

BEAM TEST OF SAWTOOTH-WAVE PRE-BUNCHER COUPLED TO A MULTILAYER CHOPPER*

M. Okada[#], H. Ishiyama, I. Katayama, H. Miyatake, K. Niki, Y. Watanabe,
KEK, Tsukuba, Ibaraki 305-0801, Japan
H. Makii, JAEA, Tokai, Ibaraki 319-1195, Japan
S. Arai, RIKEN, Wako, Saitama 351-0198, Japan

Abstract

In TRIAC (Tokai Radioactive Ion Accelerator Complex), intense bunched α beams will be utilized for measurements of $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reactions. Sawtooth-wave pre-buncher has been developed for satisfying the experimental conditions. In order to remove the background particles, a multilayer chopper have been installed upstream the pre-buncher. The chopper has 19 electrodes (40mm wide, 10mm long, and 0.1mm thick) piled up with gaps of 1.9mm in vertically to the beam direction and a square-shape electric potential (120V in maximum, 2-4 MHz in repetition frequency) is applied to each electrode alternately. The short gap makes it possible to realize sharp chopping with relatively low electric potential and weak leakage electric field, although beam particles could be lost by 5% or more, since this chopper is set on the way of beam. As a result, this pre-bunch system achieves intense bunched beam with little background.

DEVELOPMENT BACKGROUND

TRIAC is an accelerator complex facility of Radioactive Nucleus Beams (RNB) that is a joint research facilities of High Energy Accelerator Research Organization (KEK) and Japan Atomic Energy Agency (JAEA). It can accelerate heavy ions ($q/A > 1/10$) from 2keV/u to 1.1MeV/u with 26MHz SCRFQ and 52MHz IH Linac.

In the TRIAC machine time, measurements of $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction are planned. This experiment requires intense 2-4MHz pulsed α beams with little background. Especially, it is highly desirable that there is no particle in the time region of 250ns just before the pulsed beam [1]. Therefore, a pre-bunch system is developed and installed upstream the accelerators. (Figure 1) This system is composed of a variable frequency sawtooth-wave pre-buncher and a multilayer chopper. It bunches CW beams to 2-4MHz bunched beams.

PRE-BUNCHER

The sawtooth-wave pre-buncher is two gaps buncher having single drift tube. The RF voltage applied on the drift tube is synthesized with two and three times higher harmonics waves and the fundamental wave. Particles passing through the two gaps are bunched effectively by a

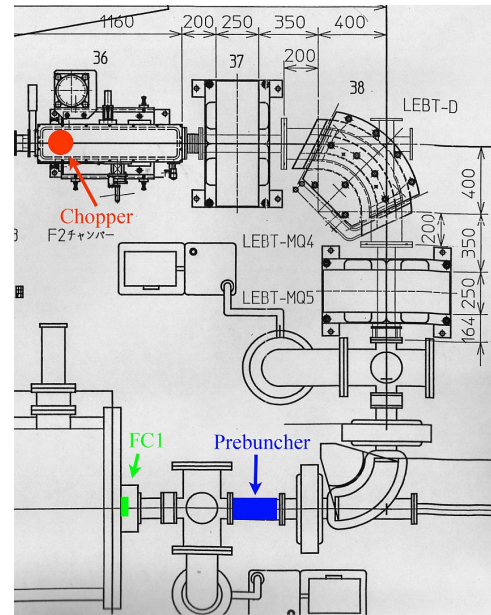


Figure 1: Layout of Pre-Bunch System.

pseudo sawtooth-wave voltage [2] as shown in Figure 2. This pseudo sawtooth-wave has unbunch phase due to the imperfect sawtooth-wave. And beam particles in the region of unbunch phase become backgrounds. Hence, chopper has been installed to cut the background particles.

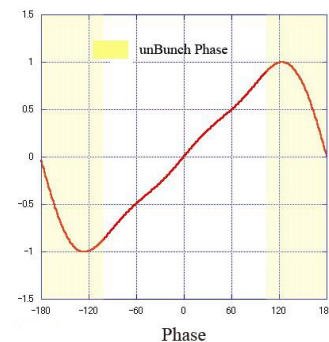


Figure 2: Sawtooth Shape by Pre-buncher.

MULTILAYER CHOPPER

Design of chopper

At the beginning, single parallel-plate electrode type chopper was considered. In order to achieve the sharp chopping, longitudinal length of electrodes should be

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*Work supported by Grant-in-Aid for Scientific Research (A) (grant No. 20244036)

[#]masashi.okada@kek.jp

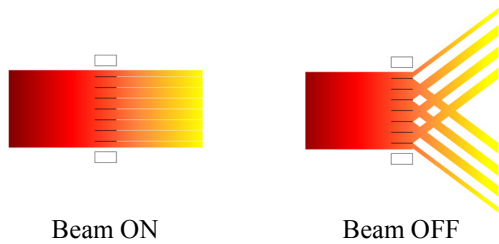


Figure 3: Chopping Image by Multilayer Chopper.

enough short as $1/10$ length of $\beta\lambda/2$, where β is particle velocity ($2\text{keV}/u$) and λ is typical wavelength of the pre-buncher. In the case of 4MHz bunching, $\beta\lambda/2$ is 15.5cm , and then we assumed 10mm for the electrode length. And a gap between the electrodes was assumed 40mm based on the typical beam size of 30mm in diameter at the position to be installed. The necessary voltage for deflection became 2kV . But, this is too high to operate under $2\text{-}4\text{MHz}$ frequencies with several tens ns rise/fall time. In addition, the electric field leakage up- and downstream would greatly affects the beam optics. Therefore, a multilayer electrode structure was adopted instead of the single parallel-plate electrode.

Multilayer electrode consists of 19 electrode-plates piled up by interval of 1.9mm . Thickness of plate is 0.1mm . The beam can be dispersed to upper and lower direction by applying the voltage alternately on each electrode (figure 3). Because the multilayer electrode can reduce the gap, required deflection voltage becomes low and the leakage of the electric field can be decreased. On the other hand, the beam that hits the electrodes will be surely lost so that the electrode is set in the beam orbit. The multilayer chopper was constructed based on this design. Figure 4 shows the photograph. The electrode plates are 40mm wide, 10mm long, and 0.1mm thick phosphor bronze plates. And, 1.9mm washers of the



Figure 4: Multilayer Chopper.

polycarbonate support the gaps. Moreover, it is possible to put the chopper in and out to the beam line using the air cylinder.

PERFORMANCE OF CHOPPER

Beam loss fraction

Beam loss by the chopper was measured by using $^{16}\text{O}^{4+}$ beam. The beam was optimized so that the beam current might become the maximum at the faraday cup (FC1) located at the entrance of accelerators. As a result, beam current was $1.10\mu\text{A}$ at FC1 without chopper. While beam current was $1.28\mu\text{A}$ with the chopper. Therefore, the beam loss by chopper becomes about 14% . Because the expected one from the geometry is 5% , measured value is about three times larger than the expected. This discrepancy might be explained by imperfect parallel beam in reality and misalignment of each electrode.

DC chopping

Performance of the beam chopping was studied by applying the constant voltage on the electrode. Figure 5 shows the result. The graph is normalized by the beam current without chopping voltage. The beam current decreases to 2×10^{-5} at 100V . This is enough for experiment although it is not complete.

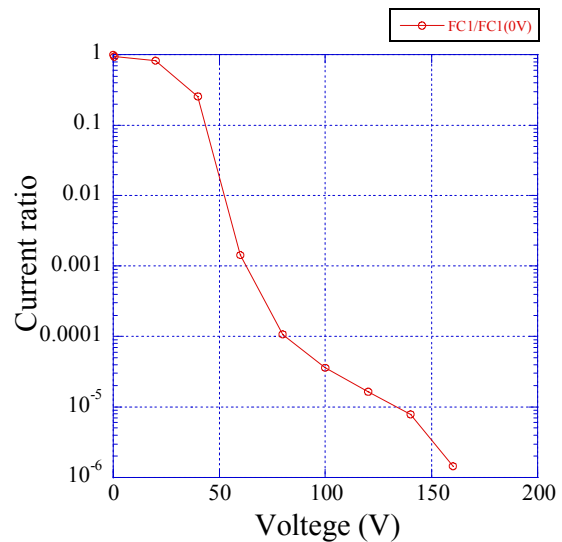


Figure 5: Beam chop test by DC voltage.

Square-shape potential for pulse chopping

The square-shape electric potential was applied to the electrode. Its repetition frequency, peak voltage, and duty are 2MHz , 120V , and 50% , respectively. Since an electric ringing was found when the amplifier directly connected to the electrode, a shaping circuit was installed to adjust the potential shape. Figure 6 shows the actual shape of applied potential. Rise and fall time between 0 and 100V is about 40ns , which is somewhat larger than the target value (10ns). Duty of the chopping cycle is adjustable for the effective beam chopping .

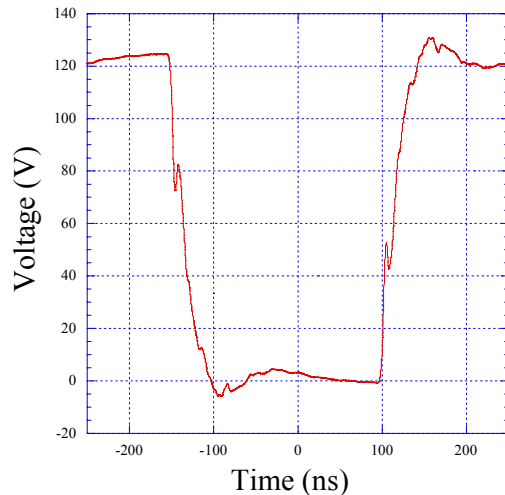


Figure: 6 Pulse form on chopper.

BEAM TEST OF PRE-BUNCH SYSTEM

In this test, $^{16}\text{O}^{4+}$ beam was bunched by the pre-bunch system, accelerated up to 1.1MeV/u and transported to the target. Beam current was measured in front of the chopper (F1), just downstream the accelerators (FC5), and target position. At target position, time structure was also measured with SSD by detecting the elastically scattered particle from the Al foil.

At first, when the pre-buncher and the chopper were turned off, the beam current was 1.4 μA at F1 and was 0.46 μA at FC5 under the 50% duty operation of accelerators.

Next, the pre-buncher was turned on. Pre-buncher was driven 2MHz frequency. As a result, the current was 1.72 μA at F1 and 0.28 μA at FC5. The observed time structure is shown in Figure 7. The ratio of particles gathered in the centre bunch to all particles of the beam is about 75%. At the 2MHz operation, there are 13 micro bunches included in the one pre-bunching cycle. The

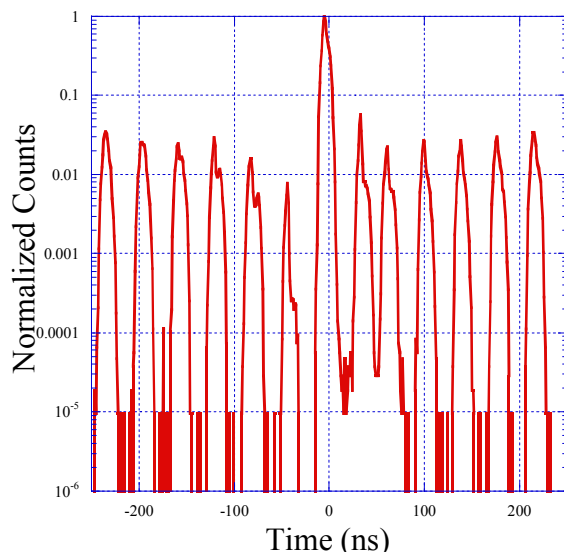


Figure: 7 Time structure of pre-bunched beam.

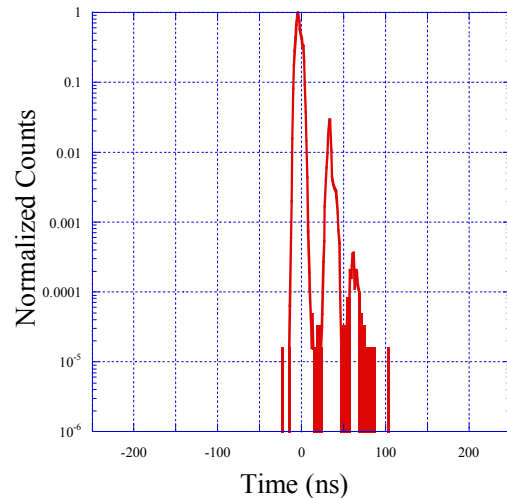


Figure: 8 Time structure of pre-bunched beam coupled the chopped and.

averaged particle fraction in one micro bunch becomes 7.7%, if the pre-buncher is turned off. Therefore, actual bunching gain becomes about 4.8. It is noted, that a lot of particles remains on the background.

Finally, the chopper was turned on. The chopper was driven under the conditions at 120V peak voltage, 33% duty, and 2MHz frequency. As a result, the current was 1.80 μA at F1 and 0.21 μA at FC5. Measured time structure was shown in Figure 8. Fraction of particles in background to the all detected particles decreases to 2%. Especially, the particle in the time region of 250ns before centre bunch was not observed. It corresponds that upper limit of the particle suppression is 2×10^{-6} to the bunched beam particles. This value is enough for the experiments. And actual bunching gain becomes 4.5. This value indicates that the chopper does not largely cut particles in the centre bunch.

SUMMARY

The pre-bunch system is developed in TRIAC for the measurements of $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reactions, and the multilayer chopper is installed as a part of system for removing the background particles. This chopper has 19 electrodes in parallel on the beam line. It makes a little beam loss by itself but can cut beam sharply with low electric potential. It is confirmed that the pre-bunch system has enough performance for the experiments. The bunching gain is 4.5 and suppression ratio of the background particles in the important time region for experiments are less than 2×10^{-6} . It is scheduled to test by the intense α beam in near future.

REFERENCES

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- [2] K. Niki et al., "Design and Test of 2-4MHz Sawtooth-wave Pre-buncher for 26MHz-RFQ", this conference(THPEB011).