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200 MW S-band traveling wave resonant ring development at IHEP*

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Abstract The resonant-ring is a traveling wave circuit, which is used to produce high peak power with comparatively smaller stored energy. The application to be considered is its use as a high power simulator mainly for testing the klystron ceramic output window, as well as for high power microwave transmission devices. This paper describes the principle of a resonant ring and introduces the structure and property of the newly constructed traveling wave resonant ring at IHEP. Our goal is to produce a 200 MW class resonant ring at 2.856 GHz with a pulse length of 2 μs and repetition rate of 25 Hz. The installation, commissioning and testing of the ring have been completed and a peak power of 200 MW at 3 μs has been achieved. The conditioning results show that all the parameters of the resonant ring reach the design goals.

Key words traveling wave resonant ring, voltage coupling coefficient, conditioning, accelerator

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1 Introduction

In the linear accelerator, the main microwave power source is the high power klystron. Its most difficult issue is the reliability of the ceramic window and it constrains the development, production and application of the klystron. For meeting the complex atmosphere outside the window demands, the window must at least withstand 2 times or even 4 times higher than the klystron's output power [1, 2]. An S-band 50 MW pulsed klystron is being developed at the Institute of High Energy Physics (IHEP) for the BEPCII linac [3]. The klystron output window must be conditioned with high power (200 MW) before their installation on the klystron. Hence, the resonant ring must be designed and constructed to meet the klystron development demands. At present, the high power S-band traveling wave resonant ring has been set up and operated well at IHEP. More than 200 MW peak power is stimulated at 2.856 GHz with a pulse length of 3 μs and with the repetition rate of 25 Hz. It can be effectively used for conditioning the ceramic windows for klystron, ceramic isolation windows, power amplifier, waveguide components, accelerator structure and other microwave components.

This paper describes the principle of a traveling wave resonant ring and introduces the design and construction of the test facility. The property, commissioning and test results of the resonant ring show that all the parameters of the resonant ring have reached the design goals.

2 Principle and description

The traveling wave resonant ring may be explained with the aid of Fig. 1 [4, 5]. In Fig. 1, f_1, f_2, f_3, f_4 and r_1, r_2, r_3, r_4 respectively express the forward and reflected wave voltage of Port 1, 2, 3 and 4, C is the coupling coefficient of waveguide input directional coupler and l_0 is the circumference of resonant ring. An input energy from klystron and then from Port 1 is partially coupled into the ring and proceeds around the ring in the direction as indicated in Fig. 1. When this energy passes the coupling region, a small fraction is coupled into the main transmission line with the remainder proceeding around the ring again. At the same time, more energy is being coupled from the main line to the ring. If the energy pro-

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ceeding around the ring and the energy coupled into the ring are in phase at the coupled section, then it is evident that the energy in the ring can be reinforced and can, in fact, become quite large in magnitude.

The geometry structure of the ring is shown in Fig. 2 [6]. The ring consists of 11 pair flanges and 10 component devices (excluding the input and output components such as load). The total length of the ring is about 3.7 m including a −14.7 dB waveguide directional coupler, a high power phase shifter, a 5-stub tuner, two −70 dB Bethe-hole couplers and corresponding vacuum systems. There are also water cooling systems to ensure temperature stability of the whole system. Table 1 gives the main design parameters of the resonant ring.

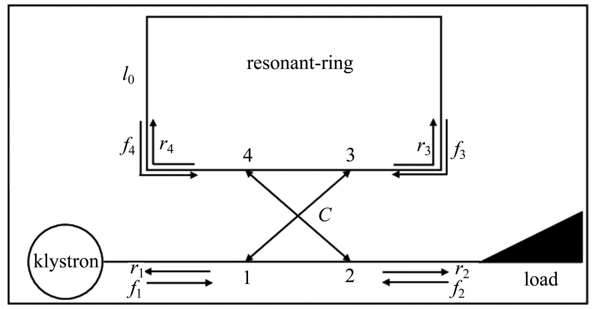

Fig. 1. Simplified traveling wave resonant ring circuit.

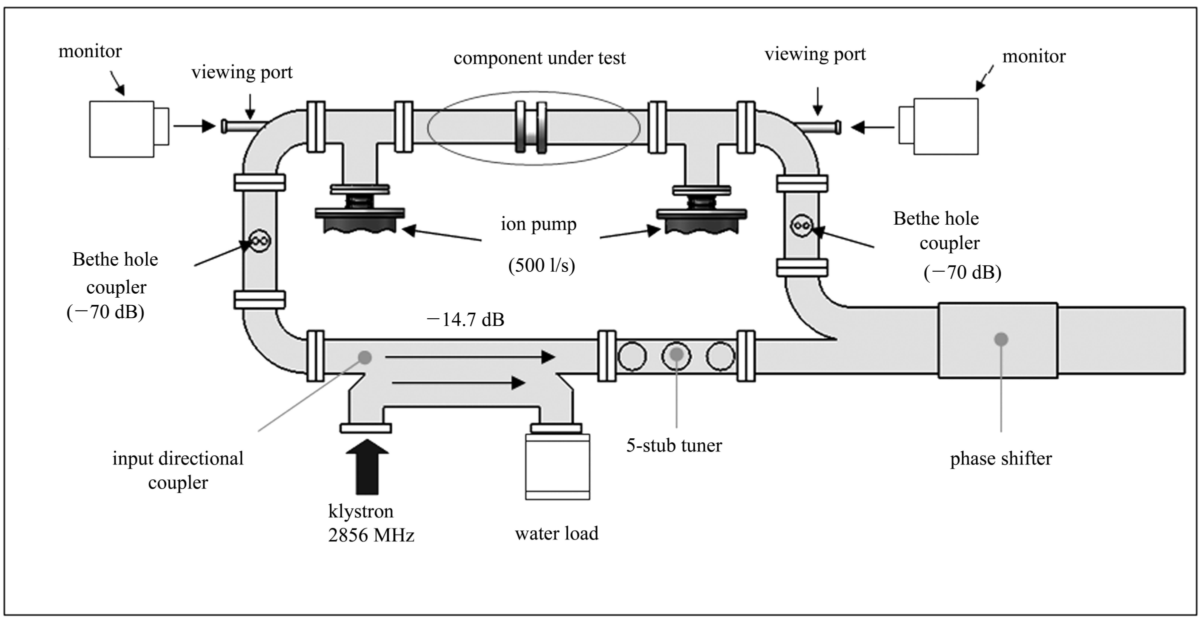

Fig. 2. The geometry structure of the resonant ring.

Table 1. The design parameters of the resonant ring.

peak power	200 MW
pulsed width	2 μs
repetition rate	25 Hz
operation frequency	2.856 GHz
length of ring	about 3.7 m
attenuation of the ring	0.15 dB
coupling coefficient of input coupler	−14.7 dB

3 Ring tuning and conditioning

The resonant ring system must be tuned and conditioned after the whole system is completely installed on the stand. The system has immediate application as a tunable resonant circuit. Tuning is accomplished by any means whereby the electrical length of the ring is changed. Thus a phase shifter may be employed, permitting a variation in the phase of the guide wavelength around the ring so that its electrical length can be made a multiple of a wavelength at resonance. An adjustable 5-stub tuner, which allows adjusting the insertion depth ±5 mm, is a means of performing simple, low-loss tuning. The phase shifter and 5-stub tuner are designed from IHEP and fabricated by another Chinese company.

The process of conditioning is started with a low power, a narrow pulse and a low repetition rate, and then gradually reaches high power, wide pulse and high repetition rate repeatedly. Each component of the ring system will be fully RF conditioned with the aid of the high power phase shifter and 5-stub tuner, as well as the related vacuum interlocking system.

Within a 2-week process, bake-out and commissioning of the system, some results have been obtained and listed as follows:

When the peak power of higher than 200 MW was stimulated in the ring, the whole system of the ring operated well without any breakdown of any component in the ring. Fig. 3 shows the pulse waveform of the incident power in the ring, which is measured by a peak power analyzer from the Bethe hole directional coupler. In this picture, the results of incident power are displayed with an 13 dB offset, that is, the peak power in the ring is higher than 200 MW. In detail, an incident power level of higher than 250 MW peak with pulse width of 2 μs at a repetition rate of 25 Hz has been produced in this ring system. The 250 MW peak power is also the highest power level of the similar resonant ring in China.

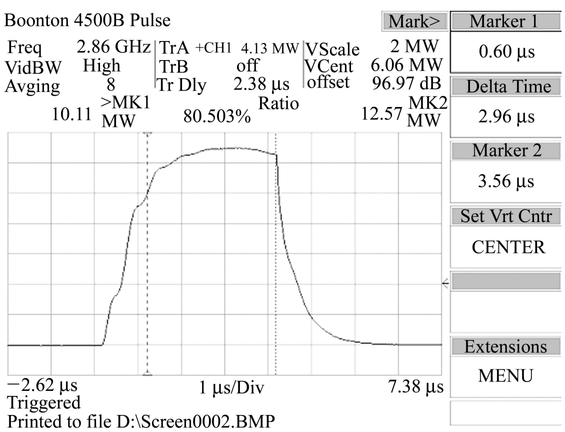

Fig. 3. Incident power waveform of the ring with 13 dB offset.

The radiation dosage must be measured during the conditioning of the whole resonant ring to check the arcing points in the ring. Fig. 4 shows two of the total 6 radiation dosimeters allocated, and the dosage measurement results at different locations are shown in Table 2, with the conditioning duration of 70 hours and with the peak incident power of higher than 200 MW. From Table 2, one can see that the radiation dosage mainly comes from the pump out waveguide (T type waveguide). It is seriously increased with the arcing and out-gassing in the ring. Therefore, the lead shield is absolutely needed in the ring conditioning.

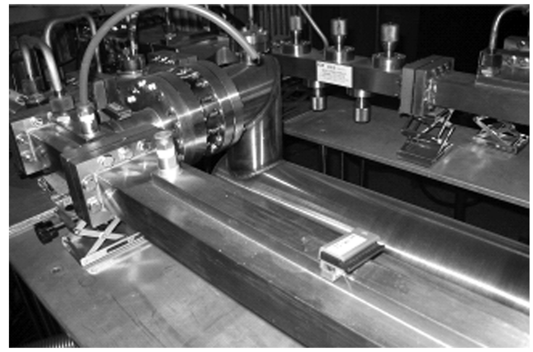

Fig. 4. The locations of radiation dosimeters.

Table 2. The radiation dose rate around the klystron and ring.

dosimeters locations	accumulated dosage/mSv
around klystron (outside lead shield)	1.2
surface on klystron (away the ring 2 m)	42.8
surface on waveguide (near klystron)	153.3
surface on phase shifter	197.9
pump out waveguide (T type)	207.2
outside (away the ring 7 m)	0.1

4 Conclusion

At the beginning of the conditioning, the serious arcing gas and RF breakdown frequently appeared. The vacuum was controlled under 2×10^{-5} Pa to protect the outside of the klystron output window. The conditioning of the whole ring needs about 10 days including 8 hours with the ring incident power higher than 200 MW and dynamic vacuum under 2×10^{-6} Pa. Now the resonant ring is being well operated to test the klystron ceramic windows and various RF components.

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