The 9th Symposium on Accelerator Science and Technology, Tsukuba, Japan 1993

Development of a Second-Harmonic Buncher for the RILAC

S. Kohara, A. Goto, Y. Miyazawa, T. Chiba, M. Hemmi,
Y. Chiba, E. Ikezawa, M. Kase, and Y.Yano
The Institute of Physical and Chemical Research (RIKEN)
Wako-shi, Saitama 351-01, Japan

Abstract: A second-harmonic buncher has been constructed and installed on the injection beam line of the RIKEN variable-frequency heavy-ion linac (RILAC) to increase beam intensity. It has a good impedance matching to power feed line without adjusting device in the required wide frequency range. Beam intensity was increased by 50 % with both the fundamental-frequency and the second-harmonic bunchers. Its structure, rf characteristics and beam test are described.

Introduction

The RIKEN Accelerator Research Facility (RARF) consists of the RIKEN Ring Cyclotron (RRC) and two injectors of the RRC; one is the AVF cyclotron and the other the RILAC.[1] The present plan is aimed at increasing beam intensity of the RILAC by adding a second-harmonic buncher to the existing buncher. The operational frequency range of the second-harmonic buncher is from 34 to 90 MHz and the total peak voltage required 3 kV at the maximum. The specifications and the design of the second-harmonic buncher were presented in a previous paper.[2] However, we modified the design of the buncher reported previously by taking into account the following problems:[3]

1) Moderating an increase of rf loss in the low frequency region.
2) Keeping a good impedance matching to power feed line (50 Ω) with a fixed coupling and non external compensation over the frequency range.
3) Reducing as much as possible the parts placed in vacuum for easy fabrication.

Buncher structure

A cross sectional view of the new buncher is shown in Fig. 1. The resonator is of a coaxial quater-wave-length type, which has two open ends oscillating in phase and at nearly equal voltage; one end is a drift tube and the other a capacitive voltage divider, through which rf power is fed. The ratio of the drift-tube voltage to the feed-terminal voltage is kept nearly constant, i.e. 30 over the frequency range. The resonant frequency is varied by using both a movable shorting plate and a variable vacuum capacitor instead of using the latter only in the previous design; this alternation moderates the frequency dependence of rf loss. Driving range of the movable shorting plate is 63 cm. Capacitance range of the variable vacuum capacitor is from 10 to 60 pF. The drift tube has two gaps at both ends and their combination is operated in 3π-mode. The separation of the gaps is 82 mm. The drift tube and its opposite electrodes, which are only components in vacuum, are sealed off with a vacuum feed-through of ceramics insulator. A photograph of the second-harmonic buncher installed on the beam line is shown in Fig. 2 together with the fundamental frequency buncher.

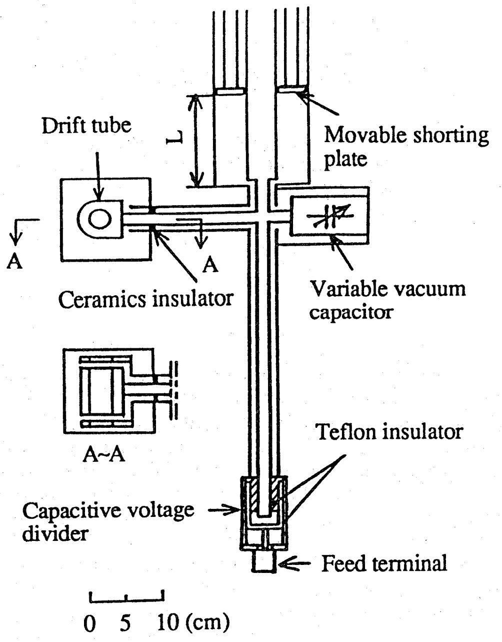

Fig. 1. Cross sectional view of the second-harmonic buncher.

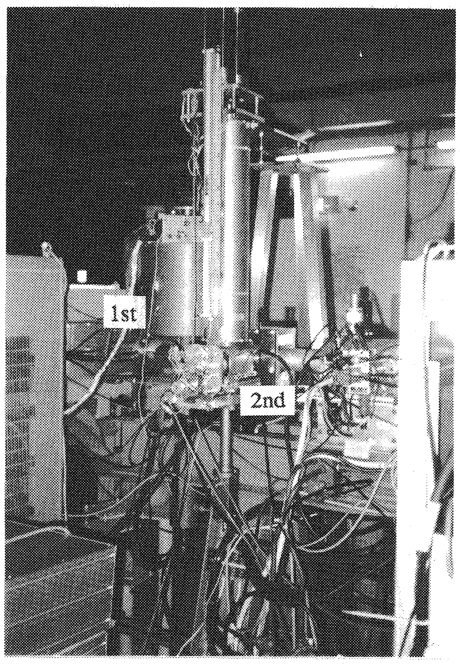

Fig. 2. Photograph of the two bunchers on the injection beam line. 1st : the fundamental-frequency buncher, 2nd : the second-harmonic buncher.

Radio frequency characteristics

Position of the movable shorting plate and capacitance of the variable capacitor are the two parameters determining a resonant frequency. Optimum combinations of these parameters, which realize the best impedance matching, are determined from measurements (as shown in Fig. 5).

The frequencies of the fundamental and higher modes measured with the nearly optimum parameter set are shown in Fig. 3 as a function of position of the movable shorting plate. The resonator has a parasitic resonance in the vicinity of 150 MHz for every position of the movable shorting plate. This is a half-wave-length mode standing on between the drift tube and the other open end terminal and having a node near the position of the capacitor. The measured Q-values are shown in Fig. 4. They are from 1000 to 1600. Fig. 5-A shows input impedances at the feed point measured with the optimum parameter combinations shown in Fig. 5-B. The input voltage standing wave ratio (VSWR) increases to 1.25 at 90 MHz, but gives practically no problem.

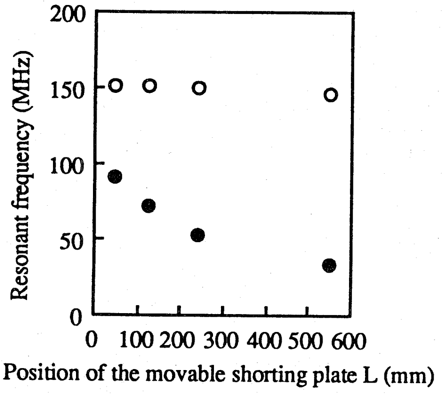

Fig. 3. Measured resonant frequencies as a function of position of the movable shorting plate for fundamental (●) and higher (o) modes with nearly optimum parameter set.

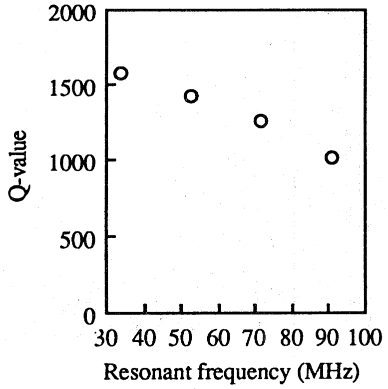

Fig. 4. Measured Q-values as a function of resonant frequency with nearly optimum parameter set.

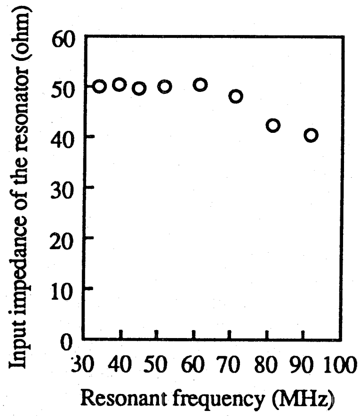

Fig. 5-A. Measured input impedances at the feed point as a function of resonant frequency with optimum parameter set in Fig. 5-B. The imaginary parts of the impedances are zero.

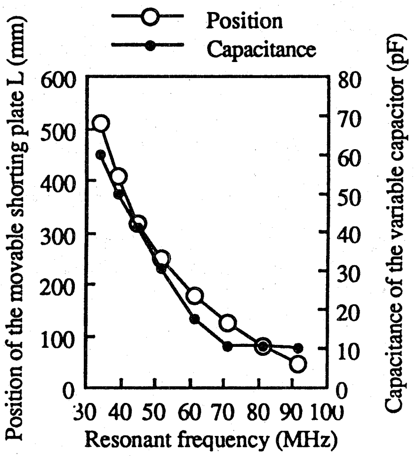

Fig. 5-B. Optimum combination of positions L of the movable shorting plate and capacitances of the variable capacitor.

Power test

An amplifier system consists of a frequency doubler, low level circuits and a solid-state wide-band amplifier of 100 W. The detail of the amplifier system was reported elsewhere.[2]

The drift-tube voltage was measured by a calibrated capacitive voltage pickup. The results of the power test under atmospheric pressure are shown in Fig. 6. The required peak drift-tube voltage of 1.5 kV (3 kV/2 gaps) was obtained in the whole frequency range. Reflected power from the resonator to the amplifier was less than 1.2 W. Stability of the drift-tube voltage was better than ± 1×10^{-3} and stability of the phase ± 0.5 °.

Amplitudes of the higher mode were observed at high power levels. They are about 3 % of the fundamental ones at the worst case typically shown in Fig. 7 and cause negligible effect on performance of the buncher.

Multipactoring phenomenon occurred in the power test under vacuum, but it was easily overcome by a pulse operation.

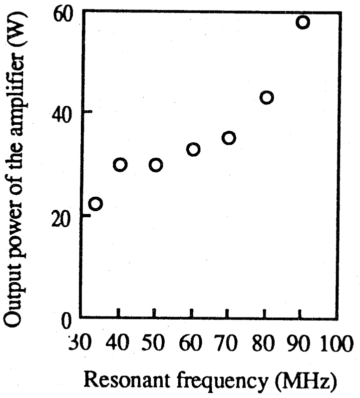

Fig. 6. Measured output powers of the amplifier for the required peak drift-tube voltage of 1.5 kV.

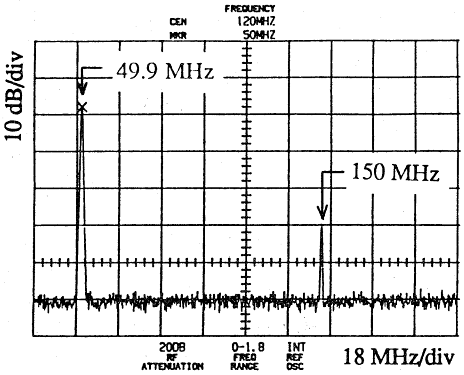

Fig. 7. Example of higher mode component in the drift-tube voltage. The output power of the amplifier is 45 W and the resonant frequency 49.9 MHz.

Beam test

The whole system was installed on the injection beam line of the RILAC in March 1993 and a beam test with Ar^{6+} ion was carried out. Results of the beam test are listed in Table 1. The beam intensity at the exit of the RILAC was increased from 1.7 to 2.5 μA.

References

[1] Y. Yano, Proc. of the 8th Symposium on Acc. Science and Technology, RIKEN, p.10, (1991).
[2] S. Kohara, M. Kase, and A. Goto, Proc. of the 8th Symposium on Acc. Science and Technology, RIKEN, p.133, (1991).
[3] S. Kohara et al., RIKEN Accel. Progr. Rep., 26, p.142, (1992).

Table 1

Results of the beam test.

RILAC	Cokcroft	Fundamental buncher		Second-harmonic buncher		Beam intensity
Freq. (MHz)	Voltage (kV)	Freq. (MHz)	Voltage (kV)	Freq. (MHz)	Voltage (kV)	(μA)
28	283	28	1.3	no use	no use	1.7
28	283	28	2.0	56	1.0	2.5