THE TWO STREAM INSTABILITY IN ELECTRON STORAGE RINGS *

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August 17, 1979

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Electron bunches in storage rings can ionize the background gas and depending on the bunch length and spacing between bunches the ions formed can be trapped by the electron space charge forces. It is the purpose of this note to show that the possibility of exciting the two stream instability then exists. This instability if excited would saturate by giving thermal velocity to the electrons i.e., by blowing up the emittance of the beam. Experiments carried out at ADONE¹ have observed an increase in the electron beam emittance in the presence of background ions.

The two stream instability has been studied extensively in the Plasma Physics Literature where one deals with high density beams. Energy is taken out of the relative beam motion and is deposited into the thermal energy of both electrons and the background ions. For an electron beam passing through a background ion plasma in a cylindrical conducting tube it has been shown² that the instability has a threshold. Figure 1 is a plot of the dispersion relation for the system under consideration.² Only if the beam intensity is high enough can the instability occur. In Figure 1(a) and 1(b) for each value of k there are four real values of ω . However in Figure 1(c) there are only two real values of ω for small k and hence two complex ω are possible for a range of k . One complex value³ of ω corresponds to growing waves (instability) and the other to damped waves. Computer simulations⁴ have been carried out to show that the excited instability saturates by giving thermal velocity to the electrons and ions. Figures 2(a) and 2(b) are the initial and final states of the distribution function of the unstable system.

*Research carried out under the auspices of the United States Department of Energy under Contract No. EY-76-C-02-0016.

DISCLAIMER

For Maxwellian type distributions

$$F_{eo} = \left(\frac{m_e}{2\pi\kappa T_e} \right)^{1/2} e^{-m_e(v-V_0)^2/2\kappa T_e} \quad \text{and} \quad F_{io} = \left(\frac{m_i}{2\pi\kappa T_i} \right)^{1/2} e^{-m_i v^2/2\kappa T_i}$$

where V_0 is the velocity of the electron beam. It has been shown³ that for equal temperatures $T_e = T_i = T$,

$$V_0 < 1.3 \sqrt{\frac{\kappa T}{m_e}} \quad \text{for stability.}$$

In conclusion, we suggest that the two stream instability could account for emittance blow-up in high current electron storage rings and one may have to place clearing electrodes in the machine. In proton storage rings when one has a coasting beam and background electrons neutralizing the beam the two stream instability could also be excited. However, because of their heavier mass the emittance blow up of the proton beam should not be such a significant effect. Detailed theoretical calculations for both electron and proton storage rings needs to be carried out before one can reach any definite conclusions.

REFERENCES

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2. The Physics of Charged-Particle Beams by J. D. Lawson.
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4. R.C. Davidson et. al., Phys. Rev. Letters, 24, 579 (1970).

FIGURE CAPTIONS

- Figure 1. Dispersion curve for an electron beam propagating through background ions in a cylindrical tube. The beam intensity is progressively increased through the instability threshold.
- Figure 2. Initial and final distribution functions of an electron beam system propagating through background ions that is two stream unstable.

1 (a)

1 (b)

1 (c)

2 (a)

2 (b)