S5-P-041002

CORRELATION BETWEEN X-RAY, MICROWAVE, NEAR-ULTRAVIOLET, VISIBLE, AND IR EMISSIONS FROM A HIGH-VOLTAGE DISCHARGE IN A LONG AIR GAP*

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The study is focused on obtaining new data in the field of electromagnetic emissions produced by laboratory discharges and revealing the mechanisms of the intense x-ray and microwave emissions. We investigate the development of a laboratory discharge initiated in a ~50 cm air gap by applying a ∼1 MV pulse (negative polarity) with a ∼1 μs duration and a rise time of about several hundred nanoseconds. The discharge formation is accompanied by hard x-ray (~10 keV–1.5 MeV), low- (~10–100 MHz) and high- (~1–6 GHz) frequency radio, near-ultraviolet (~300–400 nm), visible (within ~450–600 nm), and IR (>700 nm) emissions which we register in the experiments together with the short-exposure images of the discharge glow, employing a sCMOS gated intensified camera (with the gate of ∼55–60 ns). We discuss the temporal and spectral characteristics of the detected emissions, as well as investigate their correlation with the evolution of the discharge morphology. The energy spectra of x-ray flashes and their anisotropy are presented as well.

We show that the appearance of an initial cathode corona and propagating streamers coincides with the instant the intense near-ultraviolet emission starts. It is established that the streamer propagation towards the anode is accompanied by LF-radio emissions only. The intense x-ray and high-frequency radio emissions can appear almost synchronously in the discharge but only when a complex net of countless plasma channels forms and spans the entire discharge gap. The channel formation is closely related with the intense development of multiple streamers triggered after very fast formation of the cathode-directed streamers. Within the x-ray and microwave generation, multiple streamers develop from the electrodes and, probably, inside the discharge bulk, but without any leader formation which starts later after the instant the x-ray and microwave emissions vanish. Intense visible and IR emissions are registered only after the gap breakdown. The discharge formation turned out to have a step-wise character that correlates with temporal grouping x-ray and HF-radio bursts. We discover a complex spectral and temporal structure of the HF-radio emission. This type of the electromagnetic emission appears as multiple bursts, with their durations and the delay between neighboring bursts both being shorter than 1 ns. By employing the developed techniques for obtaining data on the spectral and temporal characteristics of HF-radio emissions, we find that a single burst of the HF-radio emission appears as a complex temporal process driven by the superposition of many subprocesses, characterized by different durations and frequencies. Indeed, the higher the frequency describing the microwave burst is, the shorter the time interval is related with this frequency.

Our findings provide a comprehensive temporal map of the electromagnetic emissions produced by a high-voltage discharge. The study and data obtained can be helpful in developing consistent models describing the mechanisms of the high-energy and microwave emissions in both laboratory and atmospheric discharges.

REFERENCES

[1] E.V. Parkevich, et al. Streamer formation processes trigger intense x-ray and high-frequency radio emissions in a high-voltage discharge. Submitted to Physical Review E. March, 2022.

* The work was supported by the Russian Science Foundation (grant no. 19-79-30086). The analysis of the microwave spectrums was funded by the grant of the Russian Foundation for Basic Research (no. 20-08-01156).