XV. RELATIVISTIC BEAMS*

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

The use of intense electron beams in plasma research is a relatively new field of very considerable interest in several areas of research. This new program at the Research Laboratory of Electronics has been made possible by a long-term loan of an EG&G facility. The past year has been spent in assembling the unit, building the drift chamber for the beam and designing the diagnostic tools that will be used initially. Preparations for the initial experiment have been completed, and production of a 100-kV, 35-kVA, electron beam lasting 30 ns has begun. The system has three parts: a Marx generator, a concentric cylinder capacitor and a field-emission diode. The Marx generator, when triggered, delivers up to 500 J at up to 400 kV to the concentric cylindrical, water-filled capacitor at 10^8 W. When the voltage on the water capacitor rises sufficiently high, a precalibrated solid dielectric switch breaks and connects the diode to the water capacitor. The water capacitor then acts as a transmission line applying a potential of up to 200 kV for 30 ns to the diode. Electrons field-emitted from the cathode are accelerated and penetrate the anode (which is a very thin film) to emerge as a 10^{10} W beam in a drifting, field-free state.

Our initial research objective concerns the interaction of the beam with another plasma. In particular, we wish to understand the various methods by which the beam deposits some or all of its energy in the plasma and thus heats the ionized medium. The coupling involves collective (turbulent) interactions of waves and particles, but the detailed nature of the instabilities is still unknown.

G. Bekefi

A. PRELIMINARY DIAGNOSTICS OF THE COAXIAL GENERATOR SYSTEM COGEN III

Investigation with the Cogen III System of a mildly relativistic high-intensity electron beam injected into a neutral gas (helium) continues.[1] Aside from the ever-present maintenance problems, our attention has focused on observation of the Marx generator discharge characteristics, "stabbed-switch" techniques, "witness-plate" damage by the beam, and some preliminary spectra.

The analysis of Marx generator beam production[1] has been extended to account for

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the transmission-line nature of the water dielectric capacitor load of the Marx generator. Measurements of the Marx generator discharge current and of the voltage rise on the load capacitor have been made. Using the time-integrated output from a dB/dt probe (a two-turn coil, of 1 in. diameter) situated near the second-stage capacitor of the Marx, the discharge current was found to have the expected shape and duration. This is shown in Fig. XV-1. The long-period oscillations represent ringing in the Marx generator; the short-period oscillations represent ringing of the load capacitor (which has a small but finite inductance). The voltage rise on the load capacitor was measured by means of a capacitive voltage divider probe with a carbon-resistor voltage divider, a 50-ft length of coaxial cable and a 6-dB attenuator producing a net reduction ratio of 8000:1. When the voltage rises sufficiently to break down the "stabbed switch," the voltage drops from the peak, V_p, to $2.5\ V_p/(2.5+Z_{diode})$. This drop can be seen in Fig. XV-2. Since the squarest pulse on the diode results when the diode impedance, Z_{diode}, matches the water capacitor impedance (2.5 Ω), this diagnostic method is useful in determining both the

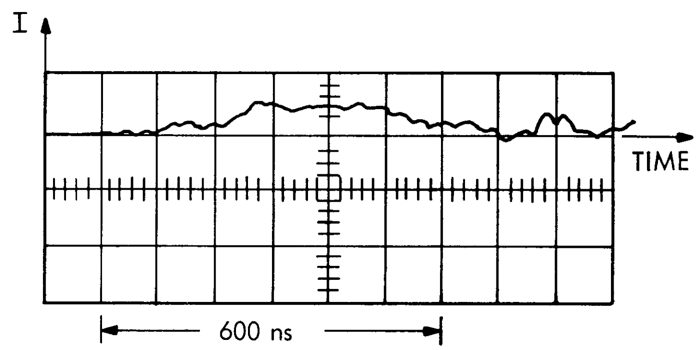

Fig. XV-1. Marx generator discharge current plotted as a function of time.

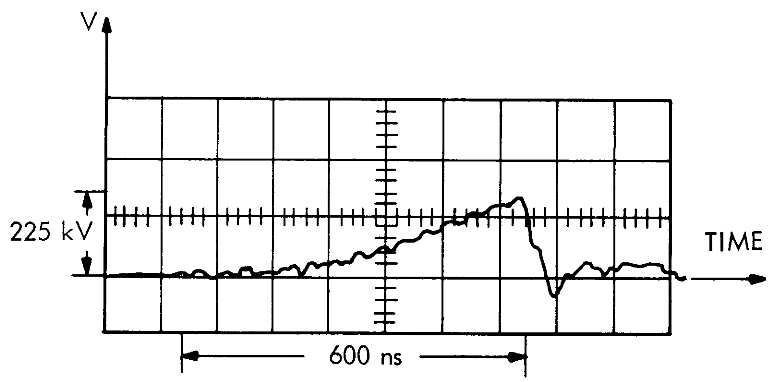

Fig. XV-2. Voltage on load capacitor plotted as a function of time.

voltage and mean impedance of the diode.

Because the peak voltage depends crucially on the reliability by which the breakdown of the "stabbed switch" can be calibrated, the manufacture of the switch deserves much consideration. At present we are applying techniques learned at a meeting.[2] The switches are two (1/16 in.) layers of low-density polyethylene sheet with approximately 50 closely spaced holes, typically 25 mil deep, near the center of each sheet. The holes are made by a sewing-machine needle and are then covered with a sheet of aluminum foil. In operation, when a spark channel forms in one layer, the other layer becomes highly overvolted, and breaks down in more than one place. Having many channels lowers the inductance.

As the electrons leave the field-emission vacuum diode and enter the gas-filled drift tube they damage the anode foil (aluminized Mylar). This damage pattern is an indication of current distribution. (The anode foil acts as a "witness plate.") We find that emission is strongest at the edge of our cylindrical disk cathode. This is consistent with the expected high-fringing fields in this region. The beam is often filamentary, and probably of very high current density, since most of the damage occupies an area much smaller (~ 3 cm^2) than the cathode area.

We use a 1.5 m Wadsworth mounting spectrograph to observe the plasma resulting from the beam penetration of the helium target gas. Because of the long optical path of the experimental arrangement and the short duration of the light emission, as many as 6 shots are required to record high-quality spectra. (The turn-around time between shots is approximately 1 hour.) Spectra have been obtained for gas pressures of approximately 1 Torr using slit widths of 50 μm. This corresponds to an instrumental width of approximately 1/2 Å. Thus either an unfolding of the density-produced linewidths or operation at higher pressures may be necessary.

We plan to refine the measurement of the diode voltage, expand "witness-plate" techniques, and begin x-ray self-photography. The spectroscopic analysis continues.

J. Golden

References

1. Quarterly Progress Report No. 103, Research Laboratory of Electronics, M.I.T., October 15, 1971, pp. 103-107.

2. J. Rome, Oak Ridge National Laboratory, and L. Bradley, Sandia Corporation, American Physical Society, Division of Plasma Physics, Meeting, Madison, Wisconsin, November 15-18, 1971.