X-BAND KLYSTRONS FOR JAPAN LINEAR COLLIDER

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Abstract

To achieve the acceleration gradient of 100 MeV/m required for X-band Linear Colliders , an RF power source of more than 100MW in X-band(11.424 GHz) will be necessary. A 1.2 micro-perveance. 100 MW class klystron named XB-72K was designed and built. The first tube had been tested in 1992 up to 600kV with the beam power of 330MW, peak RF power of 93MW with 50nsec duration, 29% efficiency was achieved at the cathode voltage of 570kV. The 2nd tube is under conditioning at 70MW 50ns RF output at 20pps. The efficiency reached to 35% and showed the good agreement to the FCI simulation. Test results of these two klystrons and some recent test result of TE11 mode ceramics window are presented.

Introduction

Since 1988, R&D of the X-band klystron in KEK has been carried out and in this R&D program the two types of the X-band klystrons have been designed and tested(REF-1,2,3). The first one is the 30 MW class klystron named as XB-50K. This rather moderate peak power klystron was designed as the first step to the 100 MW class klystron and produced 26 MW peak power. This XB-50K#1a successfully supplied the RF power to the first X-band accelerating structure test in 1992.

The second klystron named XB72K in this R&D program, was designed as the first 100 MW class klystron which could possibly satisfy the minimum power requirement for the RF power source of the X-band liner accelerator in the next generation of several hundred GeV electron positron linear colliders. The first XB-72K#1 was tested in 1992 and successfully achieved the RF output of 94MW 50ns. The second XB72k#2 is under conditioning at the RF out of 70MW 50ns.

XB-72k's and their test results

XB-72k is the 100MW class klystron designed as the prototype klystron which can satisfy the minimum peak power requirement as the possible RF power source of the several hundred Gev linear colliders. The design parameters are summarized in Table-1), and the design criteria was chosen within the reach of the present state of the art in S-band klystrons such as SLAC 5045 and also considering our experience obtained by the operations of 30MW class X-band klystron XB50k(REF-1,2). The cathode voltage, the cathode loading and other parameters such as surface field in the output gap were determined within the limits of present high power pulse technologies.

Table-1)

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

Two XB-72k's have been fabricated and tested. The first XB72k had been fabricated by TOSHIBA Corporation in 1992 and tested the fall of 1992. Fig-1) shows the experimental set up of XB72k#1. The second XB72k which was slightly trimmed in the RF circuit design was fabricated in 1993 and under conditioning. The high power test results of these two XB72k's are summrized in Table-2).

Table-2) Summary of the XB72k#1 and #2

(1)XB72k#1(1992 August -December)

1)Cathode voltage of 600 kV with 550A was achieved.(4 pps)

2)RF output reached to 94 MW(50 ns pulse width, 29% efficiency)

3)330 MW beam power was obtained.

4)Died due to the WINDOW failure.(DEC. 21st/1992)

5) An autopsy revealed that there is no evidence of the beam interception and the damage of the

RF discharge through the whole drift section including cavities.

(2)XB72k#2(1994 Feb.)

1)Tested up to 480kV,420A.

2)RF output reached to 70MW(50ns, 35% efficiency)

3)Pill-box windows are still in good condition.

4)Rf power source for the TWR(for window tests, etc..)

The high power characteristics of the XB72k#1 are shown in Fig-2)a-b. The measured perveance curve shows the good agreement with the Simulation up to the cathode voltage of 600kV. The cathode voltage was successfully conditioned up to 600kV. Through the whole conditioning process, no serious discharge which requires the re-conditioning from the lower cathode voltage was observed. Maximum peak RF output obtained in this experiment was 93MW 50ns. The RF conversion efficiency of XB72k#1 was 29%, while the FCI simulation result was 45%. This discrepancy was mainly caused by the inadequate simplification of the RF circuits shape used in the simulations. The recalculation after some correction showed the good agreement with the high power measurement(REF-4). The maximum RF pulse duration and peak output power were limited by the RF discharge problem in the ceramic windows, and at 93 MW both window was broken by the discharge in ceramic. On the ceramic surface, the discharge marks and the crack which has the air leak were observed. After the high voltage tests, this XB72k#1 was cut into half along the drift tube, and no trace of beam interception was observed on the inner surface of drift tube and cavities including the output cavity.

The second klystron XB72k#2, RF structures were slightly modified to obtain higher efficiency than that of XB72k#1. In #2, the corner radius of an aperture of the output gap was decreased to 1mm from 2mm of #1 tube to obtain better RF conversion efficiency. This change increased the maximum surface field strength in the gap by 40%. The high power test of this XB72k#2 started in 1993 Dec.. The measurement results are summarized in Fig-3)a-d). The high power conditioning was terminated after the cathode voltage reached to 480kV. This #2 has utilized as the RF power source for the several high power test such as TE11 window high power test, and X-band accelerating structure test etc. The RF conversion efficiency was improved up to 35% at 480kV of the cathode voltage, and the agreement between FCI simulation and high power measurement has been improved as shown in the Fig-3)). Two pillbox-type ceramic windows showed normal blue discharge up to the output power of 70MW(35MW/each) 50nsec pulse duration.

Ceramic windows

As described in the previous section, high power characteristic of the ceramic window is the most important problem in the R&D of high power pulsed klystron of high frequency range such as S-band ,X-band etc. The high power operation of XB50 and 72k series showed that the ordinary pillbox type window has the limit around 20-30 MW with the pulse duration of about 200nsec. In KEK, TE11 over mode ceramic window of the half wavelength ceramic was developed and tested in the X-band resonant ring. The TE11 mode X-band window consists of two TE10 rectangular-TE11 circular mode converters, and a half wave length thick alumina ceramic in the circular wave guide of 51 mm diameter. TiN coating of 40A thickness was applied on both sides. Fig-4)a and b show the first high power model of this TE11 window and high power test set up with the X-band resonant ring. The high power test was carried out up to the peak circulating power of 120MW with 300ns input RF duration, and also the circulating power of 70MW with 700MW input pulses. The RF wave form is shown in Fig-5). This window showed the promising results up to 70 MW circulating power. Up to 70MW 700ns input, only a normal blue uniform discharge was observed. Two TE11 window will be equipped in XB72k#5 in September. Furthermore, the traveling wave type ceramic window developed by S.Kazakov in BINP (REF-5)has already been delivered to KEK and it's high power test is scheduled in September.

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Fig-1) XB72k

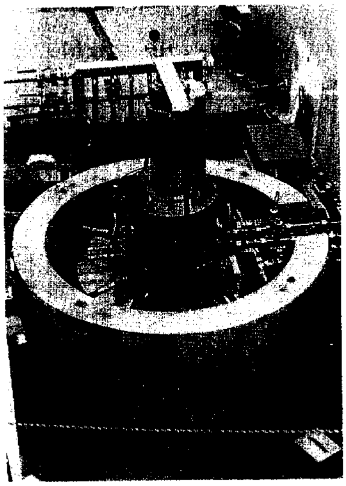

Fig-3)High power test results of XB72k#2

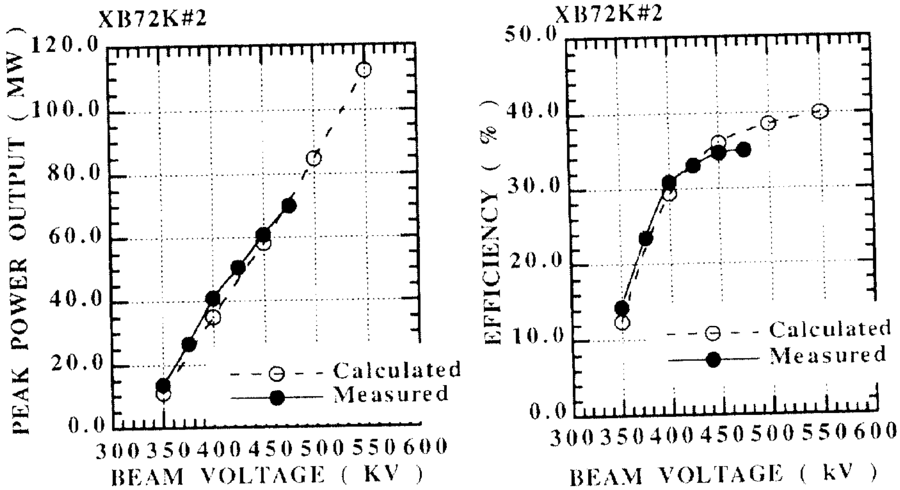

Fig-2)High power test results of XB72k#1

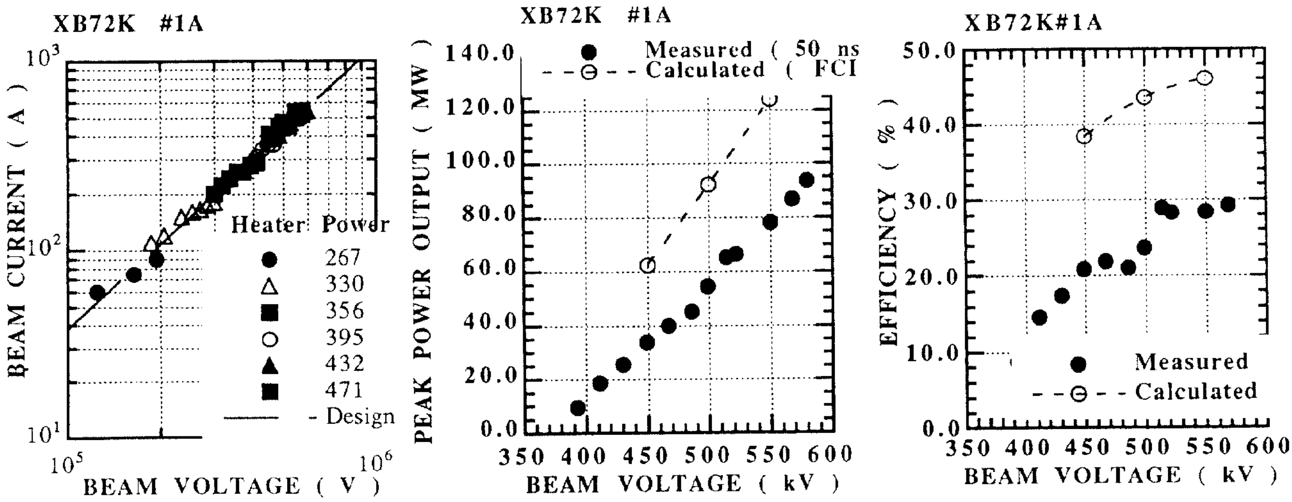

Fig-4)TE11 mode ceramic window and TWR test set up

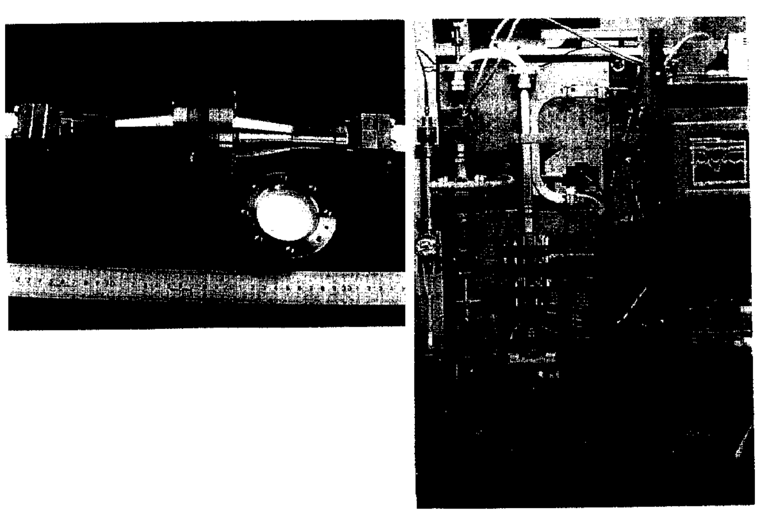

Fig-5)TE11 window high power test in TWR (700ns input pulse, 72MW peak in TWR)