ON THE OPTICAL PROPERTIES OF THE NONIDEAL PLASMA OF ELECTRICAL PULSE DISCHARGE IN WATER

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It is shown that the most important influence on the plasma of electrical pulse discharges in liquid have the processes in a zone of its contact with condensed medium. The optical properties of a channel plasma are considered through the opacity of the layer. The properties are calculated on the base of microfield theory of non-ideal plasma.

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1. INTRODUCTION

The most important influence on the plasma of electrical pulse discharges in liquid (EPD) have the processes in a zone of its contact with condensed medium. At the initial stage of EPD the small-scale irregularities in the heat flow distribution were detected on the channel surface [1-3]. The development of the perturbations was accompanied by the several effects: 1) space modulation in the irradiation intensity, 2) the strain on a surface of channels, 3) the drop on the conductance of plasma. One from reasons it is established further by the comparison in the strain on a surface of plasma channels in EPD with outcomes in the simulations dealing with the growth of the Rayleigh-Taylor instability (RT-instability). RT-instability in similar conditions was investigated with usage of the numerical methods for a problem of laser thermonuclear synthesis [4-6]. Thus in EPD it may be realized the two different regimes of discharges: the first is characterized by developed perturbation and the second – the discharges without it. Therefore the experimental studies of EPD have a number of difficulties to make clear the process in the non-ideal plasmas in EPD. In this paper the optical properties of EPD are studied in connection with the above pointed features in the discharges.

2. EXPERIMENTAL STUDY OF THE DISCHARGE

Experimental investigations of processes under electrical discharges in water were conducted on the experimental setup where the discharge was created in the chamber filled with water (see [1-3]). To initiate the discharge an explosive wire was used that had allowed us to localize the position of appeared plasma channel. The evolution of plasma channel was recorded through the window by the optical system and the high-speed photochamber.

For visualization of a channel surface highlighting with an oblong exterior radiant (flashlight valve) is applied. The discharges with various rate of input energy were researched.

The results of measuring of spectral intensity I are presented in Figs.1-3. We can see that at initial stage of discharge the registered radiation is similar to the equilibrium black body radiation due to the low absorption in the outer medium. Then the opacity of surrounding media have been changed and the slope of curves is varied. At the following stages the broadening lines are appeared in the spectrum. The Balmer's lines are sharply resolved in the spectrum.

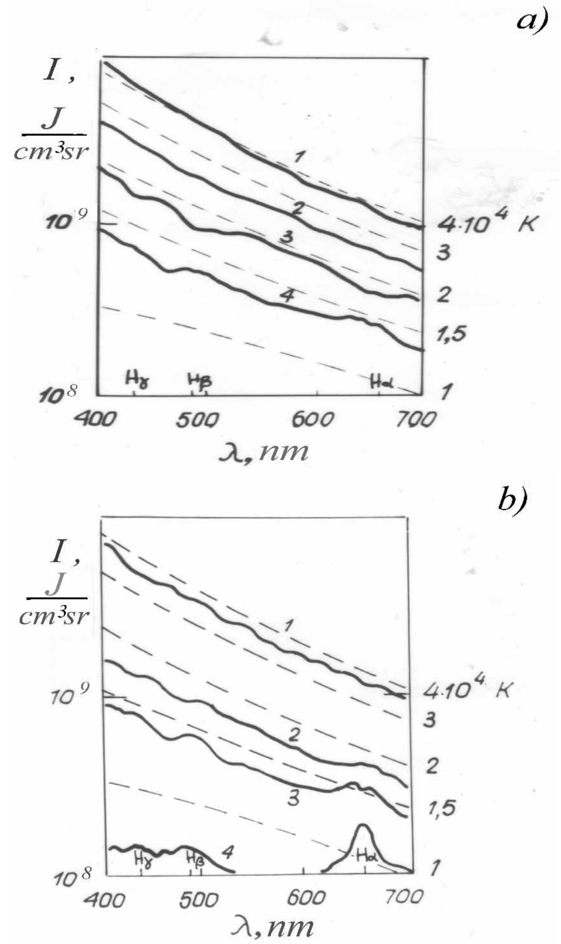

Fig.1. The evolution of spectral distributions of emission from dark (a) and bright (b) fields of EPDs (U_0=37 kV, l=40 mm). Curves 1 - 5μs, 2-10μs; 3 - 20μs;4 - 30μs; the dashed lines correspond to the black body radiation

It should be pointed that these experiments are the inversion investigations contrary to the experiments with weakly non-ideal plasmas where plasma studied toward the more high density. Here the plasma has the high density at the initial point and then the density is decreased. It also should be noted that the region near the

Balmer’s lines in the spectrum has an attractive attention due to the related problem of so-called “transparency window” (see [7,8] and reference therein).

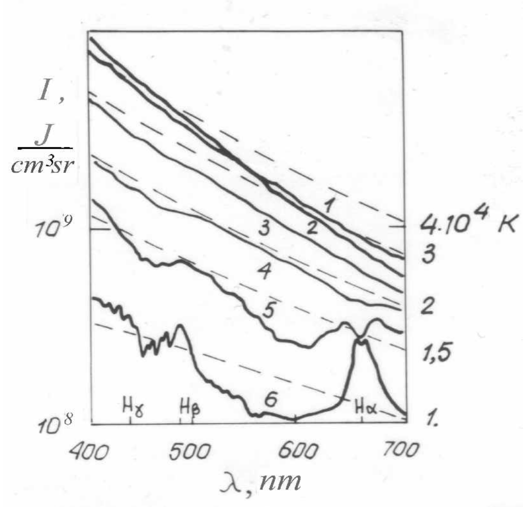

Fig.2. The evolution of spectral distributions of emission from bright field of EPDs with metal impurities (U_0=37 kV, l=40 mm). Curves 1 - 2μs, 2 – 5μs ; 3 -8μs ; 4 -10μs, 5 -20μs, 6 –30μs; the dashed lines correspond to the black body radiation

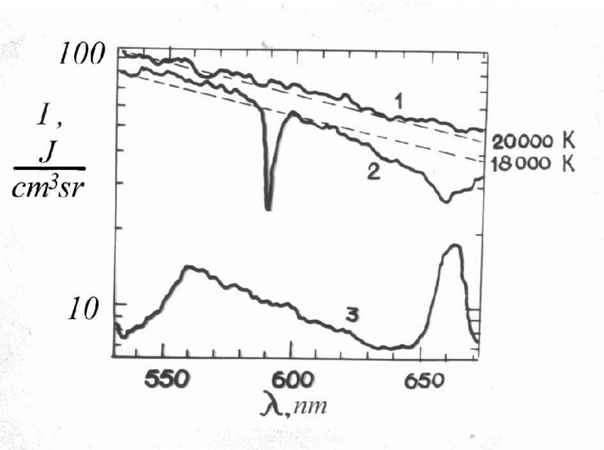

Fig.3. The evolution of spectral distributions of emission from bright field of EPDs in water solution of NaCl (U_0=12 kV, l=40 mm). Curves 1 - 2μs,2 – 27μs ; 3 - 72μs; the dashed lines correspond to the black body radiation

Peculiarities of the studied discharge are the observed irregularities on the surface of plasma channel. The perturbations look like ripple on a channel surface, which amplitude reaches 0.2-0.5 mm (5-10 % to radius). Is retrieved, that their development depends on conditions of initiation and rate to input of an energy in EPD. Spectrum of space harmonics of perturbations is bounded above by values of a wave vector k=100-150 cm^{-1}. Filing of the extension of the channel is realized by photography with the camera in the condition of slot-hole development. These perturbations can caused the variation the registered data.

To elicit the fact of distortion of registered spectral data in the liquid medium (water) NaCl salt has been added (Fig.3). The presence of irradiating Na I atom with a remarkable emission allows to resolve the changing of registered spectra.

3. PROPERTIES OF A DENSE DISCHARGE PLASMA

To study the opacity of the plasma channel is known to consider the absorption in lines and continua. The coefficients of absorption in lines are studied on the base of Voight’s profile [9] with the correction to microfield additions [10-12]. The spectra of continua are studied on the base of the Biberman-Norman’s theory in the D’yachkov’s correlations [7,13,14]. It should be pointed that the last is used the microfield Hooper’s theory as a base for calculations. Thus all of the optical properties may be calculated on the base of microfield theory of a plasma.

The cornerstone of the calculation of opacity is the following constriction of the partition function

$$G = \sum_q g_q \omega_q \exp\left(-\varepsilon_q / kT\right)$$

where g_q is the degeneracy of a level q, ω_q is the formfactor, ε_q is the energy of the level, k is the Boltzmann constant, T is temperature.

The constricting formfactor ω_q is very strong damping factor because the influence of the neighboring microfield and the resulting partition function are contracted very quickly.

If the formfactor is small then the level is weakly occupied. As a consequence of that the lines corresponding to the allowed transitions from the levels are shut down extremely. Thus the intensity of spectral lines leads to the information about the state of a plasma.

We have the following scenario of a behavior of the line intensities. Under the increasing of the plasma density the intensity of lines are decreased down to complete disappearance. For the lines closed to the continua the damping is very stronger. In the situation the occupancy of levels are decreased for the upper levels larger than for the down ones.

In our case we have temperature range 20-40 kK. At plasma density $n_e \approx 2 \cdot 10^{18}$ cm^{-3} the continua and the three first Balmer’s series lines for hydrogen were detected. At $n_e \approx 4 \cdot 10^{18}$ cm^{-3} the γ-line is disappeared. In the last turn under $n_e \approx 8 \cdot 10^{18}$ cm^{-3} the α-line are detected only.

4. CONCLUSIONS

The properties of dense plasma of electrical pulse discharges in liquid are essentially depended on the processes in the intermediate layer between dense plasma and binding water.

The perturbations of discharge channel interface caused the inhomogeneity of a dense discharge plasma. That fact is necessary to take into account under theoretical study of the electrical pulse discharges in liquid.

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ОБ ОПТИЧЕСКИХ СВОЙСТВАХ НЕИДЕАЛЬНОЙ ПЛАЗМЫ ИМПУЛЬСНЫХ ЭЛЕКТРИЧЕСКИХ РАЗРЯДОВ В ВОДЕ

П.Д. Старчик, П.В. Порицкий

Рассмотрено влияние процессов в пристеночном слое между плотной плазмой импульсных разрядов в воде и внешней средой. Показано, что излучение плазмы разряда экранируется в переходном слое вследствие процессов возбуждения и ионизации. Оптические свойства плазмы разряда рассматриваются на основе микрополевой теории неидеальной плазмы.

ПРО ОПТИЧНІ ВЛАСТИВОСТІ НЕІДЕАЛЬНОЇ ПЛАЗМИ ІМПУЛЬСНИХ ЕЛЕКТРИЧНИХ РОЗРЯДІВ У ВОДІ

П.Д. Старчик, П.В. Порицький

Розглянуто вплив процесів у примежовому шарі між густою неідеальною плазмою електричних розрядів у воді та оточуючим середовищем. Показано, що випромінювання плазми розряду екранується в примежовому шарі внаслідок процесів збудження та іонізації. Оптичні властивості плазми розряду розглядаються на основі мікропольової теорії неідеальної плазми.