JLAB-TN-01-018
24 April 2001

A Test of Energy Recovery in Large Systems

D. Douglas

Abstract
We propose a test of energy recovery in large systems such as ERL [1] or JERBAL [2] by using a minor modification of CEBAF.

Discussion
Jefferson Lab is at present uniquely positioned to contribute to the development of linac-based radiation sources such as ERL [1] and JERBAL [2]. Most of the present activity and interest surrounding these systems focuses on high current operation [1]. This work is of course absolutely vital to the success of such machines, is something that can be done in fairly short order, and indeed will be done at Cornell and JLab as a part of ongoing ERL work and as a portion of our FEL program. We are however able to address another very important issue – the problem of energy recovery in a large, high energy SRF system – quickly and inexpensively. CEBAF can be simply and non-invasively reconfigured to test at least one pass up/one pass down energy recovery. Should we be able to devote more resources to such an investigation, we could in principle test multi-pass operation with recovery.

Concept
In the most naïve case, a moderately large chicane is installed in an empty cryomodule slot in the south linac. When its "off", CEBAF is CEBAF. When its on, it would introduce a half-RF wavelength extra path length, allowing one pass up/one pass down energy recovery, and CEBAF becomes CEBAF-ER. Such a chicane need be only 8-9 m long and can be based on ~10^{o} bends. If you put the dogleg in a west extraction region, you can go up to the pass in which it is installed and then back down [3], and if you "go for the whole kielbasa", you build a fifth west arc and go up five passes and back down five passes [4].

In the simple case, the cost would be a few 10s of k$ and the project

- provides an opportunity to understand energy recovery in a large scale system over a much greater dynamic range of energy than that available in small machines such as FEL drivers [5]
- provides test operation of multiple beams in a single arc – possibly needed in multi-pass ERL systems [6]. This could test prototype multi-pass orbit/envelope management, etc.
- allows investigation of beam property/halo evolution through a long system and in an SRF environment.

Details

We note that single pass up/single pass down operation does not require use of a chicane following the south linac. It can instead be installed following the north linac – the only requirement is the introduction of an additional half wavelength of path length in the highest energy turn to be used in the machine. The precise location is irrelevant; and can thus be chosen for convenience. Use of the chicane in the north linac reduces the beam energy and thus the required dipole field strength.

In this case, a chicane based on four 1 m effective length dipoles each bending through 11.25^{o} can provide a half-RF wavelength of path length, which (when the south linac is gang-phased 180^{o} out from its nominal accelerating phase) will lead to acceleration during the first pass and energy recovery during the second. The dipoles will operate at ~3 kG at 445 MeV (with a bend radius of 5.10 m). They are similar in specification to standard east arc 1 dipoles. The proposed chicane layout is shown in Figure 1; the total required slot length is ~8.5 m. The entire system will thus nominally fit within a standard linac cryomodule slot.

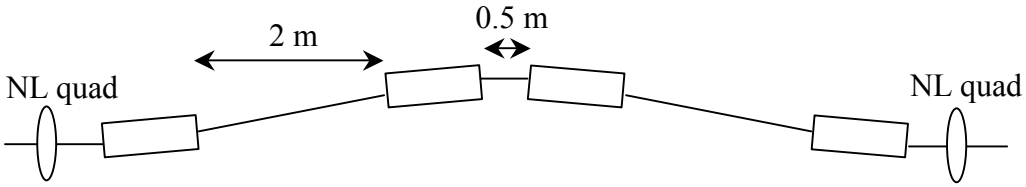

Figure 1: Chicane configuration

We note that the use of parallel-faced dipoles imposes additional vertical focusing on the beam(s). This can be locally compensated by adjusting adjacent linac quads, or, alternately, be compensated through adjustment of the east arc spreader phase matching telescope. Similarly, the chicane introduces longitudinal deviations from nominal transport behavior inasmuch as it has an M_{56} of order –0.25 m. This can be compensated through adjustment of the east arc transport as well. When implemented, activation of the chicane will allow investigation of optics and beam dynamics issues as outlined in Reference 2.

Tiefenback [7] has noted such operation will force a balancing of the north and south linac energy gains to within the acceptance of the transport system. He has proposed a method of balancing the energy gains by acceleration in the north linac and deceleration in the south linac. We note that this test energy gain balance test interfaces cleanly with the study proposed here. If the linacs are balanced *per* the Tiefenback method, one need only activate the energy-recovery chicane, and in principle (given proper west arc matching) the machine should accelerate through the entire first pass, energy recover in the second, and the beam should travel cleanly to the linac balance test 45 MeV dump. The only interface consideration are geometric details in the vicinity of the test dump; a chicane arrangement similar to that in the FEL injection/reinjection and recirculation/ energy recovery dump lines should be implemented

Notes and References

[1] G. Krafft and L. Merminga with the ERL collaboration, to be published.

[2] D. Douglas, "Design Considerations for Recirculating and Energy Recovering Linacs", JLAB-TN-00-027, 13 November 2000.

[3] Note that a chicane for a related purpose was proposed some time ago; see D. Douglas, "A Fix for Egregious Path Length Errors", CEBAF-TN-94-006, 10 January, 1994, with addendum dated 11 January 1994. Contextual recognition is an amazing thing, isn't it?

[4] Observe that through this project, the additional west arc required for the 12 GeV upgrade could be acquired and installed well ahead of the nominal upgrade schedule and provided through alternate funding sources as a portion of an accelerator physics experiment.

[5] Note that in the "one pass up/one pass down" scenario, the injection energy is an independent variable - so injection can be done at an arbitrarily low energy so as to test dynamic range.

[6] This is needed, at least, in energy-recovering systems using a symmetric, rather than asymmetric, linac geometry (see Reference [2]).

[7] M. Tiefenback, remarks in accelerator physics departmental meeting.