HIGH POWER INPUT COUPLER FOR THE TRISTAN APS CAVITY

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Abstract

A high power input coupler of loop type has been developed and installed in the cavity of the TRISTAN ring. The coupler has a cylindrical alumina window coated with TiN of 60 Å thickness and feeds the power of 225 kW (CW) to the APS cavity with 9 or 11 accelerating cells.

Introduction

In the TRISTAN accumulation ring (AR) and main ring (MR), alternating periodic structure (APS) cavities[1] operating at 508 MHz are used for accelerating the e^+e^- beams. The RF power of 1 MW generated by a CW klystron is fed to four APS cavities through a waveguide system with a 10 % power loss. A total of 112 input couplers is needed during operation. We have developed a high power input coupler with a cylindrical ceramic window, whose typical operation power is 225 kW. The couplers have been installed and operated since spring of 1985. In this paper, the design, structure, high power characteristics and long term performance of the couplers are described.

Structure

The APS cavity has a coupler port on vertically up or down side of one of the accelerating cells. The coupler is required to transform the waveguide to the coaxial mode and to feed the power to the cavity through the magnetic coupling of the accelerating mode. A cavity coupling factor is set to ß=1.3 to compensate for beam-loading during operation. The coupler was designed to stand the maximum operational input power of 250 kW. A simple structure was chosen to be suitable for mass-production. A cross section of the input coupler is shown in Fig. 1. It consists of a coaxial line with a loop antenna, a cylindrical alumina RF window and a rectangular waveguide. Dimensions of the coupler were

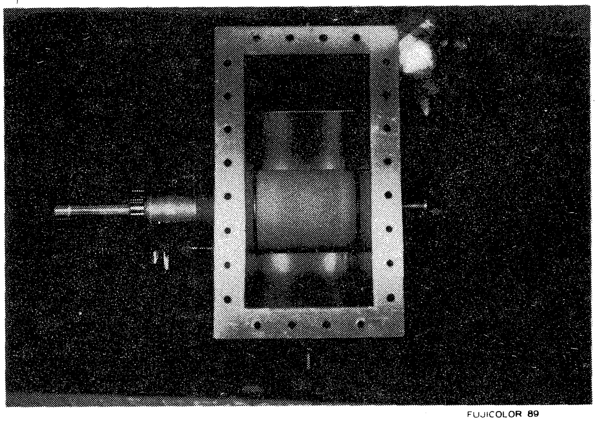

Fig. 2 Input coupler for the TRISTAN APS cavity.

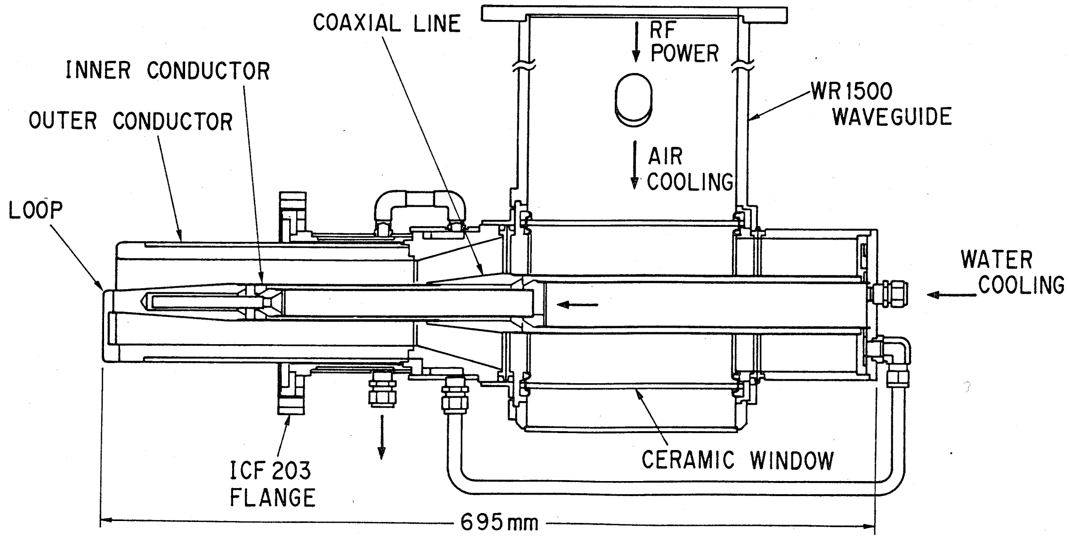

Fig. 1 Cross section of the input coupler.

adjusted to obtain a good matching through the structure using a cold model. Figure 2 shows a photograph of the input coupler.

Coaxial line

The coaxial line is of 50 Ω and terminated by the loop. It is made of OFHC copper because of its low resistive loss, low out gas and good thermal conductivity, except for the ICF-203 rotatable vacuum flange and the body jacket which are made of stainless steel. The parts are assembled by silver-brazing in hydrogen furnace.

The loop is formed by a short bar bridging inner and outer conductors. The bar is connected to the conductors with copper-plated stainless-steel bolts. The loop is separated from transition part by more than $\lambda/2$ to prevent undesirable interference between them. The coupling is adjusted by rotating the direction of the loop to vary the effective coupling area for the magnetic field. The power loss of the coaxial line is about 100 W for the input power of 250 kW. Both inner and outer conductors are cooled by water flow of 6 l/min.

When a coupler is mounted to a coupler port of the cavity, the gap between the outer surface of the coupler and the inner surface of the port forms a coaxial line. Its length is set to about $\lambda/2$ from the cavity surface to have a choke property at 508 MHz for the coaxial TEM mode. The accelerating mode still penetrates into this coaxial line in the form of the TE_{11} mode that may give rise to undesirable two side multipactoring. Thus, the coaxial gap is carefully chosen to be 1.0 mm to suppress the multipactoring.

RF Window

A cylindrical RF window, 152 mm in diameter, 193 mm long, 5 mm thick made of 95 % alumina ceramics is used for vacuum seal. It is located at the position where the waveguide mode is transformed to the coaxial one. It is welded to the outer conductors of the coaxial line with a Tig method. The dielectric or resistive heating of the ceramic window is directly cooled by forced air. The vacuum side of the ceramics is coated with TiN of 60 Å thickness to prevent the multipactoring discharge that gives rise to the excessive local heating of the ceramic window. The effect of the coating is detailed in the next section. The coating is performed by dc reactive sputtering with Ti target in the N_2 and Ar mixture gas of 10^{-2} Torr.

Waveguide

The WR1500 waveguide is made of the 6063-TS aluminum. It is equipped with two nozzles to blow RF window by air flow of 1.0 m^3/min from the blower. The air is drawn out through 60 little holes in the shorting plane.

High Power Characteristics

Prior to the final mounting on the APS cavity, the couplers were conditioned up to 300 kW measuring their high power characteristics. The surface temperature distribution of the RF window was monitored from the RF input side by an infrared thermometer 6T61(NEC SAN-EI). The surface temperature of the outside coaxial line around RF window and the cooling air temperature were also monitored by a C-C thermometer. From a view port of the cavity just below the coupler, the vacuum side of the coupler was watched by a color TV camera to observe a glow discharge phenomenon if it happened. The cavity was evacuated by a turbo molecular pump of 300 l/sec. The cavity vacuum was monitored by a cold cathod gauge and its value was used to control the conditioning process. The RF power was slowly increased by keeping the pressure below 5×10^{-6} Torr.

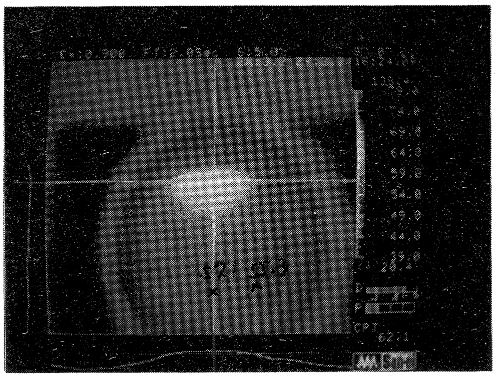

Fig. 3 Temperature distribution of the ceramic surface.

Figure. 3 shows a typical example of the surface temperature distribution of the ceramic window at input power of 150 kW. In this example, the coupler is mounted to the up side of the cavity; the loop is on the down side, while the shorting plane of the coaxial line is on the up side. One of the most characteristic features of the temperature distribution is that a hot spot appears around the center and up side of the ceramic cylinder, where the electric fields of both the waveguide mode and coaxial mode become the maximum. The temperature rise ΔT at the hottest spot of the ceramics was measured as a function of the input power. Three examples are shown in Fig. 4. Performance of the ceramic window could be characterized by the value of a parameter n defined by

$$\Delta T \sim P^n,$$

where P is input power. If the value of n is between 1 and 1.4 (shown as the example A in Fig. 4), the performance is normal revealing no glow discharge in the TV monitor mentioned above. All of the mass-produced 124 couplers were evaluated to be normal except for two couplers.

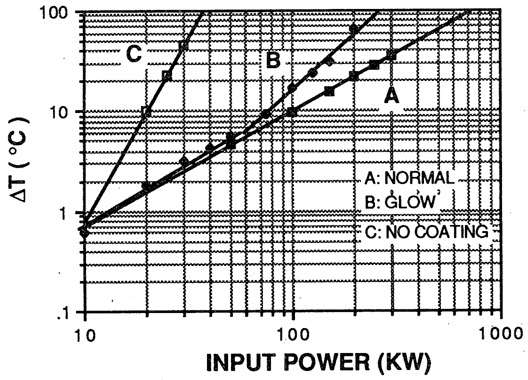

Fig. 4 Temperature rise of the ceramics versus input power.

In the early stage of development , the multipactoring discharge of the window was a primary problem. The hottest spot of the ceramics showed nonlinear temperature rise of n=3.7 (shown as the example C in Fig. 4) with the purple glow discharge. If the input power was further increased, the ceramics cracked by local thermal stress in some cases. This nonlinear temperature rise in the local spot was due to a one-sided multipactoring on the ceramic surface, which was also observed in the output window of the high power klystron[2]. To suppress the secondary electron emission, the inner surface of the ceramics was coated with a 60 Å TiN layer. After the coating, the temperature rise was remarkably reduced and the window glow was not observed.

Long Term Performance of the couplers used in the MR

One hundred and four couplers were used with mean input power of about 200 kW in the MR.[3] Eighty one percent of them were continuously operated without any troubles. Until April of 1989, the operation time of couplers amounted to about 6,000 to 10,000 hours. The failures were mainly as follows.

(1) Glow discharge

Blue or purple glow was observed in the coaxial line and window. The example B of Fig. 4 shows a typical example of the ceramic temperature rise with glow discharge. There was a critical level at around 60 kW and a nonlinear window heating and blue or purple discharge were observed above this level. This indicates that the coating effect against multipactoring was diminished. Ten couplers among the 104 couplers revealed this phenomena.

(2) Loop failure[4]

The loop is fixed by three plate-type SUS bolts copper-plated by 10 μm thick. The heads of the bolts were melted in the 10 couplers. The loop was also bent in some couplers. Figure. 5 shows the age distribution of the failed ones. It shows that this trouble is not initial failure but begins to occur at more than 5,000 hour operation and increases thereafter. The loop is not directly cooled and has the resistive loss of about 30 W at input power of 200 kW. It is also noted that the couplers are operated under hard heat cycle during the beam energy ramping. Thus, the loop should be welded or brazed to the inner and outer conductors to solve this problem.

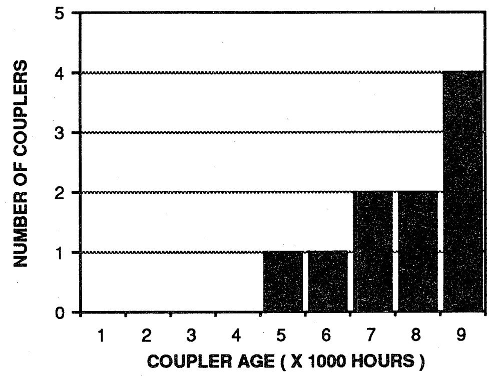

Fig. 5 Age distribution of failed couplers.

Conclusion

A high power input coupler (250 kW CW) of loop type has been developed for the TRISTAN APS cavity. The total of 112 couplers has been installed in the MR and AR and successfully operated for about 10,000 hours without any serious trouble except the loop problem.

Acknowledgements

We would like to thank to Profs. Y. Kimura and K. Takata for their encouragement. We also wish to thank members of our RF cavity group for their support and useful discussions.

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