Title
HEAVY ION FUSION YEAR-END REPORT

Author
Lawrence Berkeley National Laboratory

Publication Date
1982-10-01

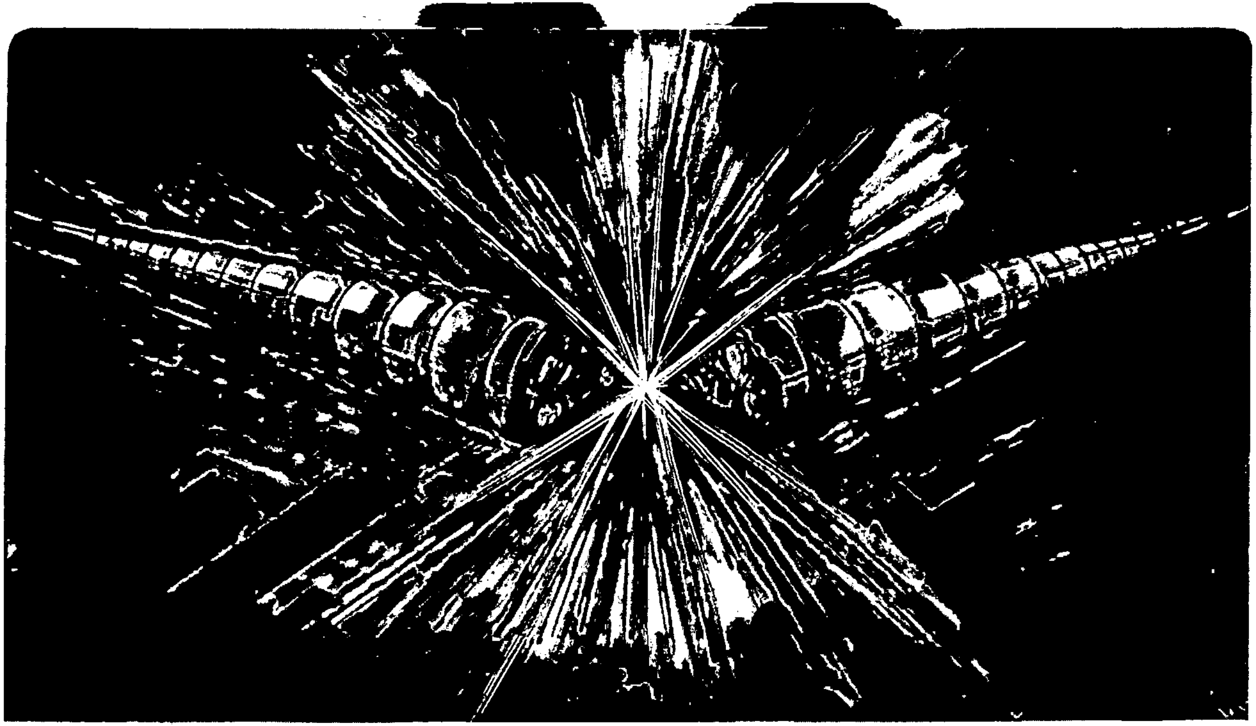
Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Accelerator & Fusion
Research Division

HEAVY ION FUSION YEAR-END REPORT

H.I.F. Staff

October 1982



Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-15123

HEAVY ION FUSION YEAR-END REPORT*

April 1, 1982 - September 30, 1982

H.I.F. Staff

October 1982

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

---

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

HIGHLIGHTS

- The 200 keV cesium ion injector for the Single Beam Transport Experiment has been operated extensively in development and measurement of the quadrupole matching system and beam emittance control. Construction of the complete transport system is well advanced.

- Beam diagnostic tools continue to be improved.

  The electron beam probe has been used extensively to study ion beams in varying stages of charge neutralization.

  Development of systems using scintillators and the EG&G Optical Multichannel Analyzer (OMA-2) continues.

- The Long-Pulse Induction Module (LPIM) is in the final stages of construction. A two-core prototype test cell has been assembled and tested to nearly 10^6 pulses.

  Development of both the switch tube (ignitron) and pulse-forming network has proceeded rapidly and successfully.

- Silica-loaded polymer insulator development is continuing at a low level.

- Theoretical studies of longitudinal beam bunch dynamics using I. Haber's computer simulation code, quadrupole and octupole transport channels and solenoid focussing channels using neutralized beams have received considerable emphasis during this time.

  The exploration of possible induction linac parameters for a High Temperature experiment (HTE) is continuing.

Continued studies with a 1-D computer program have shed considerable light on the behavior of longitudinal instabilities in bunched and coasting beams; for bunched beams a threshold criterion has been identified.

EXPERIMENTAL PROGRAM

Single Beam Transport Experiment (SBTE)

The Cs^+ zeolite source has been in operation continuously during this reporting period. Operation has been reliable and has permitted work on the matching quadrupole system and the emittance grids.

The emittance grids held only a fraction of the desired voltage before sparking down, so a redesign has been done, replacing the wires with a honeycomb material. Field stress calculations indicate that the new design will hold enough voltage to give the emittance growth needed for the experimental program.

Measurements of beam emittance using charge collectors give the same value that the scintillator-OMA measurements gave (5.5×10^{-8} π mrad). The variation of the OMA signals with light input has been checked and found to be nearly linear for signals of the size we observe, so that only scintillator linearity questions remain. The charge collectors are currently in use for beam diagnostics.

Upon placing the five matching quadrupoles (MQ1-MQ5) into the system, we find that the beam envelope is approximated rather well by the KV envelope equation. Deviations from calculated envelope parameters can be attributed to the very large tune depression caused by beam space charge, coupled with nonlinearities in beam and lens fields. These effects should be less pronounced at higher emittance or lower current for the beam. We also noted large positional and angular errors of the beam at the end of the fifth matching quadrupole (4 mm displacement and 50 milliradian steering errors), which were attributed to quadrupole misalignment. The system was more carefully aligned, and the errors are now reduced to 1 mm and 6-8 milliradians.

During operation of the source, a problem arose from contamination of the grid wires at the gun output, causing the current from the source to fail to follow the $V^{3/2}$ Child's Law dependence. This seems to have been due to local plasma formation and consequent back-bombardment of the anode emitter. This has been cured by resistively heating the grid in order to outgas it.

The remainder of the single beam transport system is under construction. Transport sections will be added as soon as the present program of matching and emittance changing measurements are completed.

DIAGNOSTICS

Electron Beam Probe

In the past six months progress has been made both in the experiment and data analysis. Experimentally greater flexibility in the diagnostics has been achieved by adding an isolated cylinder at high voltage (-20kV to +20kV) through which the ion beam passes entering the diagnostics tank. This allows control of the neutralization by regulating the electrons in the beam. Measurements of electron current, energy, and total charge can now be made.

Efforts in data analysis have yielded much better fits to the experimental data using the same five-parameter fit generated by the Pizza code. Work has also been done on a technique for obtaining both the radial and the longitudinal dependence of the space charge distribution.

A paper, Electron Beam Probe for Charge Neutralization Studies of Heavy Ion Beams (LBL-14391, UC-37), J. Shiloh, M. Lampel, R. Sah, has been accepted for publication in Review of Scientific Instruments.

Scintillation Imaging

Since it is planned to use the EG&G Optical Multichannel analyzer (OMA-2) to record a scintillator image of our heavy ion beams, we have measured the linearity of the response of the OMA-2 system to a pulsed light source in its gated mode. In the gated mode the OMA-2 can capture events with a time resolution of 40 ns. Thus work is an extension of recent work reported by Liesegang and Smith [G. W. Liesegang and P. D. Smith, Applied Optics, 21, 1437 (1981)] in which they measured the linearity for a pulsed light source in the DC (ungated) mode of the OMA-2.

The EG&G OMA-2 using the 1254 SIT detector head was set up on an Ealing Optical Bench and aimed at a Monsanto MV50A LED mounted at the end of a 2 1/2 foot long, light-tight copper tube. Kodak Wratten No. 96 gelatin neutral density filters were placed directly in front of the lens on the OMA which was 2 ft. from the LED. The lens used was a Canon 200 mm Macro lens, the same used for our scintillator measurements. Figure 1 shows the expected neutral density attentuation vs. the net area under FWHM of the image normalized to the area with no attenuation. Next to each point is shown the net counts/channel at the peak. These values cover the range of signal levels obtained from the diagnostic scintillator results. The linearity is seen to be more than sufficient to extract line shape information from scintillator images and is in good agreement with the results reported by Liesegang and Smith.

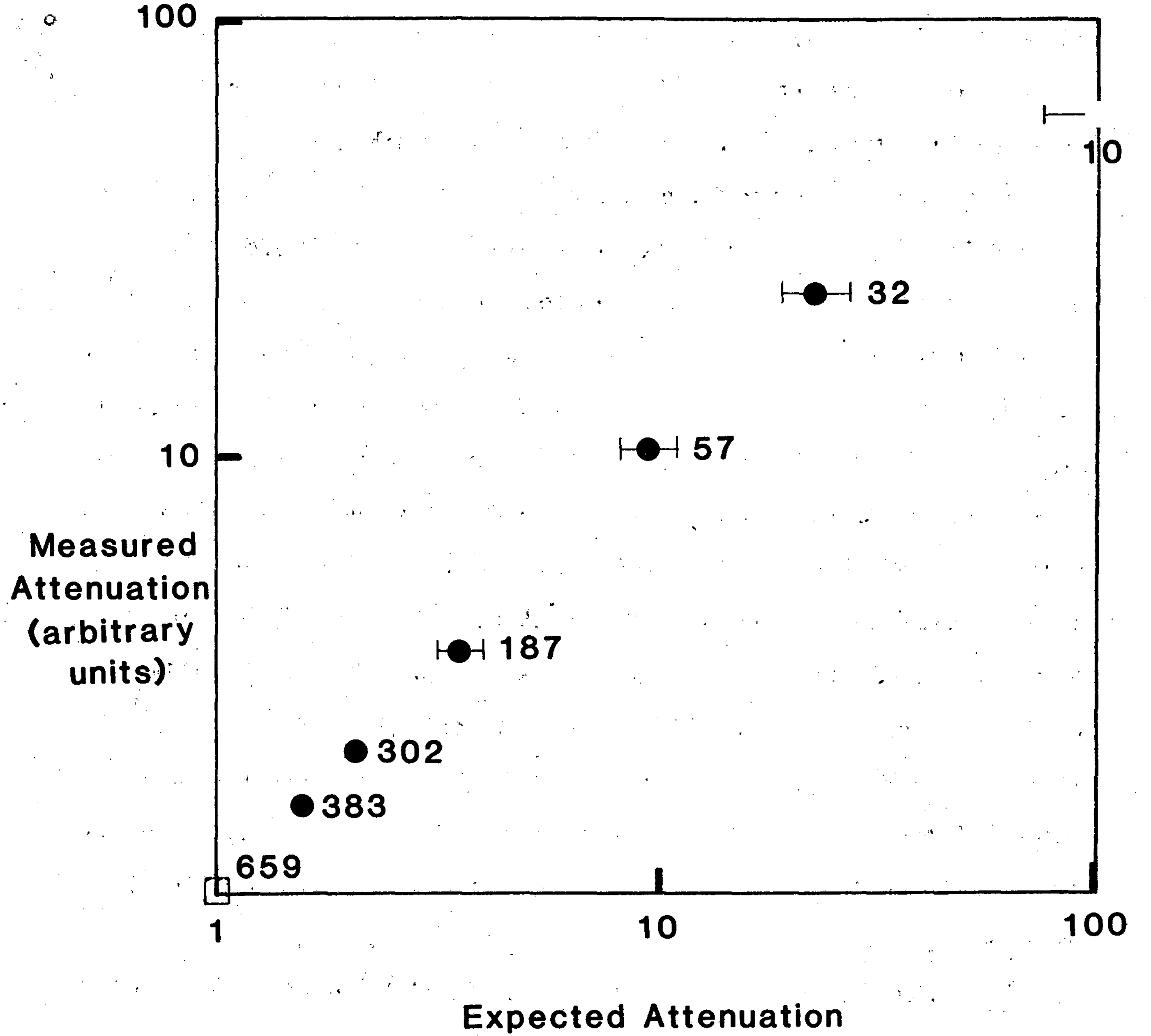

100
10
Measured Attenuation (arbitrary units)
1
10
100
Expected Attenuation
10
32
57
187
302
383
659
XBL 8212-12142

Fig. 1

COMPONENT DEVELOPMENT

Long Pulse Induction Module (LPIM)

During the past half year the design of the long pulse induction module (LPIM) was finalized, the various component parts were ordered, and life tests were performed on a prototype cell. At the end of the fiscal year all major components have been delivered and final assembly started.

Throughout this reporting period a prototype developmental cell has been pulsing for most of the time, including several periods of around the clock operation for several days. The cell consists of two induction cores which are driven in parallel by a single pulser and reset by a separate circuit in such a manner that the core is pulsed at the peak of the reset current. The major fraction of the operation was at a 0.5 pps rate which was initially determined by the power supply, but now has been designed into the triggering circuits as well. Maximum rep rate was 1.5 pps for short periods. Typical tests lasted for 10^5 pulses, the longest was $5x10^5$ pulses, and the total number of pulses is near 10^6 now. The cell and module were partly based on the requirements of the 1979 "Ion Induction Linac 500 Joule Test Bed" proposal,[1] with nominal goals of a 25 kV ignitron-switched PFN driving 2 cores to produce a 1.5 μs pulse length and a total module voltage of 250 kV. The module is simply a compact package of twelve independent cells as described.

The three major activities related to the LPIM were the inducton core selection and characterization, the switch tube development, and the pulse-forming network tuning. Based on a previous study of core material

---

[1] LBL Pub-5031

economics, the material selected for the induction cores is 2 mil thick silicon steel from Arnold Engineering with C10 interlaminar isulation. The applied voltage of approximately 3 volts/lamination for a 1.5 μsec pulse was believed to be near the maximum limit, therefore a successful test at this pulse duration would be a useful data point for similar and longer pulse designs in the future. The design here is essentially to subdivide the core material axially into thin disks to the point where the applied voltage per lamination, which is proportional to the lamination width, is less than the insulation breakdown strength. The required axial insulation is provided with mylar sheets and an encapsulant. The core material width is 1.37" and the total axial space required per core is 1.65", for an axial packing fraction of 83 percent. The radial packing fraction is 92 percent, resulting in a total packing fraction of 76 percent. The material is capable of a 27 kG field change, of which 2/3 can be applied to the risetime and flat portions of the induction pulse with the present pulser, and the remaining 1/3 is wasted during the fall time of the pulse.

An ignitron tube, the National Electronics T-2901A, was developed expressly for this program after several standard size A ignitrons failed. The standard small size ignitrons from several manufacturers behaved similarly, that is, yielding jitters of ± 100 ns, and failing at around 10^5 pulses. An experimental glass tube with a control grid was quickly constructed by National, and almost immediately reduced the jitter to ± 10 ns. The first tube operated last year for $2x10^6$ pulses into a resistive load at a current approximating the requirements of a single core. During this test the igniter voltage had to be increased several times, but otherwise the tube showed no deterioration. Because of this satisfactory test, the load was changed to a smaller resistor to approximate the current which would be required by two cores, at which level the glass insulators of the ignitron started to darken noticeably. At about this time the induction cores had arrived, and after they had been separately characterized it was decided to try operating the new cores, new pulser, and new tube together. The pulser circuit had been tuned to the point where the forward current was 8 kA and the reverse current after the pulse had been reduced from 5 kA to 2 kA. However, this amount of reverse current was enough to darken the glass of the new tube in one pulse and cause it to break down after a few pulses. This bad turn of events led to a redesign of the ignitron, and of the PFN which is detailed below. The ultimate solution in the ignitron was to shield both glass insulators with overlapping steel bells. After the last (of several) modifications, the ignitron has been pulsed 250,000 times and the test is continuing with about 20,000 pulses added per working day.

The pulse-forming network initially was conceived as a tapered-impedance lumped-element delay line with a 2:1 increase in output current at constant voltage. The after-pulse current reversal of this circuit was intolerable to the ignitron, and the circuit was changed to eliminate current reversal almost completely by use of a series saturating reactor and a resistor-diode string across the PFN. The inductance of the reactor in the saturated state slowed down the pulse risetime across the core and increased the droop to the point where an additional pulse-form correcting network had to be added across the induction cores. The correcting networks will be retuned when the LPIM is completed.

Silica-Loaded-Polymer Insulator Development

During this period the main effort has gone into a search for polymer materials with lower vacuum outgassing rates than polymethyl-methacrylate (PMMA). The following systems have been selected and evaluated after extensive conversations with manufacturer representatives and private consultants:

1. RF 4000 epoxy with RF 53 curing agent and RF 80 catalyst, a product of E. V. Roberts and Associates, Palo Alto, CA.
2. A specially formulated cycloaliphatic epoxide epoxy provided by Dr. Kirk Spurr, Union Carbide Corp., Bound Brook, N.J.
3. An alumina filled epoxy based on Shell Epon 826 developed by Jim Turner of LBL.

All of the materials had vacuum outgassing rates similar to the PMMA so there is no reason to use them on grounds of vacuum behavior alone.

It is planned to make vacuum outgassing tests on a specially formulated polyester from Reichold Chemical, Los Angeles, CA in the near future.

Following this a system of polymer-aggregates will be chosen and a large casting made.

THEORY

Computer Simulation of Induction Linac Bunch Longitudinal Dynamics

The induction linac bunches of heavy ion fusion scenarios are strongly influenced by space charge forces, and the resistive component of the machine impedance is narrowband. This situation is in distinct contrast to relativistic bunches in synchrotrons, where most of the data on bunched beam stability have been obtained. A particle simulation code to model induction linac bunches was developed by I. Haber of NRL and implemented at LBL. Induction linac impedances as well as flat resistances can be introduced through the fast Fourier transform. Finite pipe size effects which cut off the high frequency components of the space charge force may also be studied.

Results from this code indicate that the stability requirement of small growth rate relative to the synchrotron frequency characteristic of relativistic bunches can be relaxed significantly. Rather, the frequency spacing of the space charge modes of the bunch together with the growth rate determine thresholds. Runs were performed with local growth rates exceeding the synchrotron frequency by an order of magnitude with apparent long term stability. Unstable behavior, however, was observed when that growth rate exceeded the mode frequency spacing; other runs have indicated that dispersive effects introduced by the finite pipe size tend to make the higher frequency modes more susceptible to instability than the lower frequency modes. Since induction modules have a high resistive component only for the lowest bunch modes, stability is better than is the case of a broadband resistance.

Several cases which modeled possible induction module impedances for heavy ion fusion drivers were run. These results indicate that long term longitudinal bunch stability is realizable for induction linac heavy ion fusion. Short bunches together with narrow induction module impedances appear least susceptible to longitudinal instability.

Performance of Quadrupole and Octupole Transport Channels

Studies relating to the maximum ion current transportable by a single-channel periodic electrostatic quadrupole or octupole transport channel have continued, along the lines outlined in the last Half-Year Report[2]. The recent work has been devoted to computational investigation of the restrictions that nonlinearities necessarily present in periodic electrostatic quadrupole transport systems impose on usable aperture ratios for such systems, since this constraint substantially limits the system design and the magnitudes of transportable current. Such design information, in addition to being useful for the design and optimization of quadrupole transport systems, will be required in examining the relative performance of octupole _vs_. quadrupole transport systems. Future work, just recently initiated, is intended to examine these issues in regard to particle motion in _two_ transverse degrees of freedom, and also to compare or contrast aperture-ratio limits now available for electrostatic quadrupole transport lines with those pertaining to magnetic-quadrupole channels.

Solenoid Focussing of a Co-Moving Beam of Electrons and Ions

It would be convenient in many ways to use solenoids to transport and focus heavy ion beams, but the large magnetic rigidity of heavy ions combined with large defocussing space charge forces makes their use impractical, if

---

[2] LBL-14374/UC-21, covering the period October 1, 1981-March 31, 1982.

not impossible. We have become interested in a scheme proposed by S. Robertson[3] which, if feasible, would change the situation dramatically. He proposes to create a charge and current neutral stream of ions and electrons, moving together at the same velocity. When such a stream enters a relatively weak solenoid, the ions are not affected by the magnetic field, but the electrons begin to circle the axis, pulling in toward the axis to create a net negative charge density and proceed in a condition of Brillouin flow, with the inward magnetic force balancing the outward electric force and the centrifugal force. The ions are then subject to an inward electric force, which focusses them. The net result is a focusing strength for the ions greater than that for a weak beam of ions alone by the ratio of ion to electron mass, a factor of the order of 10^5 for heavy ions.

We have extended Robertson's work to include non-zero emittance for both ions and electrons and have generated parameter lists for the HTE spot heating experiment.[4] Typically, a solenoid about a meter long with a field strength of a few hundred gauss would appear to do the job.

In order for the scheme to work, the potential at the edge of the beam must be positive, with zero potential on the axis. We believe that this can be achieved by biasing the vacuum pipe through the solenoid at a few hundred volts positive. However, it is not clear how the imposed electric and magnetic fields should be related in the fringing regions, or if the beam (or other) electrons will cluster either to permit or prevent penetration. Work continues on this problem, and also on plans for a modest experimental test of the idea using the drift tube and diagnostic tank facility.

---

[3] S. Robertson, Phys. Rev. Letters, 48, 149 (1982).
[4] G. Krafft, LBL-14800 (HIF-200), September 1982.

Parameter Study for a High Temperature Experiment (HTE) Using an Induction Linac

A computer program[5] developed in 1978-79 generates "first-approximation" heavy-ion induction linac designs. Although it does not contain some ion-dynamical features (such as special pulse shapes for input-pulse matching or final momentum-tilt generation), it incorporates relatively detailed information on electrical and mechanical design features, unit costs, and transverse containment. The computed designs serve to indicate ranges of some parameters, for specific performance requirements, that are promising for more detailed study. In addition, estimated costs (at least on a comparative basis) can be obtained for each "optimum design. A range of "cases" was computed for the HTE experiment, using sodium and potassium ions. They provided a "data base" from which (with interpolation and extrapolation) optimum values of ion kinetic energy, total charge, and other parameters can be calculated, subject to certain constraints.

In making such calculations, two constraints were assumed: (1) The six-dimensional phase space constraint, which is an absolute condition, was required to be satisfied subject to an estimated and assumed phase dilution factor $D = 4$ for the system. (2) Final longitudinal bunch compression, needed to provide the required short pulse duration at the target was required to be a factor $C = 30$.

The detailed array of results from this work can be summarized as follows. "Preferred" means lower cost without requiring any parameter to have too extreme a value.

---

[5] A. Faltens et al., IEEE Trans. Nucl. Science, NS-26, No. 3, June 1979, p. 3106; Argonne National Laboratory Report ANL-79-41, Sept. 1978, p. 31.

1. The lighter ion (sodium) is preferred.
2. Small emittance per beamlet is preferred.
3. High space charge tune depression is preferred.

It was evident from the preliminary analysis that the data base should be extended; in particular, the data for sodium (the preferred ion) did not include variation of tune depression or ion energies above 100 MeV. Sixteen more cases were then computed for sodium to 200 MeV, covering some previously missing parameter ranges. Similar "optimum design" calculations confirmed the trends stated above and provided firmer results based on interpolations rather than on large extrapolations. A new result was that systems having fewer final beamlets were more costly. Cases deemed satisfactory for additional detailed design were identified. Numerical details and discussion are given in an informal report.[6]

Electrostatic Co-Axial Cylinder Lenses

A proposal for a new type of electrostatic coaxial-cylinder transport system for hollow (annular) beams has been made by P. Krejcik,[7] who claimed that such systems could transport significantly more current than electrostatic quadrupole systems with comparable field strengths and apertures, although no calculations were presented.

A detailed analysis of such systems was made. It was found that the claimed advantage was not present for the orbit geometry proposed, in which

---

[6] D. L. Judd, "Comparison of Computer-Generated Induction-Linac Test-Bed 'Designs' with Spot-Heating Requirements and Other Constraints," July 18, 1982.

[7] P. Krejcik, "The Hollow Beam Concept for Producing Intense Beams," Symposium on Accelerator Aspects of Heavy-Ion Fusion, Darmstadt, Mar. 29-Apr. 2, 1982.

the transverse (radial) focusing is of alternating-gradient type. This is due to the fact that the field gradient between coaxial cylinders is less than that in quadrupoles for the same maximum field, cancelling the advantage gained in larger beam area. Emittance and acceptance of hollow beams were considered in the analysis.

The results are valid in a "small-modulation approximation" in which the amplitude of periodic radial beam displacement is much less than the beam's mean radius. The effects of departure from this approximation are estimated. While examining this question it became evident that the opposite extreme, in which the radius of curvature of the beam (of alternating sign) in the r-z plane is significantly smaller than its mean radius, has quite different properties; here the focusing is of one sign, rather than of alternating gradient. A treatment of the general case, including these two as extremes, is in preparation.

R.F. Linac Scenarios for High-Temperature Experiment (HTE)

A preliminary survey of the possibility of performing significant spot-heating experiments using ion beams from an rf linac has been made for the special case of an ion range of 0.01 gm/cm^2 corresponding to the examples calculated by J. Mark. Tt became evident that in order to meet the phase space constraint a large value of ion mass number A is required, while performance limitations of final-focusing magnetic quadrupole systems required a small value of A. Using a quadrupole pole-tip field of 5 Tesla, employing the combination of rf linac parameters (current, frequency, and transverse emittance) generally used in recent years, and making reasonable assumptions for other parameters, it was found that these two conditions are inconsistent for spot heating requirements[8] with material temperature of order 100 eV. This is subject to the assumption that the range is constrained to be 0.01 gm/cm^2. Therefore significant improvements in rf linac parameters appear to be necessary unless some unconventional final focussing system is assumed.

Use of an Isochronous Ring for an HTE Experiment

A study is in progress on the possible use of an isochronous ring "cyclotron" to condition the train of pulses from an rf linac into a small number of intense bunches needed for an HTE.[9] Because the revolution frequency is independent of momentum the longitudinal instability should be absent. An unconventional rf system is needed for stacking; its effects on the six-dimensional emittance of the beam are the subject of ongoing evaluation.

---

[8] J. Mark, R. Bangerter, W. Fawley, S. Yu, and D. Judd, Lawrence Livermore National Laboratory Report UCRL-86189 Rev. 1, Mar. 1982.

[9] F. Selph, H. Grunder and B. Leemann, "An isochronous stacking ring approach to the HTE." Abstract submitted to IEEE Particle Accelerator Conference, Santa Fe, 1983.

PUBLICATIONS

HI-FAN-190 (LBID-593)	T. F. Wang	Beam Matching for the First Injection Drift Tube, May 30, 1980
HI-FAN-191 (LBID-541)	E. Hoyer	HIF-Accelerating System/Linear Induction Accelerator Cost Evaluating Program Comparison of cost Factors
HI-FAN-192 (LBL-14323) Preprint	E. J. Lofgren	Accelerator, Particle. (to be published as a chapter in THE ENCYCLOPEDIA OF PHYSICS, Ed. Robert Besancon, Van Nostrand Reinhold Co., New York, NY, 1982.
HI-FAN-193	T. F. Wang L. Smith	Longitudinal and Transverse Coupling in a Heavy Ion Beam
HI-FAN-194	A. Faltens	Equilibrium Charge State for Ions Passing Through Cold Dense Matter.
HI-FAN-195 (LBL-14374)	Staff	Heavy Ion Fusion Half-Year Report October 1, 1981-March 31, 1982.
HI-FAN-196 (LBL-14341)	D. Keefe S. S. Rosenblum	Berkeley Research Program on Ion Induction Linacs for Inertial Fusion, Proc. of Symposium on Accelerator Aspects of Heavy Ion Fusion, Darmstadt, Germany, Apr. 1982.
HI-FAN-197 (LBL-14391) (UC-37)	J. Shiloh M. Lampel R. Sah	Electron Beam Probe for Charge Neutralization Studies of Heavy Ion Beams, June 1982
HI-FAN-198 (LBL-14332)	R.D. Ruth A.W. Chao	Plasma Laser Acceleration: Longitudinal Dynamics, the Plasma/Laser Interaction, and a Qualitative Design Proc. of Workshop on Laser Acceleration, Los Alamos National Lab., 2/18-23, 1981, AIP Conference Proceedings No. 91, p. 94, 1982.
HI-FAN-199 (LBID-594)	T.F. Wang	A Preliminary Study of Final Focusing for the Target Test Heating Facility
HI-FAN-200 (LBL-14800)	G. Krafft	Usefulness of Collective Focusing for Final Focusing
HI-FAN-201	L.J. Laslett	The Confluent 3rd - Order Mode (8/5/82)

HEAVY ION FUSION ROSTER

Denis Keefe

- Warren W. Chupp
- Edwin R. Edwards
- Andris Faltens
- Milton Firth
- Forrest S. Goss
- Edward C. Hartwig
- Egon Hoyer
- Charles H. Kim
- Michael Lampel
- Edward J. Lofgren
- Ross G. Nemetz
- Chester D. Pike
- Stephen S. Rosenblum
- Joseph Shiloh
- Gerald L. Stoker
- Michael Tiefenback
- David Vanecek

Theory

Lloyd Smith

- Joseph Bisognano
- Victor Brady
- S. Chattopadhyay
- Elon Close
- Alper A. Garren
- G. Krafft
- L. Jackson Laslett
- Andrew Sessler
- T. S. Wang
- J. Wurtele

William B. Herrmannsfeldt, SLAC

HALF-YEAR REPORTS: Master Distribution List

Argonne National Lab.

Thomas A. Fields
Ronald Martin

University of Arizona

R. Morse

Batelle

John Hartman

Bechtel

W. Allen

Brookhaven National Lab.

Mark Barton
Alfred Maschke

C.E.A. Bruyeres-le-Chatel

R. Dei-Cas

University of Calif., Irvine

Norman Rostoker

University of Calif., Riverside

Robert Poe

Cornell University

Ravi N. Sudan
John Nation

DARPA

Richard Gullickson
Joe Mangano

Department of Energy

DP

S. Barish
John Freeman
T. Godlove
Sheldon L. Kahalas
L. Killion
G. Kuswa
H. Roser, Asst. Sec.,
Defense Programs
R. Schriever

ER

James S. Kane
Richard Kropschot
James Leiss
Gerry Peters
David F. Sutter
A. Trivelpiece, Dir.,
Office of Energy Research
William Wallenmeyer

DoE San Office

Rudolf Bredderman
Z. Zafiris

E.P.R.I.

Ken Billman

Fermi National Accelerator Lab.

Frank T. Cole
Fred Mills
Lee Teng

GANIL

P. Lapostolle

GSI

R. Bock
D. Boehne

University of Illinois

G. Miley
Joseph Verdeyen

KMS Fusion, Inc.

Alex Glass
Henry J. Gomberg

Kawazawa University

S. Kawasaki

Lawrence Berkeley Laboratory

Bob Avery
Joseph Bisognano
Warren Chupp
Tom Elioff, 50/155
Andy Faltens
Al Garren
Hermann Grunder, 50/149
Ed Hartwig
Egon Hoyer
Earl Hyde, 50A/4133E
Rob Johnson, 50/149
Dave Judd, 50A/3115
Denis Keefe
Charles Kim
John Knight, 930/315
Wulf Kunkel, 4/731
Glen Lambertson
L. Jackson Laslett
Ed Lee
Edward Lofgren
Jack Peterson
Stephen Rosenblum
Andrew Sessler, 4/111C
Bill Shanahan, 50C/001
David Shirley, 50A/4113
Lloyd Smith

Lawrence Livermore Lab.

Richard J. Briggs, L-125
John L. Emmett, L-488
William Krupke, L-488
Jim Mark, L-477
Michael J. Monsler, L-479
John Nuckolls, L-477

Los Alamos Scientific Lab.

Roger Bangerter
Richard Cooper
Robert Jameson
Don Kerr
Roger B. Perkins
Steve Rockwood
George Sawyer
Richard Stokes
Don Swenson

University of Maryland

Martin Reiser
Derek Tidman

Max Planck Inst. fur Plasma Physik Garching

Ingo Hofmann

Maxwell Laboratories

Library

National Bureau of Standards

S. Penner
M. Wilson

National Science Foundation

Edward Knapp (Director)

Naval Research Lab.

Steven Bodner
T. Coffey
Irving Haber
Philip Sprangle
Peter Turchi

Occidental Research Corp.

Wyn Salisbury

Physics International

Library

RAFAEL

Joseph Shiloh

Rutherford Laboratory

John D. Lawson
Chris Pryor

Sandia Laboratories

Everet H. Beckner
Don Cook
Tom Martin
J.P. Vandevender
Gerold Yonas

SOREQ

A. Sternlieb

Stanford Linear Accel. Center

William Herrmannsfeldt
W. K. H. Panofsky
Burton Richter

TRW

J. Gordon
Z. Guiragossian
J. Maniscalco

Westinghouse

E. Sucov

University of Wisconsin

G. Kulcinski
G. Moses
R. Peterson

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720