RF HIGH POWER TESTS OF THE X-BAND WINDOWS IN THE TWR

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Abstract

Several high power tests in X-band were carried out by the use of X-band Traveling Wave Resonator(TWR). The new type ceramic window with TE11 mode half wavelength ceramic was fabricated and tested. The Travelling Wave Resonator(TWR) was tested up to 100MW circulating power successfully, and no serious breakdown was observed. The gain of factor 7 was achieved in the TWR with the TE11 mode window. High power test of the TE11 mode ceramic window was carried out up to the circulating RF power of more than 100MW peak power.

Introduction

In KEK, SLAC and BINP, several 100MW class X-band klystrons are under R&D stage(REF-1). At present, the 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. In KEK, the high power tests of XB50k and 72k series showed that the ordinary pillbox type window has the limit around 20-30 MW with the pulse duration of about 200nsec(REF-2). In the S-band RF ceramic windows discharge on the ceramic surface was found fatal at the surface field strength of about 8 kV/mm(REF-3). To reduce the surface field strength, the TE11 circular mode ceramic window was designed and tested.

Design and low power measurements

To reduce the RF power density in the ceramic, 51mmϕ half wavelength type ceramic was selected. TE11 mode converter was selected due to it's simple structure. As shown in FIG-1), this TE11 mode window consist of 2-TE10-TE11 mode converters, 2-circular tapered wave guides and 1-circular ceramic wave guide. The cutoff frequency in the ceramic(1.125 GHz) is far lower than the operating frequency, the careful calculation of the trapped mode in ceramics and tapered wave guide were carried out by the use of several methode such as the equivalent circuits, the field matching method and "MAFIA" and "HFSS". Some of the detail of these calculation was reported in REF-4). Table-1) shows the several trapped mode in the ceramics and trapped by the tapered wave guides, two trapped modes in the tapered wave guides are clearly seen in the low power measurement shown in FIG-2). The two trapped mode in ceramics were sensitive to the ceramics dimension and the small resonance was seen at 11.3GHz.

The length of the circular wave guide between ceramic surface and the end of the tapered wave guide was found important for the wide pass band and the electric field strength at the ceramic surface. Two type of the TE11 mode windows, 1/4 and 1/2 wavelength of this circular wave guide were designed in detail and fabricated. The field strength on the ceramic surface and the bandwidth are summarized in Table-2). These values were obtained by the use of "HFSS".

High power tests

The 1/4 wavelength TE11 mode window with the 99% ceramics was fabricated and tested in the resonant ring. The frequency response of this model was already shown in Fig-2). To suppress the secondary electron yield at the ceramic surface the 4nm TiN coating was applied by the RF sputtering method. Fig-3) shows the TE11 mode high power window with it's ceramic part blazed in the 1/4 wavelength circular wave guides. The copper parts were made by the "OFC-class 1' supplied by "HITACHI". Wave guide flanges of TE10 and TE11 mode respectively had been tested up to 550 C heat cycle in vacuum.

The experimental setup is shown in Fig-4), the resonant ring has the factor 7 amplification with the TE11 window set in the ring. The high power test was carried out in 2-stages. In the first stage, the resonant ring input pulse was adjusted to 300nsec, and it's pulse shape is shown in Fig-5a). the circulating peak power in the ring was increased up to 100 MW. The discharge on the ceramic surface was ordinary uniform blue discharge, and the significant RF reflection or the blight discharge spot which shows the surface flush over was not observed. After this operation the window was opened to the air and tested as He leak tight.

After He leak check and the eye observation through the fiber scope, the high power test was resumed. In this stage the RF input pulse length was increased up to 700 ns. The conditioning history is shown in Fig-6), and most of the operation was carried out with the repetition rate of 25-50pps. The maximum RF power circulating without heavy discharge which showed reflection was 70MW with input pulse of 700ns. This circulating RF pulse shape is shown in Fig-5b), and up to this power level, the operation was stayed rather stable, and while this power level the ceramic surface flush-over discharge had started. The flushover and bright spot discharge on the ceramic surface has increased while prolonging the RF input pulse longer than 700ns. Finally reflection at the window reached the level at which the resonant ring was completely out of tune. The ceramic window was fatally damaged at the end of this conditionig process, and cracks cuused by the heavy discharge and several discharge marks were observed on the ceramic surface.

Results and Discussions

In the high power test of the TE11 mode window in the resonant ring, following results were obtained.

(1)100MW circulating power with 300ns input was successfully achieved, and after this operation TE11 window passed the He leak test.

(2) 70MW circulating power with 700ns input was achieved and slightly longer input pulse at this power level damaged ceramics by the flush-over discharge.

(3) The surface field strength on the ceramic surface for several windows are summarized in the Table-2). TE11 window has the 1/2 of the field strength of an ordinary pill-box type window. As shown in Fig-5a,b), the maximum power reached to 4 times larger than that of the pill-box type and the maximum field strength was ~8kV/mm for both windows.

The maximum peak power is apparently limited by the field strength of 8kV/mm on the ceramic surface. The next TE11 window with the 1/2 wavelength type summarized in the Table-2) is under fabrication and will be tested at the fall of this year.

References)

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Fig-1) A schematic diagram of tha TE11 window.

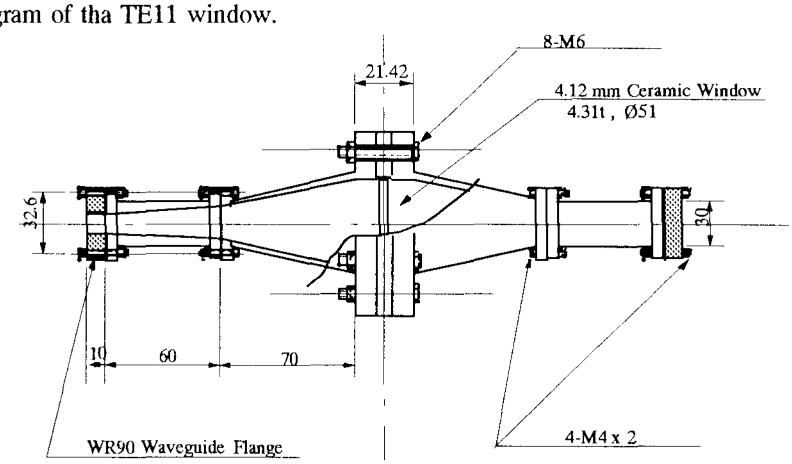

Table-1)Trapped mode around 11.424GHz

Between tapers	~11.3GHz, ~11.7GHz (Both were not identified)	
In Ceramics	(TE221 like)	~10.1GHz
	(TE131 like)	~11.5GHz

FIG-2) The frequency response of the TE11 window

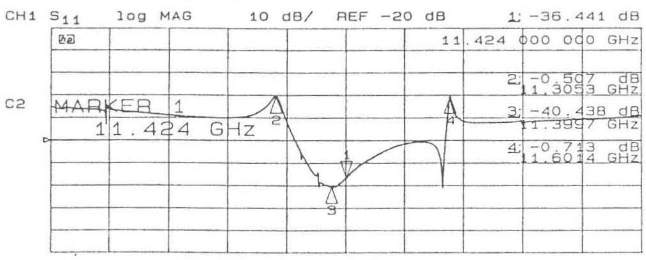

Fig-3)A TE11 high power model.

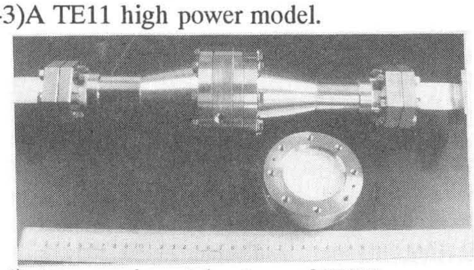

Fig-4) An experimental set-up of TWR.

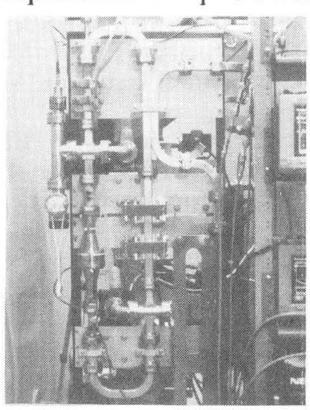

Fig-6) The conditioning history of TE11 mode window.

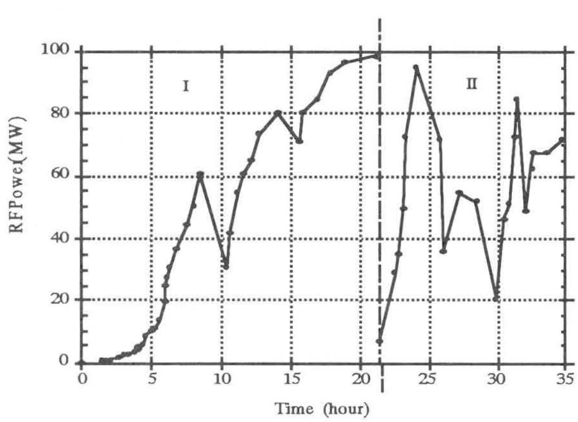

Table-2)Field strength on the ceramic surface

Type	Field strength*	Bandwidth
Pill-Box	0.868	500MHz
TE11(1/4lg)	0.424	250MHz
TE11(1/2lg)	~0.3	~300MHz

* Normalized to the TE10 rectangular waveguide.

Fig-5a) 100MW peak power with 300ns input. 200ns/div

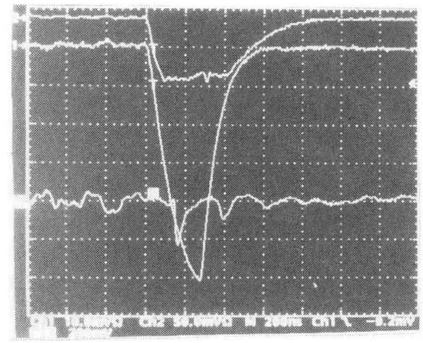

Fig5b) 70MW peak power with 700ns input. 200ns/div