TRANSVERSE ERA

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ABSTRACT

A report is given on theoretical and experimental work on a new type of collective heavy ion accelerator. Ion acceleration is produced by an electron ring which drifts perpendicularly to the external magnetic field.

1. WORKING PRINCIPLE

An electron ring can be formed in a field

$$B_z = B_o (1 - ky - s^2y^2)$$

with an average radius $\bar{r} = p/e\bar{B}$ and the center on the y=0 axis. If k=0 a closed orbit will exist. If $k \neq 0$ the equilibrium orbit will be no longer closed, but its center will shift in the x direction by a quantity $\Delta x = kr^2\pi$ for one revolution of the electrons. The ring speed can be so controlled by the k parameter, and in some cases ions captured in the potential well of the ring can be accelerated. Focusing forces are produced by the alternating gradient seen by the electrons due to the ky term and to an average field index produced by the s^2y^2 term. In the approximation $ky \ll 1$ and $s^2y^2 \ll 1$ the axial betatron frequency is

$$\nu_z^2 = \bar{r}_o^{-2} (s^2 + k^2/2)$$

while $\nu_r = 1$. It should be noted that the ring drift speed depends on the electron energy. This fact can be exploited to produce klystron bunching of the orbits to achieve higher electron densities, i.e. if the last orbits are injected with higher energy they will move faster and bunch together with the first ones injected. Of course this bunching can be obtained only over short paths. The ring can be also stopped completely by a suitable perturbation (dependent on both x and y) which brings the radial frequency to $\nu_r < 1$. These features allow compression of the ring by pulsed magnetic field. When the speed of the center of curvature of the ring becomes relativistic, the picture of a "ring" is no more suitable, but the method can still be useful to produce controlled group velocities of strongly focused, fully relativistic electron beams.

2. ANEL 1

The model machines which are now in construction are called ANEL, from the italian translation of "Electron Cloud Accelerator". The ANEL 1 is a model of static field ERA. There will be no attempt to reach high electron energy and density, but the machine will be used mainly to study the injection, stability and ionization problems. The field shape is determined by the polepiece shaping with correcting coils to vary the drift speed as a function of x. The magnet is 50 cm long along the x direction, the useful height of the vacuum chamber is 20 mm, the maximum ring radius which can be accomodated is 5 cm. The injection energy will be initially 200 keV, while a 0.8 MeV injector is being built. The first injection experiments should start at the end of the 1971.

3. ANEL 2

The ANEL 2 is a device where the electron ring moves along a circular path, with a radius of approximately 20 cm. It is designed to study the feasibility of a "collective synchrotron", where the main guiding field is magnetic, but the electron collective field produces both focusing and accelerating forces. The main field is produced by a set of 4 pulsed coils. A stainless steel cylindrical vacuum vassel contains the pulsed coils and the injecting diode. The field shape on the ring orbit will be of the type:

$$B_z(r) = B_o\left[1 - k(r-r_o) - s^2(r-r_o)^2\right]$$

The parameter s can be changed by adjusting the distance between upper and lower coils, while k is controlled by the ratio of the current flowing in the inner to that flowing in the outer coil. Static external coils will help to produce the field required at injection. The pulsed coils will produce both the orbit compression and betatron acceleration. Klystron bunching and debunching will be studied by modulation of the injection voltage. The first injection tests are planned for 1972.