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Why Put Beam into the AGS that you Cannot Get Out? (A suggestion for a pre-Linac rf chopper)

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Accelerator Division
Technical Note

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The AGS acceleration cycle begins with a capture process in which the essentially continuous injected beam is captured into phase-stable rf buckets. This process has been optimized over the years by tailoring the $\dot{B}$ and rf voltage programs such that 75% to 80% of the injected beam is captured and accelerated.

This note concerns the remaining 20% to 25% that is inevitably lost within the machine and contributes significantly to the radiation dose developed there. It is possible to reject this part of the beam even before the Linac by use of an rf chopper synchronized with the AGS rf system. An rf chopper can prepare bunches with adjustable width and phasing, on a nanosecond time scale, that are suitable for direct injection into stable rf buckets in the AGS or, eventually, into the booster. At present, such a device could, in principle, be implemented to act on the 750 keV beam from the Cockcroft-Walton, but it would require large voltages and a long beam line insertion length. With the installation of the new RFQ, however, the opportunity exists to chop the beam at 35 keV energy before the RFQ. A device of approximately 50 cm insertion length, located between the two focusing solenoids and driven by one switch tube at 500 volts could kick the beam by approximately 50 mrad. This is more than a factor of 3 above the minimum needed to extinguish the beam. The beam velocity is low, however (2.6 mm/ns), and so to get adequate rise time, a series of 20 mm length plates would be fired sequentially in a traveling wave fashion. The fixed beam energy means that the delay between successive plates can be realized simply by a length of coaxial cable (approximately 2 m).

The effect on the emittance of the beam is always a concern when putting active devices in the beam path. But by choosing the polarity of the chopper appropriately, it can be arranged that the high voltage rejects the beam and when the desired beam is passed, the voltage is switched off. Thus, the chopper represents zero aberation.

The low voltage requirement implies that the device would be driven by a d.c. coupled switch tube and no resonant components would be necessary. This means a great deal of flexibility is possible in adjusting the pulse width and spacing. In fact, on one hand it would be straightforward to modify the pulse width on a pulse-to-pulse basis to accommodate the changing size of the rf bucket due to non-zero $\dot{B}$. On the other hand, the beam could be stopped indefinitely under fault conditions, thus serving to replace the existing chopper.

This note is intended to introduce the concept of an rf chopper and to explain its utility. A treatment of the detailed technical design will be the subject of a future proposal.

Besides the primary purpose of eliminating the radiation caused by capture losses in the AGS, an rf chopper would have several other features. Since the capture stage of the acceleration cycle is eliminated, the rf program is simplified. As soon as injection is complete, the bootstrap rf control is operative and the radial loop can track the magnet program.

Diagnostics at injection would be facilitated by the time structure already present on the beam. Standard PUE electronics would be able to see the first turn of injected beam in normal operation. For special studies experiments, the time structure can be manipulated to highlight particular phenomena. Inter- versus intra-bunch instabilities could be easily isolated by accelerating only one bunch or every other bunch.

The boundaries of the stable rf bucket could be directly mapped out by varying the profile of the pulse width program. The area of the bucket would be operationally defined by just what area in phase space could be filled with no losses.

An attractive feature of an rf chopper is the ability to produce bunch-to-bunch intensity modulation by effectively changing the injection pulse length for each bunch. Used in conjunction with the single bunch extraction capability, this feature would allow different users to be supplied with different intensity beams within the same cycle.*

One may be inclined to ask, if a chopper is useful, would not a buncher be more useful in that it captures a larger fraction of the average beam. The answer is that the advantages are, if any, marginal. Any buncher could, at very best, capture 90% of the d.c. beam. Since the AGS captures 75% to 80% of the beam, a chopper would only waste 20%-25%. The marginal improvement of 20% does not justify the great added complexity of building a buncher at 2.5 MHz. Furthermore, recall that the RFQ has a capture efficiency approaching 100%, while the existing two 200 MHz cavities routinely capture only 75% of the beam. In other words, for the same source output, the same average intensity could be injected into the AGS, but 100% of it could be accelerated.

As a few final remarks, I would like to point out that now the timing is ideal for implementing this device because with the installation of the new RFQ, the entire LEBT area must be redesigned. Moreover, the performance of the existing low frequency chopper leaves much to be desired and should be replaced with a new design in any case. Also, the polarized proton source has no chopper available presently. Whereas radiation levels are not a concern at present polarized proton intensities (hopefully in the future this will not be the case), the diagnostic features and fault protection interrupt capability would justify the construction of a second rf chopper to be installed in front of the polarized source RFQ.

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*A similar device for heavy ions would be extremely useful for those experiments requiring very low intensity, by allowing an intense "pilot" bunch to close the machine's feedback loops and guide eleven weak bunches through the acceleration cycle.

Some Linac beam users have expressed a requirement for single micro-bunch capability. An inexpensive system has been proposed[1] to fulfill this requirement using a d.c. coupled beam switch (the rf chopper) and a sine wave deflector. Adding a sine wave deflector in the beam line between the RFQ and Linac to complete this system is a very economical way to achieve this unique capability of the Linac beam.

Reference

1. J.M. Brennan, Accelerator Division Technical Note #249, 1986.

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Rept. in AGS Library

GUIDE to ACCELERATOR PHYSICS PROGRAM SYNCH

— VAX VERSION —

This is an on line manual in

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