Design of Multi-Harmonic Buncher for Pulsed Proton Beam

Han-Sung Kim*, Hyeok-Jung Kwon, Yong-Sub Cho
Korea Multi-purpose Accelerator Complex, KAERI, Gyeungju
**Corresponding author: kimhs@kaeri.re.kr*

1. Introduction

Nuclear data related with fast neutron which can be generated by using proton beam on a target is essential for various fields such as development of fusion reactor, medical applications as well as scientific researches. Fast neutrons with a broad spectrum can be generated by irradiating the proton beams on target materials. To measure the neutron energy by time of flight (TOF) method, we need pulsed proton beam. The short pulse width of the proton beam is preferred because the neutron energy uncertainty is proportional to the pulse width. In addition, the pulse repetition rate should be low enough to extend the lower limit of the available neutron energy [1].

To generate short pulse proton beam, we adopted a deflector and slit system. In a simple deflector with slit system, most of the proton beam is blocked by slit, especially when the beam pulse width is short. Therefore, the available beam current is very low, which results in low neutron flux. We proposed beam modulation by using buncher cavity to increase the available beam current. The ideal field pattern for the buncher cavity is saw-tooth type. To make the field pattern similar to the saw-tooth waveform, we adopted a multi-harmonic buncher. The design for the multi-harmonic buncher including 3D electromagnetic calculation is presented in this paper.

2. Chopper System for Pulsed Proton Beam

The chopper system for short pulse proton beam generation is composed of a buncher cavity, which uses multi-harmonics, a deflector and a slit as shown in Fig. 1. The proton beam is generated in the ion source and the beam current is modulated in the buncher cavity [2]. Then the beam is deflected in the deflector. Most beam particles are blocked by the slit and only small portion of the beam pass through the slit. The voltage profile in the deflector is shown in Fig. 2. When there is applied voltage in the deflector, beam is deflected by the electric field. Only when the voltage crossed zero, beam can go straight and pass through the slit.

By using the RF cavity before the deflector, beam current can be modulated. If we control the timing of the deflector voltage and RF cavity phase, we can make beam pass the slit when the modulation is on its maximum value. Simple calculation shows that threefold increase in the beam current can be expected as shown in Fig. 3.

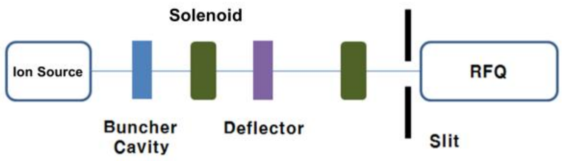

Fig. 1. Schematics of the chopper system.

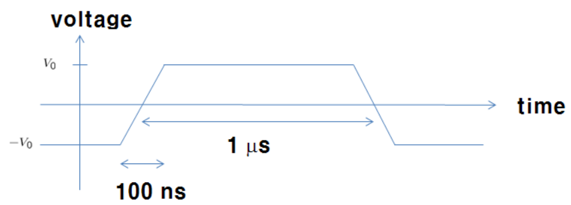

Fig. 2. Voltage profile in the deflector.

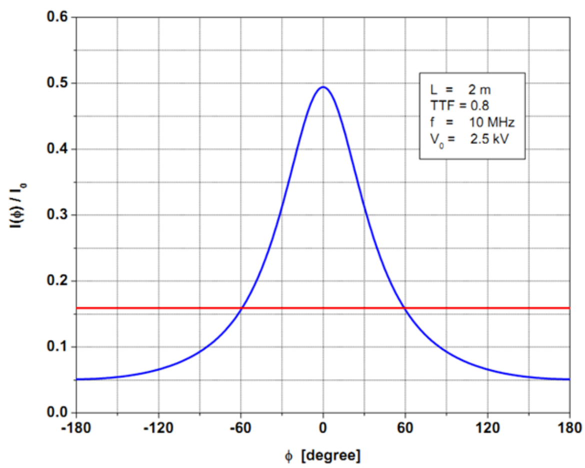

Fig. 3. Beam current increase by modulation.

3. Design of Multi-Harmonic Buncher

To generate saw-tooth waveform, we designed a cavity with harmonics up to 3rd harmonics. The fundamental frequency is determined to be 50 MHz, therefore, the 2nd harmonic frequency is 100 MHz and the 3rd harmonic is 150 MHz. The structure is two quarter-wave resonators as shown in Fig. 4. The longer resonator is for the fundamental and 3rd harmonic frequency and the shorter one is for the 2nd harmonic.

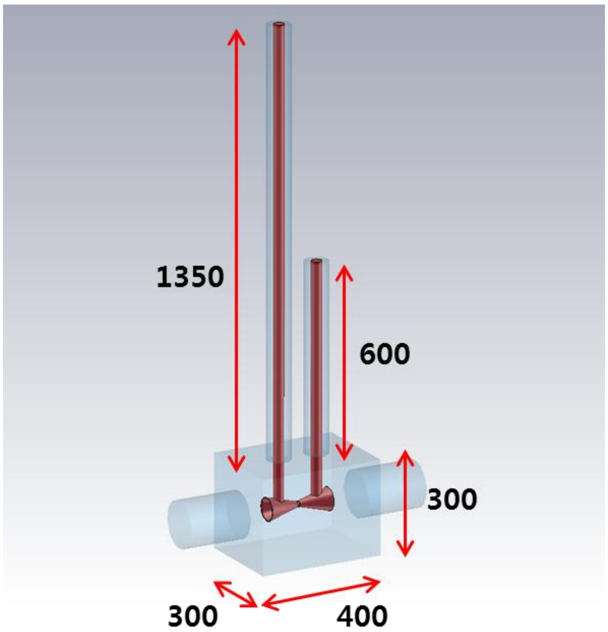

Fig. 4. Multi-harmonic cavity geometry.

We performed 3D electromagnetic analysis for the multi-harmonic cavity by using a MicroWave Studio code and the analysis results along with the field distributions are summarized in Table 1 and Fig. 5.

Table 1. Analysis results for the multi-harmonic cavity.

Parameter	Mode1	Mode2	Mode3
Frequency [MHz]	50.17	99.63	148.15
Q	2040	2913	3625
R/Q [ohm]	140	150	52
Shunt imped. [ohm]	2.86E+5	4.38E+5	1.89E+5
Stored energy [J]	1	1	1
Total loss [W]	1.55E+5	2.15E+5	2.57E+5
Integrated field [V]	2.10E+5	3.07E+5	2.20E+5

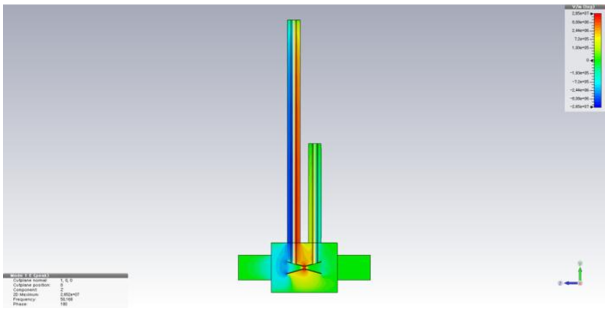

Fig. 5a. Longitudinal electric field distribution for fundamental mode.

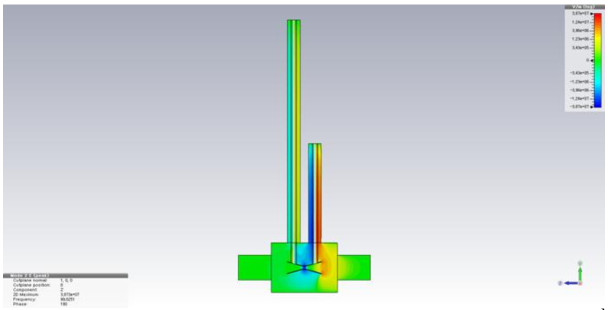

Fig. 5b. Longitudinal electric field distribution for 2nd harmonic mode.

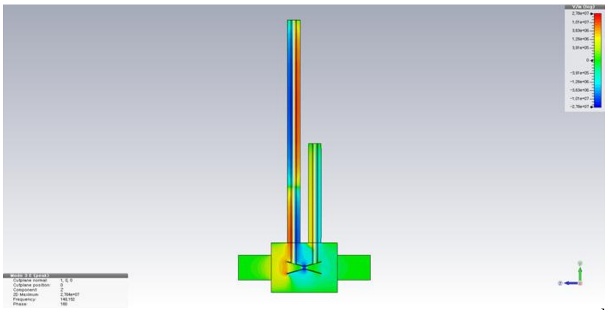

Fig. 5c. Longitudinal electric field distribution for 3rd harmonic mode.

3. Summary

A multi-harmonic buncher for a proton beam chopper system to generate a short pulse neutron beam was designed. The frequency of the fundamental mode is 50 MHz and the resonant structure up to 3rd harmonics is used. A detailed engineering design of the multi-harmonic buncher including prototype fabrication will be carried out in the near future.

Acknowledgements

This work was supported by Ministry of Science, ICT & Future Planning.

REFERENCES

[1] J. L. Fowler, John E. Brolley Jr., Monoenergetic Neutron Techniques in the 10- to 30-MeV Range, Review of Modern Physics, Vol28, No.2, p.103, 1956.
[2] A. P. Banford, The Transport of Charged Particle Beams, E. & F. N. Spon Ltd., London, 1966.