B-P17 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8.11.2019, Hefei, China

Long-gap laboratory atmospheric discharge

Alexandr Frolov[1], Karel Kolacek[1], Jiri Schmidt[1], Jaroslav Straus[1], Petr Hoffer[1]

[1] Department of Pulse Plasma Systems, Institute of Plasma Physics Czech Academy of Sciences, Prague, Czech Republic

e-mail (speaker): frolov@ipp.cas.cz

Despite in the nature a lightning is a relatively frequent and common phenomenon, in its physics there are still "white places". At present it seems to be established that the high-energy effects are caused by runaway electrons. Formerly, all X-ray effects were attributed to thunderclouds with large scale electric fields. But Moore et al. in 2001 and Dwyer et al. in 2005 detected emission of energetic radiation from rocket-triggered, as well as from natural lightning. Due to these measurements it seems to be proved that vast majority of negative leaders emit hard X-rays and hence produce runaway electrons. Our motivation is the study of long-gap laboratory high-voltage discharges in air at atmospheric pressure which it helps to elucidate some processes appearing in lightning and in this way to contribute to safety of air traffic, sensitive electronics, and to protection of human health.

A closer insight into X-ray emissions from lightning could be gained from long laboratory sparks in air. Specifically, it was found that e.g. (1) positive as well as negative polarity sparks generate X-ray pulses in the hundred keV range, usually when the voltage is near its maximum [1], (2) such discharges can have multiple X-ray pulses, (3) X-ray emission is often linked to negative streamer onset at the cathode, (4) at positive sparks the X-rays are emitted, when positive and negative streamers collide [2], (5) the production of runaway electrons can be influenced by the shape of cathode, and by the voltage rise-time, (6) bursts of runaway electrons can have a sub-nanosecond duration [3]. Neutron production of laboratory spark has been detected only by one laboratory [4]. The energies of neutrons within the range from thermal up to fast are detected. It should be emphasized that neutron emission is strongly correlated with x-ray radiation, no neutron pulses were observed out of the x-ray pulse.

In this work we present first results from experiment with long-gap laboratory discharge at atmospheric pressure. Our designed apparatus (Figure 1) consists of oil insulated 8-stage Marx generator (pulse voltage up to 1.5 MV), water-filled pulse forming line which is attached to HV electric bushing. At first, the Laplace-Poisson equation in the most exposed regions was solved in order to determine not only the minimum safe dimensions of the insulators and the optimum roundness of the conductor edges, but also mutual capacitances of individual components. In the second step, the equivalent circuit of the designed apparatus was analyzed (for prediction of electrical parameters). After designing and assembling apparatus, the device was electrically tested for a short circuit to detect weak regions (i.e. HV electrode was connect with ground

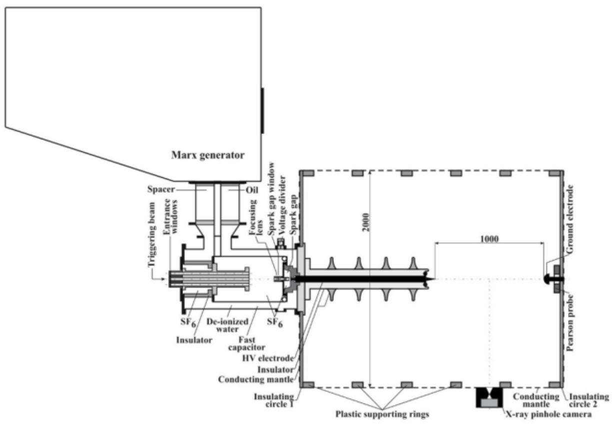

Figure 1 Experimental apparatus

electrode). Basic measurements of voltage (based on capacitor-resistor divider) and current (by Pearson current monitor) were re-calibrated. In the next step, we have tried short gap discharges (5, 10, 15 and 20 cm long). These discharges were observed optically by digital photo camera Canon EOS 550D with ND filter and by digital camera Sony RX100 VI with 1000 frames per second. In the next experiment we will prepare time-resolved measurements of X-ray emission (with the help of scintillators and photomultipliers).

References

[1] J. R. Dwyer, H. K. Rassoul, Z. Saleh, M. A. Uman, J. Jerauld, J. A. Plumer, X-ray bursts produced by laboratory sparks in air, Geophys. Res. Lett. 32 (2005), L20809

[2] P. O. Kochkin, C. V. Nguyen, A. P. J. van Deursen, U. Ebert, Experimental study of hard X-rays emitted from meter-scale positive discharged in air, J. Phys. D: Appl. Phys. 45 (2012), 425202

[3] L. P. Babich, T. V. Loiko, Subnanosecond pulses of runaway electrons generated in atmosphere by high-voltage pulses of microsecond duration, Dokl. Phys. 54 (2009), 479-482

[4] A. V. Agafonov, A. V. Bagulya, O. D. Dalkarov, M. A. Negodaev, A. V. Oginov, A. S. Rusetskiy, V. A. Ryabov, K. V. Shpakov, Observation of neutron bursts produced by laboratory high-voltage atmospheric discharge, Phys. Rev. Lett. 111 (2013), 115003

Acknowledgement

This work supported by the Grant Agency of the Ministry of Education, Youth and Sports of the Czech Republic under Contract LTT17015