Super Wide Band Cavity With an All-Pass Network

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A new type of a tuning-free cavity with an all-pass network has been developed for an ion synchrotron. We have improved the prototype tuning-free cavity reported elsewhere[1] into a super wide-band tuning-free cavity. An acceleration voltage of the cavity was found out to be generated in the rf frequency range of 0.1-8 MHz. The cavity was installed at a HIMAC synchrotron ring to make a beam acceleration test. We succeeded to accelerate 2.6 MeV/u C^{6+} up to 35 MeV/u. This cavity works quite well in the rf frequency range of 0.17243-0.61615 MHz. It was found that cavity works in the rf frequency range of 0.17243-5.25458 MHz (up to the present) .

Introduction

A study on the tuning-free cavity used a bridged-T type all-pass network has been carried out and it has been found out that basic concept is clearly appropriate through the test using the prototype tuning-free cavity[1].In other words, we can realize the bridged-T type circuit as a hardware and can experimentally confirm to generate the gap voltage in a wide range of the rf frequency without any tuning. This type of cavity have another merit, that is, the limit of a gap voltage should be higher than that of the normal type of cavity, because most of input electric power is consumed by a terminating resistor. When larger value of the terminating resistor is selected, the gap voltage is larger and, therefore, the acceleration efficiency increases and is almost the same of the normal bias-controlled cavity. In this time, we remodeled the prototype tuning-free cavity, that is, the value of the terminating resistor decreases to 22.2 Ω in order that the band width of the cavity is wider. The gap voltage of this cavity can be generated with a rf frequency range of 1:80, which is very difficult in other types of cavity. Although the remodeled cavity can not generate a very high gap voltage, we can accelerate both low-energy super-heavy ions and low-energy molecular ions by a synchrotron. It may be possible to construct the tuning-free cavity both with a high gap voltage and with a wide rf frequency band because we can choose other sets of parameters.

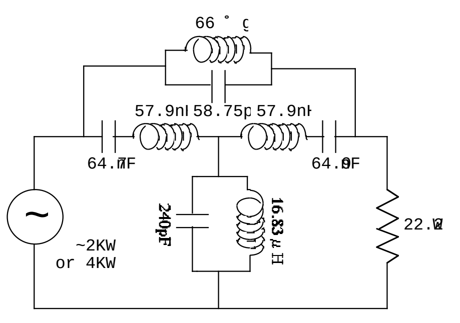

Figure 1: Designed all-pass network

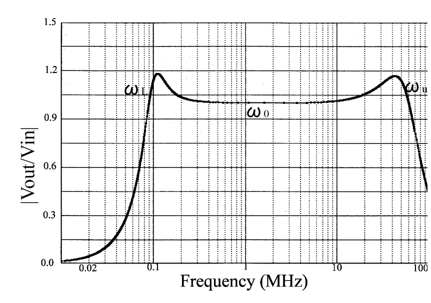

Figure 2: The theoretical range of frequency

We modified two capacitors C_2 (64.7nF), two inductors L_2 (57.9nF), the capacitor C_3 (58.75pF), the inductor C_3 (66 μ F), the register R(22.2 Ω) and the impedance transformer to widen the frequency range of the tuning-free cavity. Fig. 1 shows a schematic drawing of a new all-pass circuit. The parameter sets were selected as the lowest frequency level of the cavity becomes 0.1 MHz. Fig.2 shows the theoretical rang of freqency and Voltag ratio.

2 Experimental Study

The super wide-band tuning-free cavity was installed at a HIMAC synchrotron ring to make a beam acceleration test. The period of the HIMAC operation pattern is fixed to be 3.3 seconds. We selected C^{6+} ions as test particles and operated the synchrotron with harmonic number h=1. An incident energy of C^{6+} was 2.6 MeV/u and the ion was accelerated up to 35 MeV/u after 1.8 seconds acceleration. The ranges of the rf frequency are 0.17243-0.61615 MHz for h=1. Acceleration of the C ions was found to be succeeded. For synchrotron acceleration, the following condition is required:

$$\mathrm{Ve} \times \mathrm{Sin}\,\phi\,\mathrm{s} = 2\,\pi\,\mathrm{R} \times \rho \times \dot{B}\,, \qquad (1)$$

From the limit of the used rf amplifier, the maximum gap voltage Ve is limited to be about 300 V (average value). Fig. 3 show relative beam current of one beam bunch as a function of the time for acceleration. Slight decreases acceleration may be due to the shortage of the accelerator voltage. Clearly, more input power to the cavity is needed.

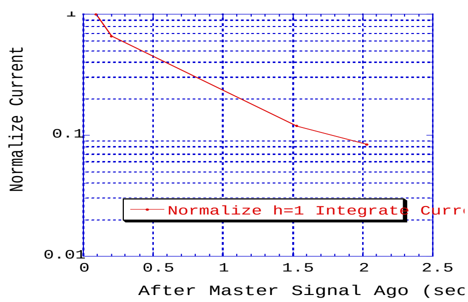

Figure 3: A change of the beam current

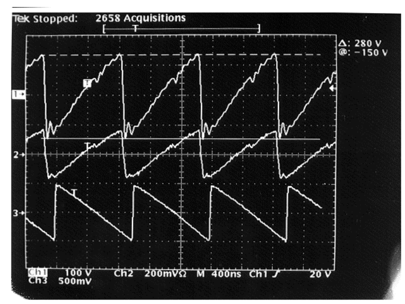

Figure 4: A triangle voltage for cavity gap

The gap voltage of this cavity can be generated with a triangle wave ,which is very difficult in other typeocavity. Fig4. Shows a triangle wave for cavity gap (CH1; 280 Vo-p at 1 MHz).

3 Discussion

In this experiment, it is confirmed that the new super wide-band tuning-free cavity works quite well in the rf frequency range of 0.17243-5.25458 MHz from the beam acceleration test. In other words, we have succeeded to construct the cavity which the frequency ratio of the upper band to the lower one of is more than 30 times. The frequency ratio is considered to be 1:670 theoretically and was measured as, at least,1:80. However, the experimental limitation, that is, the rf input power and the synchrotron operation pattern, made impossible a beam test with higher frequency operation of the cavity.

4 Conclusion

It is our great pleasure to achieve the initial purpose in this modification, that is, to modify the cavity due to the frequency ratio of which is more than 30 times. We would like to thank the HIMAC staffs and operators for their fruitful cooperation. In order to utilize the super wide-range tuning-free cavity, we plan to improve the cavity especially in point of a higher gap voltage which is required to be more than 2 kV.

References

[1] H.Tamura et al., Super Wide Band Cavity With an All-Pass Network, Procs. of the 12th Symposium on Accelerator Science and Technology, Oct. 99, p.248-250.

[2] H.Tamura et al., RCNP Annual Report 1999 p.114.