Electron Beam Generation Using a Ferroelectric Cathode

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***Abstract*— Data is presented on the production of electron beams from a ferroelectric cathode at voltages of order 0.5 MV and current densities of order 100 A/cm^2. In comparison with data at lower voltages, the beam current scales as the three-halves-power of the voltage. An interpretation of the voltage dependent scaling, based on the coupling of electrostatic energy from the ferroelectric to the gun, is presented.**

***Index Terms*—Cathode, electron beam, electron gun, ferroelectric.**

I. Introduction

FERROELECTRIC cathodes have been extensively studied over the last several years [1]–[4] in an attempt to develop a means of emitting a high current electron beam from a robust room temperature cathode for high power microwave generation. Most of the research has focussed on the following two types of cathode.

1) PLZT anti-ferroelectric compositions e.g., 4/95/5 in which emission occurs when an applied electric field causes the material to switch from the anti-ferroelectric state to the ferroelectric state. Switching occurs when an electric field of order 15–25 kV/cm is applied across the PLZT [5]. Recent work [6] has suggested that higher fields, of order 52 kV/cm, are required to initiate the electron emission.
2) PZT and PLZT ferroelectric compositions in which the emission is triggered by "switching" around a hysteresis loop. Fields of order 10 kV/cm, typically applied across a 1-mm thick sample, result in the electron emission [7]–[10].

In this paper we present data obtained with a PZT cathode in an electron gun configuration which is used to generate an electron beam at energies in the range 200–550 keV, with a beam current of up to 350 A in pulses having a duration in excess of 200 ns. These results extend emission characteristics previously reported by more than one order of magnitude in voltage and by a factor of three in the current density. A positive polarity trigger pulse is used to initiate emission from the ferroelectric. In this case, the electron emission is from the metallic grid and not from the screening charge on the surface of the ferroelectric. The data also presents the first reported results applicable to electron gun design. The planned application of the source is to high power microwave generation using a TWT amplifier in X and Ka bands. In the following sections we describe the experimental arrangement used for this work, the results obtained, and their interpretation.

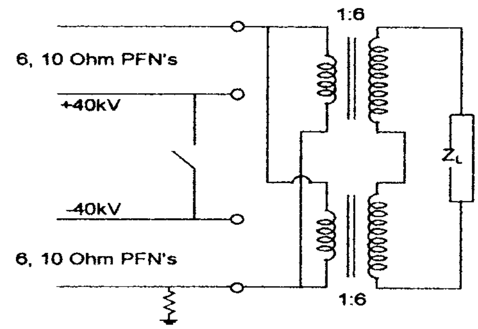

Fig. 1. Primary pulse line configuration and switching.

II. Experimental Configuration

The electron gun used in this work employs a pulse transformer system capable of generating a 500-kV, 200-A, 250-ns electron beam and uses a ferroelectric cathode as the electron source. It is designed for use in high power microwave experiments. The system operates at a repetition rate of about 0.1 Hz which is limited by the available power supplies. Vacuum levels are presently in the vicinity of $5 \cdot 10^{-6}$ torr.

We present a brief description of the modulator and beam generator used in this work. The modulator, which has been recently developed for this application, has been described previously in the Particle Accelerator Conference Proceedings [11], so the description given here will only summarize the system.

The primary power source consists of 12 transmission lines, each having an impedance of about 10 Ω. Half of the lines are positively charged and half negatively to a voltage in the range 20–35 kV. The lines are switched at the load location as indicated in Fig. 1.

Each line uses nine 3.6-nF capacitors in a transmission line arrangement. On closing the switch, a voltage is developed across the load with a rise time which is independent of

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