X-BAND KLYSTRON FOR JAPAN LINEAR COLLIDER

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ABSTRACT

To achieve the acceleration gradient of 100 MeV/m necessary for Japan Linear Collider (JLC), an RF power source of more than 100 MW will be needed. As a first step for the development of 100 MW class X-band(11.424 GHz) klystrons, a 30 MW klystron named XB-50K was designeed and fabricated. The first RF power test was carried out at the end of last August, up to the cathode voltage of 350 kV. 11 MW RF power of 70 nsec pulse was achieved at the rep-rate of 2 pps. and the efficiency was measured as 28 %. Up to this power the test results showed a good agreement with the simulation results obtained by the FCI-code. An RF window ceramic was fatally damaged while conditioning around 11 MW RF output.

INTRODUCTION

As the main linacs for JAPAN LINEAR COLLIDER(JLC), X-band linacs in 11.424 GHz with the accelerating gradient of 100 MeV/m or more are the most probable candidate(1). To achieve this accelerating gradient, RF power sources which can produce the peak output power of more than 100 MW will be necessary. As a first step of the R&D to 100 MW-class klystrons, 30 MW-class klystron, named XB-50K, was designed, fabricated and tested.

KLYSTRON DESIGN

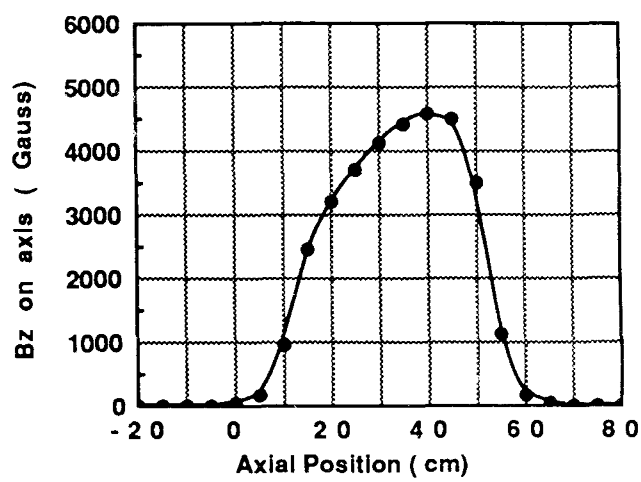
Prior to the design of the XB-50K, a Pierce type electron gun, named XB-50D was already fabricated and tested up to the cathode voltage of 480 kV and the test results showed good agreement with the computer simulation by the use of E-GUN code by W.B.Herrmannsfeldt(2). The design and some test results were reported in REF(3). The gun parameters are summarized in Table-1).

TABLE-1)

Cathode Voltage	450 kV
Beam Current	170 A
Maximum Surface Field	260kV/cm
Perveance	0.57 micro
Cathode Diameter	50 mm
Cathode Spherical Radius	60 mm

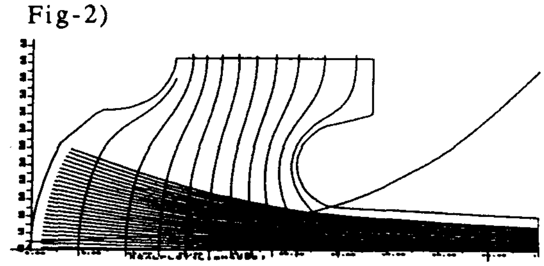
To reduce the maximum surface field strength compared to that of the XB-50D, the geometry of the cathode and anode were slightly changed and the maximum surface field strength is reduced down to 260 kV/cm at the cathode voltage of 450 kV(3). Fig-1) shows the focusing magnetic field distribution along the beam axis. The maximum field strength is 4.6 kgauss and on the cathode, 37.6 gauss was used in the beam trajectory simulation by the use of E-GUN code.

Fig-1)



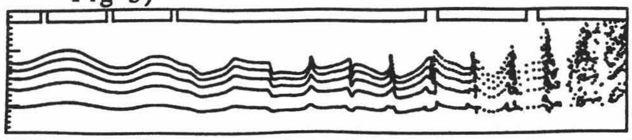
The beam trajectory obtained by E-GUN code is shown in Fig-2), and the focused beam revealing some scalloping could travel through the drift tube of 8 mm in diameter to the downstream of the output cavity which is located at 488 mm from the cathode center.

Fig-2)



The RF simulations were performed by the use of FCI-code(Field Charge Interaction) developed by T.Shintake(4), and the results are summarized in Table-2). At the cathode voltage of 450 kV with the beam current of 170 A, RF output power of 36.2 MW with the efficiency of 47.3 % was obtained. The beam snap-shot picture of this simulation is also shown in Fig-3).

Fig-3)



This result shows that the beam could travel through the output cavity with the beam aperture of 8 mm in diameter.

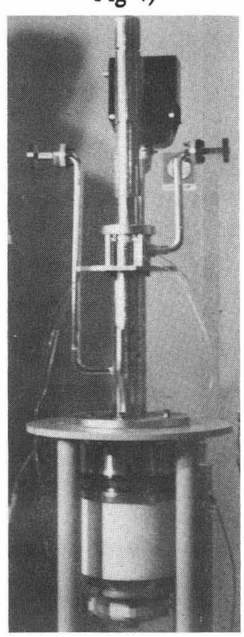
TABLE-2)

Beam Voltage	450kV
Beam current	170 A
Drift Tube Diameter	8 mm
Cathode Diameter	50 mm
Magnet Field(Bz,MAX)	4600 Gauss
(Bz,Cathode)	37.6 Gauss
Number of Cavities	5
Frequency	11.424 GHz
RF Power	36.2 MW
Gap Voltage(Output Cavity)	531 kV
Maximum surface Field (output Cavity)	102 MV/m
Efficiency	47.3%
Gain	53.5 dB

FABLICATION OF XB-50K

The first XB-50K was fabricated by TOSHIBA Corporation in accordance with the ordinary fabrication method of the pulsed klystrons. The cathode material is an Ir-coated dispenser cathode supplied by TOSHIBA Corporation(5), and the normal operating temperature is around 1000-degree Celsius. An overall view of XB-50K is shown in Fig-4). At the down stream end of the WRJ-10 wave guide, half-wavelength alminum ceramics is brazed inside of the rectangular wave guide flanges.

Fig-4)



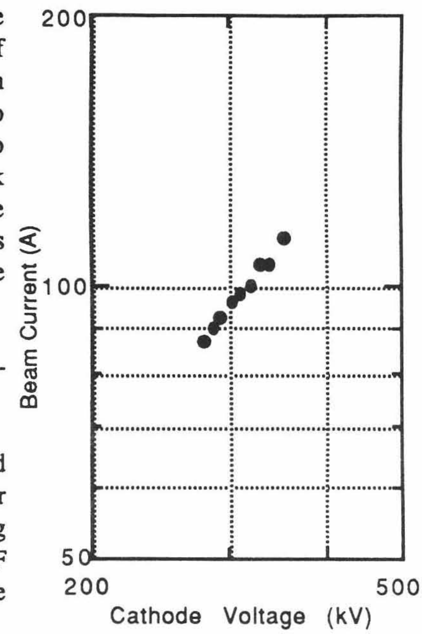
The cross sectional dimensions of this ceramics are the same as the WRJ-10 wave-guide, with the thickness of 4.55 mm. For the input window, the same window is also used. As shown in Fig-4), the gun structure and the materials are almost the same as those of XB-50D which is alresdy tested and reported(3).

TEST RESULTS

Prior to the RF processing, DC conditioning was performed at the repetition rate of 2 pps, until rather stable diode operation was achieved at the cathode voltage of 250 kV. After this preliminary processing, RF processing was started with the input RF pulse length of 500 nsec. Output RF power was monitored through the 63.2-dB directional coupler located at the upstream of the dummy load. After 20 hours of processing at the repetition rate of 2 pps, saturated RF power of 9.2 MW with the pulse duration of 140 nsec was reached at the cathode voltage of 338 kV. During this processing the input RF pulse length was shortened down to this value. Above this level, the input RF pulse was shortened down to 70 nsec, and the processing was continued up to the cathode voltage of 350 kV with the saturated RF power of 11MW. At this RF power level, due to the serious window discharge which emits a bright white and yellow light, the processing could not be completed until the stable opration of the tube was achieved.

The diode characteristics of XB-50K up to the cathode voltage of 350 kV are shown in Fig-5). Up to this voltage no serious break down or trouble were observed as long as the diode characteristics are concerned. The pulse wave-forms of a cathode voltage, beam current and RF output power observed during the RF conditioning, are shown in Fig-6).

Fig-5)



The RF output pulse duration and peak power were 140 nsec and 9.2 MW. respectively.

Fig-6)

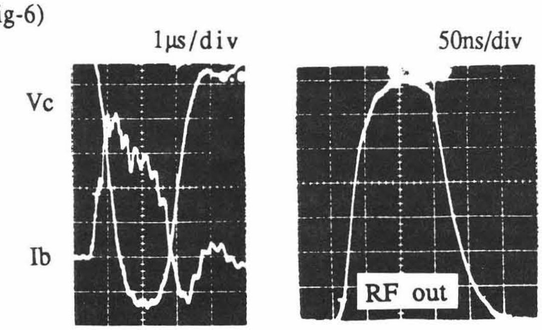
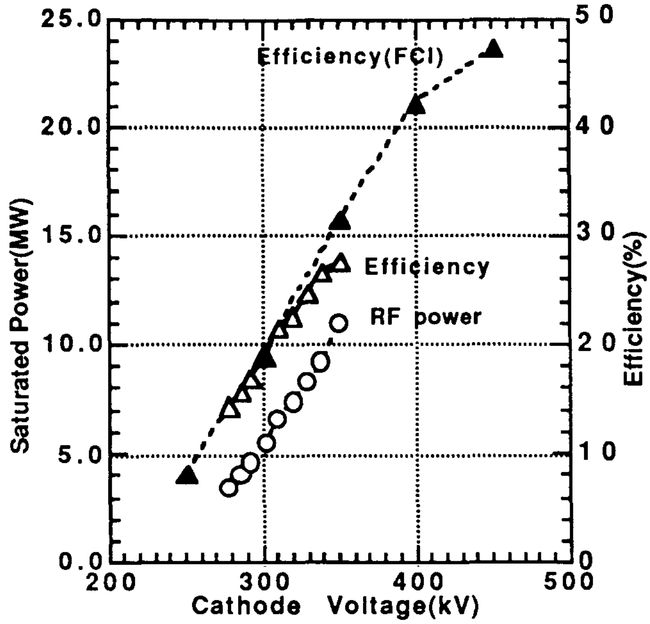


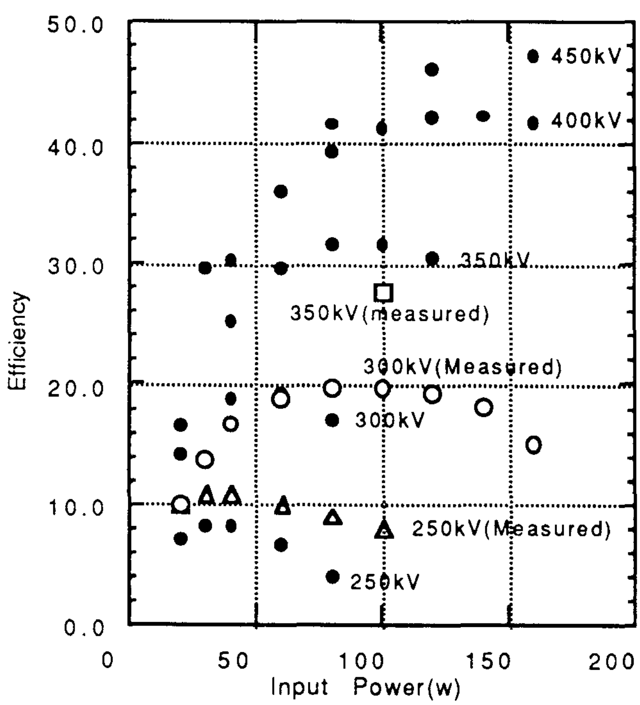
Fig-7) shows the relations of cathode voltage vs. saturated output RF power and efficiencies up to 350 kV of the cathode voltage.

Fig-7)



The efficiency and the simulation result by the use of FCI-code are also shown in Fig-7). The measured RF power and the efficiencies showed a good agreement with the FCI simulation results up to 350 kV cathode voltage and 11 MW RF output. The measured input vs. output performance with FCI simulation results are shown in Fig-8). At the cathode voltage of 250kV and 300kV, each measured curves are fairly good agreement with the FCI simulations.

Fig-8)



While conditioning the tube around or over 11 MW with the RF pulse duration of 70 nsec, the light emission from the window ceramics became brighter than before and the pressure burst in the wave guide increased up close to 1*10-6 Torr. At almost the same time RF output wave form became unstable and RF power level had to be decreased. On the ceramics surface of the atmospheric side of the RF window, a serious damage, which is apparently caused by the RF discharge, was observed and the window had an air leak fatal for a vacuum tube through the ceramics. On the surface of the ceramics, discharge marks of sputtered metal film was observed and inside of the waveguide, fine powder of the chipped ceramics was found.

SUMMARY

A X-band 30 MW klystron was built and tested. Saturated RF output and efficiencies between 250kV to 350 kV of cathode voltage were in good agreement with the FCI simulation results. As long as the diode operation is concerned, no significant trouble was observed. While processing at 11 MW with the 70 nsec pulse duration, the half wave-length aluminum ceramics output window was fatally damaged.

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