Status of the X-Band Pulsed Magnicon.

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1 INTRODUCTION

Magnicon [1, 2] belongs to the class of high power RF sources, where a modulation is provided by the beam circular deflection and it is an advanced version of a gyrocon [3].

The described magnicon is an amplifier operating in frequency doubling mode. The device has been designed for an output power of 50 MW, an operating frequency of 7 GHz and a pulse duration of 2 μsec as a prototype of RF source for "normal conducting" electron-positron linear colliders.

The paper presents a design of this magnicon, its features and status. The problems concerning acquiring a large deflection angle and also phenomena observed in the experimental study of the deflection system are considered. The results of the experimental research of the tube are given.

2 MAGNICON DESIGN

1. The beam from electron gun 1 passes the resonance system, which consists of a beam circular deflecting system and the output cavity. Beam deflecting in the drive cavity 3 and in two passive cavities 4,5 is provided by transverse magnetic field of the TM_{110} wave travelling in azimuthal direction (see Fig.1). The cavities are placed into the biasing magnetic field that is excited by coils 6.

Drive cavity 3 that is excited by external generator provides a small angle of the beam deflection. Further increase of the deflection angle up to 50–60^o is provided in passive cavities exited by a predeflected beam.

A cylindrical output cavity 7 with the TM_{210} wave (Fig.1) travelling in azimuthal direction is used to convert the beam energy to RF energy. The eigen frequency of the output cavity is twice as high as that of deflection [4]. This cavity is placed into biasing magnetic field too, the field value is determined by the conditions which are necessary to achieve an effective long-term interaction of the electron beam with RF field [1, 2]. The RF power extraction is provided by two similar waveguides, which are shifted on 135^o in azimuthal direction to support the wave travelling in the cavity.

2. One of the features of the described magnicon consists in the necessity to have a deflection angle at the output of the beam deflection system about 50–60^o in order to achieve the efficiency more than 50%. In this case RF field in the last deflecting (penultimate) cavity, in which the main deflection of the beam takes place, appears to be

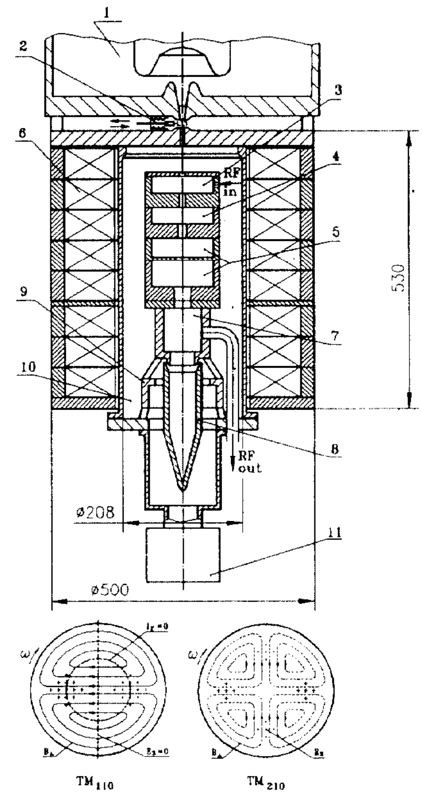

Figure 1: Sketch of the magnicon. 1 — electron gun; 2 — gate vacuum valve; 3 — drive cavity; 4 — passive deflection cavity; 5 — penultimate cavity; 6 — solenoid; 7 — output cavity; 8 — collector; 9 — pole piece; 10 — vacuum chamber; 11 — vacuum pump.

very high [1]. To decrease the RF fields several coupled cavities are used as an alternative to penultimate cavity [4]. This allows to obtain the relevant deflection angle at the moderate RF fields through the long-term interaction with the beam .

The first version of the penultimate cavity consisted of three coupled cavities. However, because of the strong coupling of these cavities on the mode TM_{010} a klystron-like instability was observed at the beam current of just about few tens amperes [5]. Thus we have chosen the version that consists of two coupled cavities with decreased coupling and increased relative difference of TM_{010} mode eigen frequencies. In this case it has allowed to eliminate this instability completely.

At a large deflection angle in the penultimate cavity it is necessary to have large beam tunnels (the tunnel radius must be about two Larmore radii). The large transverse RF electric fields appear in the tunnels which produces beam energy and angle spreads, which leads to the efficiency drop when the beam diameter increases. To obtain high efficiency it is necessary to use the beam with the minimal diameter, i.e. with the diameter close to the Brilluin one. To overcome this problem a special electron optics system with the gun that provides the beam transverse area compression about 2000:1 has been developed [6].

These transverse fringing fields also decelerate electrons, i.e. electrons of the beam transfer their energy to the RF field in the vicinity of the tunnels. For the beam current of hundreds amperes, it can lead to an instability, which is specific for magnicon. This instability is realized as a self-excitation of a penultimate cavity on the operating RF mode (TM_{110}). This problem also has been eliminated by using a special cavity geometry and a biasing field distribution along the tube axis [5].

3 EXPERIMENT

1. RF system of magnicon consists of separate copper pieces, which are connected with one another by the indium seals. This allows to replace operatively parts of the RF system if it is necessary. To save the oxide cathode under these changes the gate vacuum valve 2 (see Fig.1) with teflon gasket has been mounted. However, this design has one serious disadvantage because of impossibility to bake-up the device to high temperature. This leads to a very long process of the magnicon cavity conditioning to overcome the multipactor discharge. Preliminary baking-up of the separate parts of the RF system immediately before the assembling and warming-up to the 100^{o} C during conditioning allowed to decrease the conditioning time (in the future we plan to bake-up all the parts of the RF system at the temperature of 600^{o} C before the assembling).

The parameters obtained during first tests are listed in Table 1.

Table 1:

Frequency, GHz	7
Power, MW	20
Pulse width, μsec	1.3
Efficiency, %	25
Repetition rate, pps	2
Drive frequency, GHz	3.5
Gain, dB	47
Beam voltage, kV	400
Beam current, A	200

2. Attempts to increase the output power lead to breakdowns in the penultimate cavity. It has been found that one of the reasons of this phenomenon is caused by the existence of the strong nonlinear dependence between the

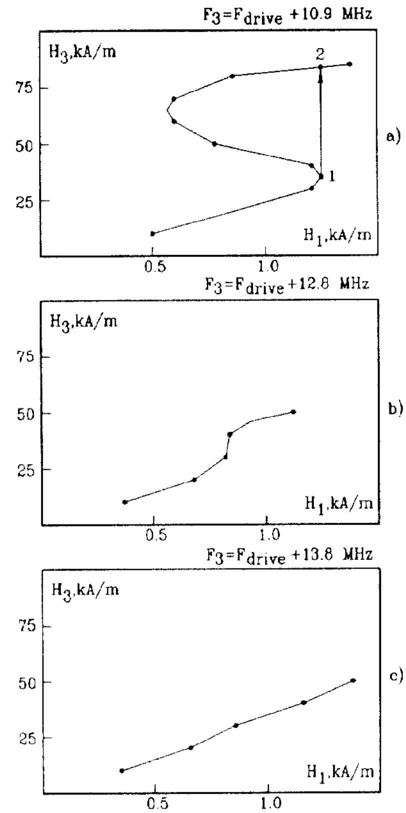

Figure 2: RF field in the penultimate cavity (H_3) versus RF field in the drive cavity (H_1) for the different eigen frequencies of penultimate cavity.

wave amplitude in the penultimate cavity versus the amplitude of the driving signal. This nonlinearity is conditioned mainly by the nonlinear dependence of beam transit time through the cavity of the beam deflecting angle ($V_z = V_0 \times \cos\alpha$, where V_z is the axial beam velocity, α — beam deflection angle). In the described version of the penultimate cavity there is a phenomenon known in the theory of nonlinear oscillations as a "amplitudes jumps", that is an appearance on the resonance curve of the instability area at the excitation amplitude above the critical level [7]. The calculated curves of the oscillation amplitudes plotted versus the excitation amplitude for different eigen frequencies of penultimate cavity are shown on Fig.2. In our case (Fig.2.a) transition from point 1 to point 2 is accompanied by an electric discharge. If one can tune the penultimate cavity so as to prevent the falling in the instability area in the operating frequency band (i.e. somewhat to increase the eigen frequency of the cavity, that corresponds to the case on Fig.2.b), it will allow to get the monotone dependence between the oscillation amplitude and amplitude of the driving signal. However, in this case an output beam deflection angle grows smaller and calculated efficiency doesn't exceed 35%. More optimal solution is the decreasing of the penultimate cavity length that we plan to do in future.

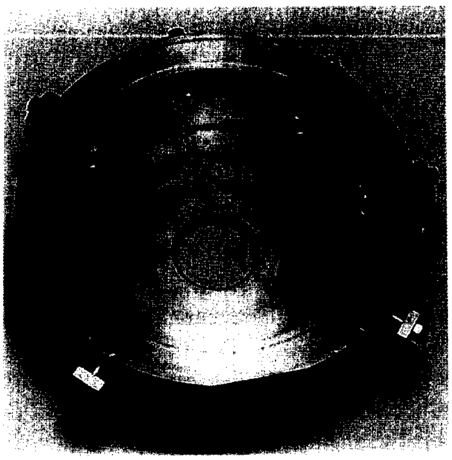

Figure 3: The autographs of electric discharge of the TM_{431} mode in the first gap of penultimate cavity.

After tuning of penultimate cavity on the lower frequency (that corresponds to the case on Fig.2.b) the autographs of electric discharge of the TM_{431} mode (see Fig.3) that limited the output power level were observed in the first gap of penultimate cavity. The measured eigen frequency of the first gap on this mode practically coincided with the four-fold deflection frequency ($F_{431} \approx 14\text{GHz}$)[1]. It turned out that in this case the first gap of penultimate cavity operates not only as a deflecting cavity but as an output cavity of the magnicon operating in frequency-multiplied mode. The interaction between the beam and TM_{431} mode turns to be sufficiently high in spite of the fact that transit angle is more than 2π and cyclotron resonance conditions are not fulfilled. This proves to be possible owing to the high quality factor (more than 20000), nonlinear dependence of RF fields from radius in beam passing area (${E_z}^{431} \sim r^4$) and to the fact that beam electrons trajectories are defined by the interaction with the operating TM_{110} mode RF fields. The strong excitation as shown by calculations begins at the deflection angles bigger than about 20°. The electric field value in this cavity reaches 1 MV/cm, the beam energy losses therewith are no more than 7–10%. This problem is solved by the choice of penultimate cavity geometry, spectra of "risky" modes so that the latter shouldn't be multiple to the drive frequency.

[1]The operating of a magnicon in frequency-multiplication mode are realized by excitation of the cavity on the frequency that is multiple to the drive frequency as well as on TM_{mnp} mode where m — multiple ratio [8].

4 CONCLUSION

Changes outlined above have been realized and the device now is under conditioning. Also an improved version of the magnicon in which these problems have been overcome more optimally has been designed and is being manufactured now. The calculated efficiency of this version is over than 50% at an output power of 50 MW and gain over than 55 dB.

5 REFERENCES

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