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IMPROVED METHOD FOR FILLING AN ELECTRON STORAGE RING FROM A SYNCHROTRON†

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By switching bunches back and forth between the storage ring and an injector synchrotron of circumference different from that of the storage ring, many bunches circulating in the storage ring can be combined rapidly into a single bunch. Such a technique can decrease the filling time for the storage ring significantly. An example is given in which it is estimated that 100 bunches circulating in a storage ring the size of Cornell synchrotron can be combined into a single bunch in 1.7 sec.

INTRODUCTION

In electron storage rings the luminosity at high energy is usually limited by the amount of rf power available. Thus to maximize the luminosity one must arrange that all of the charge be contained in one bunch circulating in each direction. In loading a storage ring operating in this mode from a synchrotron one is at a disadvantage because, while the charge circulating in the synchrotron is only one to two orders of magnitude less than that required in the storage ring (electrons only), this charge is divided up into hundreds of bunches only one[1] of which can be put directly into the desired bunch in the storage ring. In other words the effective transfer efficiency is very low.[2] The situation is doubly bad for positrons since the charge circulating in the storage ring is reduced by the conversion efficiency from e^- to e^+.[3]

This situation can be ameliorated if an economical method can be found by which a significant fraction of the total charge accelerated in the synchrotron can be combined into one or a few bunches in the storage ring. In principle a low frequency rf system using adiabatic and radiation damping of the energy oscillations in the synchrotron combined with transverse phase-space stacking in the storage ring can accomplish this task. Such a scheme is proposed for EPIC.[4]

Alternatively one may use an intermediate storage ring between the synchrotron and the main storage ring. In this case one accumulates charge in many bunches in the auxiliary storage ring and then stacks them in transverse phase space into one or a few bunches in the main storage ring. Such a scheme is proposed for PETRA.[5]

THE METHOD

It is our purpose here to suggest how this desired bunch combination might be carried out very rapidly without the use of an auxiliary rf system or storage ring. We assume that the injector synchrotron is capable of accelerating its beam to such an energy that the damping time for betatron oscillations in the storage ring (SR) is comparable with or smaller than the cycle time in the synchrotron (SYN). While the principle can be applied in a number of ways only one is recounted here.

Suppose that the SR and its injector SYN are different in circumference by a carefully selected amount, that amount to be specified momentarily. Suppose further that the SYN is filled with and accelerates bunches spaced in time by the combined rise and fall times of a fast kicker system capable of ejecting bunches from the storage ring. Having been accelerated in the SYN this multibunch beam is then extracted in a single turn and injected into the SR using a fast beam bump and septum in the SR. This process is repeated many times in the usual way, the beam in the SR being built up by stacking in transverse phase space. When the total charge stored in this multibunch beam is equal to the amount required in the single bunch the injector of the SYN is switched off, the SYN

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itself continuing to cycle. The beam in the SR is now ready to be compressed. Focus attention on one of the bunches in the SR and call this bunch the accreting bunch (AB). Assume for illustrative purposes that the circumference of the SR is larger than that of the SYN.[6] Now fire a fast extraction system in the SR which ejects the bunch following the AB but leaves the remaining bunches undisturbed. This bunch is reinjected into *the* SYN *and circulates* therein. The circumferences of the two rings are chosen different by an integral number of rf wavelengths, that number being a submultiple, n, of the separation of the bunches. Since the circumferences are different the rf buckets in the two rings slide past each other in phase, those in the SYN gaining on those in the SR. After n revolutions in the SYN the bunch in question arrives at the injection-ejection point in phase conjunction with the AB and is reinjected into the SR and stacked together with the AB in transverse phase space, the two merging through radiation damping. The next following bunch is now fast ejected from the SR and injected into the SR. After $2n$ revolutions this bunch is now in phase conjunction with the AB and can be reinserted into the SR and stacked together with the AB. This process continues until all of the bunches circulating the SR have been combined into the AB. Since the AB itself is not ejected and reinjected successively the net transfer efficiency is applied to each bunch separately and the total charge in the AB after accretion is the charge at the beginning of compression multiplied by the net transfer efficiency. This efficiency is the product of the SR and SYN injection and ejection efficiencies and the transport efficiencies and can be of the order of 80 percent without undue expense.

The transfer and combining process is best carried out at constant energy near the top of the synchrotron cycle. If desired the energies of the two rings could be adjusted during the transfer and combination process so that the bunch being manipulated always enters and leaves the synchrotron at exactly the correct energy but this is probably not necessary.

For example if a storage ring of size comparable with the Cornell synchrotron (circumference = 750 m) were built and their gross radii were different by 60 cm or more the time required for the buckets in the two rings to slip past each other by one full circumference would be 0.5 msec or less. During this time the change in synchronous energy of the synchrotron would be only 0.25 percent, the magnet excitation being a fully biased 60 Hz sine wave. Such a variation is well within the apertures involved.

To continue with this example it is estimated that kicker coils appropriate for ejecting the SR bunches could be switched on and off in a period of perhaps 25 nsec, certainly in 50 nsec.

This means that in a machine the size of the Cornell synchrotron (2.5 μsec revolution time) 50 to 100 bunches could be combined into one. If one bunch is accreted per synchrotron cycle this means that the total compression could be accomplished in $\frac{5}{6}$ to $1\frac{2}{3}$ seconds and the filling time could be reduced by a factor of 50 to 100 as compared to the situation in which only one bunch per synchrotron cycle is injected into the storage ring.

REFERENCES

1. If the rf wavelength in the storage ring is greater than that in the synchrotron a few bunches might be accommodated.
2. The same problem afflicts injection from a high energy linac but can generally be overcome by increasing the instantaneous beam power in the linac.
3. The exact ratio of e^+ to e^- current in the synchrotron depends upon the details of the injector linac and the manner in which the linac beam is modulated and converted into positrons.
4. Rutherford Laboratory Report RL-74-100, September 1974.
5. G. A. Voss, private communication concerning plans for a high energy e^+e^- storage ring at DESY.
6. The same principle can be applied if the reverse is true. Some efficiency may be sacrificed.