5–3 Realization of High-Intensity Proton Beams

— Beam-Instability Issues and the Measure at the 3-GeV RCS in J-PARC —

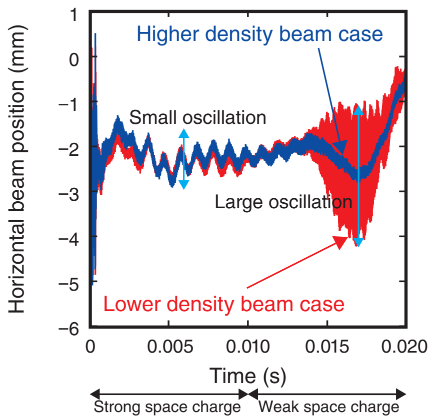

Fig.5-8 Measurement results of beam positions at the RCS
A bunch compression of only 2% makes an unstable beam (red) into a stabilized one (blue) by increasing the beam-current density.

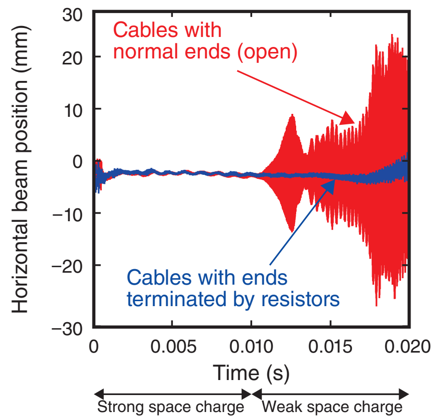

Fig.5-10 Dependence of beam positions upon terminal conditions
Termination of the cables' ends with resistors improves the unstable beam (red) into a stabilized one (blue).

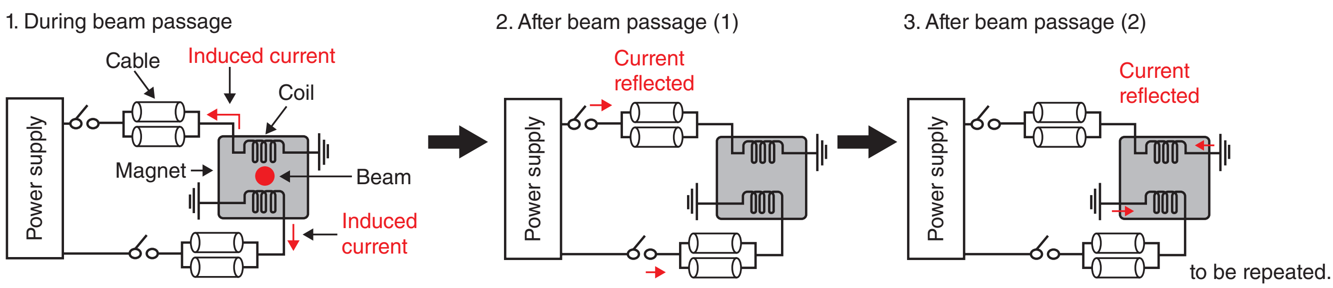

Fig.5-9 Schematic of beam-induced currents after a beam passes through the kicker magnet
Beam-induced currents are superposed every time the beams pass through the kicker, because the power supply is switched off during the ramping time.

Over the past decades, the power frontier of proton accelerators has been advanced up to the 1-MW level; such high-intensity beams largely tend to oscillate transversely, making it quite difficult to accelerate the beam. This is the so called beam-instability issues; such instabilities are excited by the interaction between the beam and the chamber walls, or the devices in synchrotrons. Recently, we have developed two new beam-stabilization schemes against beam-instabilities.

Fig.5-8 shows measurement results for the 750-kW beam at the 3-GeV Rapid Cycling Synchrotron (RCS) in J-PARC. The oscillation after 0.010 s on the red line represents the beam instability.

The RCS is equipped with kicker magnets, which extract the 3-GeV beam by exciting a pulsed magnetic field with a 300 ns rising time. The magnets are installed in vacuum, and so tend to make the beam unstable during the ramping time. We have developed a new theory, and predicted that the beam-induced current on the kicker cables should be the dominant source of beam instability (Fig.5-9). Accordingly, we have demonstrated stabilization of the unstable beam by terminating the ends of the kicker cables with resistors, i.e., by suppressing the beam-induced currents (Fig.5-10). Furthermore, we have successfully stabilized the beam instability by avoiding the resonance condition between the beam-oscillation frequency and the reciprocating frequency of the beam-induced current in the cables, without modification of the kicker cables' ends.

Our theory also predicts that the higher-energy beams tend to be unstable, due to mitigation of the space-charge-damping effect. As indicated by the red lines in Figs.5-8 and 5-10, the beam instability occurs at high energy, as expected. Finally, we successfully stabilize the high-intensity beam even after a ramping time of 0.010 s by compressing the beam length, i.e., by enhancing the space-charge-damping effects (the blue line of Fig.5-8).

These new schemes play an important role in establishing the beam-operation parameters toward the realization of a 1-MW-output beam power at the RCS.

Reference
Shobuda, Y. et al., Theoretical Elucidation of Space Charge Effects on the Coupled-Bunch Instability at the 3 GeV Rapid Cycling Synchrotron at the Japan Proton Accelerator Research Complex, Progress of Theoretical and Experimental Physics, vol.2017, issue 1, 2017, p.013G01-1-013G01-39.