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Longitudinal Impedance Measurement V

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OBSERVATIONS AND CONCLUSION

Introduction

First it should be noted that there was an error in the sign of the impedance found in AGS Studies Report 114. The sign of the incoherent frequency shift was indeed positive while this sign was negative at 27.4 GeV (Report 109) not positive. Hence, at ≈ 6.64 GeV (below transition) the impedance was inductive. Thus the value of 15.7 Ω is only about twice as large as one had anticipated and is reasonable due to the sources of error mentioned in Report 114.

Thus the purpose of this run was to go to lower energy where the impedance was expected to be capacitive. As pointed out in ISA Tech Note 69[(1)] an energy of 5 GeV or less should be satisfactory.

Procedure

As usual, a flat top was set up using time comb "F". Both frequency and radial loops were lcosed though the latter is less sensitive at the energy of ≈ 4.92 GeV used for this run by a factor of ≈ 1.7 than at 6.64 GeV. Again the coupled bunch dipole and quadrupole modes for n = 1, 11 were excited with driving frequencies in the neighborhood of h = 13. A synchronization frequency of 4,378,406 was obtained and the initial intensity was set at 4.8-5 X 10^{12} per pulse.

Results

At 4.8 X 10^{12} the upper (n = 1) dipole mode was almost neutral, i.e., no growth or damping after the excitation was removed while the lower dipole line (n = 11) showed slight damping. The lower quadrupole mode exhibited considerable damping while the upper line showed only moderate damping. One found f_d = 544 ~ and f_q = 1063 ~. Hence $(f_q - 2f_d)$ = - 25 ~ which means that the incoherent shift is = 50 ~. This is quite large as will be discussed below.

As a test of the data and technique the intensity was increased to 6.8 X 10^{12} and the lower dipole and quadrupole frequencies were measured again. As expected, the dipole frequency did not change, but the quadrupole frequency decreased by 10 ~ to 1053 ~. This corresponds to a slope of x 10 ~/.117 amp for the quadrupole frequency shift vs current. If we use this to extrapolate the 4.8 X 10^{12} data to zero current, we obtain 1063 ~ + 24 ~ = 1087 ~ while $2f_d$ = 1088 i.e., the zero current quadrupole frequency should be just $2f_d$. Finally, the rf voltage was lowered by ≈ 13% to see if this would affect the quadrupole frequency (at 6.8 X 10^{12}). An unexpected and large further shift of ≈ 70 ~ was observed. Although the dipole (lower) frequency was essentially unchanged, the nature of the signal changed considerably. Rapid initial growth occurred after excitation was removed followed by a slow (.43 sec^{-1} growth rate) growth. Longer excitation than .1 sec did not interfere with the rapid initial growth which seemed to always start at a fixed time from the beginning of the drive signal. None of these effects are understood, but it appears that for some reason the main accelerating cavities are affecting the observed frequency shifts.

Discussion

The incoherent shift of -50 ~ along with a bunch length of 36 nsec results in a $z_h \cong 158\ \Omega$ capacitive, a total effective voltage of 230 kV and a bunch area of .74 eV sec. This impedance is an order of magnitude larger than expected for reasons that are not understood. Also, the effect of a small reduction in the total accelerating voltage on the quadrupole frequency shift was completely unexpected.

A simple calculation of the detuning of the rf cavities gives a value of $\approx \pm 24$ kc or .55% $\Delta f/f_{res}$. If one computes the contribution to z/n for one of the gaps for the frequencies around h = 11, 13 and includes the fact that the quadrupole form factor increases with frequency, then the inductive contribution at h = 11 is essentially cancelled by the capacitive impedance at h = 13.

Still the 40 accelerating gaps on the ring represent a considerable impedance and must remain the prime suspects for producing the observed effects. Unfortunately, there was not enough time to try excitation at frequencies around h = 10, 11, 14 which could have helped in determining more accurately the range of the dominating impedance.

1. F. Pedersen, E. Raka, "Proposed Machine Experiments to Determine the Longitudinal Coupling Impedance in the AGS", ISA Tech. Note 69, April 1978.