

CONSTRUCTION OF A 714-MHz RF SYSTEM FOR THE ATF DAMPING RING

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Abstract

A 714-MHz RF system for the Accelerator Test Facility (ATF) damping ring has been constructed and commissioned. The RF system comprises two higher-order-mode (HOM) damped cavities, a 50-kW klystron, a WR-1150 waveguide network and low-level RF electronics. By using HOM-damped cavities, longitudinal and transverse coupled-bunch instabilities can be avoided even at a maximum beam current of 600mA. A low-level control scheme, which can manage heavy transient beam loading, was designed, and a subset of the system was implemented. We report in this paper the construction and commissioning of this RF system.

1 INTRODUCTION

The KEK-ATF is a dedicated test facility for accelerator study concerning future e^+e^- linear colliders [1]. It comprises a 1.54-GeV electron damping ring and a full-energy injector linac. Design parameters of the damping ring are given in Table 1. Beams consisting of 10-60 bunch bunch-trains are injected. During the short store time (~ 200 msec), the beam emittance will be radiation damped to about 1 nm-rad. It will be most challenging to obtain the very-low emittance beams with sufficient stability under high-intensity and multibunch conditions.

The RF system of the ATF damping ring (DR) is required to provide a sufficient cavity voltage to obtain a short bunch length (less than 5 mm) and to compensate for synchrotron radiation losses (155 keV/turn). At the same time, it must lower the higher-order-mode impedance of the accelerating cavities in order to avoid coupled-bunch instabilities. In addition, transient beam-loading effects at injection should be well regulated by the low-level system.

A 714-MHz RF system, which will meet these requirements, was designed [2] using 714-MHz HOM-damped cavities, which were developed at KEK. The original RF system was designed to use four cavities driven by a 250-kW klystron. We have so far constructed a subset of the system which used two cavities driven by a 50-kW klystron, due to limited funds. The ATF DR started commissioning using this RF system. With this system our temporary goal is to circulate a 100 mA beam with a total gap voltage of 0.5 MV. In the future, the RF system will be extended to the full system, which will allow us to attain the design beam current of 600 mA.

Table 1. Design parameters of the ATF damping ring.

Beam energy: 1.54 GeV	Circumference: 138.6 m
RF frequency: 714 MHz	RF voltage: 1 (0.5) [†] MV
Number of bunch trains: 5 - 2	Bunches/train: 10 - 60
Particles/bunch: $1-3 \times 10^{10}$	
Horizontal beam emittance: 1.4 nm-rad	
Vertical beam emittance: 0.01 nm-rad	
Maximum beam current: 600 (100) [†] mA	

[†] Parameters in parentheses indicate temporary target.

2 HOM-DAMPED CAVITY

Each cavity has four waveguide ports to extract HOM power, and additional HOM absorbers in the beam pipe. This scheme significantly reduces the longitudinal and transverse HOM impedances [3]. Cavity fabrication techniques were established through the construction of a prototype cavity [4]. This cavity was successfully tested under a dissipated power of up to 50 kW which is about three times higher than required.

With the same design, two cavities were manufactured by Toshiba corporation in fiscal year 1995. The Q-value of the cavities obtained was about 23,000, and the coupling coefficient was set to 2.3. Each cavity was conditioned on a test bench up to an input power of 44 kW for about 50 hours. The base pressures before and after the conditioning were about 1×10^{-7} and 2×10^{-8} Torr, respectively. These cavities were then installed in the

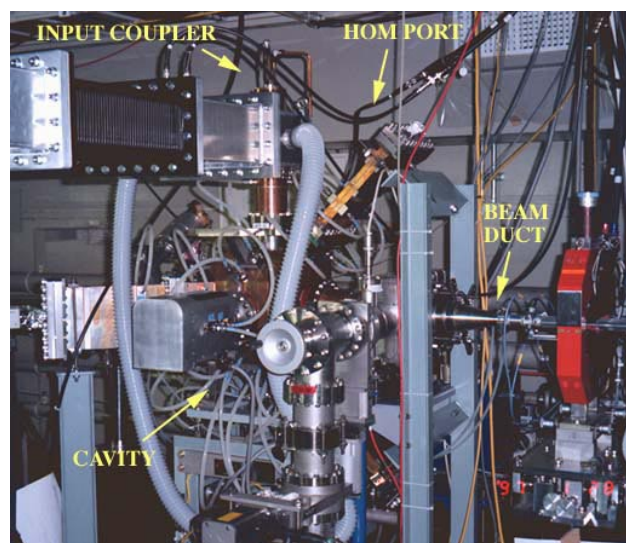


Fig. 1. The 714 MHz HOM-damped cavity installed in the ATF damping ring.

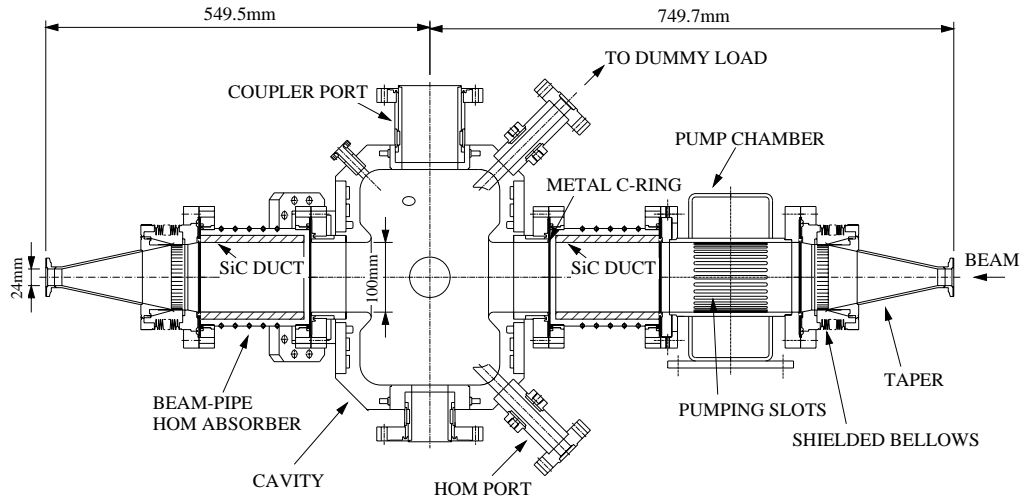


Fig. 2. Cross section of one cavity unit.

damping ring during October to December, 1996. They were further conditioned in the ring, which resulted in the base pressure of 1×10^{-8} Torr before the commissioning. Figure 1 shows the cavity as installed.

Figure 2 shows a layout of one cavity unit. Two beam-pipe HOM absorbers were installed next to the cavity. Each cavity was evacuated by a turbo-molecular pump (300 l/s) and a sputter ion pump (200 l/s) which were connected to the rectangular pump chamber. Inside the pump chamber, a smooth passage for wall currents was provided using an inner duct of 6 mm thickness with thirty pumping azimuthal slots ($105 \times 5 \text{ mm}^2$). Effective cavity pumping speeds were approximately 50 l/s (turbo pump) and 80 l/s (ion pump). The vacuum duct in the RF section was connected to the ring through taper-bellows assemblies. Each bellows was screened from the beam by beryllium-copper fingers, which are very similar in design as those used at the KEKB [5]. In order to arrange a smooth inner wall, a metal C-ring was installed between the conflat flanges used on the beamline.

3 HOM ABSORBERS

For the beam-pipe HOM absorbers, we adopted a shrink-fit technique, as was reported in ref. [6], with a small modification on its design. We first prepared a copper-duct assembly (a copper duct with both cooling-water pipe and stainless-steel collars brazed), and a duct of silicon-carbide (SiC) used for the microwave absorber. While heating the copper-duct to $\sim 200^\circ\text{C}$ in an inert-gas atmosphere, the SiC duct was inserted into the copper duct. After they were cooled to room temperature, the SiC was tightly fit in the copper duct (shrink-fit). Finally, vacuum flanges were TIG welded to the collars. In this way, five absorbers were manufactured, four of which were installed in the ring.

As the absorbing material, we investigated a special SiC material which has a conductivity of about 100 Siemens/m (about 20 times larger than the popular SiC

material) in the frequency range of about 2-10 GHz. As reported in ref. [6], we first succeeded to produce a suitable SiC material by increasing the carbon amount contained in the SiC, but we could not obtain reproducible products at the second manufacturing attempt. We then tried another SiC material containing about 700 ppm of aluminum (higher than the regular product) after consulting with Toshiba Ceramics corporation. Through trial productions, we obtained reproducible SiC samples which have an effective conductivity of $\sim 110 \text{ S/m}$ at 3 GHz and of 57-68 S/m at 5-7 GHz. We therefore decided to use this type of SiC material. The effective conductivity of the four SiC absorbers, installed in the ring, were 65-90 S/m (at 3 GHz).

We have also developed waveguide HOM loads for termination of the HOM ports. The development of the load is described in an accompanying paper [7]. The cavities were initially commissioned without attaching any loads due to some delay in fabrication. At present, nine HOM loads have been completed, and eight of them will be installed during summer shutdown in 1997.

4 RF POWER SOURCE

A block diagram of the RF system is shown in Fig. 3. A commercial TV klystron, YK1265 from Phillips, was used as a power source. It can deliver the maximum RF power of 50 kW in CW mode. A power supply for the klystron was purchased from NEC corp. The power from the klystron is delivered to the cavities through a WR-1150 waveguide network. A newly developed 100-kW circulator was used to isolate the klystron from the cavities. The performance of the circulator include an input VSWR of less than 1.2, an insertion loss of less than 0.2 dB and an isolation of larger than 20 dB in the frequency range of $714 \pm 2 \text{ MHz}$. Waveguide components, such as E- and H- corner bends and a coaxial-waveguide transformer, were newly designed using a computer code HFSS [8].

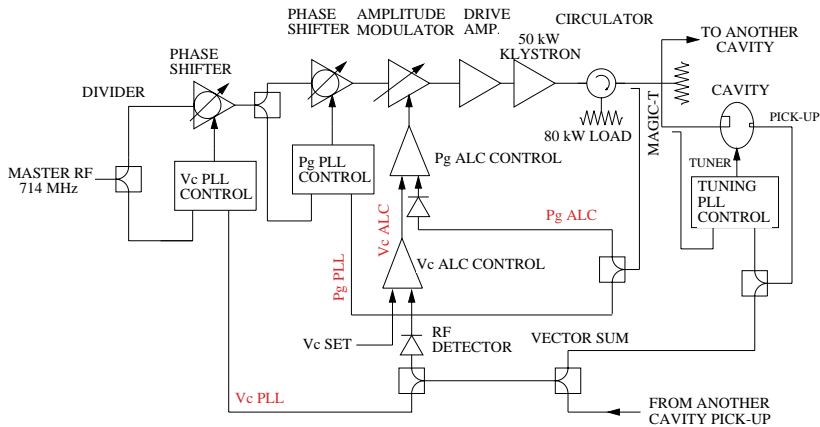


Fig. 3. Block diagram of the damping ring RF system.

5 LOW-LEVEL RF SYSTEM

The low-level RF system is required to minimize both steady-state and transient beam loading effects in accelerating cavities. In particular, a sudden change in the beam current at injection, which amounts to 120 mA per train, should be managed. Based on numerical simulations, we designed a low-level control scheme [9] that fulfills these requirements. Both cavity pre-detuning and phase jump at injection will be used. Direct feedback will be used to avoid the beam loading limit for experiments requiring high beam currents and low cavity voltages.

At present, the control scheme for the heavy transient beam loading has not been implemented, however will be installed in the near future. The current system is similar to that of TRISTAN [10], and many electronics modules for the TRISTAN were adapted. Some narrow-band modules, such as the phase shifter and the RF modulator, were newly developed.

In the main RF line (see Fig. 3), there are four feedback loops, referred as Vc PLL, Vc ALC, Pg PLL and Pg ALC. The first two loops regulate the phase and amplitude of the total accelerating voltage which is monitored by a vector sum of signals from the cavity pick-up probes. The other two are auxiliary loops to suppress both phase and amplitude fluctuations of the klystron output. Tuning of each cavity is controlled by another phase-lock loop.

6 COMMISSIONING

The ATF damping ring started commissioning on January 22, 1997, with a single-bunch beam of about 1 GeV. On January 30, the beam was successfully circulated in the ring for over 500 turns with RF turned off. Then, we applied an RF voltage of 180 kV, and succeeded to store the beam on January 31. Figure 4 shows the signal from the wall current monitor, which shows the first stored beam in the damping ring. Commissioning and tuning operations are currently underway. Multibunch operations will be started in autumn of 1997.

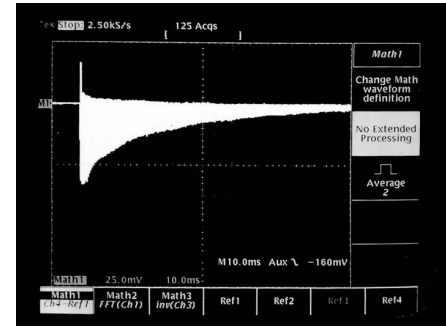


Fig. 4. Signal of the wall current monitor showing first stored beam in the ATF DR. Abscissa: time (100 msec full scale), ordinate: voltage (200 mV full scale).

7 CONCLUSIONS

The damping ring RF system was designed and constructed. The damping ring started commissioning using this RF system, and we obtained the first stored beam in January, 1997. Tuning operations of the ring are underway to obtain the full specification of the beam parameters. The present RF system is a subset of the full RF system, which allows for a straight extension of the system in future.

8 ACKNOWLEDGMENTS

We wish to thank Profs. K. Takata and Y. Yamazaki for their encouragement and valuable advice, and S. Tokumoto and Y. Funahashi for useful discussions on mechanical designs. We also acknowledge much help and support given by the ATF collaboration team and by E-CUBE corporation during the construction of the RF system.

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