Magnicon - High Power RF Source for TESLA.

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1 GENERAL

Modern accelerator projects demand increasing of the power and operating frequency from the RF sources, both in CW mode and long pulsed mode devices. One of these projects is TESLA - superconducting linear electron-positron collider for the energy of 500 GeV [1]. A complex like this requires 1264 klystrons for the power of 3.5 MW and the same quantity of ferrite circulators for the operating [1, 2]. It is evident that using of this great quantity of RF sources doesn't increase operational reliability and requires large capital costs.

Clearly that to decrease capital and operating costs it is necessary to increase power and efficiency of RF sources.

This paper describes an alternative RF source for TESLA - magnicon. Magnicon has been developed at the Budker Institute of Nuclear Physics and is a powerful amplifier with a circular deflection of the electron beam [3, 4]. Magnicon has its advantages: possibility to obtain the output power of 5-10 MW in CW mode and in long pulsed mode at the efficiency above 70%, high phase and amplitude stability. The possibility of operating with a non matched load without a circulator [3] is another good point of the magnicon because it allows to decrease capital costs of the TESLA-like complexes.

Results of the preliminary research of the magnicon for TESLA are given below.

Table 1:

Operating frequency	1300	MHz
Output power	10	MW
Pulse duration	2	ms
Repetition rate	10	Hz
Duty factor	2	%
Average RF power	200	kW
Beam voltage	250	kV
Beam current	51	A
Microperveance	0.4	
Peak power of beam	12.8	MW
Efficiency	0.76	
Gain	52	dB
RF drive power	70	W
Bandwidth (-1 dB)	~1	MHz
Total solenoids power requirements	9	kW
Maximal energy of electrons in collector	120	keV
Minimal energy of electrons in collector	20	keV

2 THE MAGNICON

The schematic design of magnicon and results of its preliminary optimization are given in Fig.1 and Table 1.

The behavior of the beam at the interaction with RF electric fields in the specific magnicon design is shown in Fig. 2.

The main technical solutions that have been approved on the first magnicon [3] are built into the presented magnicon design. The beam from the electron gun gets into the circular deflection system that consists of the input cavity and three passive cavities positioned inside the solenoid (the value and distribution of the axial magnetic field are shown in Fig. 1). The circular deflection of the beam in the cavities is realized by the transverse magnetic RF field of the TM_{110} wave travelling in azimuthal direction (Fig. 1). The drive cavity is excited by the external generator and deflects electrons to the small angle. Further increasing of the deflection angle up to 35-40° is provided by three passive cavities excited by the beam.

To prevent decreasing of the beam deflection angle while leaving the magnetic field of deflection system this field is abruptly limited by the magnetic shield.

Cylindrical output cavity is also placed inside the solenoid. There is a drift space between magnetic systems of the output cavity and deflection system in which electrons go away from the axis and increase the deflection angle up to 70-75° entering the magnetic field of the second solenoid and then release energy to the RF field during the process of interacting with the rotating TM_{110} wave.

The magnicon operating feature is that power output from the output cavity is realized through two identical couplers shifted up to the 90° in the azimuthal direction.

3 ELECTRON OPTIC SYSTEM

The electron beam is formed by the diode gun with dispenser spherical cathode (Fig. 3). The cathode diameter is 70 mm, sphere radius is 100 mm. A maximal current density on the cathode and electric field on the focusing electrode are no more than correspondingly 1.38 A/cm and 76 kV/cm. The electrostatic beam transverse area compression is 100:1. A low current density allows to expect a prolonged time of the cathode operating and relatively

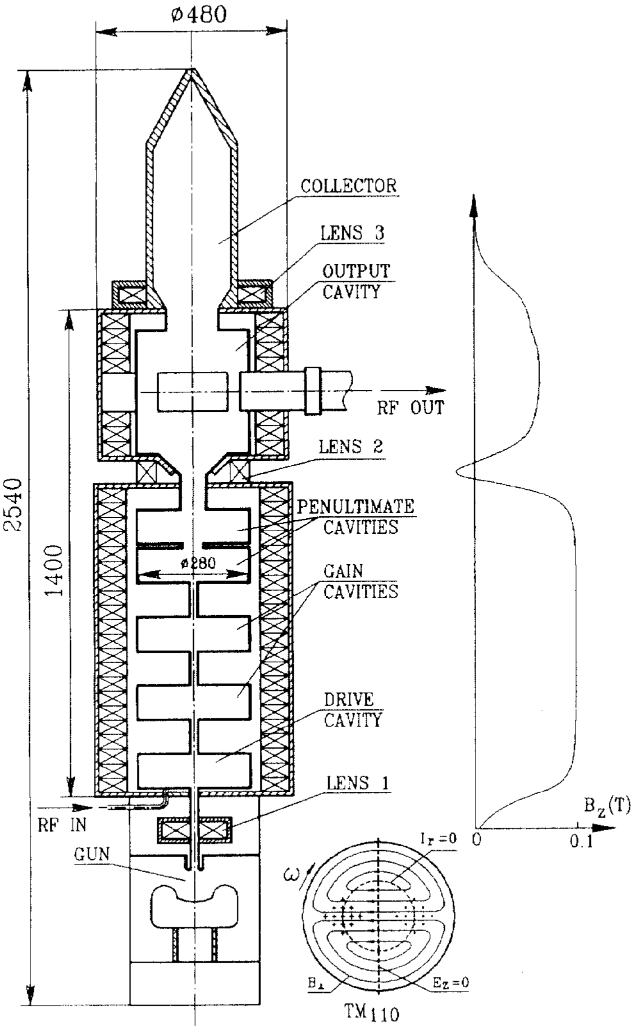

Figure 1: Sketch of the magnicon.

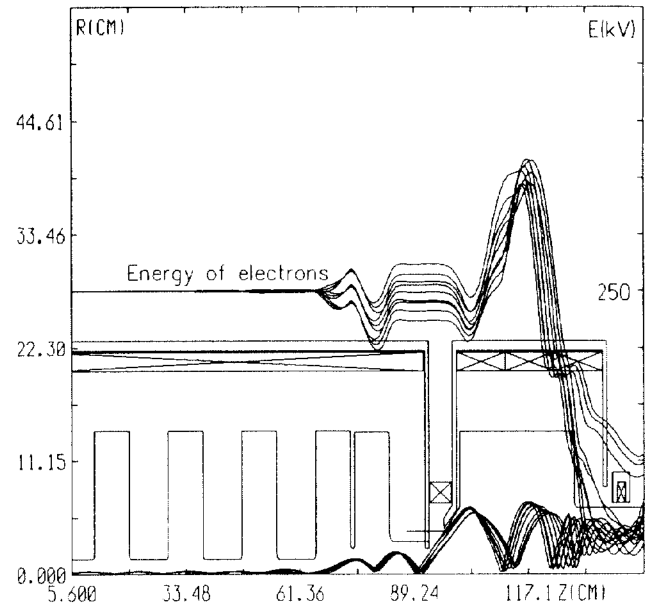

Figure 2: The beam dynamics in the magnicon

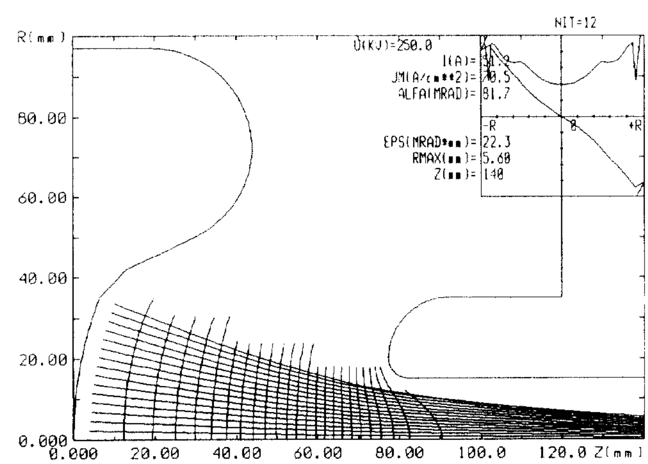

Figure 3: The electron trajectories in the gun

moderate electric field gives high reliability in CW mode.

A required distribution of the axial magnetic field is provided by the solenoids and magnetic lenses.

There are two main factors that define the electron efficiency of the magnicon - beam transverse size and electrons angle spread at the entrance of the output cavity magnetic system [3, 4]. The smaller is the beam size the smaller is the deflection angle spread of the particles and the higher is the interaction efficiency within the output cavity. This size is defined by the beam divergence by the action of space charge forces in the drift space. The drift space length in its turn depends on the deflection angle in the deflection system. For the design under consideration the optimal value of this deflection angle is 35-40^o. One can also decrease the beam size by using scalloped beam instead of Brillouin one in the deflection system. This decreases the transverse beam size at the entrance of the output cavity.

4 CAVITY SYSTEM

The cavity system of magnicon consists of deflection system cavities and output cavity. The deflection system cavities have practically equal longitudinal dimensions with the undisturbed transit angle about 180 ^{o} (85 mm). The particles acquires the biggest deflection angle in the penultimate cavity. It is assembled structurally of the two similar cavities coupled by the central hole in which TM_{110} modes are excited in the opposite phase. This deflection system design allows to achieve the deflection angles up to 40 ^{o} at moderate value of RF electric field on the cavity surface.

The longitudinal dimension of output cavity is 280 mm. This length provides a reasonably low value of surface electric RF field and small ohmic losses in cavity walls (no more than 3% of the overall RF power). The presence of two identical power outputs (an average power through each is 100 kW) expedites solving the window problem.

The magnicon gain optimization contains a choice of the passive cavities number, a distance between them as well as a choice of the biasing magnetic field value in the first solenoid in order to maximize the operating frequency band. As a result the scheme has been chosen with three passive cavities, distance between which is 95 mm at the magnetic field induction in solenoid of 0.097 T (that corresponds to the ratio between cyclotron an operating frequencies of 1.4). The frequency band of the device appears to be relatively narrow ($\approx$ 1 MHz) at the gain higher than 50 dB. However, the mutual detuning of three first cavities to 0.5 MHz allows to widen this band at a gain decreasing less than 5 dB. By this means we can expect to get a device band of 1.3 MHz at a -1 dB level (at the gain higher then 45 dB). The calculated parameters of the cavities are given in Table 2.

Table 2:

Number of the cavity	1	2	3	4	5
Maximal surface electric field (kV/cm)	0.32	1.5	6	49	61
Average power losses in the walls (kW)	0.0015	0.002	0.035	2.4	6

5 CONCLUSION

The preliminary computer analysis outlined above demonstrates a possibility to build the device with an output power at 10 MW and efficiency more than 70%. We hope to improve such device parameters as output power and efficiency at a more thorough research. Moreover, the cavities geometry optimization will allow to decrease RF fields.

6 REFERENCES

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