Investigation of the electric field of the plasma ball

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Abstract Currently produced plasma balls have various design features and purposes. At the same time, the principle of operation of the plasma ball (PB) is described only in general terms and is of both scientific and practical interest. For the possibility of using PB in various technological areas [1-6], including in medicine, it is necessary to investigate the electric field created by this device. In this work, experiments were conducted on the study of the electric field PB: the interaction of PB with the conductor, gas-discharge light sources, and the propagation of the electromagnetic field PB over a distance. The values of the electric field strength outside PB and its dependence on distance were obtained experimentally.

1. Introduction

The history of the creation of modern PB as a gas-discharge light source has more than 200 years. In 1802, a Russian professor, later an academician, VV Petrov was the first to discover the phenomenon of arc discharge and showed the possibilities of using this type of discharge in industry, as well as for lighting. He received Volta's arc when igniting a discharge between the carbon electrodes. Electrical phenomena in the atmosphere were studied by the outstanding Russian scientist a MV Lomonosov. He watched the glow of the discharged air in a glass bowl with two metal electrodes soldered into it. In 1856 the German physicist and inventor G. Geisler invented the first gas-discharge lamp. G. Heusler's glass tubes with two electrodes soldered into them proved to be convenient for studying the spectrum of discharged gases filling these tubes. Finally, in 1894, the brilliant Serb Nikola Tesla received a patent No. 514170 for the invention of "Incandescent Electric Light". Nikola Tesla received a patent for a gas-discharge lamp, which consisted of a glass sphere with one electrode inside it. The sphere was filled with argon, a high-frequency voltage was applied to the electrode and, due to the gas breakdown, a discharge was ignited in it, causing a glow of argon. N. Tesla later called his invention "gas-discharge tube with an inert gas" and used it only for scientific research. The plasma ball that N. Tesla made was not as beautiful as modern plasma electric balls. It took time to develop a technology to produce gases such as xenon, neon and krypton, and also learn how to mix these gases. American scientist’s entrepreneurs Bill Parker and James Falk managed to combine the unique invention of N. Tesla with art and to receive in the seventies of the twentieth century modern plasma electric balls.
2. Experiment

Plasma ball in working condition and its device are shown in Fig. 1. Structurally, the PB consists of an outer closed glass container 2, inside which there is an inert gas under reduced pressure. In the center of the glass container 2 is a hollow glass sphere 1, which has a conductive coating inside. To this coating, wire 4 is fed from the power source, which is located inside the base of the plasma ball. Voltage of 2 to 5 kilovolts with a frequency of 35 kHz is fed through the wire 4 to the glass sphere 1. The diameter of the glass container 2 we used in the PB tests was 10 cm, the power consumption was 8 W. The device operates from a normal AC 220V. When switched on, the electronic circuit transforms the input signal into a high-frequency voltage of large magnitude.

![Figure 1. Plasma ball (a), appliance of the plasma ball (b)](image)

Inside the glass container 2, an electrical breakdown of the inert gas region occurs. As a result, a gas discharge is ignited, similar in appearance to a glow discharge [7-17]. Some modern experimental studies of glow discharge were carried out in [18-22]. The glow of the plasma ball is not uniform and consists of individual filaments. A lot of thin luminous filaments, begins with the glass sphere 1 and ends at the walls of the glass container 2 (Fig. 1, left). The color of the filaments of a glowing cord discharge varies: at the glass walls it is pinkish, and in the middle part of the container it is bluish. The point from which the thread begins at the central electrode constantly wanders over the surface of the glass sphere 1. The thread itself changes its shape and pops up. This is due to the fact that the gas inside the filaments is heated, due to the current flow, and the buoyancy force of Archimedes acts on them. The same effect can be observed if you flip the PB so that its pedestal is at the top, and the glass container at the bottom. We also tried to apply a constant voltage of large magnitude to 30 KV to the glass sphere 1. The gas discharge was not switched on at this connection. Thus, only an alternating high-frequency electromagnetic field inside the PB creates conditions for the formation of non-stationary plasma filaments. The stability of this discharge burning regime can be explained by periodic recharging of the inner surface of the glass container 2 when the polarity of the central electrode changes. The electric current in the plasma filaments periodically changes its direction, and the lifetime of the filaments is several microseconds.

3. Results

If you touch your finger to the PN, the picture of the glow will change. Instead of uniform glow in all directions, we see that the main discharge channel is directed to the finger of the demonstrator. This is due to the fact that, due to induction, a charge of the opposite sign is induced on the finger, and the
lines of force of the electric field thicken in the direction of the finger (Fig. 2). The cord itself becomes thicker than others, its color becomes brighter and lighter, indicating a higher temperature that is felt by a person.

In another experiment, a fluorescent and neon lamp was applied to the PB (Fig. 3). The lamps were lit at a distance from the PB. In our experiments we used an 11 W fluorescent lamp, as well as a TN-0.2 neon light bulb (Fig. 4) with an ignition voltage of not more than 85 V and an operating current of not more than 0.25 mA. Since the neon bulb has small dimensions, with its help it is possible to determine the distance from the plasma ball at which the light is ignited sufficiently accurately. This distance was found to be 10 cm. The distance between the cathode and the anode of the TH-0.2 lamp is 3 mm. Therefore, the magnitude of the electric field intensity of the plasma ball at the indicated distance is of the order of 30 V / mm.

If we further bring the neon bulb closer to the PB, then its glow and, consequently, the current through it increase. Using the known volt-ampere characteristic of this bulb, it is possible to calculate the electric field strength of the PB at various distances from its external surface. The relative radius $R = 1$
corresponds to a distance of 10 cm from the outer surface of the PB. It was at this distance that the neon light was ignited. Then, with a step of 1 cm, this distance decreased, while the current through the lamp and the burning voltage of the discharge were measured. Knowing the power released on the neon lamp, it is not difficult to calculate the electric field strength of the PB. The results of the experiment are shown in Fig.4.

![Electric field strength around the PB](image)

**Figure 4.** The electric field strength around the PB

As expected, the strength electric field of the plasma ball increases with decreasing distance to its outer surface. The similar result was obtained using a conventional wire probe connected to an oscilloscope. On the oscilloscope screen, an alternating voltage was observed, the magnitude of which increased as the probe approached the PB.

### 4. Conclusions

The main condition for stable operation of the PB is the matching of the power supply parameters, the dimensions of the PB, and the composition of the gas mixture. In this paper it is shown that the glow of a plasma ball occurs only in the case of a high-frequency voltage applied to a central electrode. In this case, plasma filaments propagate along the radius from the central electrode. For a wider use and understanding of the mechanism of the PB operation, it is necessary to investigate the electric field created around it. In this paper, an experimental study of the electric field around the PB is given and its distribution is obtained as a function of distance.

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