2.1 *RF Linac-Based Ion Acceleration: Overview*

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The RF linac group was charged to find methods of using RF-based acceleration to provide a beam that matched the target requirements.

The members of the group were

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Andy Sessler	LBNL	co-chair
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Paul Schloessow	Tech-X	
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Motivation and Challenges

Short, intense beams of light heavy ions can be accelerated in induction linac cells, but at what cost? Can RF acceleration techniques be used to produce a less expensive machine that will meet the technical challenges of producing beams that satisfy the demands of the experimental requirements of the beam conditions on the target. Can RF-based techniques be competitive with other acceleration techniques?

RF accelerators have not been known for accelerating amperes of beam with masses in the so-called light heavy ion range, typically neon through argon. Typical accelerating cavity structures are better impedance matched to low current beams, providing high accelerating gradients with modest stored energy in the cavity immediately available to transfer to the beam.

RF accelerators to date use either Alvarez or Sloan-Lawrence Interdigitated H-mode resonant structures to accelerate a bunched beam usually with strong focusing quadrupoles located in the drift tubes, or between cavities with one or more accelerating gaps. The gap-to-gap spacing in Alvarez structures is an even multiple of 180 degrees RF phase advance, and an odd multiple of 180 degrees RF phase advance in Sloan-Lawrence machines. In both structures the phase velocity of the accelerating wave is much slower than *c*, and varies synchronously with particle velocity along the accelerator.

Technical limitations on quadrupole gradient and length available in drift tubes for quadrupole limits the focusing available at the low-energy end of an RF accelerator, setting a lower limit of the injection energy. New ideas using high-strength superconducting solenoids allow substantial currents of heavy ions to be accelerated and focused.

Strawman Reference Parameters

The beam conditions on target selected to provide a point of reference are:

Ion	Ne^{+1}	
Total kinetic energy	20	MeV
Total charge	1	microcoulomb
Pulse length at target	1	nanosecond
Beam radius at target	1	mm

Staples presented two linac scenarios, a 100 MHz Alvarez linac with conventional quadrupole focusing in the drift tubes and a pulsed drift tube design that accelerated a single beam pulse at the same time starting the compression process. Neither of these structures was developed further at the workshop and are summarized in section 2.7.

Recent advances in superconducting solenoid technology opens up a new parameter space where very strong, azimuthally-symmetric focusing can contain high space-charge heavy-ion beams. The important breakthrough was the realization that very high field (15T) superconducting solenoids are available and are able to focus large currents of Ne^{+1} in an RF structure. An RF-based linear accelerator scenario using these high-field solenoids and multi-gap accelerating cavities is described in sections 2.2 and 2.4.

The 1 nanosecond, 1 microcoulomb beam pulse at the target implies a 1 kA beam current, which is the product of a significant longitudinal compression in the HEBT. The degree of the compression is dependent on the energy spread resulting from the bunching and acceleration process in the linac and is limited to the range of 100:1 or so, implying a linac output of a few amperes.

Even with the help of high-field superconducting solenoid focusing, currents of several amperes are probably not feasible in a single beam, so in one scenario (1) the linac designs uses multiple parallel beams, which would be recombined in the HEBT/final beam transport. An alternative, scenario (2), is to use a single-beam linac and load an accumulator (stacker) ring, building up transverse phase space by painting, and kick a short beam pulse out and further compress it. This will be discussed further in section 2.5.

The linac requires a high injection energy, and multiple parallel beams in scenario (1). An ion source is described in section 2.3 which includes a 2 MV column with a number of parallel beams and multiaperture extraction geometry for each of the beams. Only one beam is required for the stacker ring concept of scenario (2).

High-field superconducting solenoids may open up new opportunities in the development of high-current linear accelerators for heavy ions. Substantial fractions of an ampere may be accelerated, but to satisfy HEDP target requirements of 1 nsec, 1 kA type beams, further beam manipulation beyond the linac is still required. Parallel-beam structures or accumulator rings may be used to provide the total charge and, and some sort of ballistic compression, probably with the use of an induction core, will be needed.

It appears that an RF linac scenario may be feasible. No obvious show-stoppers were identified during the workshop, and subsequent calculations done in more detail have not identified any. Areas recommended for future technology development are discussed in section 2.8.