IONIZATION PROFILE MONITOR (IPM) OF J-PARC 3-GeV RCS

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Abstract

Residual gas Ionization Profile Monitors (IPMs) are used in the J-PARC 3-GeV RCS for the observation of circulating transverse beam profile. In IPM system, the ions and electrons produced by the beam passing through chamber lead to Micro Channel Plate (MCP) by the external electric field, and the signals from the MCP are observed as the beam profile. The IPM system was performed an upgrade plan for the optimization of the electric fields and the observation of beam profile by the elections. This will be reported the status of upgraded IPM.

INTRODUCTION

The residual gas Ionization Profile Monitors (IPMs) are installed in 3-GeV RCS and MR [1]. The RCS IPM is a monitor to observe a circulating transverse beam profile in the ring, and consists of the electrodes for external electric fields, magnets for external magnetic fields, Micro Channel Plates (MCPs) for detection of produced ions and electrons, and the Electron Generator Array (EGA) [2] for calibration of the MCP gain. Details of the RCS IPM system are given elsewhere [3]. The positively-charged ions or negatively-charged electrons produced by the beam passing through the residual gas in vacuum lead to the MCP by the external electric field, and then the projected beam profile is reconstructed from the MCP signals detected on the multi anode electrodes. The external electric fields with high uniformity are required in order to project the beam profile. There are two operation modes, which are ion and electron collection mode. At present, the ion collection mode are mainly used at the beam test, however, the electron collection mode with magnetic field are needed in the high intensity beam operation from the view point of a high space charge force.

From the beam test, it found that the external electric field was distorted and the measured beam profile on the ion collection mode was also shrunk to a half [1]. The plan for the solution of the issue was discussed in [4]. The new electrode structure, electric potential patterns and MCPs of two IPMs used at present were replaced and upgraded during summer shutdown 2012. This paper will be report the result of IPM on beam test after the replacement.

RESULT OF BEAM-BASED CALIBRATION AND NEW ISSUE

After summer shutdown, the beam test was performed on October 2012. In the test, beam-based calibration of the upgraded IPM was performed.

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Uniformity of Electric and Magnetic Fields

The uniformity of electric and magnetic fields of IPM was checked by an observed beam position for a controlled one in the beam storage operation, which means the no magnetic fields ramping and no acceleration of RCS. The two IPMs has the same electrode configuration and field mapping. Therefore, the field uniformity was checked at only IPM for horizontal projection.

The horizontal IPM was located at high-dispersion point in the RCS ring, and the dispersion functions (η =4.0574 m) are understanding and controlled over the ring [5]. So, we can control the beam position by momentum shift depend on RF frequency. In the study, the frequency is fixed at first 2 ms, smoothly changing from 2 to 10 ms, and fixed from 10 to 20 ms. The momentum shift $\Delta p/p$ fixed after 10 ms were controlled the five parameters, which are −0.6, −0.3, 0, +0.3 and +0.6 %, where the time dependence of the beam profile was observed by the IPM.

The mountain plot of observed beam profile in case of $\Delta p/p$ = −0.6 and +0.6 % on ion collection mode is shown in Fig. 1. Then, the beam positions during beam circulation were estimated by fitting of Gaussian function. These beam positions for momentum shift patterns in case of ion and election collection mode are shown in Fig. 2. The observed beam position is gradually moving depend on momentum shift with time.

As the next, we made a comparison between the observed and controlled beam positions. The observed beam position for controlled one, which is shown in Fig. 3, was fitted by linear function. As the result of beam-based calibration, the ratio between the controlled and observed beam position in ion and electron collection modes are 0.934 and 1.116, respectively. For the result of ion collection mode, the uniformity of electric field was significantly improved because the ratio before the upgrade is about 0.5. For the electron collection mode, we developed the simple tracking code in order to understand the track of residual electron gas, and we found that the position shift was caused by unexpected magnetic field component of B_x. The non-uniformity of magnetic field in electron collection mode found, but it can use significantly by using the parameter of beam-based calibration.

We succeeded to significantly improve the uniformity of electric field by improvement of electric potential pattern, electrode configuration and MCP structure.

ISBN 978-3-95450-122-9

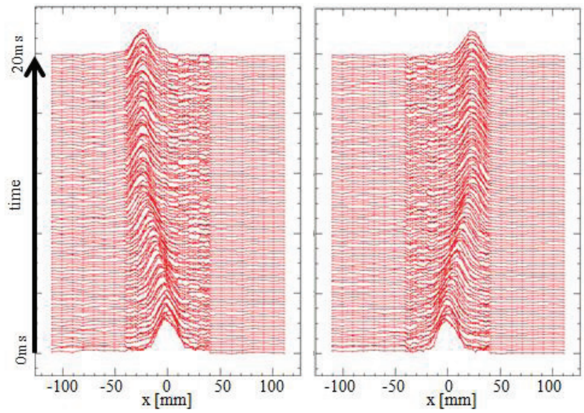

Figure 1: The mountain plot of observed beam profile by IPM. The left and right figures are the plot in case of momentum shift *Δp/p* of –0.6 and +0.6%, respectively.

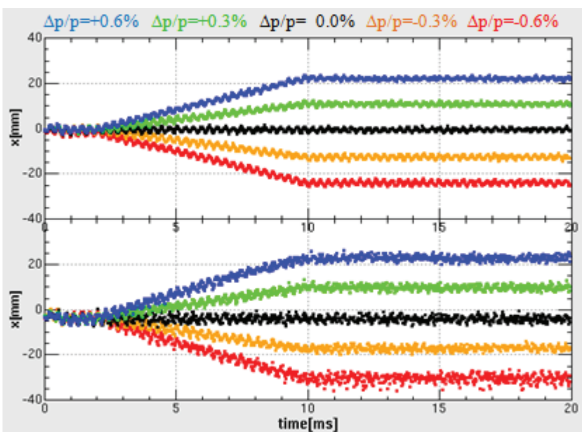

Figure 2: Observed beam positions for momentum shift patterns during beam circulation in ion (top) and electron (bottom) collection mode. Blue, green, black, orange and red are momentum shift pattern of *Δp/p*=+0.6, +0.3, 0.0, –0.3 and –0.6 %, respectively.

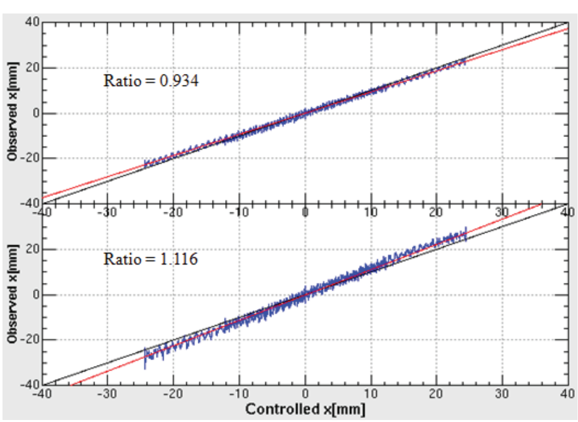

Figure 3: Observed beam position vs. controlled beam position in ion (top) and electron (bottom) collection mode. Blue, black and red lines are beam position data, line of ratio=1.0 and linear fit line, respectively.

New Issue of Noisy Output Signal

In the IPM, the amplified and emitted electrons from MCP are also detected as electrical signals at multi-anode electrodes. The signals are led to oscilloscope by cables through signal amplifier.

In the beam test, we found that the IPM output signal had a large noise at first 1.1 ms. The output signal is shown in Fig. 4. From FFT analysis of signal and some magnet ON/OFF, the noise are caused by pulsed injection magnets, which are four chicane magnets (SB) and four transverse painting bump magnets (PB). It is important to reduce these noises on the anode electrode and cables. For the fundamental solution, we will plan to change the structure of anode electrode and wiring in 2013 summer-autumn shutdown period. In order to achieve the lower noise condition, the development of anode electrode and wiring is under study.

On the other hand, we established how to analytically reduce the noise caused by pulsed injection magnets. The amplitude and timing of the noise is also fixed. So, the noise data was obtained in the condition of MCP OFF and then the analyzed signal was analytically deducted the noise data from the signal. The analyzed signal is shown in Fig. 4. At present, we can observe the beam profile by this analysis method. However, it is very important to fundamentally solve the noise condition in order to achieve the beam profile observation with higher accuracy. Especially, MCP encounters the gain saturation under the higher beam current so that operating bias voltage in the higher beam current must be lower one than that of lower beam current. It may result in lower signal/noise ratio.

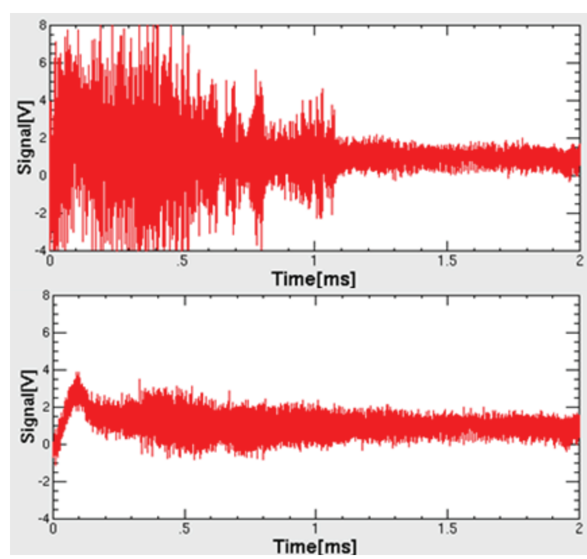

Figure 4: IPM output signal. Top plot is the signal at first 2 ms and bottom plot is the analyzed signal after deduction of noise data with MCP OFF.

New Issue of Noise by Wall Current of Higher Beam Current

In the IPM system, the beam chamber is now used as the earth ground of MCP's frame and electrodes for external electric field. As a result, it was the incorrect system.

As first problem, MCP has the over current trip in response to such as a discharge trip of high voltage power-supplying to electrode in the vacuum chamber. However, it doesn't really matter because the operation of IPM is also performed in only beam study and it do well to start up the MCP.

As major issue, it is an effect to noise from wall current caused by high-current beam. The beam with higher peak current causes the higher wall current to the beam chamber, and then MCP connected with the beam chamber is profoundly affected as noise to signal output by the wall current in the case of high-current beam operation in spite of hoping the beam profile observation under the operation. The signal in the case of MCP ON, OFF and difference of them is shown in Fig. 5. It is clear from the figure that the signal is detected in the case of both MCP ON and OFF. Additionally, it has greater effect with beam acceleration because the beam acceleration makes the bunch length short by adiabatic damping for longitudinal plane. The noise level from wall current is about ten times as large as the signal level. Even when we analytically deducted the noise data from the signal, the noise is comparable in level to signal.

For the solution of this issue, we will separate the ground earth of MCP's frame from the beam chamber in 2013 summer-autumn shutdown period.

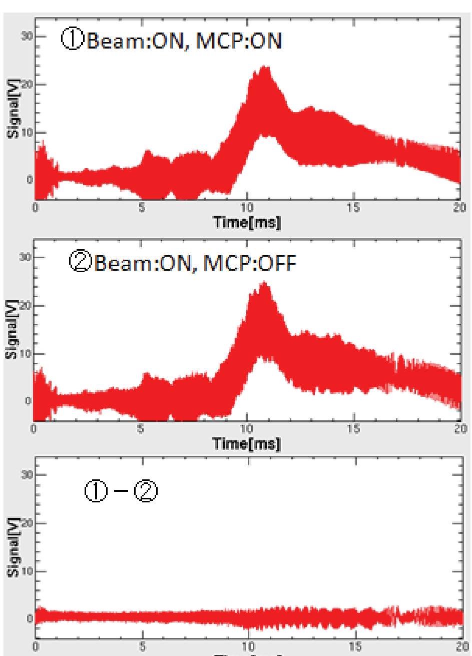

Figure 5: The signal in the case of MCP ON (top), OFF (center) and difference of them (bottom).

SUMMARY

The IPM of J-PARC 3-GeV RCS are also used in the beam test as a monitor to observe a circulating transverse beam profile in the ring. At present, the ion collection mode are mainly used at the beam test, however, the electron collection mode with magnetic field are needed in the high intensity beam operation from the view point of a high space charge force.

As report at IPAC 2012, the external electric field of IPM has non-uniformity and the observed beam profile is shrunk to a half. For the high uniformity of the external electric field, the new electrode structure, electric potential pattern and MCP structure have been planned. The developed components have been replaced during summer shutdown 2012.

In the beam test after the replacement, the beam-based calibration of the upgraded IPM was performed. From the result, we succeeded to significantly improve the uniformity of electric field by improvement of electric potential pattern, electrode configuration and MCP structure. The non-uniformity of magnetic field in electron collection mode found, but it can use significantly by using the parameter of beam-based calibration.

We found that the IPM output signal had a high noise caused by the pulsed injection magnets and wall current of high-current beam. For the fundamental solution, we plan to change the structure of anode electrode and wiring, and to separate the ground earth of MCP from the beam chamber in 2013 summer-autumn shutdown period.

ACKNOWLEDGMENT

We wish to appreciate Dr. K. Satou of KEK for educational suggestions, kind advices and supports to IPM development.

We would like to express my great gratitude to staffs of Komiyama Electron Company, Mr. M. Masuda, Mr. H. Chiba, Mr. T. Kagiwara, Mr. T. Watanabe and Mr. Y. Koike for many supports of IPM development and installation.

We would like to express my great gratitude to former staffs of Komiyama Electron Company, Mr. H. Funakubo and Mr. Y. Watanabe for many supports of IPM development and installation.

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