BEAM LOSS OF J-PARC RAPID CYCLING SYNCHROTRON AT SEVERAL HUNDRED kW OPERATION

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Abstract

A 3GeV Rapid-Cycling Synchrotron (RCS) in Japan Proton Accelerator Research Complex (J-PARC) has continuously provided more than 100kW proton beam to the neutron target since October 2009. And we also successfully accelerated 300kW beam for one hour on last December by way of trial. We found that the beam losses at H0 dump branch and the missing-bend cells in the arc section were higher and we need the measures for these losses in order to increase the output beam power

INTRODUCTION

The RCS in J-PARC has started to provide a 3GeV proton beam to neutron target since May 2008. After that, the beam intensity was increased through the beam study. Now the RCS has continuously provided more than 100kW proton beam to the neutron target since October 2009[1][2]. We have also tried to accelerate higher intensity beam, and last December we have successfully provided more than 300kW beam to the neutron target for one hour by way of trial. During these beam operation, we kept observation of the beam loss monitors (BLMs) located around the RCS beam line in order to establish the stable and low loss beam operation. We also investigated the residual dose of accelerator components during an interval of these beam operation. We report the beam losses at 120kW and 300kW beam power operations and the residual dose after such high intensity operation.

120kW USER OPERATION

The RCS is usually provided a proton beam to the neutron target continuously for two or three weeks, and accelerator conditioning/maintenance period is placed for several days in one operation. Figure 1 shows the residual dose distribution after one cycle operation at 120kW output beam power. In this case, we began the beam commissioning of RCS from 13th January, and neutron production in the MLF was started from 17th January at a beam power of 120kW. During this operation, the beam is stopped about four days for maintenance or conditioning. Finally, the neutron production was stopped in the morning on 3rd February, and the beam study was continued to the morning on 5th February with low repetition rate (less than 1Hz). After that, the residual dose was measured at 14:00 on 5th. The values in this figure are measured by the contact on the vacuum duct.

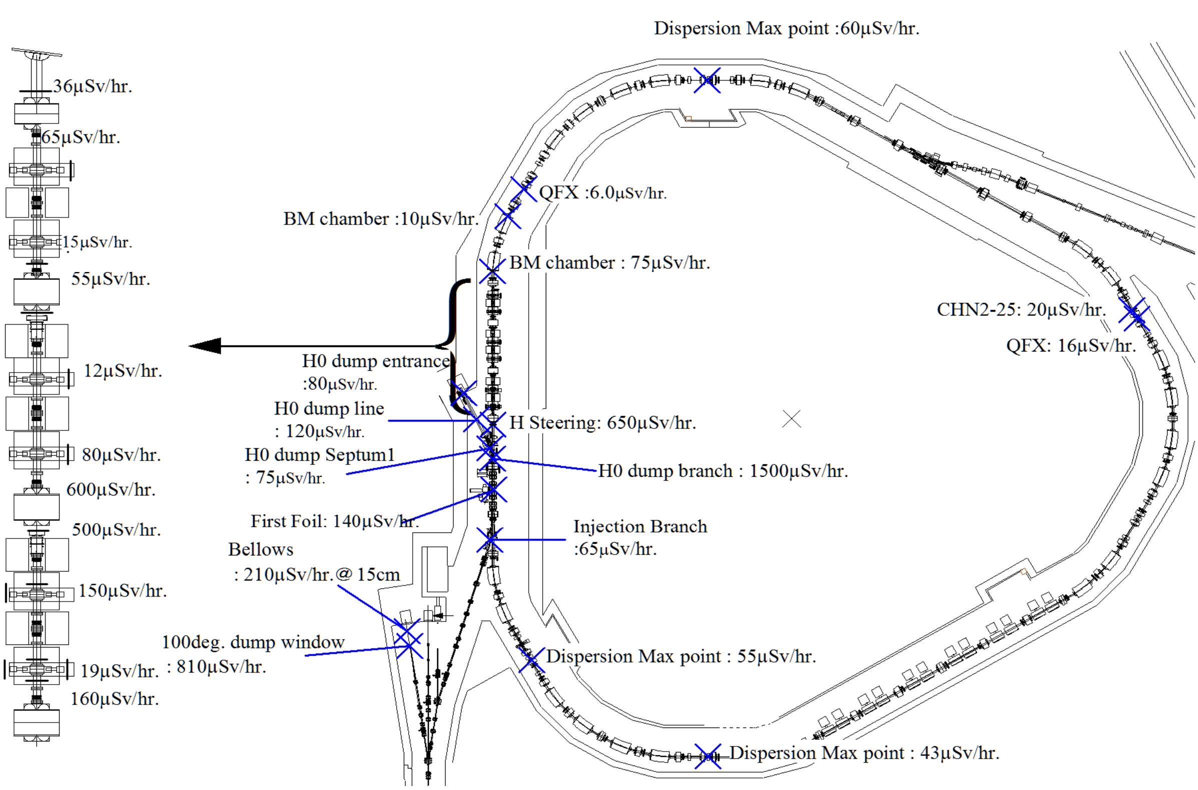

Figure 1: Residual dose distribution after 120kW operation.

During the 120kW operation, the Current Transformer indicated that the survival rate is about 99%. The residual dose around the accelerator components did not become so high after 120kW continuous operation and we were able to access almost all the accelerator tunnel. However, there were slightly higher residual dose values which could not be ignored around the injection area.

Among these, the residual doses at the H0 dump branch and the Beam Position Monitor (BPM) at the downstream of the H0 dump branch were caused by the scattering of the injection beam and the circulating beam at the charge exchange injection foil. Figure 2 shows the BLM signal dependence on the number of the foil hit at the H0 dump branch. It is shown that there is a strong correlation between the BLM response and the number of the foil hit. When we used the painting injection, the number of the foil hit was reduced and BLM signal became smaller. Our detailed beam study confirmed that it is proportional to the number of the foil hit[3][4]. Thus, now we used the painting injection and we adjusted the foil position in order to minimize the number of the foil hit.

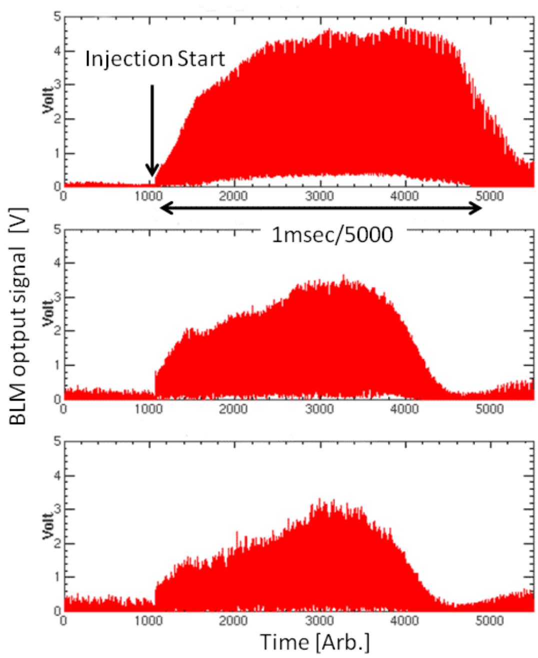

Figure 2: BLM signal at the H0 dump branch. Upper figure shows the BLM signal without painting. Middle figure shows the BLM signal with 100πmm-mrad painting. Lower figure shows the BLM signal with 150πmm-mrad painting.

In addition, dose of 65μSv/hr was observed between the injection septum magnet 1 and 2. The residual dose could be observed only at the opposite direction of the injection (H-) beam orbit of the vacuum chamber. Therefore, we consider that the beam loss was probably caused by the charge exchanged particles which was stripped its electron by any reason during the traveling through the L3BT line (such as collisions with residual gas, Lorentz stripping...).

The missing-bend cells in the arc section also have been activated as similar level (~50μSv/h). These losses were caused at the middle of the acceleration period and sensitive for the tune variations and the longitudinal painting pattern. We think that the tune shift due to the chromatic effect brought about these losses. On the one hand, since we have only DC power supply for the sextupole magnet system, the chromaticity was corrected only at the injection period. On the other hand, our rf system makes large longitudinal acceptance and some particles (that belong the longitudinal tail) have larger (or smaller) momentum than the synchronized particles. Thus the particle, that had large longitudinal amplitude, would cross the resonance and it was lost at the missing-bend cells (the missing-bend cells had large dispersion function value and there are the narrowest acceptance point except the collimator).

Other losses were localized on the collimator and there was no high activated area except above mentioned point.

300kW TRIAL

We have tried to accelerate more than 300kW beam last December in order to investigate the beam loss in such high intensity operation. Figure 3 shows the residual dose distribution after one hour operation and 4 hour cooling at 300kW beam power. Figure 4 shows the integrated BLM signals around the RCS beam line. Peak (1) in the figure 4(a) is the loss at collimator region, (2) is the loss at extraction septum, (3) is the loss at injection area and (4) is the loss at the missing-bend cell in the arc section.

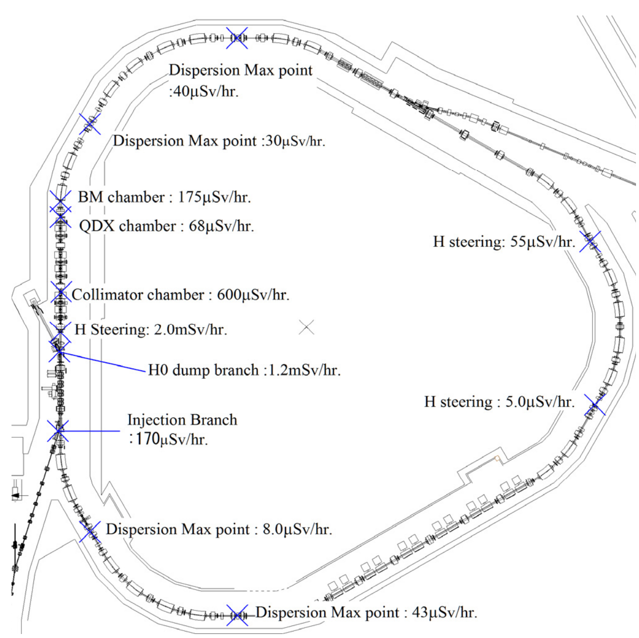

Figure 3: Residual dose distribution after 300kW operation.

The survival rate in 300kW operation is about 99%.

The residual dose measurement result shows that the BLM peak (1) is not so serious. These losses are taken into account and the radiation shield of collimator has enough thickness to mitigate the radiation influence from the collimator.

The reason of the major peak at (2) is just only the higher sensitivity of these BLMs. They contacted with the vacuum chamber and the lost beam just hit these monitors. There are no residual doses in the neighborhood of these BLMs.

Concerning with the BLM peak (3) and (4), this loss was caused by the same reason in the case of 120kW operation(of course it was enhanced).

Figure 4(b) has expanded the vertical range in Figure 4(a). It seems that almost all BLM signals become larger in the Figure 4(b) (See the circulated area (5) in the Fig. 4(b)). This phenomenon only occurred when the RCS was continuously operated at a repetition rate of 25Hz with 300 kW beam power. But in this study, we could not find any influence of these losses from the residual dose measurement around the entire ring. We need longer time operation test.

CONCLUSION

We investigated the beam loss at the 120kW continuous operation for neutron users and the 300kW trial operation. In the 120kW operation, we found the residual dose peak at the H0 dump branch and the BPM at the downstream of the H0 dump branch. These losses are caused by the scattering of the injection beam and the circulating beam at the charge exchange foil. We will change the foil design to smaller one in order to reduce the number of the foil hit. We also plan to install an additional collimator and its shielding at the H0 dump branch duct. This new collimator is going to install in summer 2011.

To reduce the loss at the missing-bend cells, now we construct the AC power supply for the sextupole magnet. It will set up in this summer.

Concerning with the beam loss at the injection septum and the losses at a 25Hz high power operation, we will study more detail of those origin.

REFERENCES

[1] M. Kinsho et al., in these proceedings.
[2] H. Hotch et al., in these proceedings.
[3] P. K. Saha et al., in these proceedings.
[4] H. Harada et al., in these proceedings.

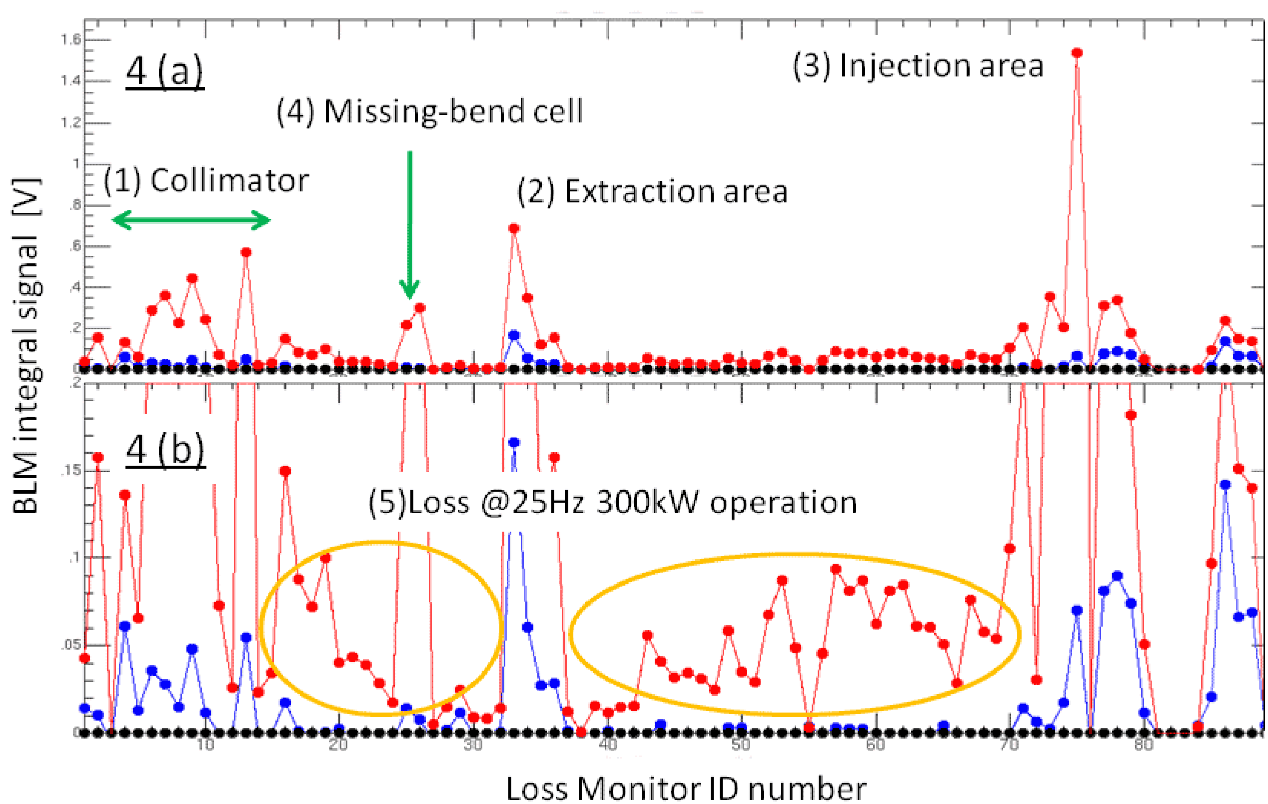

Figure 4: The integrated BLM signals around the RCS beam line. The BLM signals were integrated during acceleration period (20msec). Horizontal axis is the ID number of the BLMs. Blue line is the BLM signals at 120kW and Red line is the BLM signals at 300kW.