

## Ball Lightning in the Light of Transcranial Magnetic Stimulation

**Abstract.** The paper deals with the phenomenon which is supposed to be enigmatic and mysterious, namely the ball lightning. The exemplary hitherto explanations are quoted. New explanation, based on electromagnetic phenomena, like magnetophosphenes and transcranial magnetic stimulation has been proposed.

**Streszczenie.** Artykuł omawia zjawisko, mające charakter zagadkowy i tajemniczy, mianowicie piorun kulisty. Przytoczono istniejące do tej pory wyjaśnienia tego zjawiska. W artykule podano nowe wyjaśnienie pioruna kulistego, oparte na zjawisku magnetofosfenów i przezczaszkowej stymulacji magnetycznej. (Piorun kulisty w świetle przezczaszkowej stymulacji magnetycznej)

**Keywords:** ball lightning, magnetophosphenes, transcranial magnetic stimulation

**Słowa kluczowe:** piorun kulisty, magnetofosfeny, przezczaszkowa stymulacja magnetyczna

### Introduction

Ball lightning (BL) is being observed since the written sources quote the phenomenon (Fig.1) [1]. It is recorded in various places all over the world but all these records are not repeatable. Each of situation when ball lightning has been seen is described separately, thus it can be consider as the case study. But the case has gone. The ball lightnings which are reported by various sources are various as well. As to the shape they are pure balls, rods, ovals, spheres and, more poetically, like teardrops. As to the dimension there is also a big discrepancy since the diameter of, say, ball is from 10 cm till 40 cm but the diameter as large as 1 m appears in the reports. The time of duration varies from 10 s till one minute. The color of the lighting may be red, red-yellow, yellow, white, green and purple. The ball lightning can move with the speed 1-2 m/s with the wind but sometimes against wind. The phenomenon is really very subjective and, therefore, has a lot of explanation.

### Exemplary explanations

The ball lightning phenomenon was being explained in very different, sometimes surprising like this which includes black hole, ways. But there are a few of more serious foundation.

Piotr Kapica, very famous Russian, proposed that ball lightning is a glow discharge driven by microwave radiation that is guided to the ball along lines of ionized air from lightning clouds where it is produced. The ball serves as a resonant microwave cavity, automatically adjusting its radius to the wavelength of the microwave radiation so that resonance is maintained [2].

Julio Rubenstein and David Finkelstein proposed that ball lightning is a detached St. Elmo's fire (1964–1970). St. Elmo's fire arises when a sharp conductor, such as a ship's mast, amplifies the atmospheric electric field to breakdown. For a globe the amplification factor is 3. A free ball of ionized air can amplify the ambient field this much by its own conductivity. When this maintains the ionization, the ball is then a soliton in the flow of atmospheric electricity [3].

Oleg Meshcheryakov suggests that ball lightning is made of composite nano or submicrometre particles, each particle constituting a battery. A surface discharge shorts these batteries, resulting in a current which forms the ball. His model is described as an aerosol, but not aerogel, model that explains all the observable properties and processes of ball lightning [4].

### Transcranial magnetic stimulation and magnetophosphenes

The interpretation of the phenomenon of the ball lightning which the paper deals with is non-trivial and has a scientific background.



Fig. 1 The imagination of BL

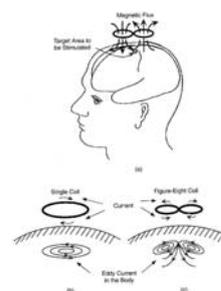


Fig. 2 The idea of TMS



Fig. 3 TMS in practice



Fig. 4 Silvanus P. Thompson

The explanation is based on the technique which is investigated by the authors for over a dozen of years, namely the Transcranial Magnetic Stimulation (TMS) [5] and by the phenomenon discovered over 100 years ago by two scientists: French physicist, Jacques Arsene d'Arsonval and British engineer, Silvanus P. Thompson (Fig.4), namely magnetophosphenes (magnetic visual effect) [6].

The TMS is widely used since 1985 both in diagnostics and therapy. The idea of the technique is based on the Faraday magnetic induction which in bulk conductor manifests itself as eddy current phenomenon (Figs 2 and 3). In therapeutic application the parameters of the D'Arsonval showed in his demonstration that a strong, low frequency electromagnetic field can induce eddy currents into living tissue and thereby cause stimulation. Using generator of 42 Hz, the frequency used at that time for energy transmission, he discovered the phenomena which links electromagnetic field with visual sensations which have been called magnetophosphenes. The parameters of Thompson's experiment were as follows: peak value of magnetic flux density up to 140 mT, frequency 50 Hz.

#### New explanation of ball lightning [7]

It is well-known that the spark-like lightnings are in about 50% discharged between cloud and ground (CG) and 90% of them are negative discharges, i.e. the ground is loaded by negative charges and cloud by positive (CG<sub>-</sub>). It appears that such a kind of discharges are initiated by the first return stroke and mostly it is followed by the series of strokes at the time comparable with the time used in the TMS procedure. Typical stroke lasts a few hundreds microseconds and the average interval time is 50 ms. It is compatible with the frequency of pulses used in TMS procedure (1-100 Hz). The number of after-discharges, i.e. repetitive strokes, is 2-5 strokes but more than 20 strokes is often reported by detection systems. It leads to the time of the duration of full lightning 1-2s. Thus, the electromagnetic state which is generated by spark-like lightning of the CG<sub>-</sub> type is similar to that evoked by TMS. The frequency of repetitive strikes is also similar to the frequency which was used by the people who discovered magnetophosphenes. On the other hand the value of magnitude of magnetic field both generated by line lightning and by TMS is such that both situations can evoke visual perception phenomena. The co-occurrence was noticed by the Austrian physicists and it led them to the conclusion that lightning electromagnetic pulses induce the TMS and it, in turn, leads to magnetic visual effect (magnetophosphenes) [4]. Such a hypothesis opens the area of scientific problems which can be investigated experimentally as the spark-like lightning is easily produced in the laboratory. Of course, one faces the

problem of the value of magnetic fields intensity which has to be comparable to that observed in natural thunderstorm. It is easily estimated taking into account that the average value of current flowing through the lightning channel is about 50 kA but the lightnings of 200 kA are also detected. The first approach to know the magnetic field strength of spark-like lightning is the simple usage of Ampere's law for the straight line wire and then for the current equal to 50 kA and for the distance from discharge, say, 50 m one obtains the rough value of magnetic field strength - 160 A/m (0,2 mT). Thus, the values is much smaller than those used in TMS. However, there are two situations which make the two phenomena, magnetophosphenes and spark-like lightning, comparable as to the final effect. First, the magnetic field pulse excited by the lightning has much smaller time of arising than that of the pulses occurring in TMS. The arising time of lightning is of microseconds (for high voltage testing it is normed as 1,2 μs), while in the case of TMS the arising time is in the range 50- 200 μs [5], thus in both cases electric field (eddy currents) generated in the brain may be similar. Secondly, the magnetophosphenes can manifest themselves with the magnetic field lower than it was previously used. The contemporary studies show that retina is the structure which can be stimulated by much weaker magnetic field – magnetophosphenes can be obtained with 10 mT (rms) and frequency 20 Hz [5].

#### Summary

The new explanation of the ball lightning phenomenon seems to be scientifically founded and may compete with the hitherto occurring. If the explanation is correct and will be confirmed by further investigations, the phenomenon known for ages as "ball lightning" will not exist any longer.

#### REFERENCES

- [1] Singer S., *The nature of ball lightning*, Plenum Press, New York, 1971
- [2] Kapica P.L. The Nature of Ball Lightning, in Donald J. Ritchie. *Ball Lightning: A Collection of Soviet Research in English Translation*, Consultants Bureau, New York, 11-16, 1961
- [3] Finkelstein D., Rubenstein J., *Ball lightning*, Physical Review, 135, 1964, 390-396
- [4] Meshcheryakov O., "Ball Lightning—Aerosol Electrochemical Power Source or A Cloud of Batteries" (PDF), *Nanoscale Res. Lett.* 3, 2007, 319-325.
- [5] Zyss T., Krawczyk A., Porównanie technik stymulacji elektrycznej i magnetycznej stosowanych w terapii depresji. *Przegląd Elektrotechniczny*, 86, 2010, nr 9, 309-314.
- [6] Krawczyk A., Łada-Tondyry E., The first experiments in magnetic stimulation – a history of discoveries within two parallel lives. *Acta Technica Jaurinensis*, vol.3, 2010, 153-160
- [7] Peer J., Kendl A., Transcranial stimulability of phosphores by long lightning electromagnetic pulses, *Physics Letters A*, vol. 374, 2010, 4797-99

**Authors:** Prof. Andrzej Krawczyk, Częstochowa University of Technology, Faculty of Electrical Engineering, Al. Armii Krajowej 17, 42-200 Częstochowa, e-mail: [ankra.new@gmail.com](mailto:ankra.new@gmail.com); dr med. Tomasz Zyss, Psychiatric Clinic for Adults at University Hospital, Krakow ul. Kopernika 21a, 31-501 Kraków, e-mail: [mzzyss@cyf-kr.edu.pl](mailto:mzzyss@cyf-kr.edu.pl); prof. dr hab. med. Wanda Stankiewicz, Military Institute for Hygiene and Epidemiology, ul. Kozielska 4, 01-163 Warszawa, E-mail: [wanda.stankiewicz@gmail.com](mailto:wanda.stankiewicz@gmail.com)