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Study on the Beam Current Measurement Based on the Beam Position Monitor

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1. Introduction

Beam current is a basic parameter to be measured in accelerator operation. In Korea Multi-Purpose Accelerator Complex (KOMAC) linear accelerator, a beam position monitor (BPM) is installed in every inter-tank space to measure the beam phase and position. And AC current transformers (ACCT) are installed only at the upstream and downstream of the DTL2 because of the limited inter-tank space as shown in Figure 1. We studied whether it is feasible to measure the beam current by using the BPM already installed.

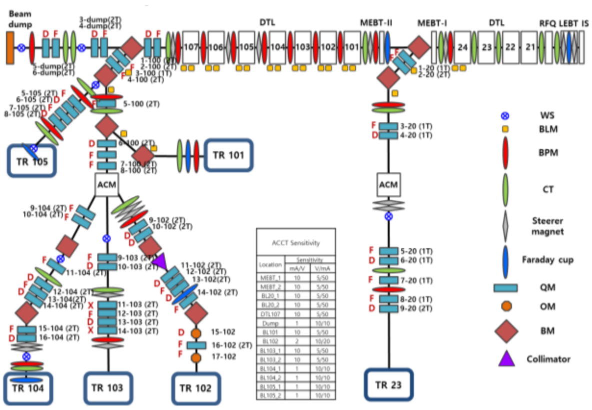

Fig. 1. Beam diagnostics layout of KOMAC linac

2. Linac Beam Position Monitor

There are two types of BPM at KOMAC, one is the linac BPM which has a compact dimension to be fitted in inter-tank space, the other is the beamline BPM which has larger bore size compared to the linac one to be fitted in beam pipe dimension. The linac BPM dimensions are summarized in Table 1.

Table 1: Linac BPM parameters

Parameters	Values
Type	Strip-line
Frequency	350 MHz
Electrode diameter	20 mm
Electrode length	25 mm
Electrode thickness	2 mm
Electrode angle	60 degree
Electrode / outer wall distance	3.5 mm
Electrode gap	6.5 mm
Downstream type	Shorted electrode

The linac BPM is used to measure the beam position and beam phase simultaneously. The layout of the linac BPM is shown in Figure 2. Four signals from the BPM electrodes are delivered and filtered. A 350 MHz signal after the band pass filter is down converted to 50 MHz. The signal process board samples four signals and calculate the beam position and beam phase [1].

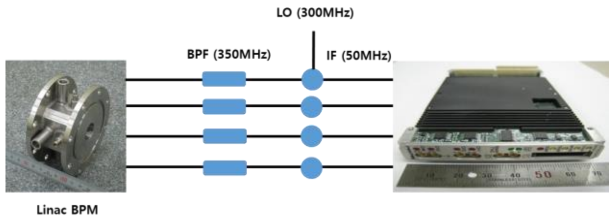

Fig. 2. Linac BPM layout

3. Beam current measurement

The BPM structure is showed in Figure 3.

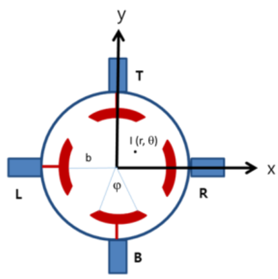

Fig. 3. Linac BPM structure

The current amplitude from the BPM electrode induced by the beam current can be describe in equation (1) [2].

$$I_n = \frac{A_n < I_b > \phi}{\pi}\left[1+\frac{4}{\phi}\sum_{m=1}^{\infty}\frac{1}{m}\left(\frac{r}{b}\right)^m \sin\left(m\left(\frac{\phi}{2}+\mu\right)\right)\cos\left(m(\theta-\tau)\right)\right] \quad (1)$$

In equation 1, the μ and τ represent each electrode and their values are as below.

$$(\mu, \tau) = R(0,0),\ T(0,\frac{\pi}{2}),\ L(\pi,0),\ B(\pi,\frac{\pi}{2})$$

And the voltage from the electrode can be describe in equation (2).

$$V = IZ_{strip}\sin\left[\frac{\omega l}{2c}\left(\frac{1}{\beta_s}+\frac{1}{\beta_b}\right)\right] = IZ_{imp} \quad (2)$$

If we sum the signal amplitude from four electrodes, the result is a constant which is proportional to the beam current with second order error as shown in equation (3).

$$\sum I_{1(i)} = 4\frac{A_1 < I_b > \phi}{\pi} \quad (3)$$

When we consider low relativistic beta particle, two factors should be considered, one is the finite gap effects which can be described by transit time factor (TTF) and the other is Bessel factor (BF) which is due to that the low velocity beam does not produce exact TEM waves inside the beam pipe. And the measured voltage is reduced by the above two factors as shown in equation (4).

$$V = I \times Z_{imp} \times BF \times TTF \quad (4)$$

Finally, the beam current can be estimated from the equation (5).

$$< I_b > = \frac{\pi V_1}{4 A_1 \phi Z_{imp}\, BF\ TTF} = K_1(\beta_b, \gamma_b, \sigma) K_2(BPM) V_1 \quad (5)$$

Here, K_1 is a factor depending on the beam velocity and longitudinal bunch length whereas K_2 is depending on the BPM geometry itself and is a constant. Therefore, if we measure the summation of the voltage signal from 4 electrodes and calculate K_1 from the beam dynamics code, the beam current can be estimated with a proportional constant K_2, which can be deduced from the measured beam current downstream of DTL2. The normalized K_1 value with respect to the DTL2 BPM is shown in Table 2.

Table 2: K_1 values

Energy	Normalized K_1
20.0	0.583
33.1	0.695
45.3	0.774
57.1	0.836
69.1	0.888
80.4	0.930
91.7	0.968
102.6	1.000

5. Conclusions

We studied whether it is feasible to measure the beam current by using BPM signals. If we sum the signals from 4 electrodes, we can measure the property proportional to beam current. In the proportional constant, we should consider two factors, one is factor depending on the beam characteristics and the other is depending on the BPM itself. If we calculate the factor depending on the beam characteristics and compare the results with the beam current from the ACCT at the downstream of DTL2, we can measure the beam currents in every downstream DTL tanks with second order errors.

ACKNOWLEDGMENT

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