DESIGN OF AN RF SYSTEM FOR THE ATF DAMPING RING

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This paper describes the overall design of an RF system for the ATF damping ring (DR). The RF system comprises four single-cell cavities, one 250-kW klystron, a WR1150 waveguide network and a low-level RF system. The system parameters, layouts and development of the principal components are given.

I. INTRODUCTION

The ATF damping ring [1,2] is under construction at KEK in order to study the production of high-intensity multibunch beams having extremely low emittance, which is required for future linear colliders. The challenges of the RF system mainly come from the large beam current (600 mA max.) and high cutoff frequencies of the beam pipe (9.6 and 7.3 GHz for monopole and dipole modes, respectively), which impose severe restrictions on the cavity HOM (Higher-Order-Mode) impedances.

The principal requirements for the RF system are: 1) to provide the accelerating voltage needed to obtain a short bunch length of 5 mm, 2) to compensate for radiation losses, and 3) to accommodate a suitable low-impedance environment for the beam. Table 1 is a list of the parameters of the ATF DR relevant to the RF system. A frequency of 714 MHz, which is one quarter of the injector linac frequency, was chosen. A total gap voltage of about 1 MV is needed to obtain a bunch length of 5 mm (which includes the anticipated bunch lengthening by a potential-well distortion). Then, the RF bucket height becomes 2.2%, which is sufficient for beam injection (requiring more than 1%). A total generator power of 164 kW is required for the power source under steady operation at a maximum beam current of 600 mA.

Table 1. RF-related parameters of the ATF DR.

Beam energy	E_o	1.54 GeV
Maximum beam current	$(I_o)_{max}$	600 mA
RF frequency	f_{RF}	714 MHz
Harmonic number	h	330
Total gap voltage	V_c	1.0 MV
Number of cavities	N_c	4
Synchrotron radiation loss per turn	U_o	156 keV
RF bucket height	$\Delta E/E_{max}$	2.2 %
Natural bunch length	σ_{zo}	3.6 mm
Shunt impedance per cavity	R_{sh}	3.6 MΩ
Unloaded-Q of cavity	Q_o	22,100
Cavity coupling coefficient	β	2.4
Dissipated power per cavity	P_c	17.4 kW
Beam loading per cavity*)	P_b	23.5 kW
Transmission power per window*)	P_{win}	40.9 kW
Total generator power*)	P_g	163.5 kW
Cavity detuning amount*)	Δf	-138 kHz

*) At the maximum beam current of 600 mA.

II. CAVITIES

In order to avoid coupled-bunch instabilities driven by the cavity HOM impedances, four HOM-damped cavities are to be implemented in the ATF DR. A single-cell copper cavity, in which the HOMs are damped by four waveguide ports terminated by broadband loads, was designed. Additional HOM damping in the high-frequency region is provided by HOM absorbers attached to the beam pipes of the RF section [3]. The design considerations and results of low-power measurements are described in refs. [4] and [5], respectively.

The design parameters of the cavity are also given in Table 1. Under a nominal gap voltage of 0.25 MV/cavity, the dissipated power on the cavity wall is 17.4 kW/cavity. The coupling coefficient of the input coupler is set to be 2.4, which gives optimum coupling at the maximum beam current. Then, the transmission power through an input window becomes 40.9 kW. Since this power level is within our experience, we have chosen a cylindrical ceramic window with loop coupling, which was designed by scaling from those of TRISTAN normal-conducting cavities [6]. The design of a prototype high-power test cavity has been completed. The design of the test cavity is presented in an accompanying paper [7].

III. SYSTEM LAYOUT

Figure 1 shows a block diagram of the RF system. RF power is supplied by a 250-kW klystron, which is operated 20% below saturation, thus allowing for automatic gain control (AGC). This output power still has a margin of 20% in order to allow for the use of some fast feedback loops, which may be required to control any transient effects during beam injections. The klystron is under design, the parameters of which are given in Table 2.

The power from the klystron is divided into four parts by magic-tees, being delivered to the cavities through a WR1150 waveguide network. In order to protect the klystron from reflected power from the cavities, we have

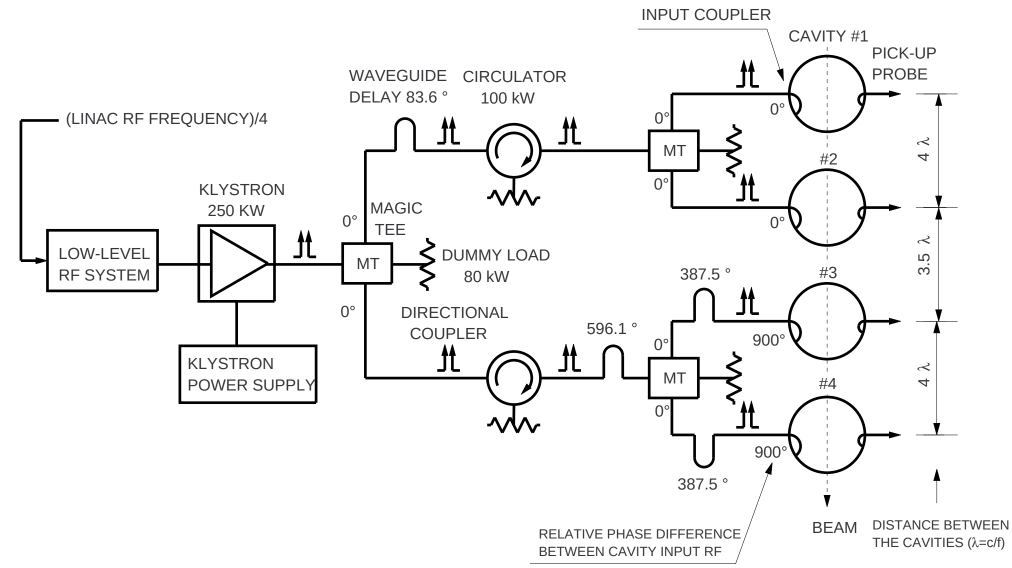

Fig.1. Block diagram of the RF system for the ATF Damping Ring.

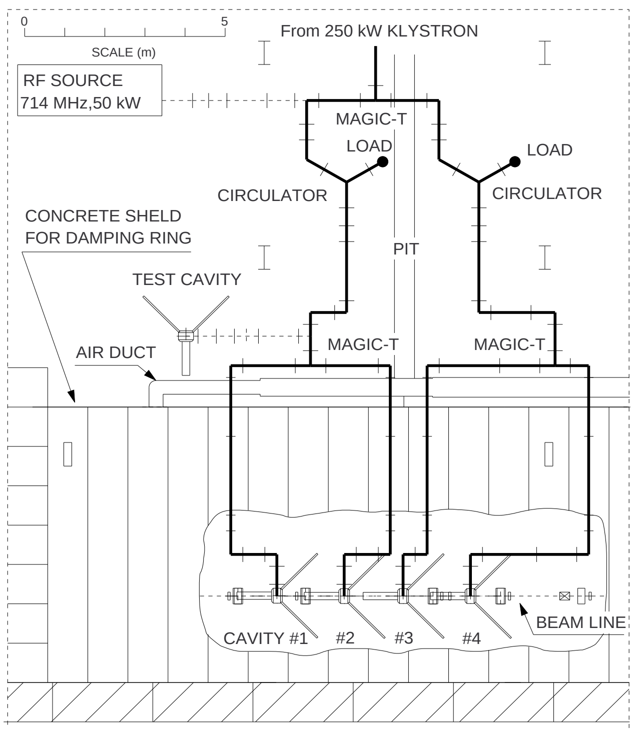

Fig. 2. Layout of the RF system. Top view.

chosen the use of two 100-kW circulators, rather than a single 200-kW circulator, by considering ease in the development. Coaxial-type 80 kW dummy loads are used at the circulator ports, which are capable of absorbing more than 80 kW for a short time.

Figure 2 shows a top view of the system layout. The distances between the cavities are 4λ or 3.5λ (see Fig. 1), where λ is the RF wavelength in free space. The feed lines for the four cavities (after the second magic-tees) are not completely symmetrical, based on the need to avoid

Table 2. Design parameters of the 250-kW klystron.

Frequency range (-1 dB B.W.)	714 ± 1 MHz
Maximum output power	250 kW
Beam voltage	44.9 kV
Beam current	11.1 A
Efficiency	51 %
Beam perveance	1.17 $\mu A/V^{1.5}$

building frames or other structures. The proper phase relation between the cavity inputs is set by adjusting the waveguide lengths (see Fig. 1). For testing the cavities, we have provided another 50-kW klystron (Phillips, YK1265) along with its power supply. The waveguide system can be easily switched for cavity tests.

IV. LOW-LEVEL CONTROLS

In the damping ring, beams are injected by a train of 10-40 bunches. When the ring is initially filled, the beam current in the ring increases in steps of 120 mA (typically). This causes an abrupt change in the cavity voltage and phase, thus leading to beam loss if no measures are taken. A low-level system should control this change, as well as stabilize the voltage and phase in the cavity.

A preliminary plan of the low-level system is shown in Fig. 3. The amplitude and phase of the cavity input RF are stabilized by an AGC and station PLL loops, while cavity tuning is made by a tuner PLL loop. The fill of the empty ring is made according to the following sequence: 1) detune the cavity so as to have a tuning angle of ψ_1 which gives optimum tuning after the first train is injected; 2) shortly (say, 50 μsec) before injection, jump the generator power; 3) inject the first bunch train; 4) detune the cavity

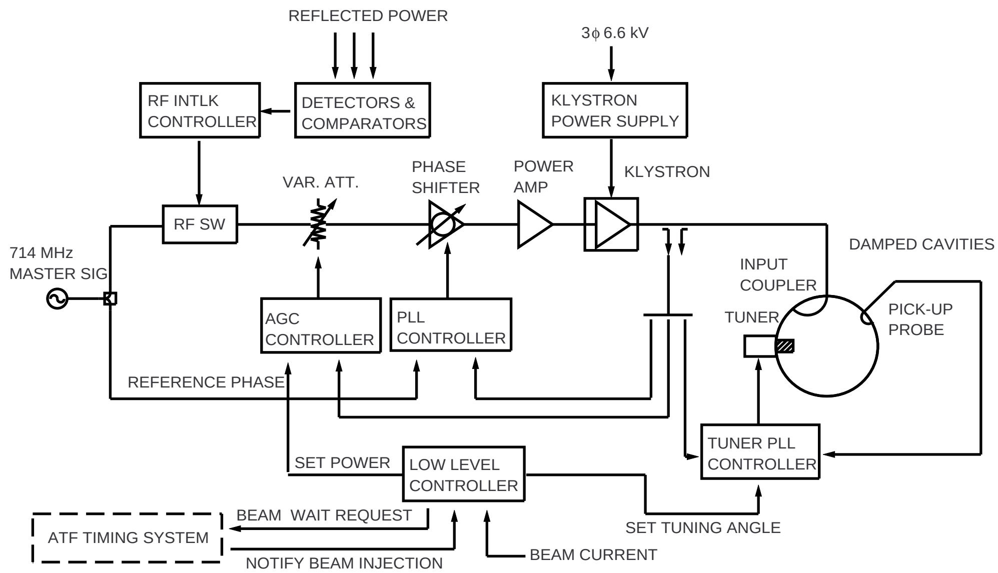

Fig. 3. Conceptual block diagram of the low-level system.

for the next injection; 5) and so on. During this procedure, a signal gives notice of the injection before the beam arrives. It takes several seconds to fill the ring due to mechanical movements of the tuners.

Tracking simulations have showed that beams can be stably stored by using this procedure. The maximum reflected power during filling is about 9 kW/cavity, which is acceptable. A difference in the injected charge of 0-120% from the expected value is acceptable.

After the ring is filled with full bunch-trains, the "oldest" train is extracted, immediately followed by the injection of a new train. Since this injection is made before the "empty" buckets pass the cavities, there is no change in the beam loading, except for that due to a fluctuation of the injected charge.

V. REDUCED RF SYSTEM FOR INITIAL OPERATION

It is planned that initial operations of the DR, scheduled for the end of 1996, will be made using a reduced RF system, due to a shortage of funds. The reduced system comprises two cavities, a 50-kW klystron and one circulator. The left half of the waveguide network, shown in Fig. 2, is to be built first, which is compatible to the full system. This system can accommodate beams of 90 mA with a gap voltage of 0.45 MV at the full beam energy (1.54 GeV). It can also accommodate beams of 400 mA with a gap voltage of 0.3 MV at lower energy (1.3 GeV). In both cases the bucket height exceeds 1%, and the natural bunch length is less than 6 mm. The system allows for many essential studies concerning the beam dynamics relevant to the production of low-emittance beams.

VI. CONCLUSIONS

A damping ring RF system has been designed, and is recently under construction. The development of cavities, circulators or other devices is progressing. A 250-kW klystron is also under development, though its use is not foreseen until after commissioning the ring. A conceptual plan of the low-level system has been made, which will be followed by further developments.

VII. ACKNOWLEDGMENTS

The authors wish to thank Dr. K. Oide of KEK and Dr. P. Krejcik of SLAC for valuable discussions, and to all members of the ATF group for their support. We would like to acknowledge the promotion of the ATF project by Profs. Y. Kimura and K. Takata.

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