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Modelling the control of the space charge dynamics in a system of two electrical glow discharge plasma

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This work present a comparative study between the experimental data on the system of two electrical glow discharge plasma and the simulated data from a system of ordinary differential equations based on van der Pol oscillators with reference to the control of the space charge dynamics.

1. Introduction

The dynamics of space charge structures in the form of a double layer, an arrangement of electric positive and negative charges localised in adjacent positions represent the subject of the present work. Experimentally it is found that these structures are very sensitive to the biasing conditions and that they cause most of the oscillatory phenomena of the plasma system as a whole [1,2].
We present a comparative study between the experimental control on of the dynamics of double layer structures and the computed results of a model consisting on two coupled perturbed van der Pol oscillators [3,4,5].
The numerical results of our computer model are in reasonable agreement with the experiment.

2. Experimental system

The experiments were carried out on the plasma created as a result of coupling of two adjacent independent glow discharges that are biased one against the other.
The experimental device consists of two short adjacent glow discharges, with plane cathodes and cylindrical anodes, all placed in the same glass tube, in argon at low pressure [2,4].
The plasma is formed in the contact region of the two negative glow plasmas, between the two anodes that are biased one against the other by a dc power supply whose voltage U_m is considered as the experimental control parameter. The ac mode of biasing is realized by connecting a corresponding power supply U_m in series with the dc biasing one U_m.
For certain experimental conditions, depending on the U_m biasing potential, coherent or non-coherent oscillations of the current I flowing through the inter-anode interval are observed. These oscillations are correlated with the dynamics of the DLs that appear in the plasma. Different complicated spatial-temporal patterns for different values of U_m have been observed [4,6].

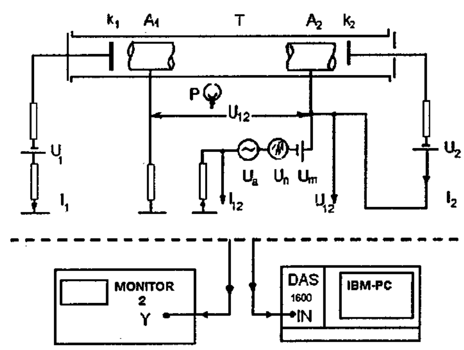


Fig. 1 Diagram of the experimental set-up

3. Mathematical model

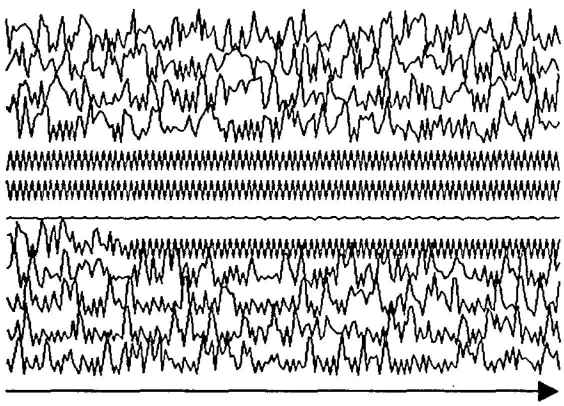
For this experimental arrangement we proposed a model with two coupled perturbed van de Pol oscillators [3,4].

$$\begin{cases} \dot{x}_1 = x_2 + mx_4 \\ \dot{x}_2 = -c\left(x_1^2 - 1\right)x_2 - x_1 + e\cos x_5 \\ \qquad + m(x_4 + x_3) \\ \dot{x}_3 = x_4 - mx_2 \\ \dot{x}_4 = -f\left(x_3^2 - 1\right)x_4 - x_3 - e\cos x_5 \\ \qquad - m(x_2 + x_1) \\ \dot{x}_5 = 2\pi g \end{cases}$$

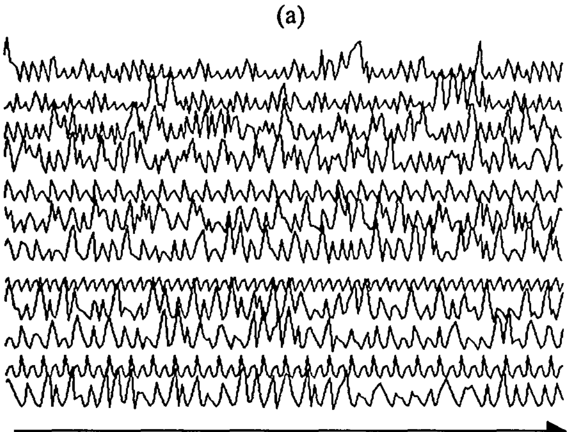
We consider the free oscillations of the plasma to be modelled by two van der Pol oscillators with dc and ac coupling.

4. Discussion and conclusion

The bifurcation diagram is a convenient way to identify values of the control parameter for which the system shows ordered and chaotic dynamics. However, there are situations, as shown in Fig.2, where the system presents intermittent transitions from periodicity to chaos. This behaviour could not be observed from the bifurcation diagram, but it can be easily discerned from a stroboscopic representation as shown in Fig.2.



(a)



(b)

Fig. 2 Plot of the stroboscopically sampled amplitude x_1 in units of *T*, recorded for different values of the control parameter *m*, for *c*=*f*=1, *e*=2, g=0.5: (a) - for *m=1 to m=1.055;* (b) – for *m=1.07 to m =1.125*

In Fig.2 is shown the temporal behaviour of the amplitude of the first oscillator (x_1) for a range of values of the control parameter *m*.
The data were stroboscopically sampled with the period (*T*) of the forcing signal. The period of the fundamental of the oscillation is found to be a multiple of the forcing period, between *T* and 7*T*. This obviously is a consequence of a frequency locking between the frequency of the forcing signal and the frequency of the free oscillation of the system (*e*=0). Spectral analysis confirms this conclusion.
The analysis of the dynamics of the system with respect to the amplitude of the forcing (*e*) for constant *m* shows that for values of *e* in excess of certain threshold values the forcing plays an important role in the synchronization of the system on frequencies which are subharmonics of the forcing.

The computed data of our model are in reasonable agreement with the experiment and shows the possibility of control of the dynamics of the system by an external source.

5. References

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