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TYPE I INTERMITTENCY RELATED TO THE DOUBLE LAYER DYNAMICS IN FILAMENT TYPE DISCHARGE PLASMA

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1. Introduction

Type I intermittency [1] is related to the appearance in signals of regular oscillations interrupted by random bursts. This mechanism drives to the loss of the stability of a periodic attractor through a tangent bifurcation. After this bifurcation, the reconstructed attractor in the states space evolves to a chaotic state due to the escape of the trajectories from the periodical orbit.

Anodic double layers in low-temperature filament type discharge plasmas confine localized regions of higher plasma concentration, usually termed fireballs [2]. They appear, either in a static or a dynamic state, by positively biasing a collector immersed into plasma, over a critical value of the potential with respect to the plasma potential. The dynamic state involves that periodic formation of double layers are followed by their departure away of the electrode and disruption from the border of the fireball, experimentally evidenced by nonlinear periodic variations of the current drawn by the collector. These current oscillations can be sustained if the excitation/ionization rates reach periodically those critical values for which current limitation effect appear in the static current-voltage characteristic of the electrode. Using the nonlinear dynamics tools applied to the oscillations of the current drawn by the collector, *i.e.* FFT's, 3-D reconstructed state spaces, return maps and log-log plots of power spectral density, we identified a scenario of transition to chaos by type I intermittency. This scenario develops at the increasing of the potential on the collector.

2. Experimental results and discussion

Figure 1 shows a schematic of the experimental setup. The experiments were performed in a hot-filament discharge plasma, into which an additional electrode of 3 cm diameter, marked by E in Fig. 1, was introduced. The anode (marked by A in Fig. 1) is grounded. The plasma parameters, measured by emissive and cold probes were: $n_{pl} \cong 5\times10^{8}$ cm^{-3}, electron temperature $T_e \cong 2\text{-}3$ eV for an argon pressure $p = 5\times10^{-3}$ mbar.

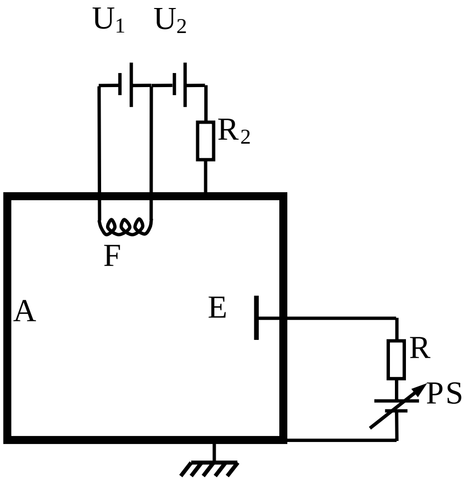

Fig. 1: Experimental setup (F – filament, E – additional electrode, A – anode, U_1 – power supply for heating the filament, U_2 – power supply for discharge, PS – power supply for the electrode bias, R, R_2 – load resistors

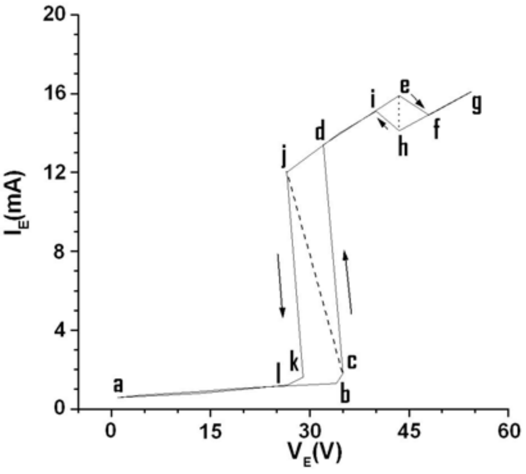

Fig. 2: Static current-voltage characteristic of the additional electrode (The small letters mark the positions on the characteristic where the behaviour of the plasma changes)

Figure 2 shows the static current-voltage characteristic of the electrode, obtained by gradually increasing and subsequently decreasing the potential on the electrode, V_E. The sudden jumps of the current collected by E, marked as I_E, are related to the generation and dynamics of double layers (DLs) [2] and show hysteresis [3]. After the first current jump (c – d in the I_E-V_E characteristic, Fig. 2) a quasi-spherical complex space charge structure (CSCS) appears in front of E. Emissive probe measurements prove that this CSCS consists of a positive core (ion-rich plasma) confined by a DL. The second jump of the current (e – f in the I_E-V_E characteristic, Fig. 2) corresponds to the transition of the CSCS into a dynamic state, in which the DL at its border periodically disrupts and re-aggregates. This dynamics causes a modulation of the current collected by the electrode, as well as of other plasma parameters like plasma potential and density.

When the structure disrupts, the particles (electrons and ions) initially trapped in the DL become free and sustain ion-acoustic like oscillations in the background plasma. The ion-acoustic instability is very sensitive to the background plasma parameters. Any small variation of these parameters modifies the frequency and amplitude of the instability and also can cause its suppression (see Fig. 3). The onset of chaotic states is due to intermittencies, as one can see in Fig. 3. The FFT amplitude spectra indicate the evolution to chaotic states by embedding the fundamental instability frequency in broadband noise, associated to the onset of the intermittencies. The reconstructed 3-D attractors of the plasma system dynamics indicate the loss of stability of a periodic attractor through a succession of bursts. During their

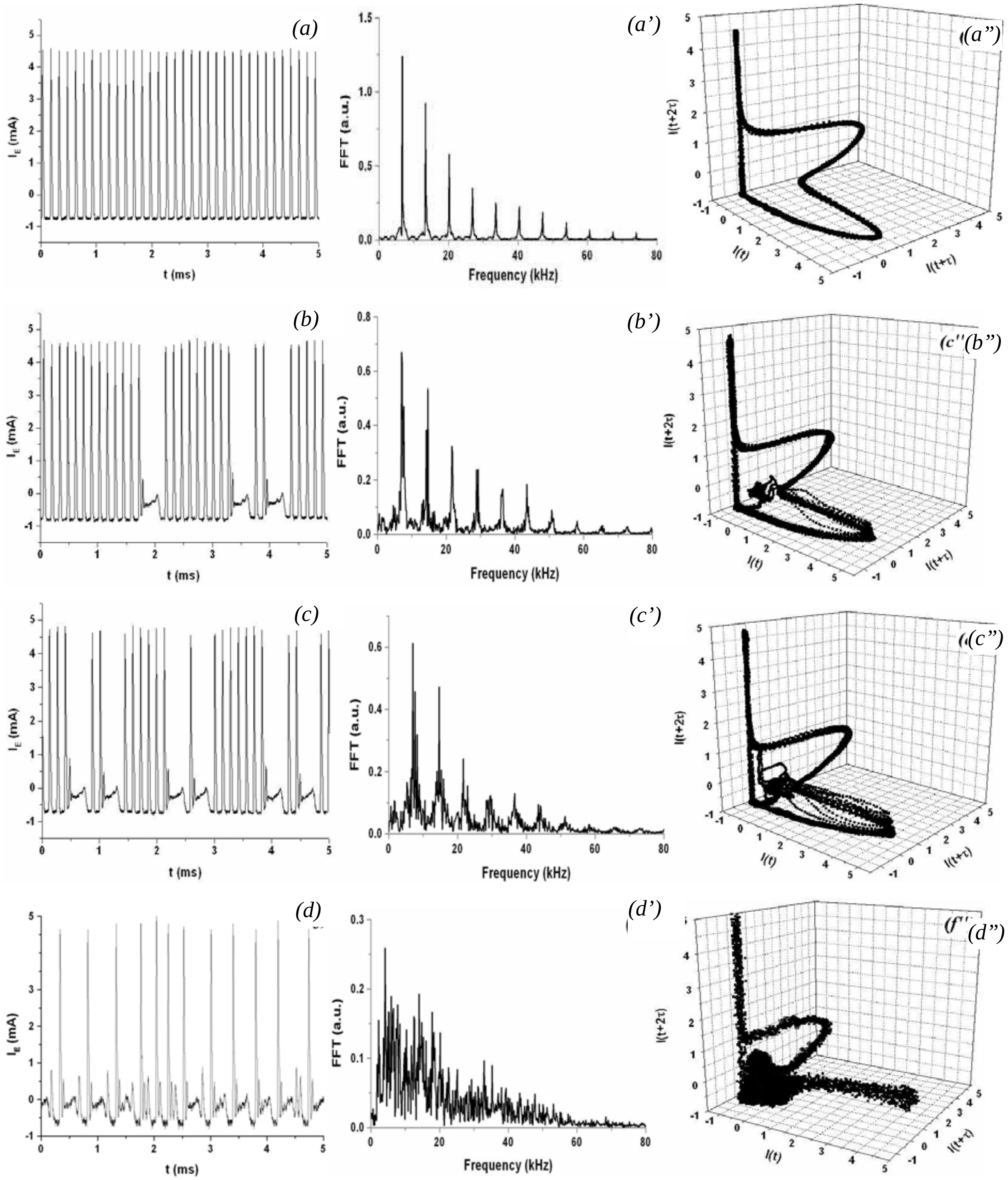

Fig. 3: (a-d) ac components of the current collected by the additional electrode, for different values of the voltage applied on it: (a) 55 V, (b) 58 V, (c) 60 V, (d) 64 V; (a'-f') FFT amplitude spectra of the corresponding signals; (a"-f") 3-D reconstructed states space of the plasma system dynamics

appearance, the ion-acoustic instability is suppressed. By performing log-log plots of the spectral power density versus frequency, as indicated in Fig. 4, we obtained a slope which confirms a f^{-1} power law associated to the chaotic development state of the instability.

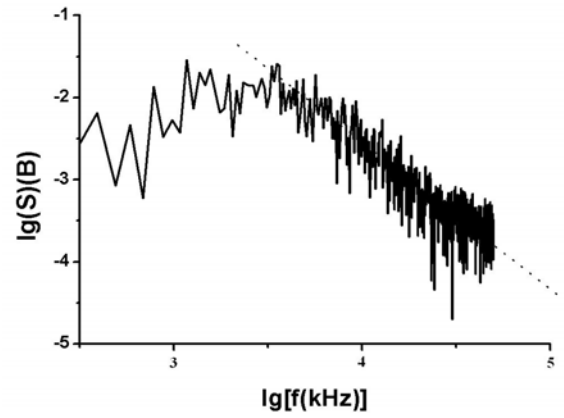

Fig. 4: Log-log plot of the power spectral density versus frequency, for $V_E = 62$ V

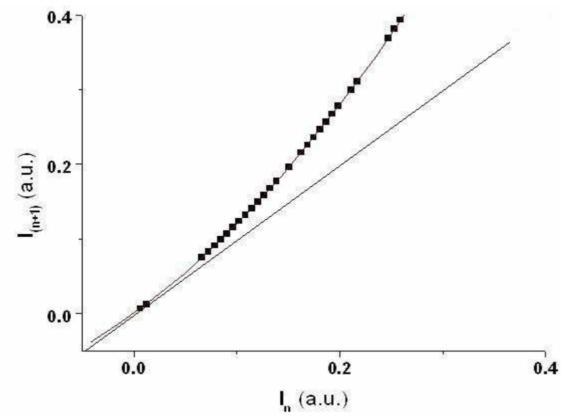

Fig. 5: The return map obtained from maxima and minima of the time series with intermittencies

Another typical fingerprint of type I intermittency is the presence of a tangent bifurcation (saddle-node point bifurcation), represented in the return map shown in Fig. 5. We reconstructed this map by plotting the maxima and minima of the time series with intermittencies.

3. Conclusion

The evolution to chaos of the double layer dynamics and associated ion-acoustic instability through intermittency is experimentally investigated. The results of the time series analysis, spectral analysis, 3-D reconstructed states space of the current oscillations and low frequency noise that scales like f^{-1}, appearing at the onset of chaos, are used to confirm the existence of type-I intermittency.

Acknowledgements

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