to the Director, A.E.R.E., for permission to work at A.E.R.E., Harwell.

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Experimental Demonstration in the Laboratory of the Existence of Magneto-Hydrodynamic Waves in Ionized Helium*

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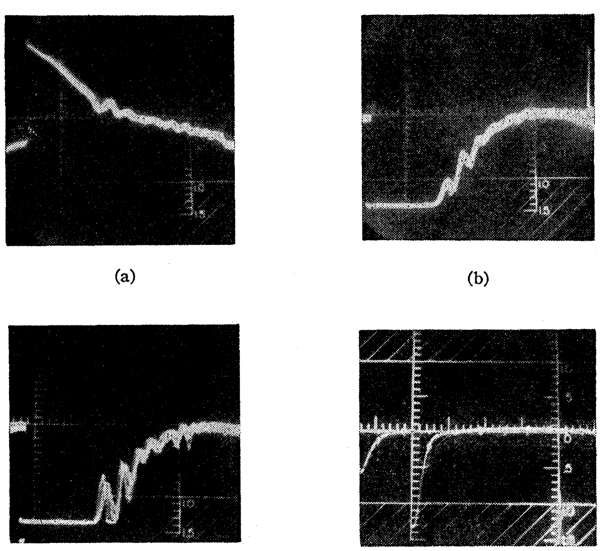
THIS laboratory has been investigating the properties of ionized gases at low pressures in a toroidal discharge tube where ion diffusion to the walls can be retarded by a magnetic field co-annular with the toroidal tube. The discharge is excited by a 2-microsecond pulse applied to a primary winding of 10 turns of wire on a pulse transformer core which links the toroid. The secondary of the pulse transformer is effectively the ionized gas in the toroidal discharge tube; the peak current in this gas under some circumstances goes as high as 8000 amperes. The densities of electrons and ions and the electron temperature can be measured in the afterglow period in this discharge tube by means of a probe which is connected mechanically to the amplifier of a synchroscope only during an "examining interval" of about 1000 microseconds. Except during this examining interval, which can be variably delayed with respect to the excitation pulse, the probe floats in the plasma and is decoupled from both the amplifier and the voltage source.

With a short probe (3-mm effective length) inserted into the region of high ion-density gradient near the tube wall, oscillations can be observed on synchroscope traces of both the positive ion current [Fig. 1(a)] and the electron current [Figs. 1(b) and 1(c)]. These oscillations are either subdued or absent when the probe is inserted to the center of the discharge tube. These oscillations are entirely absent when no dc magnetic field is present [Fig. 1(d)]. The synchroscope photographs represent the traces of several pulses on the same exposure. Although the phases of the oscillations are, in general, not coherent from pulse to pulse, it is nevertheless possible to delineate from the photographs oscillations involving several cycles of definite periods of approximately 100 microseconds. These oscillations in ion and electron density near the wall of the tube suggest the presence of standing magneto-hydrodynamic waves set up around the toroid whose length L is approximately 100 cm. The propagation velocity V of such a wave[1] is given by $V=H_0(1/4\pi\rho)^{\frac{1}{2}}$, where H_0 is the value of the dc magnetic field in gauss and ρ is the density of the gas. For a standing wave $L=n\lambda/2=nV/2\nu=nH_0/2\nu(4\pi\rho)^{\frac{1}{2}}$, so the frequency of the standing wave $\nu=nH_0/2L(4\pi\rho)^{\frac{1}{2}}$, where n is an integer. With our experimental conditions of $\rho=3\times10^{-9}$ g/cc and $H_0\cong400$ gauss the computed $\nu\cong400n/[2\times100\times(4\pi\times3\times10^{-9})^{\frac{1}{2}}]\cong10^4n$. If $n=1$ this value of the frequency ν agrees reasonably well with the observed frequency of 10^4 cycles/sec. Furthermore, if the wave is to be undamped to the extent that a standing wave can be set up in the length L, it can be computed from Alfven's relationship[1] that $LH_0>\pi^{\frac{1}{2}}c^2(\rho)^{\frac{1}{2}}/\sigma$, where σ is the conductivity of the gas in cgs units and c is the speed of light in cm/sec. If we take a reasonable value of $\sigma=10^{13}$ cgs units, the inequality is maintained for our circumstances, and we should expect to observe standing waves.

Attempts to demonstrate quantitatively the dependence of V on H_0 for these waves have not yet met with success in this toroid because of the difficulty of setting up standing wave patterns at several values of the field H_0. It has been observed qualitatively however, that at the higher values of H_0 it is frequently difficult to set up a good standing wave pattern and that the pattern presented contains noise of frequency higher than is generally observed at the lower values of H_0. The amplitude of the oscillations is lower with the higher values of H_0.

These oscillations in ionization density at the plasma periphery are ascribed to displacements associated with magneto-hydrodynamic waves. These oscillations have also been observed in H_2 and N_2.

Magneto-hydrodynamic waves very likely play a role[2] in increasing the rate of ion diffusion perpendicular to the magnetic field.



(a) (b) (c) (d)

FIG. 1. Oscillations on current to probe in He at a pressure of 0.020 mm. The examining interval begins 600 microseconds after the excitation pulse. (a) Positive-ion current, $H_0=530$ gauss; (b) electron current, $H_0=530$ gauss; (c) electron current, $H_0=410$ gauss; (d) $H_0=0$, when no oscillations occur anywhere in the afterglow period.

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Acceleration of Beryllium and Carbon Ions in a Synchrocyclotron*

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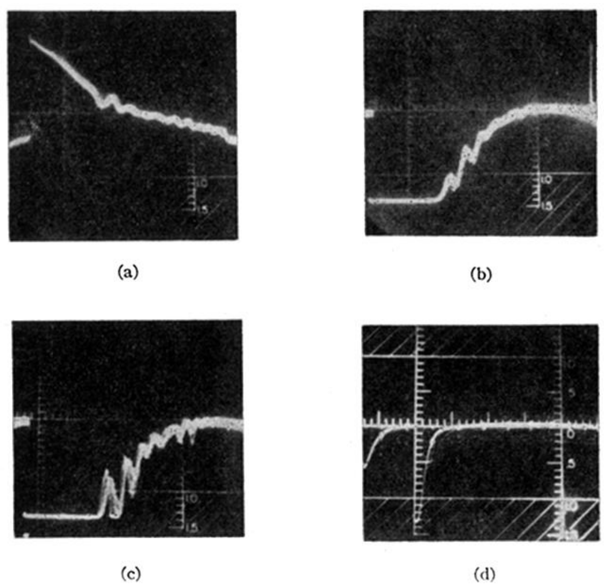
NUCLEAR emulsions have been exposed to carbon and beryllium ions in the University of Chicago synchrocyclotron. Carbon ions of energies as high as 1.1 Bev have been directly observed in photographic plates. The acceleration of carbon and oxygen ions in the Berkeley 60-inch cyclotron has been previously reported.[1–5] In the present experiment CO_2 gas was introduced into the ion source of the Chicago cyclotron in place of the hydrogen which is normally used. In order to eliminate the large number of $(H_2)^+$ ions originating from the water vapor inside the cyclotron tank, the upper frequency limit of the oscillator and the magnetic field were adjusted so that $(H_2)^+$ would not be accelerated near the center of the cyclotron. However, under these conditions, carbon ions with 5 electrons removed and Be atoms completely stripped could be accelerated. The beryllium ions are



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