IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

THE C.P.A. (A COLLECTIVE PARTICLE ACCELERATOR)

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Various collective particle accelerators have been suggested for accelerating charged particles.[1-3] These mechanisms make use of "waves" riding on an intense relativistic electron beam (I.R.E.B.) to trap ions. By manipulating beam parameters (e.g., current, magnetic field, geometry, etc.) the phase velocity of these waves can be controlled. By "accelerating" the waves (i.e., increasing their phase velocity) the trapped ions will be dragged along and gain energy. As long as the ions are in phase with the waves the energy gain will be continuous. The generation of these waves and the control of their phase velocity may require beam parameters that are not attainable(e.g., monochromatism of particle energy).

In this paper a new collective acceleration mechanism is described. This mechanism does not use a beam wave. Let us visualize that at a certain frame of reference one has stationary rings of electrons spaced in a prearranged order. These rings contract and expand radially. Ions are attracted by a radially collapsed ring of electrons and are accelerated. As the ions enter into the ring the ring expands radially and the ions move freely toward a second ring which (at that time) is in a collapsed state. The ions are attracted to the second ring, etc. One can see that the force acting on the accelerated ions is impulsive in nature. Fig. 1 shows the process schematically. Electrons can also be accelerated by the repulsive force of these rings.

The production of radially oscillating rings can be achieved by propagating a bunched I.R.E.B. through a rippled magnetic field. When viewing this system at the rest frame of the I.R.E.B. one can see oscillating rings of electrons.

When one writes the equation of motion of the rings and evaluates the nature of the electric field configuration which the rings generate (while propagating in the rippled magnetic field) one finds that this system comprises of large amplitude forward and backward "electric waves". These waves (which are not beam waves) have phase velocities which depend on the modulated beam wavelength, λ and on the rippled magnetic field wavelength, L (Fig. 2). Charge particles with velocities matching the phase velocity of the wave will be accelerated. The average electric field associate with the wave is

$$E_{zo} \approx \frac{I/c}{4\epsilon_0} \frac{r_1}{r_0 L} \qquad (1)$$

where I is the current of the I.R.E.B. r_0 is the equilibrium radius of the I.R.E.B. and r_1 is the amplitude of the oscillation. A more detailed description is given elsewhere.[4]

At the Naval Research Laboratory an experiment was built to test the above idea (Fig. 3). In the first stage of the experiment that was finished recently an I.R.E.B. was generated by applying a negative 1 MV voltage pulse to a foiless diode. The diode emitted an annular electron beam with ~30 kA current for a 130 nsec duration. The beam was guided through an evacuated drift tube for a 5-6 meter length and was focused by a semi d.c. magnetic field of ~10 kgauss.

In the next stage of the experiment the I.R.E.B. will be modulated using an automodulating technique.[5] $\lambda/4$ coaxial cavities are going to be shock excited by the front of the I.R.E.B. The mutual interaction between the cavities and the I.R.E.B. will cause the generation of equally spaced rings of electrons.

The rings of electrons will be allowed to propagate through a rippled magnetic field. Charge particles will be injected from the end of the system (counter stream) and will be emerged through a hole at the cathode.

We hope to achieve an electric field of the order of 10 MV/m and accelerate electrons protons and heavy ions.

References

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3. C. L. Olson, Phys. of Fluids 18, 585 (1975) and Phys. of Fluids 18, 598 (1975).
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Figure Captions

Figure 1. An assembly of radially oscillating rings of electrons. This is a picture as seen in the rest frame of a bunched electron beam moving through a rippled magnetic field. The interaction of this system with ions is shown for three different times (from top to bottom).

Figure 2. Phase velocity of the forward and backward waves.

Figure 3. Schematics of the experiment.

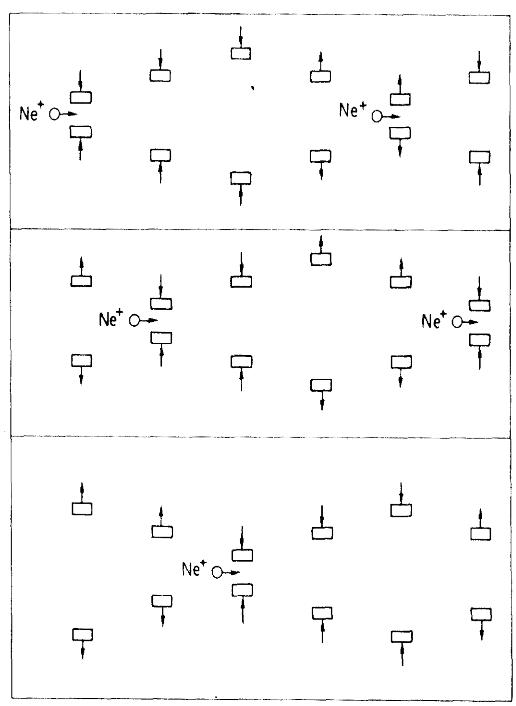

Figure 1.

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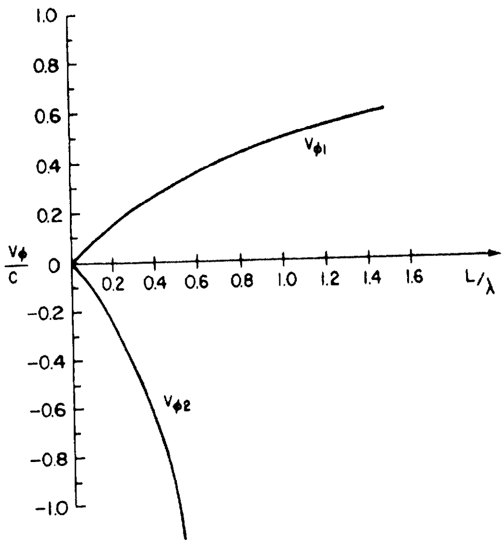

Figure 2.

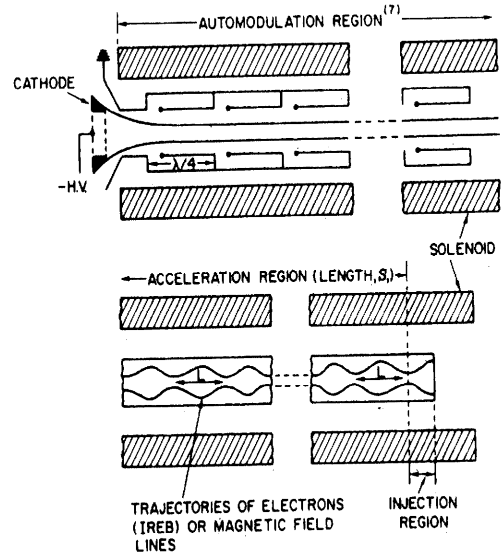

Figure 3.