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RF POWER TEST OF THE REBUNCHER FOR SARAF-LINAC

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Abstract

Three normal conducting rebunchers will be installed at the Medium Energy Beam Transport (MEBT) of the SARAF-LINAC phase II [1]. The MEBT line is designed to follow a 1.3 MeV/u RFQ, is about 5 m long, and contains three 176 MHz rebunchers providing a field integral of 105 kV. CEA is in charge of the design and fabrication of the Cu plated stainless steel, 3-gap rebuncher. The high power tests and RF conditioning have been successfully performed at the CEA Saclay on the first cavity. A solid state power amplifier, which has been developed by SNRC and has been used for the RF tests. The cavity has shown a good performance according to calculations, regarding the dissipated power, peak temperatures and coupling factor. RF conditioning was started with a duty cycle of 1% and increased gradually until continuous wave (CW), which is the nominal working mode in SARAF-LINAC.

INTRODUCTION

Three rebuncher cavities will be installed at the Medium Energy Beam Transport (MEBT) of the SARAF-LINAC accelerator shown in Fig. 1. The basic structure of the rebuncher consists of a cylinder with one side movable tuner and 2 stems which form three acceleration gaps as shown in Fig. 2. Taking into account the main requirement parameters given by Table 1, the CST Micowave Studio software was used to obtain the mechanical dimensions and the radio frequency parameters of the rebuncher cavity.

Table 1: Rebuncher Specification and Measured Value

Item	Specification	Measured	Unit
Frequency	176	176.000	MHz
Quality factor	>6600	7000	
Flange to flange distance	<280	244	mm
Tuning range	>200	>600	kHz
Max. cavity temperature	100	35	°C

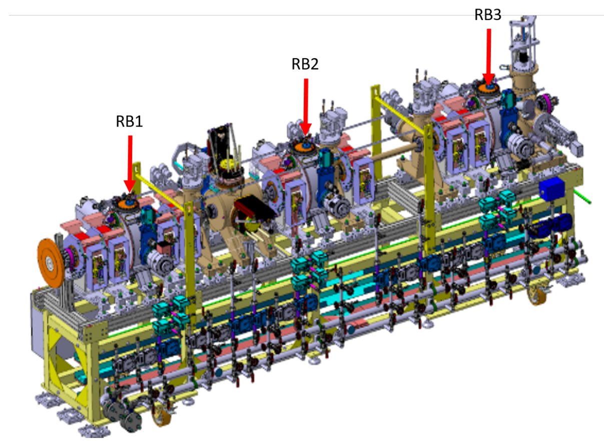

Figure 1: 3D model of the full equipped MEBT line.

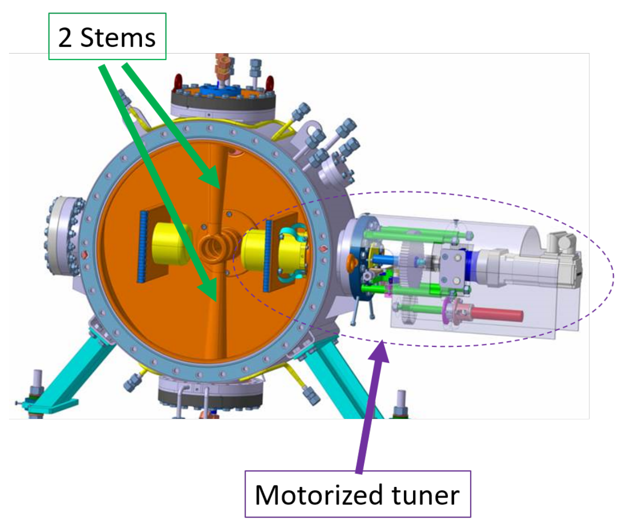

Figure 2: 3-gap rebuncher cavity components.

RF AND MECHANICAL DESIGN

Thanks to the experience accumulated with the SPIRAL2 rebuncher and further optimization study, CEA/Ganil has designed a Cu plated stainless steel 3-gap rebuncher [2] with the resonance frequency (f_0) of 176 MHz. Figure 2 shows the 3D model of the rebuncher with inside view. The RF structure of the rebuncher is composed of three gaps with two quater wave stems in opposition. It is designed for a field integral of 120 kV (required 105 kV). It is equipped on one side with a movable tuner and with an inductive coupler.

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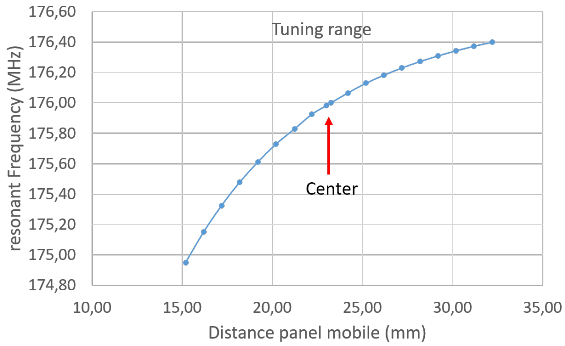

Figure 3: Frequency variation with the panel position.

The first rebuncher has been manufactured by SDMS company [3] and tested at CEA Saclay.

INITIAL RF MEASUREMENT

The initial RF measurement was performed during the factory manufacturing procedure in order to validate the design.

Quality Factor

Using vector Network Analyzer (VNA), the measured external quality factor (Q_L) of the rebuncher is 3500, so that the quality factor (Q_0) is about 7000 which meets well the requirement (6600). Thus, the required power (P) can be calculated with

$$Q_0 = \frac{\omega_0 U}{P}\,. \tag{1}$$

In order to obtain the designed voltage of 120 kV, the required power is 4 kW where the stored energy is $U = 26$ mJ and $\omega_0 = 2\pi f_0$.

Frequency Tuning

The resonance frequency of the cavity is reached with the movable panel. The frequency tuning range is about 600 kHz as shown in Fig. 3. In addition, the resonant frequency of the rebuncher decreases by about 220 kHz when it is put under vacuum. This frequency drift caused by cavity deformation has been identified in the mechanical simulation of the cavity using CST. We found that the resonant frequency of the cavity decreases by 230 kHz under vacuum condition. This simulated frequency variation is in very good agreement with the measured value.

RF POWER TEST

RF Power Amplifier

A solid state amplifier was developed by SNRC [4] as shown in Fig. 4. This RF amplifier is installed at the outside of the rebuncher RF test bunker. The amplifier was first tested by connecting the amplifier output to a water cooled 50 Ω load, and driven by a RF generator, it was tested up to maximum output power of 12kW. We found that the amplifier reaches the saturation state around 70 dBm (10 kW) as shown in Fig. 5.

Figure 4: Photo of the RF amplifier.

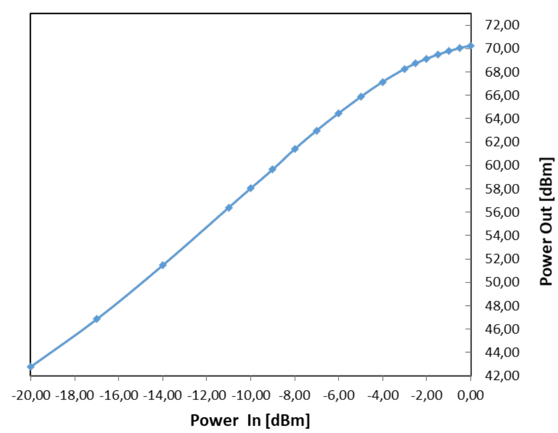

Figure 5: 10 kW RF power amplifier test result.

Figure 6 shows the rebuncher RF power test bench inside the bunker with the radiation shielding. A 1'5/8 rigid coaxial line was used to conduct the RF power from RF power amplifier to the rebuncher.

Acquisitions and Control System

The supervision software to control the test bench is implemented with EPICS 3.15 [5], using the IEE framework [6] for deployment. A single EPICS IOC controls the whole bench, managing acquisition, configuration and automatic conditioning. This IOC runs on a IOxOS IFC1210 VME card, and performs the high speed acquisitions (RF measurements and PUe) through an IOxOS ADC3111 mezzanine card (8 channel ADC 16-bit 250 Mps). It performs slower

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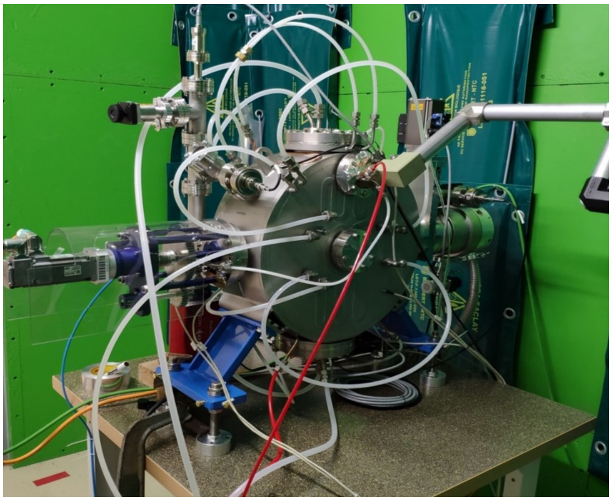

Figure 6: Fully equipped rebuncher on the RF test bench.

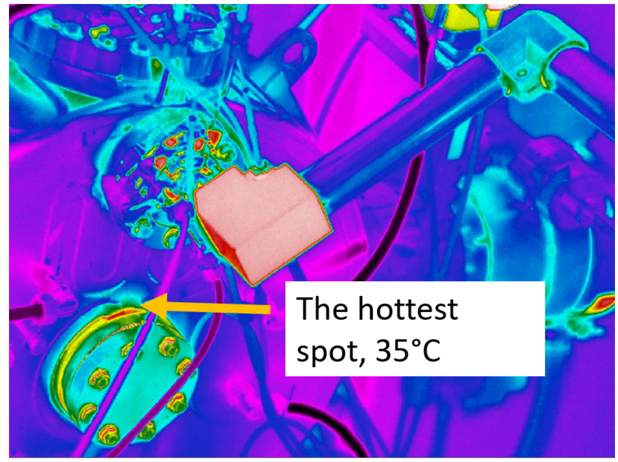

Figure 7: Infrared image of the Rebuncher at 4.3 kW power.

acquisitions and controls (analogue or binary) through remote I/O Beckhoff modules using Modbus protocol with an EK9000 coupler. The RF signal entering the test bench is controlled from the EPICS IOC through Modbus using a R&S®SMC100A Signal Generator. A Siemens 1500 PLC and a S110 speed variator are used to regulate the tuner motor position based on phase difference. The PLC and the EPICS IOC communicate using Modbus (to send commands to the PLC) and S7PLC (to send status and measurements to the IOC) protocols. Experiments measurements and controls are archived continuously using EPICS Archiver Appliance [7].

RF Conditioning Strategy

Using this control and acquisition system, the RF condition was perform with the following strategy:

- Start at low duty factor of 1%.
- Raise the input power from above the multipacting voltage to the nominal effective voltage corresponding to 4.3 kW power (power margin of 300W).
- Increase the duty factor progressively until 100% (CW).
- Repeat the above process for the input power below the multipacting voltage.
- Finally, raise the duty factor from 1% to 40% for 9 kW.

There are four temperature probes (PT100) located at different positions on the rebuncher body. Two of them are placed on the flange of the stems (one on top, another on the bottom) to measure the temperature difference of the stem. Because the cooling circuit is connected in series for the two stems, a 2 °C difference was observed during the test.

Figure 7 shows an infrared photograph of the rebuncher. The hottest spot is about 35°C and its location is the same as in the thermal simulations [2] (on the flange of the beam port).

CONCLUSION

High power tests on the first rebuncher for SARAF MEBT have been successfully performed at CEA Saclay. The results agree very well with the design requirements and the rebuncher showed stable and reliable RF performance in CW and pulsed mode. The fabrication of the second and third rebunchers is ongoing, based on the same design, and their copper coating will be done within a few months.

ACKNOWLEDGEMENTS

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