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# COLD TEST OF A 25.5 MHz DOUBLE-COAXIAL λ/4 RESONATOR

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## Abstract

A 25.5 MHz λ/4 coaxial line resonator has been constructed. The resonator has a double-coaxial structure and the total length is as short as 1.3 m. Drift tubes mounted at the open end of the central conductor compose six acceleration gaps. This resonator is to be used as a rebuncher in a linac complex for the acceleration of unstable nuclei. The cold test on the completed resonator has been made and the result is consistent with the half-scale model tests.

## 1. Introduction

A linac complex for the acceleration of the unstable nuclei produced by cyclotron beam bombardment is under construction at Institute for Nuclear Study, University of Tokyo [1]. The ions from ISOL with charge-to-mass ratio 1/30 at minimum will be accelerated first by 25.5 MHz RFQ linac of split-coaxial type [2] up to 170 keV/u and, after charge stripping, will be further accelerated by 51 MHz interdigital-H linac [3] up to 800 keV/u. The reason of the doubled operation frequency for the interdigital-H linac is to make the tank size small and to obtain higher shunt impedance. This configuration, however, requires a rebuncher between two linacs to adjust the longitudinal beam-emittance to be efficiently accelerated by the rear linac [4]. The rebuncher works also to compensate the energy loss at the charge stripper just behind the RFQ linac, about 7 keV/u. Since a linearly varying electric-field is desirable for the emittance adjustment, the operation frequency of the rebuncher should be 25.5 MHz rather than 51 MHz. The necessary peak voltage at the rebuncher is about 200 kV [4].

The rebuncher with these specifications may be prepared based upon the λ/4 transmission line resonator with a few acceleration gaps. The natural length of the λ/4 resonator for the frequency of 25.5 MHz, however, is very long, 2.94 m. To make the tank size compact, we can employ the so-called spiral resonator, even in which the length of the inner conductor stays to be the same, and we can not expect the mechanical stability of the drift tube to be installed at the open end of the conductor. Thus we have developed a double-coaxial resonator, which is a folded coaxial line, and in which the outer conductor of the inner coaxial line is concurrently the inner conductor of the outer coaxial line. Thus the length is, in principle, almost the half of the natural line length. Furthermore it is known that the resonant line length of the transmission line which is composed of two parts having different characteristic impedances becomes shorter than the one for uniform transmission line [5-6]. The capacitance accompanying the drift tubes also contributes to shorten the resonant line length.

By using a half-scale model, we have determined the detailed design dimensions of the resonator [5], and have constructed a real resonator. The length from the bottom of the resonator to the center of the drift tube is about 1.04 m, which is short enough to install the resonator between the floor and the beam level.

The outline of the completed rebuncher is described in section 2 and the result of the cold tests is given in section 3.

## 2. Construction of the λ/4 Resonator

In Fig.1 is shown the cross section of the 25.5 MHz double-coaxial λ/4 resonator constructed as a rebuncher. The dimensions of the resonator and the drift tube parameters are given in Tables 1 and 2, respectively. Due to the floating capacitance around the drift tubes, about 37 pF, the resonant transmission line length is shortened by 30%. Further reduction of the length is realized by increasing the difference in the impedances between the inner and the outer coaxial lines. Since the diameter of the outer coaxial line is limited to the extent of the six-cell drift tube length, we have to shorten the distance between the intermediate and the central conductor. To lighten possible multipactoring, the central conductor is a square pillar while the intermediate conductor is a cylinder. Thus the impedance of the outer coaxial line is 1.8 times as large as that of the inner conductor, which brings 19% reduction of the resonant transmission line length. These effects in addition to the folding of the transmission line enabled us to construct a rebuncher with a limited length.

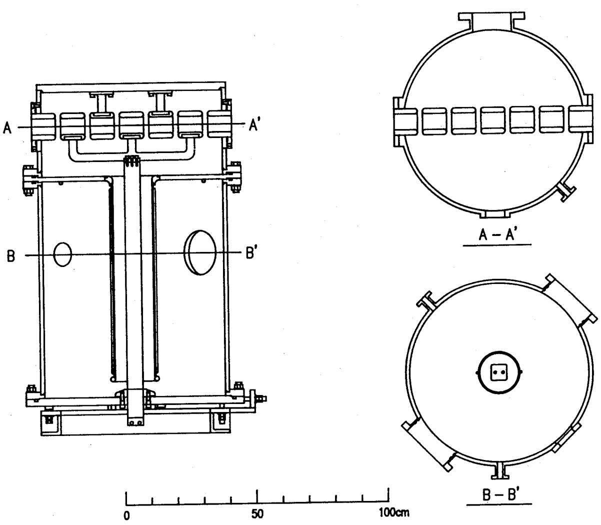


Fig.1 Cross section of the 25.5 MHz rebuncher.

The tank is composed of an upper lid, an outer conductor cylinder and a bottom flange. The intermediate conductor is supported between the cylinder and the lid. They are assembled by use of sealing gaskets and rf contactors. Drift tubes of earth potential are mounted inside the upper lid, on which are also furnished an evacuating port, a capacitive tuner, a vacuum gauge port and a viewing port in addition to entrance and exit beam

Table 1
The dimensions of the 25.5 MHz rebuncher

| | |
|---|---|
| Central Conductor | 60x60x905 mm |
| Inner Diameter of the Intermediate Conductor | 150 mm |
| Thickness of the Intermediate Conductor | 5 mm |
| Inner Diameter of the Outer Conductor | 690 mm |
| Characteristic Impedance of the Inner Coaxial Line | 48 Ohm |
| Characteristic Impedance of the Outer Coaxial Line | 88 Ohm |
| Length of the Double-coaxial Structure | 850 mm |
| Total Inside Length of the tank | 1170 mm |
| Height of the Basement | 108 mm |
| Distance from the Floor the Drift Tube Center | 1175 mm |

Table 2
The drift tube parameters of the rebuncher

| | |
|---|---|
| Number of Cells | 6 |
| Unit Cell Length | 112.3 mm |
| Gap Distance | 20 mm |
| Inner Diameter | 60 mm |
| Outer Diameter | 100 mm |
| Drift Tube Edge | 10 R |
| Fabrication and Setting Accuracy | 0.1 mm |
| Transit Time Factor | 0.84 |

ports. The outer conductor cylinder is equipped with an rf coupler, an rf monitor, a fixed and an adjustable reactive-tuners and vacuum gauge port. Since the evacuation is made only from upper part of the tank, many holes are drilled in the disk supporting the intermediate conductor and separating the tank volume.

Three drift tubes mounted at the open end of the central conductor together with the ones attached to the upper lid compose six acceleration gaps. This configuration has following significance: (1)Moderate capacitance is introduced to shorten the resonant transmission line length, (2)Necessary voltage of 200 kV in total is shared to six gaps and the voltage required at the open end of the central conductor is only 33 kV, (3)60 mm bore of the drift tube allows for the beam to satisfy the beam optics requirement without focusing element inside drift tubes. Measurement on the half-scale model proves that the electric field distribution in each gap is almost equal in spite of rather asymmetric structure of the drift tube support.

Measurement on the model resonator indicates that the necessary rf power to generate 33 kV at the drift tube will be about 1 kW. The power loss distribution in the resonator has been studied by use of the computer code SUPERFISH. The result of the calculation shows that the power loss is concentrated on the central and the intermediate conductors, especially at their lower parts. Thus one cooling water channel is equipped inside the central conductor pillar. Since the power loss at the drift tubes and their support is quite small, the water channel runs only in the pillar. Another cooling water channel is wound on the intermediate conductor getting in and out through the supporting disk edge with a thickness of 22 mm. The third water channel trails on the tank surface whose purpose is to keep the temperature of the tank constant.

The capacitive tuner and two reactive tuners, fixed and adjustable, will work as follows: The reactive tuners are both cylinder blocks of 188 mm in diameters. Insertion of these tuners into the lower tank reduces the tank volume and will increase the resonant frequency. The capacitive tuner is also a cylinder block having smaller diameter of 56.8 mm. Insertion of this tuner towards a drift tube with high potential increases the capacitance of the drift tube and will decrease the resonant frequency. When possible resonant frequency deviation of completed resonator does not exceed the capability of the adjustable reactive-tune, we need no other tuners. After the cold test on the completed resonator, the insertion length for any of the fixed-type tuner will be specified if necessary.

## 3. Cold Tests of the Resonator

### A. Resonant Frequency

We expected for the completed resonator to have the resonant frequency lower than 25.5 MHz by some tens kHz, which may be brought to proper frequency only by use of adjustable reactive-tuner. The resonant frequency without any tuner, however, resulted in rather high frequency, 25.52 MHz. This may be partly due to the installation of the cooling water channel inside the tank, which reduces the tank volume and increases the resonant frequency. Thus we have to use the capacitive tuner to bring the resonant frequency into the range covered by the adjustable reactive-tuner, which is shown in Fig. 2. As is seen in the figure, the tunable range is about 100 kHz. The characteristics of the capacitive tuner is shown in Fig. 3. The resonant frequency drastically decreases when the tuner approaches the drift tube closer than 100 mm. We

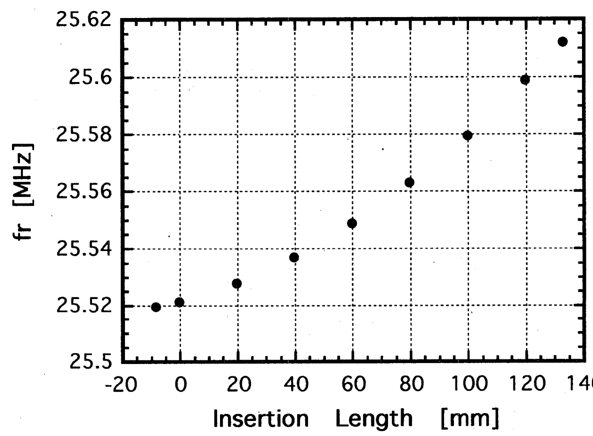


Fig. 2 Characteristics of the adjustable reactive-tuner.

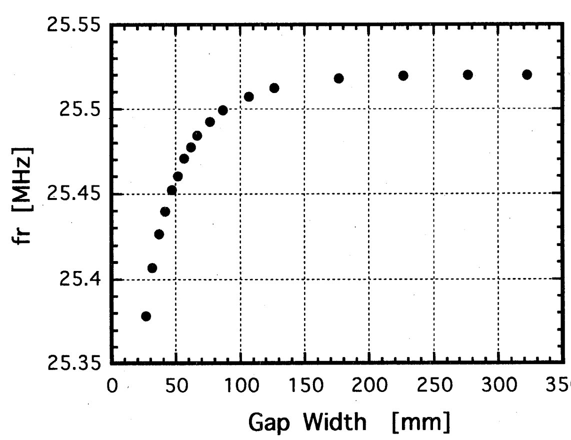


Fig. 3 Characteristics of the capacitive tuner.

decided the distance between the tuner edge and the drift tube to be 50 mm, the resonant frequency corresponding to which comes into the middle of the tunable range by the adjustable reactive-tuner.

B. Q-values

The unloaded Q-value is about 6,000, which is consistent with the value expected from the measurement on the half-scale model made of Brass [5]. We have measured Q-values under the various conditions both for the capacitive and reactive tuners. The result shows there is no significant change in Q-value.

C. Longitudinal Electric-field Distribution

The longitudinal electric-field distribution along the drift tube axis as measured by bead perturbation method is shown in Fig. 4. The bead is made of aluminum, the diameter of which is 10 mm. One can see that the field strength in each gap is almost constant, as expected from the measurement on the model.

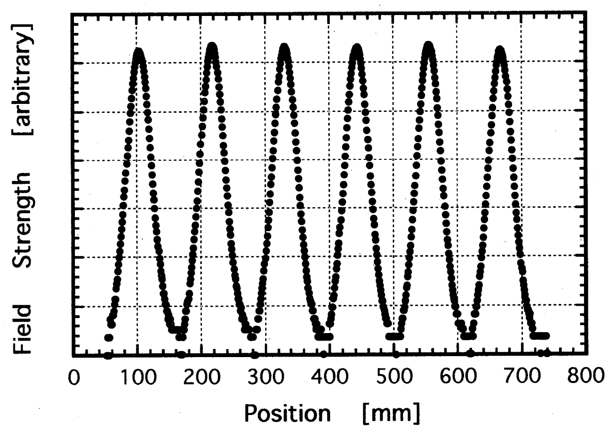


Fig. 4 Longitudinal electric-field distribution.

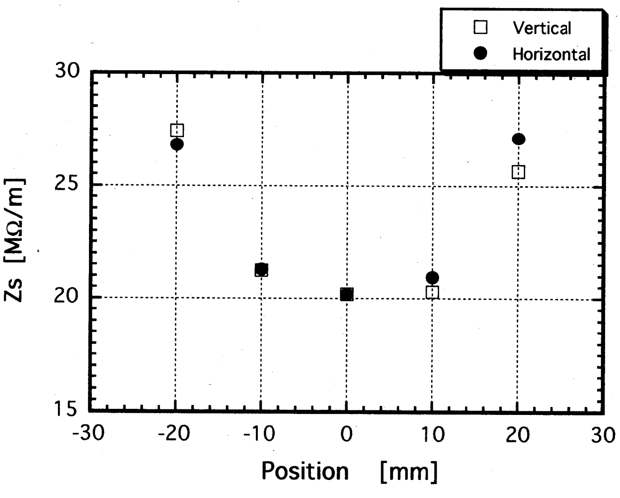


Fig. 5 On- and off-axis shunt-impedances. The horizontal and the vertical positions are measured from the drift tube center to the capacitive tuner, and to the upper direction, respectively.

Shunt impedances on and off the axis are shown in Fig. 5 to show horizontal and vertical position dependence. The shunt impedance on the axis is 20.3 MΩ/m which is close to the value expected from the model measurement. The reason why the shunt impedances become higher at the positions far from the center is that the electric field including its radial component is higher there than on the axis. Our purpose of this series of measurement is to examine possible asymmetry of the field distribution in the drift tube bore. One-sided capacitive tuner may affects the field symmetry along the horizontal direction, and the vertically asymmetric structure of the drift tube support may introduce asymmetry in vertical direction. As can be seen in the figure, there is no asymmetry in the horizontal direction, and we can say that the capacitive tuner gives no effect on the field distribution in the drift tube bore. On the other hand, obvious asymmetry in the vertical direction is seen. The origins of this asymmetry may include the effect of the dip of the bead trajectory due to the gravitation. Further examination will be made by using computer code MAFIA.

## 4. Conclusion

In constructing 25.5 MHz $\lambda/4$ resonator, we have employed a double-coaxial structure, which enabled us to make the total resonator length as short as 1.3 m. The results of the cold tests on the resonator are almost consistent with the measurements on the half-scale model made of brass. Preparation of both capacitive and reactive tuners is quite efficient to adjust the unexpected resonant-frequency shift. Next step will be to excite the resonator with high rf power. Since multipactoring is more or less expected, a pulsive aging system is prepared. Beam acceleration test is scheduled at the end of 1995 fiscal year.

## REFERENCES

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