7GHz PULSED MAGNICON: STUDY AND NEW RESULTS

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Abstract

The report presents new experimental results obtained on 7 GHz pusled magnicon amplifier. In 1996, the following parameters were achieved: maximum output power of 46 MW, efficiency of 49%. We relate the further magnicon parameters improving with elimination of electromagnetic fields disturbing in the output cavity induced by the large coupling holes with the loads.

1 INTRODUCTION

7 GHz pulsed magnicon has been designed at INP as an alternative microwave power source for linear colliders. This device is the result of extended work on a new class of high power microwave sources development for accelerator application [1, 2, 3]. This class of microwave sources has been developed at Institute (INP) since 1967. The main difference of these devices from others is the method of beam modulation which is provided by the relativistic electron beam circular deflection. This paper presents the new experimental results and the study of the magnicon operation features.

2 THE MAGNICON DESIGN

A diagram of the experimental magnicon system is shown in Fig.1. The magnicon consists of: an electron source (diode gun), RF and magnetic systems, and collector. RF system cosists of the deflection system for beam modulation and output cavity for conversion of the beam energy into the RF oscillations. The tube is an amplifier operating in frequency-doubling mode. So in all deflection cavities the circular-polarized TM_{110} mode is excited at the frequency of 3.5 GHz. In the output cavity the modulated beam excites the TM_{210} mode with the frequency of 7 GHz. The angular frequency of this mode is equal to the drive signal frequency. All the cavities are located inside the solenoid producing a longitudinal magnetic field with the required field distribution.

This tube design is the result of numerical simulations and experimental study of the various versions of the device (see [4, 5]). Beam dynamics simulation and magnicon components optimization (the electron gun, RF cavities, magnetic system) were carried out with the special computer codes SAM and SuperLANS [6, 7]. Also the computer codes were used for simulation of steady-state and time-dependent magnicon operating conditions [8].

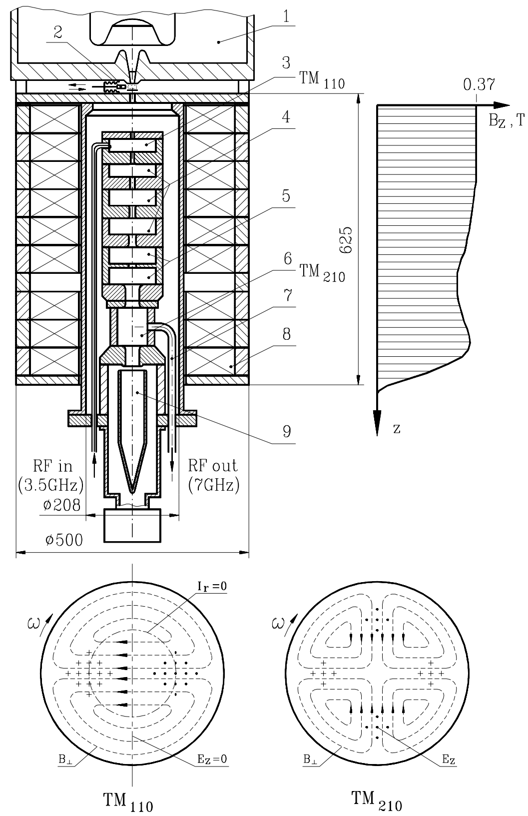

Figure 1: Sketch of the magnicon: 1 – electron source; 2 – vacuum valve; 3 – drive cavity; 4 – gain cavities; 5 – penultimate cavity; 6 – output cavity; 7 – waveguide (∗2); 8 – solenoid; 9 – collector

3 THE MAGNICON STUDY AND THE ACHIEVED PARAMETERS

The previous experiments with the device have shown that its parameters are limited mostly by the deficient matching the electron source optics with the magnicon magnetic system as well as RF field distorsion in the output cavity [4].

The deficient matching between the gun optics and magnetic system led to strong electron beam transverse size scalloping. In 1996, the electron gun was improved in order to eliminate this problem. Experiments proved that pulsing decreased, and the maximum beam diameter within the operating range of the accompanying magnetic field has decreased from 4 mm to less than 3 mm.

By the time of the new gun testing it was also found that during the device conditioning self-excitation in the output cavity arose and after a time disappeared at various frequencies [5]. Note, that the self-excitation frequencies were not the drive signal harmonics. One of possible reasons for them could be the bad vacuum.

The magnicon RF system consists of separated copper parts connected with one another by indium seals. This design allows to change the RF systems part operatively but does not allow to bake-out cavities up to high temperatures. This leads to long condition times for the cavities. In the decribed experiments the RF cavities were previously heated and then the whole magnicon quick-assembling were carried out. Moreover, the waveguide sections forming a single vacuum chamber with the output cavity and loads (there are no ceramic windows) were provided by the additional pumping system. Further experiments shown that these provisions have reduced the device conditioning time and eliminated the self-excitation. Present-time magnicon parameters are listed in the table below, which also contains the calculated values.

Magnicon parameters	achieved	design
Operating frequency, GHz	7.002	7.000
Drive frequency, GHz	3.501	3.500
Output power, MW	46	55
Gain, dB	62	55
Efficiency, %	49	56
Pulse duration, μs	1.0	1.3
Beam voltage, kV	405	420
Beam current, A	230	240
Repetition rate, pps	3	5

The oscillograms presented in Fig.2 are: beam voltage (U), signal from the drive cavity (DC), signal from the first gain cavity (GC), signal from the penultimate cavity (PC), and output signal (OUTC). The output peak power calibration was carried out by the calorimetric measurements of the average RF power.

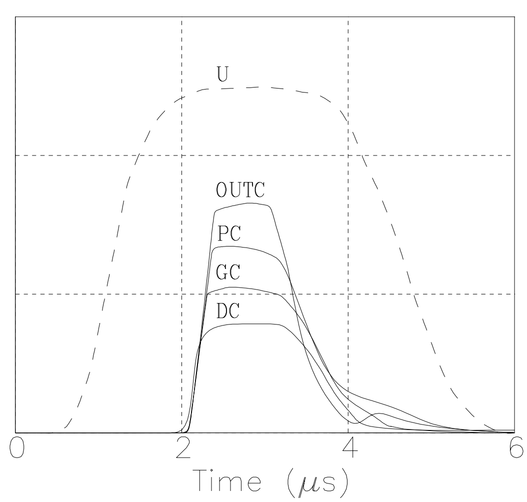

Figure 2: The oscillograms.

Figure 3 represents the measured dependencies of the efficiency versus: a) the drive signal; b) the drive frequency; c) the accompanying magnetic field; d) the electron beam power (2 – calculated curve).

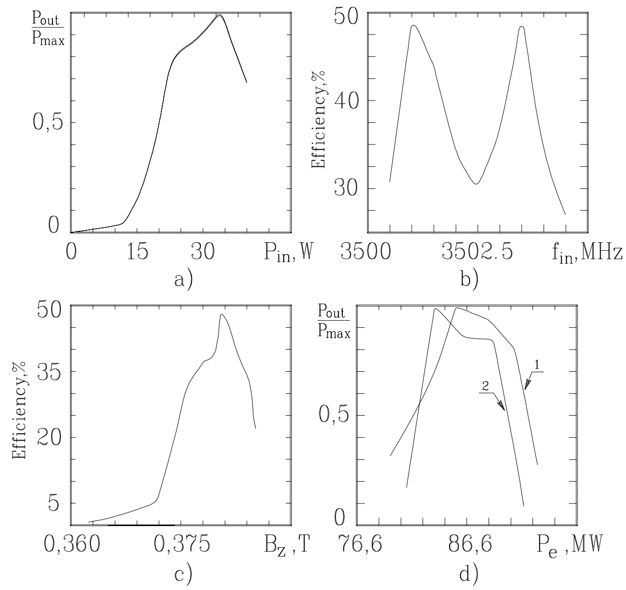

Figure 3: Experimental curves.

Strong output power dependence on the beam power and thus on the beam voltage (diode gun) explaines the decreasing of the output signal pulse duration. Numerical simulations show that for a given voltage pulse profile at the electron gun the ouput signal duration cannot exceed 1.3 μs at half-power level.

By this means the measured tube efficiency comprises 89% from the predicted value that results mainly from longitudinal and azimuthal inhomogeneity of the RF fields in the output cavity because of presence of the coupling windows with waveguides [9]. An azimuthal non-uniformity leads to a difference between the loaded Q-factors for orthogonal TM_{210} modes, superposition of which defines the RF fields distribution in the output cavity.

The calculated curve of efficiency versus the output cavity loaded Q-factor is shown on Fig.4. Numerical simulations show that the difference between Q-factors also leads to the output signal duration decreasing.

To compensate the azimuthal disturbance in that experiment the output cavity with two protrusions was used (see Fig.5a). However, 2D-simulations shown that this is not enough. The problem, can be solved by increasing the number of protrusions as shown in Fig.5b. But 2D-simulation and model tests show that this action leads to a major distorsion of the RF fields longitudinal distribution (Fig.6b). The distorsion decreases the efficiency of the given magnicon design considerably. To eliminate this effect the compensating local increasings of the output cavity diameter were made near the upper and lower cavity faces (Fig.6c). These local increasings are azimuthal homogeneous and do not give rise to an azimuthal non-uniformity.

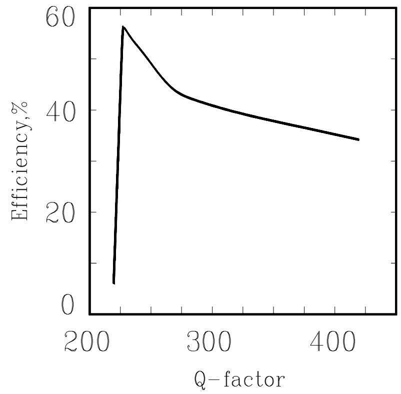

Figure 4: Efficiency versus loaded Q-factor.

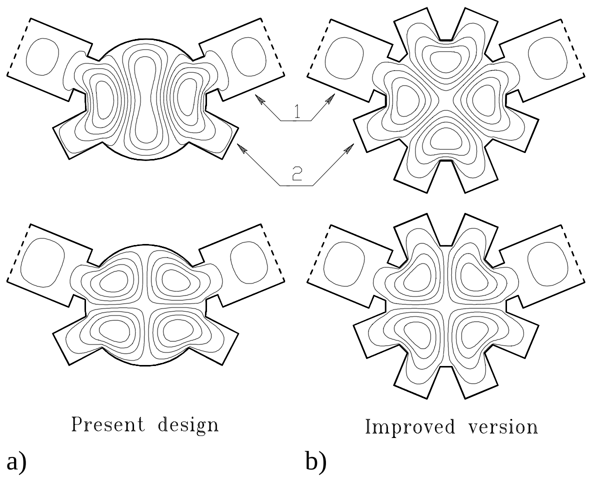

Figure 5: Output cavity design.

4 SUMMARY

In the course of 7 GHz frequency-doubling magnicon amplifier investigation the peak power of 46 MW and efficiency of 49% has been achived. The measured parameters are 89% of the calculated values. This allows to consider the magnicon as an attractive candidate for linear colider applications. The improved version of the output cavity has been produced and installed into the magnicon. The tube is under putting into operation now and we hope to obtain the design parameters in the nearest future.

5 REFERENCES

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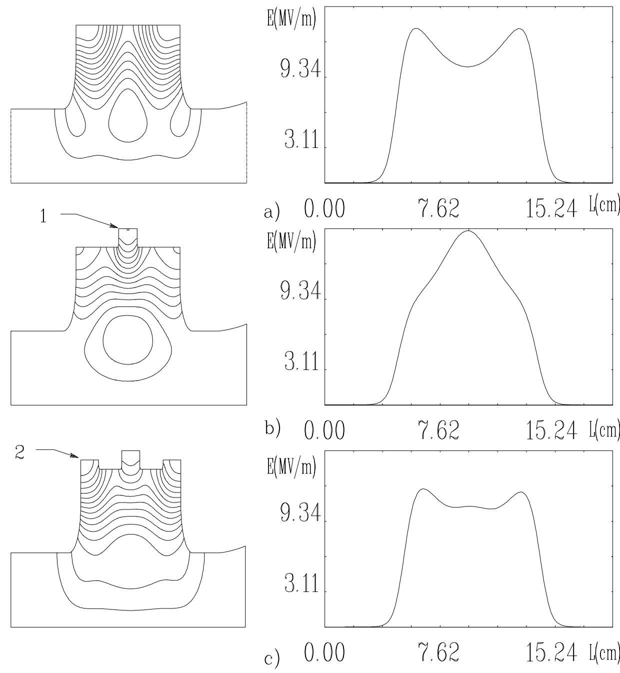

Figure 6: Field maps and longitudinal electric field distributions in the output cavity: a) without holes; b) with coupling windows and protrusions (1); c) with the additional local increasings of the cavity diameter near the faces (2).

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