AD-A135 120 INTERIM SCIENTIFIC REPORT ON VIRTUAL CATHODE OSCILLATIONS(U) NEW MEXICO UNIV ALBUQUERQUE DEPT OF MATHEMATICS AND STATISTICS E A COUTSIAS 30 JUN 83 1/1

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The purpose of my work on Virtual Cathode oscillations in electron beams is to gain understanding of nonsteady phenomena in non-neutral plasmas. The Virtual Cathode state is an important example of such a phenomenon (1).

To this effect a classical beam was modeled in one-dimensional, semi-infinite geometry and assumptions were introduced to allow the treatment of double streams. Specifically, the model is as follows: a classical, mono-energetic electron beam enters a semi-infinite drift space through a conducting grid (Fig. 1). Due to image charges induced on the grid, and the presence of an imposed adverse field the beam is reflected and returns to the grid, through which it leaves the space. Without the imposed field E, the beam would break into several streams, performing a complicated oscillatory motion that is prohibitively hard to analyse. Here it is assumed that if E is large enough there will be at most two streams present at each point. Crossing and reflection of particle trajectories inherent in this process implies the existence of caustics, or envelopes of trajectories. The assumption of the existence of only two streams is equivalent to assuming that the acceleration of the (unique) caustic is much smaller than the acceleration of the particles traversing it (Fig. 2).

Since in this geometry, the force on a particle is equal to the sum of the imposed field plus a term proportional to the total electric charge associated with particles further from the grid than the given particle, we can write the equation of motion for a given particle as

$$\ddot{x} = -E - \Delta(x,t)$$

where $\Delta(x,t)$ is the total charge that entered between the times of entry of the two trajectories crossing at the point (x,t), with proper dimensionless units employed.

This formulation allows us to derive a nonlinear integral equation for the quantity $\Delta(x,t)$. This equation allows a study of the stability of the steady two-stream flow and it is expected to yield results on the character of the oscillatory state. It also seems that a numerical study of the time dependent problem based on this equation would be a lot easier, requiring far less computing capacity, than the currently employed Particle in Cell codes, as long as the assumptions that led to it apply.

A point that this work helps to clarify is the mechanism responsible for the oscillatory behavior. Possible alternatives include the well-known two-stream instability (2) and delay effects.

A simplified model that ignores interaction between the two streams demonstrates the importance of delay effects. If we assume that particles are removed from the space upon reaching the caustic, we are led to an exactly solvable model whose solution is given in the form of an algebraic mapping. For E sufficiently strong, the mapping has only one fixed point, corresponding to a steady state for the beam but as a critical value of E is crossed two new fixed points for the map appear corresponding to the appearance of an oscillatory state for the beam. As E is decreased further the map goes through a cascade of bifurcations, leading to solutions of higher frequency in a typical period doubling sequence. Of course, the simplifying assumptions that make even this model solvable might not hold as the frequency is raised indefinitely, but the behavior of this model is indicative of the delay nature of the oscillatory behavior.

The work described above is currently being prepared for publication and a preprint will be submitted to AFOSR as soon as it is available. The integral equation describing the time dependent behavior of the beam is also under study currently.

Other work completed during the report period includes

i) "Effects of thermal spread on the Space Charge Limit of Electron Beams", submitted (5/83) to the "Journal of Plasma Physics".

ii) "Aging of Nuclei in a Binary Mixture", to appear in the Proceedings of the Conference on Fronts, Interfaces and Patterns, Los Alamos National Labs., May 1983.

Preprints of i) and ii) are enclosed.

iii) "Kapitza-Dirac Scattering", being written for publication, is a study of the scattering of an electron beam by a standing laser wave.

References

1. E.A. Coutsias and D.J. Sullivan, "Space Charge-Limit Instabilities in Electron Beams", Phys. Rev. A, 27, 1535-1543, (1983).

2. Lifshitz and Pitaevshii, Physical Kinetics, Pergamon, N.Y., (1979).

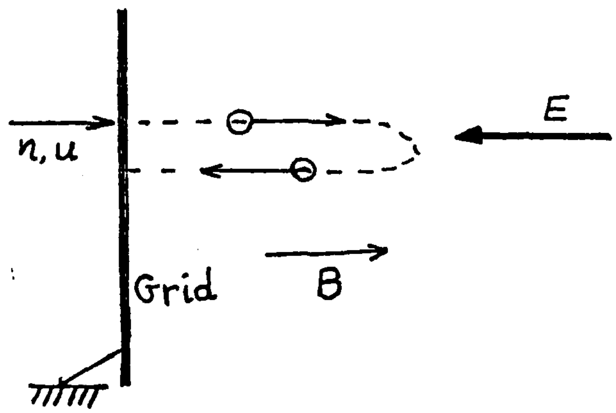

Figure 1. Schematic of semi-infinite drift space model.

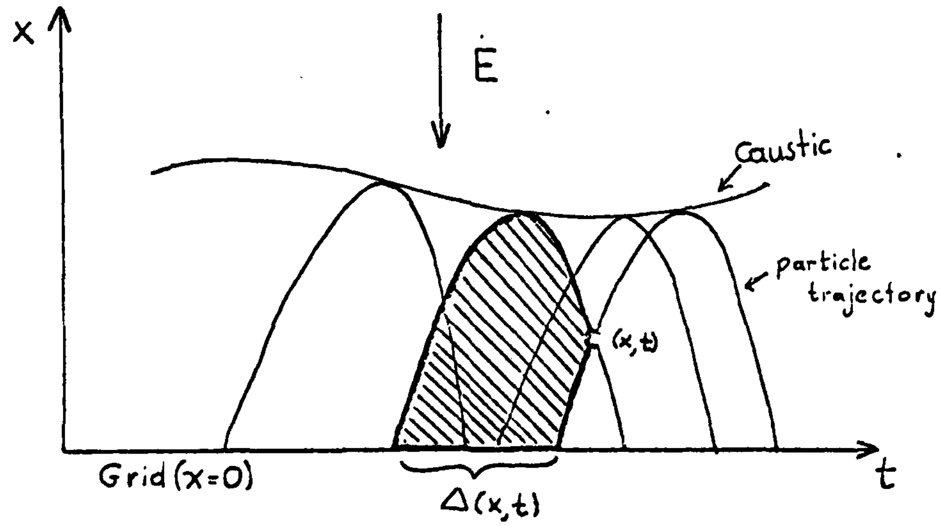

Figure 2. Some electron trajectories and their envelope (caustic) in the single-caustic case. As can be seen all electrons entering in the interval $\Delta(x,t)$ are further from the grid than the electron at (x,t) and therefore they exert a force on it. Those between this electron and the grid don't matter, their influence being neutralized by that of image charges induced on the grid.

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During this period, the single investigator produced two papers with titles, "Effects of Thermal Spread on the Space Charge Limit of an Electron Beam," and "The Aging of Nuclei in a Binary Mixture." In progress is a paper dealing with the cascade of bifurcations due to delay effects related to the two stream model for virtual cathode formation in its simplest form. A paper, "Kapitza-Dirac Scattering," is being written for publication. This report summarizes progress made under the grant during the specified period.

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