

EDITORIAL

About cold plasma Physics and the Miracle of Easter

In Physics and Chemistry, plasma is a gas in which a certain portion of the particles are ionized. Plasma temperature is commonly measured in Kelvins or electronvolts and is an informal measure of the thermal kinetic energy per particle. In most cases the electrons are close enough to thermal equilibrium that their temperature is relatively well-defined. Because of the large difference in mass, the electrons come to thermodynamic equilibrium amongst themselves much faster than they come into equilibrium with the ions or neutral atoms. For this reason, the 'ion temperature' may be very different from (usually lower than) the 'electron temperature'.

Depending on their energy, temperature and ionic density, plasmas are usually classified as thermal plasmas and non-thermal plasmas or non-equilibrium plasmas [1]. Thermal plasmas have electrons and the heavy particles at the same temperature, i.e., they are in thermal equilibrium with each other. Non-thermal plasmas, on the other hand, have the ions and neutrals at a much lower temperature, (normally room temperature), whereas electrons are much 'hotter' (typically several thousand degrees Kelvin). This is especially common in weakly ionized technological plasmas, where the ions and the reactor are often near the ambient temperature.

Sterilization of food, hydrogen production, medical equipment, and contaminated civilian and military gear is just one potential major application of so-called 'cold' plasmas [2]. These ambient-air-temperature ionized gases could also be used as a Star Trek-like protective shield around sensitive electronics-bearing devices, such as satellites; as cloaking technology for military aircraft, as a means of absorbing radar waves in order to remain hidden on enemy screens; and as components of a new generation of miniature lasers and in advanced, low-energy-consumption fluorescent light tubes.

Examples of common industrial/commercial plasma atmospheric pressure are: corona discharge (non-thermal discharge generated by the application of high voltage to sharp electrode tips, commonly used in ozone generators), dielectric barrier discharge (DBD - non-thermal discharge generated by the application of high voltages across small gaps wherein a non-conducting coating prevents the transition of the plasma discharge into an arc and is used to functionalize the surface of synthetic fabrics and plastics allowing for paints, glues and similar materials to adhere), glow discharge, microwave plasma and gliding arc discharge (Figure 1) [3].



Figure 1. Example of glidarc cold plasma discharge.

After this short introduction in the Physics of cold plasma let's come now to the main point of our editorial – the light of the Easter.

The miracle of the Holy Light of Jerusalem is a recurring miracle, happening each year with clock work precision on the Saturday preceding Easter Sunday, in the Holy Church of the Resurrection in Jerusalem, to the delight of a large congregation of Christians of the Eastern Orthodox Church. The Holy Light symbolizes and recalls in a miraculous manner the Resurrection of Christ and “therefore the Son of man is Lord also of the Sabbath” (Mark 2.28).

The ceremony surrounding the miracle of the Holy Fire may be the oldest unbroken Christian ceremony in the world. The first written accounts of the Holy Fire date from the fourth century, but authors write about events that occurred in the first two centuries. So saints John Damascene and Gregory of Nissa narrate how the Apostle Peter saw the Holy Light in the Holy Sepulchre after Christ's resurrection while Eusebius of Caesarea describes how occurred the miracle in the presence of patriarch Narcissus (II century) [*Ecclesiastical History*, Book 6, Chapter 9, 1-3].

From the fourth century all the way up to our own time, sources recall this awe-inspiring event. From these sources it becomes clear that the miracle has been celebrated on the same spot, on the same feast day, and in the same liturgical frame throughout all these centuries [4].

The substance of the miracle is the appearance of a supernatural fire in a crypt, thoroughly searched and secured beforehand to exclude any source of fire. The miracle takes place in the Hands of the Greek Orthodox Patriarch, who is ceremoniously searched before entering the crypt. These searches are witnessed by representatives of other creeds, especially of the Armenian Church, who also have certain traditional rights in the specific Church, as well as representatives of local authorities, and the police superintendent of Jerusalem.

The patriarch retires inside the crypt and prays and then appears with the miraculous light, to the ecstasy of the attending crowd.

At the same time, fire was mentioned to appear lighting the olive oil lamps and/or candles in and out of the Church spontaneously. Blue-white lightning is reported to sometimes appear and travel through the air. In fact all in the church wait with candles in the hope that they may ignite spontaneously. The miraculous fire lighting the patriarchs' candle has been reported to be different from normal fire, in that a hand placed in the flame is not burned (at least only for the first minutes after the miracle).

A limited, gymnasium-like science, explanation of the phenomenon points in the direction of use of some self-igniting material that ignites spontaneously when in contact with the air. A proposed candidate for such use is white phosphorus. If phosphorus is dissolved in an appropriate organic solvent, self-ignition is delayed, until the solvent has almost completely evaporated. Experiments showed that the ignition can be delayed for half an hour or more, depending on density of the solution and the solvent employed. However, this will never be able to explain the lighting of the candles bought from different stores and more important – the presence of the blue-white lightning.

My experience as researcher/author/reviewer in Plasma Physics and Chemistry is suggesting in fact a cold plasma phenomenon that gradually turns into a hot plasma. This seems to be in accord with the declaration made by His Beatitude Diodorus I, a former patriarch of Jerusalem: “From the core of the very stone on which Jesus lay, an indefinable light pours forth. It usually has a blue tint, but the colour may change and take on many different hues. It cannot be described in human terms. The light rises out of the stone as mist may rise out of a lake - it almost looks as if the stone is covered by a moist cloud, but it is light. At a certain point the light rises and forms a column in which the fire is of a different nature, so that I am able to light my candles from it.” [4]

Even in this case some unsolved problems remain. Why only the candles and the lamps are ignited and not the clothes or the hair of those from the audience? And where is the generator? And how large should it be?

One must notice that is easy to make cold technological plasmas at low pressures, like the near-vacuum of space, but it's much harder to initiate *and maintain* them at room temperature and atmospheric pressure. In this context we make one more remark, a similar cold plasma phenomenon, but in open space and having a much larger volume is reported to be formed each year on Mount Tabor during the night liturgy on the Transfiguration day.

A change from the rule occurred in the year 1579, under Sultan Mourad IV, when the Patriarch of Jerusalem was Sophrony IV. That year the Armenians (monophysites) paid the Turks, who then occupied the Holy Land, in order to obtain permission for their Patriarch to celebrate the ceremony in the Holy Sepulchre. The Orthodox Patriarch was standing sorrowfully with his flock at the exit of the church when the Holy Light split near the left column vertically and flashed near the Orthodox Patriarch. The above mentioned split column still

exists. The Orthodox pilgrims embrace it at the 'place of the split' as they enter the church.

In order to better understand this event from the scientific point of view, we must return to the Physics. The split column is made from limestone, an insulating material where the main component is calcium carbonate.

The atoms in insulating materials have very tightly-bound electrons, being non-conductors for the electric current. However, insulators cannot resist indefinite amounts of voltage. With enough voltage applied, any insulating material will eventually succumb to the electrical 'pressure' and electron flow will occur. However, the current through an insulator is quite nonlinear: for voltages below a certain threshold level, virtually no electrons will flow, but if the voltage exceeds that threshold, there will be a rush of current.

Once current is forced through an insulating material, *breakdown* of that material's molecular structure has occurred. After breakdown, the material may or may not behave as an insulator any more, the molecular structure having been altered by the breach. There is usually a localized 'puncture' of the insulating medium where the electrons flowed during breakdown. Thickness of an insulating material plays a role in determining its breakdown voltage, otherwise known as dielectric strength. Specific dielectric strength is sometimes listed in terms of kilovolts per meter.

Considering that in the above mentioned case it was also a plasma phenomenon due to an electric discharge through an insulating material one can determine the applied voltage. Taking into account the dimensions of the split, which I personally measured on site, and the dielectric constant of calcium carbonate, we can determine a value for the voltage of at least several hundreds of kilovolts which tend to exceed the highest values used for the production of cold plasmas [5].

However, at the time being the Physics was not developed enough in order to produce at least a theory, what to say about the equipment, necessary to perform such a spectacular event. And we still have the unexplained igniting effect, even by the today science, on the patriarch's candle and not on other combustible materials from the zone.

This year, Orthodox Easter coincided with observances by other Christian denominations, while the Jewish Pesach was celebrated on Tuesday – the Holly Week. This brought a large number of pilgrims to the narrow alleys of Jerusalem's Old City heavily secured by Israeli forces. Police spokesman Shmuel Ben-Ruby estimated that between 8,000 and 10,000 worshippers packed the church on Saturday and about 7,000 more spilled over into its cobbled courtyard [6]. Video screens set up in various places in the Old City broadcast the ceremony live for the thousands more who could not fit inside.

In this context, this year, I had the unique chance to be among those who spent the Easter Week in Jerusalem and assisted from the balcony of the Resurrection Church to the Holy Fire ceremony. And if we are discussing here about Science and Theology, I was impressed by the 'science of communication' among the pilgrims participating to the ceremonies of the Holly Week. We saw,

for example, questions asked in Spanish and answered in Greek with few or even no English words in the sentence and the understanding was total! And the example was defining for the state of spirit of the Holy Week.

In fact, I had to expect this, because Jerusalem is the entire world in a city as King David says in his Psalms:

“I was glad when they said unto me, Let us go into the house of the Lord.
Our feet shall stand within thy gates, O Jerusalem.

Jerusalem is builded as a city that is compact together:

Whither the tribes go up, the tribes of the Lord, unto the testimony of Israel, to give thanks unto the name of the Lord.” (Psalm 122.1-4)

If we remembered about the house of the Lord, I want to mention here the exquisite human quality of the priests and monks which are working and praying at the Holy Places in Jerusalem. I put on the same line the director Abu-El-Walid Dajani – a wise man, with the entire personal of the New Imperial Hotel from the Jaffa gate of Jerusalem, which is also giving an excellent image concerning the hospitality of the Greek Orthodox Patriarchate to the visiting pilgrims coming sometime as far as Australia or Russia.

The ‘science of communication’ was in fact working at all levels. Relevant is, I think, the joint Easter message ‘*We Know the Power of God to Bring Hope Out of Despair*’, proclaimed by 13 Christian leaders of Jerusalem, which was released Wednesday, 31 March, 2010 [7].

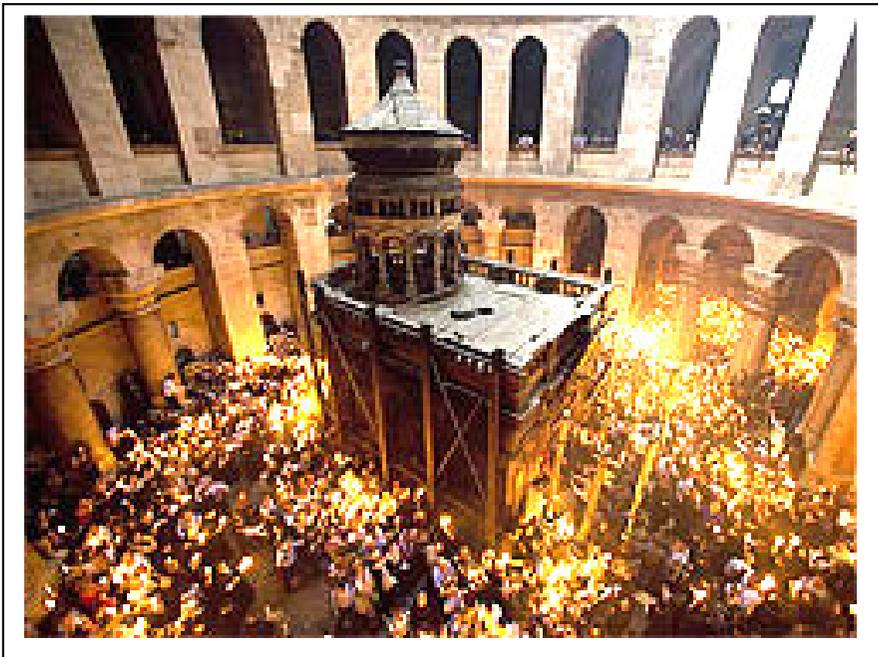


Figure 2. The Holy Fire ceremony at the Resurrection Church in Jerusalem.

Also speaking about Science and Theology, I was very pleased impressed by the dialogue between the Political sciences, represented by different diplomats from Orthodox countries in Israel (Russia and Greece must be mentioned here), and Theology represented by His Most Godly Beatitude Theophilus III, *the Patriarch of the Holy City of Jerusalem and all Palestine, Syria, Arabia, beyond the Jordan River, Cana of Galilee, and Holy Zion*. I put a special remark for the Greece ambassador, who, despite all his regular duties, attended all important religious services during the Easter Week and even the night vigils!

The thousands of celebrants who filled the Church were grouped into different areas of the church holding church flags, while others beat hand drums and sang hymns, and trust me, you never saw such an atmosphere, not even on the final of Champions League. Worshippers carrying torches or bundles of 33 tapers signifying the years of Jesus' life waited in excited anticipation as the Greek Orthodox Patriarch, Theofilos III - a really 'AXIOS' man as the entire crowd acclaimed, removed his embossed gold-and-white mitre and descended with into the tomb, which was in the morning minutely searched by the Israeli bomb squad.

I must confess that I have not seen the expected cold plasma lighting up the candles or oil lamps but the flame appeared just a few minutes after the Patriarch entered into the tomb. I was amazed by the speed with which the flame propagated from the tomb to all believers, who rushed to light their own candles and torches, illuminating the darkened church *within seconds* (Figure 2). My scientific formation also made me to notice two characteristics of the flame: a yellow very mild colour – indicating, as I expected, a lower temperature and the difficulty to extinguish it. Above all, the church bells pealed, and some of the faithful passed their hands through the flames they held, reflecting their belief in the fire's divine and beneficial nature. Light from the Holy fire was taken afterward to the Church of the Nativity in the West Bank town of Bethlehem, where tradition holds Jesus was born, and aboard special flights to Athens and other cities, linking many of the 200 million Orthodox worldwide to their spiritual core.

Maybe many don't know but only after 1246, when Catholic Christians left Jerusalem with the defeated Crusaders, did the Miracle of the Holy Fire become a purely Orthodox ceremony as the Orthodox remained in Jerusalem even after the Turks' occupation of Palestine [4]. Despite the fact that, as I told, the date of Orthodox Easter coincided with that of other Western Christian denominations, I left Jerusalem with the regret of not seeing at least one common ceremony during the entire Holy Week.

The regret was even bitter considering that I dedicated my entire effort and work at the European Journal of Science & Theology in order to create a place where with equity and arguments, and *sine ira et studio*, one may find the ways toward peace and mutual respect. And I made this risking up to sacrifice my career and what is worst – the security and health of my family.

My considerations on cold plasma Physics could bring just an idea on the possible mechanism of the Holly Fire appearance but a miracle remains a miracle and the Holly Land, with Jerusalem by excellence, is the most appropriate place for them. Because, and here I paraphrase from the speech of Professor Daniel Hershkovitz – the Israel Minister of Science and Technology at the Opening ceremony of the 55th Israel Physical Society Conference [8], if this is not the land of miracles then where else, and if this is not the time of miracles then when?

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References

- [1] J.M. Cormier and I. Rusu, *J. Phys. D: Appl. Phys.*, **34** (2001) 2798.
- [2] I. Rusu and J.M. Cormier, *Chem. Eng. J.*, **91** (2003) 23.
- [3] I. Rusu, *Environ. Eng. Manage. J.*, **6(3)** (2007) 211.
- [4] N.C. Hvidt, *Mirakler – Møder mellem Himmel og Jord*, Gyldendal, Copenhagen, 2002, 203.
- [5] E. Hnatiuc, J.-L. Brisset, B. Hnatiuc, R. Burlica and I. Rusu, *New trends in plasma sources, plasma reactor engineering and applications of non-thermal plasmachemical reactors*, Proc. of XVth Symposium on Physics of Switching Arc, vol. II, University of Technology, Brno, 2003, 297a-297j.
- [6] ***, *Holy Fire Draws Orthodox Christians to Holy Land*, CBS News World, **April 3**, 2010, available at <http://www.cbsnews.com/stories/2010/04/03/world/main6360438.shtml>.
- [7] Theophilos III - Greek Orthodox Patriarch, Fouad Twal - Latin Patriarch, Torkom I Manoogian - Armenian Apostolic Orthodox Patriarch, Pierbattista Pizzaballa - Custos of the Holy Land, Anba Abraham - Coptic Orthodox Patriarch, Swerios Malki Murad - Syrian Orthodox Patriarch, Jules Zerey - Greek Melkite Catholic Patriarch, Abouna Matthias - Ethiopian Orthodox Patriarch, Paul Sayyah - Maronite Patriarchal Exarch, Suheil Dawani - Anglican Bishop in Jerusalem, Munib Younan - Bishop of the Evangelical Lutheran Church in Jordan and the Holy Land, Pierre Malki - Syrian Catholic Patriarchal Exarch, Rafael Minassian - Armenian Catholic Patriarchal Exarch, *Easter Message of Jerusalem Religious Leaders*, Innovative Media Inc., Jerusalem, 2010, available at <http://www.zenit.org/article-28824?l=english>.
- [8] ***, *Bulletin of the Israel Physical Society*, **55** (2009) 1.