The 9th International Conference Charged & Neutral Particles Channelling Phenomena (Channelling - 2023)
4-9 June 2023 Riccione (Rimini), Italy

On the Possibility of Accelerating Charged Particles in the Atmosphere

Abrahamyan A., Chilingaryan R., Margaryan A., Mkhitaryan S., Mkrtchyan A.

Institute of Applied Problems of Physics
NAS RA

OPTIONAL CONTENT

SUMMARY

- **This work is devoted to the problem of acceleration of charged particles in acoustoplasma and plasma bunches in the atmosphere and is a logical continuation of a series of research conducted in a field Acoustoplasma by a group of scientists of the Institute of Applied Problems of Physics (IAPP) NAS RA under the leadership of the founder of the IAPP Academician Alpik R. Mkrtchyan.**
- **In order to carry out needed experimental research, an experimental setup was developed and created in the IAPP, containing several experimental devices and equipment with several know-how (AJP, Mkrtchyan A., Abrahamyan A., 19-21).**
- **During the experimental studies, the origination and acceleration of charged particles and various plasma formations in the acoustoplasma and real atmosphere were detected and observed.**
- **Experimens are in agreement with theoretical analyses & calculated data.**
- **A preliminary theoretical model of origination and acceleration of elementary particles and ions in acustoplasma was partially developed by IAPP scientists too.**
- **The phenomena of origination and acceleration of charged particles in the acustoplasma and plasma bunches in athmospere were tested and confirmed.**

Preliminary Request from the Authors

- **Good morning dear colleaguec.**
- **My name is Samvel Mkhitaryan. I am from Institute of Applied Problems of Physics (IAPP) NAS RA.**
- **It is a great honor and pleasure to participate in this conference.**
- **I would like to express deep gratitude to the organizers, especially Prof. Sultan Dabagov, for the organization of this conference and opportunity to meet with many honorable well-known scientists in this beautiful Country, and establish new contacts and working connections.**
- **At the same time, I would like to inform you, that as a new team member of a group of the IAPP scientists have been working in these target areas tens of years am presenting on their behalf a brief summary of results of many years of their research and am authorized to ask you if needed to address your possible discussable questions and remarks also directly to Prof., Cooresponding Academiccian Artak Mkrtchyan: amkrtchyan@iapp.am, +(374)94 007 775 and Dr. Aleksan Abrahamyan: arbel11@mail.ru, +(374)55 451 819.**

I. Acoustic Oscillations And Standing Waves In The Discharge Tubes

- As is known, if we originate a discharge current in a discharge tube with combination of direct and alternate sinusoidal components, then acoustic oscillations will be formed in the cold plasma.
- As a result of interactions of acoustic oscillations with the same plasma that created them plasma-acoustic interactions are formed.
- As the discharge tube is also an acoustic resonator, plasma-acoustic interactions form standing waves in the plasma at the resonant frequencies (which we called acoustic superlattices with certain parameters).

Acoustoplasma As a New State of Medium

- **As the plasma is a self-agreed (consistent) nonlinear medium, its many parameters will change when any other parameter changes.**
- **Therefore, these Standing Waves (Superlattices) can significantly change the plasma parameters.**
- **This makes it possible to consider it as a new acoustoplasmic medium, or Acoustoplasma.**
- **The word itself and the notion of "Acoustoplasma" were introduced into physics by the founder of the IAPP NAS RA Academician Alpik R. Mkrtchyan.**

II. Trajectories of a Corded Discharges

When studying the xenon acoustoplasmic corded discharge (3 mm in diameter) in the discharge tube at a pressure of 10^4 Pa, it was found that the corded discharge trajectory can make a loop (see Figure. 1b).

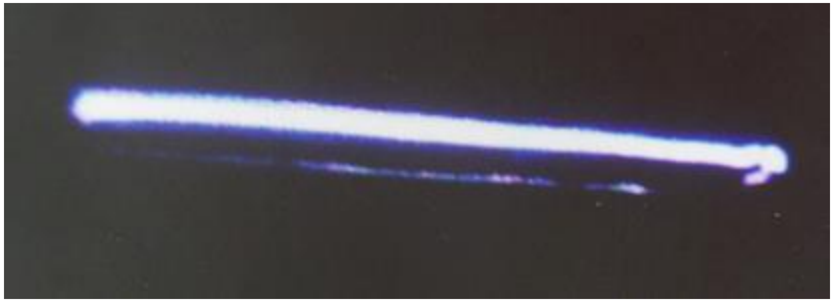

Fig. 1 Forms of Trajectories of Corded Discharges in a Discharge Tube.

a) Normal conventional discharge at direct current,

b) Acoustoplasmic discharge with a loop of a trajectory.

Internal Opposite Field Arising in The Discharge

- **In Figure 1 the accelerating field was applied on the electrodes with specific forms of the tube with diameter – 1,2 cm and length - 10 cm.**
- **Figure 1a shows the corded discharge without acoustic excitation (straight line) with 2 KV direct voltage.**
- **Figure 1b shows an acoustoplasmic discharge (with a looped line) in the presence of acoustic excitation, originated by the currency of certain frequency and modulation depth – 2 KV direct voltage in combination with about 1 KV variable voltage (Details: AJP, Mkrtchyan A., Abrahamyan A., et al. 2019-2021).**
- **Thus, it was assumed that an internal electrical field arises in the discharge (with a strength of >100 V/cm), oppositely directed with respect to the applied accelerating external field.**

Possibility of Accelerating of Charged Particles in Acoustoplasma

- **All shown figures are real photos from experiments, without any computer processing and Photoshop.**
- **They are not photos of short-term states. They are photos of stationary states that persist for tens and hundreds seconds.**
- **Based on the fact that on the certain parts of its trajectory, the discharge goes against the direction of the applied field (Figure 1b), it was assumed that in that certain points of the discharge, internal fields are formed, which are higher than the external electric field from the voltage applied to the ends of the tube.**
- **In 2005, this effect was partially explained theoretically by the IAPP group of scientists, and the possibility of accelerating charged particles in acoustoplasma was shown (JCP NSA RA, Mkrtchyan A., Abrahamyan A., et al, 2005).**

III. Parameters Affecting The Creation of an Acoustic Superlattice

- **Particularly it was explained that for creation of acoustic superlattices, some of important basic parameters are the phase of the modulation of the electron component of the current (ϕ_e) and the phase difference of two (electron and ion) components ($\Delta\phi$) that creates an interference grating (Details: JCP NAS RA, Mkrtchyan, Abrahamyan, et al, N3, 2005).**

- **It was also assumed that these parameters determine the energy increment of accelerated electrons in each act of acceleration (in the created acoustoplasmic accelerating cells).**

Electron Acceleration Effect in The Discharge Tube

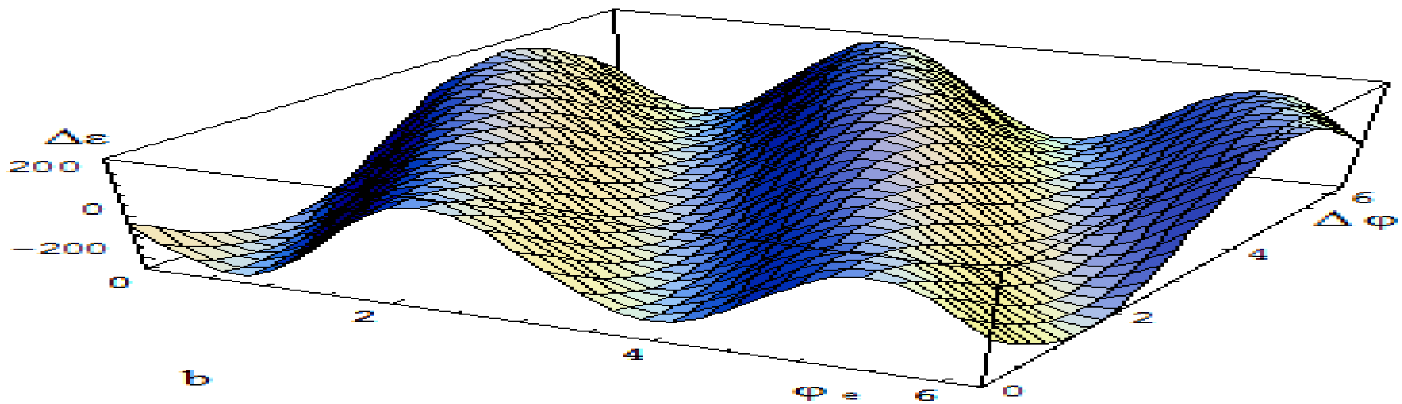

Fig. 2. Electron Acceleration Effect in The Discharge Tube (ΔU=50 V/C)

Some formulas have also been optained which showed the relation and dependence of the energy increment of the accelerated electron Δε (eV) for one act of acceleration with the ϕ_e, Δϕ (rad) and potential difference in the accelerating microcell (JCP NAS RA, Mkrtchyan, Abrahamyan, et al, N3, 2005).

Figure 2 presents the above-noted relations for the potential difference of about 50 V in the accelerating microcell.

Electron Energy Increment In the Discharge Tube

- **As we also see from Figure 2, the electron energy increment in the discharge tube has both positive and negative values (from + 200 to -200 eV for ΔU=50 V/C.).**
- **Thus, it was assumed that there are points located apart (separately) in the space, where the electron picks up a speed and accelerates and points where it loses the speed and decelerates.**

IV. Gas-discharge Neon Lamp With Cold Steel Cathodes

- **In order to test the above statements through experiments, in 2009 a gas-discharge lamp with cold steel cathodes filled with neon at a pressure of 1500 Pa was designed and created.**
- **Above noted Acoustoplasma Neon Lamp with a discharge interval of 50 cm is shown in Figure 3.**

Acoustoplasma Neon Lamp

Fig. 3. Acoustoplasma Neon Lamp

Wave-like Acceleration of Charged Particles in the Acoustoplasma

- The above-presented lamp a direct voltage of more than 1 kV required to burn and maintain the discharge at a direct current.
- On the other side, to burn and maintain the discharge in the acoustoplasma mode, it was sufficient to apply an alternating voltage with an amplitude of 150 V to the electrodes of this lamp.
- Even if we forget that the operation of cold cathodes requires about 100 V, and assume that all applied 150 V are applied to the discharge, all the same, we get a field strength just of 3 V/cm for the above noted discharge length of 50 cm.
- By the authors' opinion this is not enough to burn the discharge, but it burns only because a wave-like acceleration of charged particles by the authors' opinion occurs in the acoustoplasma.

Formation of Acoustoplasmic Strata

- **The above discharge leads to the formation of acoustoplasmic strata in the lamp which are also clearly visible in Figure 3.**
- **During the operation of this lamp, these strata moved forward and backward, which was explained as their acceleration and deceleration via the formed internal alternating fields in the acoustoplasma.**
- **Normal strata can be originated and appear at a pressure of < 150 Pa, and at a pressure of 1500 Pa they cannot be originated.**
- **During the conducted experiments there were no strata when feeding by direct current.**
- **The authors could not obtain high energy of accelerated particles with this method (Obtained energies were less than 300 eV), since alternating fields are formed in the plasma, because of which after each acceleration period began a slowing done.**

V. Energy Capacity of Acoustoplasma

- **Later, in 2010 an article about the energy capacity of acoustoplasma was published by a group of IAPP scientists in the magazine Haykakan Banak (Armenian Army. 2010 no. 2, pp. 94-100).**

- **It was shown experimentally that the energy capacity of acoustoplasma can be much higher than the energy capacity of plasma without acoustic disturbance.**

- **Moreover, it was stated that when the acoustoplasma regime is destroyed and the plasma transitions to its normal state, the stored energy can be released in the form of an explosion.**

- **Conducted experiments in low-pressure acoustoplasma showed that the stored energy can exceed 1000 J/cm^3 which must be taken into account when working with acoustoplasmic bunches having certain sizes.**

VI. Experiments on Acceleration of Plasma Bunch in the Atmosphere

- Till now we spoke about the acceleration of separate particles in the plasma. Further, we will speak about the acceleration of plasma bunches.
- In 2019 experiments on the origination and acceleration of plasma bunches in the atmosphere have begun at the IAPP NAS RA.
- In 2020-21, these works were slowed down due to Covid - 19, and in 2022 these works continued.
- It was assumed to originate and initially accelerate plasma bunches in a specially designed injector.
- Then it was assumed to ensure wake acceleration of bunches to the necessary possible parameters by a laser and microwave fields.
- One of the created injectors with a 1 m length is given in Figure 4.

The injector of the Acoustoplasma Bunches

Fig. 4. Injector of the Acoustoplasma Bunches (d=4-5 cm., L=1 m.)

Here is presented one of laboratory prototypes of an linear injector, which were created to originate and accelerate plasma bunches in the atmosphere.

Other information about the construction of these injectors is know-how and we are looking for interested in this research scientists and/or organizations for cooperation and further joint research.

Plasma Bunch Movement Along a Linear Injector

- **The origination and movement of a plasma bunch along a linear injector/accelerator with a length of L=40 cm and the emission of that bunch outside from the injector is shown in Figure 4.**
- **There were achieved small values of acceleration (less than about 1000 m/s^2) and speed (less than about 30m/s) of the plasma bunch due to the use of small magnetic fields (< 0.1 T) and discharge currents (1-2 A), which were done specially.**
- **During the experiments high-speed video cameras and ordinary WEB cameras failed from the originated and accelerated plasma bunches and high-intensity electromagnetic fields.**
- **Therefore, the video shootings were done by iPhone-type cameras at normal speed which were placed in a shielded box.**

The Injector at the Moment When The Discharge Starts

Fig. 4a. The injector in standby mode, at the moment when the discharge starts and the plasma bunch originates.

In the first plan, the protective metal mesh is seen, which is located around the entire experimental installation.

The Movement of the Plasma Bunch at 40 ms After the Discharge Start

Fig. 4b. The movement of the plasma bunch at 40 ms after the start

- **The plasma pathway is not a clear dot bat a smeared line due to the movement of the plasma bunch after the discharge.**

The Movement of the Plasma Bunch Through the Injector at 80 ms After the Discharge Start

Fig. 4c. The movement of the plasma bunch through the injector at 80 ms after the discharge start

The Moment of the Emission of the Plasma Bunch From the Injector Into the Atmosphere

Fig. 4d. The moment of the emission of the plasma bunch from the injector into the free atmosphere

- **Since the plasma bunch moved during the video shooting, its trace instead of a dot is visible as a line.**

The Plasma Bunch in Free Space After 100 ms of Emission

Fig. 4e. The plasma bunch in free space at 100 ms after the emission from the injector

The Plasma Bunch in Free Space after 500 ms of Emission

Fig 4f. The plasma bunch in free space at 500 ms after the emission from the injector

The Plasma Bunch in Free Space after 600 ms

Fig 4g. The plasma bunch in free space after 600 ms of emission from the injector

- **The intensity of the glow of the bunch decreased, and after 700 ms the plasma bunch quietly disappeared (damped).**

VII. Researches for Stopping and Stabilization of the Acoustoplasmic Bunch

- According to the authors' opinion although the originated plasma bunch's diameter was 3 mm, it could contain more than 30 Joules of energy, and if the acoustoplasmic regime was destroyed, even in a time of 10^{-3} s, the explosion could have a power of 30 kW.
- Since the acoustoplasmic bunch could damage the installations for experiments, we are also working on the problems of stopping, stabilizing, and slowly damping it, as well as increasing its lifetime and controlling temporal and spatial parameters.

VIII. Experiment to Prove the Fact of the Acceleration of the Created Bunch in the Injector

- **To prove that it is the created bunch that is accelerated in the injector and that new volumes of gas are not ionized in the channel at subsequent times, the following experiment was carried out:**
  - **A cuvette with a small amount of a substance with a characteristic glow color was placed in the initial part of the injector.**
  - **For this aim cadmium salts were used, which give a bright orange color.**
- **After the discharge originated, it was the bright orange bunch that moved along the injector's channel.**

Comparison of Bunches

Fig. 5. Comparison of bunches in cadmium vapor (a) and in the ordinary atmosphere (b).

- **Figure 5 shows the comparison of the colors of bunches from the cadmium (Fig. 5a) and the atmospheric gases (Fig. 5b).**
- **We see how different the colors of the bunches are.**

IX. Clarity of the Experiment

- **For the clarity of these experiments, after each shot, the entire injector channel was replaced with a new one, so that no traces of cadmium remained in the channel.**

- **The injector channel was not isolated from the atmosphere.**

- **The design of the linear injector made it possible (allowed) to use a voltage of 6 kV to power the discharge, even if the length of the linear injector was 100 cm.**

X. Future plans / Next Steps

- Now, before the end of this year, a new laboratory is being launched at the IAPP, where it will be possible to conduct larger experiments on the acceleration of charged particles in the atmosphere.

- In this frame to achieve wake acceleration of plasma bunches, it is proposed to use electromagnetic UHF radiation from a powerful microwave magnetron with microsecond pulses or a nitrogen UV laser with a pulse duration of about 10 ns and a power of about 40 kW, as well as a powerful pulsed CO_2 laser.

- The CO_2 laser now is in the process of being created, although this year we will not yet launch it, and therefore, we will not talk about its parameters.

- For doing so and continuing our activities in these directions we are looking for interested scientists and/or organizations for a cooperation and possible further joint research with joint interests.

- That's all I can tell. The rest, as well as additional information from photographs, are know-how.

THANK YOU FOR YOUR ATTENTION

IAPP NAS RA

https://www.iapp.am