CONTROL OF THE CHAOTIC REGIMES OF NONLINEAR DRIFT WAVES IN A MAGNETIZED LABORATORY PLASMA

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Abstract

Nonlinear drift waves are experimentally studied in a cylindrical magnetized laboratory plasma. The transition from spontaneous regular regimes to chaotic and turbulent regimes is obtained by changing the plasma parameters. Low-dimensional chaotic regimes are controlled using the Time Delay Autosynchronization method (TDAS) (K. Pyragas, Phys. Lett. **A170**, 421, 1992). A significant reduction in spectral width is obtained.

1. Introduction

Magnetized bounded plasmas are subjected to a class of low-frequency electrostatic instabilities, the drift waves, caused by the ExB motion of particles in the presence of electric field fluctuations and gradients in the background plasma parameters [1].

Drift waves are located in the maximum gradient region of the plasma and propagate azimuthally (Fig. 1) with the electron diamagnetic drift. Drift waves can be responsible for anomalous transport in magnetically confined high-temperature plasmas. Therefore, controlling these instabilities is of great interest.

Varying the plasma parameters, the transition scenario to chaos and turbulence is observed [2]. The scenario starts with a state where the density fluctuations are periodic in time. Then, changing the control parameter (azimuthal velocity of the plasma column), a bifurcation occurs leading to a mode-locked state. Next, increasing the control parameter lead to the gradual dissolution of the mode locked state. The periodic regime disappears and a chaotic regime is obtained. The next state is a turbulent regime.

The control of unstable regimes involving deterministic chaos has been for a few years an important subject of investigation. Mainly two methods, the first developed by Ott, Gregory, York [3], the second by Pyragas [4], have both proved their utility on systems presenting only purely temporal chaos. However, many systems spatially extended can exhibit space-time chaos. The two methods previously mentioned are not so clearly efficient in that case. Methods carefully dedicated to this problem, most often inspired by the Pyragas method have been developed and proved their efficiency in computer simulations [5,6,7,8]. Nevertheless, we report here on the control of a low-dimensional chaotic regime (correlation dimension about equal to 3.8) of an extended system using the TDAS method, which up to now has been essentially used in controlling purely temporal chaotic systems.

2. Experiment

The experiment is performed in a triple plasma device « Mirabelle » (Fig. 2), with a magnetized central chamber. In one chamber a thermionic argon discharge is operated as the plasma source (Argon gas pressure $P = 3.10^{-4}$ mbar).

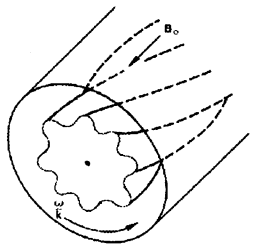

Fig. 1 : Drift wave geometry

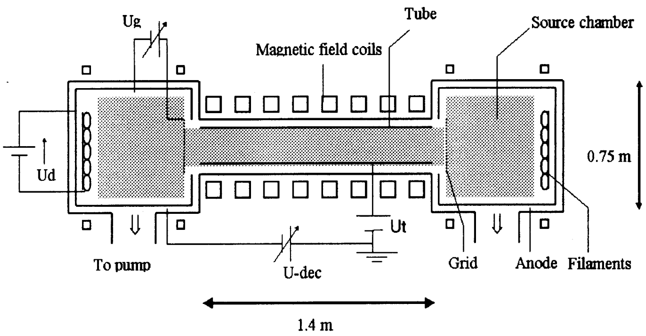

Fig. 2 : Mirabelle, a triple plasma device

The magnetic field is chosen to be B = 70 mT. In the center of the column the electron temperature is $T_e = 1.2$ eV and the electron density is $n_e = 2.10^{16}$ m^{-3}.

The spontaneous excitation of drift waves is obtained by applying a potential difference between the anode and the grid. The typical frequency of the observed waves is about 5 to 15 kHz. For the study of the transition from a regular regime to a turbulent one, the bias of the tube is taken as the control parameter determining the dynamical state of the plasma.

Biased Langmuir probes located at the radial position of the maximum density gradient are used for the measurement of density fluctuations in order to investigate experimentally the temporal and the spatio-temporal drift wave dynamics.

A semi-circular array consisting of 16 probes was developed as a diagnostic tool. In the present cylindrical geometry the azimuthal boundary conditions are periodic and the drift waves are restricted to integer azimuthal mode numbers *m* (Fig. 3).

The time series of density fluctuations are obtained by recording the electron saturation current fluctuations of a single probe, arbitrarily selected from the probe array.

The control signal *C(t)* is built from the linear control law : $C(t)=K[S(t) - S(t-\tau)]$, where τ is an appropriate time delay, and K is a constant.

The signal from the Langmuir probe is digitized and stored in FIFO memories with numerically addressed transit time (Fig. 4). The signal is then converted back into an analog signal. The difference signal is obtained through a conventional differential amplifier. After amplification, this signal *C(t)* is applied to the tube.

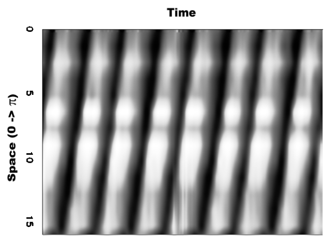

Fig. 3 : Spatiotemporal picture of drift waves

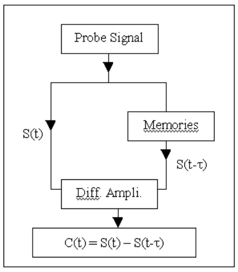

Fig. 4 : Control signal

3. Results

A slightly chaotic situation is adjusted for the implementation of the method (Figs. 5 and 6). The calculation of correlation dimension gives a value of 3.8.

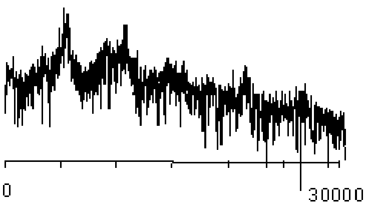

Fig. 5 : Power spectrum of a slightly chaotic regime

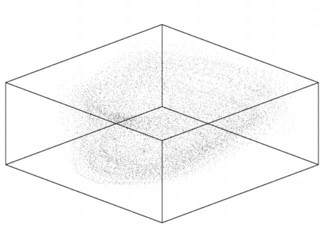

Fig. 6 : Phase Space Attractor of a slightly chaotic regime

The control method is then applied with a 100 μs delay. In a second set of experiments, delay of 200 μs is used. The first peak in the power spectrum (Fig. 5) corresponds to one period of 200 μs and the second peak to a 100 μs period.

Two typical results to each of these cases are shown on Figure 7. The changes after the control switch-on appear clearly. On the power spectra of the signals one can see that when the control is applied a significant narrowing of the peaks is obtained. In the first case portrait we obtain an attractor which displays an orbit of period 2 and in the second one an attractor with a torus corresponding to a quasiperiodic regime.

Lastly, we have observed that the control loses efficiency very quickly when the correlation dimension of the dynamical state increases.

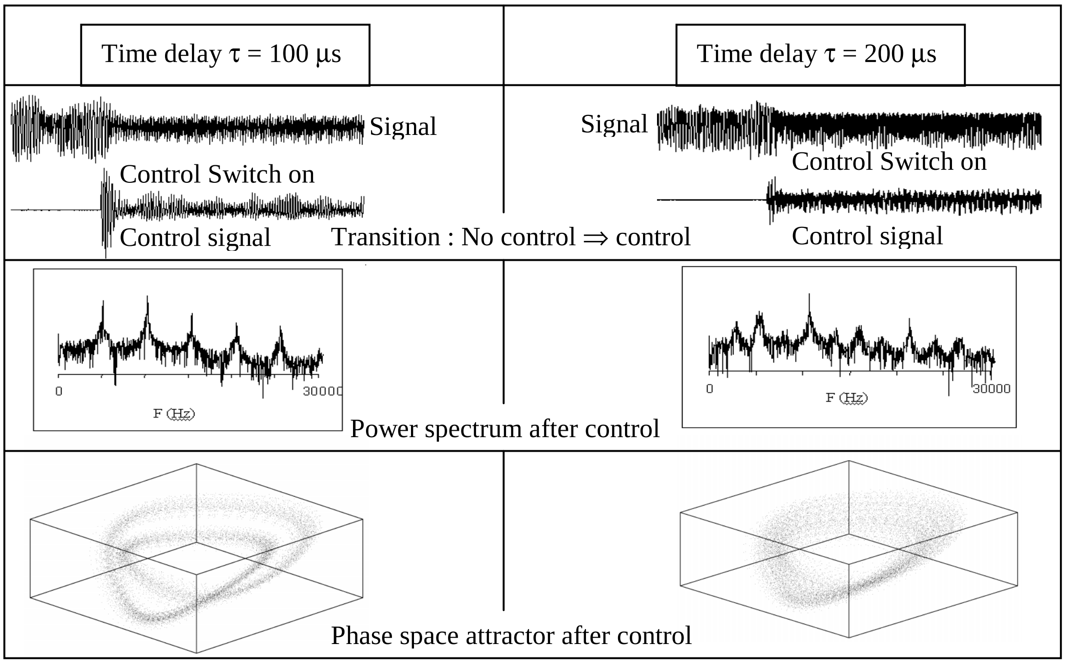

Fig. 7 : Control

4. Conclusion

This work shows that control is efficient only for a low-dimensional chaotic regime : if the control parameter is increased, thereby the correlation dimension also, the control process becomes inefficient. This can be explained by the nature of the drift waves. Drift waves present spatio-temporal chaos whereas space coherence is *a priori* necessary to obtain a fully effective TDAS control. Even if the plasma perfectly reacts to the control at some definite position, this cannot be the same for every location. Nevertheless, a significant reduction in the spectral width is obtained by using the TDAS method. With a temporal method of control it is possible to tame a chaotic regime. This makes it possible to expect a full control of drift waves by developing an experimental method adapted to the exact space-time nature of the waves.

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References

[1] T. Klinger, A. Latten, A. Piel, G. Bonhomme and T. Pierre: Plasma Phys. Contr. Fusion **39**, B145, 1997.
[2] T. Klinger, A. Latten, A. Piel, G. Bonhomme, T. Pierre, and T. Dudok de Wit: Phys. Rev. Lett. **79**, 3913, 1997.
[3] E .Ott, C. Grebogy and J.A. Yorke: Phys. Rev. Lett. **64**, 1196, 1990.
[4] K. Pyragas: Phys.Lett. A**170**, 421, 1992.
[5] M.E. Bleich, J.E.S. Socolar: Phys. Rev. E **54**, R17, 1996.
[6] S. Boccaletti, D. Maza, H. Mancini, R. Genesio, F.T. Arecchi: Phys. Rev. Lett. **79**, 5246, 1997.
[7] H.G. Schuster, M.B. Stemmler: Phys. Rev. E **56**, 6410, 1997.
[8] K. He and G. Hu: Phys. Rev. E **53**, 2271, 1996.