STATUS OF THE RING RF SYSTEMS FOR FAIR*

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Abstract

For the FAIR (Facility for Antiproton and Ion Research) synchrotron SIS100 and the storage ring CR (Collector Ring), different RF cavity systems are currently being realized. In addition to the standard RF bucket generation and acceleration, these ring RF systems also allow more complex beam manipulations such as barrier bucket operation or bunch rotation in phase space. Depending on their purpose, the cavities are either loaded with ferrite material or with MA (Magnetic Alloy) ring cores. Independent of the type of cavity, a complete cavity system consists of the cavity itself, a tetrode-based power amplifier, a solid-state pre-amplifier, a supply unit including PLC (Programmable Logic Control), and an RF control system (so-called LLRF, low level RF system). In this contribution, the different systems are described, and their current status is presented.

SIS100 RF SYSTEMS

SIS100 will be the main synchrotron of the FAIR facility [1, 2]. This chapter is dedicated to the SIS100 RF systems. The mentioned RF voltages are the total peak voltages per cavity experienced by the beam.

SIS100 Accelerating System (SIS100 ACC)

The main accelerating system in SIS100, which works at harmonic number h=10, consists of 14 ferrite-loaded cavities whose parameters are shown in Table 1. The system is optimized for fast ramping and for a variety of operating modes.

Table 1: SIS100 Accelerating System (parameters for one cavity)

Parameter	Value
Frequency range	1.1-3.2 MHz
Maximum RF voltage	20 kV
Duty cycle	CW
RF power amplifier	Tetrode RS2054, single-ended
Installation length	3.0 m

For this system, the tendering process under the leadership of the FAIR GmbH* has successfully been completed. A consortium consisting of RI Research Instruments GmbH and Ampegon AG will deliver the overall system consisting of cavity, power amplifier, and power supply unit including PLC. Most parts of the LLRF system will consist of standardized GSI components. The technical design of the cavity is similar to the existing SIS18 ferrite cavities. Water cooling of the ferrite material is realized by cooling disks in-between the ring cores. A first sketch of the cavity in conceptual design phase is shown in Fig. 1.

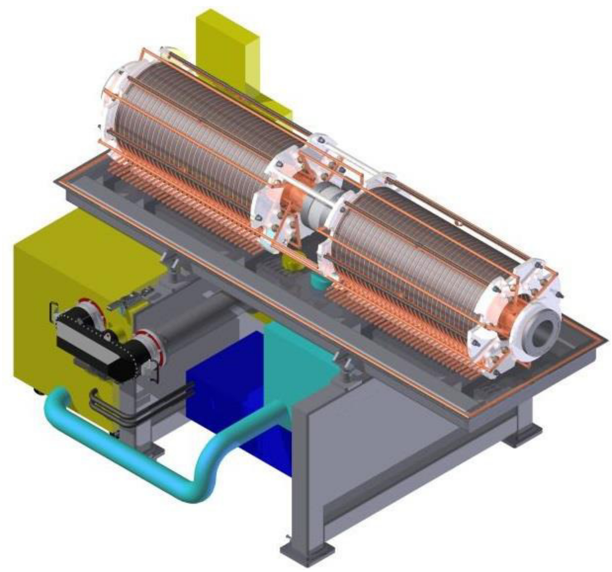

Figure 1: Conceptual design draft of SIS100 ACC cavity (image: RI Research Instruments GmbH).

In the first design phase, a specification for the ferrite ring material was agreed with the manufacturer after several ring core samples have been tested. The CDR (Conceptual Design Report) has been completed recently, the FoS (First of Series) will be delivered to GSI in 2016.

SIS100 Barrier Bucket System (SIS100 BB)

The barrier bucket system for SIS100 consists of two cavities loaded with magnetic alloy (MA) ring cores whose parameters are shown in Table 2. Each of the two cavities will create a single-sine pulse which can be shifted in time. Therefore, the beam can be captured between the two barriers (in the typical operating scenario, 8 of the 10 buckets generated by the SIS100 ACC system will be filled, and these 8 bunches will be combined to a long sausage-like bunch), and it will be pre-compressed by means of moving barriers in order to prepare the beam for final bunch rotation with the SIS100 BC system described below.

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Table 2: SIS100 Barrier-Bucket System (parameters for one cavity)

Parameter	Value
Single-sine duration	≈666 ns
Single-sine repetition rate	110 – 320 kHz
Maximum RF voltage	15 kV
Duty cycle	4 %
RF power amplifier	Tetrode, push-pull
Installation length	1.1 m

For the SIS100 BB system, a technical concept is currently worked out which will serve as a basis for the call for tenders. Due to the large power dissipation caused by required voltage per length, oil cooling will be necessary. Therefore, the system is designed based on the experience with the existing SIS18 h=2 cavity [3]. A first sketch of the SIS100 BB cavity is shown in Fig. 2.

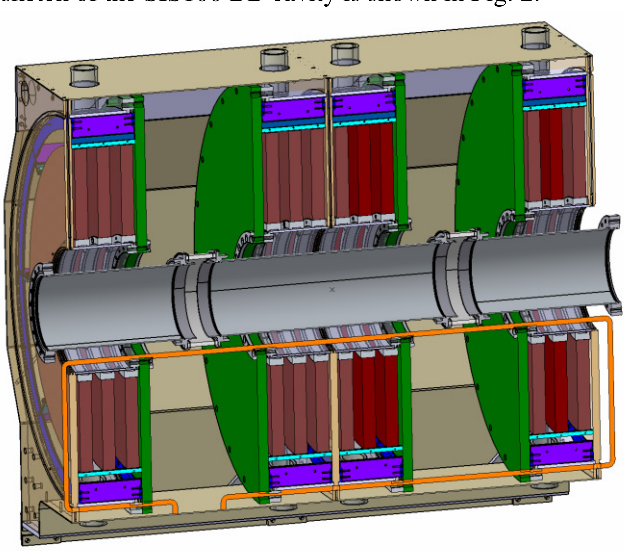

Figure 2: Draft of SIS100BB cavity (image: C. Christoph).

One of the main challenges of the SIS100 BB system is to provide the required signal quality in order to avoid micro-bunching. Therefore, lab experiments are currently performed to ensure a smooth broadband behavior of the overall system and to reduce nonlinearities. It is planned to apply pre-distortion schemes in order to generate the single-sine pulses at the gap.

SIS100 Bunch Compressor System (SIS100 BC)

The bunch compressor system for SIS100 consists of nine MA-loaded cavities whose parameters are shown in Table 3. These cavities are used in a pulsed mode in order to perform a bunch rotation in phase space (at h=2 after a pre-compression by the SIS100 BB system) which leads to a single short bunch.

Table 3: SIS100 Bunch Compression System (parameters for one cavity)

Parameter	Value
Frequency range	310-560 kHz
Maximum RF voltage	40 kV
Duty cycle	0.3 %
RF power amplifier	Tetrode TH555, push-pull
Installation length	1.2 m

The air-cooled cavity including the power amplifier will be built by Aurion Anlagentechnik GmbH. A first sketch of the cavity is shown in Fig. 3.

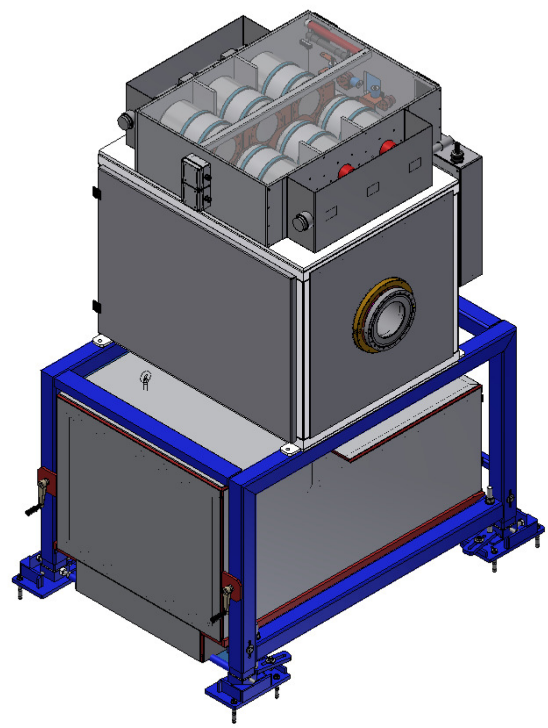

Figure 3: Draft of SIS100 BC cavity (image: Aurion Anlagentechnik GmbH).

For the power supply units including PLC, the specification has been fixed, and a separate call for tenders was initiated. The pre-qualification phase is already running.

SIS100 Broadband Feedback (SIS100 BF)

The SIS100 broadband feedback system is dedicated to the damping of coherent longitudinal beam oscillations. It is currently planned to use cavities that are similar to those planned for the SIS100 BB system because a comparable broadband behavior has to be achieved, and comparable power dissipation is expected. Apart from the cavity, the development activities focus on the closed-loop control part to allow bunch-by-bunch operation. For this purpose, several electronics components have been developed, and experiments with beam have been carried out as a proof-of-principle [4].

CR DEBUNCHER SYSTEM (CR DB)

In the Collector Ring CR, only one type of RF system is used – the CR Debuncher. It consists of five MA-loaded cavities whose parameters are shown in Table 4. The CR DB system is designed in such a way that it supports two different modes of operation. On the one hand, it is used in pulsed mode like a bunch compressor system in order to reduce the momentum spread of the beam by means of an inverse bunch rotation in phase space. On the other hand, it offers a CW mode in order to create normal RF buckets.

Table 4: CR Debuncher RF System (parameters for one cavity)

Parameter	Value for antiproton operation	Value for rare isotope operation
Frequency range (MHz)	1.1 – 1.5	1.1 – 1.25
Max. RF voltage (kV) (CW operation)	1.35	2
Max. RF voltage (kV) (pulsed operation)	21	40
Duty cycle	$2.6 \cdot 10^{-4}$	$6 \cdot 10^{-4}$
RF power amplifier	Tetrode TH555, push-pull	
Installation length (m)	1.125	

Figure 4: Final design draft of CR DB cavity (image: RI Research Instruments GmbH).

For this system, the tendering process has successfully been completed. RI Research Instruments GmbH will deliver the cavity and the power amplifier (subcontracted to Ampegon PPT GmbH) and is responsible for the overall system integration. A sketch of the cavity is shown in Fig. 4. Both the CDR and the FDR (Final Design Report) are accepted, and manufacturing is in progress. The selected Vitrovac 6030F ring cores are available and qualified. Most parts of the cavity are already manufactured and mounted. An FDR for the power supply unit which will be delivered by OCEM Energy Technology is available. Delivery and commissioning of the FoS of the overall system will take place in 2015.

COMMON RF SYSTEM INFRASTRUCTURE

A standardized low-level RF (LLRF) system [5] for the above-mentioned RF cavities allows synchronization at different beam harmonics and sophisticated longitudinal beam operations.

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