VLEPP 14 GHz Klystron Testing

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Abstract. Last results of VLEPP klystron testing are presented. "Critical" self-exitation currents are defined at various beam energies. New modifications of the klystron are examined.

As is known [1], the pulse klystron of a centimeter wave length range at a power of 100 MW is being developed for the VLEPP collider project. The main advantages of this facility are the following: the use of a grid control for current pulses, the distributed output system and a system of magnetic beam convoying made of permanent magnets. These features enable one to provide the reliable and efficient operation of the whole facility. By now, several versions of the klystron have been tested on the pulsed accelerator ELIT-L2. General view of the basic version of the klystron is given in Fig. 1.

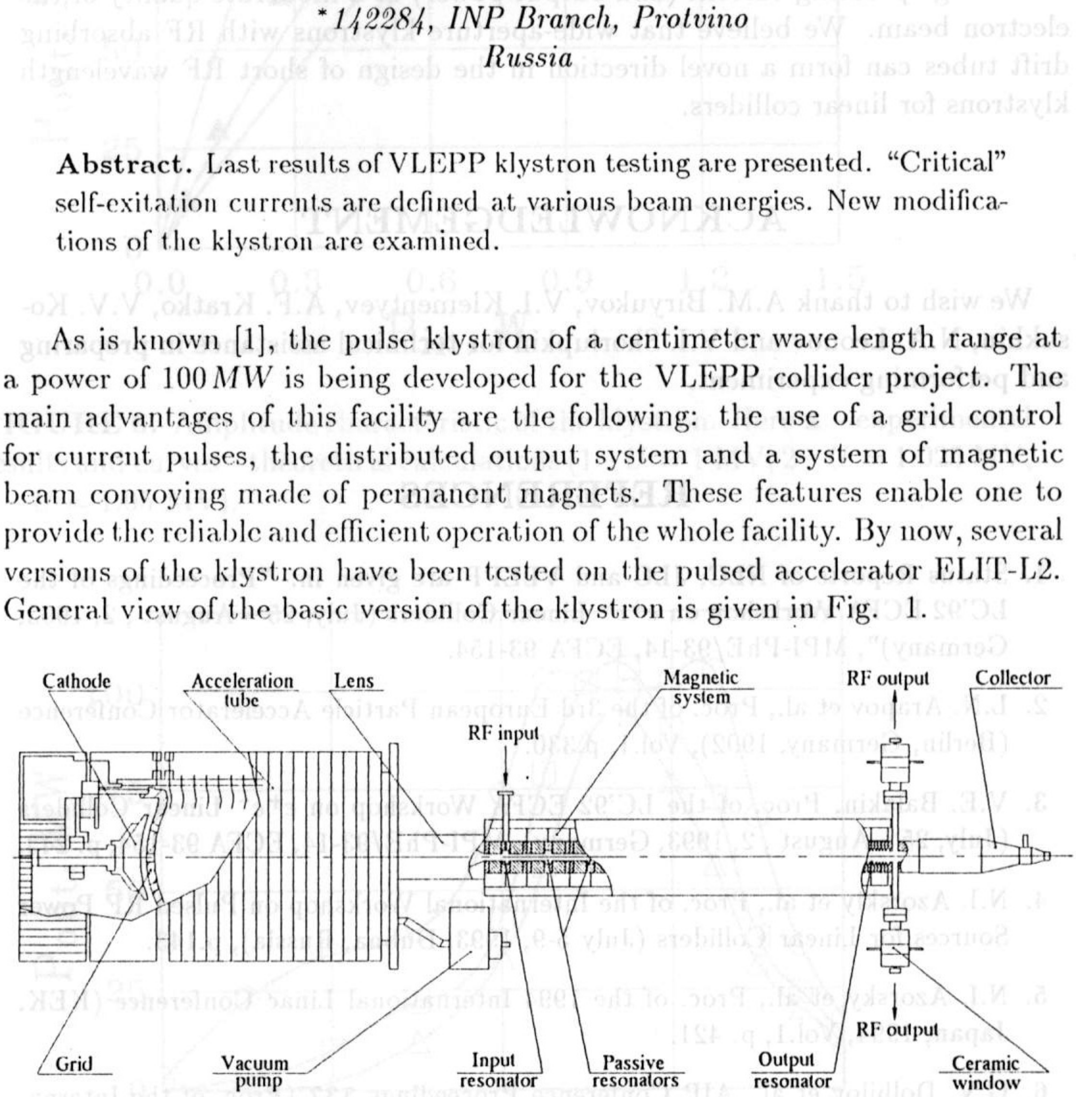


Figure 1: Schematic diagram of the klystron.

The formation of an electron beam occurs in the accelerating tube by the electron gun with the honeycomb oxide cathode and control grid. For the transport of a beam the magnetic periodically focusing system (MPFS) on permanent magnets is used which reduces the weight and does not require the feeding power. There is a matching lens between the tube and amplifying channel. An amplifying fraction of the klystron consists of 8 cavities. The output system is made in the form of disk loaded waveguide with traveling wave. It consists of 14 identical cells and transformer of the wave type with two symmetric waveguide outputs of a power. The power output occurs through the ceramic windows.

The experiments conducted on the pulse accelerator ELIT-L2 enabled the wide range of the klystron voltage and beam current variation. This provided a possibility of optimized pass of a current for each voltage value by minimizing the beam phase volume. With the use of the neodim-ferrum-bore alloy the magnetic field amplitude on the axis achieves $4 \div 6$ kGs depending upon the channel diameter and pole geometry. The experiments have shown that such a system of beam transportation provides the transmission coefficient close to 100 %. The main design and experimental parameters of the klystron are given in Table 1.

Table 1: VLEPP klystron, designed and achieved parameters.

Parameter	Design	Experiment
Operating frequency	$14\,GHz$	$14\,GHz$
Peak output power	$150\,MW$	$60\,MW$
Beam energy	$1\,MeV$	$1\,MeV$
Beam current	$300\,A$	$150\,A$
Grid voltage	$25\,kV$	$20\,kV$
Pulse duration	$0.5\,\mu sec$	$0.5\,\mu sec$
Repetition rate	$150\,Hz$	$2\,Hz$
Saturation gain	$80\,dB$	$90\,dB$
Microcathode current density	$5\,A/cm^2$	$5\,A/cm^2$
Maximum field on the gun surface	$300\,kV/cm$	$300\,kV/cm$
Cathode	37 microcathodes	
Emitter type	oxide	
Cathode diameter	$120\,mm$	
Type of magnetic system	MPFS	

The table gives the maximum parameters for all the versions of the klystron. The efficiency of all the versions ranges from 25 % to 30 %. Basically, this is determined by the collector current which is lower than the design current.

At the operation with the output windows, RF breakdowns occured at a power lower than $10\,MW$ but after training, the level of breakdowns increased up to $20\,MW$ [2]. After long operation at this power, the windows had numerous traces of multipactor burning and breakdowns. Upon design modifications the window has been tested in the traveling wave resonator at a power of up to 50 MW.

An increase in the klystron output power was limited by the occurence of parasitic oscillations. The threshold currents were measured and their occurence depending on voltage value was studied. Appearance of the self-excitation was observed both on the klystron input and output and was also attended by a decrease in the collector current at the moment of its onset. Fig. 2 shows the relation between the threshold current and voltage for two versions of electron gun.

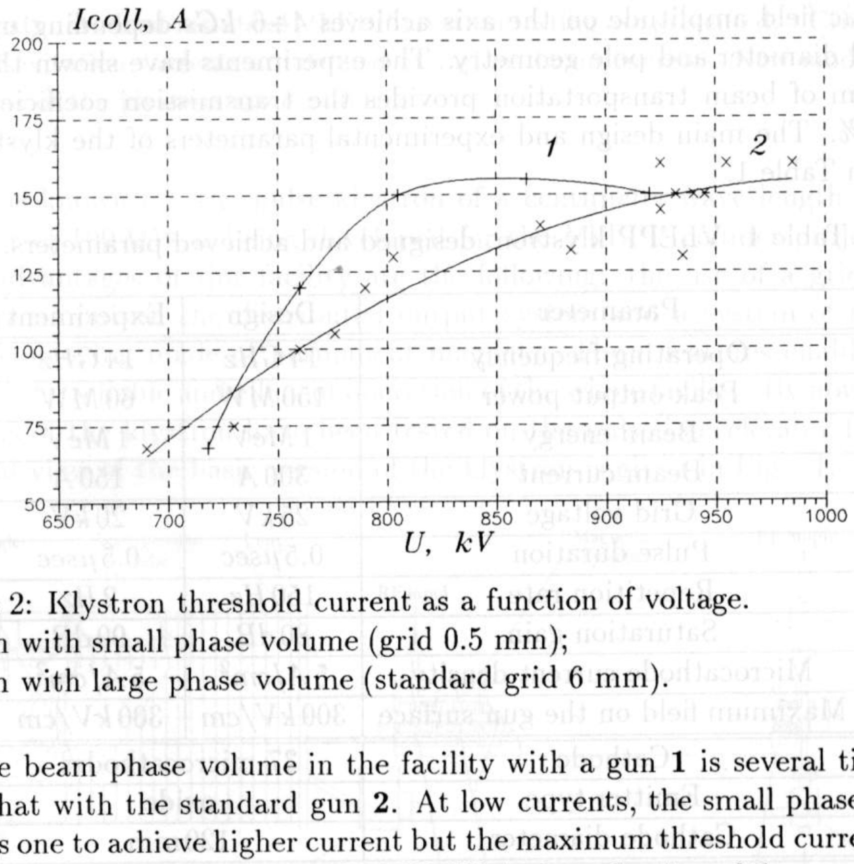


Figure 2: Klystron threshold current as a function of voltage.
1 - gun with small phase volume (grid 0.5 mm);
2 - gun with large phase volume (standard grid 6 mm).

The beam phase volume in the facility with a gun **1** is several times less than that with the standard gun **2**. At low currents, the small phase volume enables one to achieve higher current but the maximum threshold current is the same – about 150 A at voltage of 1 MV. With the reduction of the conductivity in between the cavities the oscillations were not observed up to $160\div180\,A$.

On account of the results obtained, the klystron new version is designed which enables one to provide the excitation of the injector accelerating structure for c-τ-factory being developed at the Institute of Nuclear Physics.

The distinctive features of this klystron are: special absorbing insertion between the 6th and 7th resonators, new output system matched for 120 A current and a focusing lens between output system and collector. Fig. 3 shows alterations in construction of the klystron **K3-1**.

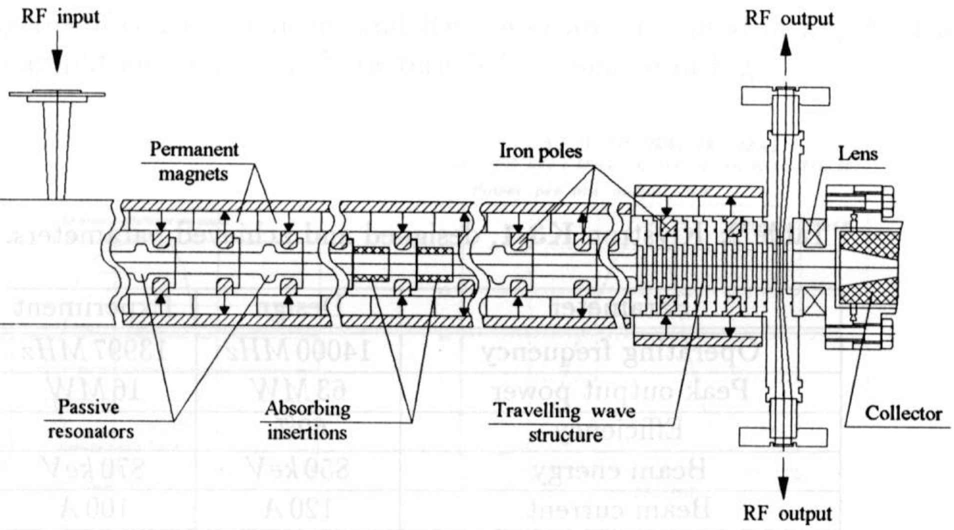


Figure 3: Schematic diagram of the klystron **K3-1**.

In first experiments with a voltage of $850\,kV$ and without operational frequency inputing, a rated current of $120\,A$ was led through the tube with transmittivity more than $90\,\%$. At currents of about 70 A, parasitic oscillations occurred with a frequency of $16050\,MHz$, which were observed in the output of the klystron only. The process has a threshold nature. With increasing focusing field in the output system, the threshold current was enhanced up to $100\,A$. The character of arising oscillations for two values of collector current is shown in Fig. 4. A current increase of $10\,\%$ leads to an oscillation amplitude growth in several times.

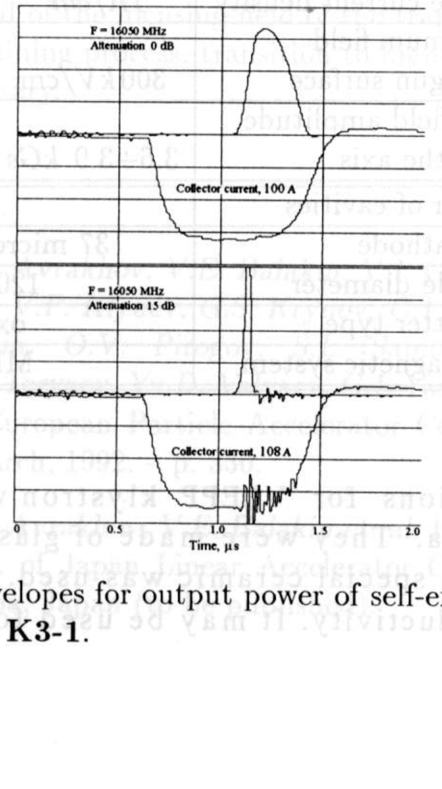


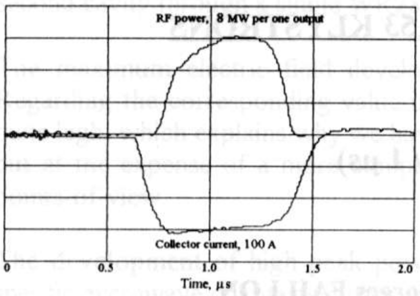
Figure 4: RF pulse envelopes for output power of self-excitation and collector current of the klystron **K3-1**.

Table 2: Klystron **K3-1**, designed and achieved parameters.

Parameter	Design	Experiment
Operating frequency	14000 MHz	13997 MHz
Peak output power	63 MW	16 MW
Efficiency	62%	–
Beam energy	850 keV	870 keV
Beam current	120 A	100 A
Pulse duration	0.5 μsec	0.5 μsec
Input saturation power	0.6 W	0.1 W
Band width	35 MHz	16 MHz
Repetition rate	–	1 Hz
Saturation gain	80 dB	82 dB
Attenuation of absorbing insertion, 256 mm long	20÷25 dB	–
Maximum field in the cavities	170 kV/cm	–
Maximum field on the output system surface	570 kV/cm	–
Microcathode current density	5 A/cm^2	–
Maximum field on the gun surface	300 kV/cm	–
Magnetic field amplitude on the axis	3.6÷3.9 kGs	3.6÷3.9 kGs
Number of cavities	8	
Cathode	37 microcathodes	
Cathode diameter	120 mm	
Emitter type	oxide	
Type of magnetic system	MPFS	

Absorbing insertions for VLEPP klystron were presented by G. Dolbilov from Dubna. They were made of glass carbon material. For the K3-1 klystron a special ceramic was used. The ceramic has high tg δ and some conductivity. It may be used for vacuum brazing.

Thereafter training of the device in a regime of amplification was started. Oscillograms of collector current and RF power are presented in Fig. 5. The klystron amplitude-frequency characteristic is presented in Fig. 6.



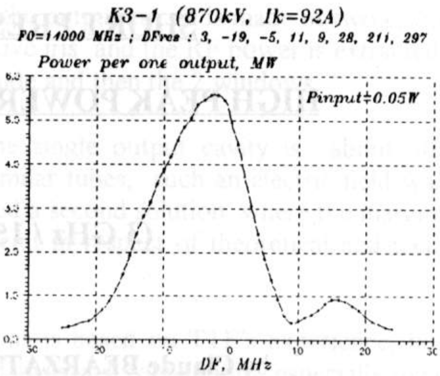


Figure 5: RF pulse envelopes for output power and collector current of the klystron **K3-1**.

Figure 6: Amplitude-frequency characteristic of the klystron **K3-1**.

Some design and experimental parameters of the **K3-1** klystron are given in Table 2. All here presented data were obtained in one and the same regime.

Training of the device is still in progress. Moreover, reasons of occurrence of oscillations at frequency of 16050 *MHz* are being studied. Estimations show that initiation of a nonsymmetrical mode of oscillations in the output system is possible. This is witnessed by the occurrence of oscillations in the output of the klystron only, the influence on it of magnetic field of the lens located at the klystron output and of the focusing field of the transportation system.

For reduction of training process, transition to high-vacuum technology of manufacturing is necessary.

References

[1] *L.N. Arapov, P.V. Avrakhov, V.E. Balakin, V.I. Chashurin, S.Yu. Kazakov, N.G. Khavin, V.F. Klyuev, G.S. Krynov, G.I. Kuznetsov, A.V. Larionov, A.N. Lukin, O.V. Pirogov, S.L. Samoilov, V.V. Shirokov, N.A. Solyak, V.E. Teryaev, Yu.D. Valyaev, G.I. Yasnov.* 14 GHz VLEPP Klystron. Third European Particle Accelerator Conference (EPAC 92). Berlin, 24 – 28 March, 1992. – p. 330.

[2] *L.N. Arapov, P.V. Avrakhov, V.E. Balakin et. al.* High power sources for VLEPP. In: Proc. of Japan Linear Accelerator Conference (Linac-94), Aug. 1994, Tsukuba, Japan (to be published).