Recent Improvement of Slow-Extraction at HIMAC Synchrotron



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Contents

- Overview of HIMAC facility
- Requirements to slow-extraction at HIMAC
- Fast beam on/off
- Time structure control
 - microscopic spill ripple reduction (kHz order)
 - global spill control (10 Hz order)
- Intensity control
- Beam size control
- Summary





Bird's eye view of HIMAC





Requirement to slow-extraction at HIMAC

Requirements from scanning irradiation....

- Fast beam ON/OFF
- Time structure control
- Intensity control
- Precise beam size control

RF-knockout slow-extraction (RF-KO extraction)





RF-knockout extraction (1)

Diffusion by <u>transverse RF-field</u>

- Constant separatrix
- Fast response of beam on/off
- Easy operation

Frequency modulation (FM)

Amplitude modulation (AM)





Fast response of beam on/off

Particles can be spilled out from the separatrix by diffusion of RF-KO.

Longitudinal motion contributes to extraction through horizontal chromaticity.





Fast response of beam on/off



By turning on/off both transverse and longitudinal RF-fields, cut-off time of $50 \ \mu$ s is achieved.





kHz order ripple reduction





Effect of synchrotron oscillation



NIRS





Global spill control (1)

Amplitude of RF-KO

time

In the RF-KO slow-extraction, global time-structure can be controlled by the amplitude modulation (AM) of transverse RF-field.

Originally, we have used linear AM function to expand the spill length.



In order to obtain square shaped spill, suitable AM function is necessary!!



Global spill control (2)





Global spill control (3)





Global spill control (4)



- 1) Without feedback: the result is in good agreement with the simulation one.
- 2) With feedback system: square shaped spill is realized.



Intensity control Preliminary test result AM+feedback sig. MY MUM **Beam current** 200ms/div Spill themation

Now, we develop intensity control system during a single flattop. Based on simple model, AM function is analytically calculated to control intensity. Dynamic range of more than 10 is expected.

2s



Precise beam size control



extracted beam at the extraction channel as initial condition of HEBI measurement!! Measurement method of outgoing separatrix was proposed and verified.



Measurement method of outgoing separatrix

- 1) Inserted and fix rod1 at x = x1.
- 2) Search a shadow of rod1 at s2 by changing the horizontal position of the rod2 every operation cycle of the synchrotron.





Simulation of measurement





Comparing simulation with measurement, twiss parameters was defined.



Optics was redesigned to match the extracted beam.







Summary

Toward requirements from scanning irradiation...

 Fast beam on/off NIM-A 489, p.59, 503, p.485.

very fast cut-off time of 50 μ s is achieved.

•Time structure control NIM-A 522, p.196.

Intensity control

Beam size control