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Longitudinal Phase Space Studies

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Date 3/29/78 Time 0900-2400 Experimenters E. Raka, E. Gill

Subject Longitudinal Phase Space Studies

OBSERVATIONS AND CONCLUSION

Introduction

The purpose of the first part of the period was to try and obtain clean, undistorted bunches after transition at 2.5×10^{12} and then to increase the intensity to greater than 9×10^{12} and observe the bunch shapes after transition. The second part of the period was used to investigate means of blowing up the longitudinal phase space area on a low energy flat top, i.e. below transition. Throughout the period, until 8 PM, considerable time was lost due to computer failure.

Procedure

The principal problem to be solved was a readjustment of the radial loop controls so that the so-called integrator would not be necessary until some time after transition. This was accomplished by changing the delay cable and generating a new radial correction program. Then, a radial jump at transition of ≈ 1.5 cm (β_{avg}) outward was obtained by the usual reduced phase jump method.[1] This provided the necessary space charge compensation for passage through transition at $2.5 - 3 \times 10^{12}$ with no blow up and essentially no bunch shape oscillations (the latter are rapidly suppressed by the bunch shape damper in any event).

Observations

The bunch widths at about 40 msec after transition ($\gamma \approx 10.7$) was ≈ 25 nanosec and very clean. Thus, the first part of the studies were successful in obtaining a beam quality similar to what had been seen often in the past, i.e. prior to 1977, say. At high intensity, i.e. 8.2×10^{12} the bunches 40 msec after transition had considerable structure due to the transition blow up and one could see oscillations about the center of the bucket. The total spread over five milliseconds was ≈ 55 nanosec. At intensities $> 9 \times 10^{12}$ this can increase to ≈ 80 nanosec.

When operating at these intensities one does not use the radial jump at transition since it does not prevent blow up above $\approx 3 \times 10^{12}$ if one has the nominal 0.5 eVsec/bunch phase space area. This blow up produces large bunch shape oscillations and since the bunches are generally not equally populated these can excite all the other coupled bunch mode besides the $n = 0$ mode which the damping circuit was designed to act upon. These other modes tend to confuse the loop since it contains a peak detector which senses the maximum bunch height. For the $n = 0$ mode all the bunches are in phase so the signal is unambiguous while for $n = 1 - 11$ the bunches have varying phase relationships. Hence, the signal is not correct for the $n = 0$ mode. Thus, the damper was normally not turned on until ≈ 0.1 sec after transition when the bunches had spread considerably and the large gyrations within the bucket had partially subsided. Still one observed that the damping loop controlled the bunch shape oscillations late in the cycle better than before this last shutdown.

This could be due to the fact that the center frequency of the loop filter was reduced from 12 kc to ≈ 2.4 kc. Thus, at the bunch shape frequencies of 350-400 cps after transition, one has more low frequency gain where it is needed relative to high frequency gain where it is not needed. Also, it appears that the bunch gyrations after transition while still considerable are less than before the shutdown. This may be due to the replacement of many vacuum chamber grounding resistors and rf damping network during the shutdown. In any event, it was subsequently observed (4/3/78) that the bunch shape loop could be closed shortly after transition without inducing beam loss as had on occassion happened in the past. On the contrary, it was able to measurably limit the amount of blow up present, resulting in a much smaller beam core than had ever been obtained previously at high intensity. One still finds tails on the beam out to 60-70 msec, but most of the beam is within 35-40 nanosec at the end of the cycle. This improved operation is clearly evident when one observes the peak detected signal from E-20.

The controlled bunch blow up was tried out on an ≈ 0.5 sec flat top at three energies, 1.38, 1.54 and 1.62 BeV. Because of the timing comb used for the flat top ("J") one could not add more than a few msec of rectify before going into invert. This altered injection conditions considerably because of the different remnant fields resulting from such a magnet cycle. At the higher energy the effect was less but even with retuning of the injection line intensities of 3.6×10^{12} were the best one could obtain.

Two methods of blow up were tested; noise excitation applied to a phase shifter in the low level rf system and gated modulation of the phase shifter in the region of the phase oscillation and twice phase oscillation frequencies. Noise modulation either had no effect at low levels or produced beam loss as well as blow up at high excitation levels. With sine wave modulation one could obtain a blow up of 30-40% with little or no loss. Observations were made with the beam current transformer and the medium bandwidth current XFMR at F-15. The latter's signal is inversely proportional to the bunch width while the former depends upon the total current. Excitation at ≈ 2.7 KHz produced a loss that occurred over ≈ 70 msec while excitation at 5.4 KHz produced a loss that occurred in about 25 msec. At too low an excitation, little blow up occurred while too much caused beam loss. The blow up occurred well along on the flat top and one could control the time to some extent by varying the rf amplitude slightly.

This behavior could be explained by the beam phase oscillation frequency changing slowly due to a non-zero $\dot{B}$ on the flat top. Then the beam would drift into resonance with the excitation frequency and blow up enough so that due to non-linearities in the bucket few particles would be left with the exciting frequency. No further dilution would then occur and the amount of blow up would depend upon the initial distribution among other factors.

The best results were obtained with the higher energy flat top and this is where one should start for further tests. Although blow up could be produced without loss, much remains to be done before one could make any statements about the usefulness of this method.

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1. E.C. Raka, Betatron Frequency Jump at Transition in the Brookhaven AGS, AGS Div. Internal Report 70-1 (1970).