

## INTENSE X-RAY, LOW- AND HIGH-FREQUENCY RADIO EMISSIONS TRIGGERED BY THE STREAMER FORMATION PROCESSES IN A HIGH-VOLTAGE DISCHARGE\*

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The study is aimed at revealing the discharge breakdown processes that are able to emit broadband radio and x-ray emissions, as well as investigating the emission properties in detail. For a laboratory discharge initiated in a long air gap by a microsecond megavolt pulse, we for the first time simultaneously register wideband high-frequency (GHz) and low-frequency (MHz) microwave emissions together with hard x-rays (up to  $\sim 100$  keV). When registering various electromagnetic emissions, we image the discharge morphology by employing a sCMOS gated intensified camera, with the camera gate being of  $\sim 55$ – $60$  ns. We thoroughly analyze the temporal relationship of the emissions, depending on the discharge evolution, and provide comprehensive data on the spectral and temporal characteristics of the LF- and HF-radio emissions during the discharge formation. We show that the intense development of the anode-directed streamers is accompanied only by the LF-radio emission (10–150 MHz), whereas the HF-radio emission (1–4 GHz) and x-rays appear within the discharge stage when a complex net of countless plasma channels forms and spans the entire discharge gap, see Fig. 1. The channel formation is closely related with the intense development and multiplication of multiple streamers, as well as starts after very fast development of the cathode-directed streamers. We directly show that the power of the LF-radio emission sharply increases almost synchronously with that of the HF-radio emission, whereas the onset of hard x-rays coincides with the appearance of the HF-radio emission. The HF-radio emission has a complex spectral and temporal structure and appears as multiple short ( $<1$  ns) bursts characterized by various frequency components, existing in subnanosecond time intervals.

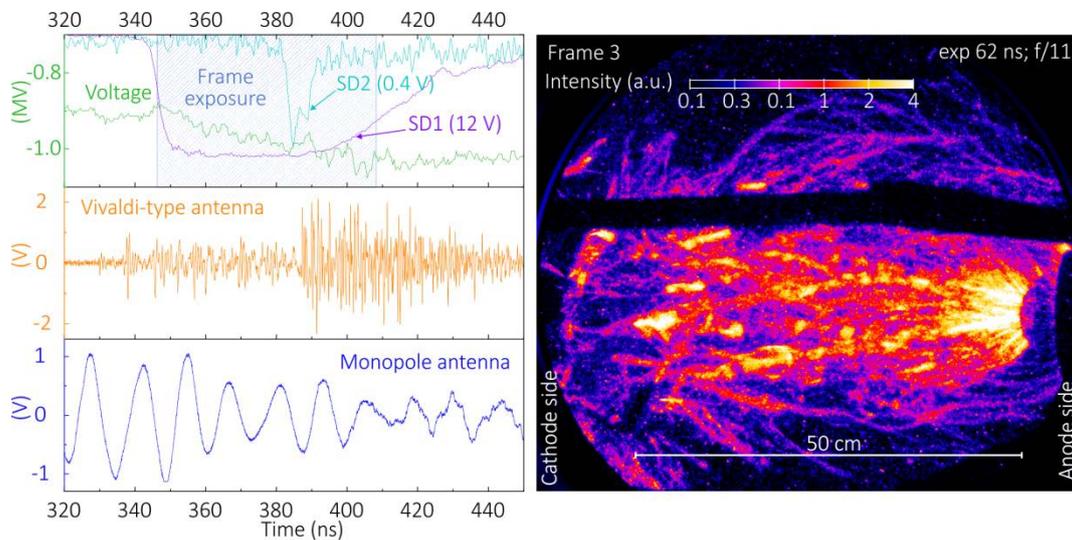


Fig. 1. On the left: voltage waveform, x-ray signals (SD1: threshold energy 20 keV and SD2: threshold energy 100 keV), monopole (MHz) and Vivaldi-type (GHz) antenna signals obtained in a single discharge event. The detector signals are shown for the time period corresponding to the exposure of the frame presented on the right panel.

### 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.

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