X-BAND KLYSTRONS FOR JAPAN LINEAR COLLIDER

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ABSTRACT
To achieve the acceleration gradient of 100 Mev/m necessary for the future linear collider in X-band, an RF power source which could produce more than 100 MW peak power with the pulse duration of 500nsec is needed even with the factor 4 RF pulse compression system. As the first step for the development of the 100MW class klystrons in X-band(11.424 GHz), a 30 MW class klystrons named XB-50K were tested several times since 1990. XB-50K was already tested up to the peak power of 18 MW with the pulse duration of 100ns. A new 100 MW class klystron named XB-72K was designed and fabricated. Some test results of this klystron is reported.

1. INTRODUCTION

At the present status of the design studies dedicated to the next generation of the linear collider, the necessary output power of the RF power source in X-band is still under complecated discussions(Ref-1). Since 1989, the R&D program aiming the 100 MW class X-band klystron has been carried out partly and still under progress. As the first step of this R&D program, 30 MW klystron in X-band named XB-50K was designed, fabricated and tested for several times.(Ref-2,Ref-3) A new 100MW class klystron named XB-72K was designed. The first XB-72K was fabricated and tested in last April up to the cathode voltage of 430 kV,at that voltage the cathode ceramics had many pin-holes possibly due to the high voltage break-down. This #1 XB-72K was repaired with the new cathode ceramics and under high voltage test this August.

2. XB-50K's

XB-50K's are the 30 MW class klystrons developed as the first step to the 100 MW or even more peak power klystrons in X-band. The main purpose of this rather moderate power klystron is to produce the RF power useful for the several high power tests of X-band parts including the high gradient tests of X-band accelerating structures. Prior to the design of this XB-50K, the Pierce type test gun named XB-50D, without the focusing magnetic field, had been fabricated and tested.(Ref-2,Ref-3) As the results of this test diode, the gun parameters designed as XB-50K was checked successfully. The design parameters of XB-50K are summarized in the Table-1). Further details of the design of XB-50K are reported in Ref-3).

Table-1) XB-50K parameters

Beam voltage	450 kV
Beam current	170 A
Max. Surface Field	260 kV/cm
Beam areal compression	80 to 1
Cathode diameter	50 mm
Current density(Max.)	10 A/cm2
Focusing field(Bz, Max.)	4.6k
Number of cavities	5
Frequency	11.424 GHz
RF power	36.2 MW
RF efficiency	47.3 %
Max. Surface Grad. (Output gap)	1000kV/cm
Gain	53.5 dB

2.1 XB-50K fablication and test results

Since 1990, #1, #1a, #2 and #3 XB-50K's were all fabricated by TOSHIBA Corporation and delivered to KEK.XB-50K #1, which had the 1/2 wavelength rectangular ceramic window had been tested in 1990 up to the peak RF power output of 11 MW with the pulse width of 70 nsec, at this level the window was broken due to the RF discharge. After this failure in the window #1 was rebuild with the ordinary pill-box type window and tested in 1991 successfully up to the peak power of 18 MW with 100nsec pulse duration. The new pillbox type window could survive up to this power, and showed only slight discharge. Following results were obtained by these tests of XB-50K#1 & #1a.(REF-4)

1) With the pulse duration of 100 nsec, 18 MW peak RF output was obtained at the cathode voltage of 403 kV.

2) RF efficiency was measured as ~30 % at the peak power of 18 MW and this value is still lower than the simulation result of 42 % at this cathode

voltage. Further trimming of the magnetic field is considered.
3) Diode characteristics, such as the perveance, fault rate etc., are all in good agreement with the gun simulation and the operation experience obtained in the previous high voltage tests of the XB-50D test diode.
4) Ceramics window of pill box type tested in the opration of #1a tube showed only slight discharge, and could survive through the 500 hours operation dedicated to the high gradient test of X-band accelarating structure. For the longer pulse operation such as 500 nsec or even more, further R&D works in window ceramics are required. For the R&D of high power windows, X-band SLED system and an X-band resonant ring are under construction.

3. XB-72K

XB-72K is the 100 MW class klystron designed as the prototype klystron which could satisfy the minimum peak power requirement as the possible power source for X-band linac in the next generation of linear collider. The main purpose of this klystron is to produce the peak RF power of 100 MW or more. Other possible problems such as a power efficiency including a modulator efficiency, focusing magnet power consumption are not discussed in this report.

3-1 Design of XB-72K

Assuming the RF efficiency of 40 %, the necessary beam power is more than 250 MW. Considering the present state of arts in the pulsed high power klystrons, The cathode voltage of 550 kV with the perveance of 1.2 micro-perveance was decided. This cathode voltage is ~30 % higher than that of present high power klystrons such as #5045 and other S-band tubes. Generally, these present tubes are operated with the pulse width of a few micro seconds. The XB-72K's are to be operated with the rather shorter pulse length such as 500 nsec flat top compared to the typical S-band tube operation. Therfore it is pretty reasonable that the cathopde voltage of 550 kV to 600 kV is safely within the reach of present high voltage pulse technologies. By the use of E-GUN code(REF-5), the diode design of the XB-72K was carried out, and the final design parameters are summarised in Table-2). In spite of the considerrable increase of the cathode voltage compared to that of XB-50K's, the surface field strength could be kept relatively low value of 273 kV/cm on the anode electrode as shown in Table-2). To achieve the beam areal compression of 110 to 1, cathode curveture is relatively small as 53 mm. Therefore the cathode loading is rather large especially around the peripheral of the cathode, it reached to 17 A/cm2 at the maximum and 10 A/cm2 in average at the cathode voltage of 550 kV. Even at the maximum cathode loading, the life of the cathode determined by the operating temperature is on the order of several tens of thousands hours(REF-6). RF design was also carried out by the use of FCI-code(REF-7). The specific point of this klystron is in the output cavity without a nose cone(REF-8). With this cavity structure, the maximum surface field in the output gap was kept lower than that of XB-50K in spite of the considerable increase of the RF output power. Two output waveguide with the pill-box type ceramic windows on each are attached to the output cavity symmetrically.

Table-2)

Beam voltage	550 kV
Beam current	490 A
Max. surface field	273 kV/cm
Beam areal compression	110 to 1
Cathode diameter	72 mm
Current density(Max.)	17 A/cm2
Focusing field(Bz Max.)	6.5 kG
Number of cavities	5
Frequency	11.424 GHz
RF power	120 MW
RF efficiency	47 %
Max. Surface Grad. (Output Gap)	720 kV/cm
Gain	53~56 dB

3-2) XB-72K fabrication and test results

The fabrication of the first XB-72K was carried out by TOSHIBA Corporation, and deliverd to KEK. The picture of the high power test set-up is shown in Fig-1). As shown in the Fig-1), the two output windows are connected to seperated high power matched load respectively, and the output power was measured independently on each wave-guide.

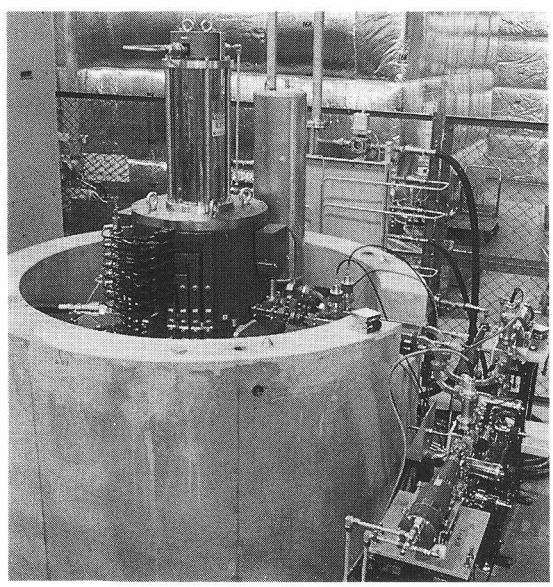


Fig-1) XB-72K with output waveguides.

The first high power test of the XB-72K was carried out last April(REF-9). At the cathode voltage of 430 kV with the Rf output power of 22 MW, the gun ceramics had small air leak and the test was terminated at this stage. The relations Observations through the drift tube from an anode to the down stream end of the output gap was carried out by the use of a glass fiber scope for medical use, and no visible damage was found on the inner surface of the drift tube. Apparently up to this voltage, no serious beam interception did exist in the beam drift section in this XB-72K.

XB-72K #1 was rebuilt with new gun ceramics, a new cathode and new windows. The high power test are under way, and following results were obtained last August.

1) 486 kV cathode voltage and 190 MW beam power were achieved.
2) 33 MW RF output with the pulse duration of 100ns was obtained.

Fig-2) XB-72K saturated power vs cathode voltage

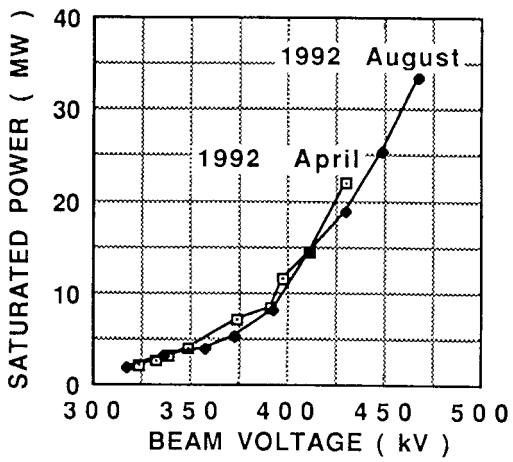
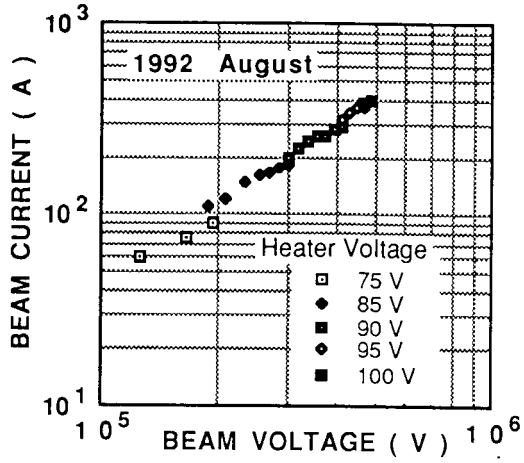


Fig-3) XB-72K perveance curve



3) RF efficiency was 18%.
4) Up to that cathode voltage no serious high voltage breakdown was observed.

Saturated RF power vs cathode voltage are summarized in Fig-2), and measured perveance curve are in good agreement with the simulation up to this cathode voltage.(see Fig-3)

4. SUMMARY and DISCUSSIONS

Two XB-50K's has been tested up to 18 MW of the peak RF power, #1a with the pill box window successfully produced RF power with the pulse duration of 100 nsec or shorter. Further high power tests of XB-50K and XB-72K are scheduled to the end of 1992. As the results of these high power tests, further intensive R&D activity is required and under progress for the X-band klystron development.

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