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Beam Intensity monitoring by using ACCT at the Proton Irradiation Test Facility

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1. Introduction

TR102 is the one of the 100 MeV proton irradiation facility at the KOMAC (Korea Multi-purpose Accelerator Complex) in the Republic of Korea, which is specialized in use the radiation effect testing of the electronics. The TR102 facility can provide the 100 MeV proton beam to the DUT (Device Under Test) with proton flux of several 10^6 ~ 10^8 [#/cm^2-sec]. The unique feature of TR102 facility is the capability of providing the sufficient large beam area appropriate for various size DUT's, the area of square-like proton beam is up to the maximum 150 mm × 150 mm in limited condition, is normally 100 mm × 100 mm with 10% spatial uniformity. Figure 1 and 2 introduce the TR102 facility and the typical beam profile of the incident proton beam at DUT position.

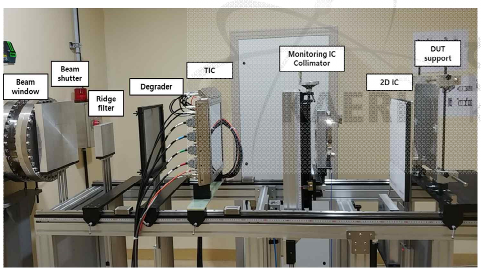


Fig. 1. TR102 radiation effect test facility at KOMAC

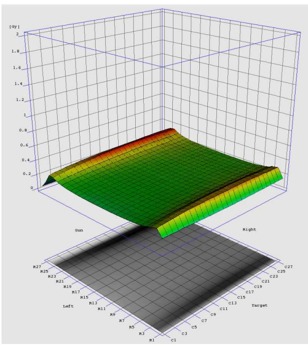


Fig. 2. The typical beam profile of proton beam at TR102 facility.

During the radiation effect testing of electronics use in the proton beam, the Determination of dose or Fluence is the key parameter. Although the BL102 facility usually provide the the users the beam intensities range from 10^6 to 10^8 protons [#/cm^2-sec], In order to match the demand of the space testing community of the South Korea, the new real-time beam flux monitoring system was developed by the combination of the high sensitivity in-air ACCT(AC current transformer) and the Bragg peak chamber detector which have the measurable range from several 10^4 to 10^8 protons [#/cm^2-sec] and the beam flux can be measured by the pulse to pulse in real time.

2. Methods and Results

2.1 In-air ACCT

ACCT (AC-current transformer) is typical non-destructive current measurement method, can measure the macro-pulse current of the charged particle beam without any disruption [1]. And then, ACCT is superior to measure the beam pulses longer than tens of sec with high sensitivity and strong voltage signal, even down to 1 mA. The typical ACCT consist of toroidal sensor head and its electronics, which is contained in the external box. They are interconnected with a twisted pair cable fitted with BNO connectors and common-mode filters.

In-air models are current transformer whose cores are potted in a copper toroidal casing, so that they can measure the beam current of proton beam which is extracted from the beam window into the air without vacuum chamber.

Fig. 3. The in-air type ACCT.

Table 1. Specification of the ACCT system

Full scale range	±1 mA (±10V)
Ratio accuracy error	<0.% FS
Lower cutoff	< 0.1% FS
Droop	<2% /ms
Upper cutoff	1 MHz
Rise time	350ns (10 ~ 90 %)

2.2 Bragg peak chamber

The Bragg peak chamber is the plane-parallel type ionization chamber, is designed to measure for proton beam dosimetry. It has a large diameter compare to others, its large diameter and volume allow to can be obtain the higher sensitivity for low flux proton beam monitoring.

Fig. 4. The Bragg peak chamber detector

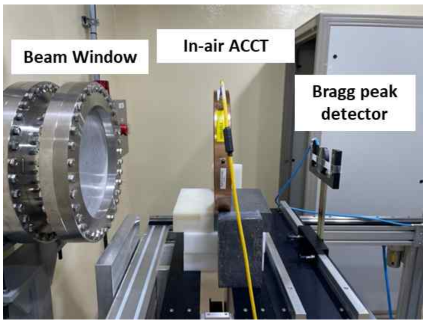
Table 2. Specification of the Bragg peak chamber

Type	Plane-parallel
Sensitive volume	10.5 cm^3
Nominal sensitivity	325 nC/Gy
Ion collection time	67 usec
Max. dose per pulse	0.9 mGy (>99.5%) 1.8 mGy (>99%)
Bias voltage	300 ~ 500V
Radiation quality	70 ~ 250 MeV protons

2.3 Experimental set-up

In-air ACCT was placed in front of the beam exit window for the entire proton beam transmission. The analog signal which generated from ACCT toroid can be monitored by high speed oscilloscope. To reduce the high frequency noise, the low pass filter was applied.

Bragg peak chamber was placed at the behind of the ACCT, it can measure the absorbed dose at the position of the irradiation sample. Thus, the coefficient between the beam intensity and the absorbed dose of the irradiation samples can be obtained through the ACCT – Bragg chamber detector system. After the beam intensity calibration, the Bragg chamber will be substituted for the irradiation samples. And then, the absorbed dose of the proton beam at the sample position, can be monitored through the ACCT output signals.



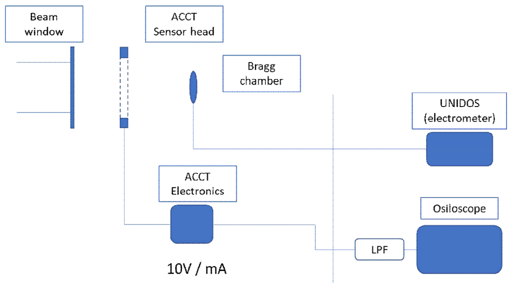


Fig. 5. The experimental set-up for ACCT and Bragg peak chamber

2.4 Result and discussion

The peak current of the incident proton beam was adjusted by beamline steerer magnet. The average beam intensity was measured and averaging during 50 pulses irradiations. The pulse width of proton beam was 100 usec, its repetition rate was 1 Hz.

As shown as figure 5, the short pulse proton beam, which is extracted into the air, can be monitored by pulse to pulse in real time during beam irradiation.

Fig. 5. The experimental set-up for ACCT and Bragg peak chamber

At the same time, the signals of Bragg peak chamber were integrated by charge integrator. The integrated charge means the total absorbed dose of the irradiation samples.

To investigate the linearity and the dynamic range of in-air ACCT and Bragg peak chamber system, we adjust the beamline steerer magnet for the changing the beam current. Figure 6 shows the changes of the total absorbed dose according to the beam current variation during the 50 pulses of proton irradiation.

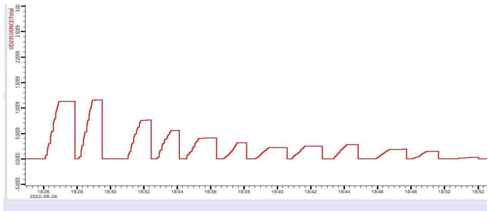


Fig. 6. The response of the Bragg peak chamber according to the change of the peak current.

Figure shows the response of the in-air ACCT as a function of the proton fluence which is measured by Bragg peak chamber detector during the 50 times of proton irradiations. As shows as figure, the response of in-air ACCT shows the good linearity according to the measurement of Bragg peak chamber detector overall, but the in-air ACCT did not have the response at the below of the proton flux 1×10^4 [#/cm^2-pulse]. This result shows that the proposed beam monitoring system consist of the in-air ACCT and Bragg chamber have the dynamic ranges from the ~ 10^4 to 10^6 [#/cm^2-pulse].

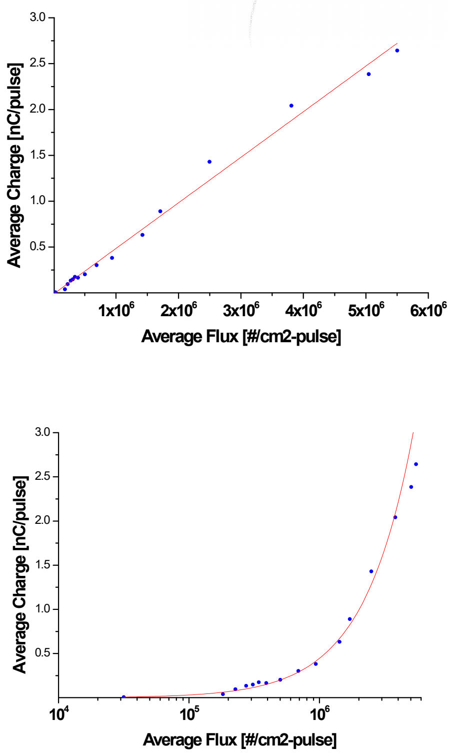


Fig. 7. the response of the in-air ACCT according to the measurement of the Bragg peak chamber detector.

3. Conclusions

The new beam intensity monitoring system for the proton irradiation facility was proposed and tested. The new beam intensity monitoring system consist of the in-air ACCT and the Bragg peak chamber detector allows to can monitor the beam current during the proton beam irradiation in the air without vacuum chamber. The preliminary test results show, in-air ACCT have a good linearity and the dynamic range of the beam monitoring was ranged from ~ 10^4 to 10^6 [#/cm^2-pulse].

Acknowledgement

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REFERENCES

[1] P. Strehl, "Beam Instrumentation and Diagnostics", Springer, 2005.