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PRODUCTION AND FOCUSING OF A HIGH-POWER RELATIVISTIC ANNULAR ELECTRON BEAM

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ABSTRACT

A new electron beam injection gun has been developed to produce pulsed relativistic electron beams with a power of 10^{10} watts. The annular shaped beam propagates in a magnetic field with efficiencies approaching 100% and its radius may be controlled by the magnetic field configuration.

Extensive work has been done in the last thirty years in developing electron guns of various designs [1-3]. In the last few years a new type of electron gun has been developed[4] which can produce a pulsed beam of relativistic electrons with power between $10^9 - 10^{12}$ Watts [5-7]. This beam is produced by applying a high-voltage pulse to a low-resistance planar diode employing a thin metallic foil or a screen as an accelerating anode through which the beam passes. Detailed descriptions of such guns are given elsewhere [4-7].

From previous experiments in the authors' laboratory it has been found that this gun configuration has the following disadvantages:

1. Destruction of the anode foil by the passing electron beam.
2. Scattering of electrons due to collisions with the foil atoms.
3. Emission of gas from the foil causing arcing in the diode region and contamination of the system.

These disadvantages, as well as lack of experience in the handling and focusing of high-current beams, have limited the application of these relativistic beams. (Some of these applications have been discussed by Tsytovitch [8]).

We describe here a diode which does not employ a thin foil as an accelerating anode. Instead a magnetic field is used to guide the electrons from the cathode-anode region into the drift tube and to focus them in the drift region.

Fig. 1 is a schematic diagram of the experimental arrangement. The diode consists of a conical cathode, with roughened area to enhance field emission, and an anode in the shape of a trumcated-cone. The configuration has some resemblance to the so-called magnetron injection gun [2]. A pulsed magnetic field with a rise time of the order of milliseconds is first applied to the system. The position of the diode relative to the solenoid, and the design of the cathode-anode structure ensure that the magnetic lines of force are roughly parallel to the cathode surface and that the diffusion time of the magnetic field to the cathode is longer than the rise time of the pulsed magnetic field. At peak magnetic field, a high-voltage pulse, of the order of 700 KV for 50 n. sec., is applied to the diode. Electrons are emitted from the cathode and guided by the magnetic field to the drift region.

The diode and the drift tube are pumped to a common pressure of $\sim 5 \times 10^{-4}$ torr.

The diagnostics applied to the system consist of:

1. 5×10^{-2}-ohm current shunt.
2. Resistive voltage divider across the diode.
3. Calorimeter at the end of the drift tube.
4. Voltage divider monitoring the applied voltage.
5. Time-integrated photograph of light coming from the drift tube.

The results obtained show that an annular electron beam, with radius r_e, propagates in the drift tube. We have found that r_e is related to the radius of the cathode, r_c, and to the magnetic field via the following relation: [3]

$$r_e = r_c \left(\frac{B_c}{B}\right)^{\frac{1}{2}} \tag{1}$$

Where: B_c is the magnetic field near the cathode and B is the magnetic field in the drift tube. The verification of Eq. (1) comes from the damage pattern on a copper plate at the end of the drift tube (See Fig. 2).

In Fig. 3 a typical diode voltage and current pulse are shown. Table 1 and **Fig.** 4 summarize the results for a 4-inch-diameter cathode.

The transmission of energy along the drift tube improves with high magnetic field and approaches 90% when $B = 13$ kilogauss. Fig. 5 shows a photograph of the integrated light from the drift region.

The reproducability of the results are excellent and the beam is always confined to the same annular dimension as long as one keeps r_c and $\frac{B_c}{B}$ constant.

Table 1: Results obtained with a 4-inch-diameter cathode

Shot No.	Peak** Mag. Field (K-Gauss)	V^{*}_{Diode} (peak) (KV)	I_{Diode} (peak) (KA)	Energy At Calorimeter (Joules)	Peak Power Watts x 10^9 (VI)
7	6.7	678	16.6	236	11.1
8	10.0	722	15.3	264	11.0
9	3.3	565	19.1	187	10.8
10	1.8	480	29.8	98	***
11	13.3	735	14.0	288	10.3

* Inductive overshoot during first 10 nanoseconds of voltage pulse is neglected.

** Measured at center of solenoidal coil.

*** Probable arc due to electron Larmor radii approaching the anode-cathode spacing at the low magnetic field.

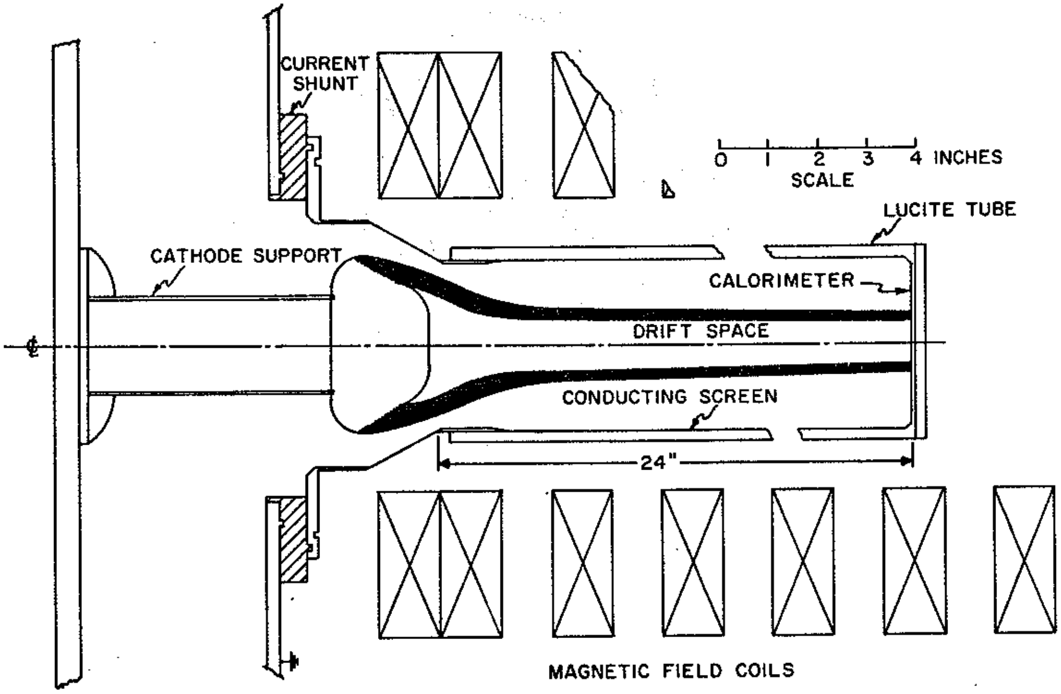

Figure 1 Experimental Schematic (Darkened area represents electron beam flow).

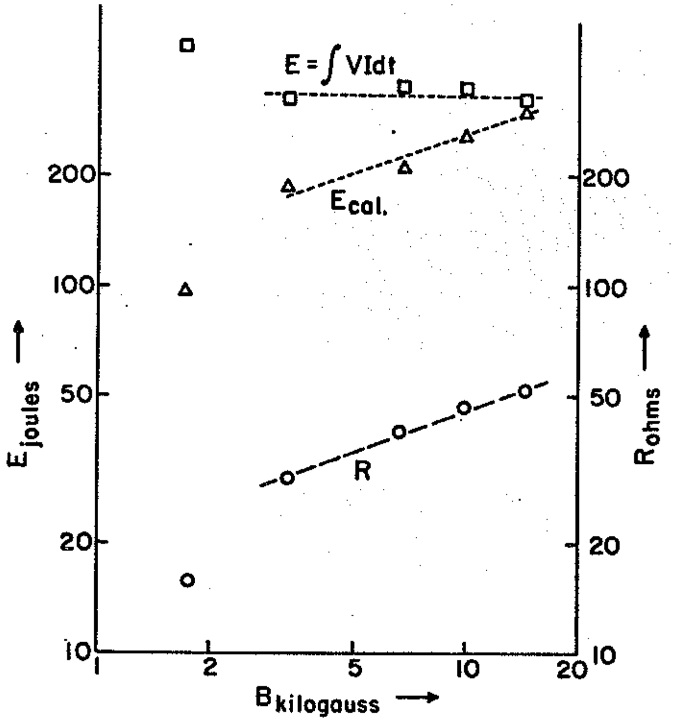

Figure 4 Diode impedance, R, Energy received by calorimeter, Ecal and energy computed from voltage and current traces E, vs. applied magnetic field, B.

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