

7 GHz PULSED MAGNICON AMPLIFIER

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INTRODUCTION

The work on creation of high-power microwave amplifiers with circular deflection of an electron beam has been carried out at INP since 1967. In 1970 the first device of that type called gyrocon [1,2] was created. Further development of this class of microwave amplifiers has been made possible with invention and development of a magnicon [2]. The first magnicon – a prototype of CW or long pulse microwave amplifier – was built and tested in the 1980's [3].

In the beginning of 1990's the work was started on the development of the advanced magnicon version (see Fig.1). That magnicon was developed as a prototype of a microwave power source for linear colliders [4]. It includes: electron gun, RF-system, magnetic system, and collector. The tube operates at 7 GHz in frequency-doubling mode, so the RF system consists of the set of deflecting cavities (the first is externally driven) for a beam modulation at 3.5 GHz and output cavity for conversion of beam energy into the microwave power at the second harmonic (7 GHz).

The creation of codes for simulation of electron optics, electromagnetic systems, and dynamics of an electron beam of finite size in realistic fields in both steady state and time dependent regimes was carried out simultaneously with the experimental study [5]. An electron source with unique parameters [6] has been manufactured and successfully tested. In the process of experimental investigation various versions of the design of the tube and its individual components [4] have been studied in order to overcome instabilities and to optimize power and efficiency.

EXPERIMENTAL STUDIES

The latest major improvements include modifications in the electron gun and output cavity. The gun geometry was modified and the matching of the electron beam with the magnetic system was also improved. This improvement was made in order to work with magnetic field of 0.38 T. As a result the beam transverse size in the magnetic system is in the range of 1.9÷2.5 mm [7] and the area compression ratio exceeds 2000:1.

It has been also found that the magnicon efficiency significantly drops due to the longitudinal inhomogeneity and azimuthal asymmetry of RF fields in the output cavity, which are caused by the coupling holes with waveguide power outputs. These problems were overcome by introducing 6 compensating protrusions and 2-side grooves (Fig.2) [8].

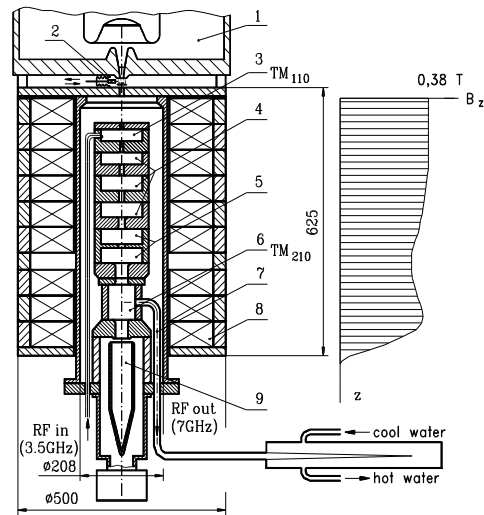


Fig. 1: Schematic layout of the magnicon: 1 - electron source; 2 - vacuum valve; 3 - drive cavity; 4 - gain cavities; 5 - penultimate cavity; 6 - output cavity; 7 - waveguide (x2); 8 - solenoid; 9 - collector.

The latest improvements allowed us to achieve the results (see Table 1) which are very close to the design parameters and simulation results.

Table 1: Measured parameters.

Operating frequency	7.005 GHz
Drive frequency	3.5025 GHz
Output power	55 MW
Gain	72 dB
Pulse duration	1.1 μs
Efficiency	56 %
Beam voltage	427 kV
Beam current	230 A

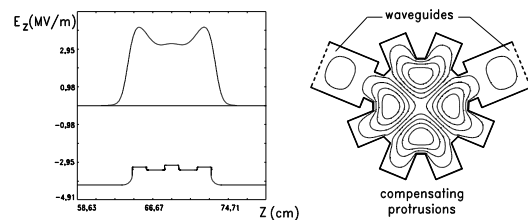


Fig. 2: Output cavity with power extraction in the mid plane: RF field longitudinal distribution at 1 cm from the axis and the filed map.

Fig. 3 presents a general view of the experimental 7 GHz magnicon assembly.



Fig. 3: 7 GHz pulsed magnicon.

Oscillograms of the pulses, experimental and calculated curves are shown in Fig. 4-5. Parameters obtained at the device optimal operating regime are marked by "•" symbol. The output power calibration was carried out by calorimetric measurements.

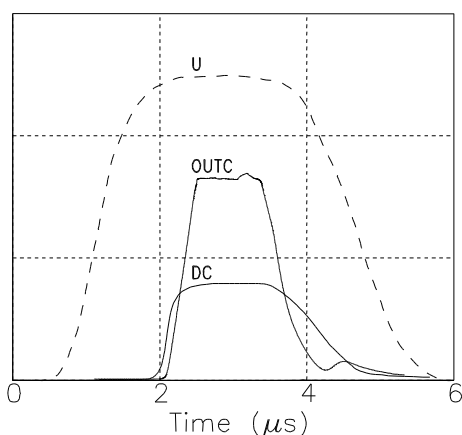


Fig. 4: Oscillograms: U – beam voltage; DC – drive cavity signal; OUTC – output cavity signal.

The output cavity with a loaded Q-factor $Q_l=230$, which is higher than the optimal value $Q_l=180$, was used in experiments (seen from the calculated curve in Fig.5a), that decreases efficiency by 2 %. The increased Q-factor has been chosen in order to move out from the region of possible instability causing a sharp efficiency drop.

Fig. 5b illustrates the magnicon efficiency response of the drive frequency.

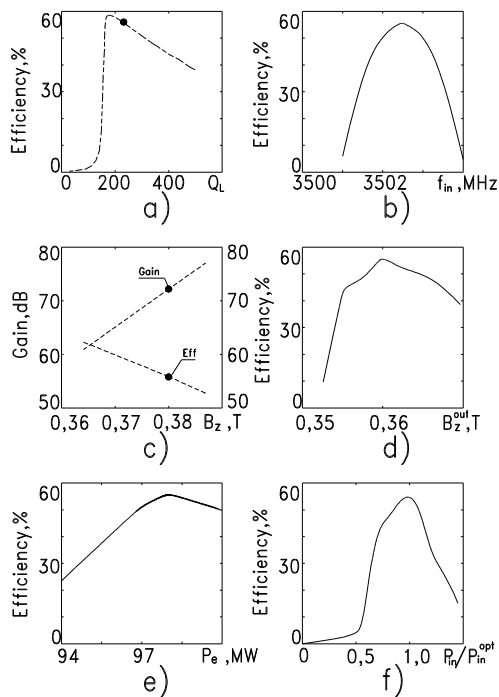


Fig. 5: Experimental and calculated curves: a) loading dependence; b) input frequency dependence; c) DC magnetic field dependence of gain and efficiency; d) output cavity DC magnetic field dependence of efficiency; e) efficiency vs. beam power; f) efficiency vs. drive power. Continuous lines correspond to experimental data, dashed - to simulation results.

Simulation results show that increasing in efficiency can be achieved by decreasing DC magnetic field (Fig.5c). In this case the gain drops but still remains high enough. In the given series of experiments we was not able to decrease DC magnetic field significantly, for a beam quality is impaired because of mismatching. However, since the magnetic system solenoid consists of two sections powered by individual sources, dependence between an efficiency and magnetic field value in the output cavity area has been studied (Fig.5d).

One of possible reasons of the RF output pulse length reduction is related to an excitation of the 0-mode of oscillations in a double-cell penultimate cavity. The penultimate cavity consists of two cells coupled through the central hole with the coupling coefficient of 0.7 % (see Fig.1). The operating mode of this cavity is π -mode. However, simulation results show, that self-excitation of the 0-mode may limit a pulse length of the

output signal. This effect was detected in the course of 11.424 GHz magnicon development.

Figure 6 shows a typical outlook of instability growth in the penultimate cavity at 0-mode exciting, obtained by simulation. This problem can be solved replacing this double-cell penultimate cavity by two uncoupled penultimate cavities [9].

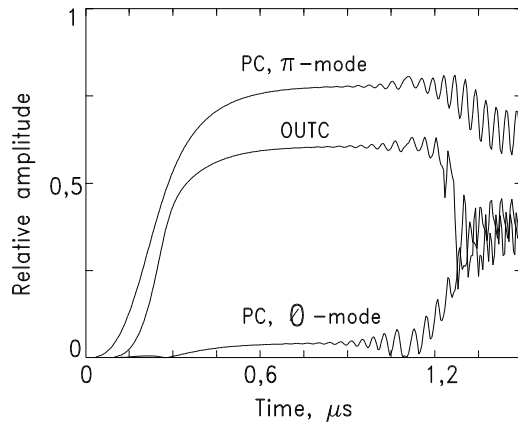


Fig. 6: Transient process in the magnicon when both 0- and π - modes are excited in the penultimate cavity; PC corresponds to penultimate cavity, OUTC – to output cavity

SUMMARY

In the latest set of experiments on 7 GHz magnicon almost all design parameters have been achieved: the output power of 55 MW, efficiency of 56 %, and gain of 72 dB. Experimental data are in an excellent agreement with simulation results obtained by the special magnicon computer codes. Achieved results allow us to consider a magnicon as an alternative power source for linear colliders applications.

ACKNOWLEDGEMENTS

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