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Explanation of abnormal behavior of ball lightning near the earth surface

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ABSTRACT

Based on the optical model of ball lightning (BL) where BL is considered as an optical space incoherent soliton in the nonlinear optical medium in a form of the conventional terrestrial air atmosphere, we explain intriguing features of the natural ball lightning to move uniformly along the earth surface at a small distance from it ignoring strong wind. The explanation is an additional confirmation of the correctness of the optical model of ball lightning.

1. Introduction

Till now there is no generally accepted explanation of puzzling and intriguing properties of ball lightning (BL). A criterion for the adequacy of BL model to a real natural phenomenon is a coincidence between the behavior of the model obtained on the basis of known physical laws and the behavior of a natural BL obtained on the basis of numerous eyewitness accounts. Such models are unknown for us. P. Sagan wittily remarked that all theories of ball lightning have one general characteristic, which indicates that they do not work [1].

In 2003, we hypothesized that the ball lightning is a self-confined light [2–4]. At first glance this is an oxymoron like a living corpse or hot ice. On closer examination, it turns out that this is not so. The knowledge of modern science has reached such a level that it is possible to explain the existence of the self-confined light on a basis of generally accepted physical laws. It was shown that the self-confined coherent light can exist in a nonlinear quadratic optical medium [5]. The confinement occurred in one of three dimensions. Such a light is called by an optical spatial soliton. The soliton is a plane beam of light propagating along the z axis, unbounded along the y axis and having a finite thickness along the x axis. It was later shown that the soliton can also be formed by incoherent light [6].

A simple justification of the physical phenomena responsible for the appearance of a soliton was also given. The refractive index of a nonlinear optical medium increases due to nonlinearity of the medium in those regions over which the beam propagates. As a result, the beam forms from the regions a planar lightguide. It is well known that the planar lightguide can retain its properties when its curvature becomes nonzero [7]. In this case, the radius of curvature should be much larger than the wavelength of light. The optical space soliton, curvatures of which in two mutually perpendicular directions are identical and differ from zero is an optical space soliton in a form of spherical film or ball lightning.

Based on this approach we have explained many BL intriguing properties [8–10]. Below we explain once more intriguing property of natural Ball Lightning connected with unordinary motion of BL near the earth surface, in particular, a movement of BL against the

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wind.

Stahanov who obtained and analyzed about thousand reports about BL notes the following [11] “most often, the ball lightning is seen moving horizontally. In our survey this amounted to 684 observations, or 75% of the total number of reports, which contained data on the preferred direction of traffic. In a survey of NASA in 58 cases (53%) it is said about horizontal movement”. we can read in the English Wikipedia in a section on the characteristics of ball lightning, “Motion: moves independently, randomly through air predominantly in a horizontal direction”.

2. Physical laws responsible for abnormal BL motion

BL behavior in the terrestrial air atmosphere is explained by action external forces applied to BL where an intense light is circulating in all possible directions. The external forces arise as a response to the action of optically induced forces (OIF) that are applied to the optical medium where a light is propagating. The optical medium is air terrestrial atmosphere where BL is located. Since time of Maxwell is known that force density *f* produced by the light propagating in an inhomogeneous optical medium is given by [12].

$$f = -\varepsilon_0 grad(\varepsilon)\frac{E^2}{4} = -\frac{grad(\varepsilon)}{\varepsilon}W \tag{1}$$

Here W is the density of the energy of the light wave [J/m^3], E is amplitude of the electrical field of light wave, ε is permittivity of the medium. As is seen from Eq. (1) the force arises in an inhomogeneous optical medium only where grad(ε) is different from zero.

The force *f* is directed opposite the gradient of the permittivity of the medium ε. In accordance with the third Newton law, there is another force –*f* applied to the light. In our case the light is circulating within the BL shell. Since the light can not exit the BL shell, the force is applied to the shell. A similar situation takes place for a conductor with current in a magnetic field. The force is applied to the moving electrons. However, electrons can not exit the conductor. As a result, the force is applied to the conductor. We can conclude that any light circulating in the BL shell produces OIF in the shell in the direction of the gradient of the refractive index of the atmosphere air in which the shell is located.

It is believed that optically induced forces are extremely small because significant efforts are required for their experimental observation. It is valid for the conventional intensity of light determined as the energy that passes through unit area per unit time. But the intensity of light in the BL shell is increased by billion times as compared with that of the light propagating rectilinearly. For example, if the BL diameter is equal D, a number of rotations N per second is given by

$$N = \frac{v}{\pi D} \tag{2}$$

where $v = 3\ 10^8$ m/s is the speed of light. If $D = 0.1$ m, we have $N = 10^9$.

Since the same light crosses the cross-section of the shell billion times per second, the intensity inside the shell is increased by billion times as compared with the intensity of the same light beam propagating along a straight line. In latter case the light beam crosses the cross-section of the unit area only one time. Thus, the magnitude of the optically induced force applied to BL is sufficient to exert a decisive influence on the behavior of BL in the earth's atmosphere.

To explain horizontal BL motion, we need to take into account the following simple well known physical facts derived from the gas equation.

The air permittivity is equal to 1 when the air density is equal to zero. The air permittivity is equal to $1 + \Delta\varepsilon$ where $\Delta\varepsilon = 0.00054$ at normal condition when the air pressure $P_0 = 10^5$ Pa, the air density is equal to $\rho_0 = 1.4$ kg/m^3 and temperature $T_0 = 300$ K.

Dependence of the permittivity ε on the pressure P at constant temperature T is given by

$$n = 1 + \Delta\varepsilon\frac{P}{P_0} \tag{3}$$

Dependence of the permittivity ε on the density ρ is given by

$$n = 1 + \Delta\varepsilon\frac{\rho}{\rho_0} \tag{4}$$

Dependence of the refractive index n on the temperature T at constant pressure P is given by

$$n = 1 + \Delta\varepsilon\frac{T_0}{T} \tag{5}$$

We can conclude from Eqs. (3)–(5) that BL has the following properties

BL moves in the direction of the gradient of the air density. Other words, BL moves in direction where air density increases in maximal degree.

BL moves opposite to the gradient of the air temperature.

BL moves along the gradient of the air pressure.

This elementary information is sufficient to explain all known anomalies of BL behavior. If the gradient of the air permittivity is constant in the region where BL is located, BL shell is spherical. Otherwise, various parts of BL surface are subject to action of various OIF. As a result, BL shell is deformed because the shell is very thin.