14 GHz VLEPP Klystron

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Abstract

Design and experimental studies are now under way in Novosibirsk Institute of Nuclear Physics (INP, Novosibirsk) and Branch of the INP (BINP, Protvino) to create a relativistic klystron as possible RF power source for linear collider VLEPP. The present status of this work is reported.

1 INTRODUCTION

RF sources are developed for VLEPP [1] in order to satisfy the power requirements. 150 MW/m RF power source is needed to provide accelerating gradient 100 MeV/m. To satisfy this requirements efforts are underway to develop a 150 MW klystron at 14 GHz. The design parameters of the klystron are presented in Table 1.

Table 1.
VLEPP Relativistic Klystron Design Parameters

Operating frequency	14 GHz
Peak Output Power	150 MW
Beam Voltage	1000 kV
Beam Current	300 A
RF Pulse Width	500 ns
Pulse Repetition Rate	150 pps
Efficiency	50 %
Saturation Gain	80 dB

2 KLYSTRON CONFIGURATION

1 MV voltage and 300 A current were set up for the VLEPP RF power source. These quantities are determined by VLEPP project high voltage supply scheme. The task is to develop a klystron with high gain (80 dB) and high efficiency (more than 50 %), which would have acceptable cost and reliability. Conventional klystron with electromagnet focusing system and modulator seems too expensive. So to reduce power consumption the permanent magnet focusing system was chosen for the VLEPP klystron. Grided electron gun of the klystron does not require a modulator, being supplied by storage line with permanent voltage.

The klystron can be divided by four main parts: electron gun, RF gain section, output system, collector (See Fig.1).

Electron gun consists of the spherical oxide cathode, multi-electrode accelerating tube and focusing lens. There are 37 oxide microcathodes on the surface of the cathode. Diameter of each microcathode is 16 mm. Electron current is controlled by 25 kV pulse voltage applied to the grid. To avoid emission from the grid it is made of the thick copper plate (width 6 mm) with holes for each microbeam. Accelerating tube consists of ceramic rings brazed through the electrodes. The electrodes serve two purposes: to divide high voltage on the insulator and to form the accelerating field for minimize transverse emittance. The focusing lens provides a desirable size of the electron beam at the entrance of the RF part of the klystron. Main parameters

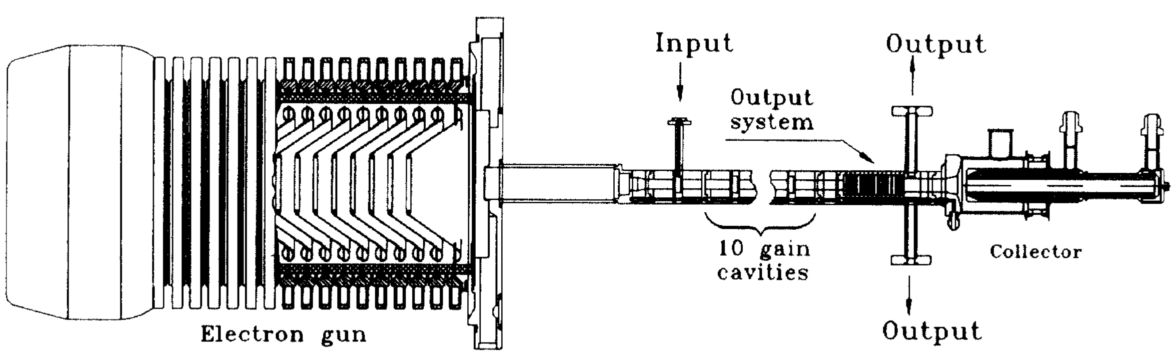


Figure 1. 14 GHz relativistic klystron

of the electron gun are summarized in Table 2.

Table 2.
Electron Gun Design Parameters

Cathode Voltage	1000 kV
Beam Current	300 A
Cathode Diameter	120 mm
Cathode Spherical Radius	110 mm
Number of Microcathodes	37
Total Emission Area	60 cm^2
Current Density on Microcathodes	5 A/cm^2
Number of Electrodes	16
Total Length of Insulator	320 mm
Maximum Surface Field	120 kV/cm
Beam Diameter at Output	8 mm
Dark Current	< 100 μA

The RF gain section consists of an input cavity and ten gain cavities. This number of cavities is determined by a required magnitude of gain, by high energy of the beam and weak interaction between beam and cavities. Diameter of the drift tube is 11 mm. The cavities are placed regularly with 64 mm period which equal two periods of magnet periodical focusing system (MPFS) - 32 mm. MPFS [2] consists of Nd-Fe-B permanent magnets and iron poles.(See Fig. 2). This focusing system was used for the output system also. Maximum magnetic field on the axis is 6.0 kG, rms focusing field is 3.3 kG. Acceptance of the channel with MPFS is about 0.1 rad×cm.

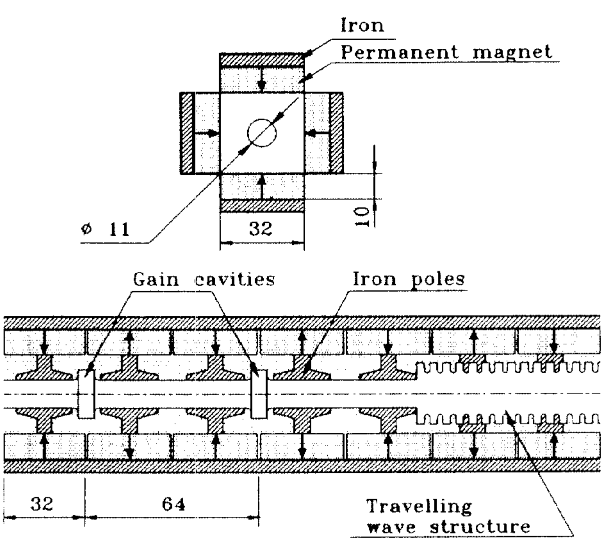


Figure 2. Magnet peridiocal focusing structure.

Numerical simulations of the klystron give the value of gain about 80 dB. Maximum electric field in the last two cavities is 200 kV/cm.

The output system of the klystron is a output traveling-wave (TW) structure.(See Fig.1). The 14 GHz TW structure is comprised of 14 identical $\pi/2$-mode cells with beam apertures of 16 mm. Such TW output structure has two advantages in comparison with a single standing-wave cavity: higher efficiency and lower surface electric fields. Computer simulations show that 65 % efficiency can be achieved with using mentioned above gain section. 150 MW output power corresponds to 600 kV/cm surface field.

To suppress a possible excitation of nonsymmetrical wave modes and improve operating conditions of output windows two symmetrical outputs were made. Main features of the output system are presented in Table 3.

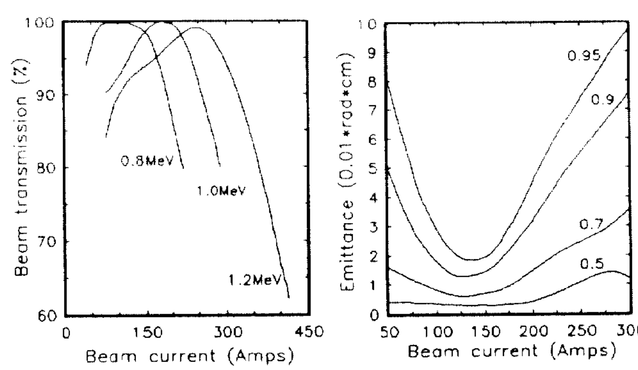
Table 3.
Klystron Output System Parameters

Total Length	7 cm
Number of cells	14
Wave Mode	$\pi/2$
Phase Velocity	0.87 c
Group Velocity	0.24 c
Max. Surface Field	700 kV/cm

Collector is made from graphite and have 100 cm^2 area. Collector is cooled by water and should utilize 15 kW heat power. It is isolated by a ceramic ring from the other parts of the klystron so it allows to measure output beam current.

3 TEST RESULTS

In the first experiments MPFS of the klystron was investigated. The channel without cavities 11 mm diameter 70 cm length with the same magnetic system as in the klystron was tested. The accelerator ELIT-L2 [3] was used as electron beam source in experiments. In contradistinction to the klystron electron gun ELIT-L2 electron gun has had single oxide cathode diameter 120 mm and thin grid. Since the electron gun is controlled by the grid, current and emittance of the beam depend on the grid voltage. The best beam transmission range at the Fig.3a corresponds to the minimum of beam emittance.(See Fig.3b). At the last experiments with the klystron the best beam transmission about 95% was achieved at the current 150-170 A.



a) b)

Figure 3. Beam transmission through drift channel without cavities(a) and emittance of the beam(b) vs ELIT-L2 beam current.

The highest RF power at this variant of the klystron was 55 MW for pulse widths of 0.7 μs. The current at the entrance of the gain section was 210 A, collector current was 150 A, input power was 60 W. The power was measured by calorimeter at a pulse repetition rate of 2 pps. Two loads were used instead of RF windows. Output RF power vs frequency of drive RF signal is presented in Fig. 4.

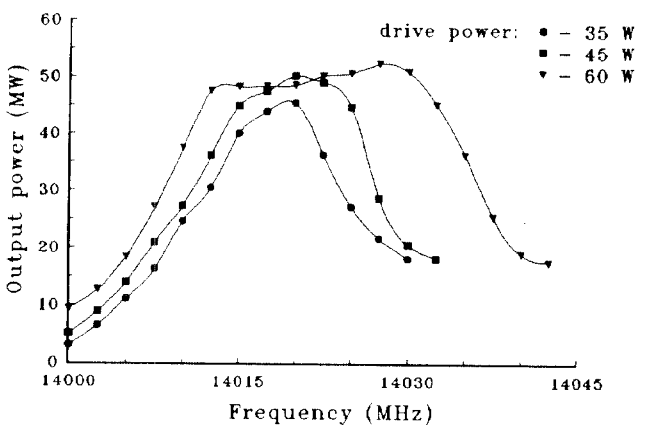


Figure 4. Output RF power vs frequency and drive power.

At the beam current more than 110 A RF self-excited oscillations were observed at the klystron input and output. Measured oscillation spectra have the maximum at the 18.5 GHz. Sometimes the oscillations caused RF breakdown and shortening of the RF power pulse.(See Fig.5).

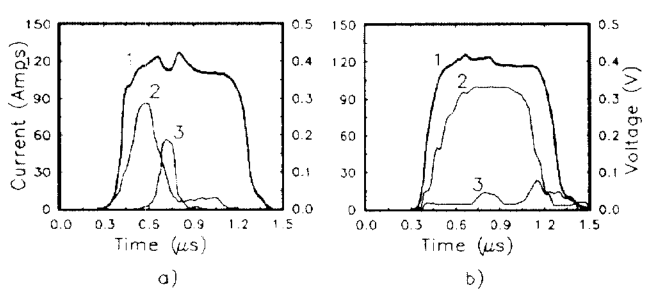


Figure 5. Collector current (1), output RF power (2) and self-excited oscillation (3): a) high level of the oscillation (18.5 GHz); b) low level of the oscillation. The signals of output power and oscillations mesured by crystal detector (right axes).

We suppose that oscillations are connected with the interaction between the electron beam and HE_{11} wave in the gain section. The special efforts for suppression of the oscillations are undertook now.

4 SUMMARY

14 GHz VLEPP klystron with a grided electron gun and permanent magnet focusing system have been designed and tested. Up to this time 55 MW RF power has been achieved with a pulse width of 700 ns and repetition rate 2 pps.

In order to increase output power, the tasks of improving of electron beam quality and suppression of the oscillations must be solved.

The next variant of the klystron with shortened (8-cavities) gain section and RF output windows will be tested in the nearest future .

5 REFERENCES

[1] V.E.Balakin, "VLEPP Status", in Proc. of 2nd Int. Workshop on Next-Generation Linear Collider, March 1990, Tsukuba, Japan, KEK, 90-22.

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[3] S.A.Astakhov et al., "Studies of Electron Optic System of Accelerator ELIT-L2", Voprosy Atomnoi Nauki i Tehniki, No. 10/18, 1990, Moscow, p. 10-14.