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MULTIPLE PSEUDOWAVES PRODUCED BY A SINGLE VOLTAGE PULSE

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Multiple Pseudowaves Produced by a Single Voltage Pulse*

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ABSTRACT

A multiple pseudowave--or a series of fast ion bursts--is emitted when a short negative voltage pulse is placed on a transmitting grid. The phenomenon resembles, but is not, a damped wave train.

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A multiple pseudowave, or a series of fast ion bursts, is emitted when a short negative pulse is placed on a transmitter grid. This behavior contrasts with the observed emission of a single ion burst when a negative voltage on the transmitter grid is suddenly reduced.[1]

The apparatus used is a simple discharge tube in which a quiescent plasma, generally xenon, is formed by a weak electron beam.[2] The electron temperature is about 1 eV, the ion temperature is about .03 eV, the electron density is about 2×10^9 cm^{-3}, the voltage pulse is -150 V, and the gas pressure is less than 10^{-3} Torr. The gas pressure is so low that over short distances, the ions can be considered collisionless. The ion bursts are generated by a fine-meshed grid, and detected by a positively biased probe that observes the burst of electrons accompanying the ion burst. The electron-collection technique greatly enhances the sensitivity of a probe used to study ion density fluctuations.[3]

The ion burst behavior is as follows: As the length of the negative voltage pulse applied to the transmitter grid is increased from zero, a single ion burst appears at a long time, and moves toward the short time given by the time-of-flight of ions which fall completely into the potential well before voltage turnoff. This single burst is shown in Fig. 1a. As the negative voltage pulse is made longer, more bursts appear at a long time, move toward the original burst, and merge with it, as is shown in Fig. 1b and 1c. We have resolved up to eight consecutive ion bursts. As the length of the negative voltage pulse is made still longer, all the ion bursts merge, and a smooth peak is obtained, as shown in Fig. 1d. Ion-acoustic waves are also produced, but they move so slowly that they do not have time enough to appear in Fig. 1.

We now easily demonstrate in a graphical fashion how such multiple ion bursts can be generated by plasma ions trapped and oscillating in the sheath surrounding the transmitting grid. Consider a large negative potential suddenly applied to a grid immersed in a plasma. Ions suddenly find themselves at rest in various positions in the resultant potential well, as shown in Fig. 2a. As time progresses, the ions oscillate through the well. However, as the well is a non-harmonic one, each ion has its own frequency of oscillation, the frequency being a monotonic function of the initial location of the ion in the well. At a given instant of time later, the position of each ion in the well is determined by its horizontal position along the smooth curve shown in Fig. 2b. At this instant, the ions located at A, C, and E have returned to their initial heights in the well, and have zero kinetic energy. In contrast, the ions at B, D, and F are at the bottom of the potential well, and have more kinetic energy than nearby ions on either side, which are either still falling into, or are climbing out of, the potential well. Thus, ions near B, D, and F constitute the leading edges of the ion bursts which are shown in Fig. 1, b and c.

As time progresses further, the curve in Fig. 2b obviously develops more and more kinks, with the upper intersections F and D moving toward the top of the graph. Thus, more ion bursts are produced, and move toward the maximum kinetic energy possible. Finally, at very late time, the curve has developed so many kinks, and so many ion bursts are produced, that all the structure overlaps and is lost, as is shown in Fig. 1d.

We thus observe that the multiple emission of ion bursts from a

grid in a plasma can be likened to a plasma "echo", because the information concerning the formation of a sheath around a grid by a suddenly-applied negative potential is stored in the sheath for a relatively long time, and may be extracted by simply turning off the negative potential. It is obvious that collective effects in the sheath can be studied by this multiple-ion-burst technique, although our simple model presented above involves non-interacting particles as a first approximation to reality. Finally, we caution plasma workers using driven grids in plasmas that many unusual wave-like effects other than those predicted by the simple linearized dispersion relations do occur!

More detailed calculations, which still do not contain detailed studies of the collective interactions, give reasonable, but not good, agreement with experiment.

REFERENCES

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FIGURE CAPTIONS

Fig. 1 Pseudowave response for various lengths of the voltage pulse on the transmitter grid. The upper trace in each photo shows the transmitter pulse (vertical scale-50 V/cm; horizontal scale-2 μsec/cm), while the lower trace shows the ion bursts (vertical scale relative receiving probe current; horizontal scale-2 μsec/cm). The gas was xenon, and the transmitter-receiver distance was 6 cm.

Fig. 2 Position of ions in the potential well as a function of time: a. Negative applied voltage just turned on; b. A short time Δt after the voltage was turned on. Horizontal axis--ion distance from grid at time of observation. Vertical axis--ion depth in well (grid would be at the bottom) at time of pulse turn-on.

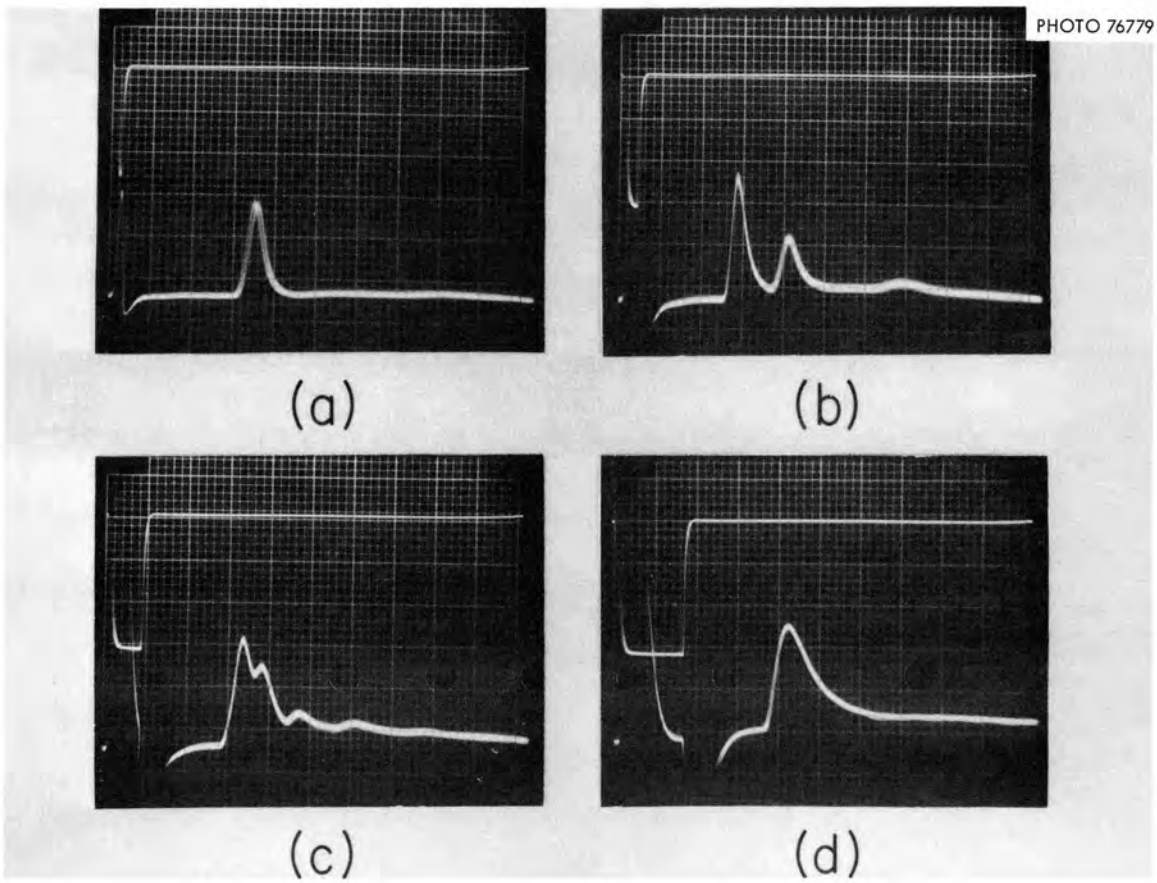

Fig. 1

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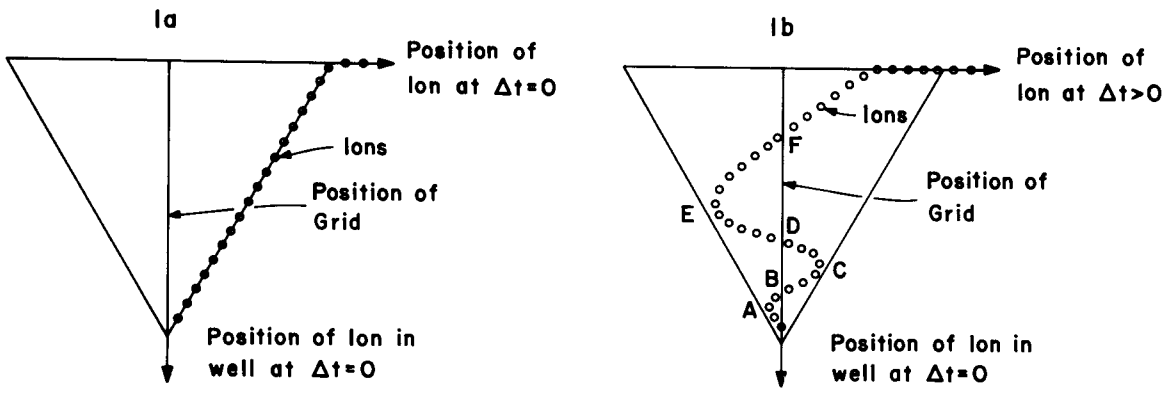

For clarity, only ions on one side of the grid are shown.

ION LOCATION IN POTENTIAL WELL AT VARIOUS TIMES

Fig. 2