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The Optimization Design and Testing of SFC Buncher

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1. Introduction

The Heavy Ion Research Facility in Lanzhou (HIRFL) is the largest heavy ion research facility in China, which consists of ECR ion source, sector focused cyclotron (SFC), separated sector cyclotron (SSC), cooling storage ring ring (CSR), radioactive beam line and experimental terminal. The injector SFC cyclotron is a 1.7m sector-focused cyclotron with the K value of 69, which adopts external ECR ion source and axial injection system. A linear buncher B02 was installed into the vertical beam line section underneath the cyclotron center area, about 2.3 meters before the inflector. On the one hand, the increased faults of B02 due to aging components have affected the stable operation of HIRFL. On the other hand, the space charge effect of the increasing beam current from ECR requires higher bunching voltage, the cascade mode of SFC and SSC requires a half-frequency bunching mode with double effective voltage. So a new Sawtooth buncher was developed.

2. The new sawtooth buncher

On the basis of the physical requirements, the relevant technical parameters of the new sawtooth buncher has been given, shown in Table.1.

Tab.1 The basic parameters of the buncher

Parameters	Value
Frequency	5.5-16MHz
Voltage	1270 V(max)
Frequency*	2.75-8MHz
Voltage*	2540V(max)
Phase Stability	$\leq\pm 0.5^{o}$
Amplitude Stability	$\leq 1\times 10^{-3}$
Effective duty	≥68%

2.1 The design choice

Several considerations led us to develop the new buncher with three harmonics across a single accelerating gap : (1) there is a severe limitation in the space available along our beam line, (2) the wide frequency band and high voltage,(3) the convenience of maintenance. The system scheme is shown in Fig.1.

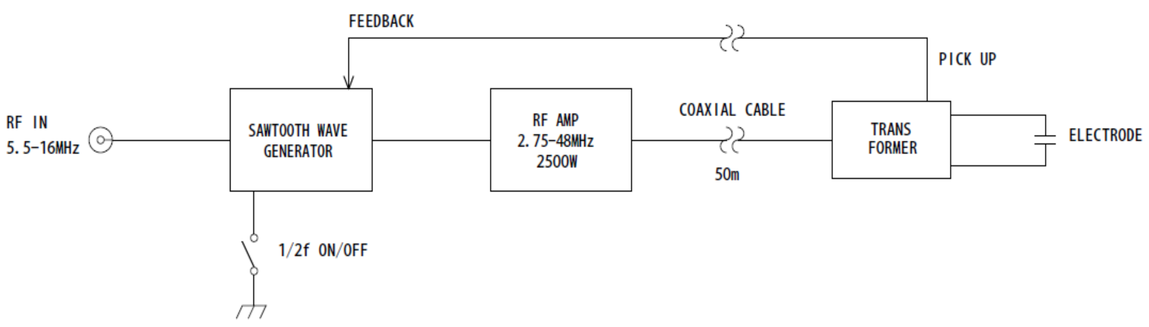

Fig.1 The cavity structure and structural parameters

2.2 Sawtooth wave generator

The sawtooth wave generator is designed to generate sawtooth waves by synthesizing fundamental waves,2nd harmonics, and 3rd harmonics whose amplitude and phase are controlled. As shown in Fig.3, in order to optimize the waveform generation both the amplitude and phase of the frequency are precisely adjustable and controlled with a feedback loop.

$$V(t) = V_0[sin(\omega t) - 1/3sin(2\omega t) + 1/9sin(3\omega t)]$$

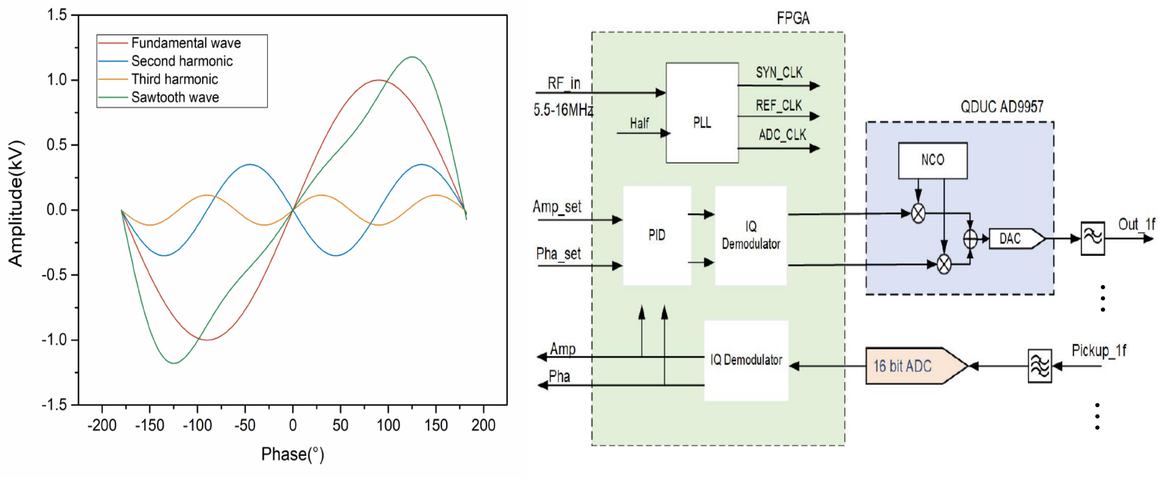

Fig.2 Schematic diagram of Sawtooth wave generation

2.3 Electrode and impedance matching unit

Figure 2 shows a diagram of the buncher electrode. A mesh type electrode was adopted to obtain a uniform electric with maximum 10% of the beam loss. The aperture and gap of the electrodes are 60 mm and 6 mm, respectively. The buncher includes a matching transformer (1:9) and a 450 Ω resister connected to the electrode..

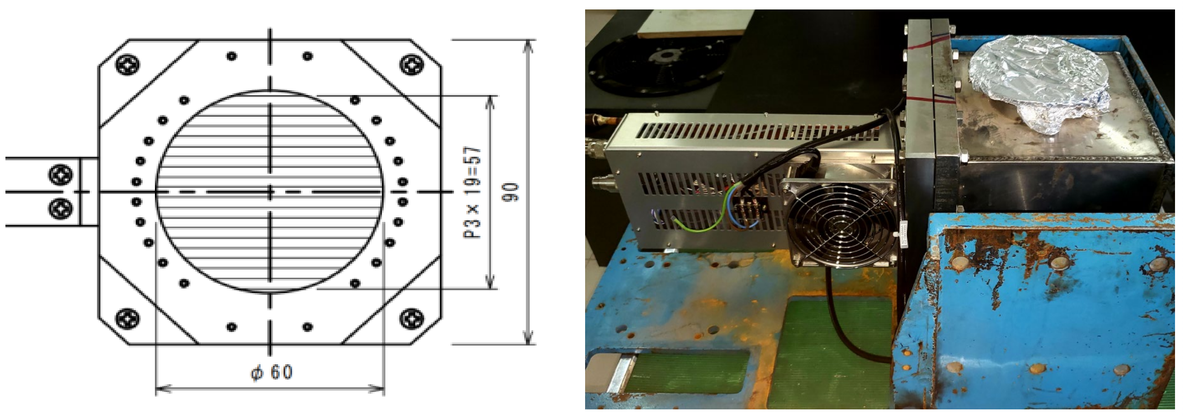

Fig.3 The electrode and impedance transformer

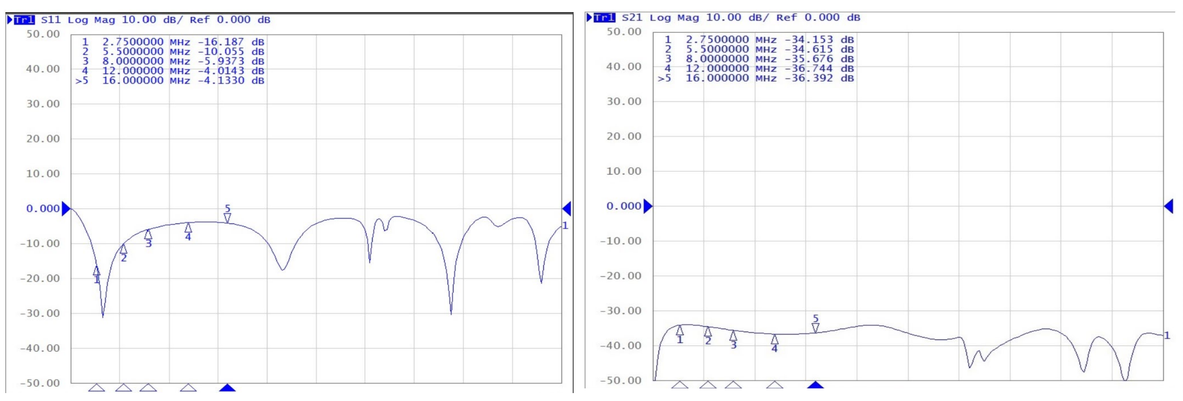

Fig.4 S11 and S21 parameters test

2.4 RF wideband amplifier

The wideband high frequency amplifier that amplifies the sawtooth wave that combines the fundamental wave, 2nd harmonic, and 3rd harmonic. It consists of one power supply unit and two amplification units. The maximum input is 4dBm, the output power is 2500W for the fundamental wave, 250W for the second harmonic and 25W for the third harmonic, and -20dB for the harmonic suppression.

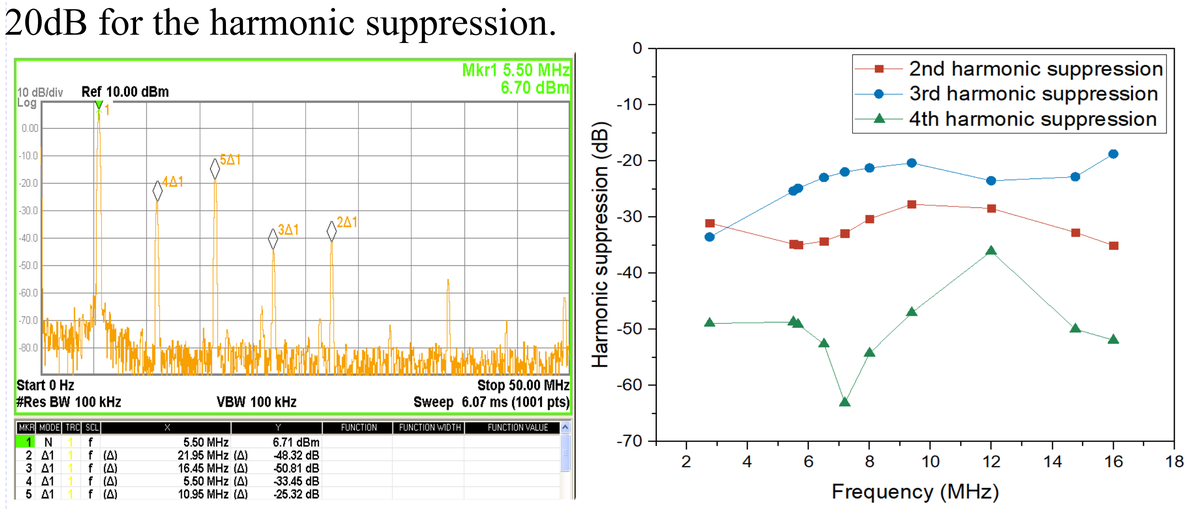

Fig.5 Harmonic suppression test

3. Performance and beam test

The new buncher has been installed online since September 2022. Several beam experiments have been carried out. The system has turned out to be reliable in operation and very useful in increasing the intensity level of the beam. In Fig.6 we have collected preliminary results for some heavy ion beams. As seen the gains in the beam intensity ranges from 4.5 up to 6.7.

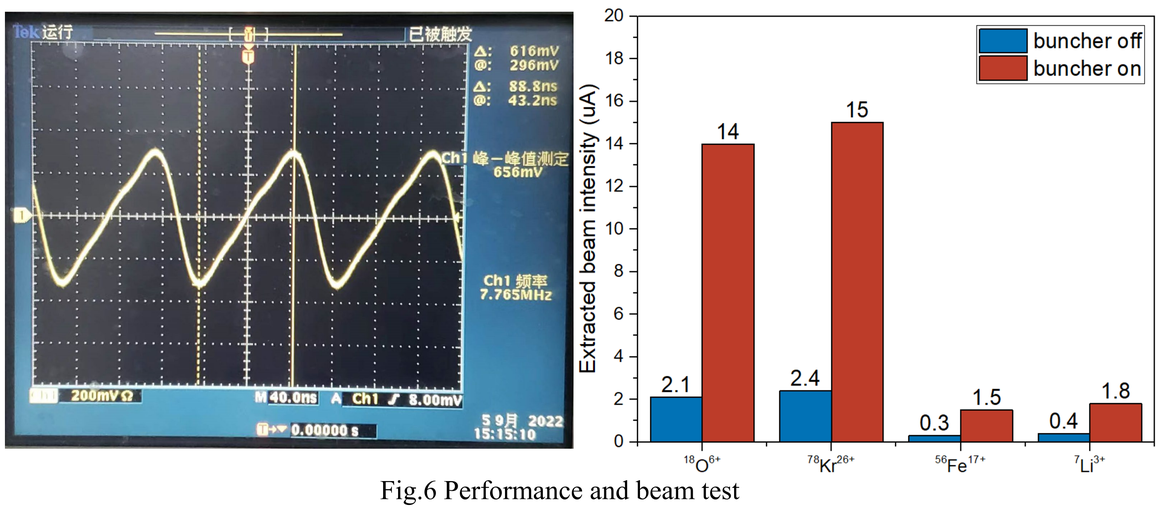

Fig.6 Performance and beam test

Next step, the detailed beam tests will be carried out, especially the half frequency mode which designed to improve SSC beam intensity.

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