

## Development of the RF System for the Smallest Storage Ring

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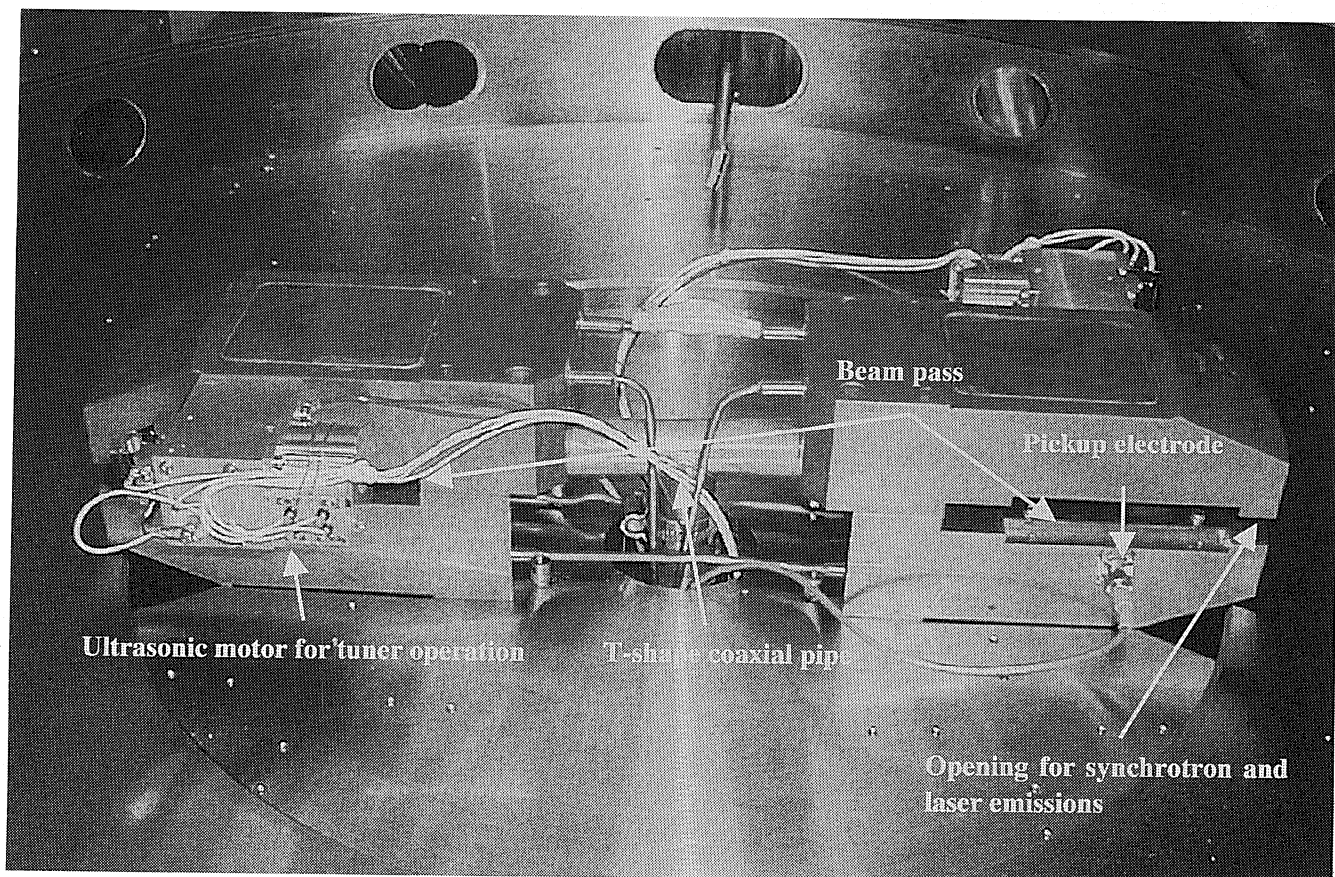
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### Abstract

The accelerator system composed of two small cavities connected by T type coaxial distributor was developed for the smallest storage ring (called the photon storage ring). Since two cavities are coupling each other, regulation of the system demonstrate special difficulties in the frequency tuning and input power balancing. Against these problems we have established the tuning technique and succeeded in supplying 1kW power on average.

### 1. Acceleration Cavities for the Smallest Storage Ring

In the designing of the present synchrotron, the possible smallest orbit radius (0.156 m) was chosen in order to obtain the photon storage ring laser gain as large as possible, and to make an economical ring for industrial and medical uses [1]. Since the cavity frequency of 2.44 GHz is available by the klystron, we have chosen 8 harmonics. One of the problems encountered in the designing was what we have to supply the cavity power from the centre of the ring, since the cavity must be surrounded by the circular optical cavity for lasing. This is the reason why we supply the cavity power through the T-type coaxial pipe. In



**Fig. 1.** A double cavity system was developed for the smallest storage ring. We have been successful in supplying 1kW average power in total through the T-shaped coaxial pipe. These cavities are featured by the slit for extracting laser and synchrotron emissions. Each cavity has one tuner and one pickup electrode. Ultrasonic motors are used to move the tuner.

In addition, we need to make an opening on the sidewall of the cavity for letting the laser light to escape from it. These were the major task forces. In this paper we namely describe the tuning problems of the coupled cavity and power test. We have reported the design problem of the cavity, and the measurement of the field earlier in the references 2 and 3.

In Fig. 1, we show the fabricated double cavity system placed in the vacuum chamber. The measured Q-value of this cavity is nearly 3000, and the shunt impedance is 0.3MΩ. When we supply 400W power to each cavity, the 10 kV acceleration voltage is generated. We have been successful in supplying 1kW average power in total through the T-type coaxial pipe of WX-20D. Each cavity has one tuner and one pickup electrode. Ultrasonic motors are used to move the tuners.

The power source is a 2.444 GHz Klystron. A schematic drawing of the high frequency regulation system is shown in Fig. 2.

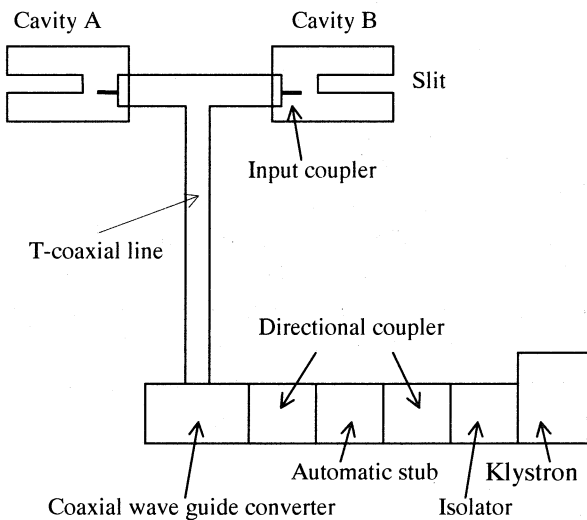


Fig. 2. High frequency power regulation system

## 2. Coupling problem of cavities

We have studied the coupling problem experimentally as well as theoretically by developing a calculation code based on an equivalent electrical circuit shown in Fig. 3. This code evaluates the case in which cavities have different eigen frequencies  $\omega_1$  and  $\omega_2$ , and different Q-values. The coupling strengths are assumed to be equal. The reflection  $|R_1|^2$  and the values proportional to current  $|I_1|$  and  $|I_2|$  were obtained on regard with the parameter  $\omega/\omega_1$ .

Figure 4 shows the calculated results to the case that the resonance frequencies are differ by  $\omega_1/\omega_2 = 0.9999$ , and the Q-values are differ by 20%. This small difference in the resonance frequency is expected to causes unbalance in the accepted power by 18% between cavities, and in the Q-value 30%.

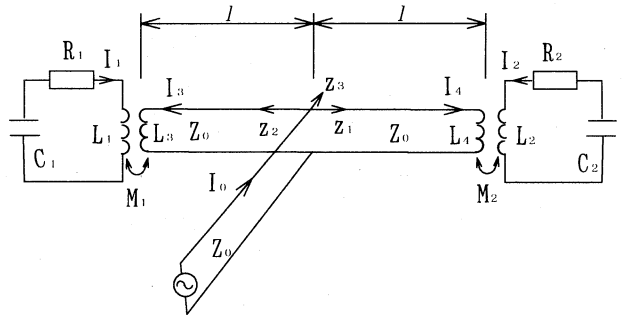


Fig. 3. Equivalent electrical circuit of the double cavity system.

Due to the coupling of two cavities, the fundamental mode is excited by two resonance frequencies when the Q-values or the eigen frequencies are slightly different each other as seen Fig. 4. Each acceleration cavity has four accelerating electrodes. We can regulate the resonance frequency of cavity by moving these accelerating electrodes. We could experimentally optimise the cavity resonance frequency by changing the position of the accelerating electrodes of the cavities to the operation point as shown in Fig. 5.

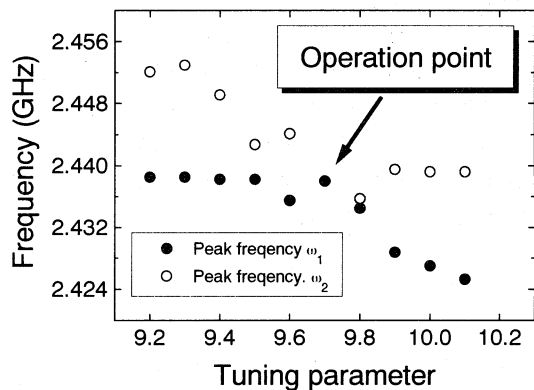
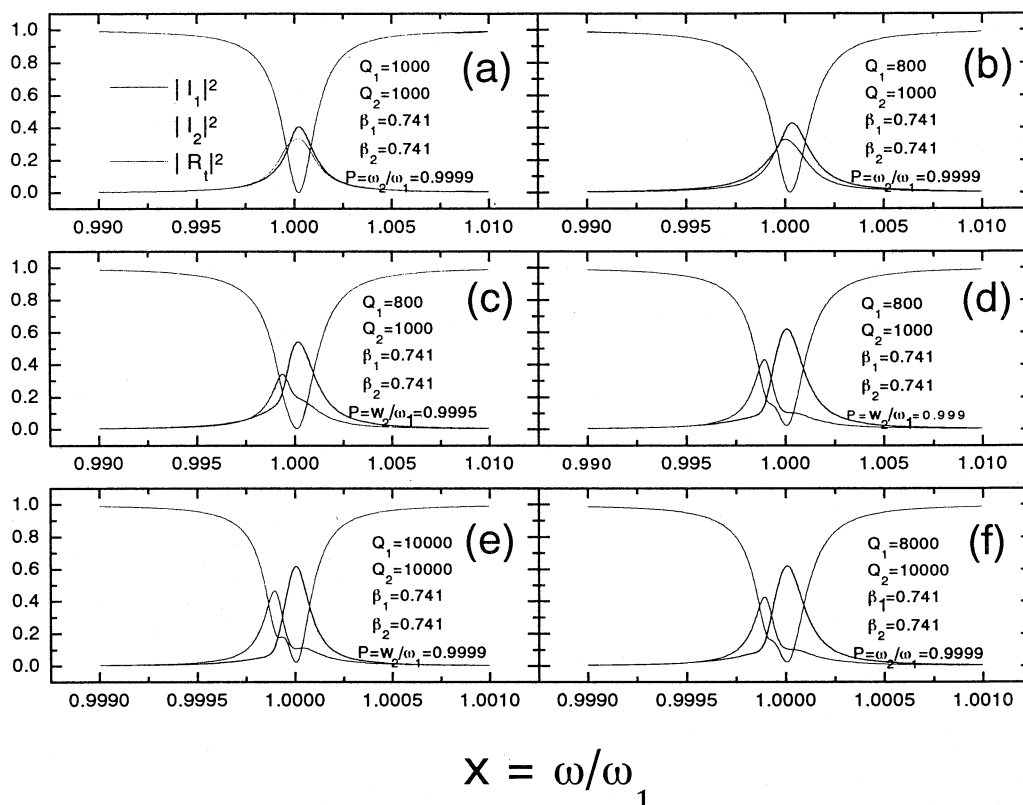


Fig. 5. Cavity resonance frequencies are adjustable by tuners to the operation point shown in this figure.

## 4. Power test

During the power test of the cavities, we monitor the several parameters such as the cavity voltage by the loop type probe, the reflection (Pr) by directional coupler at the point between the cavity and the automatic stub (see Fig. 2), and temperature of the cavities. Reflection at the point between automatic stub and isolator was kept in nearly zero all the time.

When the input power is less than 150W, the pickup voltage of the cavity A is almost equal to that of B. As the input power increases we see in the Fig. 6 that the difference in the voltage increases about 20%. This is caused by the difference in the temperature of cavities.



**Fig4.** Calculated nature of the resonating frequency; (a) Q-values of the cavities are equal as  $Q_1=Q_2=1000$  and the resonance frequencies are different ( $\omega_1/\omega_2=0.9999$ ). (b) Difference of the Q-values is 20% ( $Q_1=800, Q_2=1000$ ), and that of the resonance frequencies is 0.9999. (c) Difference of the Q-values is 20% and the difference in the resonance frequencies is 0.05%. (d) Difference of the Q-values is 20% and the difference in the resonance frequencies is 0.1%. (e) Case for the high Q-values;  $Q_1=Q_2=10000$  and the difference in the resonance frequencies 0.01%. (f) when  $Q_1=8000$  and  $Q_2=10000$ , and the difference in the resonance frequencies 0.01%. In all the calculations, the coupling constants of the cavities are assumed to be ( $\beta_1=\beta_2=0.741$ ).

### 5. Conclusion

We have established the tuning technique of the double cavity system, which is connected by T-type coaxial line and is coupling each other. We have been successful in supplying 1kW power continuously. The observed difference of the power in the cavities is, we think, not serious amount for the stability of the circulating beam. Our final goal of this development is an automatic regulation of the frequency of the cavity, which is now under development.

### References

- [1] H. Yamada, J.Synch.Radi. (1998) 5, 1326-1331
- [2] H. Tsutsui, and H. Yamada, Proc. 18<sup>th</sup> Linear Accel. Meeting in Jap., July 21-23, 1993, Tsukuba, 267.
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**Fig. 6.** Input power dependence of the cavity voltages (dotted line for the cavity A, and dashed line for the cavity B), and the reflection (solid line).

