TRANSITION TO CHAOS IN PLASMA THROUGH A CASCADE OF SPATIO-TEMPORAL PERIOD-DOUBLING BIFURCATIONS

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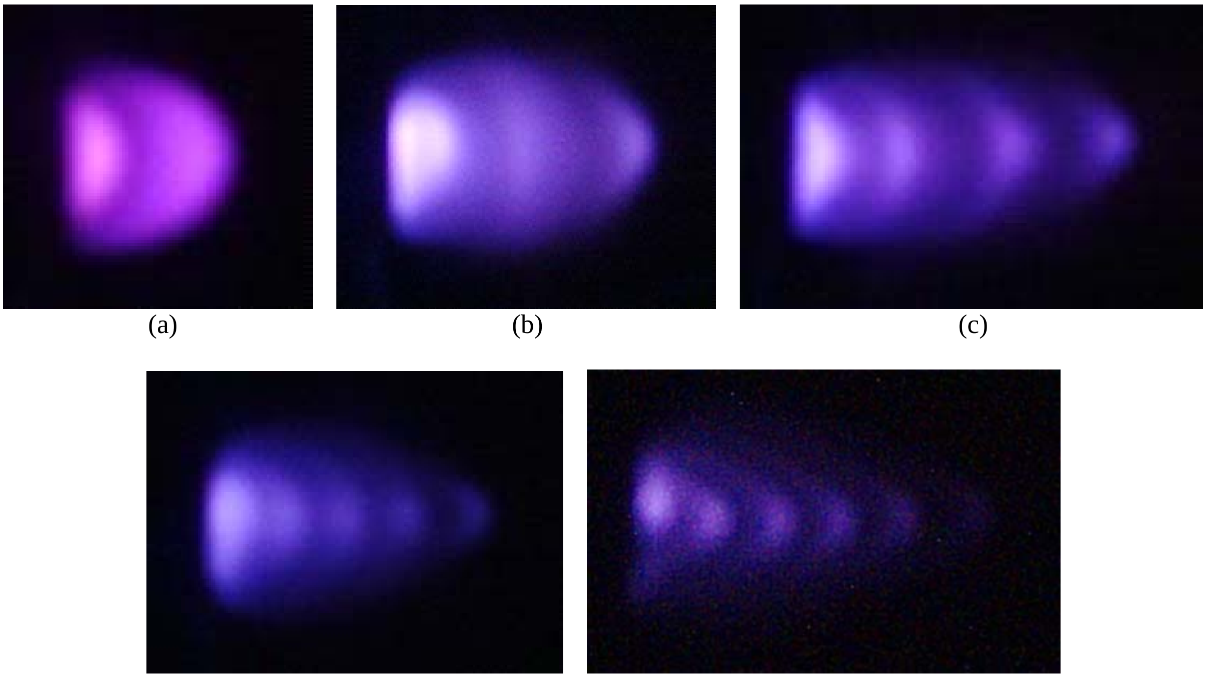
Plasma is a complex medium in which chaotic states were often observed. In most of the cases, these chaotic states appear in plasma as a result of intermittency scenario [1] or Feigenbaum scenario (cascade of period doubling bifurcations) [2] of transition to chaos. Here we report on experimental results that emphasize a more complex route to chaos in plasma, in which a Feigenbaum scenario develops simultaneously with a cascade of spatial period-doubling bifurcation, in connection with the development of a multiple double layer structure in chaotic dynamic state. Because the temporal and spatial period-doubling bifurcations simultaneously appear, we can speak about a new scenario of transition to chaos by a cascade of spatio-temporal period-doubling bifurcations route to chaos.

Multiple double layers are complex nonlinear potential structures in plasma consisting of two or more concentric double layers attached to the anode of a glow discharge [3], or to a positively biased electrode immersed in plasma [4]. The axial profile of the plasma potential has a stair step shape, with potential jumps close to the ionization potential of the used gas. In dynamic state, the constituent double layers periodically disrupt and re-aggregate, giving rise to the oscillations of the current collected by the exciting electrode [5].

The experiments were performed into a hot filament discharge plasma diode. The plasma was pulled away from equilibrium by gradually increasing the voltage applied a supplementary electrode, under the following experimental conditions: argon pressure p = $5\cdot10^{-3}$ mbar, plasma density $n_{pl} \cong 10^{8}$-10^{9} cm^{-3}. When the potential on the electrode reaches a critical value, a beautiful luminous structure appears in front of it (Fig. 1a). Simultaneously, the current collected by the electrode becomes time dependent, oscillations with a frequency of about 210 kHz being recorded (see Fig. 2a-2c, where the time series of the current, their FFT's and the 3D reconstructed attractor are shown, respectively). By further increase the



(a) (b) (c)

(d) (e)

Fig. 1: Photos of the multiple double layers in different stages (for different increasing values of the potential applied on the electrode)

potential applied on the electrode, for a second critical value of it a second double layer appears, concentric with the first one (Fig. 1b). This phenomenon corresponds to a spatial period-doubling bifurcation that occurs in the plasma region in front of the electrode. By analyzing the oscillations of the current collected by the electrode (Fig. 2d-2f) we observe that also a temporal period-doubling bifurcation occur, a sub-harmonic of the fundamental frequency appearing in the power spectrum. Thus, at this second critical value of the potential applied on the electrode, a first spatio-temporal bifurcation appears in our plasma system. Now, by further increase of the potential applied on the electrode, a cascade of spatial (Fig. 1c-1d), as well as temporal (Fig. 2g-2l) period-doubling bifurcations appear in the system. The final state of the plasma system is a chaotic one (Fig. 2m-2o).

Reference:

[1] P. Y. Cheung, S. Donovan and A. Y. Wong, *Phys. Rev. Lett.* **61** (1988) 1360;

[2] P. Y. Cheung and A. Y. Wong, *Phys. Rev. Lett.* **59** (1987) 551;

[3] L. Conde and L. Leon, *Phys. Plasmas* **1** (1994) 2441;

[4] C. Ionita, D. G. Dimitriu and R. Schrittwieser, *Int. J. Mass Spectrom.* **233** (2004) 343;

[5] D. G. Dimitriu, M. Aflori, L. M. Ivan, C. Ionita and R. Schrittwieser, *Plasma Phys. Control. Fusion* **49** (2007) 237;

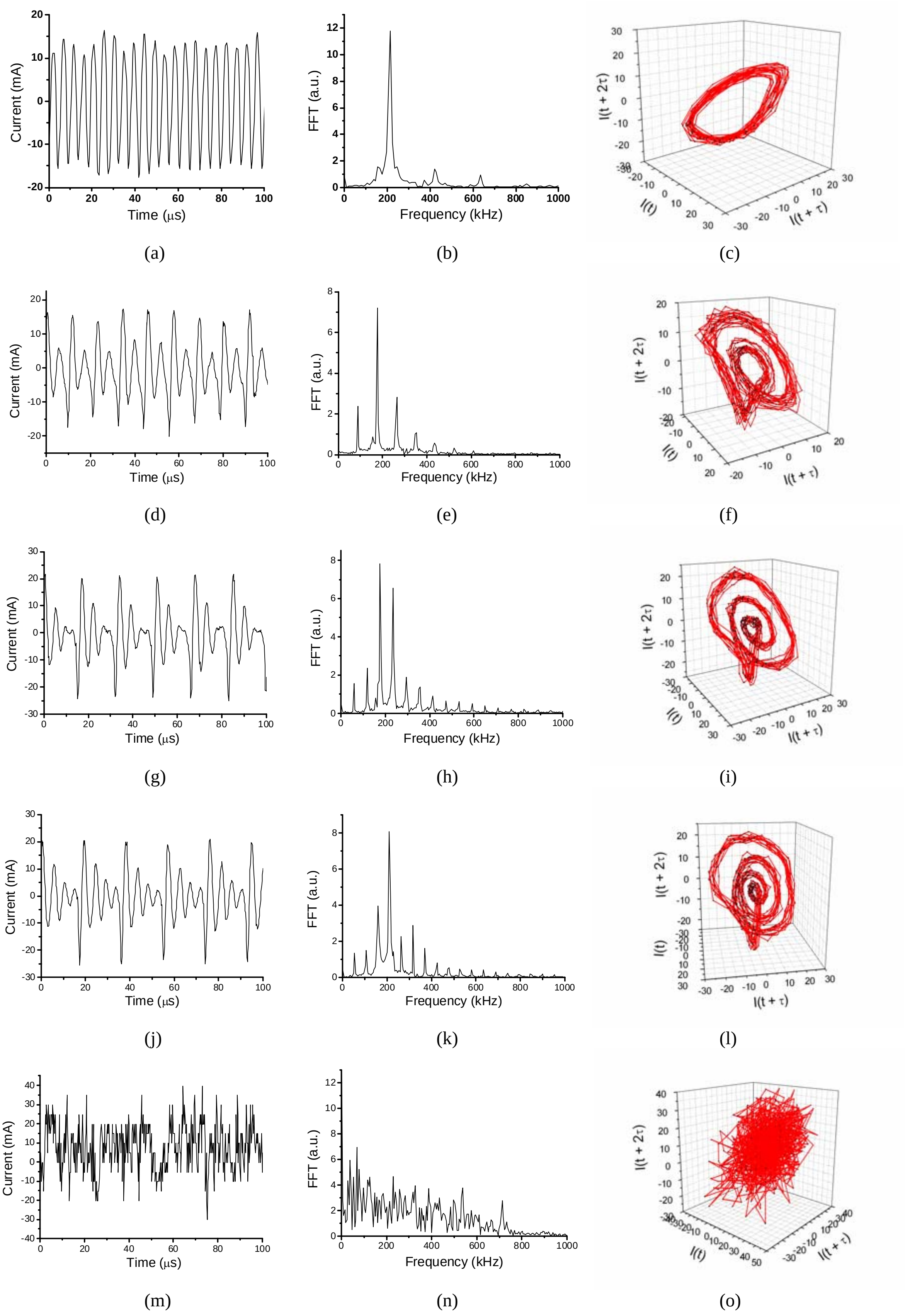


Fig. 2: Oscillations of the current (first column), their FFT's (second column) and the reconstructed attractor of the plasma system dynamics (third column), at different increasing values of the potential applied on the electrode