〔F17p12〕

High-power test of the RF window for a UHF pulse klystron

M. Kawamura , X. L. Wang* , S. Fukuda , C. Kubota , S. Miyake** and M. Sakamoto**
KEK, 1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305-0801, Japan
*China Institute of Atomic Energy, Beijing 102413, China
**Electron Tube and Device Division, Toshiba Co., 1385, Shimoishigami, Ohtawara, 324, Japan

Abstract

As an rf source of the 200-MeV proton linac for the Japanese Hadron Facility (JHF), a modulation anode-type klystron was studied. In order to develop this klystron, we had started the design of a high-power rf window and other components. Recently, a hot model of the window was completed, and this year a high-power test of it was made at KEK. After that, the 324MHz window was designed, and now a model of the window is being fabricated.

In this article, high-power test results and the design of the 324MHz window are reported.

Introduction

In the 200-MeV proton linac of the Japanese Hadron Facility (JHF), 19 UHF Klystrons are required as an rf source[1]. The operation frequency is 324MHz and the klystron ratings have a maximum power of 3MW, a pulse width of 650μsec (flat top is 620μsec) and a repetition rate of 50pps.

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; the other is a modulation anode-type beam tester. These are the key components in the klystron device[2].

Regarding the rf window, in order to establish a design procedure and to confirm its performance, we first designed the window at a frequency of 432MHz. To begin with, a cold model was designed and a low-power test was carried out at Toshiba Co.. After that, a hot model was constructed, and delivered to KEK at the end of 1997. The high-power test and a low-power test were completed by the end of March.

After the tests, for the full design of the klystron, the design of the output window for the klystron was started, and has been completed.

An outline of the hot model

A coaxial-type ceramic-window was applied, since we had much experience using it. A coaxial ceramic-window is similar to the cavity coupler windows developed for the KEKB[3]. The coaxial line is converted to a rectangular waveguide of WR-2300 through a coaxial-to-waveguide transition.

Since the first design of the JHF was developed to use an rf frequency of 432MHz, a high-power rf system of 432MHz had already been constructed at KEK[4][5], and comprises high-power rf components, such as waveguides, dummy loads, and coaxial-waveguide converters. We thus first made the design at that frequency.

The structure of the hot model is as follows: Concerning the ceramic-window, the external diameter, the internal diameter, and the thickness are 220 mm, 48 mm, 13 mm, respectively. The window ceramic was coated by a thin TiN(O) film. Concerning the hot model, it comprises the same two structures. Each structure includes a ceramic-window and a coaxial-rectangular waveguide converter. The size of the waveguide is WR-1800. The two coaxial ports were joined using special flanges, and the intermediate part between the windows was evacuated. For investigating the state of the ceramic-window during the high-power test, there are ten view-ports of two types in the hot model. These of one type are located at the vacuum side, and are used to see the arc or the glow light. These of the other type are located at the atmospheric side, and are used to investigate the temperature of the window.

Preparation for the high-power test

The high-power rf system comprises one DC power supply, two klystron-modulators and two klystrons (Thomson TH-2134, modulation-anode type)[4][5].

Since it is mainly used for beam-acceleration tests, two klystron-modulators are usually driven and two klystrons amplify the rf power simultaneously. We used this system for the high-power test, and drove the system under the following situation. The two klystron modulators were driven, and only one klystron amplified the rf power. As for the klystron which did not amplify it, we reduced the pulse width and the voltage between the anode and its cathode.

Because two dummy loads were needed to absorb 2MW of rf power, the output port was connected to a T-junction and divided the power. Figure 1 shows the experimental setup. To see the arc or the glow light, we set a camera at a view-port located at the vacuum side.

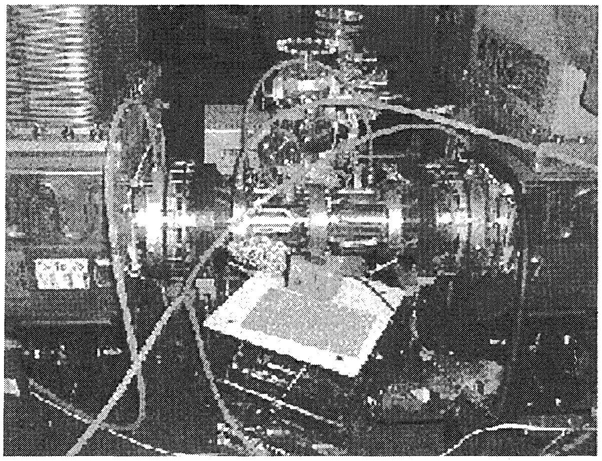

Figure 1. Setup of the high-power model

Result of the high-power test

It took about 151.4 hours to reach the maximum rating (the input power was 2MW, the pulse width 600μsec and the repetition 50pps) from the beginning of the test. There was no serious problem. The waveforms at the maximum rating are shown in Figure 2. Since the input power was 2MW and the reflection 30.7kW, the VSWR was calculated to be 1.28. The reason why the VSWR is high is due to a manufacturing error.

The glow light on the ceramic near to the inner conductor was observed (see Figure 3); no heavy arcing inside was observed. The pressure inside was very low, and after 40 hours of processing, a pressure of 10^{-9} Torr was observed.

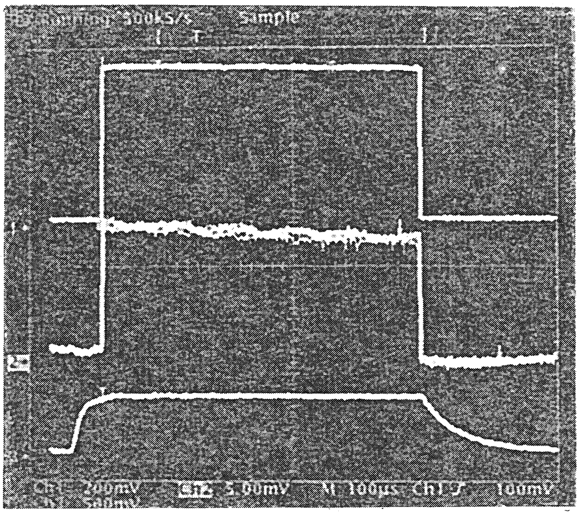

Figure 2. Waveforms at the maximum rating (input power, reflect power, beam current of the klystron)

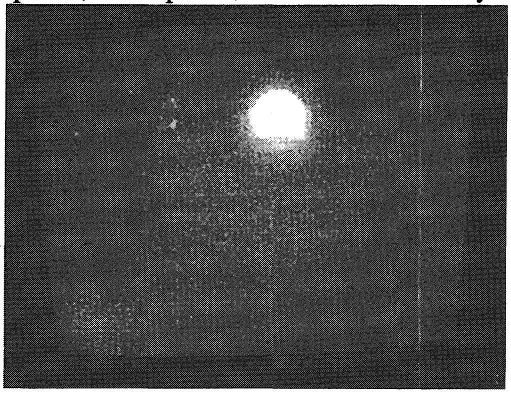

Figure 3. Photograph of the observed glow light

Design of the 324MHz window

It is known that the output window is one of the most important parts of the klystron. Since a number of problems during operation of the klystron have been related to the output window, it is known that reliability of the klystron strongly depends on that of the output window.

Experience obtained with the 432MHz window was fully taken into account in order to design the output window of the 324 MHz klystron with an output power of 3.0MW and a 3.25% duty factor. The 324MHz window consists of a WX-203D coaxial waveguide to a WR-2300 rectangular waveguide transition and the rf ceramic-window. There are several different impedance-matching structures for the rf ceramic-window. Based on our experience with the 432MHz window, we chose a disk-type coaxial ceramic-window with an under/over-cut structure. The disk-type coaxial ceramic-window has a higher power-handling capability[6], and the under/over-cut structure has a better electric-field pattern around the ceramic-window with respect to the suppression of multipactoring[3].

The ceramic-window is located in the WX-220D coaxial waveguide. Its mechanical structure was designed while referring to the ceramic-window structure of the 432MHz window. The calculated result using a computer code called "High Frequency Structure Simulator (HFSS) "[7] shows that there is a uniform electric-field distribution on the surface of the ceramic-window. Its VSWR is shown in Figure 4.

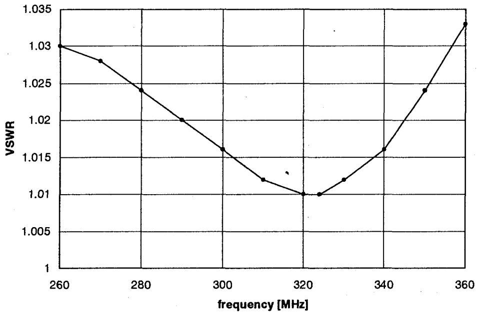

Figure 4. Calculated VSWR of the coaxial ceramic-window

For the coaxial to the rectangular waveguide transition section, we designed two different types of transitions: one is a door-knob transition; the other is a cross-bar transition. A door-knob transformer was designed while scaling the size of the 432MHz window. The simulated result shows that the door-knob is very large and close to the waveguide end-plate. It is 540mm in diameter, 170mm high, and is located only 23mm from the end-plate. The calculated bandwidth is 21MHz for a VSWR of 1.2. The VSWR of the combination of a door-knob transformer and a disk-type coaxial ceramic-window is shown in Figure 5.

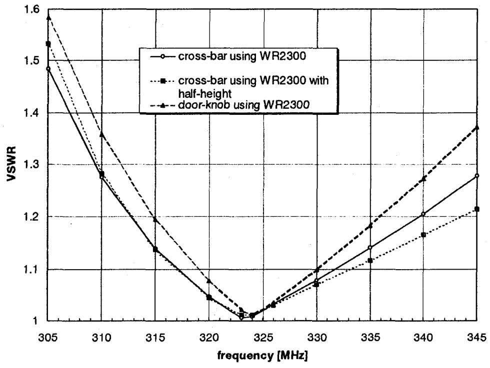

Figure 5. Computed VSWR of the window

For the cross-bar transformer, by changing the shape and size of the cross-bar, its bandwidth could be changed. Finally, we obtained a 26MHz bandwidth for a VSWR of 1.2 with a standard WR-2300 waveguide. We also made a design using a WR-2300 waveguide with a height-to-width ratio of 1:4, or half-height. The computed result shows that its bandwidth is wider (30MHz). From the view point of the spatial configuration, although using the half-height waveguide is more appropriate, its rf performance, especially the power-handling capability, needs to be confirmed by a high-power test. The VSWR of the combination of a cross-bar transformer and a disk-type coaxial ceramic window is also shown in Figure 5.

The design of the output windows with different transition structures has been completed. By making a comparison among them, a coupler with a cross-bar transition has been more compact in structure and easier to manufacture. Now, a model of the coupler is being fabricated in order to confirm its rf properties.

Conclusion

A high-power test of the hot-model was completed without any problems, and the design of the window was also completed. We will test a modulation anode-type beam tester this autumn, and will test a new klystron at the end of FY1998.

Reference

[1]'JHF Design Study Report', JHF Project Office, KEK Report 97-16, 1998.

[2]'Development of a High-Power VHF Klystron for JHF', S. Fukuda et al., Proc. of 1998 Asian Particle Acc. Conf., Tsukuba, Ibaraki, Japan, 1998.

[3] 'Input Coupler for the KEKB Normal Conducting Cavity', F. Naito et al., Proc. of 1995 Partcle Acc. Conf., Dallas, Texas, USA, 1995.

[4]'Operation of 432-MHz rf source for the JHP proton linac', M.Ono et al,. Proc. of 1994 Linac Conf., Tsukuba, Ibaraki, Japan, 1994.

[5] 'The parallel operation of UHF Klystrons for JHP', M. Kawamura et al,. Proc. of 1995 Linac Meeting in Japan, 1995(in Japanese).

[6]'Development of high power CW klystron for TRISTAN', S. Isagawa et al., Proc. of 1987 Particle Acc. Conf., Washington D.C., USA, 1987.

[7]HP Part No.85180A., HP Corp