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HEAVY ION FUSION HALF-YEAR REPORT
October 1, 1981 - March 31, 1982

Heavy Ion Fusion Staff

May 1982

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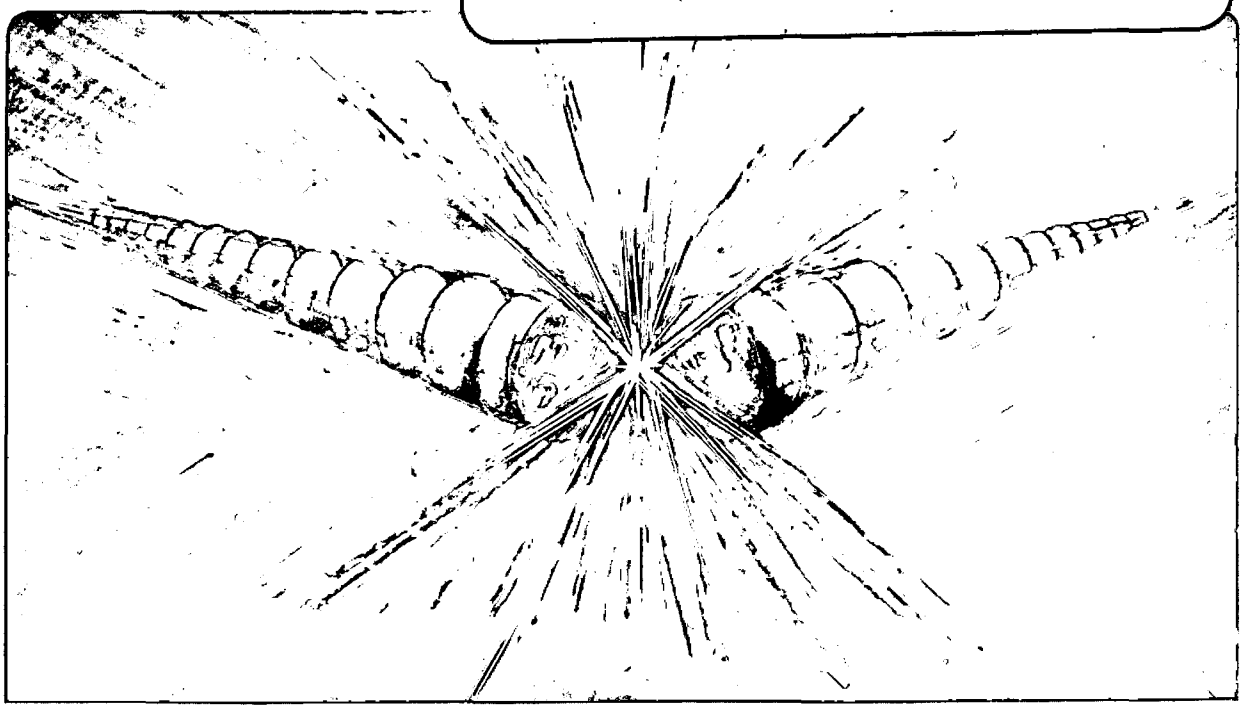

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HEAVY ION FUSION HALF-YEAR REPORT*

October 1, 1981 - March 31, 1982

H.I.F. Staff

May 1982

Accelerator and Fusion Research Division
Lawrence Berkeley Laboratory
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Berkeley, California 94720

*This work was supported by the Assistant Secretary for Defense Programs, Office of Inertial Fusion, Laser Fusion Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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HIGHLIGHTS

- The 200 KeV cesium-ion injector for the Single Beam Transport Experiment, designed to have a variable and controlled perveance, has been debugged and has now been well characterized. Operated without grids, it delivers an ion beam with an emittance about twice the thermal value computed from the temperature of the emitter.

- Measurements on the 2 MeV injector model with the Electron Beam Probe continue to be refined to understand the nature of the electron halo around the ion beam.

- Fabrication of a long-pulse ion induction accelerating module is under way.

- Development of scintillators and insulators continues at a low level.

- Theoretical studies include octupole transport systems, longitudinal beam stability, and exploration of possible induction linac parameters for a High Temperature Experiment (HTE).

EXPERIMENTAL PROGRAM

Single Beam Transport Experiment (SBTE)

The source section of the single beam transport experiment has been in operation since December 1981. Detailed measurements have been made on the source in order to check its properties, as well as to develop the diagnostic tools required for future beam measurements. The Cs^+ zeolite source delivers the required current and operates reliably. The beam properties agree with the design predictions.

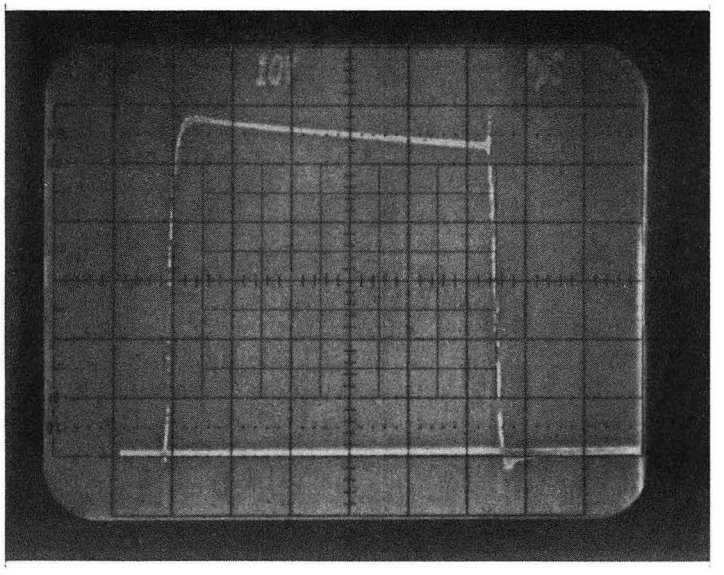
Biased Faraday cups, similar to the ones used on the 3-drift-tube accelerator, have been used for current measurements. Typical beam-voltage and beam-current traces are shown in Fig. 1. The emission of the zeolite source was checked against its temperature in the range of 800°C-1150°C (see Fig. 2). The emission limit increases with temperature, and 1100°C was chosen as the normal operating temperature, so that the maximum required current (30 mA) is below the emission limit. At this temperature the beam current follows the Child-Langmuir law as the applied voltage is varied. In addition, when the Marx power supply is not crowbarred and the applied voltage is allowed to decay, the decrease in current as a function of time also follows the Child-Langmuir law as a function of the decreasing voltage (see Fig. 3).

The divergence and emittance were studied as a function of the total current. Slits were used to generate submillimeter beamlets and an Optical Multichannel Analyzer (OMA) was used to view the beamlets on a scintillator. The measured beam divergence and radius are shown in Fig. 4, together with the theoretical predictions of the EGUN code. A slight systematic shift between the data and the calculations is observed. The normalized beam

emittance, defined as the phase-plane area containing 95 percent of the particles, was measured to be $5.5 \times 10^{-8}\ \pi$ m-rad as compared with $3.4 \times 10^{-8}\ \pi$ m-rad calculated from the source temperature.

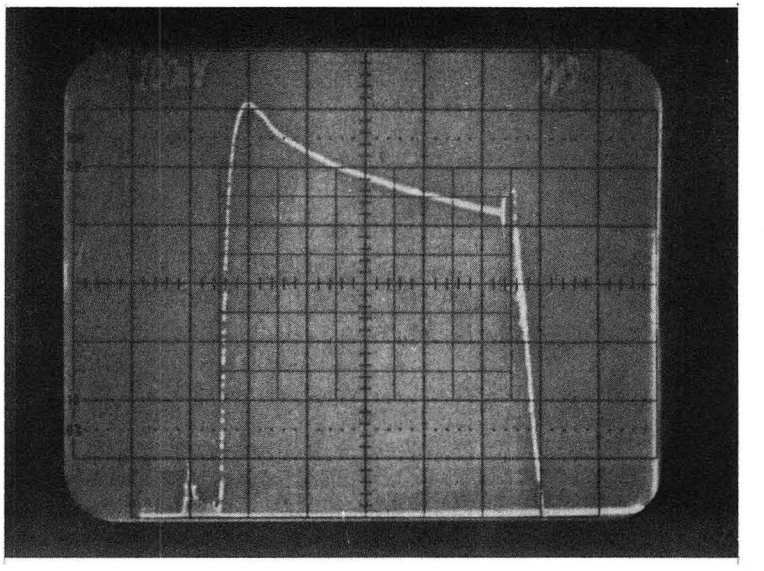
The last step planned before installing the matching section is to study the effect of the emittance grids on the measured emittance, and to compare the measurements done with the OMA to measurements using charge collectors.

The matching section and the first transport section will be completed by mid-May. Completion of the entire assembly is scheduled for the end of the fiscal year.



VOLTAGE

26.5 kV/div
2 μs/div



CURRENT

2 mA/div
2 μs/div

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Fig. 1 Oscillograms of the extractor voltage and the Faraday cup current.

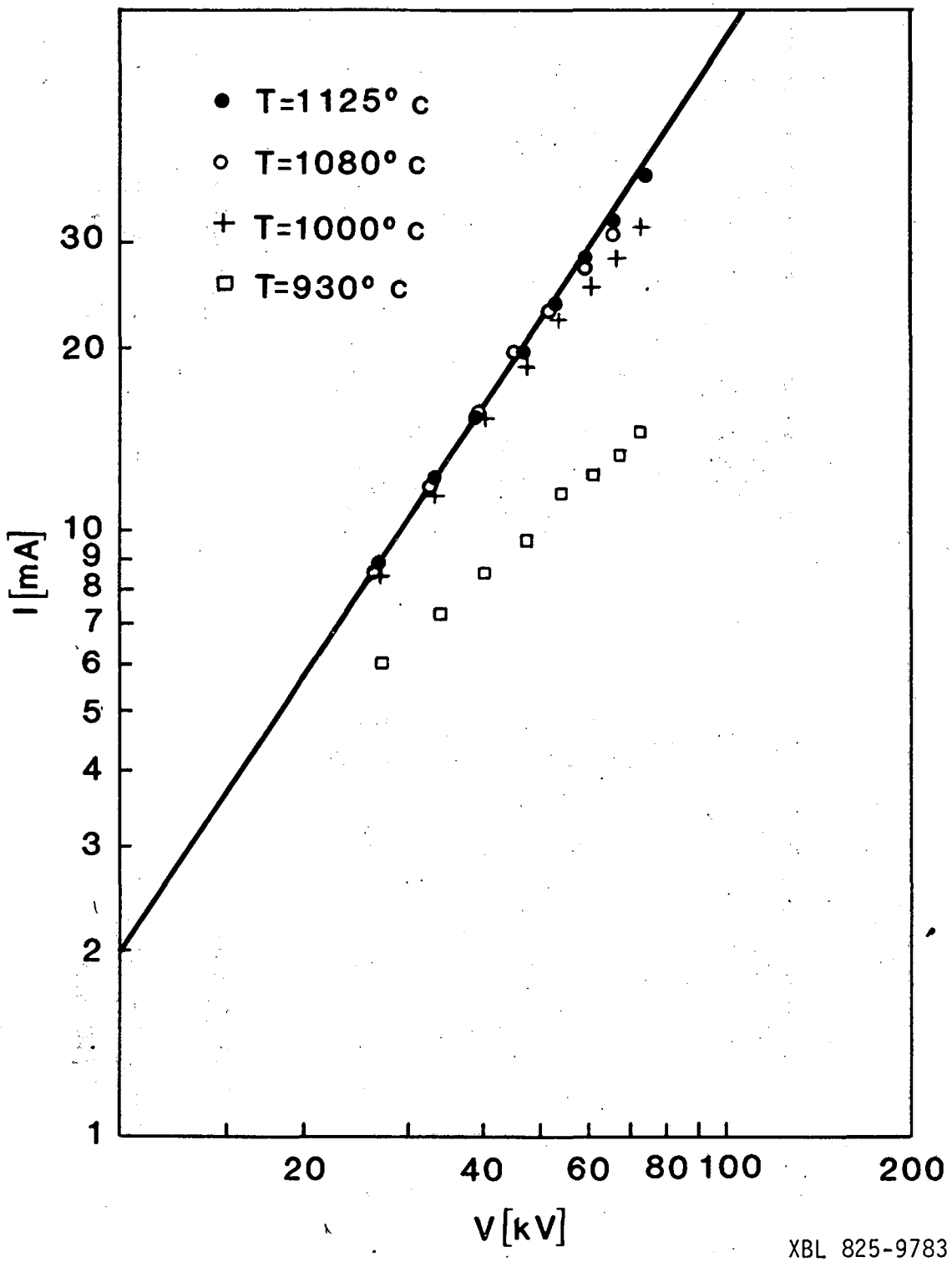


Fig. 2. Total current measurements as a function of applied voltage for different temperatures (5 μs pulse length). The voltage is applied between the source and the first electrode in the gun. The solid line is the expected space charge limited current.

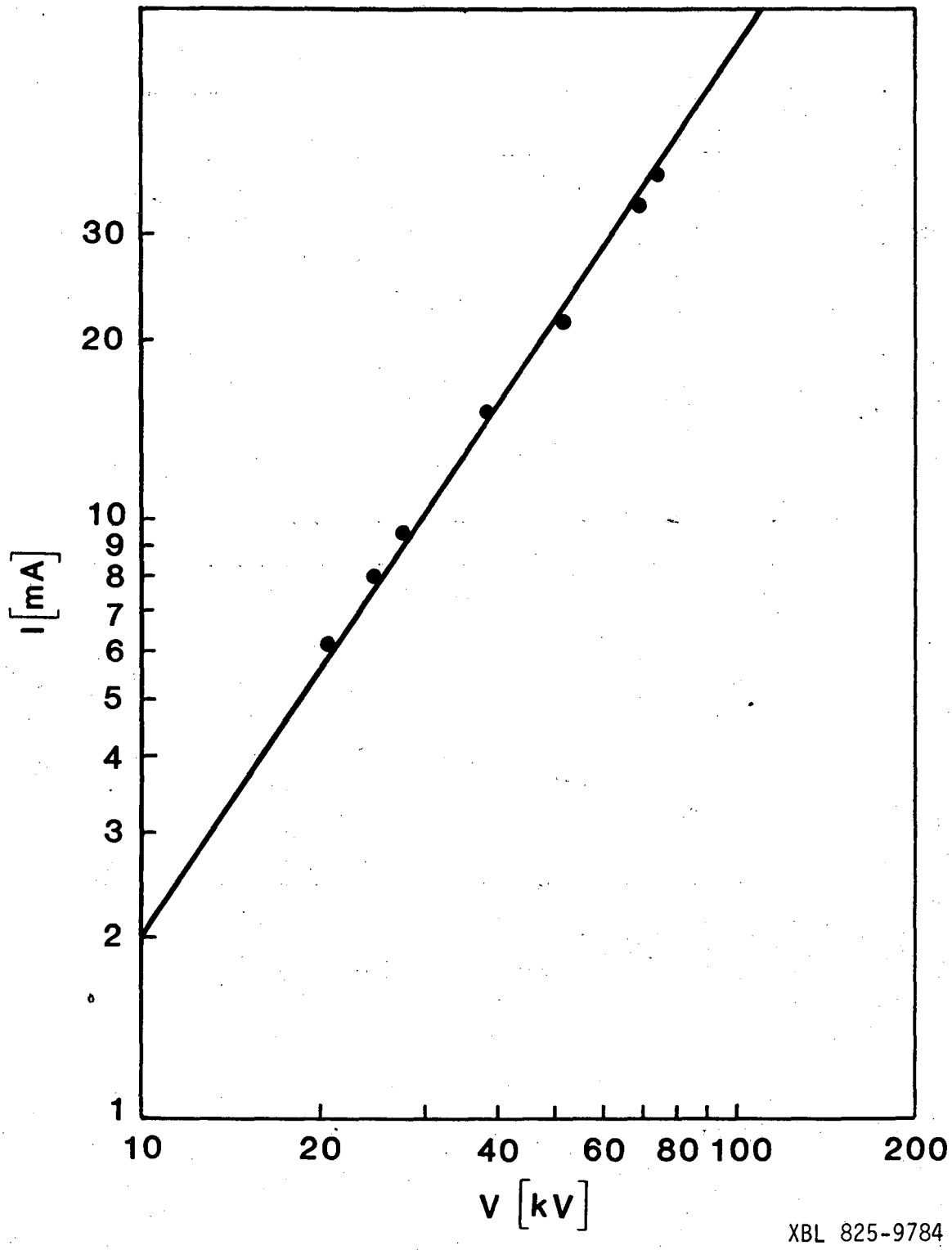
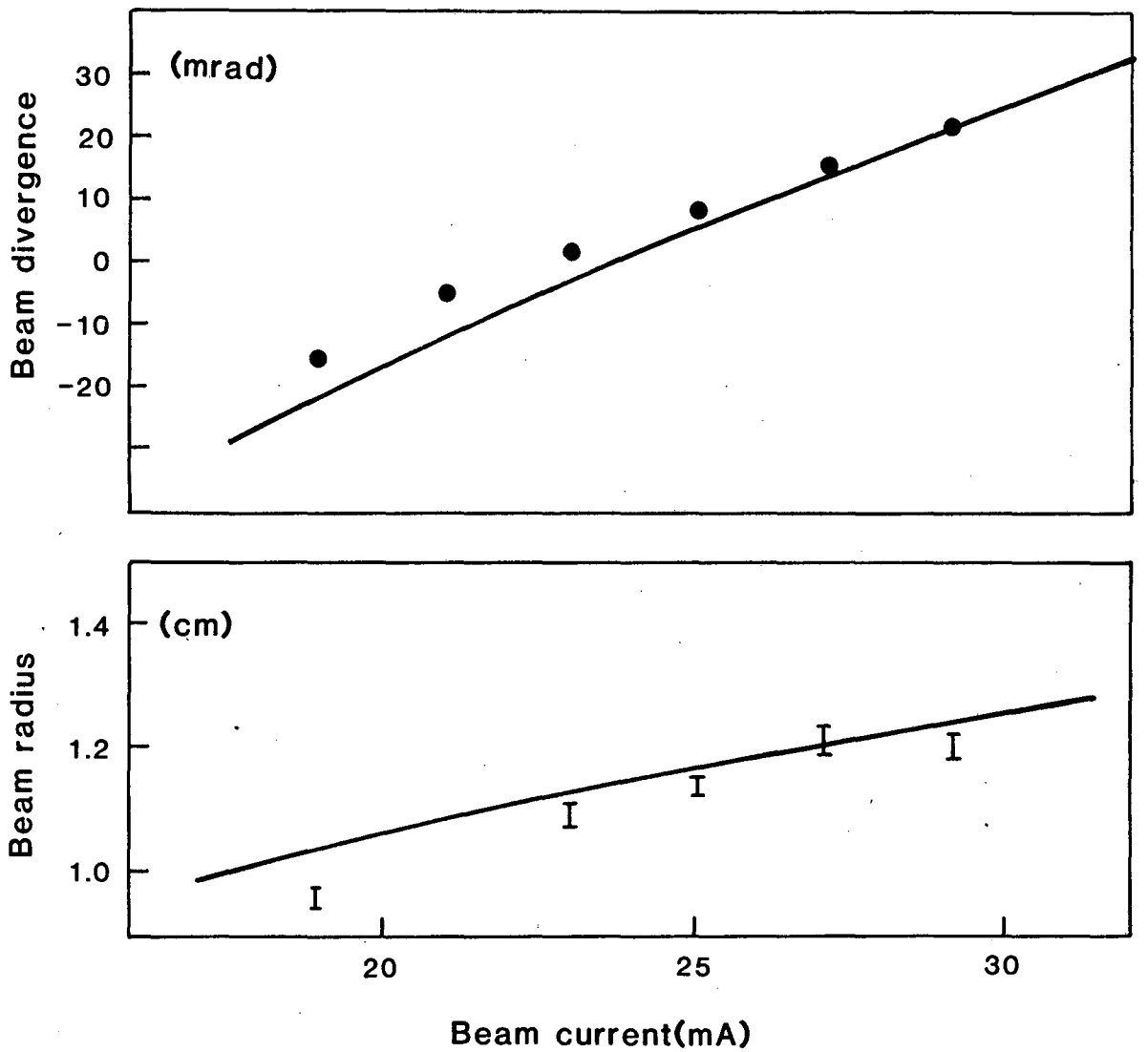


Fig. 3. Total current as a function of voltage, measured at different points in time for one long pulse (100 μs). The voltage is applied between the source and the first electrode in the gun. The solid line is the expected space charge limited current.



XBL 825-9761

Fig. 4. Divergence and radius measurements and the curves predicted by the EGUN code.

DIAGNOSTICS

Electron Beam Probe

Preliminary analysis of the data obtained with the Electron Beam Probe* (EBP) indicated the existence of a halo of electrons around the Cs^{+1} beam emerging from the drift tube accelerator. An experiment was set up to verify this partial neutralization. In this experiment, a biased cylinder was inserted 1 meter upstream of the electron gun. The cylinder diameter is 12" so that the beam can pass through it without interception. The bias voltage is varied between -17.5 kV to + 17.5 kV, in order to pull electrons away from the beam and observe the effect on the EBP deflection. The change in radial deflection as a function of voltage (Fig. 5) has shown conclusively the existence of an electron halo surrounding the ion beam. With the improvement of the cylinder's aspect ratio (from 5" long, 12" diam. to 8-1/2" long, 12" diam.) it is hoped that a meaningful analysis of the trapped halo electrons' energy vs. number will be made. Currently a dynamic model of the halo of electrons is being developed. This model aims at obtaining a self-consistent ion-plus-electron radial charge distribution necessary to maintain the radial electron distribution, assuming the ions are fixed. This may be a first step towards a model showing how secondary electrons are produced and trapped by the Cs^{+1} beam as it moves down the accelerator. It is believed that the electrons are produced inside the third drift tube where a maximum in the ion-beam envelope occurs and some of the outermost ions can impact the walls.

*See Heavy Ion Fusion Year-End Report, LBL-13529, October 1981 for a description of the probe and initial results.

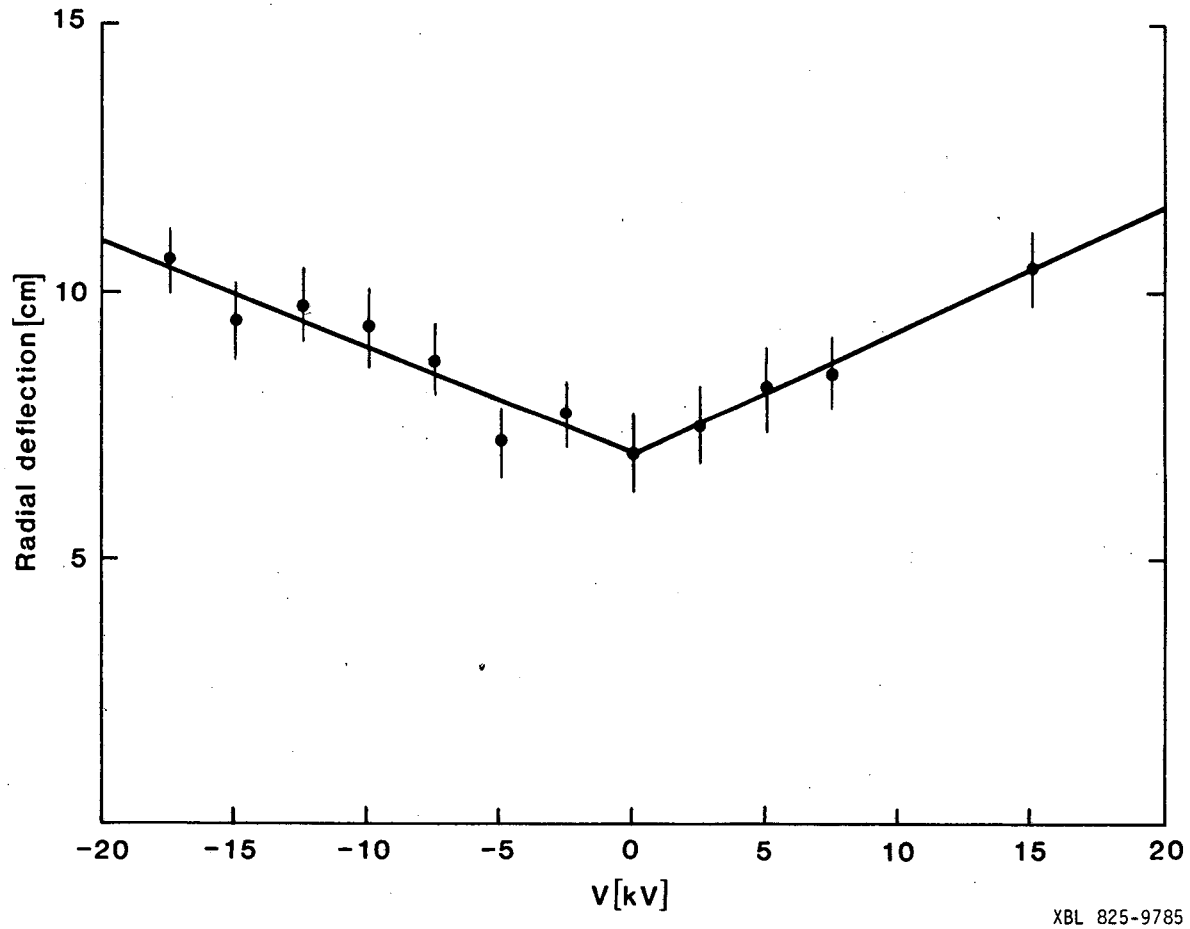


Fig. 5. Electron beam probe radial deflection as a function of the cylinder voltage. Positive voltage extracts some of the co-moving electrons, negative voltage inhibits their propagation; in either case the electron beam deflection increases with voltage indicating greater net positive charge in the beam.

Scintillator Development on SBTE

A transparent scintillator design has been tested on the SBTE and used to make extensive measurements of the beam divergence and emittance. The scintillator is a 1-μm thick layer of europium-doped calcium fluoride, vacuum-evaporated onto a 2" x 2" piece of float glass which has been coated with a very thin metallic layer (Optical and Conductive Coatings, Pacheco, CA) such that the transmission in the visible region exceeds 85 percent. The coated area is masked such that the edges of the conductive film remain accessible so that the beam charge can be bled off.

Aside from damage by intermittent sparks, the scintillator has worked as expected.

COMPONENT DEVELOPMENT

Induction Module

Work on large induction cores and on the pulsers to drive them has been reactivated in the present period. Previous economic analyses had shown that 2 mil silicon steel tape is the best near-term choice for core material when both the cost of the material and the cost of the pulser are considered, and this conclusion was not reviewed at this time. The cost of Metglas [R] has continued to decrease, to about $20/kg in quantity, and if the trend continues it would become the material of choice in about two years. The goal of the induction module design is to attain a total voltage of 250 kV for a 1.5 μsec pulse width, and the means for reaching it are to use an existing insulator stack and nominally 22 silicon steel toroids powered in pairs by 11 independent pulsers. The module is shown in Fig. 6.

The existing insulator stack and the necessary clearances led to a core with an inner diameter of 13" and a lamination width of 1.37". The desired volt-seconds resulted in an outer diameter of 33". Bids for sample cores were solicited from manufacturers and four cores were purchased. The cores were checked for mechanical tolerances and for their electrical characteristics. Mechanically all dimensions are well within 1/16". Electrically, the remanent field varied from 10.9 to 12.3 kilogauss, and the saturation field from 13.2 to 14.3 kilogauss. More importantly, in pulsed operation approximating the intended use, the excitation current per core at the end of the pulse is slightly under 5kA. Work is now in progress on

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[R] Allied Chemical Corporation Trademark

tapering the pulse forming network (PFN) which drives the cores to produce a flatter pulse.

The pulse circuit to drive the cores is a tapered-impedance lumped-element pulse forming network (PFN) switched by a gridded ignitron tube. Last year, the first example of this type of tube swtiched a 4kA pulse for > 2 x 10^6 pulses, at which time the test was terminated for budgetary rather than technical reasons. At that level, one tube would be able to drive one core. This year, on the second example of the ignitron, the test was conducted at about 10kA, 25 kV, for 2 x 10^5 pulses, to simulate a circuit where one tube drives two cores. This test was terminated when the sample cores arrived, and the tube was used to drive them. Some surface sparking along the inside of the glass envelope occurred, which may have been caused by large reverse currents flowing in some of the tests where the PFN was under-terminated.. At least two different solutions have been found to eliminate the reverse current flows by using nonlinear materials, but both of these solutions decreased the output pulse amplitude from 25 kV down to 20 kV. This work on avoiding current reversal in the tube is closely allied to the pulse flattening efforts, and is on-going.

If successful, this technology will be suitable for induction linac use for any pulse duration longer than about 1 μsec. The eventual changeover to a better magnetic material such as Metglas ^{R} will decrease the excitation current by about one order of magnitude, thereby easing the modulator requirements and allowing one PFN to drive more cores. Two Metglas ^{R} cores are being ordered now for evaluation purposes, and these could be used as substitutes for one of the 11 pairs of silicon steel cores in the induction module.

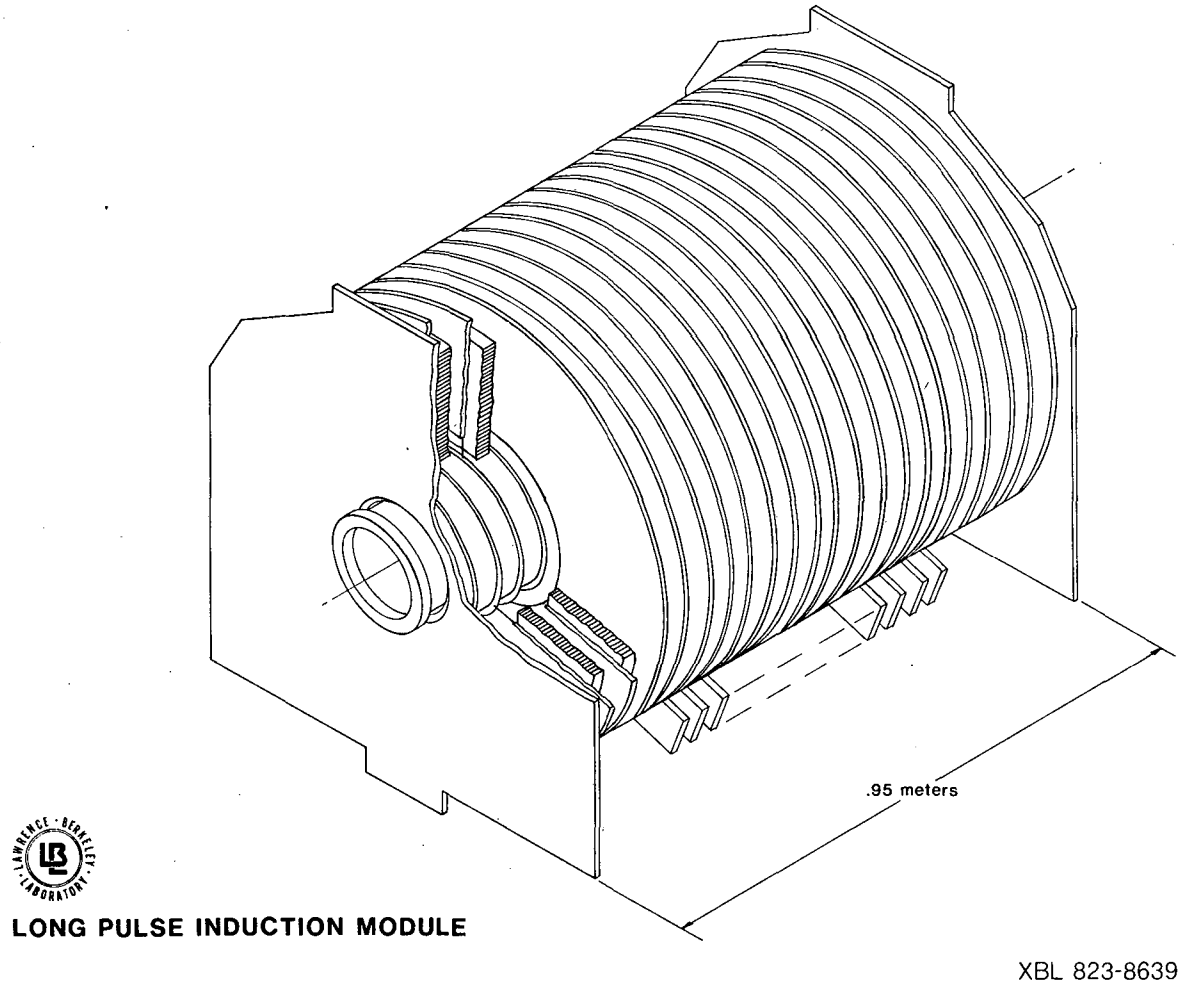


Fig. 6 Long Pulse Induction Module.

Insulator Development

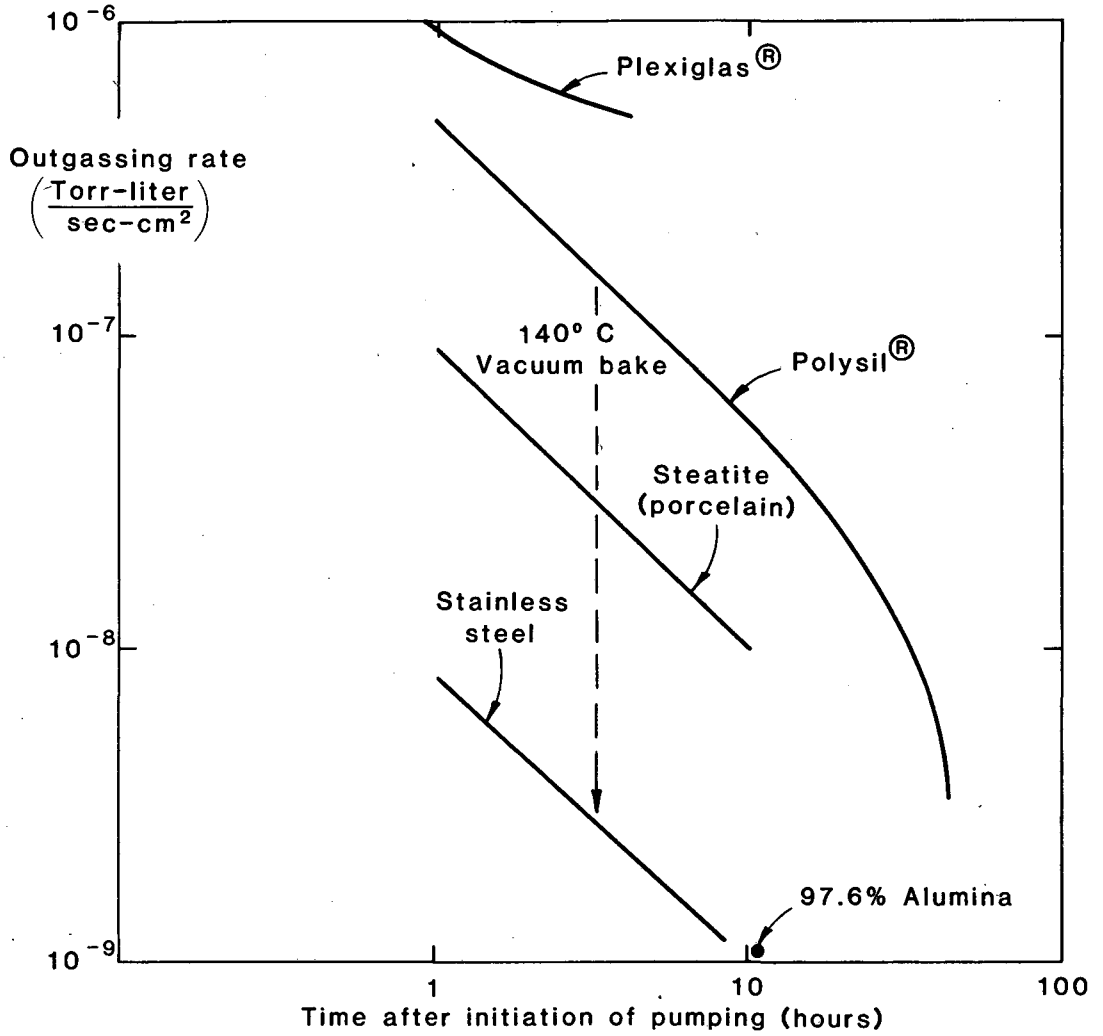
Heavy ion induction linacs for ICF require large vacuum insulators with metal embedments which may be fabricated out of sintered alumina for high vacuum applications or filled epoxies for low vacuum requirements. We have begun a program to try to develop a quartz sand-filled plastic insulator material which will have a high sand fraction. Initial tests have been done on a formulation developed by the Electric Power Research Institute (EPRI EL-1093, May 1979) called Polysil [R] based on poly-methylmethacrylate (PMMA) and sized quartz sands.

The sands have been oven-dried in air and the sand-plastic mix vacuum outgassed at a vacuum of 40 Torr. The outgassing rate of this material unbaked is shown in Fig. 7, compared with more usual vacuum materials. After baking for 10-24 hours at 140°C the outgassing rate drops to the level indicated. The largest outgassing component detected with a residual gas analyzer was water.

We have also made a casting around a stainless steel pipe (Fig. 8) which was leak tight at the joint under test when checked with a mass spectrometer helium leak detector.

Our present plan is to examine some epoxy binders which might have better vacuum properties than PMMA. Following selection of a system we plan to cast some large size demonstration insulators.

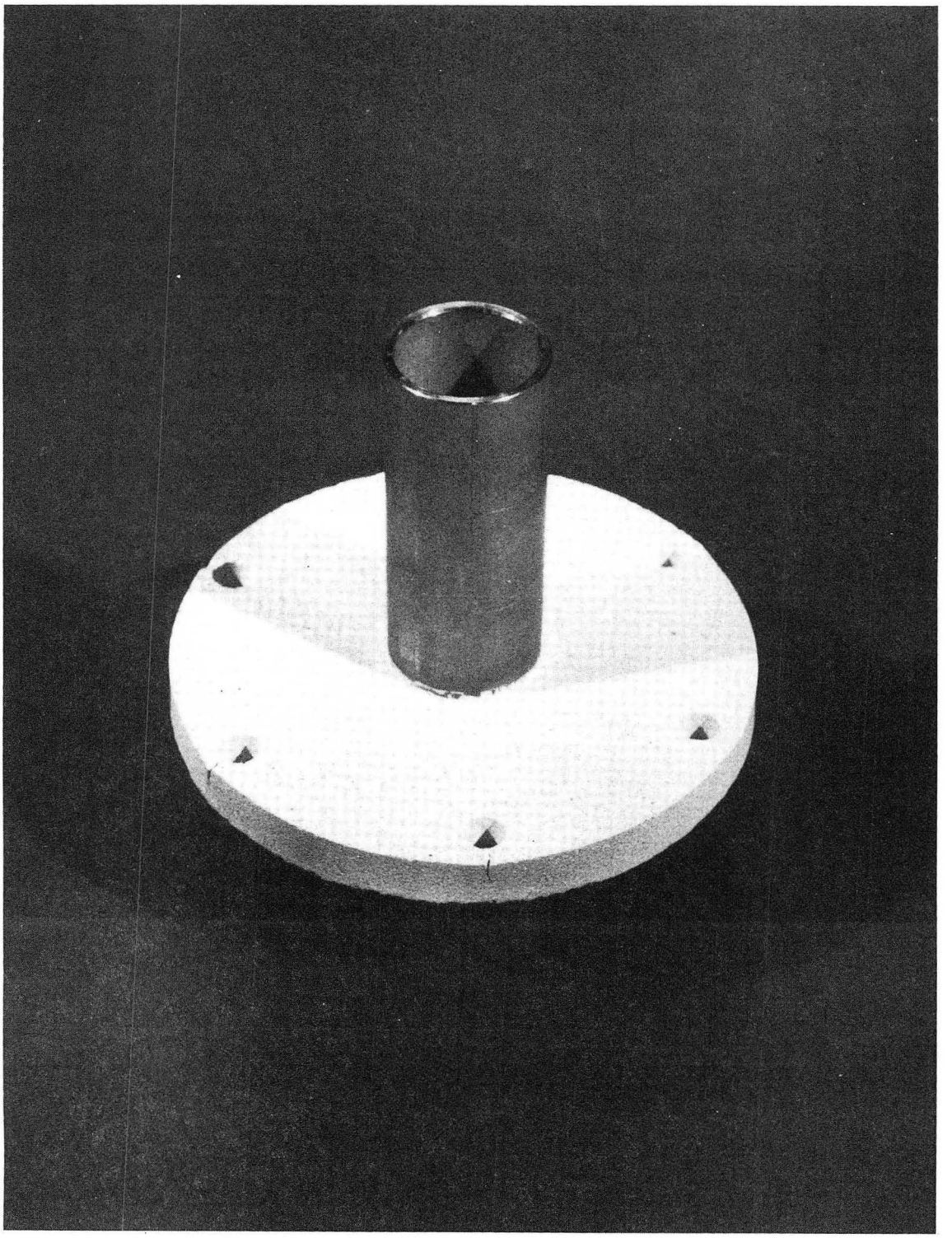
[R] EPRI Trademark



Outgassing Rates (mechanically cleaned, solvent cleaned, not vacuum baked)

XBL 823-8641

Fig. 7 Outgassing rates of polysil and some other materials for comparison. Note sharp reduction in outgassing after baking



CBB 822-1119

Fig. 8 A test casting of Polysil R around a stainless steel tube to show facility of making metal embedments.

THEORY

Quadrupoles and Octupoles

Calculations have been in progress to interpret the properties of periodic electrostatic quadrupole-lens systems intended for the transport of high-intensity beams and to investigate the comparative performance of octupole transport systems. Computations pertaining to both the quadrupole and octupole transport systems have been conducted in terms of scaled variables, with the object of minimizing the dimensionality of parameter space. The recent work relating to quadrupole transport systems has been concerned with descaling procedures to design a single-beam transport system capable of transporting a maximum current in a Kapchinskij-Vladimirskij beam of any specified ion species. Such design work must recognize the existence of certain constraints to which a practical system will be subject, and the constraints of dominant influence will depend upon the energy regime within which it is intended to operate. Thus the frequently cited Maschke formula, in its original form, regarded (i) the achievable applied field at the edge of the beam as one important limitation and (ii) implied a knowledge of a second constraint on tune depression due to space-charge forces that in practice could arise from the imposition of an upper limit to the aperture ratio (maximum beam diameter relative to the period of the transport lattice).

Alternatively, it may be necessary to restrict the applied potential at the edge of the beam in order that the ion charge times this potential not exceed some reasonable fraction of the ion kinetic energy, and this restriction would then be imposed in conjunction with a restriction on aperture ratio. We propose, moreover, that the zero-intensity tune (the phase advance, σ_0, of individual-particle oscillations per period of the

transport lattice) should not exceed 60 degrees in the interest of avoiding certain important potential collective instabilities, but we then impose no limit on the amount of space-charge tune depression. In recent analysis it has appeared that if V_Q and the aperture ratio are specified, then, for ions of a specified type and energy, the zero-intensity tune (σ_0) is determined. If σ_0 differs from 60 degrees it then appears desirable to adopt a more moderate value for one of the two aforementioned constraints, so that σ_0 becomes close to 60 degrees. When this is done, an appropriate value for the lattice period can be computed--a value that is dependent upon the maximum emittance expected for the ion beam to be transported. Illustrations of this design procedure have been included in a report now being completed.

An octupole transport system is expected to lead to a matched beam that is distinctly hollow. Our computations have been concerned with individual-particle motion in the presence of space-charge forces that arise from a beam distribution that is a consistent stationary distribution within the accuracy of a smooth approximation. Studies of individual-particle motion in a single spatial transverse degree of freedom then clearly indicate that maximum intensity is stably transported when the hollowness of the beam is very pronounced. Phase trajectories under conditions close to a stability limit, moreover, frequently are marked by very evident stochasticity. An adequate account of octupole transport, in terms of scaled variables, thus awaits the completion of a systematic study now being organized to determine stability boundaries for individual-particle motion in two spatial transverse degrees of freedom.

Phase Space Constraints

Liouville's theorem imposes an absolute constraint on an accelerator system; the volume of occupied phase space incident on a target must be at least equal to the volume passing through the accelerator system times the dilution factor. In 1978 a parametric analysis of heavy-ion-fusion igniters using rf linacs to feed storage rings or synchrotrons was performed. The example designs available then were unable, or only marginally able, to meet the six-dimensional phase space constraint if realistic dilution estimates were used.

During the report period a corresponding parametric analysis of induction linac systems was made, and applied to a 3 MJ power plant driver design. There are significant differences: (1) here there are separate two-dimensional (2-D) longitudinal and 4-D transverse phase constraints; (2) conservatively estimated dilution factors are much smaller; (3) the longitudinal momentum spread induced during acceleration is not yet known experimentally, and must be treated like the unknown dilution factors, until test systems yield data; and (4) the multiple-beam concept seems directly applicable to induction linacs and greatly eases the constraint. The 3 MJ design was found to be significantly better than the earlier ones using rf linacs, provided the fractional longitudinal momentum spread can be held to roughly an order of magnitude more than that expected from estimated random "noise".

More recently the implications of phase constraints for design of induction linacs for spot heating experiments, using lighter ions (A = 23, 39) and lower ion kinetic energies (100-200 MeV), have been and continue to be explored.

In collaboration with workers at Lawrence Livermore National Laboratory, studies have been made of (1) the influence of target requirements on heavy-ion accelerator power plant igniter design; (2) the feasibility of, and requirements for, significant spot heating experiments using induction linac test facilities; and (3) the effects of various vacuum-propagation regimes in reaction chambers on accelerator requirements.

Longitudinal Bunch Stability

Compared to the well-developed theory of the stability of a uniform beam, the understanding of the longitudinal stability of a bunched beam is not complete. The most rigorous analyses of such bunch phenomena are applications to relativistic storage rings where space charge forces are small, and the machine impedance is broadband. In contrast, in the induction linac approach to HIF, the module impedance is narrow in frequency response, space charge forces are not negligible, and the bunch is relatively cold. Experiments to date have been limited to the relativistic regime.

In response to this situation, a one-dimensional computer simulation code modeling the longitudinal stability of bunches has been developed by I. Haber of NRL in conjunction with our accelerator theory group and is now fully implemented at LBL. This simulation code follows the motion of several thousand pseudoparticles in the self-consistent electric field generated by space charge and machine impedances (plus possible external focusing). The electric fields are calculated by Fourier analysis which enables a wide class of interactions to be modeled by multiplication in the Fourier conjugate space. The effects of finite pipe size, which reduces the high frequency components of the space charge force, have been included along with a model of induction module response.

The code can be run with 1024 cells which provide sufficient resolution to study dispersive effects for realistic aspect ratios of bunch length to beam pipe radius. Dispersive propagation due to the physical short wave length cutoff of the space charge force has been observed. As a perturbation approaches the bunch end, it narrows, i.e. the shorter wavelengths become more important. The reflection process is slow (of the order of the transit time across the bunch) and is highly dispersive, yielding a wave train reflection. Computer runs with induction module impedances indicate that the narrow band width of the impedance may ameliorate stability requirements.

Analysis of perturbation calculations suggests that threshold effects for stability may be observable with the e-folding growth length as the governing parameter, and simulation studies are currently underway which address this question. Nonlinear behavior including solitons, breaking and shock wave formation have been observed in the simulation and may significantly influence longitudinal beam dynamics.

With this simulation code in place, specific induction module design parameters can now be evaluated relative to longitudinal stability considerations. The code may also be run to address storage ring HIF experiments such as those proposed for the SNS in the U.K.

PUBLICATIONS AND REPORTS

LBL - 14130 10/81	A. Faltens D. Keefe	Review of Induction Linacs, Proc. 1981 Linear Accelerator Conf., (Santa Fe, 1981), Los Alamos National Laboratory Report LA-9234-C, p. 205 (1982).
HI-FAN-177	W. B. Herrmannsfeldt	Multibeam Arrays of Octupoles, November 1981
LBL-14038	D. Judd	Phase-Space Constraints on Induction Linac Heavy-Ion Inertial-Fusion Igniters, December 1981
HI-FAN-179	M. Tiefenback M. Lampel A. Faltens	Optimization of Current Pulse Shapes in a One Dimensional Diode, January 1982. (to be submitted to a journal)
HI-FAN-181	J. Shiloh M. Lampel R. Sah	Studies of Charge Neutralization in Ion Beams Using an Electron Beam Probe (abstract), 23rd Annual Meeting, Division of Plasma Physics, Oct. 12-16, 1981, Bulletin of American Physical Society, 26, 1007 (1981).
HI-FAN-182	C. Kim et al.	Status of the LBL Heavy Ion Beam Transport Experiment (abstract) 23rd Annual Meeting, Division of Plasma Physics, Oct. 12-16, 1981, Bulletin of American Physical Society, 26, 1007 (1981). (with D. Keefe, L. J. Laslett, R. Sah, L. Smith, M. Tiefenback, D. Vanacek and T. Wang)
LBL-14194 1/82	D. Keefe	Inertial Confinement Fusion, Ann. Rev. Nucl. Part. Sci., Vol. 32 (1982) (in press).
LA-UR-81-3730 12/81	HIF Staff	Contributions to "Accelerator Inertial Fusion -- a National Plan for the Development of Heavy-Ion Accelerators for Fusion Power.
PUB-5065	HIF STAFF	A Proposed Program to Develop Linear Induction Accelerator Technology in Support of the National Accelerator Inertial Fusion Plan, Feb. 1982

HI-FAN-185	David L. Judd	Estimates of Momentum Tilt and Drift Distance for Spot Heating Using an Induction Linac Test Facility, Feb. 1982
HI-FAN-186	G. Krafft et al.	Longitudinal and Transverse Coupling in Accelerator Beam Plasmas, Feb. 1982 (with J. W-K Mark, L. Smith, T. F. Wang)
HI-FAN-187	Joseph J. Bisognano	Estimate of the Radius of Convergence of the Perturbation Expansion of Channell, Sessler, Wurtele for Particle Bunches, April 1981
HI-FAN-188	David L. Judd	A Simple Expression for Third-Order Geometric of Quadrupole Doublets, November 1981
HI-FAN-189	David L. Judd	Rough Estimates of Focusing Many Beamlets for Spot Heating: Possible Use of Permanent Magnets, February 1, 1982.
LBL-14341	D. Keefe S. S. Rosenblum	Berkeley Research Program on Ion Induction Linacs for Inertial Fusion. Presented at the Symposium on Accelerator Aspects of Heavy Ion Fusion, Darmstadt, March 29 - April 2, 1982.

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