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SIRIUS STORAGE RING RF SYSTEM STATUS UPDATE

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Abstract

Sirius's nominal operation phase consists of two 500 MHz CESR-B type superconducting cavities, each being driven by four 65 kW solid-state amplifiers, and a passive superconducting third harmonic cavity. Currently a normal conducting 7-cell PETRA cavity is being used along with two 65 kW RF amplifiers and was recently able to achieve 100 mA stored current. The performance of the storage ring RF system and the updated installation plans update are presented and discussed.

INTRODUCTION

Sirius's storage ring RF system is currently operating with a 7-cell normal conducting cavity driven by a 130 kW RF plant comprised of two 65 kW solid-state amplifiers (SSA) and controlled by a digital low-level radio frequency (DLLRF) based on ALBA's platform [1]. Sirius has been operating in decay mode for beamline tests with 100 mA stored current [2].

The RF system for Sirius's storage ring will be comprised of two CESR-B type superconducting (SC) cavities in its final design configuration to provide the 3 MV gap voltage required for the operation with 350 mA storage current. The final RF design also contemplates the installation of a SC passive third harmonic cavity.

CURRENT SYSTEM STATUS

Sirius's RF system has been in operation for over two and a half years. Trips concerning the RF system are mostly related to the cavity pressure or temperature. The following subsections will discuss further aspects related to the system performance and operation at the present status.

Performance

Figure 1 shows the SSAs global efficiency and gain. Each SSA operates with about 55 kW output power at 100 mA stored beam current. At this operating point, the global efficiency is about 50% and the gain is around 51 dB. At maximum output power (65 kW) the amplifiers operate with efficiency around 60% as usual for a class AB amplifier.

The two SSAs have been operated for roughly 15 thousand hours with reliability close to 100% since the installation and commissioning of the Sirius RF system. Even though the SSAs are not being the cause of any trip of the RF system during operation, a considerable number of modules had to undergo some sort of maintenance, where 17.8% of the modules had to be repaired, most of them due to poor quality of one pi-filter in the gate bias circuit. These faults had no effective impact on the system and these filters are being preventively replaced during scheduled maintenances, as degradation of the module's current consumption is observed.

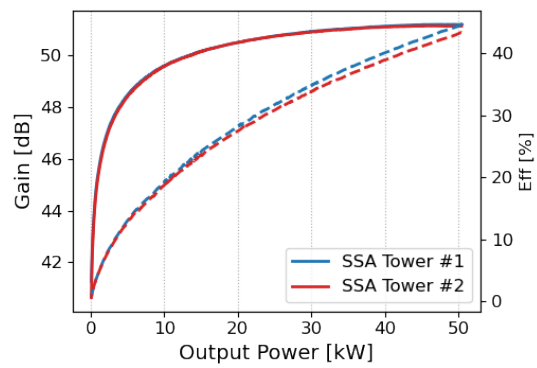

Figure 1: Sirius RF SSAs efficiency (dashed) and gain (solid).

Figure 2 shows the number of amplifier modules that have failed so far. To date, only 2 out of 264 transistors from the modules have failed during the conditioning phase of the SSAs before their installation in the machine.

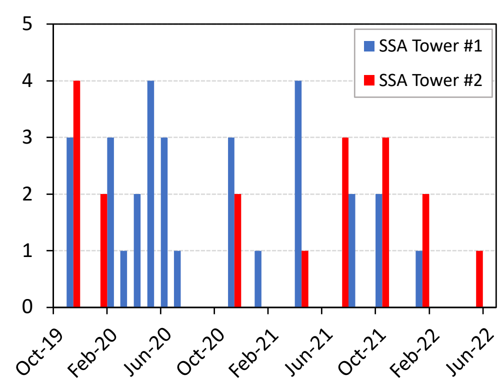

Figure 2: Repaired amplifier modules over the years.

Operation

Since the 7-cell cavity is in operation for a longer period than initially planned, some optimizations were made. This cavity has no HOM damping, but the operating temperature was adjusted to minimize the impact of these HOMs and guarantee the beam stability, supported by the longitudinal BbB system, designed to operate with a beam current up to 100 mA [3]. Despite the absence of HOM dampers, it is possible to accumulate about 85 mA of a stable beam without longitudinal BbB feedback.

Sirius is currently operating in decay mode with current starting at 100 mA during beamlines users run with bunch-by-bunch (BbB) and slow orbit feedback (SOFB) systems

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enabled. The gap voltage in the cavity is about 1.8 MV and the control temperature is 42.5 °C.

The cavity voltage standard deviation was around 0.15% in amplitude and 0.13° in phase during operation with 100 mA stored beam. Figure 3 shows the cavity voltage spectrum around the RF frequency in three different operating conditions: without beam and the DLLRF operating in an open and closed loop, and with stored beam (approximately 70 mA) and the DLLRF operating in a closed loop.

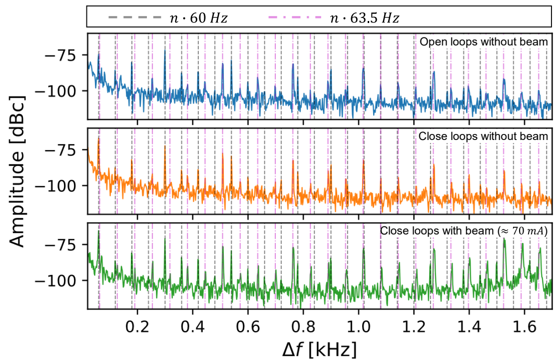

Figure 3: Cavity voltage spectrum.

It is observed harmonic components noises around 60 Hz and 64 Hz. These spectral lines are lower than -65 dBc and might be generated in the DLLRF DAC and/or LLRF up-conversion frontend.

Figure 4 shows the square root of the integrated voltage squared of these spectrums. Further studies and strategies to mitigate the instabilities and suppress the observed noises are being carried out. One approach to optimizing the DLLRF controller parameters is being made through the RF system plant identification [4].

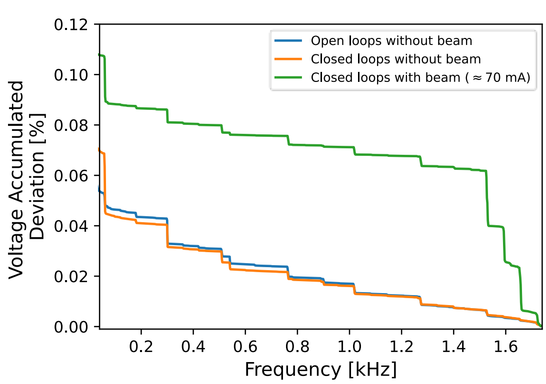

Figure 4: Square root of integrated voltage squared spectrum.

INSTALLATION PLANS UPDATE

Delays due to the long process of the selection and contract of the company responsible for the construction of Sirius's cryogenic plant impacted the initial plans for installing the superconducting cavities. The two SC cavities installation are expected to take place in 2024. The SC passive third harmonic cavity will be installed to improve beam lifetime and reduce thermal losses in the vacuum chamber.

Table 1 summarizes the current and final RF system.

Table 1: Storage Ring RF System Parameters

	Current RF system	**Final RF system**
Cavity type	7-cell NC	CESR-B
Number of cavities	1	2
RF Voltage (MV)	1.8	3.0
Beam current (mA)	100	350
E_{loss}/turn IDs (keV)	200	400
Number of SSA	2	8
RF Power/Cav (kW)	130	250
Harmonic cavity	-	1

Cryogenic System

Concerning the cryogenic system, some equipment, such as the gaseous helium (GHe) tanks has already been delivered. Construction of platforms to accommodate these tanks is underway. Each tank can store up to 100-cubic meters of GHe, which is enough to store all the helium in the cryogenic plant. It will comprise two compressors and one oil removal system along with a spare. A 4000 liters liquid helium (LHe) Dewar will keep SC cavities at 4.2 K for longer periods. A manifold box will enable the installation of a valve box from a SC cavity without having to halt the cryogenic plant operation. Besides, some cryo-plant utilities and a liquid nitrogen (LN2) distribution system are under request for quotation and will soon be hired.

Superconducting Cavities

The SC cavities were purchased from RI (Research Instruments GmbH). The first cryogenic module (CM1) has already been delivered, as shown in Fig. 5. The second cryogenic module (CM2) Factory Acceptance Test (FAT) was performed at the beginning of June 2022, and it will be prepared for delivery in the following months.

Figure 5: Visual inspection of the CM1 on-site.

Harmonic Cavity

A passive third harmonic cavity parameters specification and studies of its impact on the machine are being carried out [5]. Considering Sirius's parameters, the nominal harmonic voltage required for an optimal flat potential well will be about one-third of the main RF voltage foreseen

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during operation with the two CESR-B superconducting cavities. A beam lifetime increase of around 4.5 times is expected for a uniform filling pattern.

A collaboration between Sirius's and Shanghai Synchrotron Radiation Facility (SSRF) is expected to be established for the development of a third harmonic superconducting cavity for Sirius. SSRF has designed, built and installed a SC harmonic cavity that is operating since last year.

SSRF's cavity includes a room temperature tuner with a control system that might be suitable to reach optimal operating conditions for the machine [6].

RF Amplifiers

The current RF system with 7-cell normal conducting (NC) cavity will be decommissioned and the twos, LLRF rack, Interlock system, high-power circulator and load from this plant will be rearranged in the RF room to a new spot to drive one of the SC cavities. A second RF plant will be assembled for the second SC cavity, which will include another rack with the same LLRF system using the new design of amplifiers [7]. Each plant will include a 4-way High Power Waveguide Combiner for the full combination of four SSA. Figure 6 illustrates the planned layout for the final RF system design.

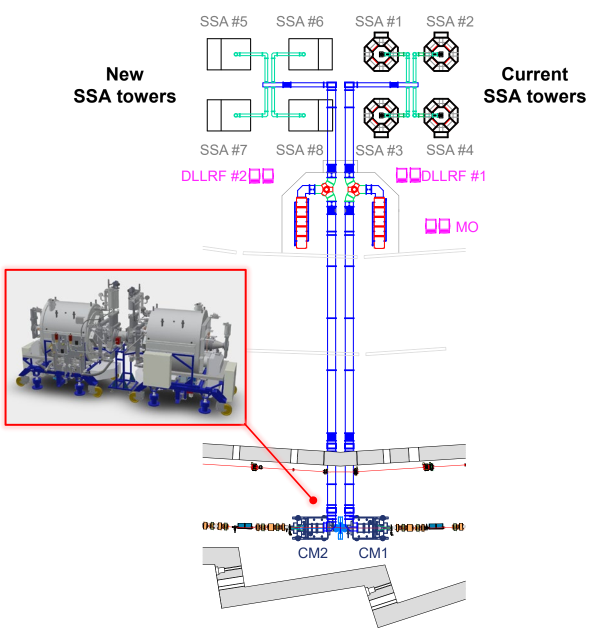

Figure 6: Layout of the RF system for the SC cavities.

Since the design of the first SSA [8], new LDMOS devices were introduced into the market. For the second SC cavity four new amplifier towers are being developed based on a newly released LDMOS transistor (BLF978P) with higher gain and efficiency. The new amplifier module with this transistor is under development and the last four SSAs will be manufactured by a local company. Following the trend seen in other facilities regarding cable-less and high efficiency RF combining solutions, efforts are being made to design and manufacture an 80-input cavity combiner (CaCo) [7].

Assembling in Progress

Figure 7 shows the assembling of the next two RF amplifiers that will compose one of the SC cavities RF plants together with the two SSAs already in operation.

Figure 7: SSA being assembled.

CONCLUSION

For over two and a half years the storage ring RF system has been operating with no major issues. The amplifiers and the DLLRF proved to be reliable for the current operation mode, as well as the cavity is working properly, and efforts to improve the performance of the system are in progress. The infrastructure for the final design of the Sirius RF system is advancing as well.

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