than the z-polarization $\pi$ components.

To measure the degree of asymmetry, characterized in this case by the ratio $E_z/E_y$, it is most convenient to investigate the difference of the two intensity distributions observed at the indicated directions of the polarization vector. The real line profiles are, of course, the result of averaging over all the possible field configurations, but the above-described qualitative characteristics of the profiles for two directions of polarization remain the same. The picture expected in this case can be calculated (see Fig. 1C) at different values of the parameters $E_z/E_y$, and the degree of the sought asymmetry is obtained by comparing the observed picture with a number of calculated ones. A rough characteristic of the asymmetry of the distribution of the electric fields may be the ratio of the distances between the maxima and minima on this picture, since they are due mainly to the $\pi$ components in the fields $E_z$ and $E_y$, respectively.

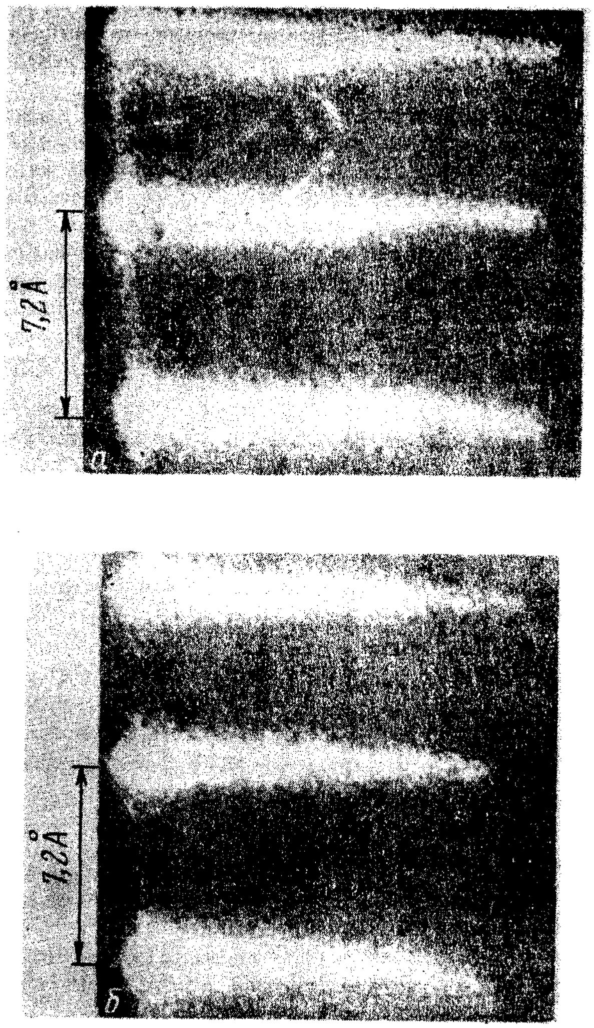

Fig. 2. Electron-optical-converter pictures of the H$\alpha$ line contour; sweep duration 25 μsec, a - z-polarization, b - y-polarization.

2. The experiments were performed with the NPR-2 apparatus, which constitutes a "probkotron" mirror machine with a mirror ratio equal to 2 [6]. The working volume was filled with plasma with the aid of film-hydride injectors, to which the direct discharge voltage was applied. The light was extracted from the center of the chamber and was analyzed with the aid of a Fabry-Perot interferometer crossed with an ISP-51 spectrograph. The time sweep of the line contour was registered with an electron-optical converter. The apparatus half-width was $\sim$0.3 Å. Light of the required polarization was separated with the aid of a polaroid filter mounted directly in front of the spectrograph slit.

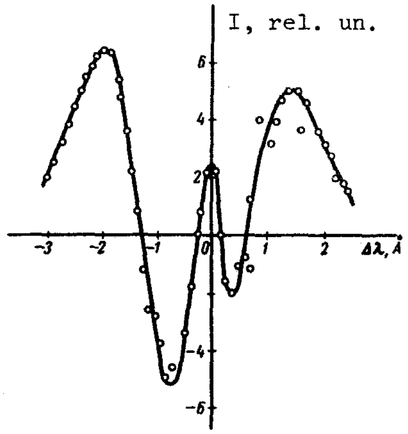

Fig. 3. Experimental plot of the difference of the Hα line controus for z- and y-polarization.

The experiments were performed under the following conditions: the magnetic field at the center of the chamber was 5 kOe, the voltage on the direct-discharge capacitor was 21 kV, the plasma concentration ranged from 2 × $10^{13}$ to 7 × $10^{13}$ $cm^{-3}$, and the plasma diamagnetism was ∿7 × $10^{15}$ eV-$cm^{-3}$. The optical conditions for the observation of the line broadening were reached with hydrogen injected into the discharge plasma to a pressure 2 × $10^{-4}$ Torr.

Figure 2a shows a time scan of three interference orders of the Hα line, obtained with the polaroid transmission axis parallel to the axis of the apparatus (z-polarization). Figure 2b shows the same for y-polarization. These photographs show the sharp broadening of the line contour, which lasts for 1 - 1.5 μsec from the start of the direct discharge, i.e., during its first half-cycle. The intensity of the line wings is larger in the case of Fig. 2a than in the case of Fig. 2b. The results of photometry with subsequent subtraction of the contours is shown in Fig. 3. The resultant curve agrees best with that calculated with a value $(E_z)_{av}/E_x)_{av} = 3$ and $(E_z)_{av} = 20$ kV/cm. (Some asymmetry in the experimental curve is due to the uneven dispersion of the interferometer.)

Thus, the procedure of polarization measurement of the Stark contours of the hydrogen lines makes it possible to determine both the asymmetry and the distribution of the electric microfields and the mean value of their intensity. An important feature of this procedure is the possibility of measuring even weak anisotropic electric fields, the influence of which on the line shape is small compared with other broadening mechanisms.

The experimentally observed anisotropy of the spectrum of the ion-acoustic oscillations, $E_z/E_y \sim 3$, points to the correctness of the model concepts on which the theory of turbulent plasma heating by currents is based [3, 7].

The authors thank L.I. Rudakov, who stimulated these experiments.

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