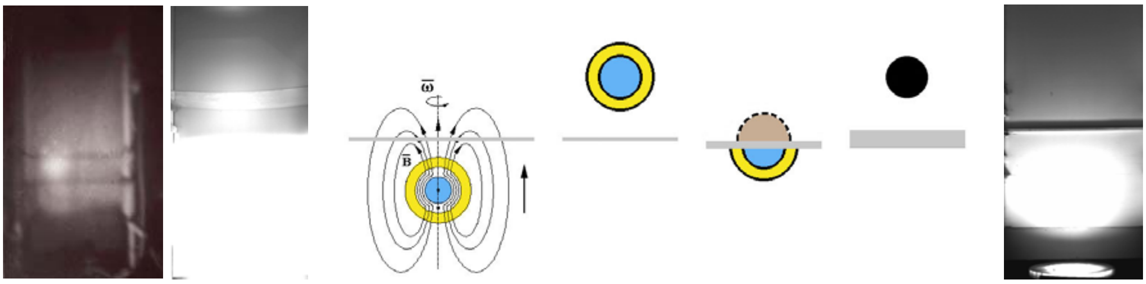
Investigation ball lightning penetration through absorbing filters

A.G.Oreshko[1], A.A.Oreshko[2]

[1] *Moscow Aviation Institute, National Aerospace Research University, Moscow, Russia*

[2] *All-Russian Scientific Research Institute of Physical-Technical and Radiotechnical Measurements, Moscow region, Mendeleevo, Russia*

The ball lightning (BL) has an ability to penetrate not only through a glass window but also through a thick absorbing metal filters [1]. Earlier it was obtained that ball lightning consists of a kernel with surplus negative charge and an external spherical layer with surplus positive charge. The ball lightning has a strong radial electric and poloidal magnetic fields. The orientation of vectors of the intensity of electric field and the induction of magnetic field in the ball lightning is similar to the orientation of such field vectors in the cyclotron type accelerator [2]. The movement of the charged particles of the ball lightning in the strong crossed fields allows them to gain ultra-relativistic values of energies similar to the ones in cyclotron accelerators (E = 20 MeV). The energy of fast particles in cyclotrons exceeds the value required for the nuclear photoeffect. The movement of ultra-relativistic particles along curved magnetic field lines is accompanied by generation of synchrotron radiation, and their radiative deceleration in the atom field of the absorbing material is accompanied by the appearance of electron-positron pairs. As it is known, a charged particle moving with relativistic velocity emits synchrotron radiation in the direction tangential to the Larmor orbit, around the field line. Bremsstrahlung is also emitted in a narrow cone in the direction of the movement of the electron. Inside the ball lightning there is a continuous process of interaction between synchrotron photons and hard quantums of bremsstrahlung radiation with the ions of the external spherical layer. The bremstrahlung radiation is emitted from the area between the kernel and the external layer. The presence of a halo outside the external spherical layer confirms the existence of photons impact on the particles of the external layer. Under the influence of the magnetic field, the protons in the ion nuclei of the external spherical layer get their spin polarization and there will be occur an excitation of nucleus. The maximum energy of the bremsstrahlung photons corresponds to the maximum value of the energy of the electrons that they aquir in the crossed electric and magnetic fields. The energy of the bremsstrahlung hard quantums is sufficient for occurance of nuclear photoeffect. As a result of the bombardment of the ions by quantums, whose energy is comparable to the binding energy of the atomic nucleus a decay of the ionic nuclei will occur in the external spherical layer. Inside the ball lightning several mechanisms of neutronless proton generation are possible. At the energy of 20 MeV a decay of ionic nuclei into protons occurs in the external spherical layer. The neutrons decay into protons and electrons. During its decay, the neutron emits an electron and an antineutrino, turns into proton and releases a certain amount of energy (0.78 MeV). The process of positrons' capture by neutrons can also lead to proton generation. It should be noted that the proton emission from the nuclei during the interaction of laser radiation with a target is observed in a number of experiments and theoretically investigated in [3]. The similarities between the electric and magnetic fields in a cyclotron type accelerator and in a ball lightning gives sufficient reason to believe that the external spherical layer of a ball lightning mainly consists of high-energy protons.



a b c d e f i

Fig.1 (a,b) An images of ball lightning between two absorbing filters and illustrations of: (c) a ball lightning entering into an absorbing filter; (d) a ball lightning that has passed through a thin absorbing filter; (e) an aura on top of the absorbing filter;(f) dark ball lightning that has passed through a thick absorbing filter; (i) big BL.

When a ball lightning enters the absorbing filter a phenomenon occurs which is similar to the phenomenon occuring in extensive air showers. The extensive air showers appear when high-energy particles enter the dense atmospheric layers [4]. As known, during the extensive air showers takes plase a cascade process of interaction between primary cosmic rays and the atmosphere due to which the secondary component of the cosmic rays, namely elementary particles, are born. Only protons can be the primary high-energetic particles. The cascade process during the interaction between the ball lightning and an absorbing filter is implemented as follows. As a result of the collision of fast protons with the nuclei of atoms of the absorbing filter the pions are generated, which include neutral π^0 and charged: π^+ and π^- ones. The neutral pions π^0 decay into two photons, which generate electrons and positrons in the Coulomb field of the nuclei. The bremsstrahlung radiation of the electron-positron pair leads to the appearance of an electromagnetic shower consisting of low-energy gamma-quantums, namely photons. By interacting with the nuclei, the charged pions generate new particle showers. As known, the decay of the pion π^- must be accompanied by appearance of a negative muon and a muon antineutrino $\pi^- \to \mu^- + \tilde{\nu}_\mu$. The decay of the pion π^+ is accompanied by the appearance of a positive muon and a muon neutrino $\pi^+ \to \mu^+ + \nu_\mu$. Then, as a result of the decay of the negative muon, an electron, a muon neutrino and an electronic antineutrino appear $\mu^- \to e^- + \nu_\mu + \tilde{\nu}_e$. Similarly, as a result of the decay of the positive muon, a positron, an electron neutrino and muon antineutrino appear $\mu^+ \to e^+ + \nu_e + \tilde{\nu}_\mu$. Since the negative and positive muons have the charge equal to the electron charge in absolute value and the mass exceeding the rest mass of electron approximately by 207 times, there is a reason to make the following assumption. The assumption is that the movement of muons retains the same character and direction of movement in the magnetic field penetrating in the absorbing filter as the charged particles of the ball lightning had before they entered the absorbing filter. The interaction between the muons emerging from the absorbing filter and the neutral air atoms causes an ionization of atoms. Simultaneously, the poloidal magnetic field of the entering ball lightning penetrates into the absorbing filter – see Fig.1(c). The induction of the penetrating magnetic field will vary in time. Following the Maxwell equation, the time-varying magnetic field will create a vortex (azimuthal) electric field in the area above the absorbing filter. The process of charge separation in the area above the absorbing filter occurs due to the diffusion of charged particles across the nonuniform magnetic field. Under the influence of the electric and magnetic fields and due to the presence of density gradient above the absorbing filter the directed drift flows of electrons and ions appear. In general form, these flows can be written out as follows:

$$\vec{\Gamma}_e = -n_e \vec{u}_e(\vec{E}) - D_e \nabla n_e \ , \qquad (1)$$

$$\vec{\Gamma}_i = n_i \vec{u}_i(\vec{E}) - D_i \nabla n_i \ , \qquad (2)$$

where n is the density, $\vec{u}$ is the velocity, and D is the coefficient of diffusion. The subscripts e and i denote an electrons and an ions, respectively. In plasmas placed in the presence of poloidal magnetic field, the transverse flows of the directed drift are determined by the particle diffusion. In a weak magnetic field, when the cyclotron frequency ω_c is much lower than the collision frequency between electrons and neutral atoms ν_m, the transverse flows satisfy the inequality $\vec{\Gamma}_{e,\perp} > \vec{\Gamma}_{i,\perp}$. Conversely, in a strong magnetic field, i.e., when $\omega_c >> \nu_m$, the reverse inequaity, $\vec{\Gamma}_{e,\perp} < \vec{\Gamma}_{i,\perp}$ is valid. Ignoring the processes of ionization, recombination and collisions, we can write the continuity equations for the ions and electrons in the form

$$\frac{\partial n_e}{\partial t} = -\nabla \cdot \vec{\Gamma}_e \,, \qquad (3)$$

$$\frac{\partial n_i}{\partial t} = -\nabla \cdot \vec{\Gamma}_i \,. \qquad (4)$$

The distribution of the electric field intensity in plasmas with the dielectric permittivity ε is given by the Poisson equation

$$\nabla\left(\varepsilon \vec{E}\right) = 4\pi e(n_i - n_e) \,. \qquad (5)$$

The electron and ion densities standing in the right side of equation (5) are excessive. After differentiating (6) with respect to time and taking into account (3) and (4), we obtain

$$\frac{\partial \vec{E}_{ind}^{rad}}{\partial t} = \frac{4\pi e}{\varepsilon}\left(\vec{\Gamma}_e - \vec{\Gamma}_i\right). \qquad (6)$$

From (6) it follows that the intensity of the radial electric field induced in the process of charge separation is proportional to the difference between the flows of the directed drift of electrons and ions. The left side of equation (6) with up to a factor $1/c$ is a bias current. The inequality of the directed drift flows leads to charging of the spherical capacitor and the appearance of ball lightning elements in the form of plasma regions with opposite in sign excess charges. The ion and electron drift in the crossed longitudinal magnetic and azimuthal electric fields ($\vec{E}_\varphi \times \vec{B}_\theta$) leads to the separation of the charges and the formation of the structural elements of the ball lightning: the kernel and the external spherical layer. The movement of the charged particles in the crossed electric and magnetic fields leads to the rotation of the structural elements of the ball lightning about the rotation axis. The ball lightning elements with excess space charges rotating by azimuth (so-called outgoing ball lightning) appear above the absorbing filter. Ball lightning can be used to solve a number of problems as a compact source of fast ions, protons, muons, neutrinos and antineutrinos. Ball lightning a diameter of 0.94 m also was obtained in an experiments - see Fig.1(i).

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