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Research on the generation and evolution characteristics of a laboratory "ball lightning"

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Ball lightning is a mysterious natural phenomenon that lacks scientifically proven explanations to date. The most characteristic feature of ball lightning is that it can remain stable and independent for several seconds, which is much longer than the lifespan of ordinary linear lightning. The unique property reveals that ball lightning may have a special energy storage mechanism or structure, making the study of ball lightning potentially scientifically significant and valuable for applications.

Ball plasmoid discharges are uniquely long-lived plasma produced by releasing energy stored in a capacitor bank over a liquid surface. The first laboratory generation of ball plasmoid was accomplished in 2002 by Russian physicists[1]. Following this initial publication, multiple other groups have successfully replicated this experiment. The plasmoid has a visible lifespan of several hundred milliseconds, during which part of the plasmoid appears to persist without any power input. The plasmoid exhibits physical properties, such as color and shape, remarkably similar to naturally occurring ball lightning. To gain a deeper understanding of the nature of plasmoid and to reveal the mechanisms by which it maintains its long lifetime, different techniques were used to measure its parameters.

Firstly, the discharge process is recorded with a high-speed camera. The entire discharge process can be divided into three stages: initial stage, developmental stage and molding stage. Figure 1 shows the images of a discharge process recorded by a high-speed camera. The relationships between plasmoid area, brightness, lifetime and experimental conditions are studied by analyzing the evolutionary process of the plasmoid. Furthermore, spectral diagnostics are utilized to determine electron density during the initial stage while microwave diagnostics are employed during the third stage. Finally, Particle Image Velocimetry (PIV) is used to unveil the vortex structure of generated plasmoid along with velocity and direction of flow within these formed structures. Our results show that the slower decay of electron density in plasmoid relative to normal processes in the atmosphere, as well as its unique vortex structure, may be important in maintaining its existence.

References

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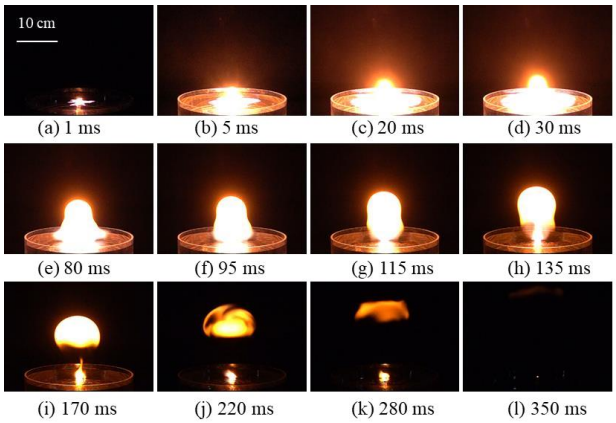

Figure 1. Discharge images at different moments.