MICROWAVE PLASMA MODE CONVERSION

H.S. Torres*, P.H. Sakanaka
Instituto de Física, Universidade Estadual de Campinas
C.H. Villarroel*
Departamento de Engenharia Elétrica, Universidade Estadual de Campinas
(*) Permanent address: Universidad de Tarapacá, Arica, Chile

ABSTRACT

Microwave (laser) experiments and simulations are reported on hot electron production and microwave (laser) absorption due to resonant absorption and parametric instabilities, excited near the critical surface. It is very difficult to identify the dominant mechanism. In this paper, we show through mode conversion that both mechanisms are active, but in different regions of plasma.

I. INTRODUCTION

The are use of high-power lasers to compress and heat a pellet to thermonuclear conditions is being intensely investigated. One of crucial problems that strongly affects pellet performance is the generation of high-energy (hot) electrons due to resonant absorption(1) and parametric instabilities(2), but several effects as electric field saturation, density profiles modification, collisionless damping,harmonics generation and diagnostic problems make that the detailed physical process of the hot electron acceleration, and absorption and so on, are still open questions. When the product $E^2\lambda$ is the same at laser and microwave frequencies, microwave-plasma interactions study is the best model to simulate laser--plasma interactions.

Considering recent result(4,5), we discuss mode conversion (Electromagnetic to eletrostatic wave) and we show that resonant absorption and the oscillating-two-stream instability are active simultaneously but in different plasma radii.

SIMP. INT. DE MICROONDAS NO DESENVOLVIMENTO INDUSTRIAL. Campinas, 22-25 julho 1985.
... INDUSTRIAL DEVELOPMENT - BRAZIL.

II. BASIC EQUATIONS OF MODE CONVERSION

The density profile of magnetized plasma is determined by the balance between the plasma pressure, magnetic pressure, the microwave ponderomotive force and the quasineutrality condition. But recent results[6,7] about anomalous collision frequency (wave-particle interaction) indicate that the collisional term cannot be neglected. Through the generalized Ohm's law[4] it is obtained the self-consistent term in the electron equation of motion.The steady-state density is

$$n = n_o(x)\ \exp\left|-\alpha|E|^2/8\pi n_c T_e\right| \tag{1}$$

where, E, N_c, Te are the microwave electric field, the critical density and the electron temperature respectively, the collisional effect is given by the factor α. Now, we derive the wave equations by combining the linearized electron equation of motion with the full Maxwell's equations:

$$\nabla\times\nabla\times\vec{E} + \frac{1}{c^2}\frac{\partial^2\vec{E}}{\partial t^2} + \frac{\omega_p^2}{c^2}\vec{E} = \beta^2\nabla(\nabla.\vec{E}) \tag{2}$$

Here $\beta^2 = 3\frac{v_e^2}{C^2}$, ve is the electron thermal velocity and C is the light speed. If we take a wave vector of the incident electromagnetic wave in the x-y plane and the x-axis along the density gradient, equations(2) is separated as

$$(k^2 + P)E_x = RkEy$$
$$(k^2 + Q)E_y = SkEx$$

where, P, Q, R and S are defined as

$$P = K_o^2(\varepsilon - \mathrm{sen}^2\ \theta_o)/\beta^2;\ R = (1-\beta^2)k_y/\beta^2$$

$$Q = k_o^2(\varepsilon - \beta^2\ \theta_o);\ S = (1-\beta^2)k_y$$

where θ_o and k_o are the incident angle and wavenumber. Note here that equations (3) are nonlinear equations since $\varepsilon = 1 - n(x)/nc$ depend on $|Ex|^2$ and $|Ey|^2$, so the system (3) can be solved only by numerical methods.

III. RESULTS AND DISCUSSION

The normalized density and electric fields magnitudes profiles are obtained from (1) and (2) when inicial temperature is 1.0 eV, microwave power is 500 watts, f = 2.45 Ghz, $\alpha = 0.8$, and $\theta_o = 30^o$.

The mode conversion from TE_{10} to resonant electrostatic mode is shown in Fig. 1.a when $k_o x \sim 0$. The temperature of electrons accelerated by electrostatic peak mode is about 25 e V. That agrees with experimental results[5,8]. The effective collision effect is observed through the increase (decrease) of $k_o x$ (electric field).

Fig. 1.b. shows that the mode conversion seems to develop beyond the critical surface. This fact was observed experimentaly by Rapoz (5), where electromagnetic wave decay in electron wave and in [illegible] wave are reported. The threshold for the decay instabilit[illegible] $E^2_{Th}/8\pi n_e T_c \sim 0.2$ which agrees with other results[8].

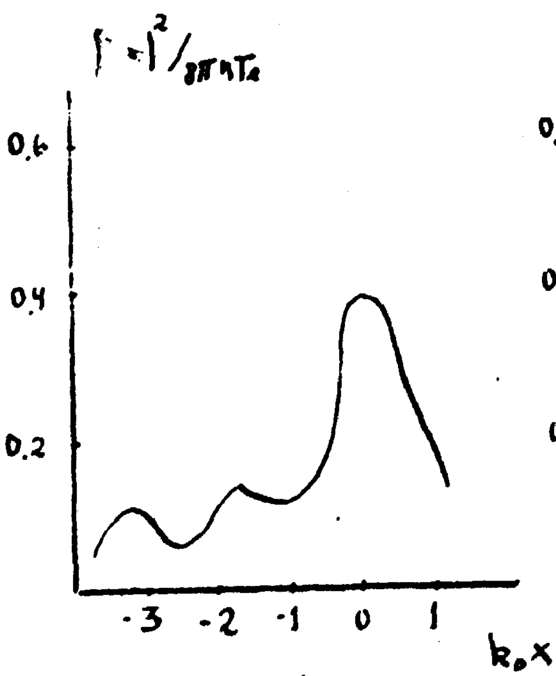

Fig 1-a

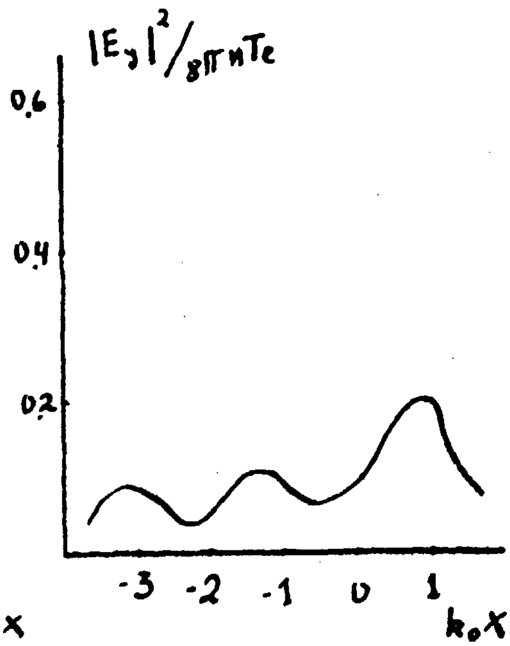

Fig 1-b

In this form we are able to show that resonant absorption and that of parametric instabilities appear simultaneously, but in different plasma regions.

This work was supported by SUBIN, CNPq, FAPESP, CNEN, FINEP, Universidade de Tarapacá.

REFERENCES

1. M. Herbst et al Phys. Rev. Letters 52, 192 (1984)
2. D. Bach et el PRL 50, 2082 (1983)
3. G. Grebogi et el Public nº 83079 Maryland, 4 (1982)
4. H. Torres, P.H. Sakanaka, IV Japan-Brazil Symp. on Science and Technology 10, 17 (1984)
5. C. Rapozo, P.H. Sakanaka, IV Japan-Brazil Symp. on Science and Technology 10, 17 (1984)
6. K. Mizuno et al PRL 52, 271 (1984)
7. K. Mizuno et al PRL 49, 1004 (1984)
8. Y. Lazanev, N. Sitnikov, Sov. J. Quantum Elect., 13, 1570 (1983)