THE SSRF BOOSTER CAVITY SYSTEM

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Abstract

In February 2007 a system consisting out of two 5 cell 500MHz cavities has been delivered to SSRF to accelerate the electrons in their booster ring. The two cavities are controlled by one low level RF system, which forms part of the delivery. The paper will describe the general layout of the booster RF system and the architecture of the low level RF system controlling one amplifier and two cavities. Results of the commissioning phase will be presented and compared with expected and guaranteed values of the system.

THE SHANGHAI SYNCHROTRON RADIATION FACILITY SSRF

The Shanghai Synchrotron Radiation Facility SSRF is currently under construction [2, 3]. First beam at the Linac was produced at May of this year.

The SSRF will operate at up to 300mA electrons with 3.5MeV at the storage ring with a circumference of 432m.

LAYOUT OF THE BOOSTER RF SYSTEM

Two 5 cell 500MHz cavities have been delivered to SSRF by ACCEL [1] to accelerate the electrons in their booster ring to 3.5MeV. The electrons are injected with energy of 150MeV from the Linac.

The two cavities are driven by one klystron amplifier followed by a circulator, a high power splitter and two phase shifters.

The Booster LLRF system is also part of the delivery. It controls the two cavities and provides the input signal to the high power klystron amplifier.

Cavities

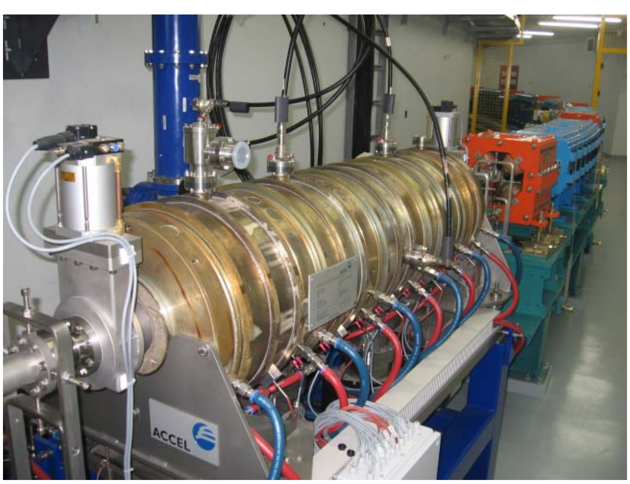

Figure 1: One of two cavities in the booster ring

The cavity, based on the DESY/PETRA design, is established in booster rings of synchrotron light sources. ACCEL delivered this kind of cavity also to CLS, ASP and DLS [4] in recent projects for example.

The 500MHz cavity consists of 5 cells. An inductive loop couples the high power to the cavity. The frequency and the field balance are tuned by two motor driven plungers. Inductive pickup-loops inside the cavity and one directional coupler at the input of every cavity give control signals to the LLRF system. The specified quality factor amounts at least 29000 per cavity, hence 34.5kW are required to achieve the designated accelerating voltage of 1MV per cavity. The measured quality factor amounts 29390 and 29620 for the two cavities hence the required power is even lower.

LLRF System

The delivered LLRF system, based on I-Q modulators and demodulators, controls the amplitude and the phase of the cavity voltages with a guaranteed amplitude stability of 1% (RMS) and a guaranteed phase stability of ±4° (RMS) during ramp and ±1° (RMS) for injection and extraction.

The LLRF system also has the function to tune the resonator resonance frequency and the field flatness of each cavity using the two motor driven plunger tuners. For resonance tuning, the phase difference between the signals from directional coupler (forward power) and pickup-loop is kept constant.

COMMISSIONING OF THE BOOSTER RF SYSTEM

After delivering the system in February 2007 to SSRF it was installed inside the booster ring environment by SSRF (see figure 1). In May 2007 the booster cavity system was successfully commissioned within 3 weeks by ACCEL. All specified parameters are achieved and the system is accepted by SSRF.

Cavity Conditioning

The cavities were conditioned in two cycles. During first cycle the cavities were conditioned within less than 24 hours to a power of 60kW per cavity at a vacuum level of about 10^{-7}mBar. In order to reach a high stability for long time operation, the cavities were conditioned to 60kW per cavity at a vacuum level of some 10^{-8}mBar during a second cycle.

Figure 2 shows the achieved cw power over the effective conditioning time. In figure 3 the vacuum level during the two conditioning cycles is illustrated.

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The temperature characteristic of both cavities is shown in figure 4. The temperature of the warmest cell 3 conforms to the theoretical calculated characteristic (red line). At later operation the temperature of the warmest part will not exceed 40°C.

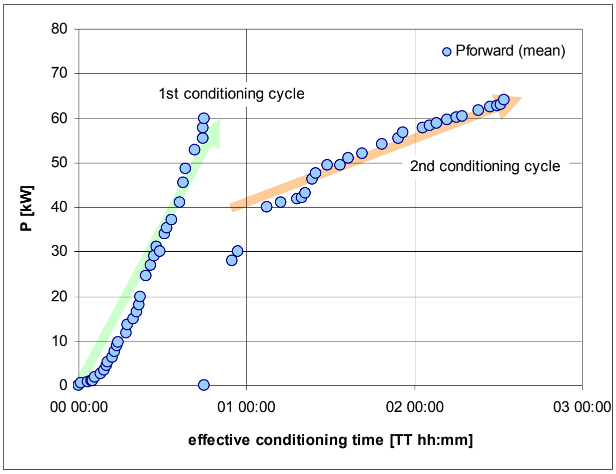

Figure 2: Conditioning progress, achieved cw power over the effective conditioning time, 2 conditioning cycles were performed

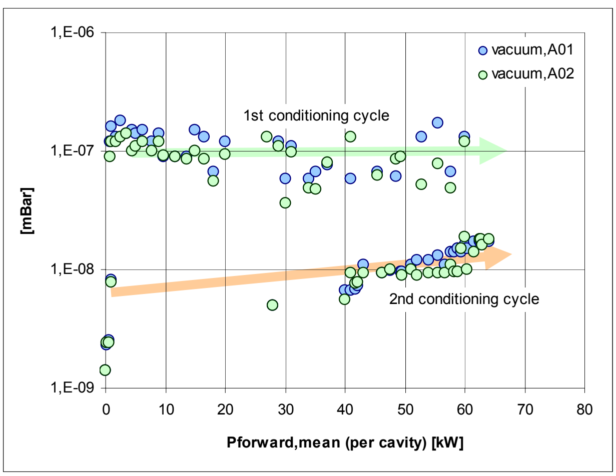

Figure 3: Conditioning progress, vacuum level over the achieved cw power for the two conditioning cycles

Long time stability test

After carefully conditioning of the two cavities an 8h-long-time test took place in order to approve the stability of the system. The test was successfully finished without any interruption.

For the test the same conditions, foreseen for later beam operation, were used. Hence the system was operated with closed amplitude and phase control loop at ramped mode. The only difference was, that the system was operated at 60kW peak power per cavity, thus at twice of the later operation power, in order to approve stability also at higher power levels.

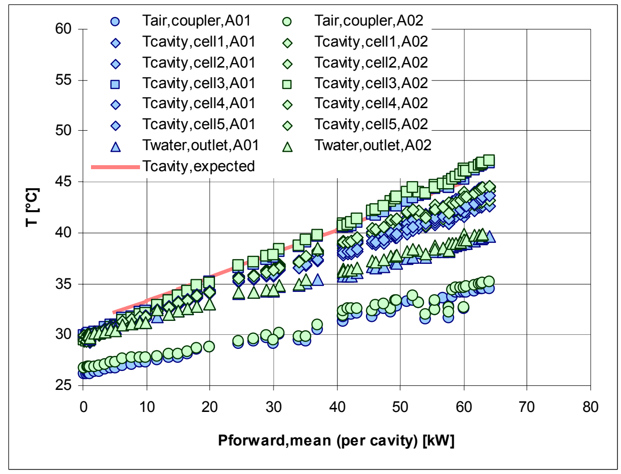

Figure 4: Cavity temperature over the cw power level

The amplitude and the phase stability were monitored during the long time test. Figure 5 shows that the phase stability was better than +1/-2° during 8 hours with 0.17° RMS. Also the amplitude stability was better than the specified value of 1%.

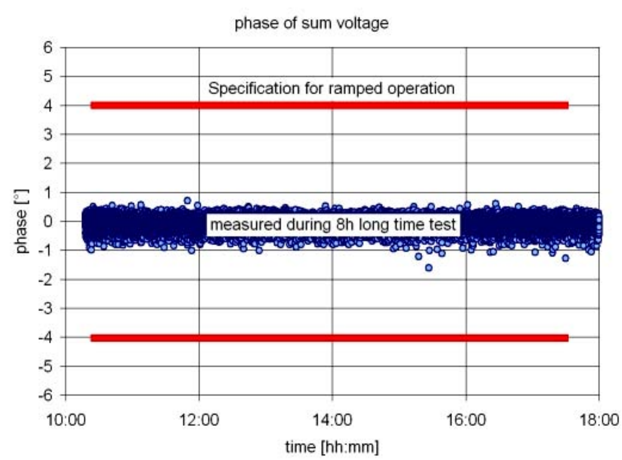

Figure 5: phase stability during long time test

Reached Performance

Table 1 summarizes the performance of the delivered booster RF system.

A big challenge for the LLRF system is the specified stability over the high dynamic range. The cavity voltage has to be stable from 0.1MV to 2MV (sum voltage), leading to 26dB dynamic range, during ramped mode.

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Table 1 : Reached performance

parameter	**guaranteed performance**	**reached performance**	
		cavity 1	**cavity 2**
cavity quality factor	29000	29620	29390
cavity field flatness	±5%	<1%	<1%
sum voltage amplitude stability	1% RMS over 26dB voltage range	0.07…0.96% RMS over 26dB	
sum voltage phase stability at injection and extraction	±1° RMS	0.1…0.5° RMS	
sum voltage phase stability during ramp	±4° RMS over 26dB voltage range	0.16° RMS over 26dB	

CONCLUSION

The two 5 cell 500MHz cavities and the LLRF system for the SSRF Booster ring were successfully commissioned within 3 weeks in May 2007. All specifications are met.

After intensive conditioning in the 10^{-8}mBar vacuum range, the system was operated over 8 hours without interruption and with amplitude and phase stability better than specified.

REFERENCES

[1] http://www.accel.de

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[4] C.Christou, V.C.Kempson, K.Dunkel, A.Fabris, “The Diamond Light Source Booster RF System”, EPAC2006, Edinburgh, June 2006

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