Improvement of Energy Stability of the Tohoku Dynamitron Accelerator

V. 1. Improvement of Energy Stability of the Tohoku Dynamitron Accelerator

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Introduction

The microbeam system at Tohoku University has been applied to various fields[1-7]. Recently, higher spatial resolution down to several hundred nm and higher beam current with a several μm resolution is required and a triplet lens system was newly installed. While the triplet system has larger demagnification, chromatic aberration is much larger than the doublet system. To get best performance of the high demagnification system, improvement of energy resolution of the accelerator is required. In the previous studies, adjusting the feed back system was carried out and the voltage ripple decreased to ±1 keV. While this adjustment improved the beam current stability at the microbeam target, energy resolution is not sufficient for the larger magnification system. In this study, various source of the voltage ripple of the accelerator was investigated and reduction of voltage ripple was carried out.

High Voltage System of the Tohoku Dynamitron Accelerator

High voltage generator of the Dynamitron accelerator is a parallel-fed, series-cascaded rectifier system (Shenkel type high voltage generator)[8]. Figure 1 shows schematic diagram of the high voltage generator and control system of the Tohoku Dynamitron Accelerator. The L-C tank circuit consists of transformer (toroidal coil) and capacitances between corona rings, tank vessel and RF electrodes (upper and lower dees). The oscillator is a tuned anode and untuned grid circuit. RF voltage from the dees is capacitively coupled into the cascade rectifier stages. Ninety six stages are used in our accelerator. Positive grid feedback to maintain oscillation of ca. 120 kHz is provided by a voltage pick-up from the grid feedback plate located between the upper dee and accelerator tank vessel. The maximum voltage of the accelerator is 4.5 MV and the maximum beam current is 3 mA. Voltage stability is better than 2 kV_{p-p}. Vacuum rectifier tubes (Kenetron) had been used as rectifier and were replaced by diodes made by Origin Electric Corporation. High voltage of the terminal is controlled by varying the RF voltage which is varied by adjusting a plate voltage of the triodes (5771s). The plate voltage was controlled by a high voltage DC power supply. High voltage DC power supply for the RF oscillator is stabilized by a fast feed back loop and a precise DC amplifier (inner loop amplifier). The high voltage is further stabilized by a feedback system (auto regulator). A proportional integration (PI) circuit is used to stabilize the high voltage. The PI controller acts on the error signal from the comparison of the set reference voltage and the voltage generated on the precise register connected to the resister network (high voltage divider, HVD) which is connected from the high voltage terminal and ground. The third feed back loop is efficient for low frequency fluctuation less than several Hz. In the previous study, feedback response was adjusted by measuring the beam fluctuation on target[9)]. However, higher frequency ripple could not be measured. In this study, a capacitive pick-off (CPO) unit is newly installed to measure the voltage ripple. The Dynamitron accelerator has unpowered dee (grounded dee) which consists of two semicircular plates and circular flat plate at the end and covers high voltage terminal as shown in Fig. 1. The CPO plate of 355 mm in diameter is mounted on the center of the plate at the end. Distance between the CPO plate and the high voltage terminal is 685 mm. Cascade generator like Dynamitron has many ripple components. Therefore CPO has to measure wide frequency region, at least up to oscillation frequency. If CPO output is directly measure by an oscilloscope, frequency higher than 100Hz can be measured with a sensitivity of 150 mV/kV. If CPO output is measured with amplifier, frequency less than 1 kHz can be measured with a sensitivity of 8 V/kV. Frequency less than 1Hz, we can measure the ripple with HVD current.

Improvement of Voltage Stability

Voltage ripple of the Dynamitron accelerator was measured with CPO with and without an amplifier. Main components of the ripple are 120 kHz and 50 Hz. Peak to Peak voltages (V_{p-p}) of 120 kHz and 50 Hz components were ca. 2 kV and 1.5 kV at a terminal voltage of 2 MV with no beam load. Loading current without beam is a sum of HVD current and beam tube divider resister current which determines voltage of the acceleration tube and is more than 100 μA. Since beam current in many application is in an order of several tenth μA, voltage ripple was not increase drastically with beam loading. RF modulation of the oscillator is superposed on the high voltage. The terminal ripple of the oscillation frequency has two origins, one is the inherent ripple of the cascade rectifier and the other is related to asymmetry in the L-C circuit composed of the toroidal coils and dees[8,10]. The inherent voltage ripple is estimated to be 20 V_{p-p}, this larger ripple stems from asymmetry of L-C circuit. The asymmetry comes from the unbalance of the capacitances related to the upper dee and the lower dee. The grid feedback signal is picked up from the grid feedback plate located between the upper dee and the vessel. To compensate the difference of capacitance[8,10], a balance plate with same shape and size is installed between the lower dee and the tank. The balance plate can be moved from outside and adjust the capacitance of the lower dee. CPO output of 120 kHz component decreases corresponding to lowering the balance plate, but not eliminated. It is apparent that the capacitance of the upper dee is too small to compensate the capacitance by the balance plate motion. To increase the capacitance of the upper dee, additional balance plates were attached on the upper dee. Figure 2 shows the voltage ripple at a terminal voltage of 2 MV. By adding the additional capacitance on the upper dee, voltage ripple was reduced down to 1 kV_{p-p} even at a balance plate position of upper limit. The ripple voltage was further reduced down to 200 V_{p-p} at the lowest balance plate position. Since the lowest value was obtained in the lowest balance plate position, the asymmetry is still remaining. We are planning to add more capacitance to the upper dee.

The 50 Hz component is apparently related to the power line frequency. The 50 Hz component increased with feedback gain and decreased without feedback. It is apparent that power line noise mixes with HVD current. In the previous study, we reported that the increase of feedback gain improved stability of target beam currents[9]. While the increase of ripple improves target current stability, beam intensity might decrease. To reduce the 50 Hz component, a notch filter was installed between the auto regulator and the inner loop amplifier. After the modification, voltage ripple of the low frequency components less than 1 kHz were reduced down to 400 V_{p-p}. While peak to peak voltage is 400 V, averaged voltage ripple distribution is 150 V FWHM as shown in Fig. 3. Since CPO signal is affected by the noise from cooling fans in the vessel and is around 300 V equivalent voltage, ripple of terminal voltage for lower frequency is much less.

Conclusions

The microbeam analysis system installed at Dynamitron laboratory has applied to various fields. To obtain higher spatial resolution down to several hundred nm and higher beam current with a several μm resolution, update to a triplet lens system which has larger demagnification by adding a quadrupole lens was carried out. Since the system has higher demagnification, effect on chromatic aberration is larger and energy resolution should be improved. To get higher energy resolution, various source of the voltage ripple of the accelerator was investigated and minimization of voltage ripple was carried out. Voltage ripple of the accelerator for low frequency components were reduced less than 150 V. However, voltage ripple of 120 kHz components was 200 V_{p-p} since the perfect symmetrization was not achieved yet. It will be achieved by adding the additional capacitance on the upper dee.

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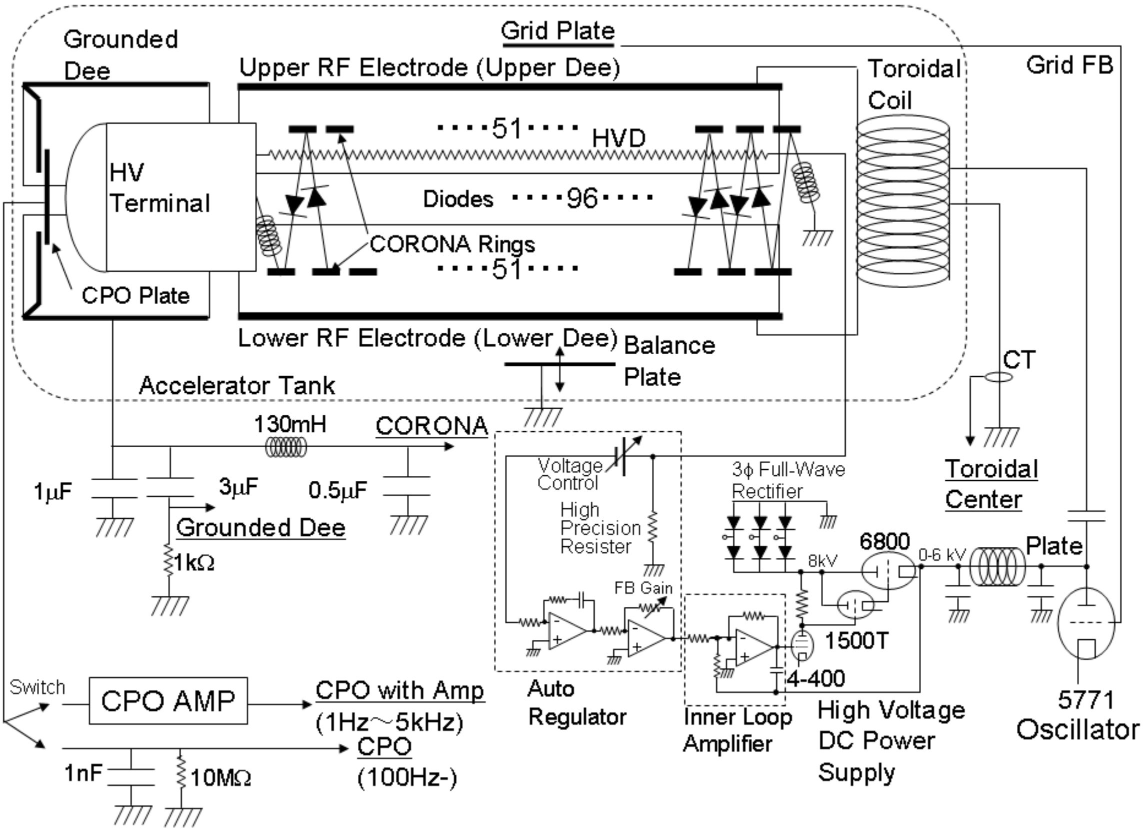

Figure 1. Schematic Diagram of the High Voltage Generator and Control System.

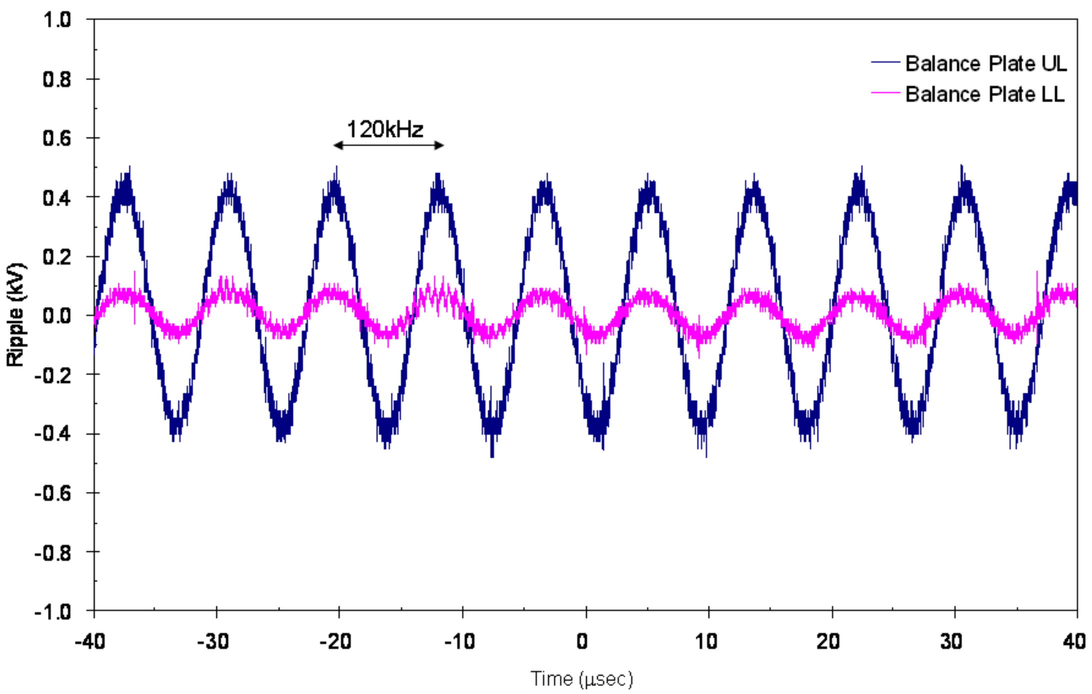

Fig. 2. Measured Voltage ripple at a Terminal Voltage of 2MV for Balance Plate Position of Upper Limit and Lower limit.

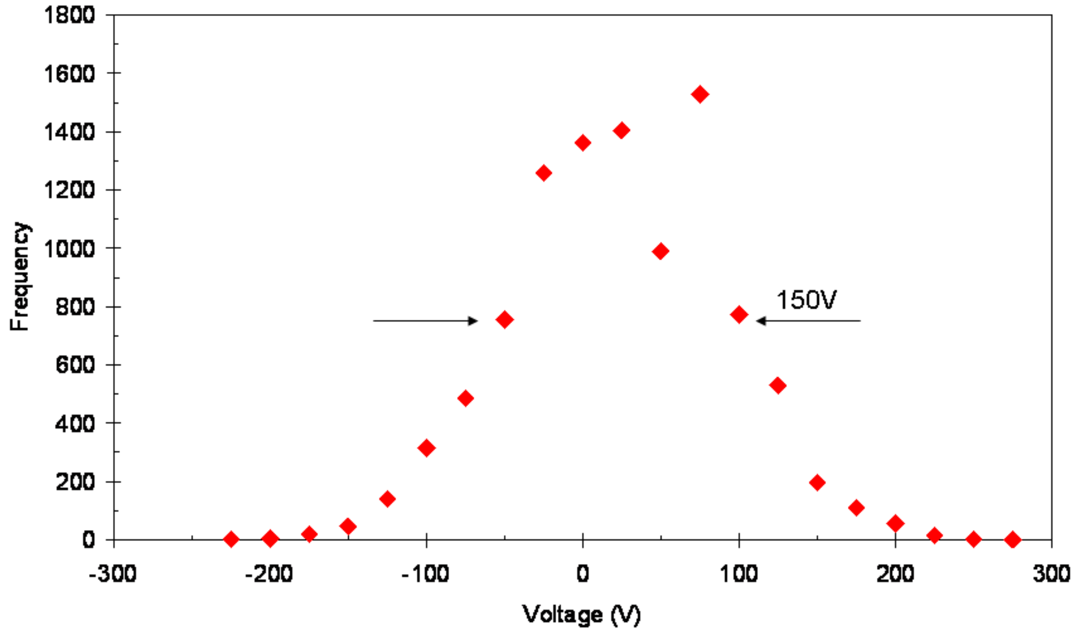

Figure 3. Voltage Ripple Distribution for the ripple frequency less than 5 kHz.