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Publication Date
1980

LBL-10363
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Accelerator & Fusion Research Division

Submitted to Research Notes of Physics of Fluids

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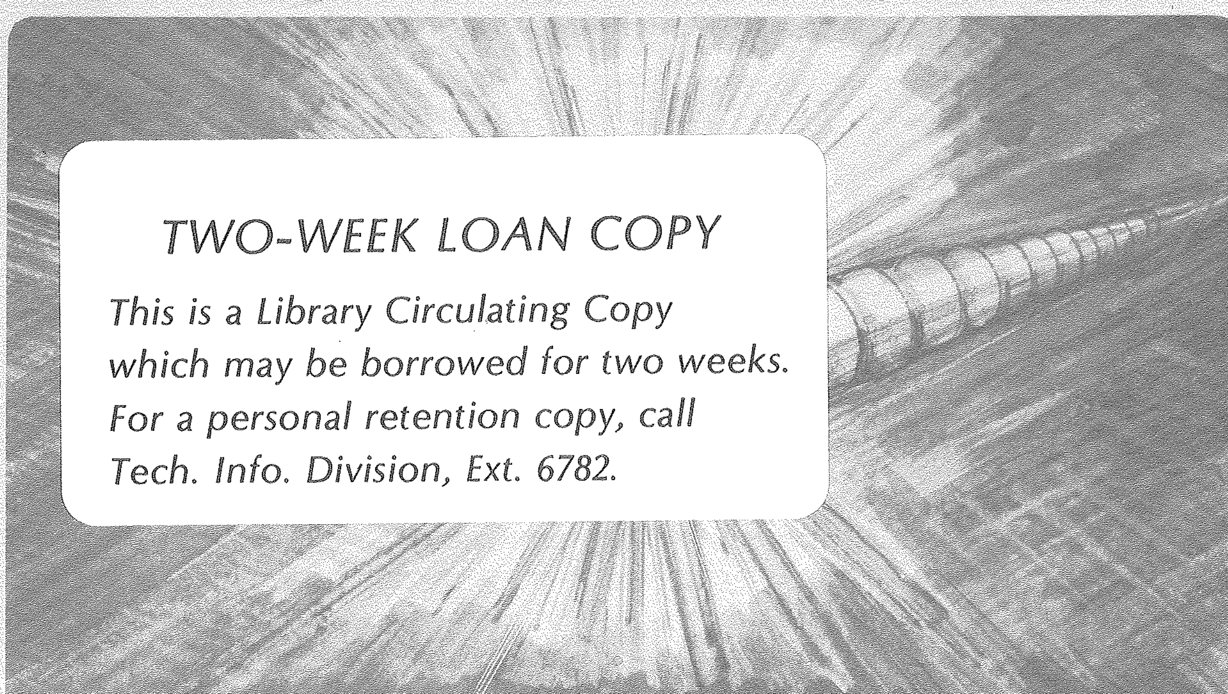
January 1980



Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

LBL-10363

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Rate of Electron Heating in a Multidipole Plasma*

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Abstract

The rate of increase in electron temperature in a multidipole device due to the interaction of a group of test electrons with an argon plasma is determined.

*Work started at James Madison University and supported in part by Research Corporation and in part by the U. S. Department of Energy, Office of Fusion Energy, under contract W-7405-ENG-48.

The relaxation of a system of particles in a background plasma has been both studied theorectically and experimentally by a number of authors.[1-6] In particular, Hsu et al.[5] have investigated the spatial development of the energy distribution of a group of monoenergetic electrons interacting with a background plasma. It is shown that electron-electron collision is the main process for degrading the test particle energy. In this paper, the time evolution of the background electron energy distribution for a group of test electrons interacting with a multidipole plasma is presented. It is found that the thermalization time for these electrons is approximately 15 μs.

The experiment was performed in a 40 liter thin-walled stainless steel chamber (35 cm diameter by 40 cm long) with ceramic magnets ($B_{max} \approx 1.7$ kG) mounted externally to generate a full-line cusp configuration.[7] The entire chamber wall served as the anode for the discharge. The plasma parameters were measured by a small disc Langmuir probe. A background argon plasma was produced initially by 150 mA of 60 eV primary electrons emitted from one set of tungsten filaments. A plasma density of 10^{10} ions/c.c. with $T_e \approx 1.5$ eV was obtained at a neutral pressure of 2×10^{-4} Torr. A separate group of primary electrons with energy less than 60 eV were injected into the plasma from a <u>second</u> set of filaments. Figure 1 shows the plasma electron temperature T_e as a function of the injected voltage V for a fixed injection power (5 W) of low energy primary electrons. It can be seen that there is no significant change in T_e for $V > 20$ V. As V is reduced below 20 V, T_e increases rapidly, reaching a maximum value of 3.6 eV at $V \approx 6$ V as the injected electrons thermalized with the background plasma. Detailed study of the increase in T_e by this low-energy electron injection process has been reported by Hershkowitz and Leung.[8]

The rate of increase in T_e when the group of test electrons were injected with energy 6 eV has been measured by means of a sampling technique. The experimental arrangement is illustrated schematically in Fig. 2. A steady-state background argon plasma was maintained by the 60 V discharge. The bias voltage of the second set of filaments was pulsed on and off by a fast transistor switch which was energized by a pulse generator. The Langmuir probe was connected through a dc power supply to the input of a sampling oscilloscope which was triggered by the pulse generator. Probe characteristics at various times after the 6 V bias voltage was switched on were obtained from the gated output of the sampling oscilloscope whose delay time could be adjusted. A plot of the background electron temperature T_e as a function of time t is shown in Fig. 3. It can be seen that T_e increases exponentially and gradually reaches the equilibrium value of 3.6 eV. From this data, the thermalization or rise time is found to be approximately 15 μs.

The increase in the background electron temperature is mainly due to the dynamic friction between the 6 eV primaries and the plasma electrons.[5] Calculations show that the electron-electron collision time τ_{ee} is approximately 3 μs for a 6 eV electron. Therefore, the injected test particle makes about five Coulomb collisions with the background electrons before its energy is degraded.

On the other hand, the test electron also experiences short-range electron-neutral elastic collisions ($\tau_{en} \approx 1.7$ μs) and long-range electron-ion Coulomb elastic deflections. However, the result of these encounters is to change the trajectory of the test particle, but not its energy.[5] In fact, it is these elastic interactions together with the reflections by the magnet dipole fields that help to maintain the electron distribution isotropic.

The magnetic confinement time τ_c of the primary electron in a multidipole device varies inversely as the electron energy.[9] In this system, it has been measured that $\tau_c \approx 5$ μs for a 60 eV electron.[10] Hence, for a 6 eV electron $\tau_c \approx 50$ μs, which is approximately three times longer than the thermalization time.

The authors wish to thank Professor Noah Hershkowitz for suggesting this experiment. This work was started at James Madison University and was supported in part by the Research Corporation and in part by the U.S. Department of Energy, Office of Fusion Energy, under contract No. W-7405-Eng-48.

References

1. D. M. Cox, H. H. Brown, Jr., I. Klavan, and B. Bederson, Phys. Rev. A 10, 1409 (1974).
2. S. T. Butler and M. J. Buckingham, Phys. Rev. 126, 1 (1962).
3. M. N. Rosenbluth, W. M. MacDonald, and D. L. Judd, Phys. Rev. 107, 1 (1957); W. M. MacDonald, M. N. Rosenbluth, and Wong Chuck, Phys. Rev. 107, 350 (1957).
4. I. B. Bernstein, in Advances in Plasma Physics, edited by A. Simon and W. B. Thompson (Wiley, New York, 1969), Vol. 3, p. 127.
5. T. Hsu, J. L. Hirshfield, and Ira B. Bernstein, Phys. Fluids 21, 413 (1978).
6. H. H. Brown Jr. and D. Taggart, Bull. Am. Phys. Soc., 24, 1006 (1979).
7. K. N. Leung, T. K. Samec and A. Lamm, Phys. Lett. A 51, 490 (1975).
8. N. Hershkowitz and K. N. Leung, Appl. Phys. Lett. 26, 607 (1975).
9. K. N. Leung et al., Rev. Sci. Instrum., 49, 321 (1978).
10. K. N. Leung, R. E. Kribel, A. P. H. Goede and T. S. Green, Phys. Lett. A 66, 112 (1978).

Figure Captions

Fig. 1 Plasma electron temperature as a function of discharge voltage for a fixed injection power of 5 W at a neutral pressure of 2×10^{-4} Torr. Background plasma is produced by 150 mA of 60-eV primary ionizing electrons.

Fig. 2 Schematic diagram of the experimental apparatus.

Fig. 3 Electron temperature at various times after the 6 V bias voltage was switched on.

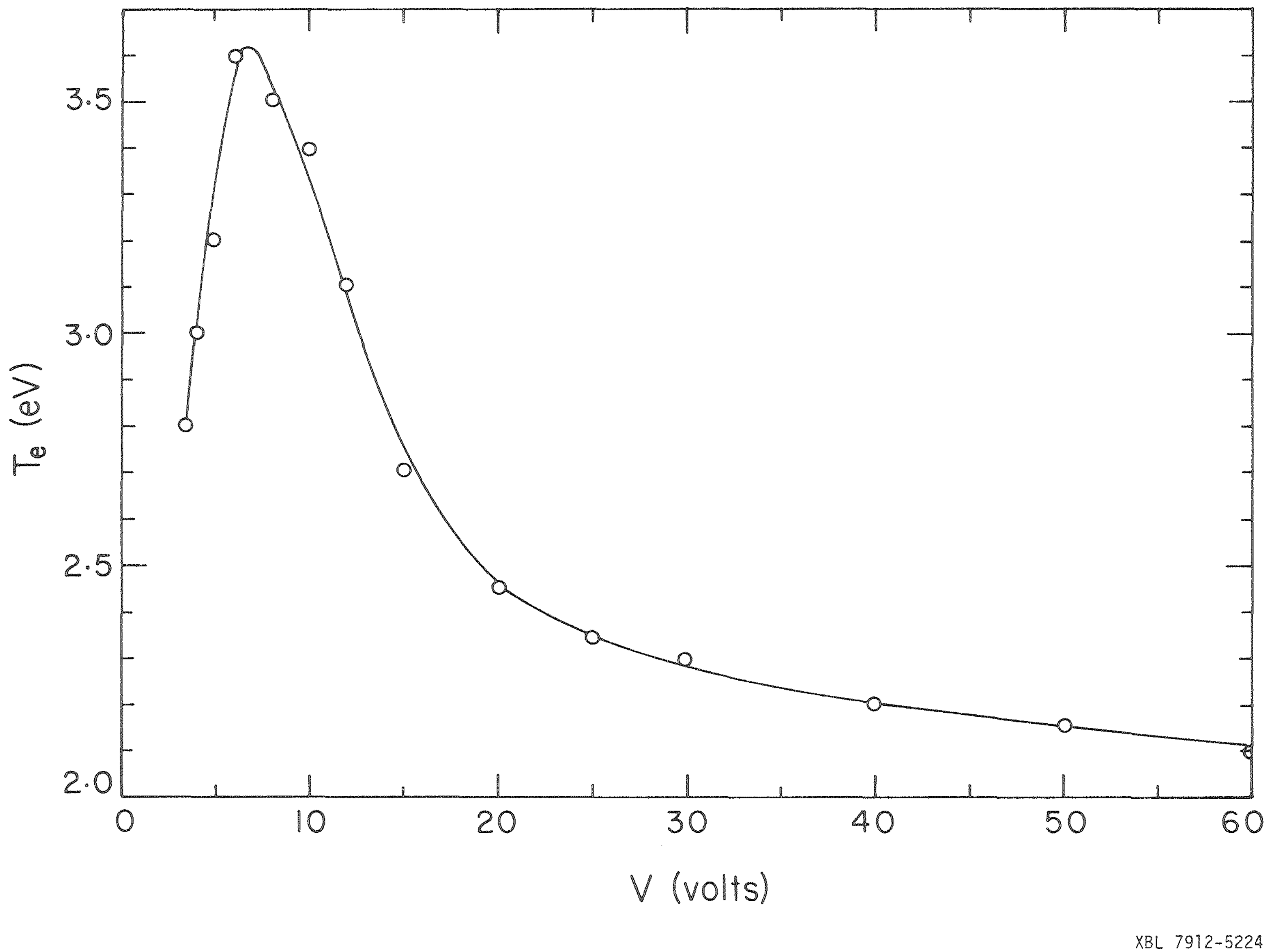

Fig. 1

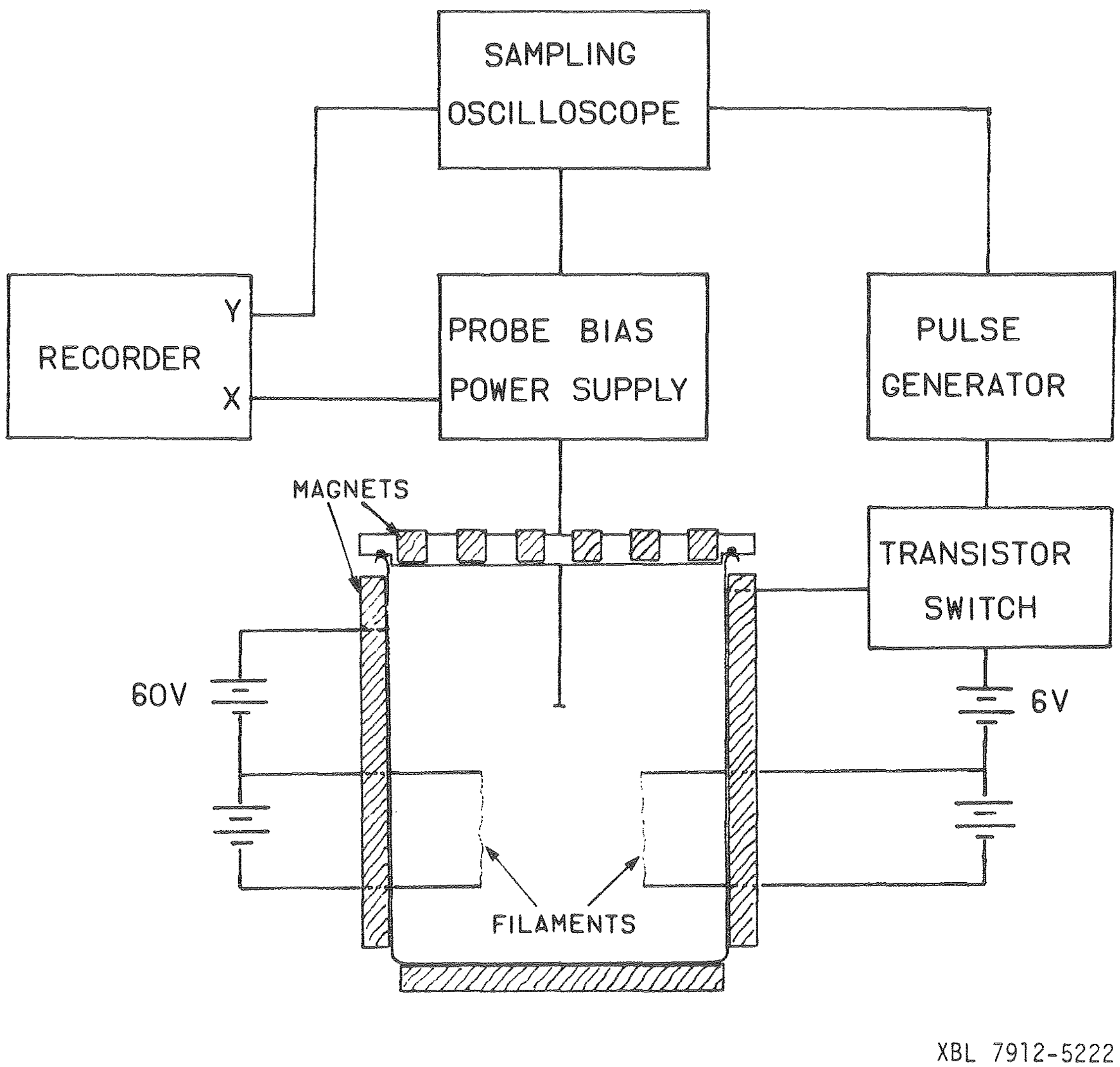
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Fig. 2

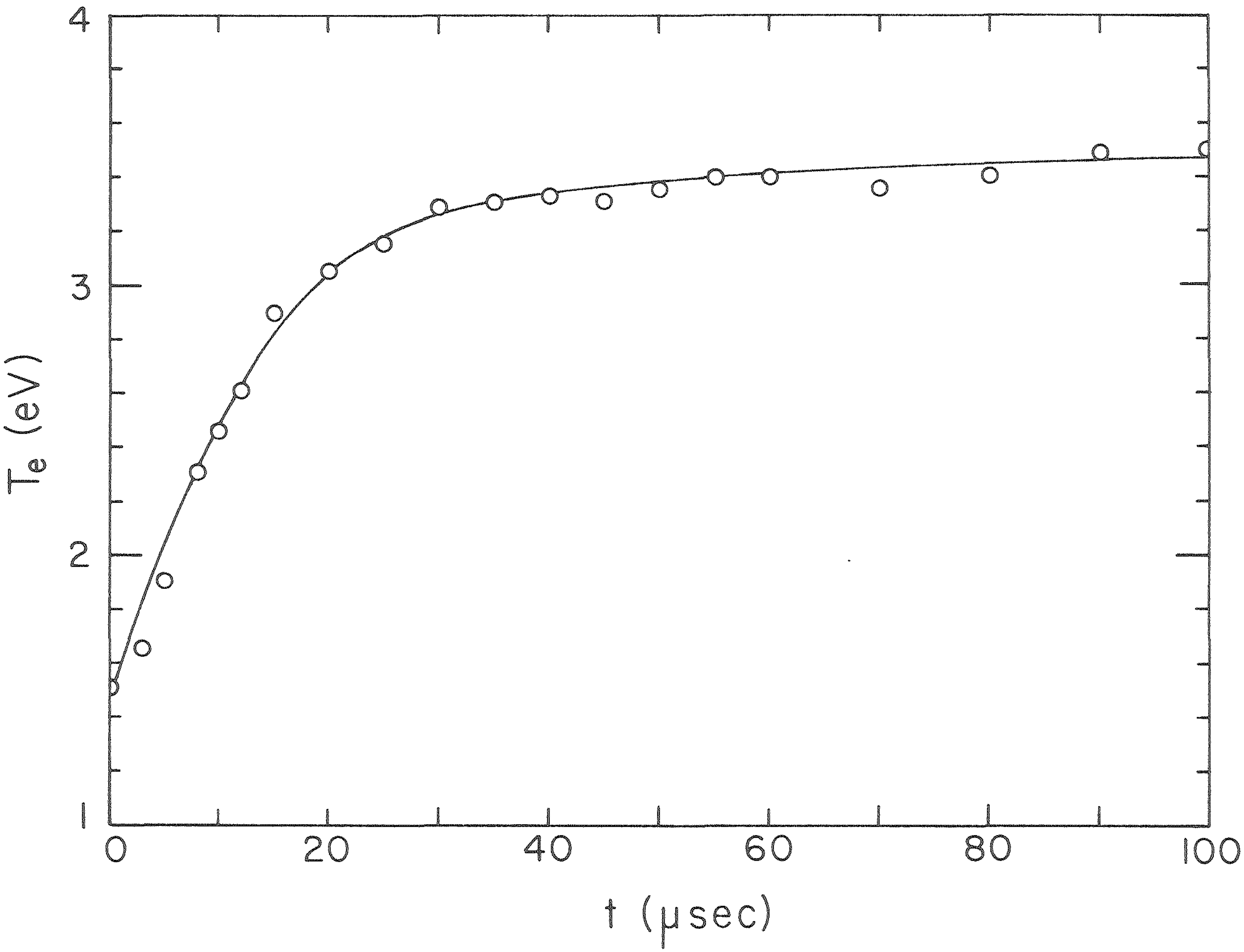

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Fig. 3