ELECTROSTATIC INSTABILITY OF A BOUNDED ION BEAM

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It is known [1] that in an unbounded plasma an ion beam is stable against excitation of longitudinal electrostatic oscillations in the velocity range

$$1 > V^2/c_e^2 > (\omega_1^2/\omega_e^2)[1 + (\omega_2/\omega_1)^{2/3}]^3. \tag{1}$$

Here ω_1, ω_2, and ω_e are the Langmuir frequencies of the beam ions, the plasma ions, and the electrons, V is the beam velocity, and c_e is the thermal velocity of the electrons.

However, if the ion beam is bounded and passes in the plasma between two surfaces having the same potential, it may turn out to be unstable against formation of a "virtual anode," in spite of condition (1). This is connected physically with the fact that the number of electrons in the volume is constant under positive perturbations of the potential.

We consider for simplicity a one-dimensional ion beam of length L, compensated by electrons. The system of equations for small perturbations is

$$\frac{\partial n_1}{\partial t} + V\frac{\partial n_1}{\partial x} + N\frac{\partial v_1}{\partial x} = 0, \tag{2}$$

$$\frac{\partial v_1}{\partial t} + V\frac{\partial v_1}{\partial x} = \frac{e}{M}\frac{\partial \varphi}{\partial x}, \tag{3}$$

$$n_e = (eN\varphi/mc_e^2) + n_0, \tag{4}$$

$$\frac{\partial^2 \varphi}{\partial x^2} = -4\pi e(n_1 - n_e). \tag{5}$$

The boundary conditions are

$$\varphi(t)\big|_{x=0} = n_1(t)\big|_{x=0} = v_1(t)\big|_{x=0} = \varphi(t)\big|_{x=L} = 0. \tag{6}$$

The conservation of the number of electrons in time is given by

$$\int_0^L n_e dx = 0. \tag{7}$$

In (2) - (7) we use the standard notation, with indices I and e pertaining to ions and electrons, respectively.

A similar problem for an electron beam compensated by infinitely heavy ions was solved in [2]. In our problem the electrons may be non-inertial, with a spatial Boltzmann distribution (4). We shall seek the solution of the system (2) - (7) in the form $a(x)\cdot\exp(\omega t)$, where a(x) are the amplitudes of the perturbations. Then, assuming that $\omega \to 0$ ($\omega \ll V/L$) and retaining only the terms linear in ω, we can obtain the following condition for the existence of the solution:

$$2(\cosh \kappa L - 1) - \gamma \kappa L \sinh \kappa L + \gamma \frac{L\omega}{V} [\kappa L \sinh \kappa L - 2(\cosh \kappa L - 1)] = 0, \quad (8)$$

where $\kappa = (\omega_e/c_e^2 - \omega_1^2/V^2)^{1/2}$ is a real positive quantity, and $\gamma = mc_e^2/MV^2 < 1$. We see from (8) that if $\kappa L = (\kappa L)^*$ satisfies the equation

$$2(\cosh \kappa L - 1) - \gamma \kappa L \sinh \kappa L = 0, \quad (9)$$

then the only solution of (2) - (7) is the solution with $\omega = 0$. If $\kappa L > (\kappa L)^*$ a solution is possible only for real $\omega > 0$, and if $\kappa L < (\kappa L)^*$ - only with real $\omega < 0$. If $\gamma < 0.5$, then a highly accurate solution of (9) is

$$(\kappa L)^* \approx 2/\gamma \quad (10)$$

and the critical current density is

$$j^* \approx [1/[\gamma(1 - \gamma)]](2/\pi)(2e/M)^{1/2}(\varphi_0^{3/2}/L^2). \quad (11)$$

Putting $\gamma = mc_e^2/MV^2 = T_e/2\varphi_0$, where T_e is the electron temperature and $e\varphi_0$ is the beam-ion energy, we find for

$$T_e \ll \varphi_0 < (M/2m)T_e$$

that

$$j^* \approx (\varphi_0/T_e)(4/\pi)(2e/M)^{1/2}(\varphi_0^{3/2}/L^2). \quad (12)$$

The increment on the instability threshold at $\gamma \ll 1$ is

$$\omega \approx \alpha \frac{V}{L}, \quad (13)$$

where $\alpha = [\kappa L - (\kappa L)^*]/(\kappa L)^*$. We can therefore expect that when $j \approx 2j^*$ the growth time is of the same order as the time of flight.

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[1] A. A. Vedenov, E. P. Velikhov, and R. Z. Sagdeev, UFN 73, 701 (1961), Soviet Phys. Uspekhi 4, 332 (1961).

[2] J. R. Pierce, J. Appl. Phys. 15, 721 (1944).

POLARIZATION OF ANTHRACENE FLUORESCENCE EXCITED BY TWO PHOTONS

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Peticolas, Goldsborough, and Rieckhoff [1] and Singh and Stoicheff [2] were the first to observe two-photon absorption in anthracene. Later, several workers investigated two-photon-excited fluorescence of anthracene in the crystalline state and in solutions, in order to determine the mechanism of fluorescence excitation with the aid of a laser [3-7].

In this communication we present some new results of an investigation of the polarization of fluorescence of anthracene single crystals excited with red light from a ruby laser.