Conf-7703

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Prepared for

Particle Accelerator Conference
Chicago, Illinois
March 16-18, 1977

ED

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NEW INJECTION SCHEME AT THE ZGS*

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Abstract

A new scheme of injection into the Zero Gradient Synchrotron (ZGS) from the 50 MeV linac was implemented, and we have obtained a factor of two in the accelerated beam intensity. The new scheme consists of lowering the Ḃ during the early acceleration period in order to enlarge the RF bucket area and injection period, tuning the debuncher to achieve the minimum instantaneous energy spread of ±100 keV, and ramping the debuncher phase so that the instantaneous momentum of the injected beam during the injection period follows the rise of the ring magnetic field strength. By doing so, the betatron amplitude is set close to minimum, and the total energy spread accumulated during the injection period due to the energy ramp by the debuncher phase ramp would fit the RF acceptance. This method has been used for all three operating modes of the ZGS (unpolarized proton, polarized proton, and H^- injection).

Introduction

The usual method of multi-turn injection into a circular accelerator from a linac has been stacking of injected beam in the betatron phase space of the circular accelerator. For the ZGS, this method of multi-turn injection has been very inefficient. Coasting beam studies have shown a coasting efficiency of about 25%, and that the ZGS accepted only 150 µs of the injection pulse.

The new method of stacking the linac beam in the synchrotron phase space of the ZGS has shown that the coasting efficiency is about 40% for H^+ injection, and that the injection period can be extended to about 250 µs. An additional advantage of this injection is that, because the beam fills the ZGS aperture uniformly due to the energy ramp, the space charge detuning effect during the early accelerator cycle can be somewhat alleviated.

Energy Acceptance

The normal operating condition of the ZGS had been a $\dot{B} \approx 17$ kG/s, the peak RF voltage = 24 kV, and the harmonic number of 8. With this condition, the RF phase acceptance $\Delta\phi = 210^\circ$, and the energy acceptance $\Delta E = \pm 420$ keV. One way to increase the synchrotron acceptance is to raise the RF voltage, however, the present RF system cannot hold a higher voltage. Thus, we chose to lower the Ḃ from 17 kG/s to 12 kG/s for normal proton operation. This Ḃ was chosen intuitively giving consideration to injection time, efficiency, available linac pulse width and the requirement to miss the inflector. For H^- injection,[1] we use a Ḃ of 8 kG/s. There is no inflector to miss and the injection efficiency is not Ḃ dependent and Ḃ is determined to produce a minimum space charge density during the early acceleration period. The details of H^- injection can be found elsewhere.[1] For 12 kG/s, $\Delta\phi = 260^\circ$, and $\Delta E = 470$ keV. This low value of Ḃ is kept up to 2.5 kG of accelerating field, and then the Ḃ switches over to a normal 17 kG/s. The purpose of changing to a higher Ḃ is to maintain the normal repetition rate. Also, by the time the ring magnetic field has reached 2.5 kG, the beam longitudinal phase space has damped sufficiently allowing a change in the RF bucket area without beam loss.

Energy Ramp

The details of the previous operating conditions of the ZGS linac and the method used to tune the linac have been described elsewhere.[2] A summary of these conditions is: the energy spread ≈ ± 300 keV, and the energy ramp produced by the linac RF level ≈ dE/dt = 2.1 keV/µs during the pulse period of 150 s.

In the new scheme, the linac RF level was set to give a constant output energy, then the RF voltage on the debuncher is tuned to give the minimum energy spread. The energy spread is measured by a Segmented Faraday Cup (SFC) located in a straight section, L3, of the ZGS which acts as a spectrometer.[3] The SFC has an additional feature of variably gated sampling time, which can be used to study the beam parameters of 10 µs segments along the injection period of ~300 µs. Using this technique, set the debuncher voltage was set to have a minimum energy spread of 100 keV during the entire injection period. During this voltage tuning of the debuncher, the RF phase of the debuncher was held at a constant value of 0°.

In order to fill the synchrotron phase space of the ZGS, the energy of the injected beam needs to be ramped. This is accomplished by ramping the RF phase of the debuncher. The beam position was sampled in 10 µs segments during the 300 µs injection period using the L3 SFC. If the instantaneous momentum were to follow the rise of the B field, the beam position monitored at L3 should be constant. Thus, the debuncher phase ramp was adjusted to achieve the momentum space stacking.

Conclusion

We have successfully used this method of injection into the ZGS for normal proton, H^-, and polarized proton injection. Figure 1 shows the weekly average of number of protons accelerated/pulse for both the normal proton and the polarized proton operations. The marked increase in the beam intensity is evident.

References

1. C. W. Potts, "Negative Hydrogen Ion Injection into the ZGS," to be published in IEEE Transactions on Nuclear Science this conference.
2. E. F. Parker, "Recent Measurement of the ZGS Injector Beam Characteristics," Proceedings of 1972 Proton Linac Conference, p. 63, (1972).
3. R. L. Kustom, E. F. Parker, C. W. Potts, R. B. Wehrle, F. R. Brumwell, "A New Diagnostic System for Studing the Injector and Injection at the Zero Gradient Synchrotron," IEEE Transactions on Nuclear Science, Vol. NS-20, No. 3, p. 518, (June, 1973).

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*Work supported by the U. S. Energy Research and Development Administration.

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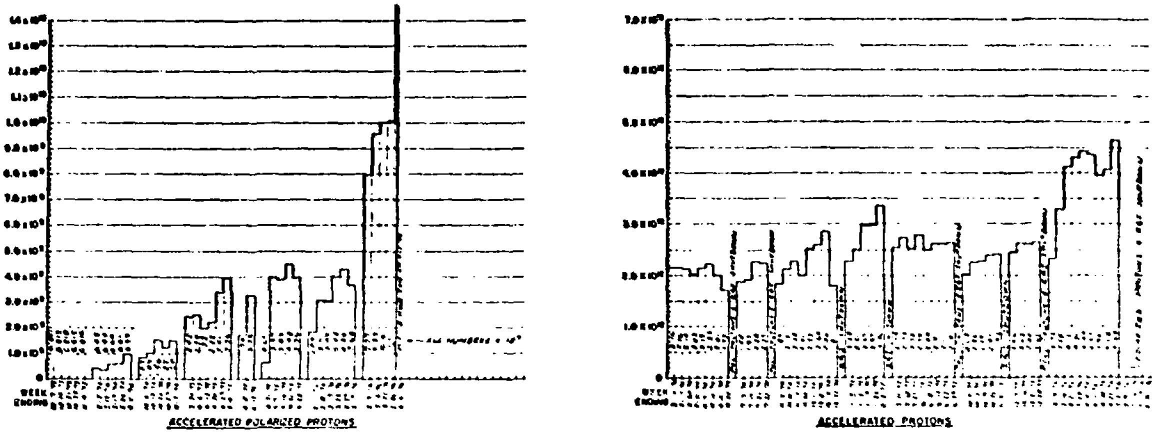

Fig. 1 Weekly Averages