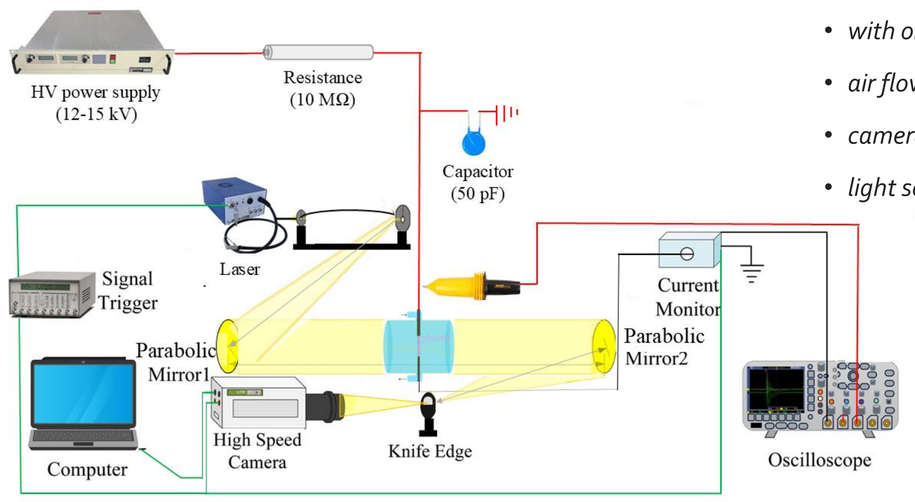
Thermal memory and gas dynamics of transient spark

Abstract

Transient spark (TS) is a dc driven self-pulsing streamer-to-spark discharge in atmospheric pressure air [1, 2]. Repetitive rate of breakdowns and spark pulses exceeds 1 kHz. This implies strong influence of previous pulses on breakdown mechanism – a memory effect. This is studied by schlieren imaging using a high-speed camera (20,000 fps) synchronized with electrical measurements. The influence of weak external air flow and the circuit capacitance is tested. The discharge development has three phases, pre-breakdown preparation phase with streamers, breakdown with formation of hot gas channel, and collapse of the hot gas. During the collapse, the hot gas moves from needle anode towards the cathode at velocity ≈4–5 m/s. In developed TS, this gas remains in the gap facilitating subsequent breakdowns. For this reason, the preparation streamer phase is very short, with each streamer leading to the breakdown. Without this hot gas, the preparation phase is longer, with more streamers needed to induce gas breakdown. Weak air flow makes the developed TS more regular. Probably by diluting chemical products, nitrogen oxides, which may also influence breakdown processes.

Experimental setup



- *gap ≈ 8 mm, DC 13 kV, R = 10 MΩ*
- *with or without an additional 50 pF capacitor*
- *air flow ≈ 0.75 l/min (from top and bottom)*
- *camera: Photron UX100 with 20 000 fps*
- *light source : Laser Leukos SAMBA 20 kHz*

FIGURE 1. Schematic of the experimental setup with a z-type schlieren imaging system

Results

1 First spark: three phases

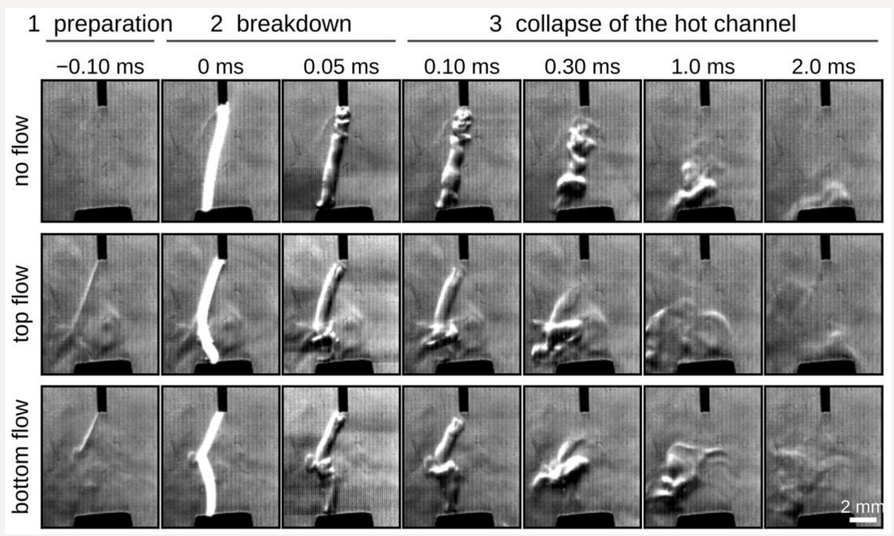


FIGURE 2. Schlieren frames of the first spark, C_{ext} = 50 pF: 1 – preparation, 2 – breakdown, 3 – collapse of the hot channel.

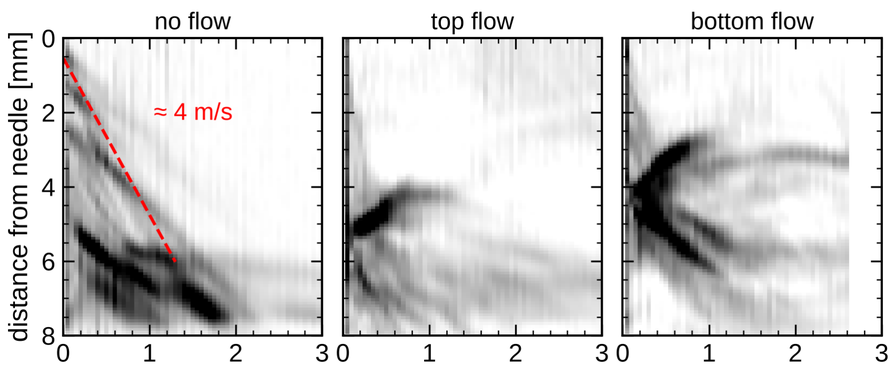


FIGURE 3. Schlieren images along the gap vs time after the first spark (50 pF)

2 Influence of additional capacitor (0 pF vs 50 pF)

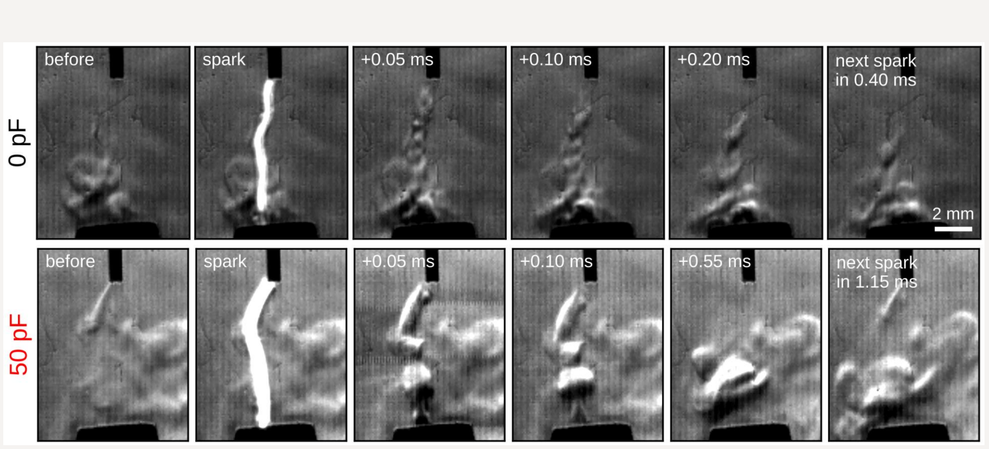
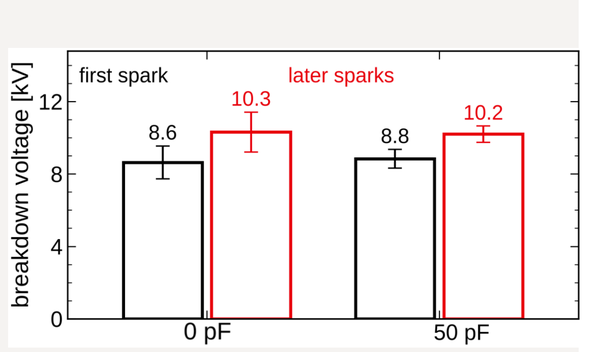
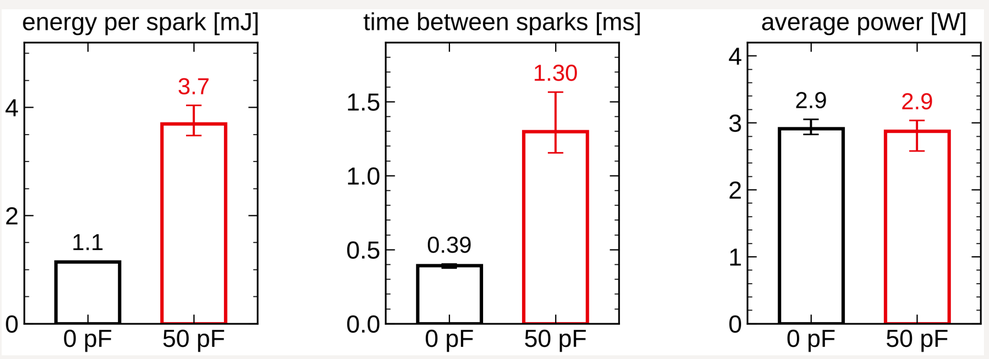
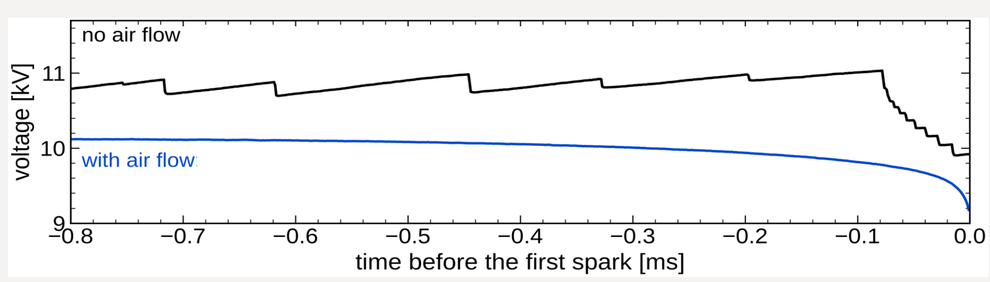
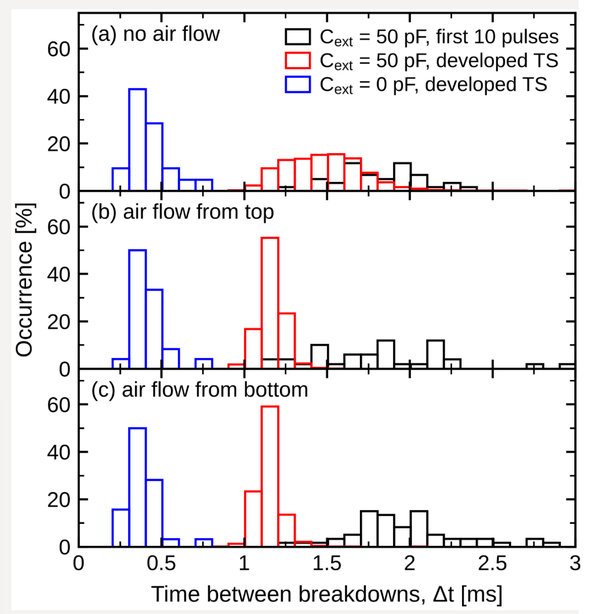


FIGURE 4. Spark channel and hot gas, 0 vs 50 pF (top flow).









Conclusions

Our fast schlieren imaging measurements improved our understanding of the processes driving the memory effect in transient spark discharges. This memory effect alters the breakdown mechanism by shortening the pre-breakdown streamer phase. A weak gas flow does not remove this hot, pre-ionized gas from the gap; rather, it may even stabilize the discharge properties. Combining these experimental findings with ongoing computational modeling could provide an even deeper understanding of these processes.

References

[1] M. Janda, V. Martišovitš, Z. Machala, Plasma Sources Sci. Technol. 20 (2011) 035015.
[2] M. Janda, Z. Machala, A. Niklová, V. Martišovitš, Plasma Sources Sci. Technol. 21 (2012) 045006.
[3] M. Janda, P. Tóth, S. Smirnov, Eur. Phys. J. D 79 (2025) 153.

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