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# AN INTELLIGIENT TRIGGER ABNORMAL BEAM OPERATION MONITORING PROCESSOR AT THE SSRF*

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*Abstract*

An intelligent trigger abnormal beam operation monitoring processor has been designed at the SSRF. By applying digital signal processing algorithms in FPGA, the processor keeps monitoring the beam operation status. It will output a trigger signal and store the turn-by-turn beam position data when abnormal events detected. The abnormal events include injection, beam loss, and abnormal disturbance. This ability makes the processor a powerful tool for abnormal operation causes analysing and machine study.

## INTRODUCTION

SSRF beam current was increased from 220mA to 240mA at the end of 2013. Occasionally partial beam loss happened during the current upgrade period. BPM turn-by-turn data around the abnormal operation event is very useful to analyse the possible causes. SSRF has more than 140 Libera DBPM processors distributed around the 20 cells storage ring. Only when external interlock signal is received the DBPM to lock TBT data for analysis. Interlock signal is given only when beam lost completely or the beam orbit out of the preset range, partial beam loss is not included. This character makes Libera DBPM helpless for analysing the possible causes when partial beam loss happened. SSRF plans to increase the current to a higher level, final aim is 300mA. There is a very necessary to have an efficient tool for future current increasing.

SSRF storage ring runs at top-up mode since December 2012. To maintain the current at 240±2 mA, electrons are injected every 10 minutes. The injection disturbance introduced transverse oscillation gives opportunity to monitor the real-time tune value. Tune value is a very important indicator to evaluate the machine status. By applying FFT method on sampled BPM turn-by-turn data during injection, we can get tune value every 10 minutes.

Above applications require a specific DBPM with functions monitoring the ring status, when partial beam loss and injection are detected, it can intelligent triggered to store BPM turn-by-turn data automatically.

## DBPM PROCESSOR

SSRF have developed a DBPM processor since 2007 [1, 2], the processor consists of two boards: a mezzanine board with four channels RF conditioning modules and ADCs, a carrier board with an ARM and a FPGA. Signals from four channel BPM pickups are fed into RF conditioning modules on the mezzanine board firstly. Then signals are filtered with band pass filter (Surface Acoustic Wave filter) to centralize in 500MHz with band width of 20MHz. Then the signals are maintained at an appropriate level with attenuators and amplifiers. After the conditioning, signals are sampled with ADCs (16bits, 117MHz) by means of undersampling theory. The digitized signal is processed with FPGA (Xilinx xc5vfx70t) on the carrier board. The implanted distributed control system (EPICS) on the ARM(s3c6410) made it an all-in-one instrument. Figure 1 is the architecture of DBPM processor, Figure 2 is the picture of the processor.

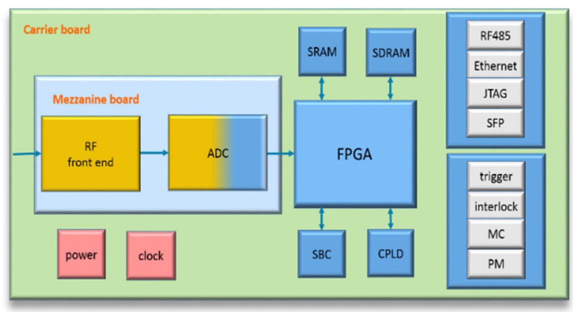


Figure 1: DBPM processor architecture.

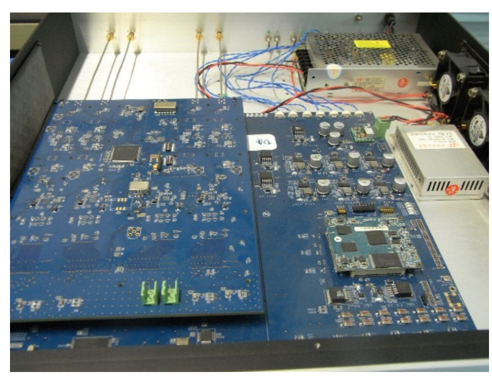

Figure 2: DBPM processor.

By applying FPGA, the DBPM provides different rate beam position data, including 694 kHz turn-by-turn (TBT) data, 50 kHz data, 10 kHz fast application (FA) data and 10 Hz slow acquisition (SA) data. The spatial resolution of TBT data is about one µm. The FPGA's powerful programmable ability enables us implement the abnormal beam operation monitoring function on the DBPM.

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## FUNCTION DESCRIPTION

The whole function is depicted in Figure 3. We have designed two abnormal trigger occasions: beam loss (trigger0) and injection (trigger1). The FPGA will output trigger signal and a tag (indicating the trigger type) to CPU processor (ARM) once it meets one of the occasions. At the same time, the trigger signal is output to a 16384×4 points FIFO on the FPGA, which stores four channel TBT data in continuous mode before trigger. When trigger received, the FIFO will turn into capture mode. It will capture 8192×4 points more TBT data after trigger. Now the FIFO has store 16384×4 points TBT data, half before trigger and half after trigger. ARM begin to read and store the data according to the tag when trigger received and the FIFO is full.

### *Trigger0*

Firstly, TBT data is processed with a mean filter to delete noise interference. Then sum the four channels data. By comparing the around sum values, the beam loss judge module will generate trigger signal once the difference between the values is bigger than a preset threshold.

### *Trigger1*

Firstly doing sub/sum calculation to the data from channel 1 and 3. The calculated data contain beam horizontal and vertical movement information. Then applying 1024 points FFT algorithm on the data. We have designed a two stage FIFO before the FFT to avoid events missing. By comparing the maximum FFT value with a preset threshold, the abnormal judge module will generate trigger signal once the value not in the range.

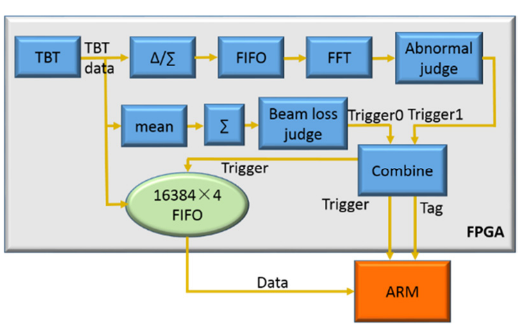

Figure 3: Function diagram.

## ONLINE TEST

After the design finished, processor has been moved from lab to SSRF storage ring cell 11 for on-line beam tests, connecting to the backup BPM.

### *Tune Measurement*

Figures 4 and 5 are the spectra waterfall plot of the measured 3 hours horizontal and vertical beam position at 2014.09.02. The spots indicate the tune value. Figures show that the horizontal tune vibration is about 0.003 and vertical tune vibration is about 0.002 at that time.

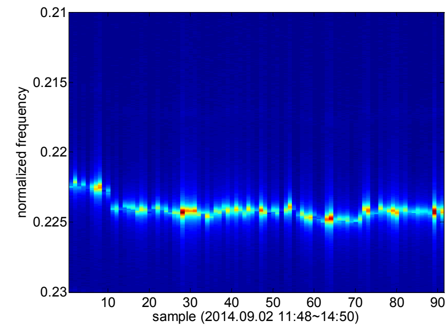

Figure 4: Horizontal position spectra.

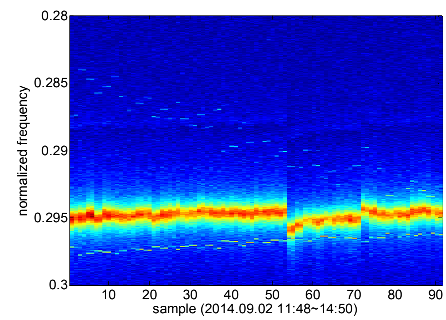

Figure 5: Vertical position spectra.

### *Beam Loss Measurement*

The processor kept monitoring the beam status for a long period. We observed totally beam loss at 2014.11.19 and 2014.11.21, they are show at figure 6 and figure 7 respectively.

Figure 6 shows that before beam loss, the beam horizontal position gradually deviated from normal orbit, till the beam lost. Checking with Elog, we found that the RF 1# of storage ring was breakdown at that time. When RF doesn't work properly, the horizontal orbit will drift firstly, this is because the horizontal orbit depends on the RF frequency, power and phase. This explains the recorded phenomenon in figure 6.

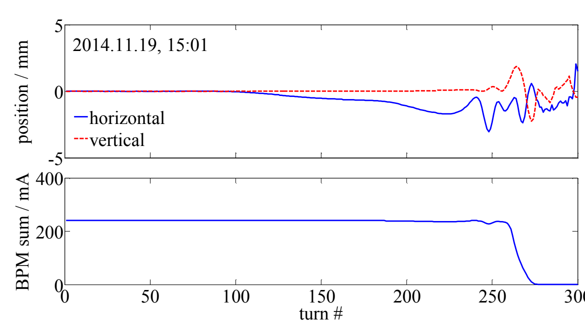

Figure 6: RF breakdown introduced beam loss.

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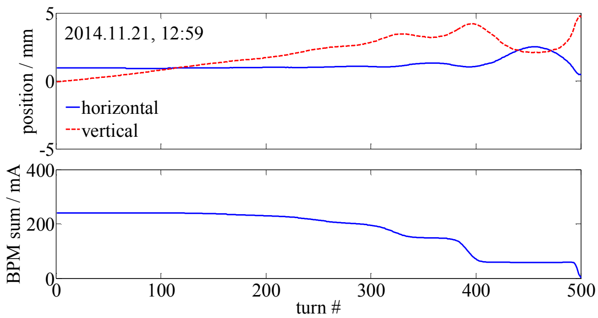

Figure 7: Quadrupole magnet introduced beam loss.

Figure 7 shows that the beam vertical position drifted increasingly before and during the beam loss, but the horizontal position doesn't change much. Checking with Elog, we found that the C13 quadrupole magnet power has been over temperature protected at that time. Quadrupole breakdown will lead to vertical orbit drift. When the beam overflow physical aperture, it will lost for scraper.

Above two beam lost events fitted very well with the recorded beam position phenomenon.

## CONCLUSION

Preliminary applications show that the intelligent trigger processor can monitor storage tune value and store beam position data for analysing when beam loss happened. Because the partial beam loss didn't happen again, partial beam loss data didn't get yet. The processor can be a useful tool for SSRF status monitoring and machine research. Next step we plan to develop an online beam lifetime monitoring module on it.

## REFERENCES

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[2] L. W. Lai, Y. B. Leng, et al., "The Study and Implementation of Signal Processing Algorithm for Digital Beam Position Monitor", MOP174, PAC2011, New York, USA (2011), p.414-416.