RESONANT RING FOR HIGH POWER TEST

T. Shidara, S. Anami, S. Fukuda, Y. Saito, H. Honma,
K. Nakao, H. Hanaki, N. Matsuda, J. Tanaka and H. Tanaka*

National Laboratory for High Energy Physics
* Fujitsu Laboratories Ltd.

Abstract

Resonant ring for the high power test of microwave components was constructed. Design parameters and the present status of the system are described.

Introduction

The testing of the power-handling capacity of microwave components, at far more severe conditions than the normal ones, has been considered. Especially, as we have reparted before, the failure rate of RF windows is very high in our linac[1], it is required to achieve at least four times larger power than that in normal operation for the development of good RF windows. This means we need 120 MW or more power. We can supply only 30 MW from our klystron. (150 MW klystron was developed under the Japan-U.S.A. Collaboration[2], but it's not practical for our use.) To achieve a high power in a waveguide for a given input power, we adopted to use a traveling wave resonator[3] (resonant ring). Design parameters and the present status of the resonant ring will be described in the following sections.

Design parameters of the resonant ring

Design of the practical resonant ring is illustrated in Fig. 1. The resonant ring consists of the following microwave parts; input directional coupler, phase shifter, measuring directional couplers, viewports and so on, all designed for handling high-microwave power.

The operation of the resonant ring can be described with the aid of Fig. 1. The incident wave from the generator is divided between terminals (c) and (d) of the input coupling structure. The emergent wave from (d) is returned to the coupling structure through the ring structure via terminal (b). This wave then also divides between (c) and (d) but in a reciprocal manner. If the electric length of the ring circuit is tuned to obtain resonance conditions by the phase shifter, the fields will add in phase at the coupling structure and the field in the ring circuit will build up to a value that is larger than the field in the main line. Using the nomenclature described in Fig. 1, ring voltage gain for properly adjusted ring circuit may be described

$$|M|_{MAX} = \frac{C}{1-T\sqrt{1-C^2}} \qquad (1)$$

For a given attenuation there is an optimum coupling factor C_{opt} given by

$$C_{opt} = \sqrt{1 - T^2} \qquad \left(\frac{\partial |M|_{MAX}}{\partial C} = 0 \right) \qquad (2)$$

Substituting in eq. (1)

$$M_{opt} = \frac{1}{\sqrt{1-T^2}} = \frac{1}{C_{opt}} \qquad (3)$$

If we consider the insertion VSWR Γ of the ring, we must change eq. (1) as follows.

$$|M|_{MAX} = \frac{C(1-\sqrt{1-C^2}\sqrt{1-\Gamma^2}\ T)}{1 - 2\sqrt{1-C^2}\sqrt{1-\Gamma^2}\ T + (1-C^2)T^2} \qquad (4)$$

Roughly speaking, the input reflection Coefficient Γ_{IN} as seen by the generator is,

$$\Gamma_{IN} = \frac{C^2\Gamma}{1 - 2\sqrt{1-C^2}\sqrt{1-\Gamma^2}\ T + (1-C^2)T^2} \qquad (5)$$

This will become appreciable even the insertion VSWR of the ring is small. Then a matching transformer is also required in the ring circuit to reduce it.

In order to optimize the operation of the resonant ring, one must use a variable input directional coupler. On the other hand, it's not easy to operate this type of directional coupler in a high power condition. So, we decided to use 10 dB coupler instead of a variable type. As the attenuation of the ring circuit is estimated about 0.16 dB, calculated ring voltage gain is 4.61 from eq. (1). If we optimize the input coupling (i.e. 14.4 dB), we can get M_{opt} = 5.26 from eq. (3).

The phase shifter enables the adjustment of the length of the ring circuit to obtain resonance conditions. This unit consists of a 3-dB directional coupler and of two plungers simultaneously moved in order to ensure a common short plane. The insertion loss and VSWR should be low. So we designed each of then should be less than 0.05 dB and 1.1, respectively. This must be operated without breakdown discharge up to 120 MW.

For measuring directional couplers, we used 80 dB Bethe hole couplers.

An evacuating system for ultra high vacuum is also designed, which enables us to measure the pressure dependence of the breakdown power of the microwave components.

The present status of the resonant ring

The waveguide parts and the vacuum components for the resonant ring have been assembled and the entire system is being leak checked. Photograph of this system is shown in Fig. 2. RF measurements were made on the individual ring components before assembling the ring. The coupling of the input directional coupler was 10.75 dB which was slightly smaller than the designed value. After assembling the ring, low level RF measurements were made. The measured Q_L and the attenuation of the ring circuit were 5,000 and o.18 dB, respectively. These measurements show that at least 9 times of the input power will be built up in the ring circuit.

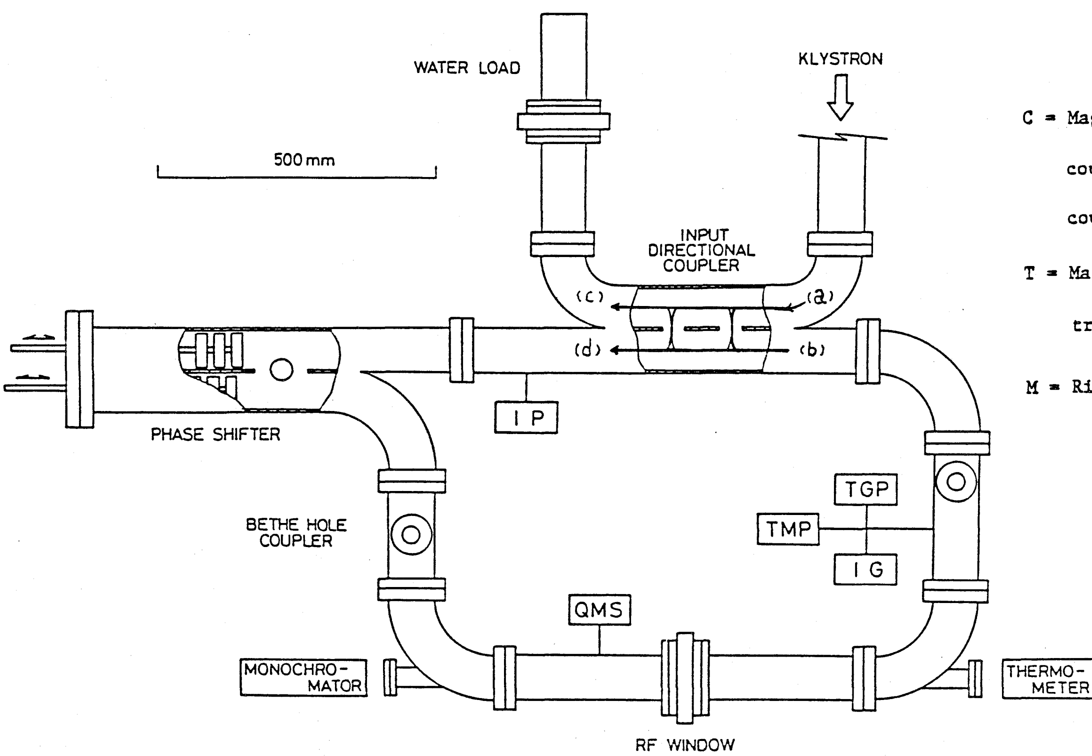
The ring is now evacuated at about 1.5×10^{-8} Torr without baking. We are preparing the baking of this system to obtain ultra high vacuum.

References

1) T. Shidara, et al.: Proc. of the meeting on linear accelerators in Japan (1983) 141.

2) S. Fukuda: ibid. 138.

3) L.J. Milosevic, et al.: Trans. I.R.E. vol.MTT-6 (1958) 136.



Nomenclature:

C = Magnitude of directional coupler forward voltage coupling ratio

T = Magnitude of ring voltage transmission coefficient

M = Ring voltage gain

Fig. 1 Schematic diagram of the resonant ring system.

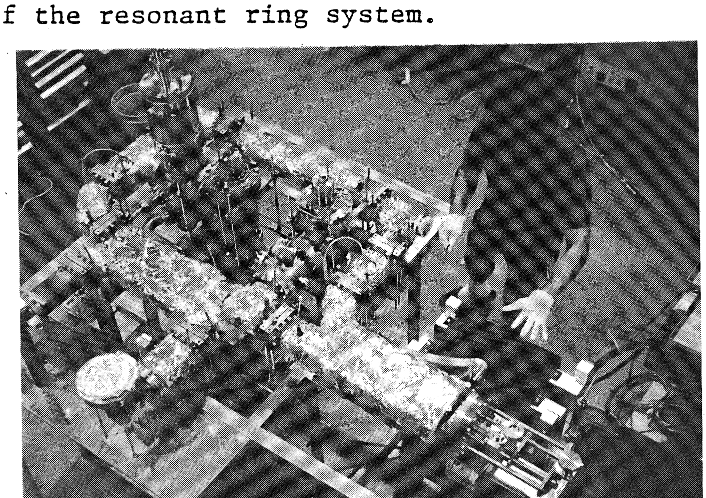


Fig. 2 Photograph of the resonant ring.