Status of the Intra-bunch Feedback at J-PARC Main Ring

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LINAC
40mA (50mA)
3 GeV RCS
500 kW (1MW) ← operation

30 GeV MR
350kW (750kW) ← one shot

ν detector

Kamioka

295 km

Kamioka

MLF

Hadron hall

ν detector
Outline

• Introduction
  – Upgrade history of the J-PARC MR transverse feedback

• Feedback during acceleration
  – Timing slip
  – Timing matching
  – Initial result

• Summary and prospect
J-PARC MR parameters

- Circumference: 1567.5 m
- Injection Energy: 3 GeV
- Extraction Energy: 30 GeV
- Revolution at injection: 5.384us (185.7kHz) RF 1.67MHz
  at extraction: 5.231us (191.2kHz) RF 1.72MHz
- Harmonic number: 9
- Repetition time for fast extraction: 2.5 s

At high beam power
- Collective motion causes beam losses, other than non-linear resonances (due to space charge).
Two obstacles

(1) Injection error & succeeding collective motion

\[ N_B \sim 1.67 \times 10^{13} \text{ ppp} \]

2 bunches

\[ \xi_x \sim -7.5 \]

\[ \xi_y \sim -7.0 \]

In the image, the circulating beam is kicked by the kicker pulse-tail and reflection.
(2) Instability during acceleration

Instabilities has been observed at the beam power 230kW, with chromaticity $\xi_y=-0.3$. We avoid this instabilities by tuning chromaticity $\xi_y=-3.2$.

Keigo Nakamura, et al., IPAC2014, Dresden, Germany
B x B feedback

Bunch-by-bunch (BxB) feedback
slice ~ 590 ns

Kick

Beam bunch
Intra-bunch feedback

Intra-bunch feedback slice ~ 10 nsec

Kick

Beam bunch

FIR filter in iGp12
For the horizontal (x) plane

- Beam
- Stripline BPM
- Stripline kicker
- Oscilloscope
- DAC+
- DAC-
- ADC+
- ADC-
- DC offset
- RF clock
- x64
- x2
- Revolution clk
- Revolution clk
- Power Amp.
- Injection timing

Same as the vertical (y) plane

DC offset

RF clock

x64

Revolution clk

Revolution clk

Power Amp.

Injection timing

Attenuator

iGp12

DAC+

DAC-

Attenuator

x2

Revolution clk

RF clock

x64

Revolution clk

Power Amp.

Injection timing

Same as the vertical (y) plane
For the horizontal (x) plane

Beam

Hybrid 100KHz-200MHz

Stripline BPM

Stripline kicker

DC offset

RF clock

revolution clk

trig. for timing table

 Oscilloscope

iGp12

Power Amp.

100KHz-100MHz

Attenuator

Same as the vertical (y) plane
Trigger for timing table

iGp12 for y

iGp12 for x

2015/01/13
3 GeV injection flat bottom
Oscillation of one bunch slice

Without FB

Without FB

BxB FB on

Bunch signal every 5 turns

Without FB

BxB on

+ intra-bunch FB on

+ intra-B on
Timing slip

Parameters are changing during acceleration up to 30 GeV

Observing the beam and the RF kick simultaneously
Example of revolution frequency

\[ f_{\text{rev}} = 185.7 \text{kHz} \rightarrow 191.2 \text{kHz} \]
Example of synchronous phase

We need rapid parameter optimization
Sampled by iGp12 $\leftrightarrow$ Compare $\rightarrow$ signals on the stripline kicker

$\Delta \phi_B(t)$ beam transit time

Stripline kicker = directional coupler
can observe
beam signal
RF power from the feedback system

$\Sigma$ – signal of stripline kicker

Sampled signal @iGp12

marker @slice#5

marker @slice#570
Unit in oscilloscope (kicker) = \textit{time (sec)}

Referencing the marker #5, 570 scaling and shift

Unit in iGp12 RF CLK x 64
Unit in oscilloscope (kicker) = **time (sec)**

Referencing the marker #5, 570
scaling and shift

Unit in iGp12
RF CLK x 64
Unit in oscilloscope (kicker) = \textbf{time (sec)}

Referencing the marker #5, 570
scaling and shift

Unit in iGp12
RF CLK x 64
Unit in oscilloscope (kicker) = time (sec)

Referencing the marker #5, 570 scaling and shift

Unit in iGp12 RF CLK x 64
Unit in oscilloscope (kicker) = time (sec)

Referencing the marker #5, 570 scaling and shift

Unit in iGp12 RF CLK x 64
Unit in oscilloscope (kicker) = time (sec)

Referencing the marker #5, 570 scaling and shift

Unit in iGp12
RF CLK x 64
Unit in oscilloscope (kicker) = time (sec)

Referencing the marker #5, 570 scaling and shift

Finally superpose the beam signal by shifting horizontally the amount of shift = the delay time that we want
Timing CNTL by preset table

2.48 sec cycle

Kinetic Energy [GeV]

STATE 1  2  3  4  5  ....

Time from P1 (sec)

f rev
Timing CNTL by preset table

External trigger initiates each "STATE"
STATE specifies the delay, filter gain, phase, # of tap

a function of "iGp12"
Timing CNTL by preset table

STATE 1  2  3  4  5  ......
Timing CNTL by preset table

2.48 sec cycle

Kinetic Energy [GeV]

STATE 1  2  3  4  5  ......

Time from P1 (sec)

f rev

188000
187500
187000
186500
186000
Timing CNTL by preset table

2.48 sec cycle

Kinetic Energy [GeV]

STATE 1  2  3  4  5  .....
Timing CNTL by preset table

2.48 sec cycle

STATE 1  2  3  4  5  ……

Kinetic Energy [GeV]

Time from P1 (sec)

\[ f_{rev} \]
Timing CNTL by preset table

STATE 1  2  3  4  5  ...
Timing CNTL by preset table

2.48 sec cycle

Kinetic Energy [GeV]

STATE 1 2 3 4 5 ......

f [rev]

Time from P1 (sec)
Timing CNTL by preset table

2.48 sec cycle

Kinetic Energy [GeV]

STATE 1  2  3  4  5  ......

Time from P1 (sec)
Timing CNTL by preset table

2.48 sec cycle

STATE 1  2  3  4  5  .......

Kinetic Energy [GeV]

Time from P1 (sec)
Timing CNTL by preset table

2.48 sec cycle

STATE 1  2  3  4  5  ......
Timing CNTL by preset table

2.48 sec cycle

Kinetic Energy (GeV)

STATE 1 2 3 4 5 . . . .
iGp12 parameter settings

FIR filter parameters

Injection flat bottom

This trial

Acceleration

FIR filter parameters
2015. 7. 1
2 bunches, ~80kW, ~4.2×10^{13} p

BEFORE

shot513300

Δx

Δy

ξ_x \sim -5.9
ξ_y \sim -5.2

P1+100ms P2

Acceleration

STATE 1
STATE 2
STATE 3
STATE 4
STATE 5
STATE ...

20 ms/div
BEFORE

shot513300

\( \xi_x \sim -5.9 \)

\( \xi_y \sim -5.2 \)

AFTER

shot513301

Stabilized

only by switching on

STATE 2

\( \Delta x \)

\( \Delta y \)

P1+100ms P2

Acceleration

2015. 7. 1
2 bunches, ~80kW, ~4.2\times10^{13} \) p
Summary

✓ Transverse intra-bunch feedback during acceleration period was successful upto P2 + ~80 ms.
  • Horizontal instability at the beginning of acceleration was suppressed.
  • Stable parameters (delay, gain, frequency) are obtained

Prospect

➢ Further parameter optimization for further accel. period
➢ Stability check both with experiments and simulations
➢ Contribute high beam intensity upgrade