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ELECTRON DIODES AND CAVITY DESIGN FOR THE NEW 4-MeV INJECTOR* OF THE RECIRCULATING LINEAR ACCELERATOR (RLA)

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Abstract

We have designed and constructed four types of electron-beam diodes for the new 4-MV RLA injector: a non-immersed foilless diode, a magnetically immersed foilless diode, a foil diode and an ion-focused foilless diode. They are tailored to fit the new injector cavity. The design goals were to produce high quality 10-kA to 20-kA electron beams with a $\beta_\perp$ smaller than 0.2 and a beam radius of the order of 2 cm. These beams will be matched to the RLA IFR channel so $\beta_\perp$ must be equal to or smaller than the square root of the ratio of the beam current versus Alfven current for $f_e = 1$. A reentrant anode geometry was selected for the injector cavity design, because it offers substantial savings on the required amount of feromagnetic cores. The inner radius of the outside shell, now only 30 cm, would have been twice as large (60 cm) if a coaxial non-reentrant geometry had been adopted. The shape of the anode and cathode electrodes were carefully selected to minimize the electric field stresses. The field stresses on the inner surface of the outer shell do not exceed 200 kV/cm.

Introduction

Figure 1 is a schematic diagram of the Sandia Laboratories recirculating linac (RLA). The focusing of the intense relativistic electron beam (IREB) is accomplished with the aid of an ion focusing channel (IFR). The plasma channel is generated by the ionization of 0.1 to 0.4-mTorr argon or xenon gas. The usual Sandia technique of low-energy electron-beam (LEEB) ionization[1] is utilized to form the plasma column. Figure 1 depicts a closed racetrack; however, an open-ended spiral configuration[2] is as easy to implement, and it is being studied in parallel with the racetrack.

In the recirculating experiments reported up to now we have utilized two IREB injectors; a 1.3-MV Radial Isolated Blumlein (RIB) and the 4-MV IBEX accelerator. Both injectors have the shortcoming of a triangular voltage wave form with a very small flat top (~ 10 ns). This makes the design and operation of the electron diode sources difficult and the matching of the produced beam to the transport and injection system inefficient[3]. In addition, since the beam erosion in the IFR channel is dependent, the remaining beam pulse length following the first recirculation would be very short.

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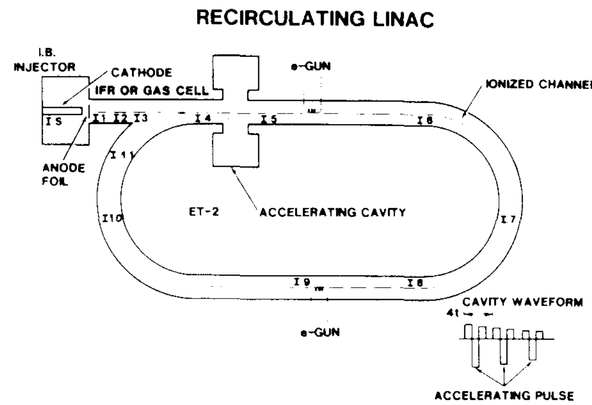

Fig. 1: Schematic diagram of the RLA. Closed racetrack channel configuration.

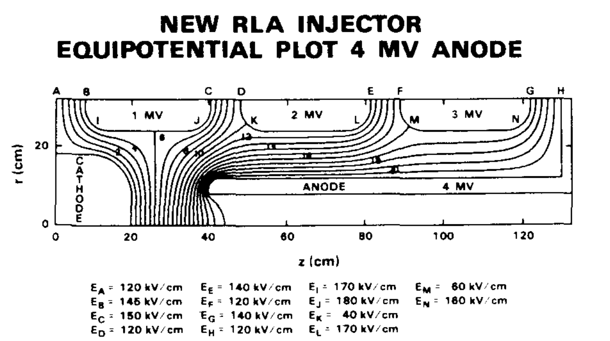

Fig. 2: The new 4-MV RLA injector cavity design and equipotential plots. The magnetically non-immersed foilless diode geometry is also shown.

A new 4-MV injector which produces a longer duration (40 ns FWHM) voltage pulse with almost rectangular shape (25 ns full width at 90% peak) is currently being constructed. Figure 2 shows a drawing of the new injector cavity. Four series-stacked, 1-MV ferro-magnetically isolated cavities provide the voltage waveform of Figure 3 at the A-K gap of the electron beam diode. MAGIC PIC CODE[4] was utilized to calculate the voltage waveform at the diode. The timing and voltage of each of the four feeds was estimated using several network solver code models. A number of 4-MV electron diodes were designed to fit the new injector and will be discussed in this paper.

Electron Diode Sources for the 4-MV Injector.

a. Non-Immersed Foilless Diode[3]:

This diode is our best choice because it produces the lowest temperature electron beams which can be magnetically transported in a vacuum channel with minimum losses or beam quality deterioration. It operates with minimum gas load release from the cathode and large (~ 20cm) A-K gap. However, in order to obtain good beam quality and transport, fine tuning of the solenoidal coils and voltage pulse with substantial flat top is required. Figure 2 shows the accelerating cavity fitted with the non-immersed foilless diode. The electrode surface shapes and the location of the A-K gap are selected in a way to minimize the field stresses on the electrodes and keep them below 200kV/cm.

The electron emitting area of the cathode surface is defined by a layer of felt cloth. The emitting threshold for felt is of the order of 60 kV/cm. Figure 4 shows the electron trajectories obtained with TRAJ[5] code.

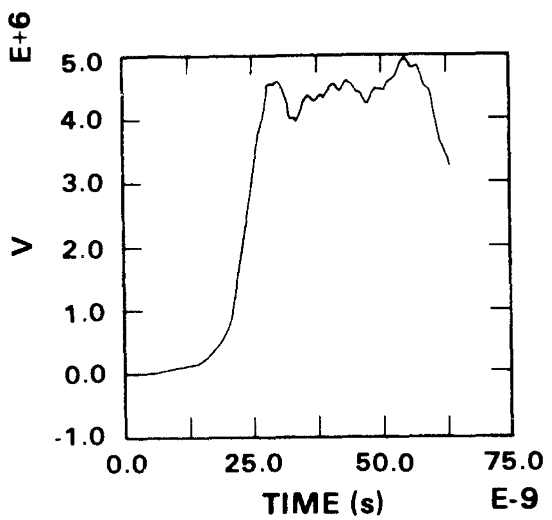

Fig. 3: MAGIC calculated output voltage wave form of the new injector.

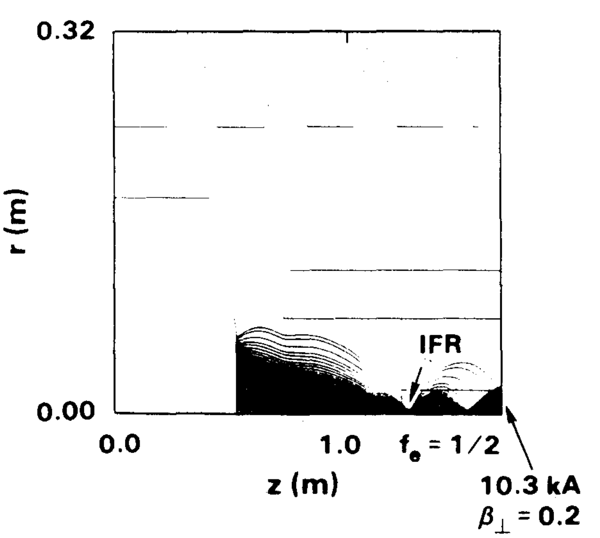

Fig. 4: Electron trajectories for a 4-MV, 10-kA beam.

b. Magnetically Immersed Foilless Diode.

Figure 5 shows a schematic diagram of the hardware accommodating both an immersed foilless diode (solenoidal coil on) and a non-immersed foil diode (solenoid off). The magnetically immersed foilless diode produces (Figure 6) a relatively low temperature beam. The required large magnetic field makes it somewhat difficult to match the beam to the IFR channel. However, we have designed magnetic flux excluders which minimize plasma column deterioration at the injection point. Figure 6 shows an electron map of the magnetically immersed foilless diode. A 1.6mm radius cathode tip produces 10-15 kA electron beams with similar emittances to the non-immersed foilless diode. Because of the small cathode radius the contribution after extraction from the magnetic field to the total beam transverse velocity $\beta_\perp$ of the canonial angular momentum is small.

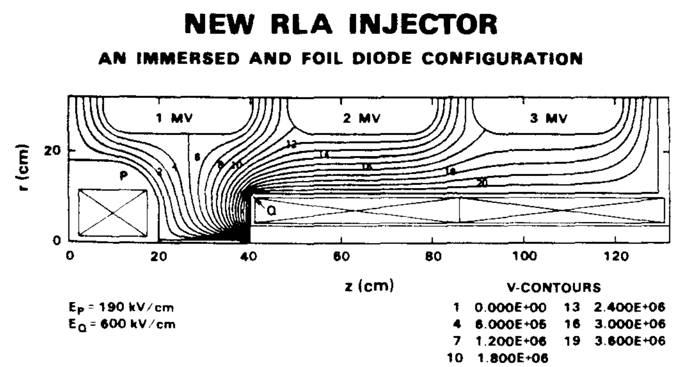

Fig. 5: Schematic diagram showing how the same hardware can accommodate two types of diodes: magnetically immersed and foil diodes.

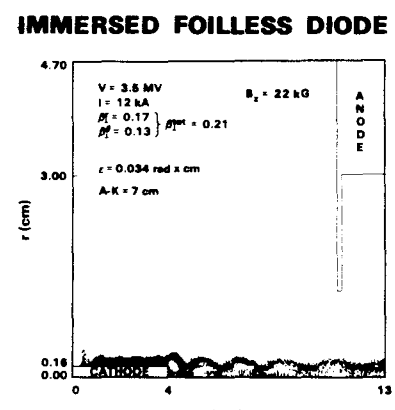

Fig. 6: The magnetically immersed foilless diode produces a low emittance beam.

c. Apertured Foil Diode.

By properly aperturing the anode foil (Figure 7) we can select a fairly cold, 10-15 kA beam. Fortunately the current coming from the shank does not mix with the central part of the beam which has a very low transverse velocity component and can be apertured easily.

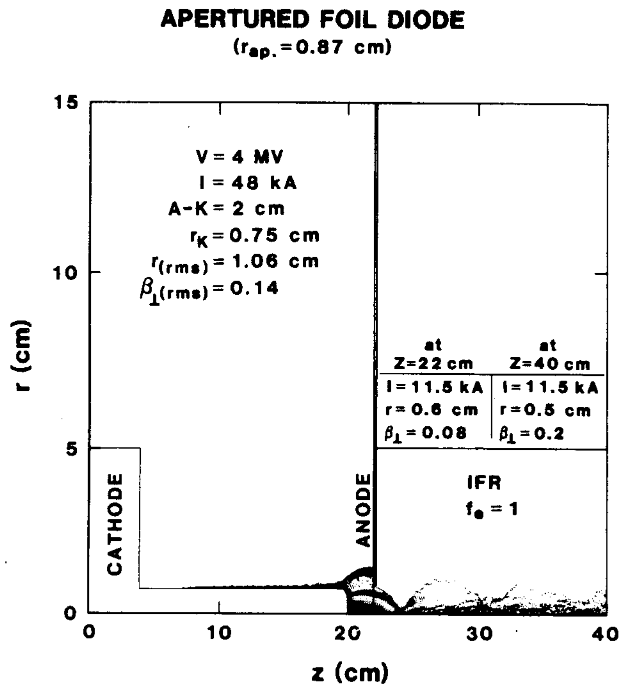

Fig. 7: 4-MV foil diode electron map.

d. Ion Focused Foilless Electron Diode[6]

This diode is similar to the apertured foil diode but without the anode foil, and it has a smaller bore aperture and larger A-K gap. We recently postulated the mechanism of operation of this diode and experimentally verified it with the IBEX accelerator. At the beginning of the pulse the electron beam diverges and hits the aperture, depositing enough energy to create a surface plasma sheathe. Positive ions from the sheathe are accelerated towards the cathode, providing space charge neutralization and focusing the electron beam into the aperture. A 700 A ion current (Figure 8) moving in the direction opposite to the beam can focus 15 kA of the electron beam into the 3 cm aperture.

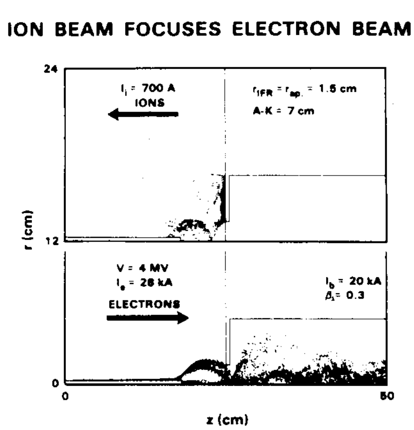

Fig. 8: Foilless apertured diode focused with the positive ions emitted from the anode plasma sheathe

Conclusions

Four types of electron diode sources have been designed and constructed to fit our new 4-MV injector. They produce low temperature and low emittance electron beams that can be injected and propagated inside the IFR channel with high transport efficiency. The injector assembly is approaching completion, and the first beam tests are projected for October 1990.

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