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Original research article

Explanation of abnormal motion of glowing silicon balls in a framework of optical model of ball lightning

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ABSTRACT

We explain the anomalous motion of glowing silicon droplets, which can perform numerous jumps on the surface of the table. The movement of droplets is taken from the Internet video clip. We show that the usual laws of mechanics are insufficient to explain the anomalous droplet movement, and it is necessary to take into account the optically induced forces arising from the interaction of light and matter. These forces are the basis of the optical model of ball lightning and allow one to explain the anomalous motion of ball lightning. We came to the conclusion that artificial luminous droplets and natural ball lightning are a special case of a wide range of phenomena in which optically induced forces play a decisive role. The article can be considered one more step on the way to explaining the nature of ball lightning.

1. Introduction

Brazil scientists reported in 2007 about abnormal properties of glowing balls of 1–4 mm diameter appearing at a low-voltage arc discharge through Si wafer plates of 350 μm thickness [1]. They believe that their balls are a certain form of ball lightning (BL). Unlike conventional sparks which accompany any arc discharge, the balls have unusual properties. In first, their life time is essentially greater than that of the sparks and can achieve eight seconds. In second, they jump in process of their moving, can bypass obstacles, and penetrate through splits, width of which is smaller than their diameter. In opinion of Brazil scientists, ball behavior reminds a BL behavior. Video film where ball behavior is demonstrated was presented in Internet. New videos where investigators from various countries present analogical experiments appeared in Internet later. There are videos of investigators from USA [2] and Spain [3]. The most informative is video presented by Gooses et al. from Holland, Eidhoven [4]. They accompany their video with a description in detail of their experimental installation and features of experiment.

Bouncing balls had been observed not only after publication of paper [1]. A photo of bouncing balls in a form of their continuous trajectory obtained in a dark with an open shutter of photo camera had been presented in paper [5]. Since there is a horizontal component of ball velocity in the photo, the ball trajectory is a set of clearly-defined parabolas. Each parabola corresponds to one jump. There are 20 parabolas in the photo. Lifting and falling branches of parabolas are identical. On assumption that the horizontal component of the velocity is constant, we obtain that the time of lifting and time of falling are identical. In 2009 we carry out own experimental study where abnormal ball bouncing has been analyzed [6].

Unlike investigation of behavior of BL that is a seldom natural phenomenon, investigation of ball behavior are accessible to any schoolboy by means of studying videos in YouTube. This provides means to answer the question whether these objects are a certain type of BL.

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As is known there is no generally accepted explanation of anomalous behavior of BL in the air atmosphere up to now. On assumption that BL is a material objects which preserves its integrity, a motion of BL center mass is determined only by external forces and is independent on any inner forces. Taking into account all known types of external forces such as Newton force of gravity, Archimedes buoyant force, and drag force applied to a body moving in the air atmosphere, it is impossible to explain why the object in a form of BL can move against wind, can catch up and accompany flying airplanes. An additional type of forces applied to the object is required.

We have shown that all anomalies of BL behavior can be explained on the basis of our optical model of BL [7]. From point of view of a modern science, BL is an incoherent spatial optical soliton, curvature of which is different from zero. Because of great density of the energy of the light, well known forces arising at an interaction between light and matter should be taken into account. We call these forces by optically induced force (OIF). BL consists of two components only. It is the white light and conventional air compressed by the light. The energy of the light exceeds the energy of air by a factor about 20. In a framework of this model, BL is a self-confined light where conventional terrestrial air shows itself as a nonlinear medium [8,9]. That is why a behavior of BL in the air atmosphere is determined by laws of optics mainly. Of course, the laws of mechanics continue to be fulfilled.

Unfortunately, a generally accepted theory of OIF does not exist at present. It is believed that OIF are extremely small and can be neglected. Possibly, it is a main reason why our optical model of ball lightning did not win a general recognition. We spent the last 7 years for explanation of properties of the OIF. These properties were derived from the laws of mechanics without any assumptions about the type and physical origin of the OIF. Over the years, more than two dozen articles have been published in leading international journals on optics and physics. We concluded that the modern approach based on the Lorentz force is incorrect, unlike classical one. Because of this we use well known classical approach.

Now we apply OIF for an explanation of abnormal behavior of luminous silicon balls presented in video film [4]

2. Kinetics of bouncing balls derived from video film

One can see in a video [4] that the ball can be bouncing on the a white plane surface of a table during 8 s. Comparing the sizes of the red glove and height H at which ball jumps above the white surface, one can conclude that the height is in range 5–20 cm. There are 2 the most indicative sequences of bounces beginning at time marks I (17, 07) and II (21, 23) where the first number in brackets corresponds to the number of seconds from begin of the video and the second one corresponds to the number of the frame within the given second (from 0 till 23). It is convenient to designate events in each sequence by time t from beginning the sequence. In this case the sequences of events are the following

The first sequence {0(B), 0.76(T), 1.44(B), 2.00(T), 2.6(B), 3.24(T), 4.00(B), 4.8(T), 5.32(B)} is presented as follows

$$0, 0.76, 1.44, 2.6, 3.24, 4.0, 4.8, 5.32 \tag{1}$$

The second sequence {0(B), 0.44(T), 0.88(B), 1.28(T), 1.64(B), 2.04(T), 2.56(B), 2.92(T), 3.44(B), 3.76(T), 4.36(B), 4.80(T), 5.16(B), 5.52(T), 6.08(B)} is presented as follows

$$0, 0.44, 0.88, 1.28, 1.64, 2.04, 2.56, 2.92, 3.44, 3.76, 4.36, 4.80, 5.16, 5.52, 6.08 \tag{2}$$

where symbols (B) and (T) designate bottom and top ball positions, respectively. The error of each time mark is ± 1 frame or ± 0.04 s.

Let us designate time interval between adjacent touches by T. The average time intervals between adjacent contacts with the surface are $T_m = 1.33 \pm 0.02$ s and 0.870 ± 0.011 s for the first and second sequences, respectively. The following conclusions can be derived from Eqs. (1) and (2).

Ball touches the table in the first sequence at the following 4 time instants

$$0, 1.44, 2.6, 4.0, 5.32 \tag{3}$$

Ball touches the table in the second sequence at the following 7 time instants

$$0, 0.88, 1.64, 2.56, 3.44, 4.36, 5.16, 6.08 \tag{4}$$

Balls achieves the maximal height in the first sequence at the following 4 time instants

$$0.76, 2.0, 3.24, 4.8 \tag{5}$$

Ball achieves the maximal height in the first sequence at the following 7 time instants

$$0.44, 1.28, 2.04, 2.92, 3.76, 4.8, 5.52 \tag{6}$$

Difference T between the current time instant the ball touches the surface of the table and previous one for the first sequence is the following

$$1.44, 1.16, 1.4, 1.32 \tag{7}$$

Difference T between the instant the ball touches the surface of the table and previous one for the second sequence is the following

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