A coaxial high current electron beam accelerator design is discussed. A novel feature of this design is that it stores energy in a Marx-like circuit. After acceleration, the beam is focused between coaxial biconic conductors to a small cross section. The design incorporates features which have been discussed by others. A specific accelerator module design storing 70 kilojoules and capable of producing beam currents greater than a million amperes at 1 million volts is described. The principal advantage of this design is that its compact size will make possible multi-module machines which will have an output far exceeding anything thought practical today.

The predicted current limiting effect has been observed experimentally. However, strongly accelerated beams, such as those generated in present-day pulsed electron accelerators, are often subjected to electric fields in excess of 1 MV/cm. The analysis does not apply under these circumstances, as Lawson points out. Complex beam instabilities have nevertheless developed in such devices, even during the relatively short time duration of the pulse (typically, less than 100 ns).

The most common instability has been self-magnetic con- 

The PULSITRON design concept circumvents these problems, and is now described.

A One-MeV, One-Ohm Accelerator Design

The accelerator system shown in Figure 1 is a synthesis of ideas put forward during the past decade by several independent workers and groups. First, the concept of guiding a drifting electron stream around a central current-return conductor was suggested by Mr. J. C. Martin of the AWRE in 1966. He proposed this arrangement to circumvent Lawson's critical current limit. The PULSITRON utilizes this concept, providing a return current path inside the electron stream. This stream is accelerated in the form of a hollow, cylindrical beam. The inner current return path is provided via a low-inductance array of capacitors, which stores half of the accelerating energy and delivers it to the surrounding beam. Secondly, in 1968, experiments by Yonas at Physics International and Rostoker at Cornell showed that the current limit could be overcome in special circumstances. A hollow beam propagating mode similar in some respects to that proposed by Rostoker has been incorporated in the PULSITRON design. Third, the concept of accelerating a drifting electron stream by passing it along the axis of a string of series Blumlein pulse generators was proposed by Hartwig at the Lawrence Radiation Laboratory in early 1968. Hartwig intended this structure for synchronous acceleration of electron rings. However, the PULSITRON concept used his basic "distributed" accelerator idea as a pulsed beam accelerator, for beam pulse durations in the 10 to 200 ns range.

The experiments of Yonas and others at Physics International have shown that beams exceeding the Lawson current limit could be guided in cylindrical pipes, which would be electrically insulated from the energy store and the diode and switching structures. The PULSITRON concept uses these data as a basis for proposing to guide the hollow beam between two converging coaxial metal cones, to achieve a large gain in power density. The authors of this paper have performed an equilibrium and stability analysis of a beam in this configuration, concluding that stable propagation should be possible in such a guide structure. If an axial magnetic field is applied to the guide, stable propagation is even more certain.

The operating sequence of the accelerator shown in Figure 1 is as follows. First, between adjacent conducting rings in the accelerator column, energy storage capacitors are charged. Each such capacitor comprises a series connection of two equal sub-capacitors, as shown in Figure 2. These sub-capacitors are oppositely charged so that no net potential difference appears between adjacent rings in the column. A low-energy Marx generator traverses the column along its axis and provides triggering impulses to a set of spark gaps as shown in Figure 2. When these spark gaps are triggered, one of the two sub-capacitors in each pair between the adjacent rings is polarity. Ten capacitor sections are shown in Figure 1, and 20 series sub-capacitors, each charged to 50 kV, are included in these ten sections. When the reversed voltage is complete, 100 kV potential difference appears between adjacent rings in the accelerator.
A one-MeV, one-ohm PULSITRON accelerator.

Figure 1

When the beam has traversed the column, it has achieved its full 1 MeV energy and is injected into the converging-cone beam guide for compression to higher power density.

As the beam accelerates down the column, equal return currents are induced in the inner and outer columns of energy storage capacitors. This is easily shown to be a condition of stable equilibrium. This circumstance is sketched in Figure 3. Performing an analysis along the lines of Lawson for this case shows that the new limiting current is given by

$$I_{\text{MAX}} = \frac{34000 \ V \sqrt{V+1/v}}{2b-b-a}$$  (3)

The limiting current indicated by equation (2) for a one-MeV beam is independent of beam dimensions, and is approximately 48 kA. However, the current given by (3) does depend on beam geometry. For the column dimensions indicated in Figure 1, this current exceeds two MA.

The inductive limitations encountered in "discrete" accelerator systems are largely circumvented in the PULSITRON since the volume of magnetic field external to the beam, which represents the beam inductance, can be made quite small in the accelerating column. This is a consequence of the low electric field at which the column operates; the storage capacitors can be moved quite close to the beam trajectory, since the column insulator geometry is non-critical.

A schematic diagram of PULSITRON accelerator.

Figure 2

Hollow beam with equal inner and outer return currents.

Figure 3

References