

SPATIO-TEMPORAL DYNAMICS AND STABILIZATION OF UNSTABLE PERIODIC ORBITS IN AN UNDRIVEN DC GLOW DISCHARGE

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1. Introduction

The understanding of pattern selecting mechanics and of transitions to spatio-temporal chaos in extended non-linear dissipative systems is one of the most challenging problems in physics. Moreover, recent theoretical and experimental studies have demonstrated the possibility to achieve control of low-dimensionnal chaos in non-linear dynamical systems, by means of small time dependent perturbations of an accessible control parameter [1]. In order to get an efficient control of chaos in spatially extended systems, it is necessary to have a good understanding of the local or global influence of the control process on the the system. Owing to the fact that various dynamical behaviours of different complexity, including low-dimensional temporal chaos, pattern formation, spatio-temporal chaos and turbulence, can be observed in the glow discharge [2], and that optical diagnostics are easy to apply, the glow discharge represents an excellent model system for the investigation of complex spatio-temporal dynamics in 1D reaction diffusion systems.

In the present contribution we report on two aspects of the spatio-temporal dynamics of ionization waves in the positive column in a glow discharge :

- The transition from stability to chaos and turbulence
- The spatial transient dynamics in controlling chaos.

2. Experiment

The experiment is carried out in a discharge tube (50 cm in length and 4.4 cm in diameter) filled with Neon gas (1 to 10 torr). The discharge voltage and discharge current vary from 300 to 1000 Volts and from 0 to 100 mA, respectively. A fast 16-channel VXI digitizer plug-in unit (sampling frequency 200kHz, 16 bits data) is used for performing synchronous acquisition of the signals from sixteen photo-diodes located around the positive column of the discharge. The dynamical states are characterized by time series analysis. Typical spatio-

temporal signals of the ionization waves are shown in Fig. 2 ; the upper image corresponds to a regular regime, and the lower image to an irregular one.

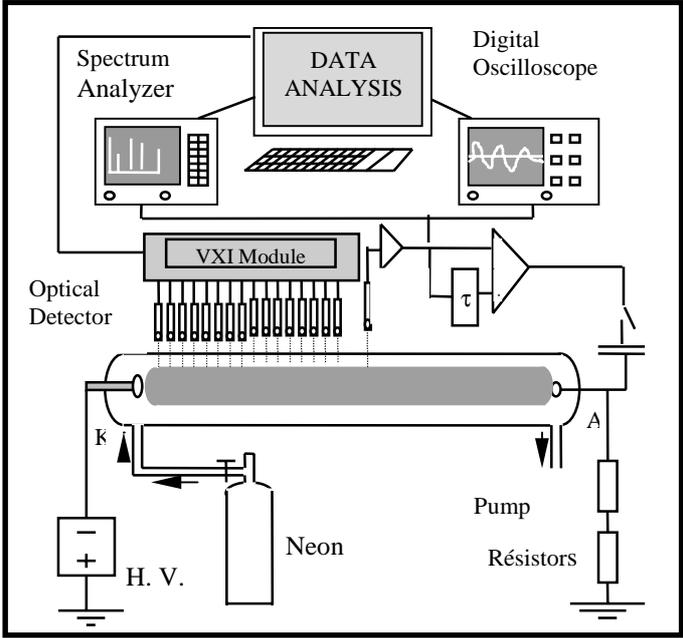


Fig. 1. Experimental Set-up

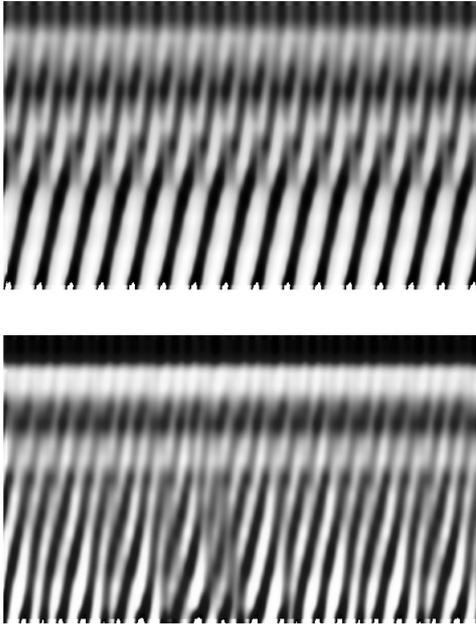


Fig. 2. Spatio-temporal images of ionization waves

3. Transitions from stability to chaos and turbulence

The bifurcation diagram is obtained (Fig. 3), by plotting the maxima and minima of light intensity recorded during all the duration of the discharge current variation at one point of the discharge when varying continuously and slowly the discharge current in the operating range. The zones where the dynamics is regular can be clearly distinguished from the irregular ones in this bifurcation diagram.

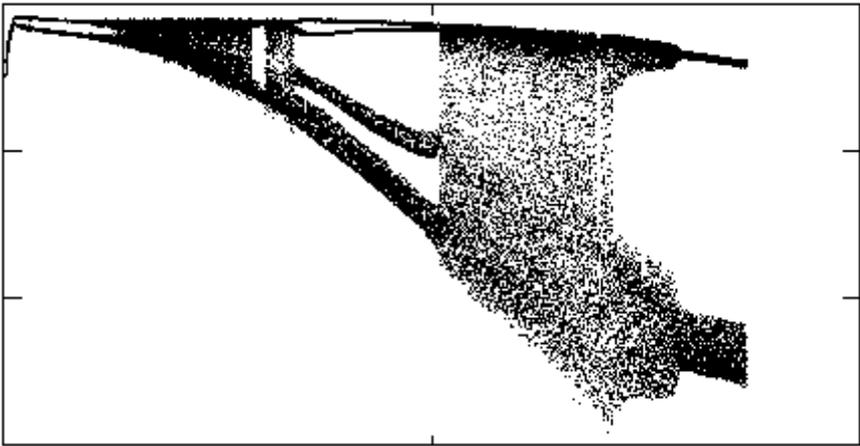


Fig. 3. Bifurcation diagram (Discharge current increases from left to right)

Let us examine more closely the transition from regular behavior towards an irregular one in order to understand how chaos appears in the discharge. The scenario shown in Fig. 4, is the most usually observed. Each column in Fig. 4 corresponds to a given value of the discharge current. When increasing the current, the quasi-periodicity route is observed. (First row in Fig. 4).

For a given discharge current, spatial transitions are also observed along the discharge (e.g . period doubling and spatial transition to chaos from the anode to the cathode shown in the first two columns from the left).

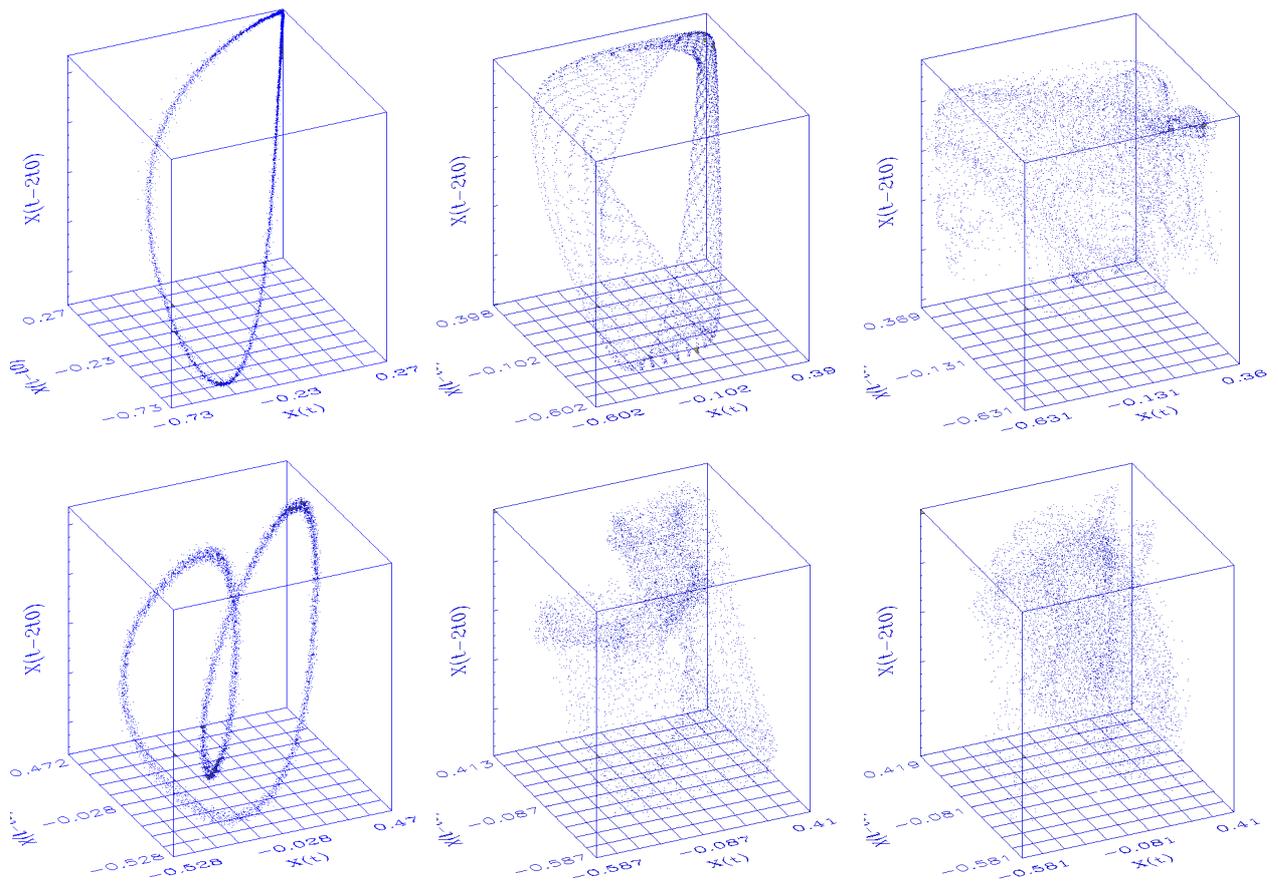


Fig. 4. Transitions to chaos at the anode (first row) and the cathode (second row), for three values of the discharge current : $i=50$ (first column), $i=53$ (second column) and $i=76$ mA (third column)

4. Spatial transient dynamics in controlling chaos

The TDAS method [3] has proven its efficiency in controlling chaotic regimes of ionization waves [4]. Here we analyse space-time data from the transient regime just after applying the TDAS control to stabilize a chosen unstable periodic orbit of a chaotic regime. When switching on the control in the chaotic regime, the system remains chaotic during a certain

time interval until the stable orbit is approached. In spatially extended systems, the duration of the chaotic transient is not the same at each point in the system.

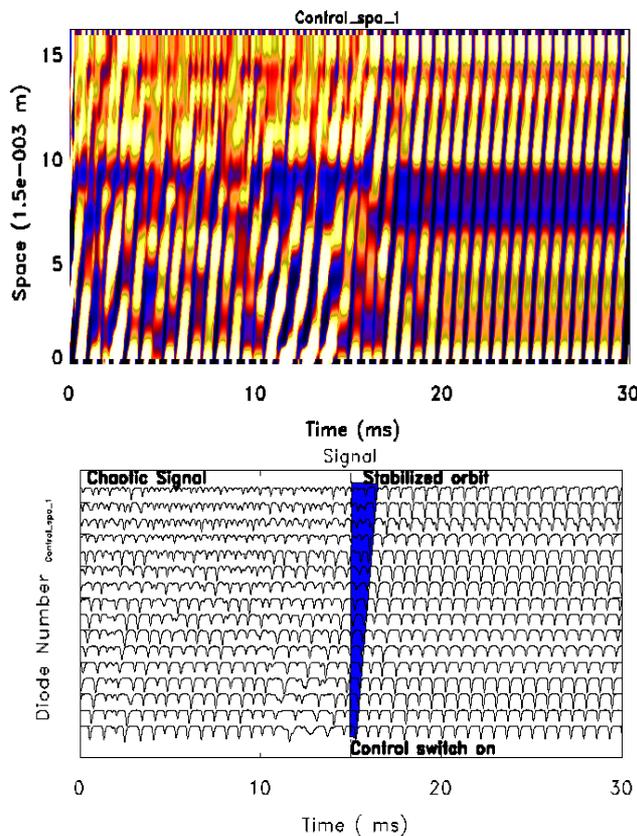


Fig. 5. Spatiotemporal image of controlling chaos

At a given position the length of the chaotic transient depends on the interaction of the control signal with the local system behaviour. In Fig. 5, the propagation of the stabilization front from the anode to the cathode is highlighted (shaded area in the lower image). This stabilization front propagates with a velocity equal to the ionization waves phase velocity. In the situation of Fig. 5, the stabilization is quasi-instantaneous at the anode, while the duration of the chaotic transient increases with increasing distance from the anode. The duration of the chaotic transient at the cathode is found to be greater than three times this duration at the anode.

5. Conclusion

We have reported on experimental investigations of ionization waves transitions to chaos and turbulence, and of spatial transient dynamics in successfully controlling ionization waves chaos.

References

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