DOUBLE-SIDED RELATIVISTIC MAGNETRON

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Abstract

A new scheme of a symmetrically powered relativistic magnetron and several methods of localized electron flow forming in an interaction region are proposed to increase the efficiency of relativistic magnetrons (RM).

As was reported for many experiments, the efficiency of RM is about 10 — 30% and considerably lower than that of $\geq$ 70% for the classic magnetrons. A very important reason is the effect of nonsymmetric feeding of power from one side of a magnetron, which is typical for experiments. One-sided powering leads to the axial drift of electrons, to the transformation of transverse velocities of electrons to a longitudinal one and to the generation of a parasitic electron beam which does not take part in energy exchange between electrons and waves at all.

A special driver was designed for double-sided powering of RM. The proposed system is compact, rigid and capable of reliable operation at high repetition rates, which is advantageous for many applications.

Several smooth-bore magnetrons were tested by means of computer simulations using PIC code KARAT. The results showed a difference between the dynamics of electron flow for one- and two-sided power feeding of the structure under test. It was shown that all electrons emitted from the cathode are captured inside the interaction region under the condition of proper choice of the electrostatic and/or external magnetic field distributions. This situation is practically impossible for a one-sided magnetron.

Design of a driver and computer simulation results are presented.

1 INTRODUCTION

The high efficiency of "ordinary" classic magnetrons has been achieved as a result of intense experimental and theoretical investigations [1]. Relativistic magnetrons, in spite of a 20-year history of development, are in an "initial" stage. The main purpose of experimental investigations was the demonstration of achievement of extremely high RF-power [2], [3]. Note that most results were obtained using high-current accelerators in existence as drivers, but not specialized drivers.

Actually RM generators were adapted for use with those drivers and looked like an additional part to alien drivers. However, achieved levels of pulsed power exceeding several GW are attractive, though the efficiency of RM is low as compared with low voltage classic magnetrons.

It appears that one way of increasing the efficiency of RM is symmetric powering of RM that suppresses parasitic beam current in the longitudinal direction, i.e., the construction of a specialized driver for this purpose.

2 COMPUTER SIMULATION

The main idea of symmetric powering is rather clear and will not be discussed here. Calculations of beam dynamics inside a simple model of a smooth-bore RM were carried out with 2.5-D electromagnetic PIC-code KARAT [4]. In Fig. 1 configurations of electron flows inside a coaxial diode with an insertion are presented under conditions of symmetric and nonsymmetric powering. In the latter case a TEM-wave is launched through the left side of the diode. The diode is embedded in a longitudinal magnetic field of 8 kGs. A maximum voltage of 500 kV and maximum emission current of 10 kA were taken in the calculations.

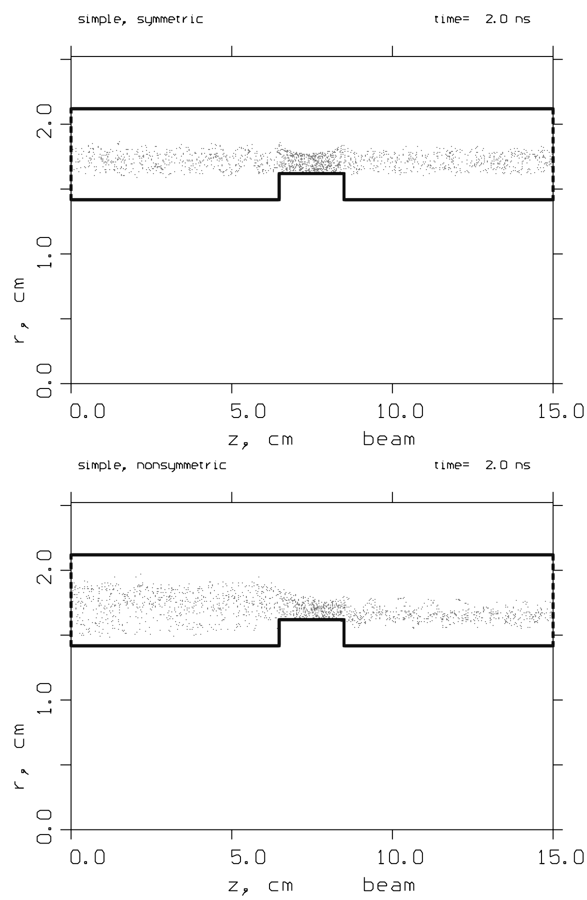

Figure 1: Configurations of electron flows for double-sided (above) and one-sided powering (below).

Fig. 2 illustrates two possible methods of localizing electron flow within the interaction region: use of symmetric

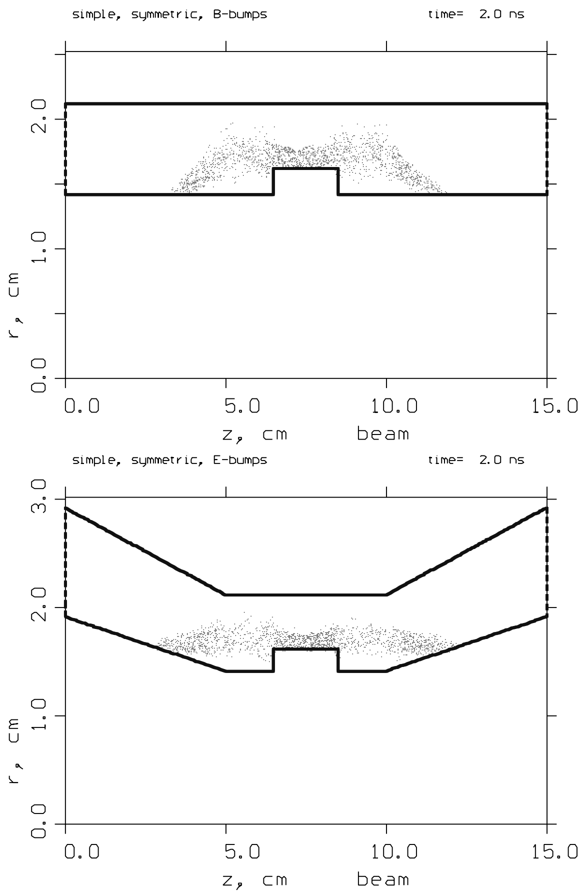

Figure 2: Configurations of electron flows for double-sided powering with magnetic bumps (above) and electrostatic bumps (below).

magnetic bumps or electrostatic mirrors on both sides of the diode, under condition of symmetric powering. In the latter case electrostatic mirrors are formed by curved coaxial electrodes embedded in a longitudinal magnetic field.

Variation of magnetic field distribution and/or form of electrodes permit to form a desirable geometry of electron flow. Comparison of characteristics of flows inside diodes with magnetic and electrostatic bumps shows that the scheme with electrostatic bumps is preferable for RM.

3 DRIVER

From our point of view a symmetric induction driver correspondes to a certain extent the idea of two-sided powering of RM. Fig. 3 shows the scheme of such a driver integrated with a magnetron. The driver consists of two identical sections of LIA (areas 1 and 2 in Fig.3) placed symmetrically relative to the magnetron (area 3) and connected with a magnetron by a common central electrode — the voltage adder. Both ends of the central electrode join to flanges which are at ground potential. The central part of the electrode performs as the RM cathode. Merits of the driver are the merits of LIA with a voltage adder. Such a

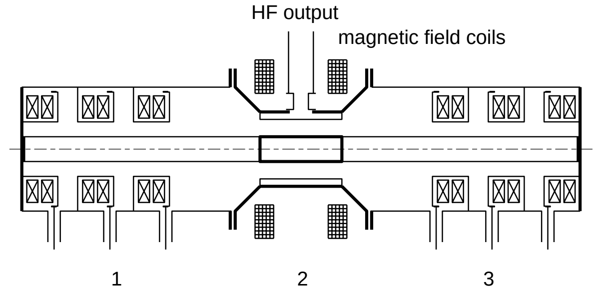

Figure 3: Schematic of a driver with a magnetron.

scheme are broadly used in modern high-current accelerators (HERMES-III, COBRA etc.).

RF-power is led out through slots in resonators of the magnetron to radial waveguides followed by short matching sections — transformers of impedance. This scheme has been successfully used in experiments with pulsed high power RM [2], [3].

4 MELF PROJECT

To realize the idea of two-sided powering of RM we have developed a project of an multipurpose experimental laboratory facility (MELF) with the following parameters:

- maximum voltage of 250 kV on a load of 25 — 50 Ohm;
- pulse duration of 80 ns;
- 5 induction cells per section;
- maximum voltage of 50 kV for exciting induction cell.

4.1 Sections of LIA

Fig. 4 shows the design of a LIA section. The section con-

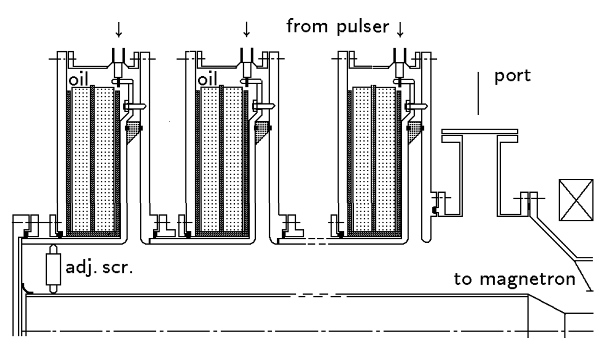

Figure 4: Section of LIA.

sists of 5 inductions cells, a short transition section to a magnetron region and a mechanism for fastening and aligning the voltage adder.

Each inductor cell contains two high quality magnetic cores made of metglass with a polymer interlayer insulation of 12-cm inner diameter, 22-cm external diameter and

2-cm thickness. With the project parameters given above maximum alteration of magnetic induction is as little as 2.4 T.

Cores and high voltage inputs are embedded in transformer oil. All metallic parts of the inductor cell are made of aluminium. Parts of the transition section to the magnetron region are made of stainless steel to reduce distortion of pulsed magnetic field.

4.2 High voltage generator

As the first step we plan to modify one of the existing modulators at the base of a water-insulated, coaxial pulse-forming line with a gas switch.

We have developed and later we are going to construct a new compact high voltage generator with a repetition rate of several Hz. The key elements of the generator are fast capacitors with internal circuits forming quasirectangular pulses of ns-duration. We have chosen the following parameters of industrially produced capacitor-shaper:

- 80-kV charge voltage;
- 1.7-Ohm impedance;
- 80-ns duration of output pulse;
- 28-nF overall capacitance.

Fig. 5 shows the scheme of the generator. This approach

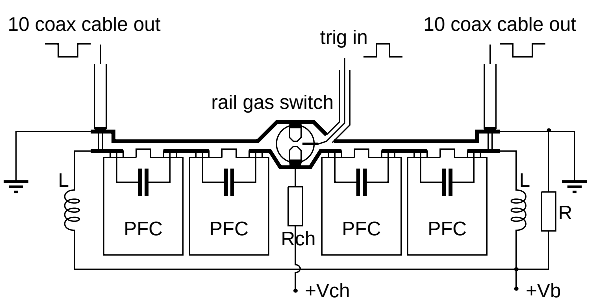

Figure 5: Scheme of high voltage generator.

simplifies the construction of generator and decreases its dimensions. Successful operation of a compact 400-kV generator was reported in [5].

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