# Beam Current Monitoring using BPMs at KOMAC

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## 1. Introduction

The linac beam position monitor (BPM) is one of the beam diagnostics installed in the 100 MeV proton linac. The 9 strip line-type linac BPM are located between drift tube linac (DTL) tanks, shown in Fig. 1. The space between DTL tanks is congested with gate valves and steering magnets, so placing additional current transformers (CTs) in the linac is not an easy task. Instead of installing extra CTs, we utilized the already-installed BPMs for the beam current monitoring at more locations of the linac. Main aim for monitoring beam currents in every DTL tank is to recognize the beam loss location and rectify beam losses. The signal amplitudes from the BPM electrodes are converted into the beam current using BPM coefficients that we calculated. In this paper, we present implementation of beam current monitoring system using linac BPMs and show preliminary results obtained 100 MeV proton linac at KOMAC.

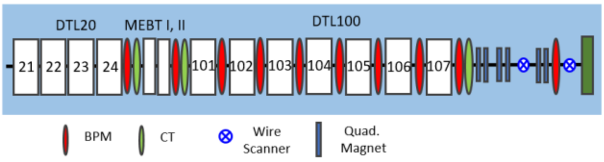


Fig. 1. BPM positions in the proton linac at KOMAC

## 2. Methods and Results

In this section, we show theoretical expressions related to the beam current measured by a BPM. The Fig. 2 shows a linac BPM used in the proton linac. The BPM specification is summarized in Table 1. Based on the theoretical expressions shown in the following section, we built our strategy to measure beam currents in the various sections of the linac.

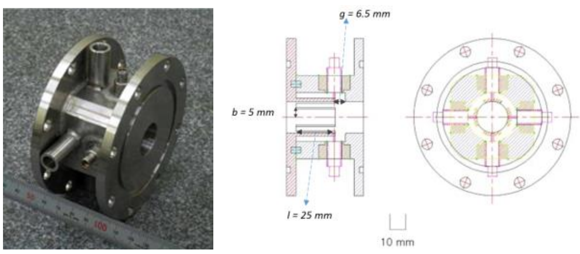


Fig. 2. Linac BPM.

Table I: Linac BPM specification

| Parameter | Linac BPM |
|---|---|
| Beam Energy | 20MeV ~ 100MeV |
| Peak beam current | 1mA~20mA |
| Pulse width | 50us~1.33ms |
| Position accuracy | 2% of beam pipe radius |
| Position precision | 0.2% of beam pipe radius |
| Position measurement range | 40% of beam pipe radius |
| Electrode aperture radius | 10mm |
| Total length | < 49mm |
| Electrode angle | 60 degree |
| Signal frequency | 350MHz or 700MHz |
| Electrode thickness | 2 mm |
| Electrode length | 25 mm |
| Electrode gap | 3.5 mm |
| Feed through | SMA |

### *2.1 Beam Current measured using a BPM*

Beam current of a pencil beam at $(r, \theta)$ at an electrode of a BPM can be obtained from Laplace equation and is given by

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

where $n$ = harmonics of the bunching frequency
$A_n$ = harmonic amplitude factor
φ = electrode의 angular width
$b$= electrode radius
$\langle I_b \rangle$ = beam current

For each electrode R (right), L(left), T(top) and B(bottom), values of $(\mu, \tau)$ are $(\mu, \tau) = R(0,0), L(\pi, 0), T(0, \pi/2), B(\pi, \pi/2)$ .

For the case where harmonic n = 1,

$$I_{s1} = I_{R1} + I_{T1} + I_{L1} + I_{B1} = \frac{4\, A_1 \langle I_b \rangle\, \varphi}{\pi}$$

Two high frequency effects are considered; the gap transit time factor (*TTF*) and the Bessel factor (*BF*).

$$I_{s1} = TTF\ \times BF\ \times \frac{4\, A_1 \langle I_b \rangle\, \varphi}{\pi}$$

Therefore, the beam current measured by the linac BPM is expressed as,

$$\therefore \langle I_b \rangle = \frac{\pi}{4 \times TTF \times BF \times\ A_1\, \varphi} \times I_{s1}$$
$$= \frac{\pi}{4 \times TTF \times BF \times\ A_1\, \varphi} \times \frac{V_{s1}}{Z_{strip}\ sin\left(\frac{\omega l}{2c}\left(\frac{1}{\beta_s} + \frac{1}{\beta_b}\right)\right)}$$

where $I_{s1} = \frac{V_{s1}}{Z_{strip}\ sin\left(\frac{\omega l}{2c}\left(\frac{1}{\beta_s} + \frac{1}{\beta_b}\right)\right)}$

*2.2 Coefficient Calculation*

Beam current expression from the previous section can be written as

$$\langle I_b \rangle = K(\beta_b, \gamma_b, \sigma) \times V_{s1}$$

where $K(\beta_b, \gamma_b, \sigma) =$
$$\frac{\pi}{4 \times TTF \times BF \times\ A_1\, \varphi} \times \frac{1}{Z_{strip}\ \sin\left(\frac{\omega l}{2c}\left(\frac{1}{\beta_s} + \frac{1}{\beta_b}\right)\right)}$$

K is the BPM coefficient which encompasses the geometry of the linac BPM, TTF and BF at beam energies from 20 ~ 102.6 MeV. *K* values are evaluated and are plotted as a function of proton beam energies (Fig. 3).

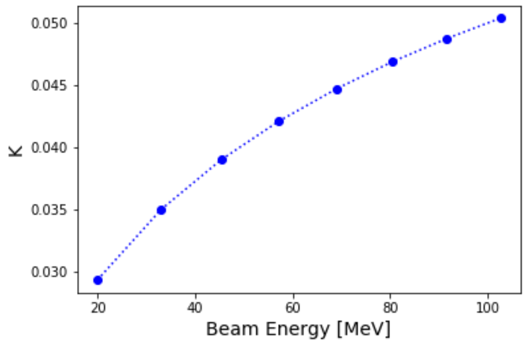


Fig. 3. *K* values are plotted as a function of beam energies

*2.3 Beam Current Monitoring*

Along with the BPM coefficient *K*. we implemented the additional $K_c$ for every BPM *i* to match the real beam currents measured from the CTs in the linac.

$$\langle I_b \rangle = K(\beta_b, \gamma_b, \sigma) \times K_c(i) \times V_{s1}$$

$K_c(i)$ is found from the beam measurements by comparing the actual beam current measured by the CT installed in the proton linac. Both $K(\beta_b, \gamma_b, \sigma)$ and $K_c(i)$ are implemented in the Current monitoring system at KOMAC.

## 3. Conclusions

BPM coefficients for measuring the beam current is calculated from the theoretical expressions. And to match the actual measurement, we estimated the additional coefficients by comparing the beam current measured by the CTs installed along with BPMs in the proton linac. In this paper, we present implementation of beam current monitoring system using linac BPMs and show preliminary results obtained 100 MeV proton linac at KOMAC.

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