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YEAR-END REPORT: HEAVY ION FUSION PROGRAM

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Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

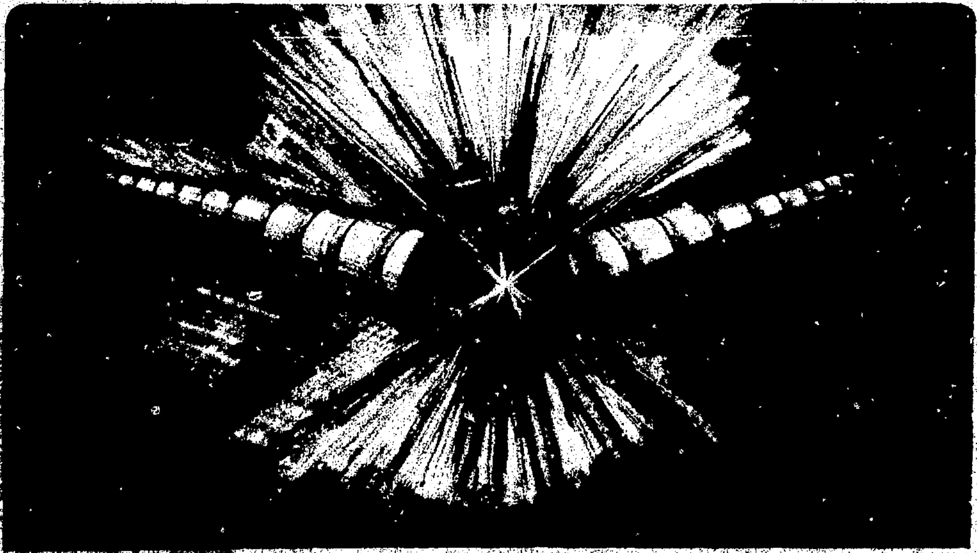
Accelerator & Fusion Research Division

YEAR-END REPORT: HEAVY ION FUSION PROGRAM

MASTER

Heavy Ion Fusion Staff

October 1978 through September 1979



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LBL-10291

YEAR-END REPORT
HEAVY ION FUSION PROGRAM
LAWRENCE BERKELEY LABORATORY
FISCAL YEAR 1979

OCTOBER 1978 - SEPTEMBER 1979

Contents

FOREWORD

The requested DoE reporting procedure calls for a formal Half-Year Report and a formal Year-End Report. This report is technically the Year-End Report and activities throughout the year are referred to; practically speaking, however, matters occurring in the first six months receive here only the briefest of mention since they have already been covered in detail in the Half-Year Report (Oct. 1978 - March 1979), LBL-9019 -- to which the reader may wish to refer. In future years we expect to cover the full year's activities in two Half-Year Reports, first half and second half, that are non-overlapping.

The reader may also wish to consult another Laboratory Report "500 J Induction Linac Test Bed" LBL Pub. 5031 (Sept. 1979) as an additional companion piece to this report. Because of the existence of this detailed Technical Description, the test-bed description in Section II below has been kept brief.

Heavy-Ion Fusion Year-End Report
October 1978 - September 1979
Lawrence Berkeley Laboratory
University of California

HIGHLIGHTS

The more significant activities and results reported for this year are:

- Commissioning, in January 1979, of a large-area Cs^{+1} ion source of 1.2 amperes at 500 kV. This source has a repetition rate of 1 per second and is on a scale suitable for an induction linac.
- Commissioning, in July 1979, of the first drift-tube of the three drift-tube accelerator. Characterization of the emergent beam is underway. The system is now at the 2 J, 1 MW level.
- Acceleration, in January 1979, of a high-brightness, 40 milliampere Xe^{+1} beam through a Cockcroft-Walton column to 500 kV and confirmation of satisfactory emittance and charge distribution.
- Presentation at the IEEE Particle Accelerator Conference, San Francisco, March 1979, of eight papers bearing on topics of interest to induction and rf linac drivers.
- Development of a conceptual design for a 500 J induction linac test-bed facility to test many of the features needed for the success of an igniter (LBL PUB 5031).
- Improvements to the systems studies of a Heavy Ion Induction Linac Driver over a wide parameter range with emphasis on cost and efficiency trade-off.

- Start-up of a (Cs^{+1}, Cs^{+1}) ion-ion cross section measurement program. Initial results of the scattering of Cs^{+1} ions on Xe gas (electronically similar to Cs^{+1}) have shown some surprising results.

- Expansion of theoretical studies on the behavior of space-charge dominated ion beams. A workshop on these topics has been organized to take place at the Claremont Hotel, Oakland, Oct. 29 to Nov. 9, 1979.

PART A: CONCERNING INDUCTION LINACS

I. High Current Cesium-Ion Beam Experiment

We have previously reported on the satisfactory operation of the large aperture contact ionization cesium ion source (Ref. 1 and 2). In July, we installed the first of the three pulsed drift tubes (Fig. 1) and, since then, have been studying the beam behavior after this additional acceleration stage. For most of these studies the system has been operated somewhat below its full capability; typical operating parameters were: source voltage, 400 kV; first drift tube voltage, 400 kV; beam current, 0.7 amperes, and pulse duration, 2 μsec. Typical wave forms are shown in Fig. 2. The measured current is found to scale with the voltage as expected from the Child-Langmuir law.

The beam diameter, measured at the exit of the first drift-tube, is found to be considerably smaller (by about one-half) than predicted theoretically from the steady-state EGUN code computations by W. B. Herrmannsfeldt. This could be a result of several possible mechanisms, e.g., charge-neutralization by electrons, or the known and undesired concavity of the iridium hot plate which has occurred in the last few months because of thermal expansion and fatigue. The presence of a large number of electrons has been established and could be sufficient to neutralize the beam. The origin and effects of these electrons on the beam are being investigated by use of electric and magnetic sweeping fields. For example, application of an axial magnetic field does not

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1. S. Abbot, W. Chupp, A Faltens, W. Herrmannsfeldt, E. Hoyer, D. Keefe, C. Kim, S. Rosenblum, J. Shiloh, "Large Aperture Contact Ionized Cs^{+1} Ion Source For an Induction Linac", IEEE Trans. on Nuc. Sci., Vol. NS-26 No. 3, (June 1979), p. 3095

2. Half-Year Report, Oct. 1978-Mar. 1979, Heavy Ion Fusion Program, Lawrence Berkeley Laboratory, LBL-9019.

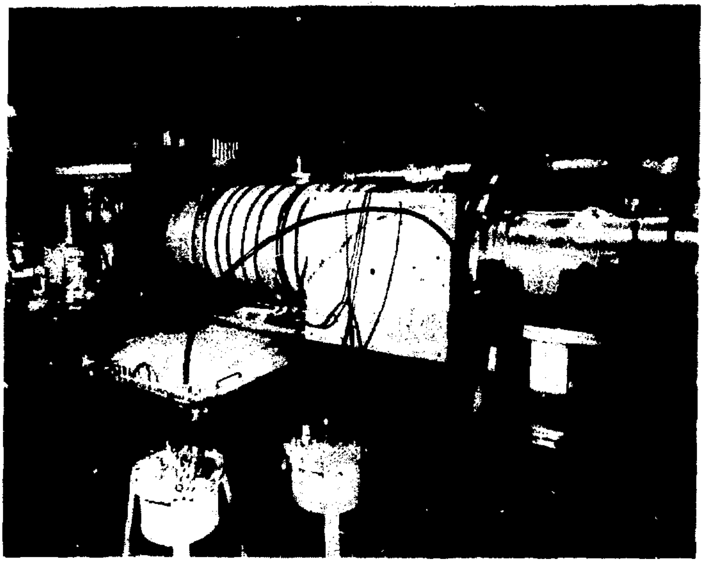

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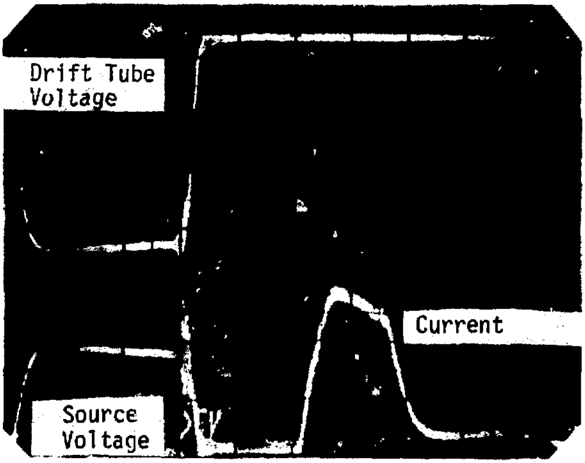
Figure 1

CONTACT IONIZATION Cs^{+1} SOURCE WITH DRIFT TUBE NO. 1 & DIAGNOSTIC TANK



Time Base 1 µsec/div

XBB 790-15075

Figure 2

TYPICAL WAVE FORMS

affect the electron signal, and the inner surface of the drift tube can thus be ruled out as a source of electrons. Although the second and third drift-tubes and their modulators are ready, their installation will be delayed until the present beam behavior is properly understood. If, indeed, neutralization is occurring and if it is stable and reproducible it could have profound and agreeable consequences on the design of an induction-linac injector.

Although the measured pulse duration is 2 μsec, the applied voltage pulse needs to last longer (3.5 μsec) to compensate for the beam rise-time and the ion transit-time from the hot plate to the entrance of the first drift tube. The source and the first drift-tube voltages are turned on simultaneously to minimize the beam rise-time and, also, turned off simultaneously to minimize the generation of slow (low energy) ions. The beam envelope is independent of the two Marx generator voltages as long as they are kept at the same value.

A one-dimensional simulation code has been developed by M. Tiefenback to enable us better to understand transient effects in the ion-gun when the voltage is first switched on. Transients such as oscillations in ion-energy and current occur for a characteristic time of about 1 μsec, viz., roughly the ion transit time, before the gun settles down to steady-state behavior.

We have experienced some minor difficulties in operating the Marx generators at the full design voltage of 500 kV, due partly to oil contamination in the Marx column air supply, and also to limitations of the drift-tube Marx charging power supply.

II. Ion Induction Linac Test Bed

We have developed a conceptual design and cost estimate for an Ion Induction Linac Test Bed. This concept is set forth in a Technical Description submitted in September 1979 entitled "Ion Induction Linac" LBL PUB-5031. This document presents the design of the Test Bed and the engineering development needed on crucial components, and describes the experimental and theoretical program that will answer uncertainties regarding beam behavior. The 160 meter long Test Bed will accelerate a Cs^+ ion beam with a total charge of 20 microcoulombs. The ions will originate from a large contact ionization source and be further accelerated through two drift tubes before injection into an induction linac consisting of approximately 80 induction modules. The output kinetic energy will be 25 MeV. The Test Bed will be located on a long pad behind an existing building on the LBL site. Depending on the funding schedule, the project could span from 30 to 44 months, as described in the Cost and Schedule section of LBL-PUB-5031. The reader is referred to that Report for a description of the design details, and this section will describe only the work to date in preparation for the Test-Bed Construction.

The desired bunch trajectory requires bunch shortening in length by about a factor of one-half during the transit of the bunch through the accelerator. This requirement translates into specific voltage-versus-time requirements at different locations in the machine, with the general trend that these voltages are steeply ramped at the low-energy end and essentially flat at the high-energy end, with a ramp that decreases with increasing energy at intermediate locations. The precise specification of these required waveforms is most easily handled with the help of a computer code "SAVE 1" developed by L.J. Laslett; preliminary results are just now being obtained.

The waveform within any accelerating module will be generated by sequentially firing a small number of independent pulse-forming networks into independent core segments. The voltage seen by the beam will be the sum of the core segment voltages. The required number of pulsers will be 5-10 per module, with the exact number to be determined by consideration of beam sensitivity to waveform errors and peak voltage constraints. A typical pulser will have an impedance of $\approx 1\ \Omega$, will be charged to 25 kV, and will deliver 150 MW to the core for a few micro-seconds. One prototype pulser of this type has been constructed and operated at full power for more than 10^5 pulses at a 1 Hz repetition rate into a resistive load. This pulser will be used in conjunction with induction cores as soon as enough large cores become available. Some impedance tapering of the network will be needed to match the core. One large induction core, 91 cm outer diameter, 62 cm inner diameter, and 5 cm deep, has been wound of 2 mil silicon steel with mylar insulation and is ready for testing.

The Ion Induction Linac will consist of three sections (Figure 3); within any one section all the accelerating modules will be identical. The low-energy end of the accelerator will have the largest modules, the high-energy end the smallest. Preliminary layouts of module configurations have been made for each of the three sections. At present, alternative core configurations are being examined, and some preliminary discussions have taken place with potential vendors (Allegheny-Ludlum, Magnetics Inc.) who could supply the core material and/or deliver the fabricated cores.

Insulator development has started. A number of candidate materials for insulator assembly have been surveyed, and, at present, we are exploring the possibility of using Pyrex glass. Some test samples of glass bonded to stainless steel to form a graded column have been produced and will be tested soon for structural and voltage-holding properties.

Computations are currently underway to examine the proposed pulsed quadrupole magnet designs; in particular, the fringing field and the quality of the field within the bore are being studied.

III. Evaluation of Ferromagnetic Core Materials for the Induction Linac

Because the magnetic cores make up a large part of the volume and cost of an induction linac it is important to pick a material for the core that strikes an optimum balance between its electrical behavior and its cost. Because a heavy ion induction linac needs to accelerate over a wide range of pulse widths, several different types of core materials will be needed in different parts of the accelerator.

1. General Materials Research and Development

We have, therefore, begun to measure the magnetic properties and core losses of a variety of materials using a thyratron pulser shown schematically in Fig. 4. Each sample is in the form of a tape-wound toroid with a single

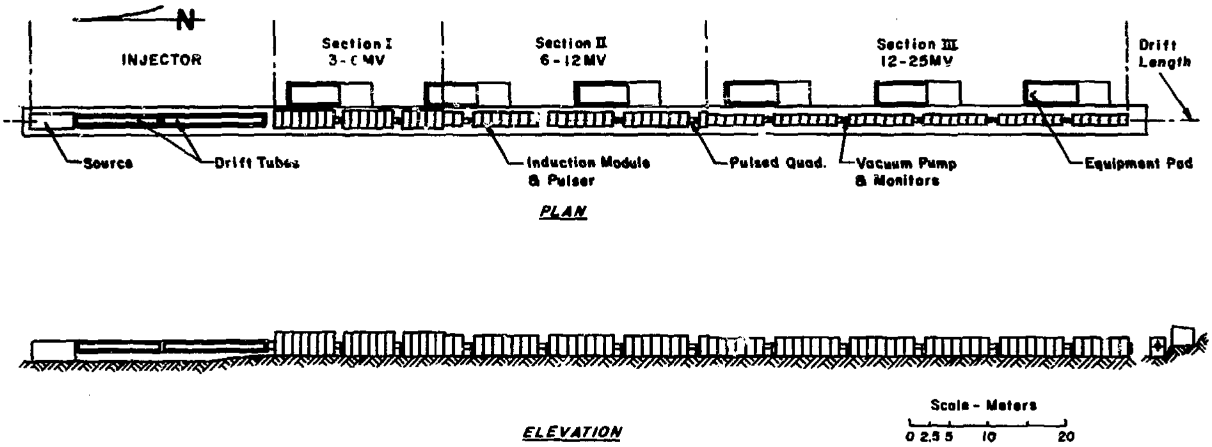


Figure 3

25 MeV Cs^{+1} 500 JOULE INDUCTION LINAC TEST BED LAYOUT

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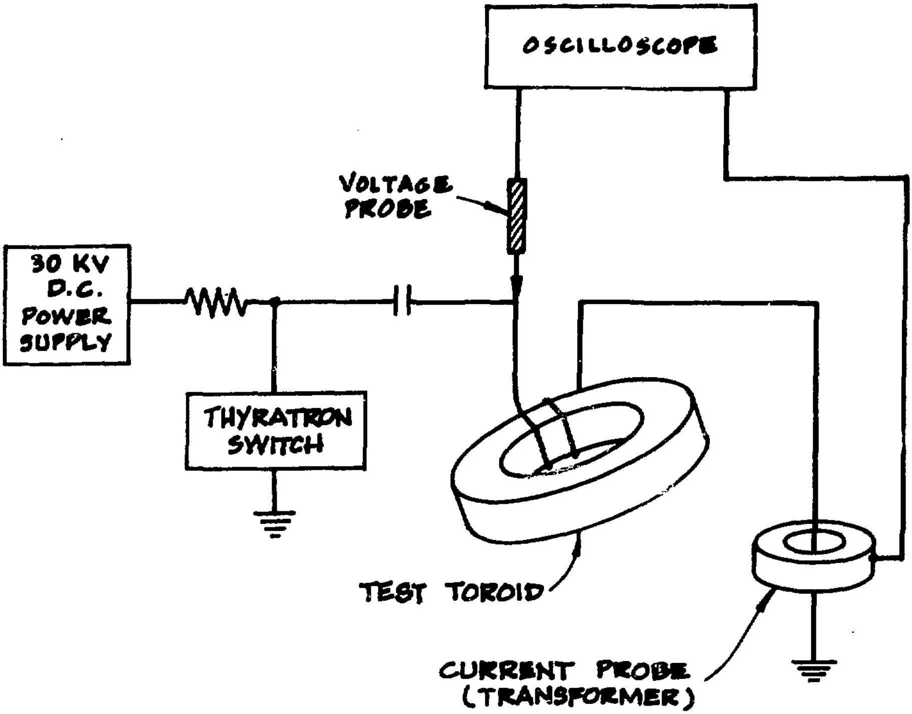

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Figure 4

SCHEMATIC DIAGRAM OF CORE MATERIALS TEST PULSER set of windings. Pulse durations have ranged from 500 ns to 100 μs thus far and we plan, soon, to extend the range down to 40 ns. The materials studied to date thus far have included .001" thick molybdenum-iron, .001" $Ni_{50}Fe_{50}$, Stackpole C11 ferrite, .012" Silectron (Arnold Engineering) and three different amorphous magnetic materials—Allied Metglas 2826 and 2826 MB as well as General Electric $Fe_{82}B_{15}Si_3$.

These latter new materials show great promise, being inexpensive to manufacture (50¢/lb., projected) as well as having very attractive properties as a core material to replace $Ni_{50}Fe_{50}$ ($10 - $20/lb.). Although the experimental materials tested thus far have not reached the expected performance based on short sample measurements it is hoped that improvements in fabrication will lead to this result shortly. This promise is strikingly demonstrated in Fig. 5 which shows the core loss for a possible induction module.

At present there is great interest in the $Fe_{82}B_{15}Si_3$ material (called Metglas 2605S by Allied Chemical) for use in motors and power distribution transformers because of its low manufacturing cost, good magnetic properties and low electrical losses. Both Allied Chemical and General Electric have corporate research programs to develop these materials for the motor and transformer markets. The Allied program is the more ambitious, and is partly funded by a $6 million, 3-1/2 year contract (in conjunction with Westinghouse) from the Electric Power Research Institute. At present, Allied can produce 50-100 pounds of ribbon a month and is now constructing a pilot plant which is expected to come on line in August, 1979. This pilot plant will increase the capacity at least by a factor of 10. General Electric's program on the production of ribbon material is totally internally funded; they do all their own materials fabrication and testing. They also have a large effort, partly funded under DoE contract, to develop flaked amorphous magnetic material for the motor-transformer application.

The ribbon material, as it can now be produced, has properties that are acceptable for at least part of our core materials needs. Because fabrication of these materials has not yet emerged from the developmental to the production stage, however, the volume of material available and its cost (largely

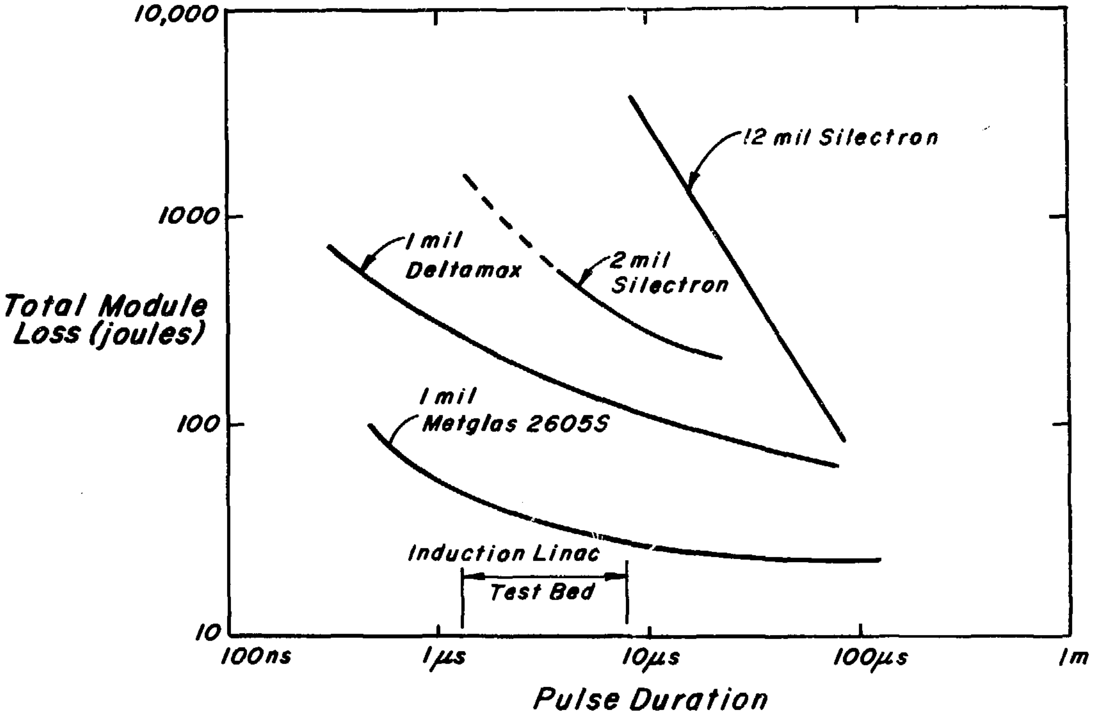

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Figure 5

INDUCTION MODULE COMPARISON USING VARIOUS CORE MATERIALS

A module having 15 cm. inner radius, 1 meter length and 0.5 volt-second flux change is designed using results obtained in our pulse measurements. This should represent module losses in actual linac service and provides the crucial information about ferromagnetic choices.

development-related) are not acceptable at this time. We keep in close contact with GE and Allied both directly and, also, through Carl Cline who is supervising a program at Livermore on the development and testing of these materials for switching and accelerator applications. Contact is also maintained with Drs. Ken Klein and Jitendra Vora of DoE.

It is interesting to note that when these materials are in full production the transformer-motor market expects to need some 560 million pounds/year. In contrast, the total amount required for an HIF induction linac would be a tiny fraction of this, and HIF needs will, therefore, not require any significant new production capacity.

2. Evaluation of Materials for Ion Induction Linac Test Bed Accelerator

As a result of indications from DoE at the end of FY '79 that a start on an induction accelerator test bed for heavy ion fusion would be funded in FY'80, we began to investigate what material one should use for the cores. The main criteria would be:

1) low core loss;
2) immediate availability;
3) low price.

The materials tested thus far in the thyratron core test pulser (Fig. 4) have been: .002" x 2" wide Silicon steel, .003" x 2" mild steel (partially annealed), .002" x 2" and .003" x 2" mild steel shimstock (full hard). As a preliminary result, it appears that the .002" silicon steel is the best compromise. We are now investigating whether there are deleterious effects of winding tension and bending on core properties. We have also held discussions with representatives from Arnold Engineering and Magnetics Inc. to determine what the approximate costs would be for them to wind the toroids for us, and are still examining the relative cost or other trade-offs of fabricating the cores in-house.

PART B: CONCERNING R.F. LINACS AND STORAGE RINGS

I. High Current Xe^{+1} Ion Source for Conventional rf Linac Systems

A multi-aperture Ehlers-type source has been constructed and operated to produce a 60 mA Xe^{+1} beam (Ref. 1). The multi-aperture source utilizes 13 apertures closely spaced in a circular pattern to produce a beam 25 mm in diameter. The "accel-decel" extraction system delivered a 22.5 keV beam whose normalized emittance at 29 mA was 0.027 cm-rad. The source was mounted in the high- voltage terminal of a Cockcroft-Walton generator and the neutralized beam was transported one meter through two magnetic quadrupole triplets to the entrance of the 20 cm long accelerating column which consists of five intermediate electrodes with a total voltage drop of 500 kV. The vacuum in the extraction region was held to 10^{-5} torr by using a puff valve and two 1500 l/sec turbo-molecular pumps. Multi-wire profile monitors just ahead of the column entrance measured the beam size, which was in good agreement with single-particle transport calculations, if one assumes the beam to be 97% neutralized. The normalized emittance of the full 500 keV beam was measured to be 0.1 cm-mrad for 35 mA and the population of charge-state +1 ions was determined to be > 90%.

These achievements -- and subsequent comparably successful small-aperture ion-source work by Hughes Research Laboratoreis for ANL -- attest to the reliability of judgment expressed as long ago as the Claremont meeting in July, 1976, that scaling to this level of parameters, was readily achievable.

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1. W. Chupp, D. Clark, R. Richter, J. Staples, and E. Zajec, "Operation of a High Current Xenon Source," IEEE Trans. on Nuc. Sci., Vol. NS-26 No. 3, (June 1979), p. 3036.

PART C: THEORY

At the time of the Argonne Workshop (Sept. '78), we had made a preliminary comparison of our analytic work on a third-order instability, which occurs in the transport of a Kapchinskij-Vladimirskij beam through a quadrupole system, with some of the results of Irving Haber's particle simulation calculation of the same instability. We were encouraged to believe that theory and computation were in agreement, but there remained a number of gaps and unresolved questions. Since then we have obtained the complete record of that run and find that over a range of about ten quadrupole periods, after the instability has grown out of the computational noise and before signs of non-linear saturation appear, the relevant moments of the distribution grow at the predicted rates to a remarkable accuracy. We are therefore quite confident in our double conclusion that the theory is correct and that the simulation computations are correct. It should then be justifiable to believe the computational results, also, for more realistic initial distribution functions that are beyond the capability of analytic treatment.

Our analytic work thus indicates that the maximum current that can be transported without emittance degradation is achieved by using a lattice designed for a zero intensity phase advance of 60° (to avoid envelope and third order instabilities), depressed to 24° by space-charge forces (the threshold for higher-order instabilities). This criterion should be conservative, since the K-V distribution is somewhat more sensitive to instability than other more realistic distributions. The corresponding "figure of merit," $Q/u_m^{2/3}$, in the formula for current given in equation (3) of Ref. 1 depends on the fraction of transport channel occupied by quadrupoles, ranging

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1. G. Lambertson, L.J. Laslett, L. Smith, "Transport of Intense Ion Beams", IEEE Transactions on Nuc. Sci., Vol. NS-24, (June 1977), p. 993.

from 0.76 for full occupancy down to 0.23 for 10% occupancy (see Ref. 2). This coefficient is not drastically different numerically from that proposed by Maschke at the time of the first HIF workshop (Ref. 3).

What is needed now to advance the study of beam transport is an analysis of the three-dimensional problem, including longitudinal forces and the resulting coupled motion. As a first step in that direction, we are using a one-dimensional code for longitudinal motion and developing an analytic approach to that problem. A distribution function has been found for which the space-charge forces are linear and which leads to an envelope equation similar to the familiar one for transverse motion (see Ref. 4). A perturbation analysis shows that this distribution is stable at all intensities if the (linear) external focusing force is continuous.

If the discrete character of the restoring force due to the spacing between modules is taken into account, small regions of instabilities arise when the mode frequencies are rationally related to harmonics of the pattern of accelerating in pulses. Since the frequencies are very low compared with the frequency of encountering gaps, these instabilities should be inconsequential except possibly in the presence of a very long wavelength systematic variation in gap voltages.

If one adds to the model a resistive self-force, representing a first

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2. L. J. Laslett and L. Smith, "Stability of Intense Ion Beams" <u>IEEE Transactions on Nuc. Sci.</u>, Vol. NS-26, No. 3, (June 1979), p. 3080

3. ERDA Summer Study of Heavy Ions for Inertial Fusion, Claremont Hotel, Oakland/Berkeley, California. July 19-30, 1976 (LBL-5543).

4. D. Neuffer, "Longitudinal Motion in High Current Ions Beams - A Self-Consistent Phase Space Distribution with an Envelope Equation", <u>IEEE Transactions on Nuc. Sci.</u>, Vol. NS-26, No. 3, (June 1979), p.3031.

approximation to the impedance of the accelerating gaps, coasting beam theory indicates instability for the derived momentum spread and the anticipated gap resistance. The computer program shows that a current bump at the center of the bunch propagates toward the end at the predicted velocity and growth rate but appears to die out when it reaches the end. Work is in progress to investigate the validity of the computer results and to treat the problem analytically.

PART D: OTHER ACTIVITIES

I. System Studies

System studies for a Heavy Ion Driver using the Induction Linac approach have continued. The Induction Linac driver can be viewed as consisting of three systems: an injector, an accelerator and the final beam transport. Of these, the dominant cost system is the accelerator, so it has received the most attention to date.

Preliminary work (Ref. 1) with the computer code LIACEP (Linear Induction Accelerator Cost Evaluation Program) has been extended to Induction Linac accelerator systems for 100 kJ, 1 MJ, 3 MJ, and 10 MJ, with a wide variety of input assumptions. Information on accelerator cost, length, efficiency and detailed arrangement of magnets and accelerating modules has been developed for the following matrix of parameters:

Ion Type: Cesium (133), Thallium (204), Uranium (238)

Charge State: 1+, 2+ and 4+ (1+ only for Thallium)

Normalized Beam Emittance: 2, 3, 4, & 6 (x 10^{-5} m-rad)

Electrical Beam Charge: 25 - 1000 μC (in ten suitable increments)

Betatron Tune Shift (due to space-charge): 60° → 24°

Repetition Rate: 1 Hz

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1. A. Faltens, E. Hoyer, D. Keefe, L.J. Laslett, "Design/Cost Study of an Induction Linac for Heavy Ions for Pellet-Fusion", IEEE Transactions on Nuc. Sci., Vol. NS-26, No. 3, (June 1979), p. 3106.

The base-line induction linac concept is considered to have a superconducting quadrupole beam transport system and amorphous iron induction cores. In each case, the step-by-step design of successive parts of the accelerator used the minimum acceleration cost per megavolt to arrive at an overall minimum-cost accelerator. This criterion usually generates a design in which the beam current is not far from the space-charge limit throughout the length of the accelerator.

Some generalized results from our studies for a 1 MJ driver are as follows: (These results apply only to the accelerator portion of the driver.)

1. Considering a choice of particle, minimum accelerator cost is generally less for a lower atomic weight particle for a given charge state and normalized beam emittance.

2. For a particular particle, minimum accelerator cost becomes less as the charge state of the particle is increased for the same normalized beam emittance.

3. Minimum accelerator cost was the least with particles of charge states 2+ and 4+ for the maximum normalized emittance examined (6 x 10^{-5} m-rad) but for charge state 1+ a minimum existed in the 3-4 x 10^{-5} m-rad range of normalized beam emittance.

4. Accelerator lengths vary from 3 to 7 kilometers. Generally a machine designed to transport higher emittance will be shorter.

5. Accelerator efficiency at 1 Hz varies from 7 to 12% for the minimum cost options obtained, and at higher repetition rates, more suited to a driver, range up to 30%. Higher efficiency is generally obtained with a higher emittance beam. There is a trade-off between capital cost and efficiency and the minimum cost accelerator is not necessarily the optimum choice.

6. Accelerator cost is sensitive to core material. Nickel- and silicon-iron cores show an increased accelerator cost and decreased efficiency.

For a 100 kJ driver, a cursory examination of an accelerator, using Cs, yielded the following results for a normalized beam emittance of 3×10^{-5} π m-rad. Silicon iron was considered for the core material.

Charge State	Beam Charge (μC)	Accelerator Cost (M$)	Accelerator Length (kM)
+1	40	185	2.1
+2	80	145	1.7

II. Program Reviews

This has been an unusual period in regard to the number of reviews in which the HIF activity has been involved. Generally, each review has generated questions and requests for information that take several weeks to clear up after the date of the Review. Among the reviews which generated a sizeable amount of effort and diversion on our part were:

- March 23: Foster Committee (J. Foster, chairman):
Back-up details generated over subsequent weeks with Richard Briggs (for Burton Richter).

- April 10: EPRI Review: (K.A. Brueckner, chairman):
Back-up details later worked over for R. Kidder and I. Smith.

- April 30, May 1: Annual Outside Review of Accelerator and Fusion Research Division (F. Mills, chairman):
This committee reports to the Director, LBL.

- June 6: DoE Review of Institutional Plan and New Initiatives (Doug Pewitt - for John Deutch, chairman):
As a new initiative, the Induction Linac Test-Bed was a major topic on the agenda.

- June 26: DoE HQR Program Review (G. Canavan, chairman): Responses to questions on several schedule options have been generated through the end of the fiscal year, and appear to be required in various forms responsive to changing signals on budget projections well into the coming fiscal year.

III. Status Report for Ion-Ion Cross Section (Cs^{+1} + Cs^{+1}) Measurements

Ion-ion charge-changing collisons may affect the lifetime of stored beams for heavy ion fusion drivers. Many ion species are presently under consideration and the final choice may be determined by which species has the smallest charge-changing cross sections. Theoretical work has varied somewhat in predicting these cross sections and there is scant experimental data on these processes.

The theoretical studies suggest that an important calibration point can be obtained by measuring the Cs^{+1}, Cs^{+1} cross-sections. We have set up an experiment to measure the cross sections for both charge exchange:

$$Cs^{+} + Cs^{+} \rightarrow Cs^{++} + Cs^{*} \qquad (1)$$

and ionization

$$Cs^{+} + Cs^{+} \rightarrow Cs^{++} + Cs^{+} + e \qquad (2)$$

in the energy range 10 to 300 keV relative energy. Our experiment consists of a cesium plasma target (Q-Machine) through which a beam of Cs^{+} ions is transmitted. Cross sections will be determined by measuring the growth in Cs^{+} and Cs^{++} as a function of plasma density.

A measurement using the crossed-ion beam technique recently has been reported yielding a sum of the cross sections for (1) and (2) of (1.5-2.8) x 10^{-16} cm^2 in the 40-280 keV cm energy range (Ref. 1). This is in fair agreement with theoretical estimates by Olson (Ref. 2) of 4 x 10^{-16} cm^2. However, experimental work by our group on the electronically similar system Cs^+ + Xe gives ionization cross sections of approximately 2 x 10^{-15} cm^2 (Ref. 3). We will complete measurements of (1) and (2) for comparison with Olson's calculations and the results of Ref. 1.

Progress in the past six months includes:

1. Cs^{+1} Ion Source: A surface ionization source for our accelerator has been completed and used extensively for other experiments (Cs^+ + Xe) and systematic checks on the plasma target experiment.

2. Accelerator: Upgrading of our accelerator from 150 kV to 300 kV has been excruciatingly slow; we now expect it to be completed by November 1979. Preliminary measurements are being done with the 150 kV accelerator.

3. Q-Machine Plasma Target: We had originally planned (and set up) for longitudinal injection of the beam into the Q-Machine. However, we have discovered from the Cs^+ + Xe experiment that large scattering cross sections will make it necessary to inject the Cs^+ beam transverse to the target (and magnetic field). The target has been rotated by 90^0 for transverse injection. This will result in a lower plasma line density and we are planning for a second cathode to increase the plasma density. Disgnostics include Langmuir probes, a microwave interferometer, and possible atomic beam probes.

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1. K. F. Dunn, G. C. Angel and H. B. Gilbody; to be published in J. Phys. B.

2. R. E. Olson, Proceedings of the Heavy Ion Fusion Workshop, Argonne National Laboratory, September 1978.

3. J. A. Tanis, K. R. Stalder, J. W. Stearns and A. S. Schlachter; to be presented at the 1979 D.E.A.P. meeting, Houston, Texas.

4. Beam Analysis Chamber: The analysis chamber has been completed and used for system checkout.

The entire system is operational and cross section measurements are beginning. We expect preliminary data from the rotated target by the end of November. We hope to get complete results by April.

It should be noted that this activity has been supported by the LBL Director's Program Funds, a discretionary allocation, and not by the Office of Inertial Fusion.

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HI-FAN-58	HIF Staff	Linear Induction Accelerator Conceptual Design	9/6/78
HI-FAN-59	L. J. Laslett	Letter to Dr. Ingo Hofmann, dated 10/25/78	10/25/78
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