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RF Phase Scan for Beam Energy Measurement of KOMAC DTL

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1. Introduction

The energy gain through the drift tube linac is a function of the synchronous phase, therefore, the output beam energy from DTL can be affected by the RF phase setting in low-level RF (LLRF) system. The DTL at Korea Multi-purpose Accelerator Complex (KOMAC) consists of 11 tanks and the RF phase setting in each tank should be matched for synchronous acceleration in successive tanks. That means a proper setting of RF phase in each DTL tank is critical for efficient and loss-free operation.

The matching RF phase can be determined based on the output energy measurement from the DTL tank. The beam energy can be measured by several methods. For example, we can use a bending magnet to determine the beam energy because the higher momentum of beam means the less deflection angle in the fixed magnetic field. By measuring the range of proton beam through a material with known stopping power also can be utilized to determine the beam energy. We used a well-known time-of-flight method to determine the output beam energy from the DTL tank by measuring beam phase with a beam position monitor (BPM). Based on the energy measurement results, proper RF operating point could be obtained [1]. Detailed measurement set-up and the beam energy measurement results are presented in this paper.

2. Energy Measurement Setup

To measure the beam energy by using a time-of-flight method, we used two BPMs and the DTL tank to be measured is located between them [2, 3]. The output signal from the BPM contains the 350 MHz fundamental frequency and higher harmonics. Here, 350 MHz is a resonant frequency of the DTL tank and the beam bunch accelerated in the tank has same time structure. By comparing the phase difference between two BPM signal, the flight time can be obtained and from the flight time and known distance between two BPM, we can determine the beam velocity or beam energy. Figure 1 shows the schematics of the measurement set-up.

The BPMs installed behind each DTL tank is a stripline type. To make the BPM fit into the inter-tank space, the overall dimension is determined as compact as possible as shown in Fig. 2. The electrode aperture is 20 mm in diameter and the stripline electrode length is 25 mm [3]. To measure the beam phase by using BPM signal accurately, the electrical length of the signal line from the BPM located in the accelerator tunnel to the signal processing system installed in the klystron gallery should be compensated. The physical length of the signal line is about 30 m. We measured the phase shift of each signal line of BPM and compensated the phase shift when we measured the phase difference between the phase signals of two BPMs during the time-of-flight measurement.

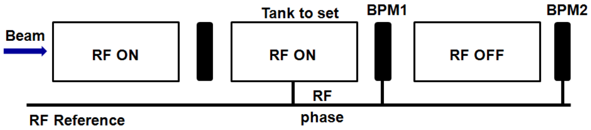

Fig. 1. Schematics of DTL tank output beam measurement by using two BPMs with a time-of-flight method

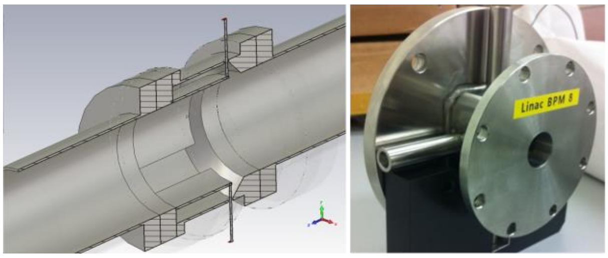

Fig. 2. Stripline type BPM model and photo

3. Measurement Results

Typical signal waveform from the BPM is a superposition of a fundamental sinusoidal wave with higher order modes like shown in Fig. 3. The fundamental frequency is 350 MHz. Because the phase signal has a periodicity of 2π, we should be careful when we analyze the phase signals and determine the beam energy from them.

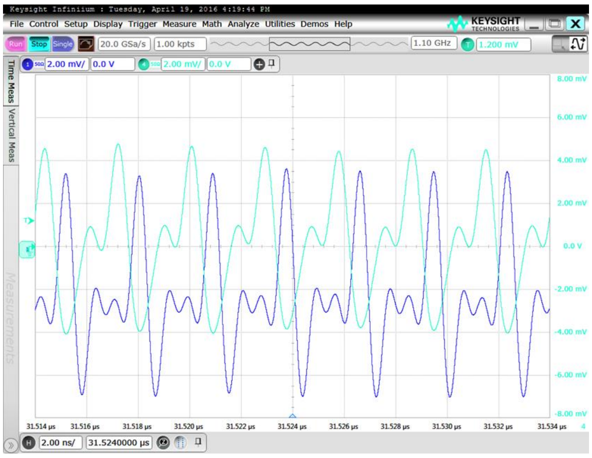
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Fig. 3. Typical waveform from BPM

From the study of the beam dynamics, the energy dependency on the phase setting can be estimated as shown in Fig. 4 for DTL103 case. By comparing the measured results with calculated ones, we can determine the proper RF operating point for each DTL tank. The measured output beam energy from the DTL103 is compared with PARMILA calculation result as shown in Fig. 5. We can't measure the phase signal reliably at some RF phase sets due to the low current at that RF phase and this explains the missing data point in the measured result in Fig. 5.

To check the reliability of the beam phase measurement, we performed the measurement two times with one day separation between two measurements on DTL105 case. The result showed a good agreement between two measurements as shown in Fig. 6.

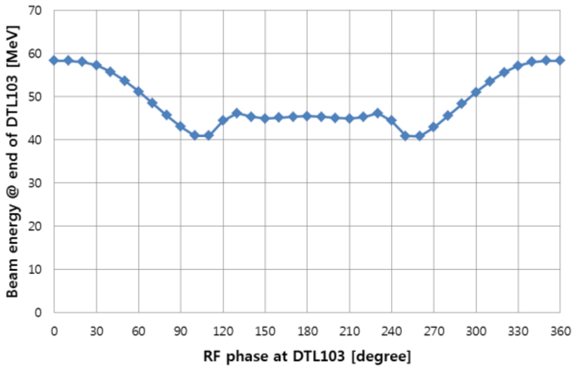

Fig. 4. PARMILA calculation of DTL103 case

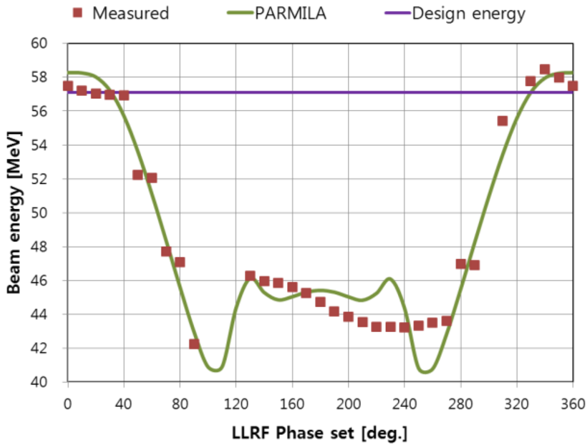

Fig. 5. Comparison between the measured beam energy and calculated energy for DTL103

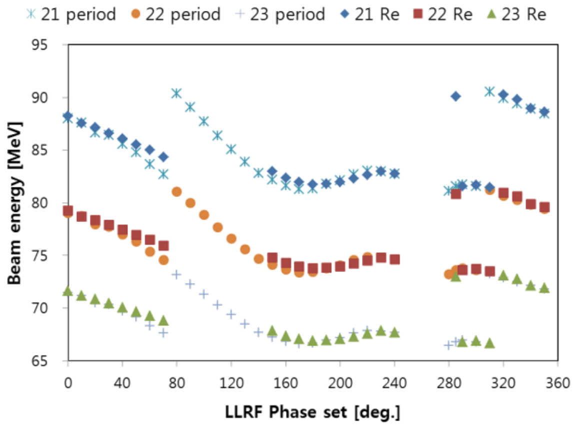

Fig. 6. Reproducibility check for DTL105 case

4. Summary

We performed a RF phase scan to determine the output beam energy from KOMAC DTL by using a time-of-flight method and to set RF operating point precisely. The measured beam energy was compared with a beam dynamics simulation and showed a good agreement. RF phase setting is critical issue for the efficient operation of the proton accelerator, we have a plan to implement and integrate the RF phase measurement system into an accelerator control system for future need.

Acknowledgment

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