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PRELIMINARY RESULTS OF 200 MeV BUNCHING EXPERIMENTS

G. Danby, E. Gill, J. Keane and A.W. Maschke

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Abstract

The AGS was apertured down to a small value, and the injected beam was bunched as abruptly as possible. An instantaneous current was measured corresponding to $\Delta v^2 \approx 30$. This corresponds to an instantaneous tune shift of ~ 1.9 units, or about 7.5 times the "classical" space charge limit. No intensity dependant losses were observed. The instantaneous current was limited by the energy spread in the injected beam.

The Heavy Ion Fusion approach to thermonuclear pellet ignition requires short bunches of beam (~ 10 ns) with instantaneous currents on order of thousands of amperes. If the beam, prior to being tightly bunched, is stored in a circular accumulator ring, the question arises; what is the maximum instantaneous current achievable?

Typical considerations of transverse space charge leads one to consider the tune shift Δv allowable for stable operation. In general the maximum current is proportional to Δv , and typically values of $\Delta v \approx 0.25$ represent a limit. However, if one considers bunching the beam by an abrupt application of a high rf voltage, the tune shift might occur so rapidly that harmful resonances are crossed with negligible phase space dilution. In fact, numerical simulations indicate that this indeed may occur. If, instead of the $\Delta v = 1/4$ limitation, we suppose that the ring has sufficient aperture so that the effects of space charge might double its size, we obtain a current limit a factor of $\sim 3 \nu$ times the 0.25 tune shift value, where ν is the number of betatron oscillation per revolution.

For the AGS, with 200 MeV protons, the "conventional" current limit for a beam with $\epsilon_v = 10^{-5}$, $\epsilon_H = 10^{-4}$ is ~ 0.35 amperes. Therefore, using this argument, one might expect to achieve peak currents as high as ~ 9 amperes. The figure of merit for these purposes is the value of Δv^2 computed as follows:

$$\Delta v^2 = \frac{i_{\max} T}{e} \cdot \frac{2}{\pi} \frac{r_p R}{a(a+b)} \cdot \frac{F}{\beta^2 \gamma^3}$$

$T \equiv$ revolution period
 $r_p \equiv$ proton electro-magnetic radius

where F is the Laslett factor given by

$$F = 1 + \frac{a(a+b)}{h^2} \left\{ \epsilon_1 (1 + B\beta^2 \gamma^2) + \epsilon_2 B\beta^2 \gamma^2 \frac{h^2}{g} \right\}$$

where $\epsilon_1 \approx 1/5$ and $\epsilon_2 \approx 2/5$.

Using AGS injector parameters we obtain:

$$\Delta v^2 = \frac{i_{\max}}{a(a+b)} \cdot F \cdot 6.5 \times 10^{-3}$$

with $F \approx 1.1$.

In the experiment that was performed on the AGS, the vertical beam size was limited by an aperture stop, and the peak current after bunching was measured on a fast current transformer. Strictly speaking, we did not measure the beam size but only that it was less than a certain amount. We measured $a \leq 0.88 \times 10^{-2}$ m, and $i_{\max} \approx 1.6$ amperes. Assuming $b = 4a$, we obtain:

$$\Delta v^2 \geq 30$$

This is a factor of ~ 7 over the "steady state" space charge limit, and about a factor of 2 under what one might expect for a beam whose size has blown up a factor of two.

The injected beam current was about 0.5 amperes, with the linac current at ~ 0.085 amperes. When the beam was cut down at the inflector so that we reduced the input current in the ring by a factor of 10, there was no change in the resultant bunch shape. This demonstrates that neither space charge nor beam loading were responsible for the poor bunching. With the linac current reduced to 0.03 amperes, a substantial improvement in the bunching occurred. Therefore, we conclude that intensity dependent effects in the linac and its transport system significantly increase the resultant energy spread.

The next set of measurements will repeat the above experiment, but using the active debuncher cavity to reduce the linac energy spread. Preliminary computational results indicate that the effective spread in

the beam is about 600 keV at 0.03 amperes, and perhaps twice this at 0.09 amperes.

In order to compare theory and experiment, it is important to know the net rf voltage applied to the beam. This can be measured at each station with the regular voltage readout system. In addition, by measuring the synchrotron oscillation frequency at low intensity we obtain an independent check of the voltage. If T is the time in milliseconds for a synchrotron oscillation, we obtain:

$$V = \frac{6}{T^2} \text{ kilovolts/revolution}$$

These two methods agree to within about 10%. On 3 February we obtained about 250 kV, and on 5 February about 350, with one cavity off.

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