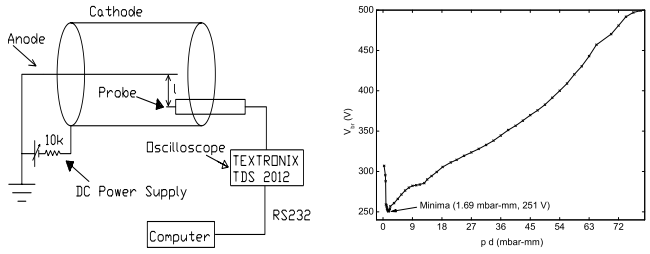
Homoclinic bifurcation of nonlinear oscillations in a dc glow discharge plasma

Md.Nurujjaman[1], P. Parmananda[2] A.N.Sekar Iyengar[1]
1. Saha Institute of Nuclear Physics,1/AF,Bidhannagar,Kolkata-700064,India.
2. Facultad de Ciencias, UAEM, Avenida Universidad 1001,
Colonia Chamilpa, Cuernavaca, Morelos, Mexico.

Glow discharge plasmas exhibit various types of self excited oscillations for different initial conditions like discharge voltages and filling pressures. The autonomous dynamics is found to be homoclinic bifurcation. The behavior of such oscillations have also been investigated using nonlinear time series analysis.

Plasma is a typical complex medium exhibiting a wide variety of nonlinear phenomena such as self oscillations, chaos, intermittency etc. In this paper we report on the observations of the chaotic and homoclinic bifurcation in glow discharge system.



(a)Schematic Diagram of experimental Setup.

(b)V_{br} vs pd (Paschen curve) for our experimental system.

FIG. 1:

The experiments were performed in a hollow cathode dc glow discharge plasma [fig 1(a)]. By varying the neutral pressure, we observed the breakdown of the gas at different voltages as shown in Fig 1(b). The experiment were performed at high pressures.

We carried out linear and nonlinear analysis of the fluctuations for three typical pressures viz. 0.89 mbar, 0.95 mbar and 1.0 mbar.

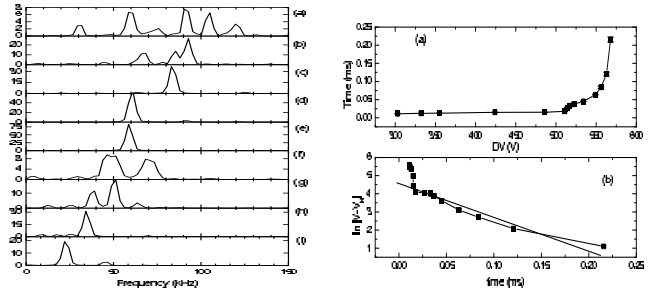
Figs 2(a) shows the power spectrum calculated for the signals at 0.95 mbar for different DVs. The figures show that with increasing DV, the number of peaks present in the power spectrum, decreases. We have observed the same trend for the other two pressures.

Another interesting feature that has been observed is that the fluctuation shows homoclinic bifurcation . The time period (T) of the fluctuations increases exponentially with DV [fig 2(b) (up)] until the fluctuations cease at the bifurcation point (V_H) and $\ln|V - V_H|$ vs T can be fitted linearly near V_H, which show the bifurcation is homoclinic type.

The presence of relaxation oscillations have been attributed to the formation of highly nonlinear structures like double layers. We therefore estimated the correlation dimension (D_{corr}) and the +ve Lyapunov exponent.

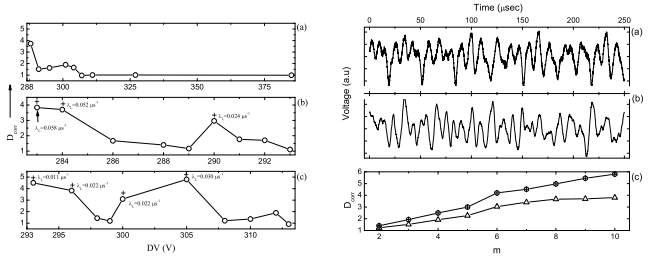
The D_{corr} at 0.89, 0.95 and 1 mbar for different DVs have been shown by open circle(○) in Figs 2(c)$_{(a)-(c)}$ respectively. It is observed that there is a decreasing tendency of D_{corr} except for some intermediate values of DV at higher pressures. Figs 2(c) also shows that λ_L becomes positive [+ sign] for 283, 284, and 290 V at 0.95 mbar and for 293, 296, 300 and 305 V at 1 mbar respectively. Therefore at these DVs the system becomes chaotic.

We have also carried out the surrogate data analysis to detect nonlinearity in the sysstem [Fig 2(d)].



(a)Power spectra at 0.95 mbar. (a) 283 V; (b) 284 V; (c) 286 V; (d) 288 V; (e) 289 V; (f) 290 V; (g) 291 V; (h) 292 V; (i) 293 V.

(b)exponential increase in Time period with DV near bifurcation point (BP) (up), Straight line fit of $\ln(V - V_H)$ vs T. near bifurcation point (bottom)



(c)D_{corr} vs discharge voltages. +ve λ_L has been shown by +ve sign. at (a) 0.89 mbar; (b) 0.95 mbar; (c) 1 mbar.

(d)Surrogate data using phase randomizing method: (a) original data; (b) surrogate data; (c) Correlation dimensions vs m for original (Δ) and its surrogate data (⊕).

FIG. 2:

In conclusion, the nonlinear time series analysis has been used to quantify and differentiate complex and coherent processes at different parametric conditions.