ANL LOW BETA DEVELOPMENT (PHASE 0)

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Introduction

The HIF group at Argonne National Laboratory is currently developing the initial Accelerator Demonstration Facility (ADF) for the rf linac reference concepts. This has been dubbed Phase 0 since it is a preliminary step before our two proposed ADF's which could deposit 10 kJ (Phase I) and 500 kJ (Phase II) on target. Phase 0 is a $25 million project over a three-year period. Unfortunately, much of the funding expected for this project was withdrawn from the FY 1980 budget, thereby delaying its completion by a year.

The basic configuration of Phase 0 is shown in Fig. 1. The low-beta front end consists of a high voltage preaccelerator followed by an array of 12.5 MHz independently-phased linac resonators and Wideröe linacs to accelerate 25 mA of Xe^{+1} to 20 MeV. The beam is then stripped to charge state +8 and accelerated in a 25 MHz Wideröe to 220 MeV. It will be injected into a ring (using the Princeton-Penn accelerator magnets) housed in the ZGS tunnel. The extracted beam will be compressed, split into four beams and focussed onto target foils.

Phase 0 could demonstrate adequate beam quality and intensity through many stages common to a HIF driver:

- Ion source
- Low-beta acceleration
- Charge stripping
- Frequency jump with simulated funneling
- Multi-turn injection into a storage ring
- Storage ring vacuum and instabilities
- Extraction
- Compression
- Beam splitting
- Final focus
- Energy deposition

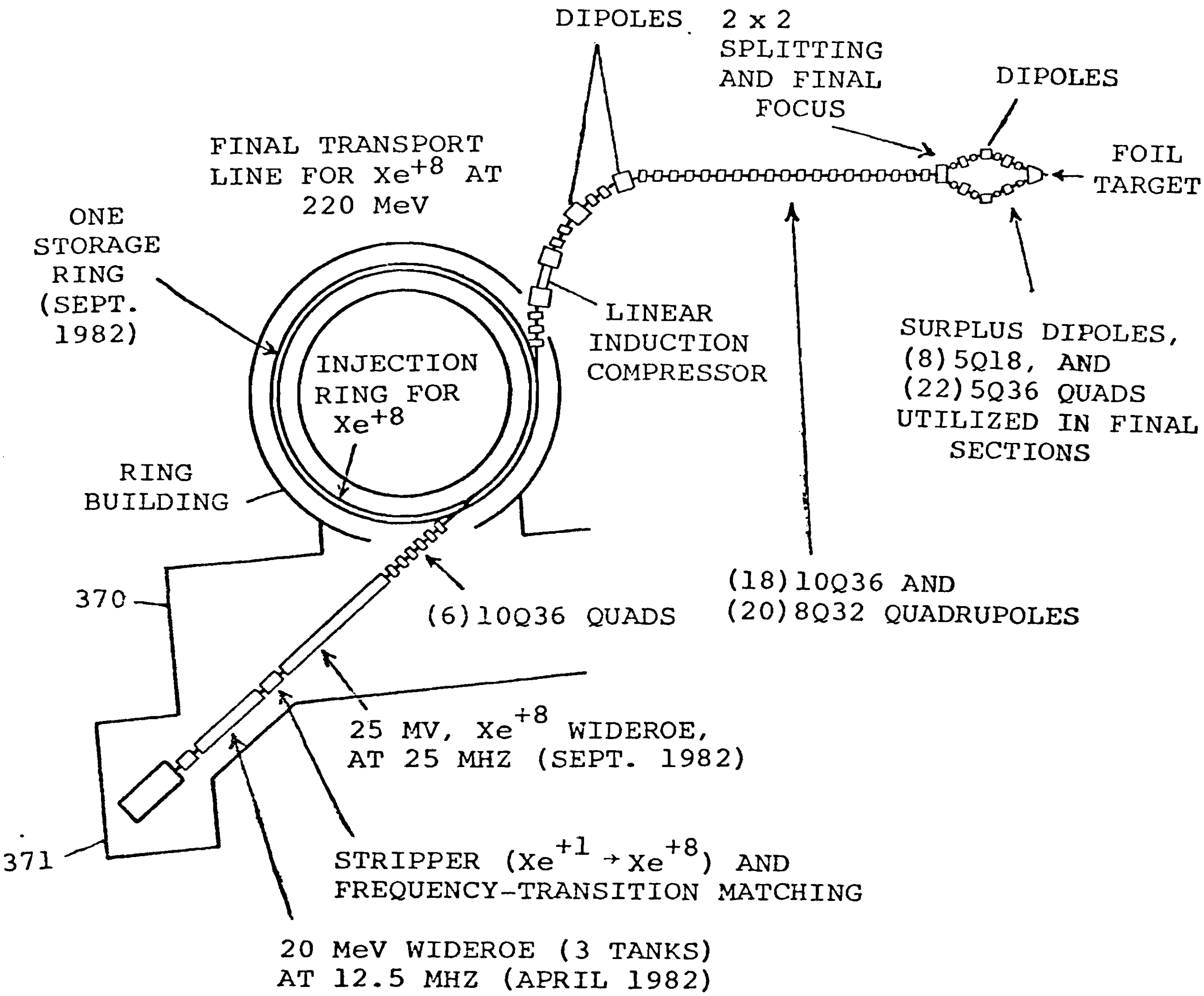

Fig. 1 ANL Phase 0

Because we are trying to demonstrate accelerator technology at many stages in a short time, it is important that we develop and extend upon the techniques which have a reasonable probability of early success. To do the storage ring and final focus studies we will need a front end which can perform reliably over long periods. This has been among our considerations in determining the configuration of the accelerator. Even so, the HIF requirements are a considerable extrapolation from any existing heavy ion accelerators. The development of an ADF will require more extensive computer simulations during its design than has been typical for HEP accelerators. They will also require a new generation of diagnostics for the evaluation of the beam characteristics in six-dimensional phase space as it passes through each stage of the facility.

Preaccelerator

There are several advantages to operating the preaccelerator at the highest voltage possible. The current limit of the first linac tank is substantially increased and the very lowest frequencies and their associated frequency jumps are avoided. The high brightness of the source can be best maintained with minimal dilution during the difficult initial acceleration stage by using electrostatic acceleration with a Pierce geometry as far as practical.

We have chosen an operating voltage of 1.5 MV for our Phase 0 preaccelerator. We have high confidence that such a machine will be reliable for 50 mA operation. At this energy, a linac current limit of 25 mA can probably be achieved using conventional magnets. The preaccelerator and source have been described in detail elsewhere [1,2]; therefore, I will primarily discuss our recent experience and present status.

The current layout of our injector is shown in Fig. 2. The equipment shown is installed and operational with the exception of the independently-phased linac cavities C2 and C3. Their construction will be completed in a few months. The magnet BM1 is used for energy and charge analysis of the beam. A Faraday cup has been placed immediately behind the independently-phased cavity C1 in our initial operation. The PAPS 1 and PAPS 2 monitors provide non-destructive horizontal and vertical profiles of the beam,and the toroids T1 and T2 non-destructively measure the current. The accelerating column was high voltage conditioned to 1.4 MV and 50 mA Xe^{-1} beams were reliably extracted at 1.3 MV. A pulse length of 100 μsec and a repetition rate of 1/sec were typical during these tests. The protective grading rings on the inner surface of the accelerating column shell would not hold off the voltages involved above 1.4 MV. We also found that the ceramic at the high voltage end of the column was experiencing damage due to the overvoltages during conditioning sparkdowns. For the former problem, half of the rings were modified to increase the spacing. For the latter, a third intermediate electrode was added. This reduced the voltage across the last gap from 900 kV to 450 kV and spread this reduced transient from a sparkdown over twice as many insulators; thereby reducing overvoltages by a factor of four. We have since conditioned to 1.1 MV with much less sparking and have experienced no additional damage. The present tests are being carried out at 1 MeV until a new outer shell has been fabricated. At that time, it will be conditioned as high as possible.

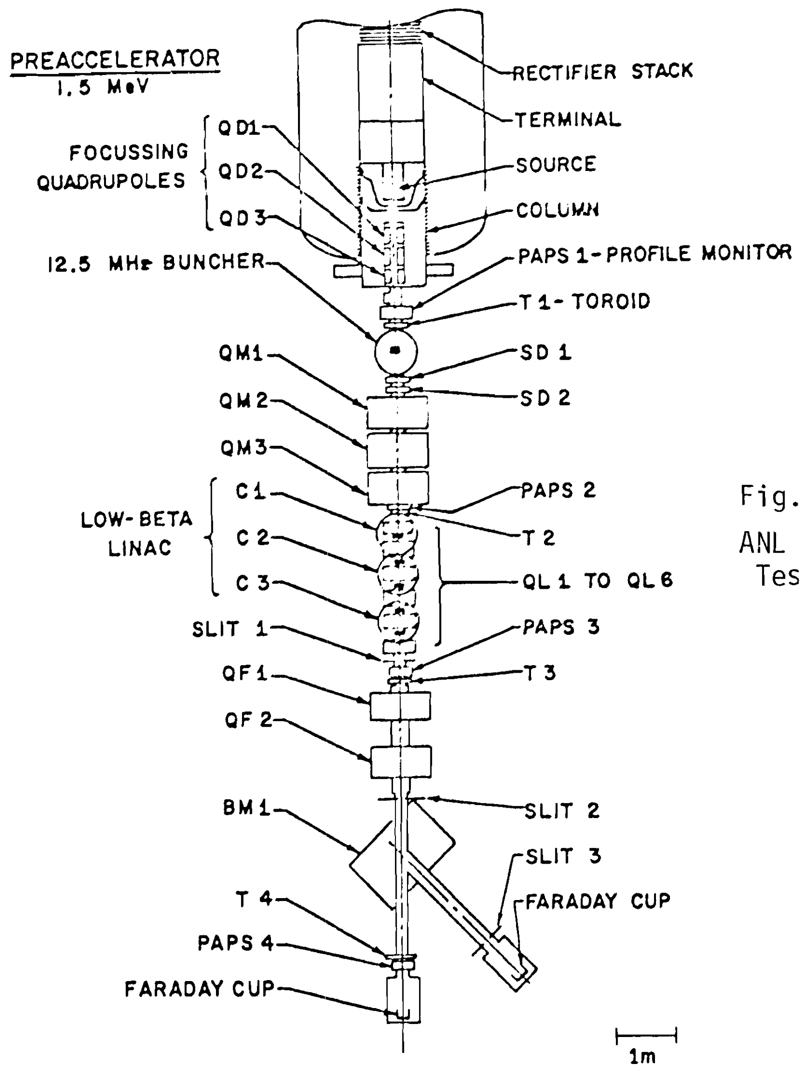

Fig. 2
ANL Injector
Test Facility

At this time we are tuning the beam line and column electrostatics to minimize beam losses through the rf buncher and first accelerating cavity. Bunching factors greater than 4 have been measured at C1 at 1 MeV. In fact, this provides a fairly clean resolution of the various xenon isotopes (approximately 15 nsec/amu) when using gas which has the natural abundances. Once the beam is transported cleanly through this section, the transverse emittances will be measured. Beam scraping on the vacuum pipe has been seen to cause time-varying beam parameters (apparently due to partial neutralization developing) and forward directed electrons which are more intense than the lost ion beam. The expected normalized transverse emittances out of the preaccelerator at 1.5 MeV are 0.03 cm-mrad.

Low Beta Linac

The low beta linac consists of three independently-phased short resonators followed by 12.5 MHz Wideroe linacs. The independently-phased cavities are in essentially a $\pi/5\pi$ configuration. These are expected to transport 25 mA of Xe^{+1} to 2.3 MeV. The three Wideroe tanks which are $\pi/3\pi$, $\pi/3\pi$, and π/π will accelerate the beam to 22 MeV. A detailed description of this system is available elsewhere[4]. The three independently-phased cavities and first Wideröe tank are sketched in Fig. 3. The first independently-phased cavity (C1) is installed and operational. The next two will be completed in a few months. Construction of the first Wideröe tank has just begun; however, its completion will require more funding than is available in our FY 1980 budget.

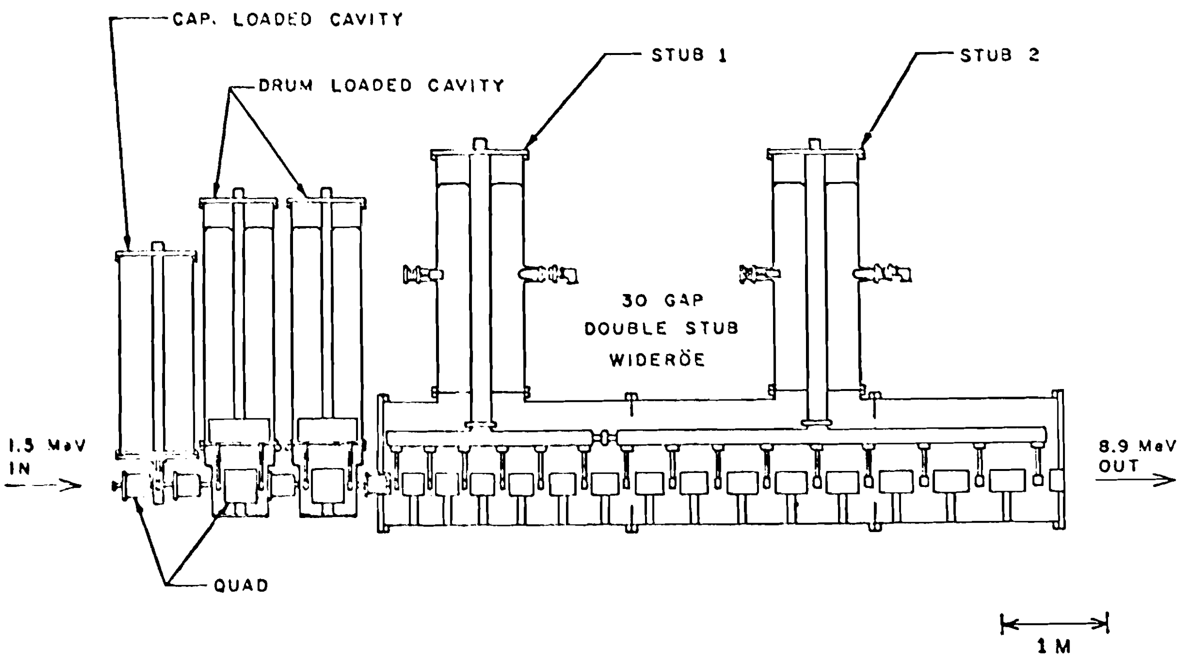

Fig. 3 30 Gap $\pi/3\pi$ Double Stub Wideröe (Tank No. 1) and Independently-Phased Cavity Linac: 1.5 MeV to 8.84 MeV

The use of independently-phased cavities provides a great deal of flexibility in attaining the injection requirements for the Wideröe linac. They can make up varying deficiencies in the preaccelerator performance and allow optimization of the accelerating gradient for minimal emittance growth. With the $\pi/5\pi$ configuration adequate focussing is available to transport the 25 mA beam.

A Wideröe linac is the only low-velocity structure with operational experience with heavy ions (albeit at low currents). After considering Wideröe's with electreostatic focussing and RFQ's, it is evident that the structure with the highest confidence of performing reliably at present is a Wideröe with magnetic focussing. Our experience has been that the reliability of electrostatic quadrupoles has been too variable. RFQ's are not yet operational; they represent a more uncertain alternative.

In Phase 0 the beam properties will be measured through the various sections of the linac. By comparison with realistic computer simulations, the optimal operating conditions for maximum current and minimum emittance growth (within reasonable economic constraints) can hopefully be defined. Preliminary results of simulations through the first Wideröe tank indicate a transverse emittance growth by a factor of three[5]. Further studies are now in progress to determine if this can be reduced by lower accelerating gradients or higher injection energies by using more independently-phased cavities[6] Also, to achieve 25 mA of Xe^{+1} through the first tank may require "overstuffing" with some beam loss. The above mentioned studies will also attempt to minimize these losses.

Conclusions

The rf linac ADF is getting underway with a high brightness beam of 50 mA of Xe^{+1} at 1.3 MeV already available. The short independently-phased linac cavities are nearing completion and construction of the first Wideröe tank has begun. Because of the stringent current and emittance requirements, realistic computer simulations are needed for initial designs of the ADF as well as for understanding the performance of each section. The experimental measurements will require a new generation of diagnostics which will accurately characterize the beam without altering it or being destroyed by it. The low beta section of the ADF is a challenge, but now appears solvable with the proper mix of simulation and experimental measurements.

References

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