FIZIKA 5 (1973) 125—127

NONLINEAR EFFECT IN A PLASMA

R. TAVZES and M. ČERČEK

University of Ljubljana and Institute »J. Stefan«, Ljubljana

Received 23 Decembar 1972

Abstract: Experimental results have been obtained which show that a collisional drift instability in a bounded plasma column behaves like a classical Van der Pol oscillator. The plasma is produced by microwave heating at ECR and plasma density is varied periodically by amplitude modulation of the hf power at a modulation frequency close to the instability frequency. The experimental results are in good agreement with a behaviour of a Van der Pol oscillator for drive frequencies near the center frequency of the oscillator.

1. Introduction

A number of experimental and theoretical papers have shown that some low frequency types of self excited oscillations in a weakly nonlinear unstable plasma can be represented as a Van der Pol oscillator. Recent works[1,2] have shown that an ion sound instability in a plasma behaves in such a manner. A nonlinear effect called periodic pulling, which is characteristic of any system that can be described by the Van der Pol equation, was also observed on an ion acoustic and a drift instability[3].

The nonlinear phenomena considered in this case is frequency entrainment (synchronization-mode locking) of $m = 1$ collisional drift instability. This mode of plasma oscillations was perturbed by a density fluctuation at the modulation frequency of modulated hf power. Therefore, we consider a perturbed mode as represented by the Van der Pol equation with a harmonic forcing term

$$\frac{d^2 n}{dt^2} - \frac{dn}{dt}[a - 3\nu n^2] + \omega_0^2 n = A\,\omega_0^2 \sin \omega t, \qquad (1)$$

where the quantity n represents the perturbed part of plasma density, A the perturbation amplitude, ω the perturbation frequency and ω_0 the instability frequency. a is linear growth rate and y is associated with the saturation mechanism. As we consider a weakly nonlinear unstable plasma, the following condition must be fulfilbed

$$\nu n^2 \ll a \ll \omega_0.$$

Theoretical prediction for the behaviour of the plasma instability are shown in Fig. 3. The amplitude of drive frequencies is large enough, that for ω close to ω_0 synchronous quenching occurs.

2. *Experimental apparatus and results*

A block diagram of an experimental apparatus used is shown in Fig. 1. A vacuum system made of glass tube (3.5 cm in diameter and 1.2 m long) was situated in an uniform magnetic field. The plasma was produced by end -on irradiation by continuous microwave power (27 W, 9.3 GHz). Argon gas was continuously leaked through the system at a pressure of 2 millitorr which with a resonance magnetic field resulted in charged particle density of approximately 10^{11} cm^{-3} and an electron temperature of approximately 3 eV on the axis of plasma.

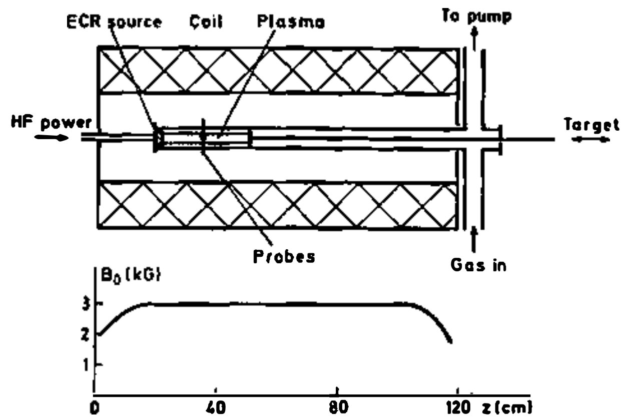

Fig. 1. Block-diagram of the experimental set up.

The center frequency of the observed instability was at 35 kHz. The direction of the azimuthal propagation of the oscillation was ascertained by means of four probe arrangement shown in Fig. 2. Using probe 1 as a reference, the phase correlation of oscillation between a pair of probes was measured as shown in Fig. 2. It was found that the oscillation rotated in the direction of ion diamagnetic drift. The phase difference between density and potential waves, which is known to be responsible for the growing of drift waves[4)], was also measured. The phase angle was found to be about 90°.

The axial distribution of the instability amplitude and phase showed the pattern of a standing wave of a half wavelength. The instability was identified as a $m = 1$ axialby standing drift wave.

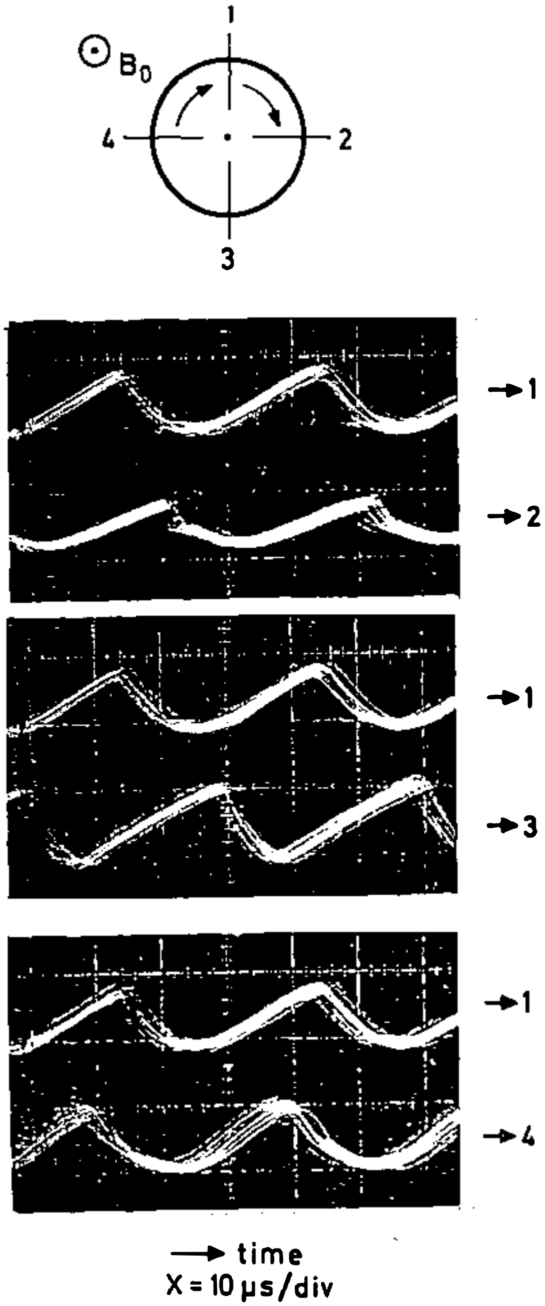

Fig. 2. Phase correlation of oscillation in azimuthal direction.

The simultaneous measurement of instability amplitude, the amplitude of the drive frequency and the beat frequency were done by spectrum analyser. Fig. 3. shows the amplitude of the instability and the drive amplitude obtained by this method, and Fig. 3 a shows the beat frequency obtained. It is clearly seen the synchronization between the drive frequency and the instability. The beat frequencies decrease linearly until the drive frequency reaches the synchronization region.

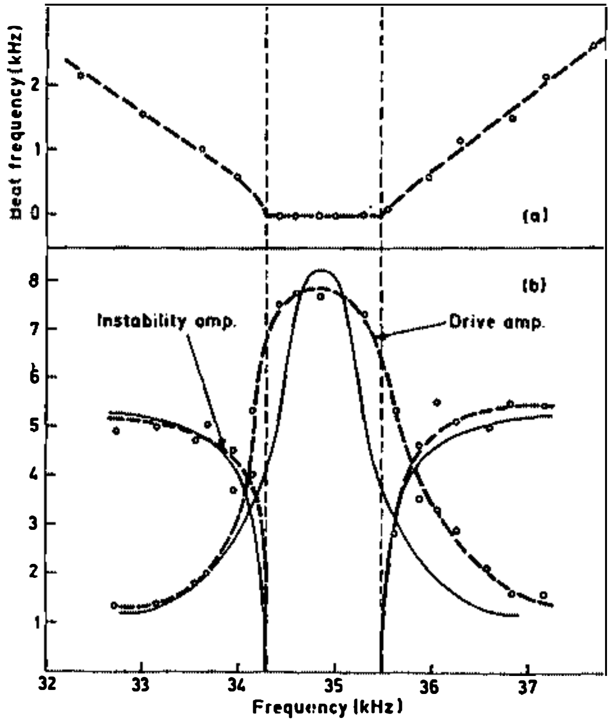

Fig. 3. Experimental behaviour of (*a*) the beat frequency and (*b*) theoretical (solid curve) and experimental (dashed curve) behaviour of the instability amplitude in the plasma for drive frequencies near ω_0.

The experimental results fit quite well the solution of Equ. (1)[1]. The parameters a, y, and A were evaluated from the experimental curve.

The resulting measurements of frequency entrainment (synchronization) shows that the collisional drift instability of a weakly nonlinear plasma behaves like a Van der Pol oscillator.

References

1) B. E. Keen and W. H. W. Fletcher, Phys. Rev. Lett. **23** (1969) 760;
2) R. W. Boswell, P. J. Christiansen and C. R. Salter, Phys. Lett. **38A** (1971) 67;
3) R. H. Abrams, Jr., E. J. Yadlowsky, and H. Lashinsky, Phys. Rev. Lett. **22** (1969) 275;
4) F. F. Chen, Phys. of Fluids **8** (1965) 912, **8** (1965) 1323, **9** (1966) 965.

NELINEAREN POJAV V PLAZMI

M. TAVZES i M. ČERČEK

Univerza v Ljubljani in Institut »Jožef Stefan«, Ljubljana

Vsebina

Merjenja v omejeni plazmi so pokazala, da se driftna nestabilnost vede kot klasični Van der Polov oscilator. Plazmo je proizvajalo mikrovalovno gretje pri elektronski ciklotronski resonanci. Amplitudna modulacija visoko frekvenčne moči je spreminjala plazemsko gostoto v ritmu modulacijske frekvence. Eksperimentalni rezultati se dobro ujemajo z rešitvami vsiljenega nihanja Van der Polovega oscilatorja.