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Fabrication of Multi-Harmonic Buncher for Pulsed Proton Beam Generation

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1. Introduction

A short pulse proton beam can be used to generate neutron beam and it is possible to evaluate nuclear data which 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, 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].

Pulsed proton beam generation system is designed based on an electrostatic deflector and slit system as shown in Fig. 1. 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. To increase the available beam current, we chose to use beam modulation effect by using a buncher cavity. The ideal field pattern inside the buncher cavity is saw-tooth wave [2]. To make the field pattern similar to the saw-tooth waveform, we adopted a multi-harmonic buncher (MHB). The design for the multi-harmonic buncher including 3D electromagnetic calculation has been performed.

Based on the design, a multi-harmonic buncher cavity was fabricated. It consists of two resonators, two drift tubes and a vacuum chamber. The resonator is a quarter-wave coaxial resonator type. The drift tube is connected to the resonator by using a coaxial vacuum feedthrough. Design summary and detailed fabrication method of the multi-harmonic buncher is presented in this paper.

2. Design of Multi-Harmonic Buncher

To generate saw-tooth waveform inside the cavity, we used 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. 2. The longer resonator is for the fundamental and 3rd harmonic frequency and the shorter one is for the 2nd harmonic. The drift tube electrode has conical shape to reduce a coupling between to electrodes [3].

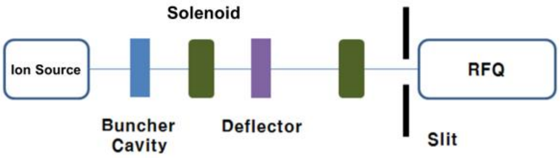

Fig. 1. Schematics of a pulsed beam generation system.

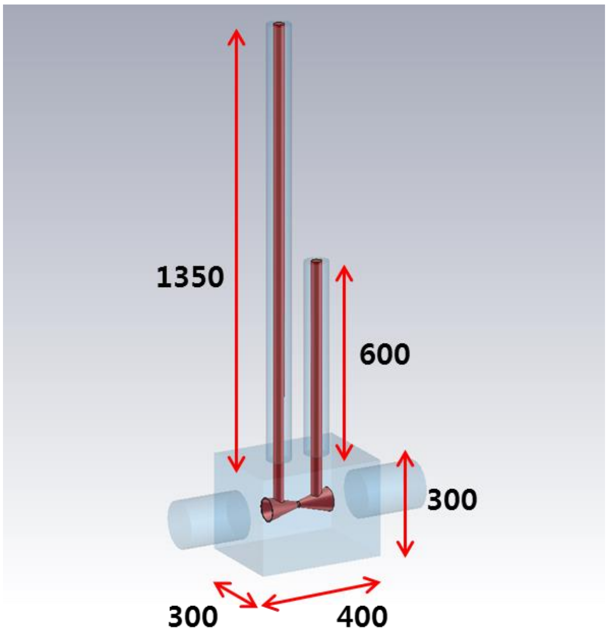

Fig. 2. Multi-harmonic cavity geometry.

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

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
Total loss [W]	1.55E+5	2.15E+5	2.57E+5
Integrated field [V]	2.10E+5	3.07E+5	2.20E+5

3. Fabrication of Multi-Harmonic Buncher

The overall engineering drawing of the multi-harmonic buncher is shown in Fig. 3. The resonator has been fabricated by using 3-1/8" rigid coaxial line mode of copper with movable end-plug to tune the frequency. The canted coil was used for RF seal at the boundary between the end-plug and coaxial conductor. The conical drift tubes (Fgi. 4) made of copper was connected to the inner conductor of the resonator. The RF vacuum feedthrough with alumina window (Fig. 5) was fabricated by using vacuum brazing process. The vacuum chamber has several ports including beam pipe ports, RF pickup port and an additional pumping port. Figure 6 shows the assembled multi-harmonic buncher.

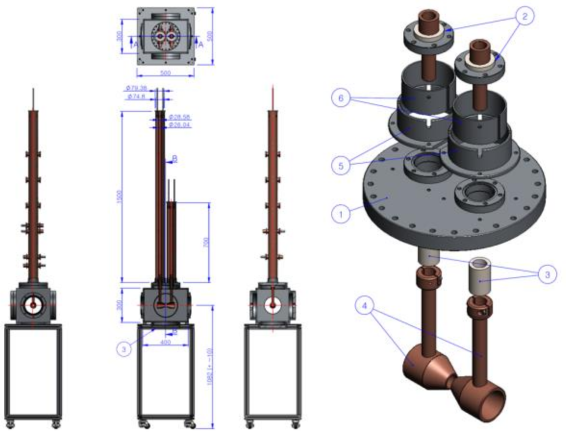

Fig. 3. Engineering drawing of MHB.

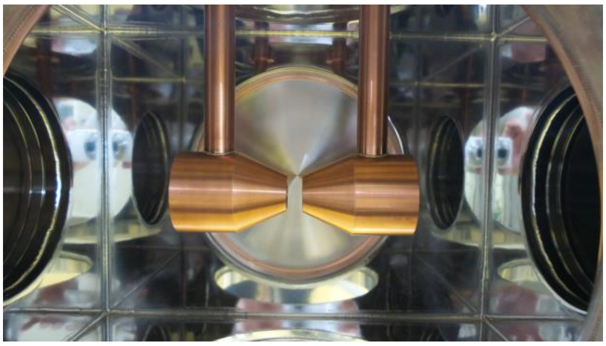

Fig. 4. Conical drift tubes installed inside a vacuum chamber

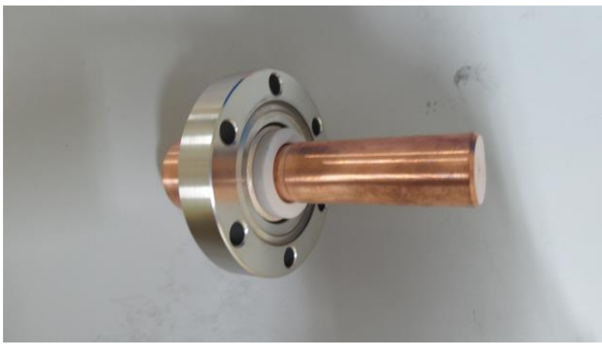

Fig. 5. RF vacuum feedthrough

Fig. 6. Assembled multi-harmonic buncher.

4. Summary

A multi-harmonic buncher for a proton beam chopper system to generate a short pulse neutron beam was designed, fabricated and assembled. The frequency of the fundamental mode is 50 MHz and the resonant structure up to 3^{rd} harmonics is used. Performance tests including low power RF property measurement will be carried out in the near future.

Acknowledgements

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