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Conceptual Design of Chopper for Pulsed Proton Beam

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1. Introduction

Nuclear data related with fast neutron 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 conceptual design for the chopper system to generate short proton beam pulse with high beam current is presented in this paper.

2. Chopper System

The chopper system for short pulse proton beam generation is composed of a buncher cavity, deflector and 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.

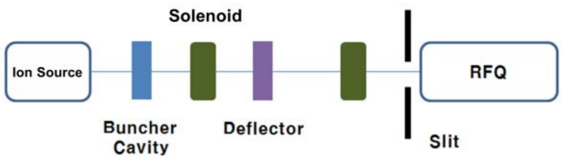

Fig. 1. Schematics of the chopper system.

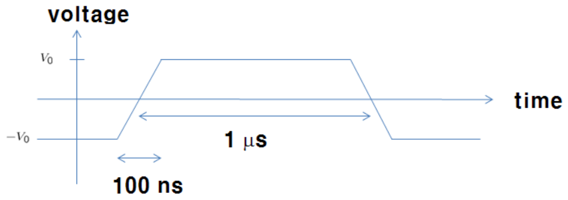

Fig. 2. Voltage profile in the deflector.

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.

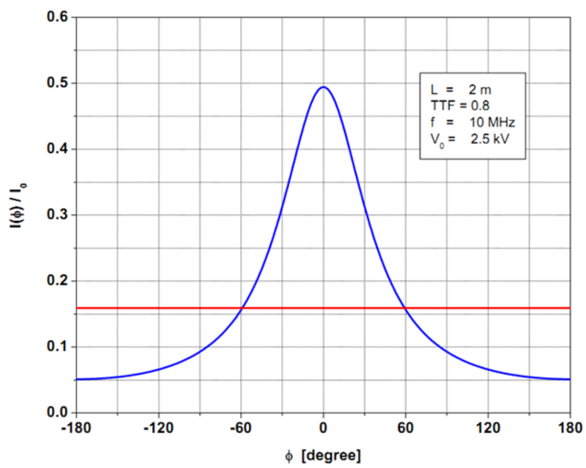

Fig. 3. Beam current increase by modulation.

To estimate the required deflector voltage, the deflection angle and the slit aperture size, we performed a simple calculation based on the analytic formula. Fig. 4 shows the deflection angle as a function of deflector voltage. As expected, the deflection angle is directly proportional to the deflection voltage. If we want to deflect the beam with the deflection angle of 200 mrad, we should apply the 10 kV to the deflector.

The aperture radius of the slit as a function of deflector voltage is shown in Fig. 5. If the applied voltage is increased, the slit aperture can be lager because the time variation of the applied voltage is increased with higher applied voltage on the deflector. If the applied voltage is 10 kV, the slit aperture can be about 20 mm.

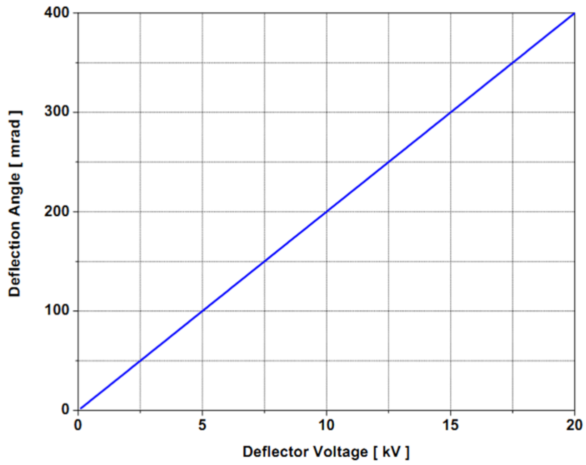

Fig. 4. Deflection angle.

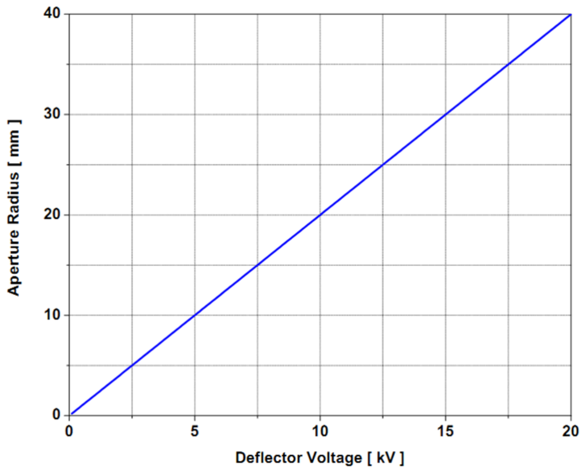

Fig. 5. Slit aperture.

3. Summary

A proton beam chopper system to generate a short pulse neutron beam was designed. The short pulse neutron beam with a low repetition rate is essential for the high energy neutron related nuclear data. A detailed engineering design of the chopper system and the system verification with prototyping will be carried out in the near future.

Acknowledgements

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