Ghost-vibrational type resonance in double discharge plasma configuration

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We present experimental results on the ghost vibrational resonance type phenomenon, experimentally observed in a double electrical discharge plasma configuration. Using two harmonic perturbations with a high frequency ratio, we identified in the spectral response of the inter-anode discharge current a low frequency component (ghost frequency) which is not present in the spectral structure of the perturbing voltage or the specific oscillatory regime of the plasma. The ghost frequency and its harmonics shows resonance like phenomena for optimum values of the amplitude of the high frequency perturbation.

1. Introduction

Particular interest in experimental research on the low temperature discharge plasma is shown to the effect of various perturbing external factors such as periodic signals or coloured noise [1,2]. The response of the system to a weak periodic signal can be enhanced by the application of noise or of a high frequency periodic perturbation of appropriate amplitude (termed as stochastic resonance). Noise-induced resonance phenomena or those generated when noise is replaced by a high-frequency periodic force (termed as vibrational resonances) were reported for plasma and other nonlinear systems as in biophysics, acoustics or laser physics [3-6].

When the driving force contains several frequencies higher-order harmonics of a certain fundamental frequency, then a nonlinear system is found to show a maximum response at the missing fundamental frequency for optimum noise intensity The underlying resonance phenomenon is known as ghost-stochastic resonance [7]. A ghost resonance induced by a high-frequency deterministic force rather than a noise (known as ghost vibrational resonance) was theoretically investigated in a Duffing model oscillator [8].

We report experimental results related to the possibility of a ghost–vibrational resonance in the intensity oscillations of inter-anode current of a low pressure plasma generated in a double discharge configuration, when two harmonic perturbation with a high frequency ratio (≅ 15) and variable amplitude is superimposed.

2. Experimental set-up

A sketch of the experimental device is shown in Fig. 1.

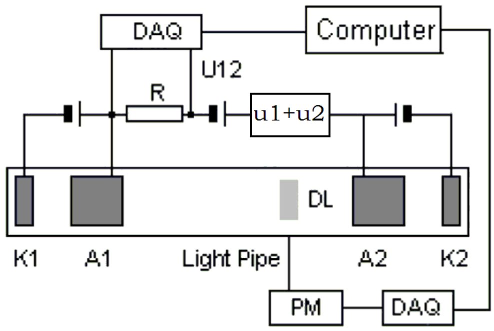

Fig.1 Sketch of the experimental set-up: K1, K2 – plane cathodes; A1, A2 – cylindrical anodes; u1+u2 bi-harmonic perturbation; U12 – d.c. inter-anode biasing, DL – double layer structure, PM – photomultiplier, DAQ – data acquisition system

The measurements were carried out on the plasma created by coupling two adjacent independent glow discharges that are biased one against the other by a d.c. voltage U12 (inter-anode voltage).

The two independent electric discharges take place in the same glass tube, in flowing Argon at low pressure (40–70 mTorr), running with equal discharge currents (around 7 mA) between the electrodes K1–A1 and K2–A2, respectively. A supplementary biasing consisting in a superposition of two harmonic voltages, u1 (≅ 6 kHz) and u2 (≅ 70 kHz and amplitude up to 5 V) is connected in series with the d.c. source. Experimental details on this type of discharge configuration and also on the plasma parameters can be found in our previous papers [9].

3. Results and conclusion

3D spectrograms show the presence of a low frequency component (fg = 830 Hz) - ghost frequency in the sub-harmonics domain (below the range of the two periodic perturbation) at a value which is not present in the spectral structure of the perturbing voltage or the independent plasma oscillation. The amplitude of the ghost frequency is sensitive to the amplitude of the high frequency perturbation and, when appears, the response can be enhanced up to some maxima. We detect similar behaviour for its first four harmonics.

Figure 2 shows the curves of resonance plotted as the amplitude of the ghost frequency (and its first harmonics 2fg, 3fg, 4fg) versus the increasing amplitude of the high frequency perturbation, for constant values of the low frequency signal characteristics.

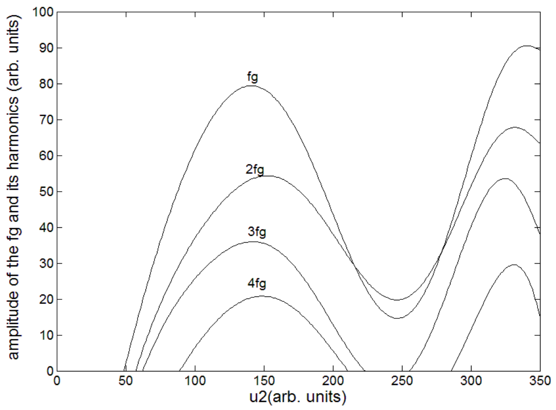

Fig.2 Resonance curves for the fundamental ghost frequency (fg) and its four harmonics

The curves in Fig. 2 are plotted using 3D spectrograms as in [10].

When the d.c. biasing (U12) is slightly exceeding the threshold value for the appearance of the coherent plasma oscillations in the unperturbed system, in addition to the ghost resonance an increasing of the amplitude of the low frequency component (f1) with increasing of the high frequency amplitude (u2) is also observed. This is a fingerprint of the vibrational resonance phenomenon simultaneously present [6,10].

A computational model for the ghost vibrational type resonance based on coupled nonlinear oscillators is in progress.

3. References

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