Generation of UV Photons Produced by Lightning in Vacuum Conditions: Electrodynamic Model of Near Field

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Abstract—In the following work, a theoretical proposal is presented on the mechanism of generation UV photons produced by lightning in vacuum conditions under anisotropic medium (gas) using the quantum model of near field electrodynamics through paths integrals. The aim is calculating and sensing the number of photons that can generate a lightning discharge under a voltage of 2000 volts AC in t seconds.

Index Terms—Anisotropic Medium, Generation UV, Lightning in Vacuum Conditions, Quantum Model.

I. INTRODUCTION

In the model of near-field electrodynamics [1], the possible trajectories of a particle to choose from, in this case a load carrier, depends on the conditions imposed by the medium, whether it is isotropic or not and how permissive it is electromagnetically it is. Just at the first moment of time and an elemental volume with N particles.

In the present experimental theoretical development, the factor of fluctuations of the beam in the discharge is calculated, but under vacuum conditions, which in turn lead to calculate the number of photons per unit volume, this associated with the possible trajectories of a flow of charge carriers, which become the generators of the discharge in the storm cloud. It is proposed, through the theory of near-field perturbations [2], to demonstrate how the first discharge is generated, at the first moment of time and in an elementary volume with N molecules.

II. THEORETICAL MODEL

Taking into account the near field electrodynamics model [1]-[4], the possible trajectories that a certain particle can choses (in this case a charge carrier), depends on the conditions imposed by the environment, it is isotropic or not, and how much electromagnetic permissive it is. Just in the moment when the discharge begin on the storm cloud [5]-[8], the propagation medium of charge carriers beam becomes very electromagnetic unstable and locally conductive.

In this theoretical and experimental report, the number of UV photons generated by lightning in vacuum conditions, were calculated using the near field perturbations model [8]-[11], demonstrate how the first discharge is generated, in the very first moment of time and an elemental volume with N particles.

Using the theoretical model proposed by Feynman [12], [13], the quantum behavior of possible trajectories that could chose a certain charge carrier between a point X(t) and X0 in an electromagnetic field configuration, is expressed as:

\[ \langle x_i, t_b | x_a, t_a \rangle = \langle x_b | H(\tau) | x_a \rangle = \int dx_1 \ldots \int dx_j \left( e^{-\frac{i}{\hbar} S(x)} \right) \langle x_j+1 | x_j \langle x_j | x_a \rangle \] (1)

Where the electromagnetic interaction Hamiltonian operator is:

\[ H = \left[ \frac{1}{2m}(\hat{p} - \frac{e}{c} \hat{A})^2 - \frac{k_e}{\epsilon_0} \hat{r}^2 + eV(r) - \mu B \right] \] (2)

Being: \( \hat{p} \) – momentum operator; \( \hat{A} \) – magnetic potential; \( \hat{r} \) – dipole moment; \( \mu \) – magnetic moment; \( B \) – magnetic field; \( V(r) \) – electric potential; \( k_e \) – dielectric constant; and \( m \) – electron mass.

The matrix electron that distinguishes the moment operator action over the propagation beam function is defined as [14]-[16]:

\[ \langle x_{j+1} | p_j | A_1 \rangle \] (3)

And the energy system (gas - charge carrier) could be expressed as:

\[ U^* = \frac{1}{2m}(\frac{e}{c} A_j)^2 + eEx_j - \mu B \] (4)

Then, the trajectory integral for the carrier is:

\[ \langle x_0, t_0 | x_a, t_a \rangle = \int dx_1 \ldots \int dx_j \langle x_{j+1} | p_j A_1 | x_j \rangle \langle x_j | x_a \rangle = \int dx_1 \ldots \int dx_j e^{\frac{i}{\hbar} S(x)} \int dp_j e^{\frac{i}{\hbar} \frac{p_j^2}{2m} + \frac{i}{\hbar} \frac{e}{c} p_j A_1} \langle x_{j+1} | x_j \rangle \langle x_j | x_a \rangle \] (5)

And using the results of Poisson integrals, the equation (5) lets calculate the fluctuation quantum factor of the possible beam trajectories or generated discharge on a storm cloud as:

\[ \langle x_0, t_0 | x_a, t_a \rangle = \frac{1}{\sqrt{2\pi \hbar m}} \exp \left( \frac{i}{\hbar} U(x) x \right) \left( \frac{e}{2c} B \right) \left( \frac{e}{2c} \right) \exp \left( \frac{i}{4a} \right) \] (6)

Where is obtained the fluctuation quantum factor to the trajectories for a charge carrier beam, given the expression:

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\[ F_j = \sqrt{\frac{2m}{\hbar c}} \left( \frac{e}{2\hbar} \right) \left( \frac{e}{2a} \right) \exp \left( \frac{b^2}{4a} \right) \]  

(7)

This expression leads to the direct calculation of the distribution of UV photons in the discharge and to their experimental confirmation.

III. SIMULATED MODEL

The first steps in the presented work were found and simulate one of the possible trajectories of a charge carrier on the cloud and later find the behavior of the fluctuation quantum factor of a group of trajectories. After this, the investigation was oriented to the measurement and calculation of the number of photons generated in the lightning discharge, as shown in Fig. 2.

In the simulation process, the conditions imposed on the generation of the beam, and therefore the number of UV photons in the discharge, are strongly related to the vacuum conditions, the temperature in the plasma chamber, the material that constitutes or makes the times of the leader in the discharge in the storm cloud and the vacuum pressure.

IV. EXPERIMENTAL DEVELOPMENT

To develop the objective set out in the present research work, a series of sensors, including magnetic field, UV photons, voltage in the core of the discharge and vacuum pressure, were conditioned in a plasma chamber. A 2000-volt AC source was used to emulate lightning discharge conditions in the storm cloud. One of the electrodes (main) was fitted with a Li filament, which served as the leader or guide of the beam. It should be noted that on several occasions the sensor system was affected by the intensity of the fields in the chamber, which led to the design of an in-situ protection system.

The acquisition of data was carried out with a card with USB port of direct communication and in real time to the MatLab program. These data were taken from a series of internal pins in the plasma chamber and connected through shielded cables to avoid interference with the electromagnetic fields produced by the lightning plasma at discharge (Fig 3).

In addition to the above, the power control system of the voltage source was conditioned, complying with RETIE standards, which are established for these cases.

V. DISCUSSION AND CONCLUSIONS

What is the mechanism immersed in the lightning discharge generated in vacuum conditions?

There are two kinds of mechanism that make it possible to generate a UV photon.

First mechanism: energy transfer between particles (charge carriers) by collision effect. At the initial moment of the reduction of the pressure in the chamber, by the action of the vacuum pump, the power source is turned on (voltage of 2000 volts AC) and the generation of the beam is started, through the filament that it serves as a guide. The charge carriers then acquire the energy from the source that accelerates them through the electric field and generate multiple collisions of different types, elastic and inelastic. The above generates, therefore, in the atoms of the medium, absorption of energy by collision, which, in turn, causes the electrons of that atom to transit between levels and in response to this, photons in the expected band are produced in probabilistic terms.

Second mechanism: radiation by braking. It is a mechanism proper to electrically charged particles (electrons, positive and negative ions) that when accelerated by an electric field is suddenly braked by a barrier (atom) and consequently irradiate a UV photon. This mechanism is not the most common under the imposed conditions of the experiment proposed in the present work of degree.

The foregoing, in both mechanisms, infers that the process of generating UV photons in lightning discharge under vacuum conditions is due to the effect of the first of them.
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