CONF-810314--189

CONF-810314--189

DE83 009482

A CONCEPTUAL DESIGN FOR AN ACCELERATOR SYSTEM FOR A VERY HIGH-INTENSITY PULSED NEUTRON SOURCE USING A LINEAR-INDUCTION ACCELERATOR*

Martyn H. Foss
Argonne National Laboratory
Argonne, Illinois 60439

Summary

Several accelerator-based intense neutron sources have been constructed or designed by various laboratories around the world. All of these facilities have a common scheme of a linac and synchrotron or accumulator ring, and the system produces the proton energy of 500-1000 MeV. The average beam currents range from a few mA to a few hundred mA. The protons are then used to generate high-flux neutrons by spallation out of heavy-metal targets. In a synchrotron system, the protons are already bunched, and thus the pulse rate of the neutron beam is that of the repetition rate of the synchrotron. For an accumulator system, the pulse rate is determined by the extraction repetition rate of the accumulator. We have conceptually designed a new system that uses a linear-induction accelerator which can be operated for an average beam current up to a few mA with a repetition rate up to 100 Hz. The details of the design will be given.

Introduction

An induction linac might be a suitable source of protons for an Intense Pulsed Neutron Source (IPNS). A preliminary look at bunching of the low-current beam from an ion source to a high-current beam suitable for an induction linac is presented here. The buncher discussed is itself an induction linac. It is found that the kinematics are reasonable, but other factors are not considered.

Induction Linac Buncher

The purpose of the IPNS is to deliver short, intense pulses of neutrons at a rate of about 60 Hz.[1] An induction linac seems well-suited for this goal. In order to deliver the desired number of neutrons, the average proton current needed is about:

$$\bar{I} = (E - 120)^{-1} + 3 \quad \text{Amp}$$

where E is the energy of the proton beam (MeV) at the target. When the ion source current and neutron pulse rate are also known, then the duration of the ion source pulse can be calculated. This ion source pulse length may be too long for an efficient induction linac and also too long for producing the desired burst of neutrons. The purpose of the buncher is to shorten this low-energy proton pulse.

Bunching is best done when the velocity of the protons is low. However, a lower limit to the ion velocity is set by the beam transport space charge limit. An approximation of Maschke's equation for beam current space charge limit is:

$$I_{max} = 2 \times 10^{6} \, (\beta\gamma)^{5/3} \, (B\epsilon_n)^{2/3} \qquad \text{(Amps)}$$

where:

$\beta\gamma = \eta \sim$ momentum,

B = maximum useful magnetic field (T), and

ϵ_n = normalized beam emittance (m-rad).

In the following examples, B is assumed to be 1.2, and ϵ_n is assumed to be 2×10^{-5}. The problem of building the transport system is not considered.

Substituting a given ion source current in this equation gives the minimum η, and thus the minimum beam energy. Thus, the input conditions for the buncher are: the assumed ion source current, the required pulse duration, and the minimum beam energy or preaccelerator voltage.

Bunching is accomplished by making the trailing edge of the beam travel faster than the leading edge. To keep the velocity of the leading edge of the beam as low as possible, it is carried at the space charge limit. The transport problems connected with containing an intense trailing edge in a line designed for the lower energy leading edge of the beam have not been considered. Instead, it is assumed that a line designed to carry the leading edge at the space charge limit can carry this same current at up to twice the η. In the bunchers discussed here, the trailing edge is kept at twice the η of the leading edge wherever possible.

Figures 1 through 5 illustrate.** Figure 1 shows the ratio of the momentum of the trailing edge of the beam pulse to the momentum of the leading edge. This ratio may be limited by a variety of factors. It is assumed that beam transport problems will set a maximum of 2. Note that the ratio is below 2 at the entrance and at the exit of the buncher. The momentum ratio of 2 could be established in the first gap. However, gap voltage vs. time must be precisely controlled, especially in the low energy end of the buncher. For this reason, the initial acceleration is limited. Near the exit, the momentum ratio is limited by core size.

Figure 2 shows the ratio of the beam current to the space charge limit for the leading edge of the beam. At each accelerating gap, the increase in $\beta\gamma$ causes the beam to drop below the space charge limit. The buncher is designed so that, as the current increases, the leading edge comes to the space charge limit at the next gap. The current vs. position is also shown in Fig. 2.

Figure 3 shows the core requirements and rate of acceleration as functions of position. As was discussed above, the initial rate of acceleration is limited. This limits the required core size (volt seconds per meter). To maintain the momentum ratio and keep the leading edge at the space charge limit requires increasing core-per-unit length. It is assumed that the core is limited to 0.1 Vs/m. This causes the drop in the momentum ratio in the high energy end of the buncher shown in Fig. 1.

Figure 4 shows the energy of the leading edge, center, and trailing edge of the beam pulse. The acceleration is done in such a way that the current, while the beam is passing, is constant at each position.

---

*Work supported by the U.S. Department of Energy.

**All of the figures relate to the same example. The spacing between accelerating gaps is 10 m. This large spacing is used to make the figures less confusing. No particular emphasis is placed on properties in the accelerator.

DISCLAIMER

Since energy goes with velocity squared, the energy profile in the buncher turns up sharply in the trailing edge of the beam.

Table I gives some numerical examples. The first row gives the results for the example presenced in the figures. The second row is the same except that the accelerating gaps are spaced at about 1 m instead of 10 m. Since the difference is not important, the remaining examples were calculated with a gap spacing of about 5 m.

The following rows are presented in pairs. The first member of each pair is for an 8A,750 kV buncher input and the second for a 0.8A,50 kV buncher input. The first pair is for a target energy of 1000 MeV, the second 560, and the third 340 MeV. As the last column shows, the buncher length varies inversely with the target energy and ion source current.

Conclusion

The cost of the buncher may be high because the initial acceleration must be precise. The overall cost of the system has not been estimated. The variable repetition rate possible with a linear induction accelerator is an advantage, since, for example, radiation damage experiments could be run at a higher frequency and thus a higher average neutron flux.

References

1. John M. Carpenter, *Pulsed Spallation Neutron Sources for Slow Neutron Scattering*, Nucl. Instrum. Methods 145 (1977).

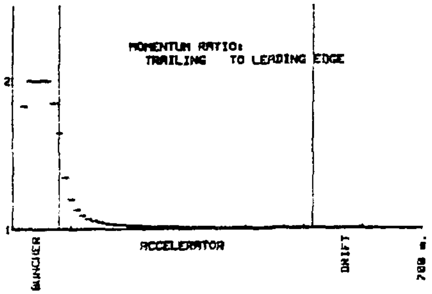

Figure 1

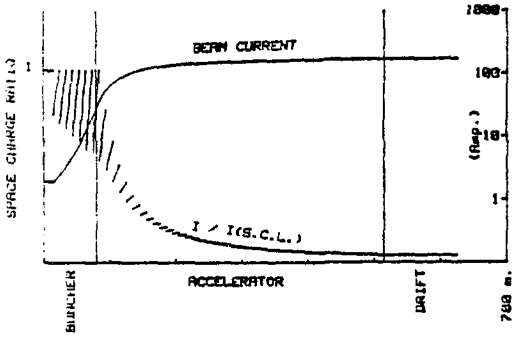

Figure 2

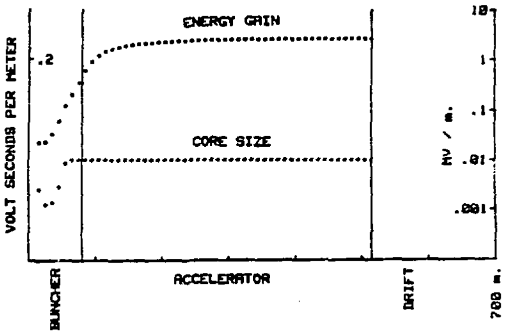

Figure 3

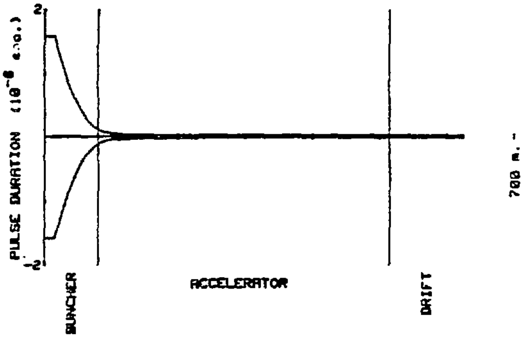

Figure 4

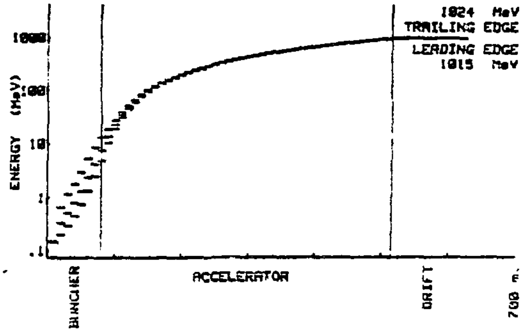

Figure 5

TABLE I

Given Target Energy	Given Pulse Rate	Given Ion Source Current	Average Target Current	Preaccelerator Voltage	Ion Source Pulse Length	Buncher Energy	Buncher Length
(MeV)	(Z)	(Amp)	(µ Amp)	(kV)	(µ sec)	(MeV)	(m)
1000	60	2	400	150	3.	7.6	70
1000	60	2	400	150	3.	5.5	59
1000	60	8	400	750	0.8	7.0	30
1000	60	0.8	400	50	8	6.4	100
560	60	8	800	750	1.6	15	80
560	60	0.8	800	50	16	15	220
340	60	8	1600	750	3	54	220
340	60	0.8	1600	50	30	54	500