DEVELOPMENT OF A HIGH-POWER VHF KLYSTRON FOR JHF

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Abstract

A VHF high-power klystron for the Japanese Hadron Facility (JHF) was studied at KEK and Toshiba Co.. The main parameters of this klystron are a frequency of 324 MHz, a 3 MW output power and a 650 μsec pulse width. In order to develop this klystron, we had started to design the klystron and to prepare tests for the key components: the high-power rf window and a modulation-anode type beam tester. Using the existing VHF (432MHz) high-power klystron we completed a high-power test of a coaxial window, which was designed with the HFSS code. The full design of the klystron is also under progress. In this article, the specifications of the VHF klystron, the mounting configuration, the design of the klystron and the high power-test results of the coaxial windows are reported.

1 INTRODUCTION

In the 200-MeV proton linac of the Japanese Hadron Facility (JHF), 19 VHF-klystrons are required as a rf source[1]. The operation frequency is 324 MHz and the klystron ratings have a maximum power of 3 MW, a pulse width of 650 μsec and a repetition rate of 50 pps. In order to develop this klystron, we started the klystron design and the preparation of tests for the important components: one is the high-power rf window and the other is a modulation-anode type beam tester, since they are the key components in the klystron device.

The window is a coaxial-type window and is connected to a WR-2300 rectangular waveguide through the transition between the coaxial to rectangular waveguide. In order to establish the design procedure and to confirm the performance of the window, we first designed the window at a frequency of 432MHz, since we have a power source including the Thomson TH2134 (the 2-MW, 432-MHz high-power klystron) and the 110-kV power supply. We finished a high-power test using this klystron.

2 SPECIFICATION

The choice of a klystron as the rf source of JHF seems to be a realistic solution. Concerning the frequency of the klystrons, so far 352-MHz CW tubes used at CERN were operated at one of the lowest frequencies. Our tube must be operated at a lower frequency than this CERN tube, and is not commercially available. We thus need to newly develop a 324-MHz high power klystron. One of klystron manufacturers strongly recommends us to use a multiple-beam klystron. A multiple-beam klystron uses several low-perveance beams in one tube, which enables us to increase the efficiency, decrease the applied voltage and stabilize the operation. Since this technique has just started, and there is not much experience to be used in the world, it seems to be risky for our project. Among the conventional klystrons, that with a modulation anode was chosen due to the long pulse width of 650 μsec. In this case we can avoid manufacturing a large pulse-forming network (PFN) of the modulator and the large-pulse transformer[2]. The general specifications for the JHF klystron are given in Table 1.

Table 1: Specifications of the klystron for JHF.

Item	Unit	Max.	Working(Sat.)
Operating frequency	MHz	324	
Peak output power	MW	3.0	2.5
Beam pulse width	μs	700	
RF pulse width	μs	650 (flat top: 620)	
Repetition rate	pps	50	
RF duty	%	3.25	
Beam current	A	50	45
Beam voltage	kV	110	102
Mod. anode voltage	kV	93	86
Beam micro-perveance		1.37	
Efficiency	%	55	
Gain	dB	46	
Number of cavity		5	
Input / Output port		N-type / WR-2300	
RF window		coaxial ceramic window	
Mounting position		horizontal	
Focusing		electromagnet focusing	

3 MOUNTING CONFIGURATION

Before describing the klystron design, we discuss the tube size and the mounting position in the klystron gallery, since the frequency is a VHF band. Generally, the klystron size is proportional to the wavelength of the operation frequency. For the JHF klystron operated at a frequency of 324 MHz, the estimated size is about 4.6 m long. Thus, how to set the klystron, i.e., which is better between horizontal mounting and vertical mounting is important. Figure 1 shows the horizontal mounting configuration; the klystron is installed on an oil tank which has a heater circuit insulated for high voltage. For the vertically mounted klystron, the crane reach should be high enough to pull up the tube; thus a strong and stable supporting girder is required and a stage to connect the output waveguide. The system thus becomes large and expensive. In the horizontal mounting case, the klystron assembly is carried in the horizontal position by a crane from the test hall. The 352-MHz CW klystrons, which are used in CERN, have the same mounting position as in Figure 1. This position is simpler and less expensive than the vertical mounting configuration. If we choose the horizontal mounting configuration, we can expect to take delivery of a completely assembled klystron with focussing coils, an oil tank, an output waveguide adapter and X-ray shields around the collector from the manufacturer. In the test hall and the klystron gallery, the klystron assembly will be installed as it is, and can be operated only by connecting cables, cooling-water pipes and a waveguide. For shielding X rays from the klystron body, we must prepare an X-ray shield room surrounded by lead-plate walls in every klystron station.

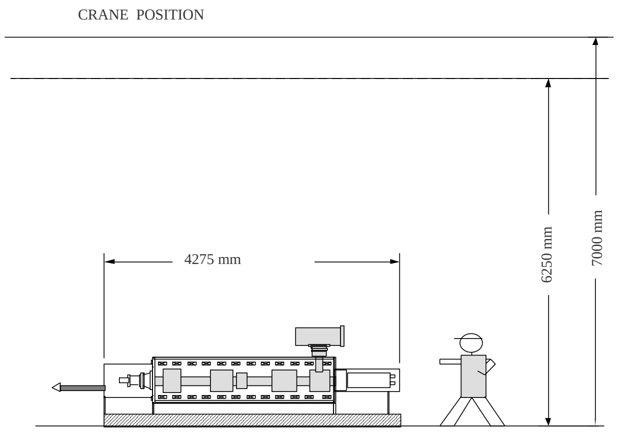

Figure 1: Horizontal mounting of the klystron

4. KLYSTRON DESIGN

4.1 Klystron Window

Klystron R&D studies are presently being developed. General key points of the klystron design are the electron gun and the output window. A coaxial-type ceramic window is applied for the window research. The coaxial line is converted to a rectangular waveguide of WR-2300 through a coaxial-to-waveguide transition. The coaxial ceramic window is similar to the cavity coupler windows developed for the KEKB[3]. In order to investigate the design procedures and power-handling capability, a prototype window with an operation frequency of 432 MHz was manufactured. Then, a high-power test was carried out using the existing power source for the test linac (Thomson TH-2134, 432-MHz frequency and 2-MW peak output power). After a high-power test of the 432-MHz window, its design procedures will be applied to 324-MHz high-power windows. Figure 2 shows the structure of the prototype 432-MHz coaxial windows, including the coaxial-to-waveguide (WR-1800) transition, which was simulated with the HFSS code. This prototype was completed and tested as described in 4.3.

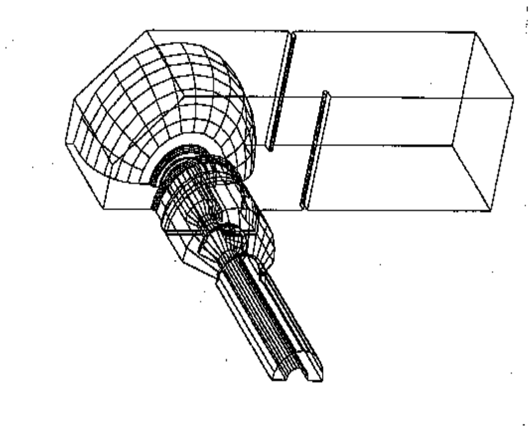

Figure 2: Window and coaxial-to-waveguide transition design of the klystron

4.2 Klystron Gun

Figure 3 gives examples of simulations for the modulation anode gun calculated with the Arsenal Code, which was developed at Moscow State University[4]. In this example, the drift-tube diameter is 4.8 cm, and the beam diameter is about 3 cm under a focusing magnetic field of about max. 200 Gauss. The applied voltages to the cathode and the modulation anode are 110 kV and 101 kV, respectively and the predicted microperveance is 1.33. An output power of 3 MW will be achieved if the efficiency is more than 55% under this beam condition. As mentioned in many references, the gun with a modulation anode becomes unstable at an applied voltage of more than 120 kV. Thus, prior to the whole tube manufacturing, a test beam tube comprising the gun and the collector will be fabricated to test the reliability of the gun under a high voltage of 120 kV in the summer of 1998.

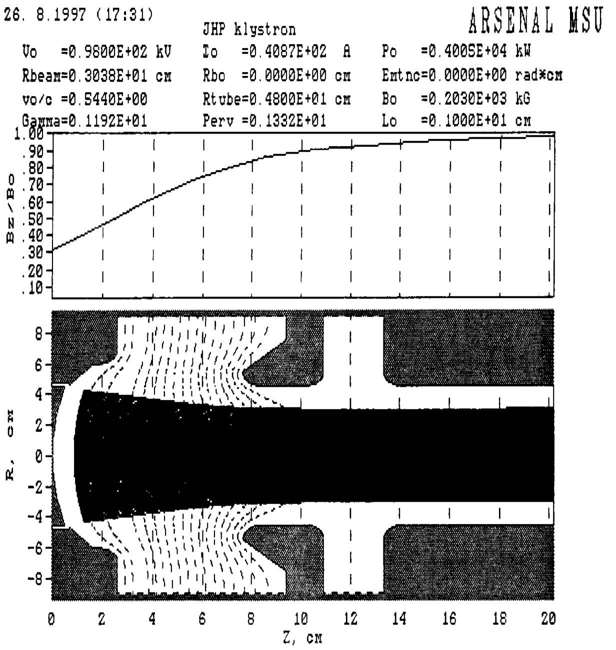

Figure 3: Modulation anode gun design of the klystron

A rough design of the whole tube has been also completed using a one-dimensional simulation code; an efficiency of 55% and an output power of 3 MW was achieved for the beam parameters mentioned above. Now, a 2.5-dimensional PIC code, such as the Arsenal code, was used to obtain a more realistic design. The calculations using various different codes lead to a crosscheck of the design, resulting in a more reliable and realistic design. This work will be finished in the summer of 1998.

4.3 Window Test

A high-power test of a co-axial window was performed in order to confirm the computer simulation. In this test, two identical coaxial windows with a coaxial-to-rectangular waveguide transition were connected and the intermediate part between the window was evacuated. Figure 4 shows the experimental set-up. The window ceramic was coated by a thin TiN(O) film. The window assembly was connected to a magic T in order to divide the power; each port of the magic T was connected to a water load. Using the Thomson TH2134, the window assembly was tested up to a peak power of 2 MW with a pulse width of 650 μsec and a repetition rate of 50 pps. The glow light on the ceramic near to the inner conductor was observed. Figure 5 shows the glow light there. No heavy arcing inside was observed during the high-power test. Due to the manufacture error, a VSWR of 1.25 was evaluated, and sometimes a VSWR sensor was tripped to stop the klystron operation. The pressure inside was very low, and after 40 hours of processing, a pressure of 10^{-9} Torr was observed. From this test, we could confirm the design procedure of the HFSS code, and we started to the 324 MHz window in the same manner.

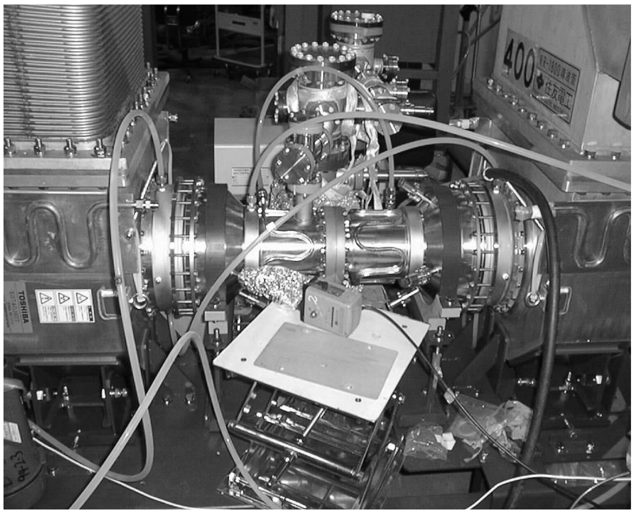

Figure 4: High power test of the co-axial window

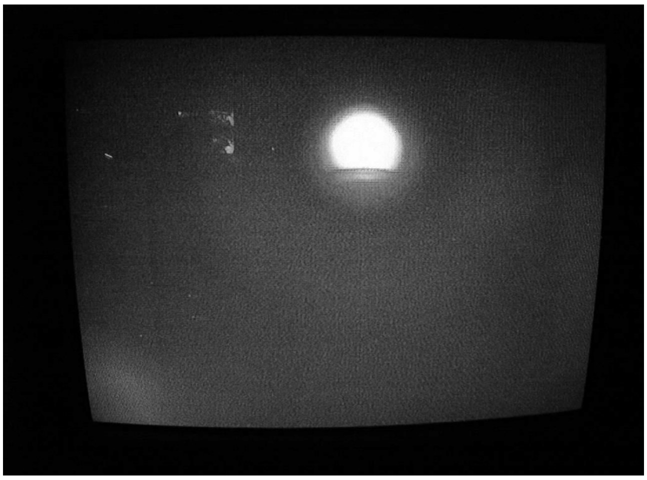

Figure 5: Glow light observed near to the inner conductor

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