First Test of the X-Band Pulsed Magnicon.


Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia.

I. GENERAL

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 first magnicon has been built and tested in Novosibirsk in the middle of 80-ths. The power of 2.6 MW has been obtained for the frequency 915 MHz and pulse duration 30 mcsec, the electron efficiency has been 85% [1].

Good results obtained during investigations show that the magnicon can be an adequate RF source for the next generation of accelerators, especially for future linear colliders [4] and accelerators for transmutation of nuclear waste [5].

The magnicon conception described in present paper allows to increase significantly the beam perveance, compared with the first magnicon, and to achieve the pulse power of tens and hundreds megawatts at the beam voltage not greater than 400-600 kV. The device is an amplifier working in frequency doubling mode [2,6] and is a prototype of RF source for linear colliders with high acceleration gradient.

Magnicon is designed for an output power of 50 MW, an operating frequency of 7 GHz and a pulse duration of 2 mcsec.

II. MAGNICON DESIGN

The magnicon sketch is shown in Fig 1. The beam source is the diode gun 1 with oxide cathode of 120 mm diameter. The voltage pulse from a step - up transformer is applied to the gun. The main feature of the gun is a high degree of a beam transverse area compression (over 1500). The step - up transformer is placed in the tank with SF6 under pressure of 4 atmospheres.

The pulse voltage source of the step - up transformer is a modulator based on Blumlein PFN.

The beam from electron gun pass the resonance system, which consists of a beam circular deflecting system and an output cavity. Beam deflecting in the drive cavity 3 and in two passive cavities 4,5 is provided by transverse magnetic field of the TM110 wave travelling in azimuthal direction (see Fig 1). The cavities are placed into 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 deg is provided in passive cavities excited by a predeflected beam.

A cylindrical output cavity 7 with the TM210 wave (Fig.1) travelling in azimuthal direction is used to convert the beam energy to RF one. The eigen frequency of the output cavity is twice greater than deflection one [6]. 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 slots in side

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 flange; 12 - vacuum pump.
cavity wall, which are shifted on 135 deg in azimuthal direction to support the wave travelling in azimuthal direction.

The RF system is made of separate cooper parts which are assembled by indium gaskets. A collector is made of cooper, is cooled by water too and is insulated for current measurements.

III. CHALLENGES

1. Because the electric field in output cavity of magnicon is considerably small [1,2], the main problem with electric breakdown takes place in the last deflecting (penultimate) cavity, where the main beam deflection is produced. In described magnicon design unlike the classic design [1,2] the relevant deflection angle (that is about 50-60 deg) is achieved in the last passive cavity. Here, if a single cavity would be used as a last deflecting one, the surface electric field will exceed reasonable values. To overcome this problem two means are used in present design.

First, because the output frequency is twice higher than the deflecting one, the gaps of deflecting cavities are two times greater than for a magnicon working as an amplifier.

Second, the penultimate cavity 5 (see Fig.1) consists of a pair of coupled cavities, which are excited by a predeflected beam in a counterphase mode. Thus, a "deflection angle addition" mode, or a long term interaction between the beam and deflecting RF field is realized [6].

These means allow to decrease the maximal surface electric field to the value 200 kV/cm (approximately the same as in the output cavity).

2. Some more problems appear because of necessity to have a large deflection angle in the beam deflecting system. In this case it is necessary to have large beam holes in the walls of cavities (the holes diameter must be about four Larmore radii). This holes produce perturbation of RF field distribution, mainly, near the holes there appears the large transverse electric field. In Fig.2 a fringing field distribution near the beam holes for penultimate cavity is shown. (Note that the surface electric field of the penultimate cavity is determined by these fringing fields.) The action of fringing field on beam dynamics produces two problems.

First, these fields produce beam energy and angle spreads, which lead to the efficiency drop when the beam diameter increases. Simulated picture of behavior of electrons in process of deflecting and deceleration is shown in Fig.3 for initial beam diameter of 2.5 mm. Thus, to obtain high efficiency it is necessary to use the beam with the minimal initial diameter, i.e., with the diameter close to Brilluin one. To overcome this problem a special electron optics system has been developed [7].

![Figure 3. Beam behaviour in process of deflection and deceleration. R - radii, U - energies of the beam particles.](image)

Second, transverse fringing fields decelerate electrons, i.e. near the beam holes electrons of the beam transfer their energy in the RF field. For the beam current of hundreds Ampers, it can lead to an instability, which is specific for magnicon. This instability is realized as self - excitation of a single cavity on the operating RF mode, without any external feedback. For coupled cavities the current threshold is lower than for a single cavity. It is possible to overcome this problem using a special cavity geometry and a biasing field distribution along the tube axis. In particular, decreasing the biasing field near penultimate cavity increases beam loading of this cavity, decreasing it's quality factor and so increasing the current threshold of the instability for relevant value. Simultaneously, it allows to reduce a quality factor of other deflecting cavities to obtain compromise between gain and a bandwidth.

3. For coupled cavities there may be a klystron-like instability, i.e. instability with the frequency lower than operating one (on the mode TM010). In the first design version of the present magnicon three strongly coupled cavities have been used as the penultimate cavity. The coupling coefficient was about
20% [2.6]. This cavity was selfexcited on the frequency 2.6 GHz when the current reached 50 A. It corresponds to the \( \pi/2 \) mode, which has a minimal current threshold because of a large bunching distance. In present design this problem is solved by using two coupled cavities with small coupling (coupling coefficient is 0.5% for TM010). Besides, the relative difference of TM010 mode eigen frequencies for those cavities is greater than coupling value.

**IV. EXPERIMENT**

1. At the first stage of the experiment the electron gun was tested. While testing the following data were obtained: power \( P = 100 \text{MW} \) at \( U = 430 \text{kV} \) and microperveance 0.82, pulse width 2 msec and the repetition rate up to 5 pps.

The beam diameter, measured with the help of special movable graphite diaphragms [8] is less than 3 mm (i.e. area compression ration exceeds 1500:1 and energy density is 5 kJ/cm²).

The main problem arising in the process of investigation were caused by the last passive cavity. A few different version of this cavity had been examined (with three and two coupled cavities) before succeeded to do away with selfexcitation of both, klystron-like and operating mode TM110.

2. For the time being the very initial test of the magnicon have been carried out. The parameters obtained are listed in Table 1. Figure 4 presents the oscillogram of the output pulse.

**Table 1.**

<table>
<thead>
<tr>
<th>Frequency, GHz</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power, MW</td>
<td>20</td>
</tr>
<tr>
<td>Pulse width, msec</td>
<td>1.1</td>
</tr>
<tr>
<td>Efficiency, %</td>
<td>25</td>
</tr>
<tr>
<td>Repetition rate, pps</td>
<td>2</td>
</tr>
<tr>
<td>Drive frequency, GHz</td>
<td>1.5</td>
</tr>
<tr>
<td>Gain, dB</td>
<td>47</td>
</tr>
<tr>
<td>Beam voltage, kV</td>
<td>400</td>
</tr>
<tr>
<td>Beam current, A</td>
<td>200</td>
</tr>
</tbody>
</table>

This tests have been started only a month before this conference. The tube is being in the state of conditioning and we expect to get better parameters in the nearest future.

**V. REFERENCES**


