

LONGITUDINAL BUNCH SHAPE MONITOR USING THE BEAM CHOPPER OF THE J-PARC

F. Naito*, KEK, Tsukuba, Japan

Abstract

We propose the longitudinal bunch shape monitor for the beam from the RFQ of the J-PARC linac. The monitor uses the beam chopper cavity installed in the MEBT line between the RFQ and the DTL of the J-PARC as a kind of the bunch rotator. Consequently the longitudinal bunch shape can be measured along the horizontal direction. If we can measure the energy distribution of the bunch also, the longitudinal emittance of the beam is derived. In the paper, the basic idea of the monitor is being discussed.

INTRODUCTION

The construction of Japan Proton Accelerator Research Complex (J-PARC) has been started in the Tokai campus of the JAERI. The injector linac consists of the radio-frequency quadrupole (RFQ) linac, the drift-tube linac (DTL), the separated DTL (SDTL) and several beam transport lines[1]. The beam from the linac is injected into the rapid cycle synchrotron (RCS) ring. For the beam injection into RCS without beam losses, the beam from the linac has to be chopped before the DTL by a chopper.

The measurement of the beam properties is quite important for the stable beam operation. In particular, the emittance of the beam is one of the most important parameters since the behavior of the beam in the phase space must be compared to the results of the beam dynamics calculation in order to improve the linac system of the J-PARC.

The shape of the 3-MeV beam, emitted from the RFQ, is tuned to be matched to the DTL by the Q-magnets and bunchers in the medium energy beam transport (MEBT) line between the RFQ and the DTL [2].

STRUCTURE OF THE CHOPPER

The chopper cavity is installed in the MEBT. As the chopper deflects the micro bunch in order to chop the beam by rf power, it is an rf deflector (RFD) [3]. The resonant frequency of the chopper cavity is 324 MHz which is the same frequency as that of RFQ and DTL. The chopper consists of two RFD both of which are coupled resonantly[4]. The each micro bunch of the beam is kicked horizontally by the crest of the rf electric field applied to the cavity. The performance of the chopper has been confirmed by using the beam from RFQ [5].

The photograph of the inside of the chopper cavity is shown in figure 1. The principle of the chopper is shown in figure 2. The deflected beam by the chopper is removed by the scraper. Figure 3 shows the layout of the MEBT components which include the chopper and the scraper.

* fujio.naito@kek.jp



Figure 1: Inside of the chopper.

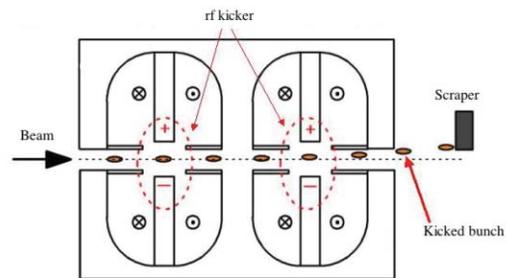


Figure 2: Principle of the chopper.

PRINCIPLE OF THE MONITOR

Measurement of the Longitudinal Bunch Shape

The chopper cavity is a main component of a longitudinal bunch shape monitor we proposed. Because the rf-system of the chopper is very flexible, we can easily use the cavity for another purpose by changing the rf phase. The principle of the bunch shape monitor is following:

1. Shift the rf-phase by $\pm\pi/2$ for the chopper cavity from the normal chopping mode as shown in figure 4. In this case the chopper cavity spreads the longitudinal distribution horizontally. Namely it works as a kind of the bunch rotator. The middle part of the figure 5 shows the behavior of the bunch;
2. Measure the horizontal shape bunch at the downstream of the chopper by a wire scanner for instance. The measured width has the information about the longitudinal distribution of the micro bunch.
3. Set the slit which limits the bunch horizontal width before the chopper. It increases the spatial resolution for the longitudinal bunch distribution;

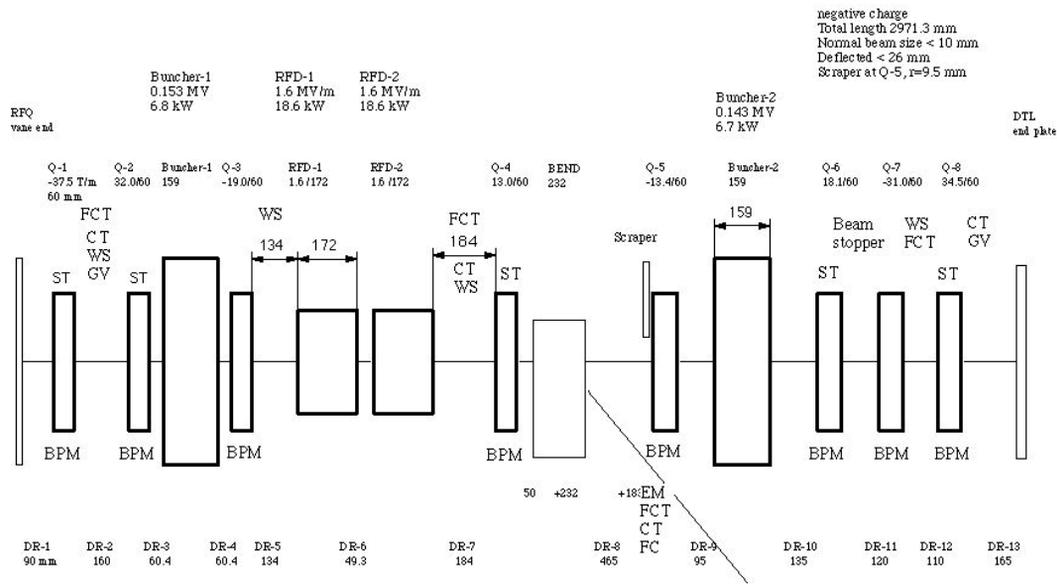


Figure 3: Layout of the MEBT components.

The principle of the monitor is very simple. We will be able to carry out the experiment for item 2 described above soon [6].

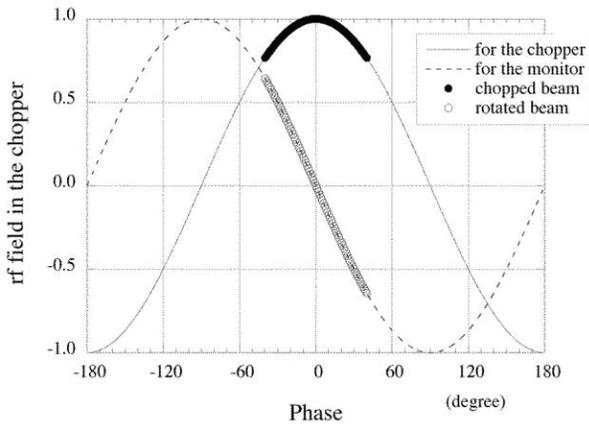


Figure 4: Phase relation between the beam bunch and rf in the chopper.

- : beam to be chopped and be removed
- : beam to be measured

Measurement of the Longitudinal Emittance

There is no longitudinal emittance monitor in the MEBT of J-PARC. However it is possible to construct the longitudinal emittance monitor in the MEBT if we can add the one more slit and momentum analyzer system at the down stream of the chopper. The principle of the system is shown in the figure 6. The desired phase is adjusted by moving the slit-2 or changing the rf phase of the chopper. Most difficult part of the monitor is the measurement of the energy of the cut beam since the energy spread of the beam from

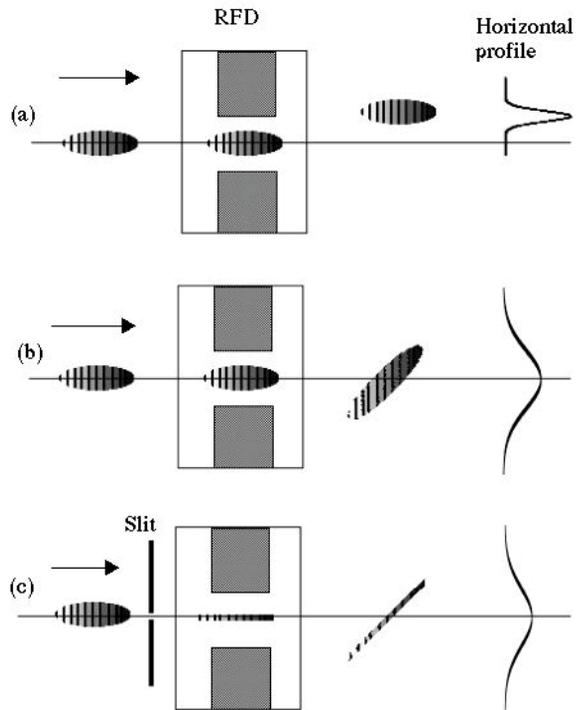


Figure 5: Schematic picture of the bunch behavior.

Beam comes from the left.

- (a) chopper mode
- (b) longitudinal beam shape monitor mode
- (c) monitor mode with slit

RFQ is less than ± 20 keV, which is described in the next section. Although the energy can be measured by an analyzer magnet or time of flight method in principle, it is hard

to put the detecting system which has such high energy resolution into practice.

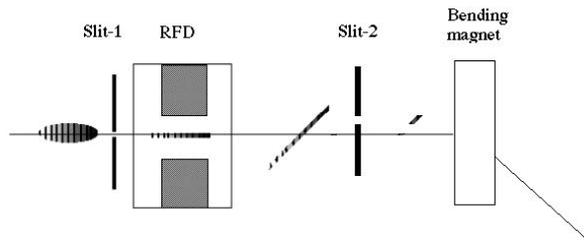


Figure 6: Principle of the longitudinal emittance monitor.

ESTIMATION OF THE SYSTEM PERFORMANCE

In this section, the practical performance of the longitudinal beam size monitor described above is estimated. The known beam parameters are follows:

1. the phase spread of the beam near the chopper is ± 20 degree in RMS[7].
2. the energy spread of the beam at the RFQ exit is about ± 20 keV [8]. (The value will be changed by the effect of the space charge and the tuning of the first buncher).
3. the transverse rms width of the beam for the horizontal direction in the chopper is about ± 1.8 mm.
4. the expected maximum deflecting position of the beam at the scraper kicked by the chopper is 25 mm in the chopper mode[5].

From the item 1 and 4 described above the beam width is expected approximately ± 10 mm ($= \pm 25$ mm * $\sin 25 / \sin 90$) for the longitudinal bunch size monitor mode at the scraper in the MEBT. It is enough for the measurement of the longitudinal shape of the bunch since the original horizontal width of the bunch is ± 2 mm (item 3 described above). Because the beam scraper moves from -10 mm to + 25 mm for x-direction and it can measure the current of the irradiated beam, it is possible to confirm the principle of the monitor with the chopper. If we can add the slit just before the chopper, the wire scanner near the quadrupole 4 is usable for the measurement.

Although the phase difference between the two cells of the chopper is neglected for the rough estimation described above, it must be evaluated for the precise measurement.

For the longitudinal emittance monitor, it is not easy to measure the beam energy distribution since the energy spread of the beam from RFQ is small. The energy resolution must be less than 10 % of the beam energy spread. Thus the required energy resolution beam is less than 4 keV for 3 MeV.

It has been evaluated by a simulation that the energy spread can be measured by the bending magnet in the

MEBT with slits. The simulation results show that the measured energy spread of the beam is bigger than the real one by the effect of the dispersion of the bending magnet. However the real energy spread can be estimated from the measured one by the comparison of the simulation results [9].

CONCLUSION

We proposed the longitudinal bunch shape monitor which can be set in the MEBT line for the J-PARC linac by using the beam chopper. The experiment of the proof of the principle for the longitudinal bunch shape monitor will be done in the beam test facility at KEK. Furthermore the possibility of the longitudinal emittance monitor with the chopper is also described. However the energy measurement of the beam with high accuracy is required.

ACKNOWLEDGMENTS

We would like to thank Prof. T. Kato for his valuable comments and discussions.

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