RF SYSTEM FOR SESAME

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Abstract

The SESAME (Synchrotron light source for Experimental Science and Applications in the Middle-East) accelerator consists of a 22 MeV Microtron, an 800MeV Booster synchrotron and a 2.5GeV Storage Ring (SR). Each accelerator has its own RF system. The Microtron RF frequency is 3 GHz generated by a 2 MW pulsed Magnetron while the Booster and SR have a common 500 MHz CW RF source. The Booster RF system consists of a DORIS cavity fed by a 2kW CW solid-state RF amplifier but the SR RF system has been designed based on four 500 MHz plants, each comprising a normal conducting (NC) single-cell cavity, powered with 140 kW (CW) RF power via a WR1800 waveguide line. In the initial phase, it has been decided to start with two ELETTRA type cavities and in final phase, four cavities will be accommodated in one straight section in the SR to have nominal energy and current in the machine. This paper presents status of installed Microtron RF system and modified Booster RF system from BESSY I, as well as designed SESAME SR high power RF system and low level electronics.

INTRODUCTION

The RF system for any particle accelerator has to provide the accelerating voltage and make up the power losses of the beam no matter the cause. This paper describes possible solutions for the RF system for the SESAME storage ring as well as status of existing RF systems for the booster and the Microtron.

First the basic parameters that affect the RF system for the storage ring are examined and an RF specification derived. Possible solutions for the SR RF system are identified, and the proposed low level electronic is discussed.

Then the refurbishment of RF systems from BESSY I for the booster synchrotron and the microtron is reported.

STORAGE RING RF SYSTEM

Table 1 gives the basic parameters of SESAME storage ring which affect the RF system [1].

At the nominal energy of 2.5 GeV and beam current of 400 mA, the radiation power to be restored by the RF system for the bare machine is 236 kW. A peak accelerating voltage of 2.4 MV (at 500 MHz) is needed to achieve the energy acceptance of ±1.45%.

The implementation of storage ring RF system has been planned in two phases; in phase one, SR will be commissioned with two normal conductive cavities of ELETTRA type, each one fed by maximum possible RF power, without Insertion Devices and with low stored current in the storage ring. In phase two, other two RF cavities and transmitters will be added in order to provide enough power for fulfilling nominal parameters with 400mA stored current in the storage ring and compensating all the losses due to the Insertion Devices.

Table 1: SESAME main RF parameters

Parameter	Value
Energy	2.5 GeV
Circumference	133.20 m
RF frequency	499.654 MHz
Radiation loss/turn	590 keV
Beam current (maximum)	400 mA
Beam power loss (bare machine)	236 kW
Harmonic number	222
Momentum compaction factor	0.00833
Total RF voltage (maximum)	2.4 MV
Over voltage factor	4
Number of cavities	4
Energy acceptance	±1.45 %
Synchrotron frequency	37 kHz
Synchronous phase	165.5 °

A simplified block diagram of the proposed SESAME RF system and RF distribution is shown in Figure1.

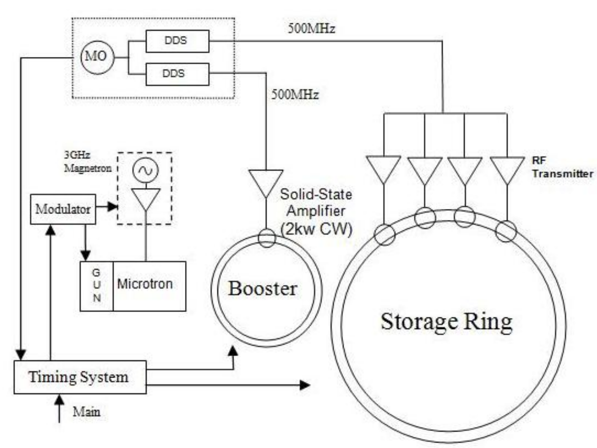

Figure 1: Simplified block diagram for RF distribution.

RF Generator

A common precise Master Oscillator (MO) must be used for the Storage Ring and the Booster. This RF generator can be implemented by a very low noise, stable and temperature stabilized crystal oscillator mixed with the output of two DDSs to generate the 500MHz RF signals. The advantage of using two DDSs and a common MO is that the booster oscillator may be tuned independently or phase-locked to the main ring oscillator.

RF Power System

The RF power source for the storage ring, so far, has been planned based on the IOT tubes. 140 kW CW RF power will be available for each cavity by combining of the output power of two 90 kW IOTs.

Using solid-state high power amplifiers instead of IOT as an alternative for RF power sources for SESAME storage ring is being studied. The practical results of using this state-of-the-art technology in other synchrotron light sources show reliable and satisfactory operation [2].

RF Cavity

Four NC single-cell cavities of the ELETTRA type [3] with a shunt impedance of 3.4 MΩ and a quality factor of 40000 will provide the required RF voltage and power in the SR. The parameter values in Table 2 show that, using four such cavities, the RF system has the potential for achieving the SESAME requirement with a cavity input power ($\boldsymbol{P_{RF}}$/cav) lower than 140 kW. Besides, using 2 cavities in day one each fed by 141 kW, 300 mA (at 2.5 GeV) can be stored in the SR for commissioning without IDs, with lower energy acceptance and beam lifetime.

In the final phase, it has been foreseen to accommodate four RF cavities in one 4 meter long straight section. In this case, in addition to have better energy acceptance and beam lifetime, there will be enough margins to compensate the additional losses due to the Insertion Devices also at full current.

Table 2: RF operating parameters for 2 and 4 cavities

Nb of Cav.	I_b mA	$\boldsymbol{V_{RF}}$ MV	$\boldsymbol{P_{Cav}}$ total kW	Over Volt. factor	RF accep %	$\boldsymbol{P_b}$ kW	$\boldsymbol{P_{tot}}$ needed kW	$\boldsymbol{P_{RF}}$/cav needed kW	Available Power for IDs kW
2	300	1.2	106	2	0.75	177	283	141	0
4	400	2.4	212	4	1.45	236	448	112	112

The input coupler must be capable to feed into the cavity a CW RF power of at least 140 kW (forward) and also to handle the full reflection. It will be similar to those operating in ELETTRA which are of the coaxial type, terminated by a coupling loop. Although the operating power at ELETTRA does not exceed 120 kW, the same coupler has successfully been tested up to 330 kW and therefore should be capable to fulfil the SESAME requirement. The coupling coefficient shall be adjustable within a range of 1 to 3 in order to match different beam loading conditions.

We are also investigating the performance of the newly developed EU HOM damped cavity especially on its power handling capability. This cavity is an attractive alternative in relation to the suppression of longitudinal and transverse multibunch instabilities driven by HOM's of the RF cavities.

Feeder System

The power feed from the RF power source to the cavity will be waveguide WR 1800. Commercially available circulators will be used to isolate the cavity, and provide a matched load for the transmitter. Monitoring directional couplers will also be incorporated, but at present no special waveguide components, such as filters, are being considered

LOW LEVEL ELECTRONIC SYSTEM

Each one of the four RF plants of the SESAME RF system has to be equipped with four low level loops. The temperature loop for stabilizing the reference temperature of the cavity, a mechanical tuning loop and an amplitude loop for beam loading compensation, while a phase loop must be used to maintain the phase stable. All of these loops interact with each other and will be coupled trough the beam.

Basically, the operation of the RF plants is strongly influenced by the loading due to the circulating beam current. At high current the system stability may be affected. Moreover, during the various phases of machine operation (injection, ramping, beam storage), which require different power levels from the amplifiers, amplitude and phase of the cavity fields must be kept stable for a proper operation of the system. To compensate these effects, three feedback loops have to be installed: a tuning loop, an amplitude loop and a phase loop. Besides these loops, a temperature feedback will stabilize the reference temperature of the cavity.

A simplified block diagram which is proposed for SESAME [4] is shown in Fig. 2.

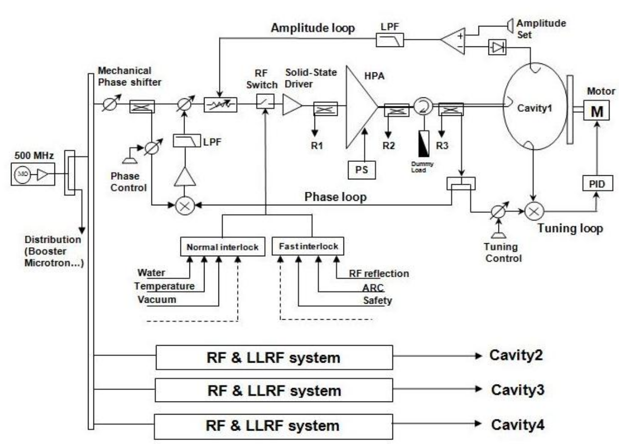

Figure 2: Simplified block diagram of SESAME low level RF system.

The frequency regulation loop must have a tuning range of about ± 200 kHz which corresponds to a reasonable change in the cavity length. From the experience of similar systems with ELETTRA type cavity, this allows to handle cavity temperature variations of about ± 20 °C with a sufficient margin for the compensation of the largest beam loading effect (around 25 kHz as reported from similar systems).The maximum tuning speed must be fast enough for injecting the full beam in proper time and the sensitivity of the loop has to be adjustable in order to make a smooth tuning.

The 3dB bandwidth of amplitude loop should be adjustable up to 5 kHz to regulate the cavity accelerating voltage with stability better than 1 % by controlling the drive power.

The phase loop should compensate for the phase changes in the amplification chain with variable power. It also has to have a 3 dB bandwidth adjustable up to 5 kHz and must ensure a phase stability of ± 0.5 °.

The bandwidth of both phase and amplitude loops must be optimized to provide enough damping while remaining insensitive to the synchrotron frequency.

In the driving chain the signal from the 500 MHz master oscillator, after being split, phase and amplitude regulated, is amplified with a 500 W solid state amplifier to drive IOT. A fast RF switch at the input of the chain should remove within a few ms the driving RF signal under certain conditions such as RF reflections, arcs, safety, or any problem in water, vacuum, temperature and so on.

BOOSTER RF SYSTEM

SESAME Booster and Microtron are the legacy of BESSY I. In the Booster, there used to be a 2 kW klystron as the RF source but due to the availability and better functionality of solid-state RF amplifiers, it has been decided to be substituted, but it is intended to use other high power RF components where possible. Low level electronic system is being refurbished and tested to be used with the new amplifier.

The Booster RF system consists of a single 500MHz accelerating cavity, the new amplifier and refurbished electronic circuits. The existing DORIS type cavity including feedthroughs for the driving loop and new plunger mechanism will be used.

The radiation loss at 800 MeV is ~14 keV/turn and with an accelerated current of 5 mA the power delivered to the beam will be ~70 W. The peak cavity voltage will be 50kV and with a shunt impedance of 3 MΩ the dissipation power in the cavity will be 415 W [5]. So the total RF power will be 485 W CW at 500 MHz.

In order to work in the linear area of amplifier output and have a good safe margin for further upgrades of the Booster, a 2kW CW solid-state RF amplifier was ordered and will be used for feeding the cavity via a coaxial cable. Using a solid-state amplifier instead of an RF tube has many advantages like low voltage power supplies, more reliability, more MTBF, etc.

MICROTRON RF SYSTEM

RF system of the Microtron consists of a 3GHz magnetron, waveguide system, circulator and the cavity.

Magnetron produces a 2 microsecond RF pulse with 2MW peak power. A 45 kV voltage pulse from the modulator is used to supply the magnetron.

The old RF system of Microtron was installed and conditioned in SESAME with satisfactory results.

Figure 3 shows the measured RF pulse (push detected), gun current and magnetron current. All the results show good matches with the operational values in the BESSY I.

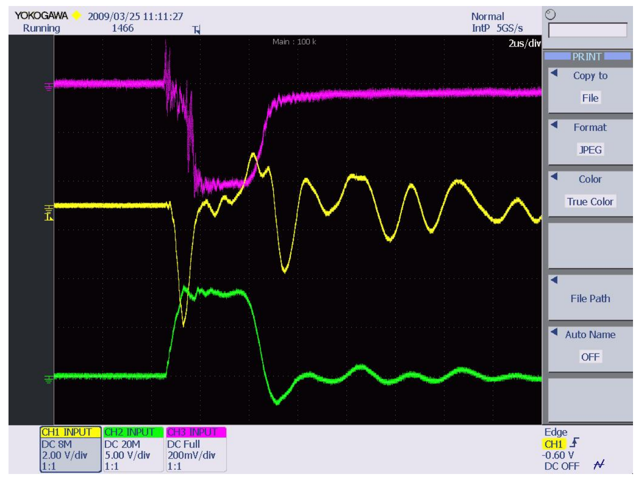

Figure 3: Microtron measured signals, RF pulse (upper), Gun current (middle), Magnetron current (lower).

SUMMARY

The Microtron RF system has been installed and conditioned and now is ready for Microtron commissioning. The new Booster RF source and control system is ready and conditioning of the Booster cavity will be done in the RF lab in June. Although the SR RF system has been designed, the strong alternatives for cavity, LLRF and transmitter choices are being studied.

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