OPTICAL SYSTEM OF THE POWERFUL MULTIPLE BEAM L-BAND KLYSTRON FOR LINEAR COLLIDER

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Abstract

An optical system reported here was proposed and designed for Toshiba MBK (E3736). Toshiba MBK is the 10MW L-band multiple beam klystron being developed for TESLA (XFEL) project. The key features of this device are following.

1. A new compact scheme of confined flow focusing, which allows using ring shape cavities at the klystron, operating on the fundamental mode.
2. Low cathodes loading (<2.1A/cm^2) in comparison with analogues.
3. Controlled beamlet size (diameter) at the drift tubes of klystron.

The first successful tests of E3736 at Toshiba allow concluding about possibility to develop next generation of powerful MBK, using such focusing scheme of a beam.

INTRODUCTION

At present, the powerful multiple beam L-band klystrons are considered as the basic type of RF sources for power supply of a superconducting linear accelerator (projects TESLA, XFEL). The known and developed for these purposes MBK Thales TH1801 is already used at TTF and demonstrates efficiency about of 65 % with the peak RF power 10MW [1]. However the serious disadvantage of this device is the high cathodes loading, which attains up to 5.5 A/cm^2 with 1.5-2 msec pulse, resulting in limited life time.

The MBK CPI VKL-8301 [2], that is being developed now, can be considered as the attempt of cardinal solution of this problem. This device consists of a package of one –beam klystrons, which are connected together by common HOM (High Order Mode) input and output cavities. The use HOM cavities allows to increase distance between beamlets, to increase diameter of cathodes and relatively easy to solve the beamlets shaping problem. The design cathodes loading in VKL-8301 makes up 2.5 A/cm^2, and the expected life time exceeds 100000 hours. The disadvantage of the CPI approach is complexity and bulkiness of a design that will probably affect on the cost of this tube.

In our opinion, the best alternative for the mentioned above klystrons is also now being developed MBK Toshiba E3736. The paper design of the optical system of E3736 is described below.

Notice that the ring shape cavities operating on the fundamental mode and 6 beamlets are used in this device. Design efficiency exceeds 65%. At the cathode loading 2.1 A/cm^2 the cross-section size of E3736 is 1.6 time less, than size CPI VKL-8301.

OPTICAL SYSTEM

The schematic diagram of Toshiba MBK E3736 is shown on fig.1. Its essential design parameters can be seen in Table 1. The confined flow multiple beam gun with the six off-axis beamlets are used in this device. The beamlets are arranged in a circle with a diameter 120 mm in regular intervals. The diameter of the individual cathode is 38 mm.

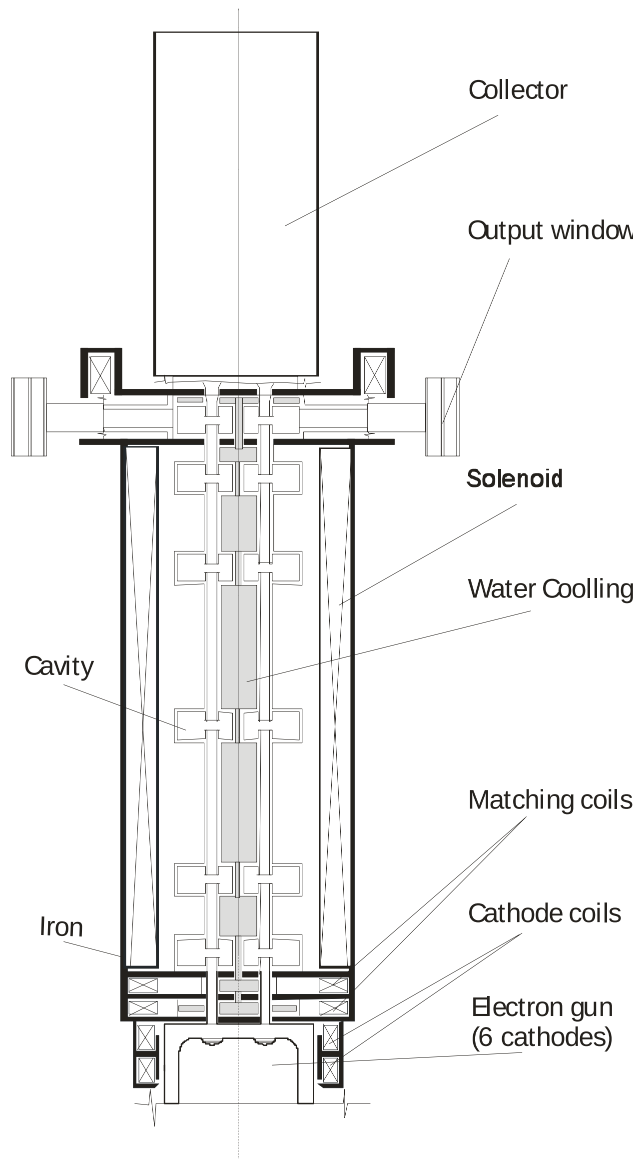

Figure 1: Schematic diagram of Toshiba MBK (E3736)

Table 1: Design Parameter of E3736

Operation Frequency	1300 MHz
Peak Output Power	10 MW
Average Output Power	150 kW
Cathode Voltage	115 kV
Beam Current	132 A (6×22 A)
Efficiency	> 65%
RF Pulse Duration	1.5-2.0 msec
Repetition Rate	10 pps
Saturation Gain	47 dB
Number of Beams	6
Cathode loading	<2.1 A/cm^2
Solenoid Power	≈ 4 kW

Notice that, the majority of known multiple beam klystrons use Brillouin focusing, which limits high power operation. At the same time, the known and proposed schemes for confined magnetic flow multiple beam guns are structurally very complex. For example in work [3] it is offered to place the local non symmetric iron around of each individual micro-gun. The design of these micro-guns are non axial-symmetric too.

The problem of the confined flow multiple beam shaping is being solved in klystron E3736 by the use of two common cathode coils, which are placed around of (macro) gun (see fig.1). The necessary level of a local symmetry of a magnetic field at the region of beamlet shaping is being reached by the corresponding choice of the iron shape and coils currents. A simulation by ANSYS show, that the transverse magnetic field, i.e. field component which is non symmetric about beamlet axis, can be reduced to 0.2 % here, that is sufficient condition for bemlets shaping.

The choice of the shape of gun electrodes also has been aimed to minimize 3D beamlets displacements and perturbations, including effects of self magnetic field. Different computer codes were used for the modeling.

The example of the klystron gun simulation by GUN3D is shown in fig.2. The 3D stationary gun modeling code GUN3D has been under development at PTC of LPI (Protvino). One of the features of code is the computation model of the beam self-magnetic field, corresponding to the ideal conducting surfaces of the gun electrodes. Thus, the 3D multiple beam shaping problem is being solved here as the quasi-stationary.

The final gun design has the maximal electric field on the surface equal 5.6kV/mm (for comparison in MBK Thales 1801 7kV/mm) and cathode current density up to 2.1A/cm^2. The common result of 3D modeling is the fact that beamlet displacement from optical axis and also different beamlet cross-section deformations are small enough. The characteristic value of these displacements and deformations does not exceed 0.3-0.5 mm for the typical beamlet diameter 10-12 mm. On this basis, the faster 2D modeling codes can be used for the finally designed gun that allows solving, for example, beamlets matching problem with a solenoid. The use of 2D model

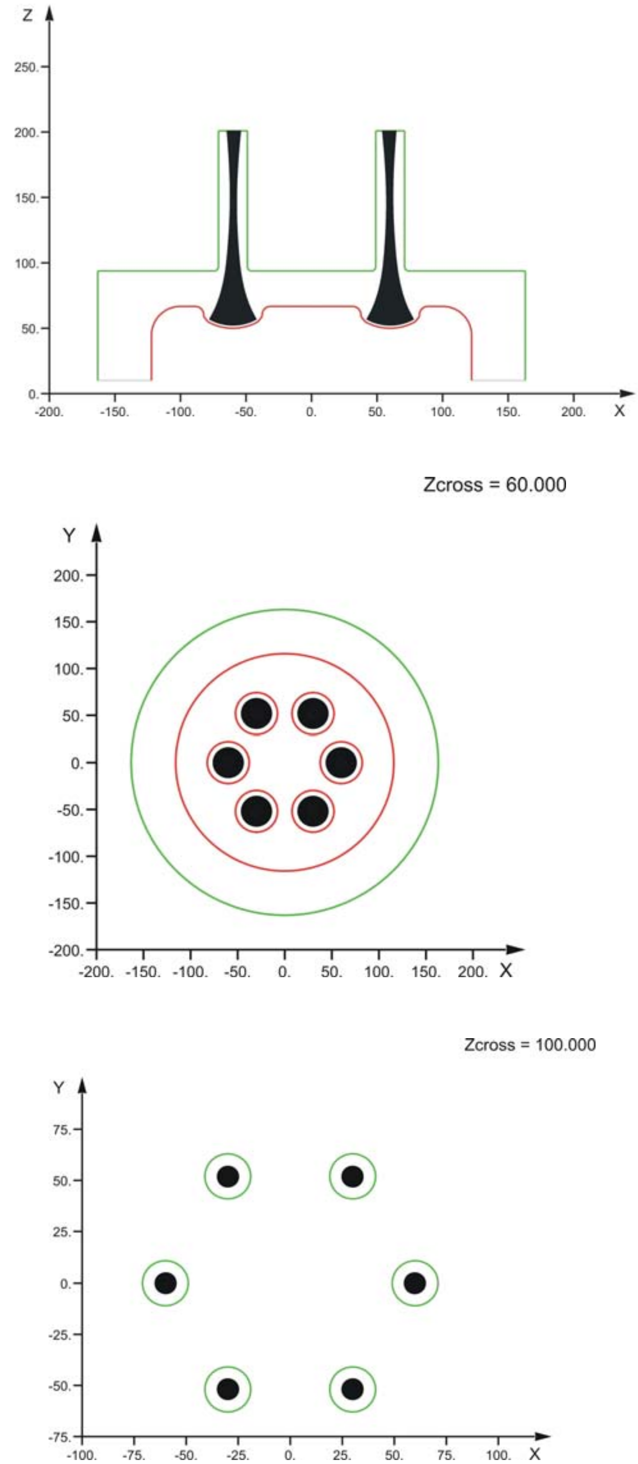

Figure2: Example of GUN3D simulation of the klystron multiple beam gun (Case without external magnetic field)

is also very important for the simulation of the klystron dynamic mode. The example of such modeling, by DGUN code [4] is shown in fig3.

For the beamlets match with a solenoid magnetic field, two magnetic lenses are used in klystron. The lenses structure is closely to main solenoid structure. The use of two lenses makes available high adaptability of the

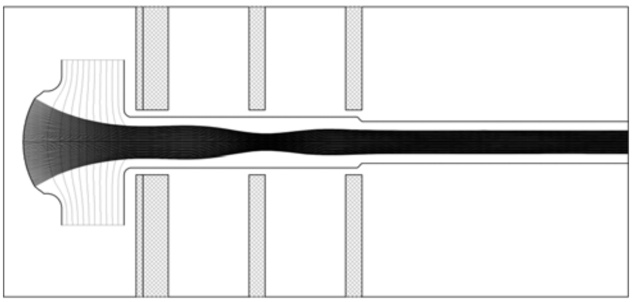

Figure3: 2D modelling of the beamlet matching with a solenoid

klystron optic, that allows matching beamlets in a wide ranges of solenoid fields and magnetic fields on the cathode. The approximate limits of ranges, obtained by DGUN, can be specified as the following.

$B_{cathode}$ ~ 0 -100 Gs

$B_{solenoid}$ ~ 500 -1300 Gs

For these ranges the beamlet size (diameter) at the drift tubes of klystron can be changeable more than twice (6-14mm) and 2D pulsations of beamlet enveloped curve do not exceed 3%. The multiple beam with the controlled (changeable) beamlets diameters allows to realize additional and effective "fine tuning" of klystron, for example, to optimize RF efficiency, current passage in a dynamic mode, to depress spurious oscillation in case of appearance and etc.

Also notice that the combination of the presented optical system and ring shape klystron cavities allows realizing simple and highly effective cooling of device body, by the use of the inner space (see fig.1). As the consequence, the acceptable level of beam losses at the klystron can be very high.

FIRST TOSHIBA MBK TESTS

Current passage at the klystron above 98% was obtained in recently started tests at Toshiba. (Diode mode, U=115 kV, τ=1.5msec, Rep. rate 10 Hz). The peak RF power 10.3 MW was reached during the short pulse (τ=40 μsec) for the voltage 115 kV, that corresponds to the klystron efficiency 67-68%! [5]

CONCLUSION

Thus, the presented optical system is relatively simple, compact and affording the high reserve reliability of klystron. The first successful tests of E3736 at Toshiba allow concluding about possibility to develop next generation of powerful MBK, using such focusing scheme of a beam.

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