LONGITUDINAL BEAM MOTION IN THE KEK BOOSTER SYNCHROTRON

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Abstract

The measurements of the longitudinal beam properties and high intensity effects of the KEK booster are presented. The beam intensity is limited mostly by the loss during capture process. Operation of the new RF station in cooperation with the existing one reduces the loss after capture. Severe longitudinal beam instabilities have been cured by modification of the phase-lock system and by introducing the $2f_s$ feedback loop.

1. Capture

For the single turn injection, about 90 % of the injected particles are captured.[1] As the number of turns is increased, the efficiency is reduced. This is mainly associated with the radial beam size enlarged up to the aperture limit in consequence of the multi-turn injection. Fig.1 shows the variations of the number of particles during capture, measured for several RF voltage programs. In present operation No.3 type of program is used. Further increase of the voltage makes the capture efficiency decrease, because of the radial expansion due to synchrotron oscillations.

Though the emittance of the injected beam must be small for efficient capture, too small energy spread creates severe filamentations during bunch formation and causes particles to spill from the bucket. For the normal operating voltage (No.3 in Fig.1), the optimum spectrum width is around 1.8 % for 95 % of the particles. In this case, the bucket would be 80 % filled at the end of the capture, provided the capture were adiabatic.

2. Transmission after Capture

Beam transmission from 1 ms after injection to the end is 0.75 ~ 0.80 at the present intensity of $\sim 5 \times 10^{11}$ p/p. Possible causes for the beam loss during this period are 1) small bucket area, 2) radial expansion due to synchrotron oscillations, 3) longitudinal blow-up and 4) transverse blow-up. Among them, lack of the bucket area is considered to be the largest factor. A typical bucket area curve derived from the voltage measurements is shown in Fig.2. It is clear that more voltage is needed during the first half of the cycle. To increase the voltage, the new RF station has been installed.[2] Test of parallel operation shows that the new station works well, though it needs further tuning. Parallel operation improves the beam transmission after capture from 0.81 (for single staion) to 0.92 as shown in Fig.3. The remaining loss may be attributable to the other factors mentioned above.

3. High Intensity Effects

As the beam intensity gradually increased toward the first target of 6×10^{11} p/p, a number of improvements were introduced to cope with the increased beam loading. Main modificatons are 1) provision for reducing the Q of the cavity and 2) improved beam feedback system for damping the longitudinal instabilities. Beam-loading instabilities occur just after injection where the voltage is still low. This is cured by increasing the dissipation in the power tubes, thus reducing the Q of the cavity system (containing the power tubes). The halving of the cavity Q makes the gap voltage acceptably smooth as shown in Fig.4. This is, however, not enough to overcome heavier beam loading which the cavity encounters when adiabatic capture is tried. Therefore it is necessary to provide another cure.

Longitudinal instabilities which were observed at the intensities over 3×10^{11} p/p are mainly dipole and quadrupole oscillations. The dipole oscillations are now suppressed by modification of the phase-lock system, and the quadrupole oscillations are completely damped by the $2f_s$ feedback loop introduced recently.[3]

References

1) M. Kondoh, et al.: IEEE Trans. NS-24, 1533 (1977).
2) K. Kudo, et al.: contribution to this conference.
3) S. Takeda, et al.: contribution to this conference.

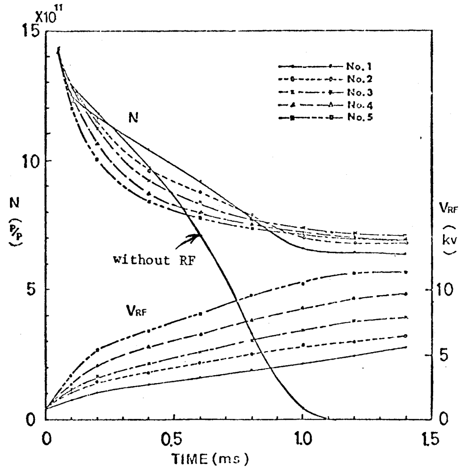


Fig.1. Number of particles just after injection; RF voltage as the parameter.

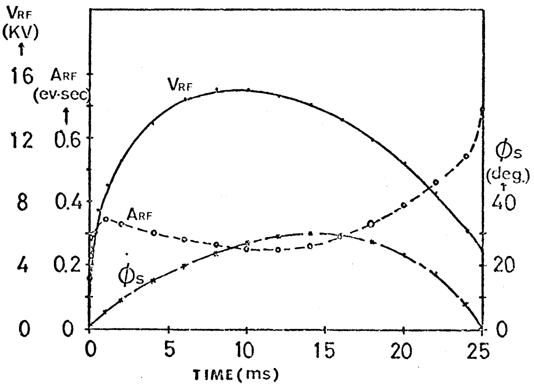
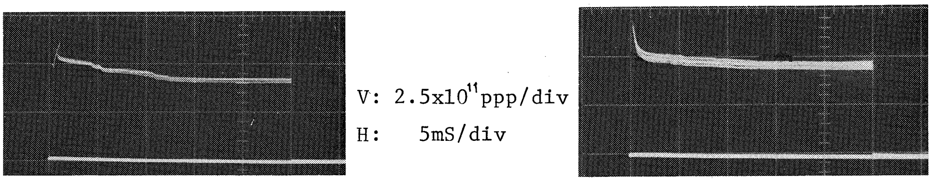


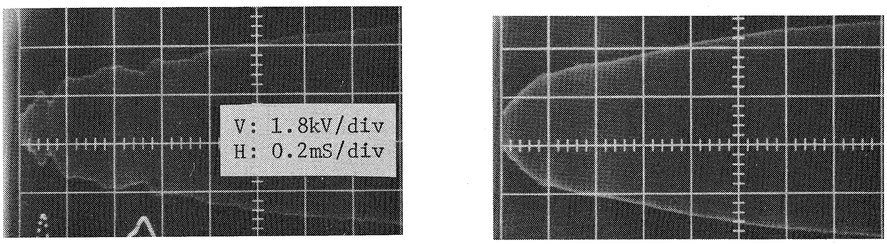
Fig.2. RF voltage, bucket area and equilibrium phase angle in present operation.



V: 2.5×10^{11} ppp/div
H: 5mS/div

(a) single RF station is operated. (b) two RF stations are operated in parallel.

Fig.3. Number of particles during acceleration (5 pulses are overlapped).



V: 1.8kV/div
H: 0.2mS/div

(a) with normal Q value. (b) with reduced Q value.

Fig.4. RF voltage in the early stage of acceleration.