LONGITUDINAL STABILIZATION OF BUNCHED BEAM IN THE BOOSTER BY A $2f_s$ FEEDBACK LOOP

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During the running of the KEK main synchrotron, longitudinal stability at the end of acceleration of the booster has been an increasing problem to get high intensity beams as stable as possible for main-ring-injection. At lower intensities than 3×10^{11} ppp, the problem could be handled by operating the machine with a properly chosen energy spread from the LINAC. It is, however, very difficult to damp the instability at higher intensities than 3×10^{11} ppp with this procedure. A damping system has been developed and tested on the machine. Complete stability is obtained at the highest intensities of 5.5×10^{11} ppp.

Longitudinal instability is observed by sidebands appearing around the revolution frequency f_{beam}. The KEK booster, like many other proton synchrotrons, incorporates a beam feedback system. It eliminates largely coherent phase oscillations of the bunch which is a sideband of the synchrotron frequency f_s or a dipole mode of instability. But the beam feedback has no effect on the bunch shape oscillations in first approximation. A main mode of the instability in the booster is a quadrupole type or the oscillation at $2f_s$ as shown in Fig.1.

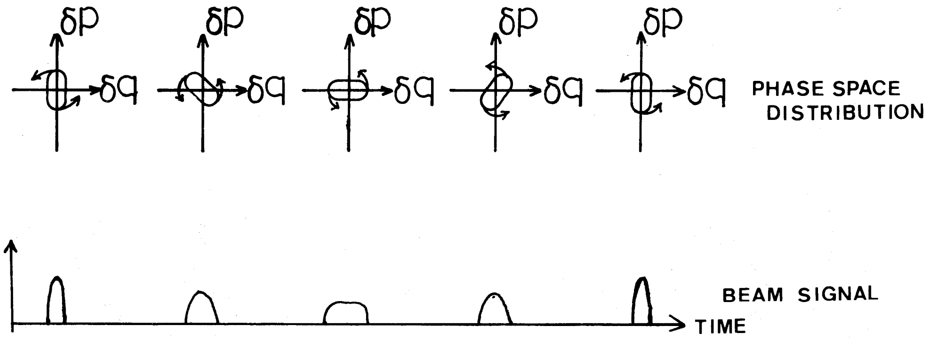

Fig.1. Quadrupole bunch shape oscillation.

As seen from Fig.1, the leading edges of the bunches are sensitive to the bunch shape oscillation. This fact is utilized to detect the feedback signal.

A block diagram of the feedback loop is shown in Fig.2. A phase pickup signal is passed through a saturable amplifier and a fast discriminator to maintain constant damping rates independent of intensity. The detector is a digital phase detector which determines the "lead" or "lag" phase relationship and the time difference between the leading edges of the waveforms. The detector is followed by a tracking bandpass filter tuned to $2f_s$. The output signal of the filter is feeded into a linear gate and a phase shifter to give a proper phase relation to the cavity. Finally the signal is added to the amplitude modulation signal. Fig.3 shows the effect of this additional modulation for the acceleration voltage. The cure is now used during the last 1/3 of the cycle. The intensities well over 5.5×10^{11} ppp can be accelerated with this technique.

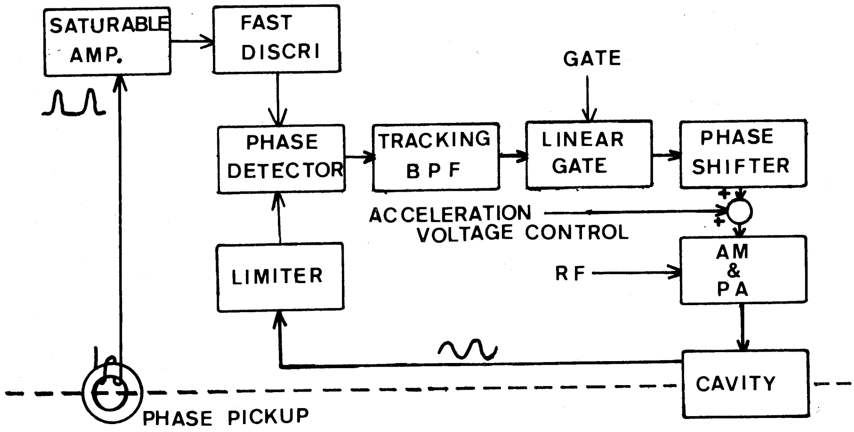

Fig.2. Block diagram of the $2f_s$ feedback loop.

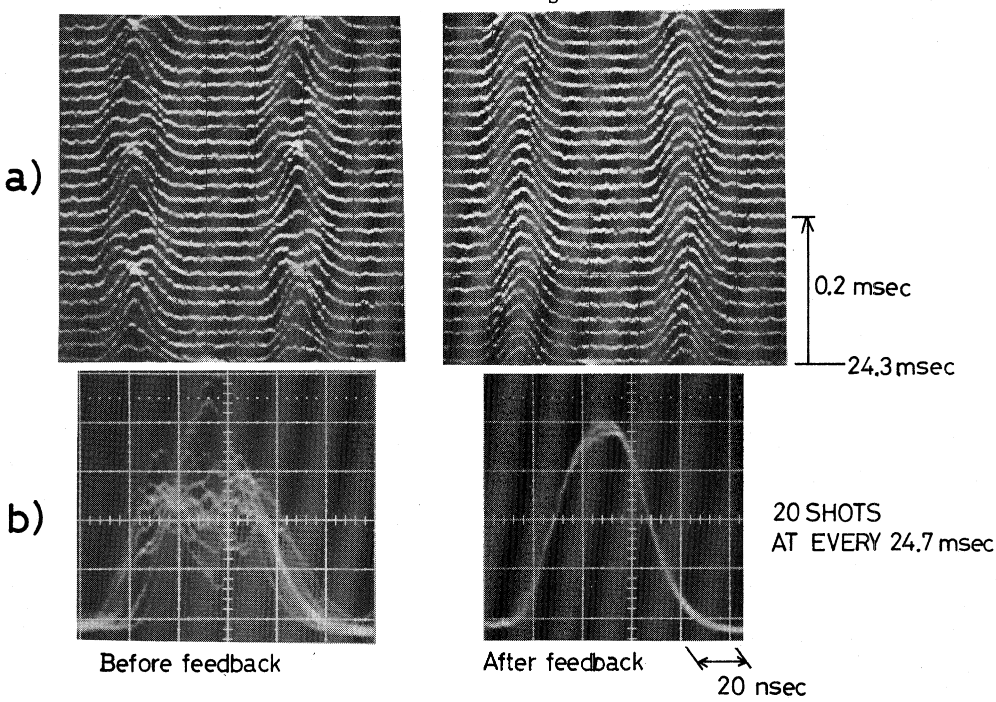

Fig.3. (a) Mountain-range display.
(b) Superimposed