BEAM COMMISSIONING OF THE J-PARC LINAC MEDIUM-ENERGY BEAM-TRANSPORT AT KEK – II

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Abstract

A Medium-Energy Beam-Transport line (MEBT) of J-PARC was installed in KEK for beam test. An rf deflector, as a chopper, was constructed and test. During the test of the rf deflector, some deviation between the resonant frequency and the operating frequency was found. By designing new coupling loops for the two rf deflectors, the resonant frequency of two deflectors are all changed to 324MHz, while the bandwidth were kept unchanged. The rise time of the RF deflectors is studied by both high power test and beam test. Some measurements with the bending system of MEBT were also done, and the beam energy and related measured results are given.

1 INTRODUCTION

A Medium Energy Beam Transport line (MEBT) of Japan Proton Accelerator Research Complex (J-PARC) was installed in KEK for beam test. The layout of the MEBT is shown in figure 1. As a key component of MEBT, an rf deflector was proposed[1] and designed[2] as a chopper, because of its merits of high deflecting field, compact structure and easy to manufacture. An rf chopper, consists of two RFD (RFD-A and RFD-B), has been successfully developed. Because of the very low loaded Q of the RFD, a coupled RFD system was adopted in operation for decreasing the demanded rf power by half[2]. Some frequency deviation was found after the construction of the RFDs. The difference between resonant frequency and operating frequency is about 2MHz, and this can not be compensated by the tuner. Although the bandwidth of the RFD is very large, the frequency deviation still induces some negative effects: additional reflection and mismatch between two RFDs. The modifications of the RFDs were made for tuning the resonant frequency to the operation frequency of 324 MHz. The measured results indicate the good performance of the modifications. The rise time of the RF deflectors is studied by both high power test and beam test.

Some measurements with the bending system of MEBT were also done, and the beam energy and related measured results are given.

Much more detailed descriptions on the beam study of the chopper cavity are presented in a separated paper in this proceeding [3].

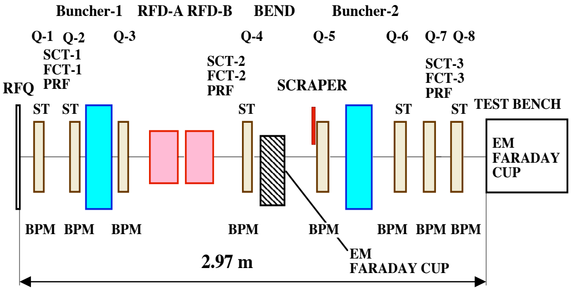

Figure: 1 The layout of the MEBT

2 THE DEVELOPMENT OF THE RF CHOPPER

2.1 Design of the new coupling loops

The RFD cavity consists of two parts: the cavity body and the two end plates with large coupling loops. Tuning the resonant frequency by modifying the coupling loop has two merits: easy to fabrication and take less cost. The difference between resonant frequency and operation frequency is about 2MHz. To tune the resonant frequency to 324 MHz, one idea is to move the large coupling loops about 3 mm towards the electrode. In practice, just about a 3mm gasket is needed between the loop and the end plate, then the resonant frequency is tuned to 324 MHz. But in this case the bandwidth of the RFD cavity is increased to 36 MHz, this means much more input power is needed than design. To tune the resonant frequency to 324 MHz and keep the bandwidth and the other parameters unchanged, a new coupling loop is proposed. The RF simulation code HFSS is used in the design of a new coupling loop.

Figure 2 shows the shape and parameters of the coupling loop. The thickness of the loop is 3mm. In design calculations by HFSS, the resonant frequencies are firstly tuned to the measured values by changing the gap distance, for RFD-A and RFD-B respectively to

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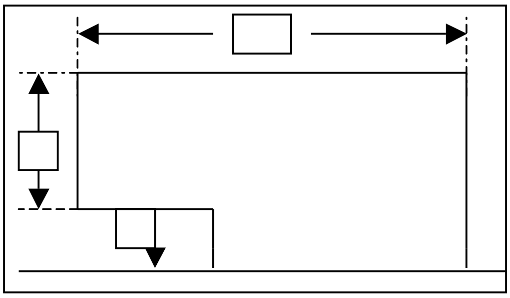


Figure 2: The shape and parameters of coupling loop

compensate the manufacture error of the cavities, then the width *w* and height *h* of the loop of the two RFDs are modified respectively to tune the resonant frequency to operating frequency of 324MHz. The tuner effect with 15mm insertion is included in calculations, and the insertion of 15 mm is set as the default value.

2.2 The measured results with new coupling loops

The above designed loops were fabricated and installed in the RFD cavities. The cold model test and high power test show the good performance of the modification. Table 1 show the designed and measured frequencies of RFD-A and RFD-B with new coupling loops. The measured frequencies have a good agreement with design values, and the resonant frequency was changed to 324MHz for two single RFD cavities.

Table 1 The measured frequency with new coupling loop (for RFD-A)

	Res. Freq.(MHz)				Bandwidth(MHz)	
	Tuner=0mm		Tuner=15mm		RFD-A	RFD-B
	RFD-A	RFD-B	RFD-A	RFD-B		
Old loop	322.30	321.90			30	30
New loop (design value)	323.75	323.75	324.00	324.00	30	30
New loop (Measured)	323.81	323.88	324.00	324.15	30	30

Figure 3 and figure4 indicate the waveforms of the RFD-A in coupled RFD system in high power test. With the new coupling loops in figure 4, the reflection is smaller than that of the old coupling loops, the matching between two cavities are much better in comparison with figure 3.

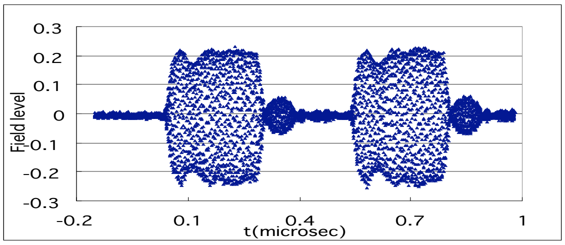


Figure 3: The waveforms of the RFD-A with old loop

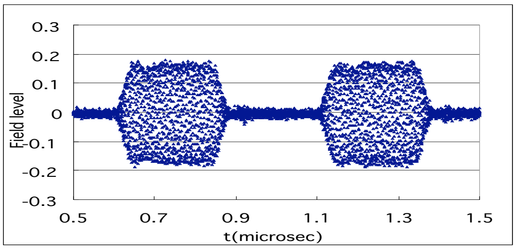


Figure 4: The waveforms of the RFD-A with new loops

2.3 The measurement of the rise time of RFD

Short rise time is an essential requirement for clean chopping. The Figure 5 indicates the measured rise time of the rf pulse, which is obtained from the rf monitor of RFD. The directly measured rise time, the field level from 10% to 90%, is about 27 nsec, or 9 rf periods. This is much longer than _= 10.6nsec which is obtained from the measured loaded Q value. The reason is that the rise time of 27 nsec includes the effects of the rise time of the power amplifier, which is about 15 nsec, 5 rf period.

Another method for measuring the rise time of the RFD is using the BPM signals of beam test. Figure 6 shows the fifth BPM signals under the case of only RFD-B is excited and no scraper. In this case, no deflected beam is stopped, and the signals of the fifth BPM reflect the beam position, which is proportional to the deflecting field during the rise time of the RFD. It shows that the rise time is about 9 rf periods, which is same as that obtained in the high power test.

It should be noticed that the above measured results are for investigating the rise time of an RFD. Because of the large input power and adoption of the coupled RFD system, the rise time of beam is about 10 nesc[3]

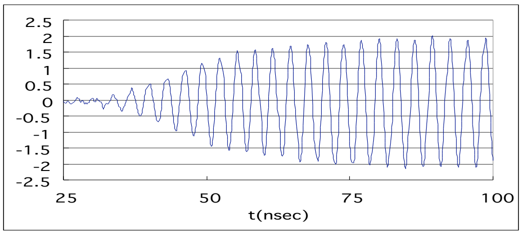


Figure 5: The measured rise time of rf pulse

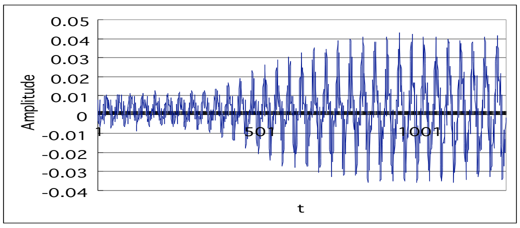


Figure 6: The measured rise time by fifth BPM

3 MEASUREMENTS WITH THE BENDING SYSTEM

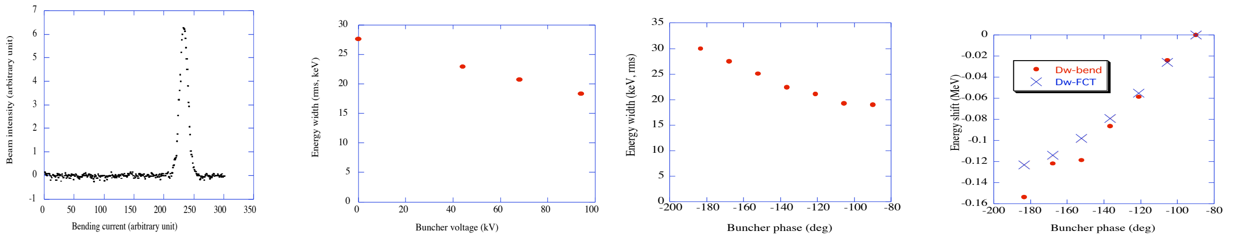
One of the main purposes of the MEBT is to measure the characteristics of a 3-MeV beam: a beam energy, an energy width and transverse emittances. The measured beam properties are utilized for achieving the matching of the MEBT beam to the DTL acceptances, and also utilized as the fundamental parameters of the simulation in the linac. Therefore, a bending magnet system was installed between the second chopper cavity and the beam scraper. Since a maximum beam current is 50 mA, a space-charge effect is very strong in the MEBT. One of the authors showed that the detailed three-dimensional simulation with space-charge effects in a double slit system combined with a bending magnet of 45 degrees gives sufficient information for the beam properties. In the MEBT system, the energy width of the beam can be changed by using the first buncher. This procedure provides a lot of useful information in a non-acromatic bending system. The preliminary experiments by using the bending system and the two-slit emittance monitor were performed. Both measured and calculated results are described.

3.1 Energy measurement

The relative energy and the energy width were measured as a function of the buncher voltage. Figure 7a shows the raw data. Figure 7b shows the measured rms energy width as a function of the buncher voltage. Figure7c indicates the measured rms energy width as a function of the buncher phase. The measured energy shifts due to the bumcher phase are shown in figure 7d, in which the results measured from two different methods are plotted: energy analyzing system with the bending magnet and time-of-flight methods with two phase monitors on the straight beam line.

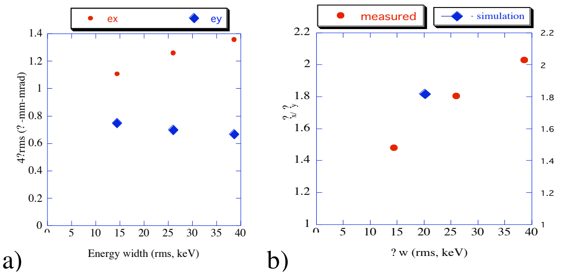
3.2 Transverse emittance measurements

There are large effects due to the momentum spread on the measured transverse emittance in the horizontal phase space after the non-acromatic bending system (dispersion), while there is no such effect on the vertical transverse emittance. Figure 8a shows the measured transverse emittances in the both phase spaces by using the bending beam line as a function of the energy spread, changed by the applied buncher voltage. Figure 8b shows the ratio of the measured horizontal emittance to the vertical one. The calculated result on the equal beam parameters is also plotted. It should be noted that the momentum spread varies rapidly along the beam line from the position of the first buncher to that of the emittance monitor. Thus, careful comparison between the measured data and the results of simulation is required for obtaining the meaningful results.



(a) (b) (c) (d)

Figure 7: Results of energy measurements: I=23mA: a) beam signal,b) rms energy width vs. the buncher voltage, c) rms energy width as a function of the buncher phase, d) average-energy shift vs. buncher phase by both the time-of-flight method and the bending system



a) b)

Figure 8: Measurements of transverse emittances, I=21mA: a)emittances vs. the energy width at the buncher position, b)Ratio of the transverse emittances (horizontal to vertical) as a function of the energy width at the buncher position. The calculated result is also plotted

4 CONCLUSION

The modification of the chopper cavities were done by designing new coupling loops. By adoption of the different size of the coupling loops for first chopper cavity RFD-A and second chopper cavity RFD-B, the resonant frequency of two chopper cavities are all changed to 324MHz, while the bandwidth and the other parameters are almost kept unchanged. The measured results indicate the good performance of the modifications. The rise time of the RF deflectors is measured by both high power test and beam test, and the results have a good agreement with each other. A beam energy, an energy width and transverse emittances are measured at MEBT by bending system.

REFERENCES

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