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Self-organization acting as physical basis for stimulation of oscillations in plasma devices

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Oscillations stimulated by two kinds of negative differential resistance related to self-organized spatial, respectively spatio-temporal patterns are presented and discussed.

1. Introduction

When a gaseous conductor in a plasma device is subjected to an external constraint (electric field) that gradually drives the gaseous conductor away from the thermodynamic equilibrium, two phases of self-organization can be observed [1-3]. The first one is finished with the emergence of a stable complex space charge configuration known as fireball (FB). The second one is related to the transition of FB into an unstable steady state (regular in behavior) during which a proper dynamics of the double layer (DL) from its border ensures its existence [2,3]. Both phases of self-organization are related to abrupt nonlinear variations of the current transported by the gaseous conductor experimentally observed as an S-shaped, respectively a Z-shaped bistability. Their appearance attributes to the gaseous conductor the ability to work as an S- respectively an N-shaped negative differential resistance (NDR) [2-5].

2. Experimental results and discussion

In this paper we present experimental results obtained on the DP-machine of the University of Innsbruck, Austria [6]. Thus, in Fig. 1(a) the current I_E collected by a positively biased disk electrode E immersed in the plasma of the DP-machine is plotted as a function of the potential V_E of E. The critical points on this characteristic are marked by letters. Note that the external dc power supply was connected to E through a resistor $R = 10\ \Omega$. Fig. 1(b) presents the oscillations that appear simultaneously with the abrupt increase of I_E (branch **c-d**), respectively those that appear when I_E suddenly decrease (branch **e-f**). The corresponding power spectra are shown in Fig. 1(c). The electrode potential values for which the signals were collected are marked with the same letters in all graphs.
From Fig. 1(a) results that the abrupt increase of I_E marked by the branch **c-d** is accompanied by the appearance of strong oscillations in the voltage range **d-e**, the frequency of which depends on V_E. The shape of the oscillations and the corresponding power spectra immediately after their appearance (point **d** in Fig. 1) and the abrupt transition of the system into another oscillation regime (point **e** in Fig. 1) are shown in Fig. 1(b) respectively Fig. 1(c). When the voltage of the external dc power supply is gradually decreased the

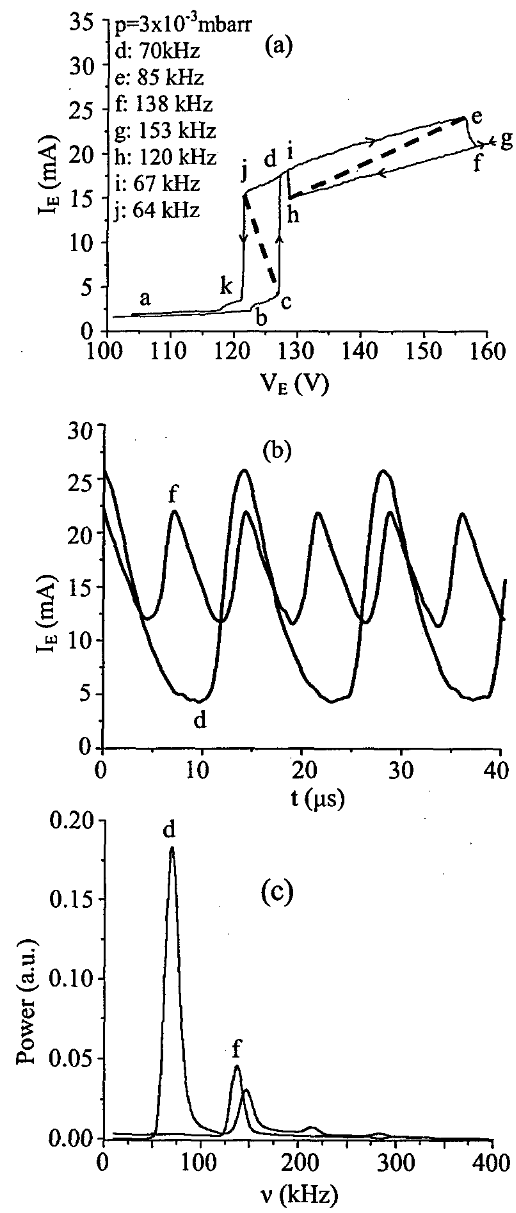

Fig. 1 (a) Current *versus* voltage static characteristic; (b) oscillations stimulated by S-, respectively Z-shaped bistability; (c) power spectra of the oscillations shown in Fig. (b)

I(V)-characteristic presented in Fig. 1(a) emphasizes two hysteresis loops, the first one proving the presence of an S-shaped bistability (that corresponds to an S-shaped NDR [3,4]) and the second one the presence of a Z-shaped bistability (that corresponds to an N-shaped NDR [3,5]). The NDR corresponding to the voltage intervals in which the gaseous conductor reveals bistability are marked in Fig. 1(a) by broken lines.

For explaining the two kinds of the oscillations generated by the DP-machine we take into account that the oscillations with lower frequencies (64-85 kHz) are related to the presence of the S-shaped NDR, whereas the oscillations with higher frequencies (120-153 kHz) to the presence of the N-shaped NDR. As already shown [4], the S-shaped NDR stimulates oscillations only when the system is suitably connected to a resonant circuit able to perform natural oscillations with an amplitude sufficient to trigger the self-assembling and de-aggregation of FB formed in front of E. In that case the oscillations appear spontaneously with the maximal value of their amplitude. Such a stimulation mechanism corresponds to a subcritical Hopf bifurcation. In the case investigated by us the oscillatory circuit contains as reactive elements the capacitance of the DL from the FB border and an inductance related to the phase difference of the electrons and positive ions emphasized during the self-assembling and de-aggregation processes of the FB. The other kind of oscillations, the frequency of which is twice the frequency stimulated by the S-shaped NDR, is related to the N-shaped NDR. Usually the amplitude of these oscillations softly increases, so that this can be classified as a supercritical Hopf bifurcation.

The experimental results presented in Fig. 1 emphasize two essential facts. First, during the self-assembling process of FB matter and energy delivered from the external dc power supply are used to produce the ordered arrangement of opposite space charges inside FB, *i.e.* its self-organization process. Secondly, during FB de-aggregation the stored matter and energy can be used for stimulating oscillations when FB is suitably connected to a resonant system [4] or when FB acts itself as a resonant system. The sudden change of the oscillations regime at a frequency twice the frequency related with the self-assembling and de-aggregation of the FB and half of amplitude proves the appearance of a shelling-off process of FB (the DL periodically detaches from the FB border [2]), a dynamics that involves the presence of two DLs that form and disrupt successively. Since every of these DLs contains at its negative side a well located net negative space charge acting as a barrier for I_E, this new kind of oscillation regime appears simultaneously with the decrease of I_E, *i.e* the appearance of the N-shaped NDR.

For explaining the obtained experimental results it is necessary to elucidate the physical processes at the origin of the FB emergence. The knowledge of these physical processes also offers answers to the mechanism that explains the genuine origin of the nonlinear behavior of the studied gaseous conductor. These phenomena are explained in detail elsewhere [3,4]. The most difficult problem that must be solved concerning the phenomena described in this paper resides from the discrepancy between the well-located optical phenomena observed when FB emerges and the values of the mean-free path of electron impact excitation and ionization processes. For example, typical for the DP-machine plasma, the mean-free path for the ionization processes is in the range of 2m. Considering the very small value of the excitation and ionization probabilities corresponding to such large value of the mean-free path, such a plasma is usually considered collisionless. However, the observed light phenomena contradict this assertion. The emergence of FB with dimensions (2-3 cm in diameter) much smaller than the mean-free-path of inelastic electron-neutrals collisions proves that the collision-less plasma model spectacularly fails when common experimental data, as those presented in this paper, have to be explained. In this context it is worth to mention that many important plasma theorists [7,8] have already expressed the opinion that the understanding of plasma experiments needs a substantial improvement of the used theoretical models. In this context, we agree with the opinion expressed by T. Sato [9], that this improvement is possible only by a paradigmatic shift in plasma theory. We consider that this shift needs the abandonment of the collisionless plasma model when the nonlinear phenomena related with self-organization, and implicitly the stimulation of instabilities have to be explained. We consider that unsolved problems as those mentioned in [8] become potentially resolvable when collective effect related to the symmetry breaking and spatial separation of the regions where the excitation and ionization cross-sections suddenly increase are considered [3]. Such phenomena always appear when a gradient of electrons kinetic energy is locally maintained. In magnetically confined plasma as those produced in fusion devices such phenomena appear at the plasma edge where conditions for DL assembly are present. The collisionless plasma model remains, however, as a useful model for solving a part of the problems of the plasma physics, namely that do not imply the nonlinear behavior.

References

[1] E. Lozneanu *et al.*, *IEEE Trans. Plasma Sci.* **30** (2002) 30.

[2] E. Lozneanu, M. Sanduloviciu, *J. Plasma Fusion Res. SERIES* **4** (2001) 532.

[3] M. Sanduloviciu *et al.*, *Chaos, Solitons &Fractals* **17** (2003) 183.

[4] E. Lozneanu *et al.*, *J. Appl. Phys.* **92** (2002) 1195.

[5] E. Lozneanu *et al.*, *J. Plasma Fusion Res. SERIES* **2** (1999) 389.

[6] R. Schrittwieser *et al.*, *Physica Scripta* **T84** (2000) 122.

[7] H. Alfven, *Trans. Plasma Sci.* PS **14** (1986) 669.

[8] D. Montgomery, *J. Plasma Phys.* **56** (1996) 387.

[9] T. Sato *et al.*, *Phys. Plasmas* **3** (1996) 2135.