HEAVY ION FUSION ACCELERATOR RESEARCH (HIFAR) YEAR-END REPORT*

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TABLE OF CONTENTS

Highlights	1
MBE-4 Acceleration.....	6
Modifications to MBE-4.....	7
Carbon Arc Source Development	8
2-MV Injector.....	9
2-MV Injector Control System	10
Progress Toward a Self-Consistent Physics Design for ILSE.....	11
Engineering Design for ILSE Beam-Combining	12
Packaging Study for the ILSE Magnetic-Focus Induction Cells.....	13
Field Characteristics of ILSE Magnetic-Quadrupole Lenses	14
Conceptual Design for the ILSE Electrostatic Focusing Accelerator Support and Alignment.....	15
Transverse Mis-Alignments in a Driver.....	16
Tolerance on Longitudinal Position of Quadrupoles	17
Publications and Internal Notes	18
H.I.F. Staff Roster.....	23
Distribution List	24

FOREWORD

The basic objective of the Heavy Ion Fusion Accelerator Research (HIFAR) program is to assess the suitability of heavy ion accelerators as igniters for Inertial Confinement Fusion (ICF). A specific accelerator technology, the induction linac, has been studied at the Lawrence Berkeley Laboratory and has reached the point at which its viability for ICF applications can be assessed over the next few years.

The HIFAR program addresses the generation of high-power, high-brightness beams of heavy ions, the understanding of the scaling laws in this novel physics regime, and the validation of new accelerator strategies, to cut costs. Key elements to be addressed include: 1) Beam quality limits set by transverse and longitudinal beam physics; 2) Development of induction accelerating modules, and multiple-beam hardware, at affordable costs; 3) Acceleration of multiple beams with current amplification -- both new features in a linac -- without significant dilution of the optical quality of the beams; 4) Final bunching, transport, and accurate focussing on a small target.

HIGHLIGHTS

D. Keefe

1. We began experiments with the newly-completed MBE-4 apparatus at the beginning of FY88. The early design of a few years ago called for (a) a final kinetic energy of 200 kV + 24 x 30 kV = 920 kV corresponding to the 200-kV injector and the 24 accelerating gaps, and (b) a current amplification factor (CAF) of 4 to 4.5, in what was considered an "aggressive" acceleration schedule. The highest kinetic energy observed to date was 950 kV, and the highest CAF about 8.0 - both in excess of the original goals. Experiments are beginning now with less extreme acceleration schedules, to address the detailed question of proper control of the bunch ends.

For context, we note that the CAF is made up of two factors, one in velocity $\frac{v_f}{v_i}$ and the other in pulse length $\frac{L_f}{L_i}$. Typical values for a driver are:

Velocity factor = 50; Length factor = 4; (for a CAF of about 200);

whereas, for the above-quoted results from MBE-4:

Velocity factor = 2.1; Length factor = 3.8.

Since HIFAR is constrained to conduct scaled experiments at energies orders of magnitude less than a driver we cannot, therefore, realistically attain a large velocity factor.

Nonetheless, in terms of the length factor we observe that MBE-4 can provide a stringent test of longitudinal manipulation in the relatively short length of the experiment.

With such a large current amplification, the final beam-current pulse shape in MBE-4 is dominated by rise-time effects (pulsers typically 200 ns, gap-transit 300-150 ns) which, for a driver with a much longer pulse (10-20 μ sec), would be very much less significant. For this reason and for improved operational stability, detailed studies of the beam dynamics will be made at an energy and CAF both about 20% below the highest values.

Long-term stability of operation, i.e., shot-to-shot reproducibility, is important for effective data-gathering. Again for context, we note that in the Single Beam Transport

Experiment (SBTE) data was acquired at various z -locations for the beam position and angle coordinates $[x_0(z), x'_0(z), y_0(z), y'_0(z)]$, and for the density-in-phase-space distributions $[f_x(z), f_y(z)]$. Data-gathering in MBE-4 is more complicated by far because of the higher dimensionality of the measurements; for example, each of the above quantities must also be measured as a function of t , the time-coordinate within the pulse. In addition, the energy $E(z_f, t)$, and energy spread $E(z_f, t)$, must be measured although the beam is only accessible for precise measurement at the end of the accelerator, z_f . (The usually rather good agreement with the SLID macro-particle code allows the inference of $E(z, t)$ at other locations). Finally, of course, four beams rather than the one in SBTE, need to be diagnosed. An extensive program to improve and extend the diagnostic capabilities is a major part of the MBE-4 program. We note that in ILSE, with 16 beams, the complexity will become further increased.

2. The carbon arc source, with a fast on-gate, developed by S. Humphries (UNM) has satisfactory emission current-density, as reported in the previous half-year report (LBL-24519). Extensive measurements of emittance have now been made and the time-averaged emittance (over 1000 shots per scan) is larger by a factor of four than hoped for. The raw data, however, show considerable fluctuations from shot to shot so that the actual emittance (if it could be measured in a single shot) is less, and a true value cannot be stated until the problem of irreproducibility has been solved. Changes in the geometry, materials and circuitry are being pursued in a systematic semi-empirical manner to improve reproducibility and lifetime. Since we wish to use the SBTE (where the source is mounted at present) for fundamental beam physics measurements, a separate 200-kV test-stand is being prepared for future tests of the source.
3. Upon receipt of the parts of the 2-MV injector from LANL in September 1987, we assembled the components in the 750 kV configuration first tested at LANL. After upgrading some of the components to improve reliability, successful testing (50 shots) was achieved. Because of Congressional action (continuing resolution), a delay occurred in ordering the

inductive corona rings and longer support beams needed for the re-configuration to an LC-generator. Electrical punch-through of the molded plastic tray supports emerged as a recurring problem and we have begun to replace them with lucite trays. Preparations are underway for proceeding to a 750-kV LC generator test in the latter half of FY88 before proceeding to the finally intended 2-MV LC configuration.

The architecture of the control system has been mapped out. Development of components is being done in close conjunction with the Controls Group for the Advanced Light Source (ALS) with mutual design and cost advantages.

4. The conceptual engineering design of ILSE began to come up to full speed toward the end of this reporting period with the addition of a strong team of mechanical and electrical engineers. We are fortunate to have, in addition, the participation (on a part-time basis) of a number of engineers from the Beam Research Group at LLNL, who have had extensive experience in the construction of electron induction linacs.

There have now been several generations of the physics design for ILSE. Each of the separate sections of ILSE (e.g., electrostatic-focussed, combiner, magnetic focussed, bend) taken by itself, has its own preferred set of parameters such as lattice half-period, or undepressed tune, σ_0 . In general, these do not match across the interfaces between adjacent sections and the iterations have involved a succession of compromises (usually minor) to make the physics design properly self-consistent.

With the entry of significant engineering expertise into the picture, we recognize that further changes to the design are inevitable. The physics design, by itself, naturally emphasizes a short lattice period, which allows (a) more current to be transported and (b) a higher gradient because of more frequent accelerating gaps (one per half-period). The basic engineering challenge, however, lies in the optimal packaging of the three fundamental sub-systems — focus elements, accelerating elements, vacuum system — all of which are in strong competition with each other for axial space. Taken together, the engineering realities create pressure for longer lattice period and lower volt-seconds per meter, i.e., exactly

counter to the most-favored physics designs. The challenge is to find the best trade-off among these conflicting requirements.

Two points need emphasis. That the physics and engineering desires are in conflict, on the one hand, and the engineering subsystems compete among themselves, on the other, comes as no surprise, and has been generally recognized for years. The supreme value of the ILSE design process lies in facing up to a realistic self-consistent design for hardware that must perform, and in learning the best course to steer among the conflicts. That process will develop a methodology of compromise invaluable to understanding the design of a full-scale driver. Second, it must be noted that the competition among conflicting requirements outlined for ILSE are illustrative of the most difficult design problems in a driver - the low-energy end, where the fraction of axial space occupied by the lenses is 50% or more. As one proceeds down the length of a driver, the fraction of length devoted to focussing drops rapidly below 50% and is typically 10% or less for the major part of the accelerator, whereupon the conflicts alluded to are greatly alleviated.

5. We report herein on some specific issues for the ILSE conceptual design:

- The physics design is close to being complete but some incompatibilities with the present configuration of the 2-MV injector have been identified; these will dictate some further minor changes.
- A new solution for the optics of the beam-combining section has been found in which electric and magnetic elements are used both to bend and to focus the beams. This so-called "combined-function system" has been translated into an engineering conceptual lay-out.
- There has been progress on the fundamental packaging problem of the engineering subsystems for the magnetic-focussed section.
- The difficult 3-D problem of non-linearities introduced at the ends of the magnetic lenses has been treated with the aim of finding a conductor-winding configuration which nulls - in an integral sense - the effects of the most damaging multipole component (dodecapole).

- A kinematic mounting system devised for the 16-beam electric-focus array can achieve tolerances better than needed in ILSE and looks a promising approach for a driver. The survey reference is provided by a laser beam.

6. The question of the alignment tolerance of the focussing system in a driver has been extended to include the effects of acceleration and changing half-period for a reference case derived from the HIFSA study. For a driver with the unrealistic assumption of no steering corrections whatsoever, a typical tolerance is 0.4 mils transversely. The question of the tolerances in the longitudinal placement of the lenses has been also examined quantitatively; these are much more relaxed than the transverse tolerances and pose no particular engineering problems.

MBE-4 ACCELERATION

H. Meuth and A. Warwick

In the past few months, following the completion of all MBE-4's accelerator sections A through F we have implemented a complete acceleration schedule for the entire accelerator. We use the SLID code,¹ starting from measured currents (~10 mA) and energy profiles (~200 keV) at box M04. As a first step, we concentrated on a rather vigorous schedule that utilizes all the accelerator modules to their currently available voltage limits. We achieved a final peak current in excess of 80 mA per beam, see Fig. 1 (20 nA/div), as measured at box 30. Simultaneously we performed SLID computations that incorporate all the actual acceleration waveforms, taking into account corrections for the transit times of the bunch through the accelerator gaps. The resulting overall schedule achieved the proposed² final beam energy of 0.9 MeV at the beam bunch center (Fig. 2). Aside from details in current and energy pulse waveforms we find that the computed and measured waveforms at all diagnostic boxes agree generally well. An energy calibration factor required for the code was based on time-of-flight drift measurements on the current bunch through the entire MBE-4 device thereby providing a substantially higher calibration accuracy than that for the earlier results with a shorter device.³ Similarly, the g-factor was determined by the head and tail erosion of the drifting beam.

As can be seen from Fig. 1 we have not yet been able to produce a square-type current waveform at box 30. The waveform becomes increasingly trapezoidal, until at box 30, the flat top has vanished altogether. Figure 3 shows this effect already taking place by the time the beam has reached box 10. In comparison to the pulse shape at box M04, the rise and fall times of the pulse have doubled while the bunch width has halved by pulse compression with a resulting current amplification of 1.8. The reasons for lack of containment of the bunch head and tail are: (a) the rise times of the acceleration pulser waveforms are limited to at least 200 ns. With a final pulse width of about 600 ns (at the base), there is therefore not much left for a flat top. Secondly (b), there is a crucial limitation due to the SLID code which attempts to faithfully replicate at every gap, the waveform of the preceding gap, no matter how much the latter deviates from the desired square shape, thereby accumulating errors in the beam pulse shape. Future work will tackle a slightly less vigorous schedule to eliminate pulser trigger failure and cross-talk, and will also include "manual" tuning improvement that starts from a SLID-based tune.

References

1. C.H. Kim and L. Smith, Particle Accelerators **18**, 101 (1985).

2. R.T. Avery, Program Plan for the MBE-4 Multiple Beam Experiment, PUB-5142, LBL-19592 (1985).
3. A.I. Warwick et. al., Proc. of the Conf. on Heavy Ion Inertial Fusion, Washington, D.C., 1986.

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Fig. 1

XBL 884 10191

Fig. 2

101 884 10192

Fig. 3

MODIFICATIONS TO MBE-4

A. Warwick, H. Meuth, D. Vanecek and W. B. Ghiorso

The construction of MBE-4 was completed in September, FY87. However, modifications continue to be made as difficulties arise or improvements are needed.

Replacement parts for the four hot surface ionization sources are continually required. With slow thermal cycling and no accidents, a set of filaments lasts typically two to three weeks.

Stepping motors have been added to all insertable diagnostics, allowing each device to be remotely controlled by the diagnostic computer keyboard. Measurements of the current waveforms along this length of the accelerator are now more easily made.

At the end of the accelerator the beam energy varies with time through the bunch. We have measured the approximate shape of this energy waveform in the past and now require improved energy and time resolution to observe any rapid fluctuations of the kinetic energy as a function of time. To this end new detectors have been built with improved frequency response. Use of a x50 amplifier with 200 Ω input impedance, mounted at the detector, gives a time response of approximately 10ns. The energy resolution is then determined by the collimation, limited by the smallest usable signal. Collimating with 0.004" slits at two locations 18" apart upstream of the analyzer deflecting plates and using a detector with sense wires separated by 0.04" gives an energy resolution better than 0.2%.

Improvements have been made in the sensitivity of the transverse emittance measurements. The width of the all slits was reduced to 0.004" and a new fabrication technique was adopted whereby slits for all four beams are electro-formed in a single metal sheet. This ensures precise relative alignment between the four beams. The optical techniques for the relative alignment of the upstream and downstream slits (see figure) have been perfected. Signals from this equipment are now quite low and the signal-to-noise ratio is improved by integration on a 1k Ω resistor close to the detector. A line driver is then used to transfer the signal through 50 Ω cable to the oscilloscope. The time resolution is approximately 150ns which is adequate for resolving emittance variations through the 2 μ s bunch duration.

Emittance measurements with increased sensitivity revealed a halo around the beam caused by the non-linearities of the focusing fields at the edge of the aperture. The particles at the edges of the beams experience these non-linear forces

during the large envelope excursions in the second and third quadrupoles during matching. Elliptical collimators, corresponding to the measured beam size, were introduced in diagnostic box M1 to remove some of the halo (about one percent of the total beam intensity). These greatly reduced the effect of the halo on the measured r.m.s. emittance. We find the r.m.s. emittance that includes 95% of the intensity at the beginning of the accelerator to be:

$$\pi\epsilon_n = 4\pi\beta\gamma\epsilon_{r.m.s.} = 1.5 \pm 0.3 \times 10^{-7} \pi \text{ m rad}$$

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Figure 1. Equipment developed for the precise alignment of the emittance measuring system.

CARBON ARC SOURCE DEVELOPMENT

H. L. Rutkowski

The two main activities for the last period have been the attempt to get source performance to be uniform and reproducible, and, to measure the source emittance. The quality of the emittance measurements depends on the reproducibility of the source because we measure emittance with two slits, getting one data point on each shot.

Initially, we thought that the most important thing was to get a good trigger plasma in order to get a good main discharge which creates a more uniform plasma for extraction. Simultaneously we want the source to have long life. Consequently, we installed an alumina trigger insulator and tried to tune the source by sliding the trigger to different distances from the main arc. Our indices of performance were: temporal conformity between the ion-plasma signal from the source with the arc discharge pulse shape and ease of ion shut off with the plasma switch. We never obtained good shut off with this trigger and we had a high misfire rate.

Emittance plots contained holes at random points where one would expect to see beam. Before changing the source, we checked the extractable current density with a gridless deep Faraday cup that was scaled from a standard LBL design. The results are shown in Fig.1. Clearly, the extraction of adequate current density is not a problem for the arc source, but getting adequate reproducibility is.

The next step was to try the type of trigger that I. Brown uses in the MEVVA sources. This method uses a solid carbon cathode rod with a ceramic insulating ring around it at the arc discharge end and a stainless steel electrode ring around the ceramic. The front surfaces of all three components are flush. Thus, the trigger plasma does not need to migrate into the main arc gap from the cathode interior. The emittance scans again showed holes in the data. Before changing the source we installed a shallow gridless cup designed by S. Humphries and again verified that the gun was emitting the expected Child-Langmuir current density, up to 28 mA/cm^2 . Finally, we verified that the secondary electron amplification, which we were using in the slit-cup to get usable emittance signals, was not the source of the data variations. A line driver was placed in the system and the slit cup biased normally. Both slits were left on center and six shots were taken. The signals were non-reproducible shot to shot.

Finally, we have replaced the single cylindrical cathode with three carbon rods equally spaced so that the outer diameter of the array is the same as the outer diameter of the original single cathode. The cathode internal trigger is replaced by a two-wire surface flashover on alumina inside the three-rod array. The concept was to have multiple arcs and smooth out the statistical fluctuations of any one arc. Other than these changes, the source remained the same. To remove all current density saturation during extraction the arc current

has to be 300 A. The emittance data still showed holes though the source seemed to be behaving better at the beginning, indicating that aging might be occurring during the scan. Later, a recent scan at higher plasma switch voltage showed fewer holes even though the source had not been rebuilt. The switch voltage was 160V, which is in a region where switch breakdown has normally occurred in the past. This effect is still being investigated.

In order to facilitate the testing of different versions of the arc, and to allow the SBTE to return to its original mission, an ion source test stand is being assembled which will have 200kV capability and considerable diagnostic flexibility.

Fig. 1

2-MV INJECTOR

H. L. Rutkowski

After the parts for the injector Marx generator were obtained from LANL, and the experimental facilities had been prepared, we reassembled the system in the same configuration that was used at LANL. The first test firing occurred on Dec. 22, 1987. The insulating gas used was 65 psig. of N_2 and the load resistor was the $CuSO_4$ dummy load which was sent from LANL. The system experienced some conditioning breakdowns but eventually fired successfully several times at 90kV charge voltage (100kV is full charge). At full charge, however, there was breakdown and upon opening the pressure vessel, it was discovered that most of the liquid was gone from the dummy load and that several trigger resistors and charging resistors had been destroyed. In the next test, the dummy load was a pair of Ion Physics Corp. solid composition resistors in series, each rated for 500kV and each with $4k\Omega$ resistance. After researching the available information on the energy and power handling capabilities of the trigger resistors, they were changed from singlets to triplets to increase their chances of surviving the 200kV impulse load that they experience when the Marx fires. The insulating gas was 65 psig. 30% SF_6 - 70% N_2 . The system worked at full voltage for a few shots and then broke down. The failure mode was breakdown of the trigger capacitors which were installed by LANL to reduce jitter. These capacitors were underrated for the impulse voltage that they experience when the Marx fires.

At this point, attention shifted to the question of how to ensure trigger component reliability while still fitting components into the limited space available. Because there was no SF_6 recovery system available, all subsequent tests were carried out in 65 psig of dry air, the logic being that the most robust configuration should be found that would place the least reliance on the insulating gas. Several trigger resistor combinations were tried, but adding more resistors to increase reliability caused congestion of components which resulted in flashover problems between adjacent components. The trigger capacitors were no longer a problem after one capacitor was added to each set. The maximum number of shots obtained at full voltage in any configuration without incident was 50.

In the original design, there are two parallel trigger lines that run down the entire system along the upper corners of the trays. One set of trigger components is connected across two stages, at firing, resulting in a 200kV pulse across it. Also, they are located very close to the corona rings which, in the new inductively graded design, will be replaced with inductive corona rings. The design was changed to place the trigger components on the interior of the trays away from the corona rings, and to change to a single trigger string with each component set connected across only one stage thus cutting

the voltage it experiences in half. Two trays were assembled in this new configuration and were used to replace the upper two trays of the system. The lower two trays were left unchanged. The first tests started at the beginning of March. Problems were encountered due to penetrations through the Maxwell trays and to surface tracking. A quick test revealed that the surface hold-off of the tray material was different on each side of the tray and in general inferior to the surface hold-off of lucite by almost a factor of 2. Lucite barriers have been constructed on the two trays with the new circuit and the system is currently being tested. An SF_6 recovery system is being set up and subsequent tests will use SF_6 . Another aspect of the design being pursued is the possibility of triggering only the first few stages of the Marx thus eliminating much trigger circuitry together with its additional weight and its additional failure potential.

Other activities are underway towards the completion of the 2-MV generator. After being held up for budgetary reasons, the order for the inductive corona rings was placed in January. All of the lucite coil forms and 12 of the spinnings are finished and being shipped to LBL. Once five rings are finished, which requires coil winding and some high voltage testing at LBL, they will be installed in the five tray Marx that we now have to study the final circuit configuration and to test the inductively loaded Marx concept on a small scale.

The longer support beams needed for the inductively graded Marx are on order as are the pressure vessel extensions. Both are expected in the first half of May due to surprisingly long delivery times.

The capacitors chosen for the 2-MV system are undergoing life tests under pressure. So far, one 100 kV capacitor has been tested in a pressure vessel filled with 65 psig SF_6 , using a critically damped test circuit that duplicates the design waveform. The capacitor has 300,000 shots on it and is still running. The capacitor has experienced some pressure cycling because from time to time other components in the test circuit have failed, requiring the pressure vessel to be opened for repair work.

Design of the column electrodes for the 500-mA-per-beam C^+ tests has continued. There is now a layout drawing of the high voltage connections to the new shorter column. The high voltage design with no beam appears satisfactory. Of course, there is always risk of breakdown with beam present especially in a column which pushes the known technology limits. The problem of matching the beam into ILSE is also being investigated. The reentrant geometry of the column, the size and divergence of the beam make this a challenging problem.

2-MV INJECTOR CONTROL SYSTEM

Don Brodzik

A system to implement remote control of the 2-MV source and support electronics is described. This system must be consistent with both immediate local control and eventual integration within an overall IISE control system concept.

Control philosophy will follow that of a highly distributed microprocessor-based architecture. This will track and make use of the work done by the ALS Control group.^{1,2} Initially the source and the Marx generator will be controlled. Later, status information for the vacuum and interlock systems will be provided. Further, there will be a requirement for control of the 2-MV water load and shell cooling. The control system will provide a means for accessing machine components so that their values may be set and/or monitored remotely. Machine status will be displayed and software will be provided for archival saving and retrieval of machine parameters. The control system will be a distributed system based on many high performance microcomputers of the Intel family (80C186, 80286, and 80386) operating in parallel. By using a compatible family of processors the interface among the various parts of the system will be greatly simplified. Programs will be written mostly in high-level languages (Basic, Fortran, PLM, C, and Pascal). The processor used in the main part of the control system will be an Intel 80386. General system architecture is as shown in Fig. 1. This microprocessor has the hardware-supported capability to run multiple operating systems simultaneously [MS/PC DOS, OS 2 UNIX (XENIX), or RMX, a real-time operating system]. The basic features that will be as incorporated into the design are:

- Local debugging capability.
- High level programming languages.
- Homogeneous processor architecture throughout the system.
- Ease of maintenance and repair.
- Use of work stations.
- Data driven software capability.
- Built in help functions.

ILC (Intelligent Local Controller)

The ILC is shown schematically in Fig. 2. The unit presently exists on a 6U Eurocard form and will later be made

available in a 3U form. Chips are CMOS; power consumption is 10 watts. The cpu is a 80C186 running at 16Mhz. The memory will be 64Kbytes of battery-backed RAM. A serial communications cpu will exchange data and/or programs with a remote external Collector Micro Module. The board resources will include a math coprocessor, a SBX bus interface (to match other buses e.g. GPIB or RS 232), and four channels of ADC, four channels of DAC and finally 24 I/O channels.

Arc Source

We plan light pipes, one for a real time trigger the other for transmitted and received data. The total length of this cable is approximately 15 feet. The time available between shots for data extraction and processing is 10 seconds. If one assumes a 1Mbaud light-pipe rate, data extraction should be possible within 50 milliseconds.

Shell ILC Summary

The shell source would constitute at a minimum one ILC (Intelligent Local Controller, see Fig. 2) input/output work station. This would exist on a 485 multidrop bus. The fiber optics would just be an extension of the 485 bus. Gradually a number of ILC's (source, water, vacuum, water load) could be connected to this bus. Initially, they would communicate with and be controlled by an IBM AT via an expansion card with an SBX bus capability. Formulation of diagnostic and/or emittance stations would follow a similar philosophy. System implementation would then be by sections, yet with each section able to stand on its own, with the IBM AT and the software that was developed for that section serving as a potential work station/debugging tool. Sections would then have the capability of being integrated via their serial links to a central CMM (collector memory module) as described in Fig. 1.

References

1. Conceptual Design Report - July 1986 for the 1-2 GeV Synchrotron Radiation Source Pub - 5172 Rev.
2. The Uranium Beams Project (Lancaster et al., 1979; Magyary et al., 1981a; Magyary et al., 1981b)).

PROGRESS TOWARD A SELF-CONSISTENT PHYSICS DESIGN FOR ILSE

T.J. Fessenden

During this past period the physics design of the Induction Linac Systems Experiment (ILSE) was further refined. Calculations¹ of the cumulative effects of misalignments indicated that a maximum specification of 0.1 mm on the placement of the focusing electrodes in the electrostatic quadrupole focusing arrays and the injector electrodes was required to assure that the beam offsets at the combiner would be no more than one millimeter. Engineering indicated that this could be accomplished with the dynamic support system described in this report. This support system requires that approximately 20 cm per half lattice period be devoted to the support elements which restricts the space available for the induction accelerators. To accommodate the need for more axial space and to provide as much axial space as possible for the accelerator units, a strawman physics design² was developed with half-lattice periods near the maximum determined by the beamlet current at each point in the accelerator.

The physics design was developed with the aid of the code INDEX developed by Charles Kim. In the design each eighth half-lattice period contains no accelerator so as to provide pumping and diagnostic access. To limit the length of the accelerator and combining section to approximately 30 meters, an average accelerator gradient of 375 kV/m was chosen. This gradient will be difficult to achieve. Table 1 contains a summary of some of the parameters of the design.

Table 1: Some parameters of the Physics Design

# beams	periods	energy (MV)	current (A)	period (m)	quad bore (mm)
16	1-23	2-4 MV	8-11 A	0.4 m	27.0 mm
16-4	24-29	4	11	0.5	27-55
4	30-44	4-6.5	11-17	0.5	55
4	45-62	6.5-10	17-20	0.6	55

Fig. 1 Size of Accelerating units versus length

Figure 1 shows the size of the accelerator units along the length of the accelerator as calculated by INDEX. The unit of size is volt-seconds/meter. The physical dimensions of the units will be set by the properties of magnetic material used in the accelerator units. If the waveforms requested by INDEX could be perfectly synthesized, 4.8 volt-seconds of magnetic material are required for the entire accelerator. If allowance is made for the rise and fall of the waveforms as suggested by Falten³, a total of 10.3 volt-seconds is required.

Figure 2 shows INDEX calculations of the beam tail, center, and head along the accelerator. The relative velocity

tilt ($\Delta B/B$) at the combiner is 24 % and at the end of the accelerator is 9.6 %. The current growth along the accelerator is shown in fig. 3. The dots represent calculations of the size of the K-V beam that would occupy one half the aperture radius at the corresponding beamlet current and energy.

Fig. 2 Energy of the beam along the accelerator

The integration of this physics strawman design with the 2-MV injector and further study of the beam combiner have revealed several conflicts. At present parameters it appears impossible to match the circular diverging beams from the injector to an electrostatic quadrupole transport at the separations between beams in the injector design. The beam-to-beam separation must be increased or the beamlet size and therefore current decreased to find a match. The shortest lattice period of 40 cm is still too short for a satisfactory resolution of the conflict between the alignment system and the accelerator core. Because of the beam-to-beam spacing downstream of the combiner imposed by the injector, there is not enough space for the magnetic quads and aperture necessary to transport the design beamlet current.

Fig. 3 Total accelerator current versus length

The multiple-beam, space-charge-limited nature of ion induction linacs for heavy ion fusion imposes many constraints and conflicts in the design of the accelerator. It is clear that additional physics compromises will be needed to develop an engineered conceptual design of ILSE.

References

1. L. Smith, HIFAR Note 182, Feb. 1, 1988
2. T. Fessenden, HIFAR Note 180, Jan 14, 1988
3. A. Falten, HIFAR Note 179, December 11, 1987

ENGINEERING DESIGN FOR ILSE BEAM-COMBING

E. Lee and M. Calderon*

The design of a beam combiner for ILSE has recently incorporated combined function elements.¹ That is, electrodes and magnets simultaneously focus and bend the sixteen accelerated beams as they are maneuvered into the desired four beam clusters of the stonehenge configuration. The primary impetus for combined function is to avoid a serious loss of ions by scrape-off in the final bend, which appears to be intrinsic in the usual separated-function designs. Thus, at least the final bend and quadrupole must be combined. It is found that combined function has several additional good features which can be exploited through the whole combiner. These are (1) fewer beam line elements (by a factor of two), (2) lower fields (also by a factor of two), (3) larger ratio of element length to bore, which reduces some aberrations. These three qualities are important in ILSE because the very short half period ($L=40$ cm) places a premium on available space. The potential disadvantage in combined function is the complexity of shapes and positions of the electrodes and magnets. There may also be an increased level of aberrations, which would increase the effective beam emittance. These matters are being studied at present.

The specific layout of beam-line elements which has been tentatively selected is a first-order double achromat containing three full focal periods. Element lengths are all 24 cm (60% of the half period), including the final half strength quadrupole/bend. This achromatic lattice layout, shown in Fig. 1, consists of five electric combined-function elements in the entrance and middle areas and two magnetic, combined functions elements at the exit. The choice of magnetic elements is made to eliminate possible electrical breakdown. Six of the elements shown in the figure are symmetrically located about the center-line of the 40 cm, half-period locations and a seventh has been offset a small amount to provide a properly matched beam at exit.

A quadrant of the typical electric combined-function (C-F) element shown in Fig. 2 is an array of tubular electrodes which produce a quadrupole field. The center electrode in each quadrant is shaped² to give positive (inward) bending of the beams. At the next downstream location, negative bending occurs when the potentials are reversed.

To provide small-displacement corrections to the beam trajectories (± 2 mm), the element located in the middle of the combiner has been divided into quarters to permit small voltage adjustments.² This electrode feature derives from a requirement to form the stonehenge beam pattern within ± 1 mm at the exit.

In the last two locations of the combiner the focusing and bending functions are provided by a pulsed magnetic element of "birdcage" geometry.^{3,4} These elements focus and bend the beams by current distributed fields formed by the conductors around the beams. A laminated iron structure encloses the "birdcage" magnet structures to shield each magnet from the others^{3,4} and to return the flux. To accurately locate each of the conductors, placement grooves are machined in the iron and a thin, 300-series stainless steel sheet is welded over the insulated conductors to capture and prevent movement due to the small magnetic forces. Small vent holes from the grooves obviate trapped volumes.

While heat loads from the power pulse (a few msec) are calculated to be low, cooling can easily be provided to the iron structure if it should later seem appropriate.

At this point in the design we envision all the focusing/bending elements supported from a stable, kinematically functioning platform that is isolated from the vacuum tank envelope. The alignment and adjustments of the elements would be made relative to the support platform. Alignment of the entire combiner array and support platform assembly to the machine center line would be by external electro-mechanical sensors penetrating the tank wall.⁵

At present the engineering effort is directed to identifying the type and placement of the elements in the combiner design. This work has guided the development of a general design in the form of a layout. In a next phase, detailed designs for individual components can begin.

References

1. E. Lee, 3/3/88, Archromatic Beam Combiner with Combined Function Elements. HIFAR Note-191.
2. A. Faltens 3/11/88, Oral Communication.
3. D. Judd, 8/87, HIFAR Note-162.
4. A. Faltens, 8/14/88, HIFAR Note-163
5. R. Fulton and D. Vanecek, 3/22/88, Oral Communication.

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Schematic of Beam Combiner

Fig. 1

XUL 886-1988

XUL 886-2077

Fig. 2 Combined Function Electrostatic Array.

PACKAGING STUDY FOR THE ILSE MAGNETIC FOCUS INDUCTION CELLS

D. Bupp,* D. Ravenscroft,* L. Reginato,* A. Faltens, and D. Vanecek

A detailed packaging study for the ILSE magnetic focus induction cells was initiated in March. The emphasis to date has been to integrate the magnetic focus quadrupoles with the induction cell design. The basis was the physics strawman contained in reference 1 with a 50 cm half-period and an interbeam separation or pitch of 14 cm.

As the initial packaging study a cell block was laid out. The configuration consists of seven cells with both acceleration and focus capability, and an eighth, dummy cell. The dummy cell has the magnetic focus capability, but no acceleration potential. The dummy cell provides the vacuum pumping station, and the space for beam diagnostics. The initial packaging study yielded the following conclusions:

Packaging of the metglas cores necessitated large diameter (> 1.5 meter) geometries. However, standard widths of nonferrous materials range from approximately 1.2 m to 1.5 m maximum;

The pulsed quadrupole arrays were badly squeezed, and would be very difficult to fabricate;

The vacuum tubulation for the proposed eight-cell block configuration was restrictive. Although detailed vacuum calculations were not done, the elastomer seals chosen would provide an appreciable gas load for the available vacuum conductance. Elastomer seals were chosen to minimize the radial build factor for each of the four (merged) beampipes;

A monolithic ceramic insulator at the induction cell accelerator gap was favored over four individual ceramic insulators for ease of assembly and lessened expense of machining for the adjacent hardware;

The utilization of a gaseous dielectric in the core area was favored over a liquid for high voltage insulation. Liquid dielectrics were considered (Freon, transformer oil, MIPB, etc.) but rejected, since the high vacuum system would be badly contaminated with the liquid dielectric in the event of a ceramic insulator failure;

Both 2" and 4" metglas core windings were considered in the initial study. Although the 2" cores result in a

longer axial build, conventional thyatron/SCR switched pulses can be used. The 4" metglas core designs require spark gap switched pulsed-power sources or step-up transformers coupled to thyatrons.

In late March, beam transport calculations were shown to overfill the individual beam tubes were considered in the initial study.

A second phase of the packaging study was immediately initiated for magnetic quadrupoles with interbeam spacings of 18 and 20 cm. The pulsed quads for the larger spacings require increased power, but cooling of the quads is easier. Also, enhanced vacuum pumping is a gain for the larger designs. Figure 1 shows design concepts for the pulsed quadrupole windings. Figure 1A depicts the initial concept of using solid square conductor with indirect cooling via axial air flow. Figure 1B shows a monolithic aluminum mandrel for the four individual windings in each quad. This design concept utilizes low conducting water cooling channels as shown and relies on tangential heat conduction to the cooling channels. The potted assembly must stand off an estimated 10 kV to ground (coils in series electrically, hydraulic channels in parallel). The cooling channel connections must exit through the laminated iron core to minimize the radial build factor. Figure 1C incorporates a printed circuit array approach. Multiple printed circuits would have to be utilized to achieve the conductor cross section for the necessary power dissipated. Figure 1D utilizes a water cooled capillary conductor. Preliminary calculations indicate that for the postulated rep. rate of 1/10 Hz, laminar flow cooling will be adequate.

FIGURE 1A

FIGURE 1C

FIGURE 1B

FIGURE 1D

Figure 1 A quadrant of each pulsed quadrupole design concept is shown above. The arrays as pictured show a cut in the midsection of the quadrupole perpendicular to the ion beam.

*T. Fessenden, "A Straw Physics Design for ILSE," HIFAR Note-180, Jan. 1986.

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The focusing elements to be employed in the ILSE device downstream from the combiner region will be pulsed room-temperature quadrupole lenses, with the current windings placed in a configuration that could be adapted to a superconducting D.C. design for a driver. The main windings in such a design are longitudinally placed in two layers on the surface of a circular cylinder, in an approximately cos 2θ pattern, and a sharp 90-degree transition to the end windings serves to economize on the overall length of the assembly (see Fig. 1). The detailed angular locations and lengths of the individual turns have been so computed as to suppress the dodecapole component of the field in the integral sense (i.e., when integrated over a quarter lattice period), as has been considered a desirable procedure in the design of similar components for the projected Superconducting Super Collider.

This quadrupole design has been described by V. O. Brady in HIFAR Note-147 (corrected copy, dtd. 5 June 1987) and it will provide a clear aperture of about 5.5 cm radius for an element intended to form a part of a transport lattice of half period as short as 40.0 or 50.0 cm. Although past experience presents no basis for supposing that this rather large aperture ratio could be detrimental to the single-particle dynamics in such a lattice, it can be informative to examine the effect of the associated field nonlinearities upon individual-particle motion and prudent to undertake simulation computations relating to the collective stability of a beam traversing this lattice. To this purpose we have made computations designed to indicate the type of magnetic field (including the nature of the end fields) to be expected from such a quadrupole design, to organize the results in a manner convenient for subsequent simulation computations, and to examine the characteristics of individual-particle motion (with and without space charge) in such a lattice.

Fig. 1 Developed view of upper windings for one half of current-dominated quadrupole. The half lengths of the individual turns increase steadily from $L_{12} = 6.6$ cm to $L_1 = 8.8$ cm.

The magnetic field components of the proposed quadrupole element have been evaluated (ignoring the presence of possible ferromagnetic shielding) through use of the Ampere-law program MAFCO. The results have been analyzed (after adjustments made in recognition of the periodicity of the assembled lattice) to provide coefficients for expressions that specify the field components in terms of power series in r (for example through r^7 for the transverse components, and through r^6 for B_z), circular functions of arguments 2θ and 6θ , and a periodic trigonometric development in z (or, alternatively, at definite specified periodic locations in z -- for use in numerical integration in connection with subsequent multi-particle simulations).

For orientation computations concerning individual-particle dynamics, such representations of the applied-field components can be supplemented, when desired, by a C-W linear defocusing field as an approximate representation of the action of space charge to effect a depression of tune. The results of such computations have provided guidance concerning the number of terms that may be suitably used to describe in a consistent way the character of the applied fields from the quadrupole lattice (e.g., using 10-term or 12-term trigonometric developments and power series extending through r^7), and indicate values of current strength and intensity parameters that will result in the attainment of desired small-amplitude tune values (σ_0 and σ). Similar computations also provide an interesting indication of the variation of such tune values with oscillation amplitude (see Fig. 2) and also serve to corroborate our expectation that individual-particle motion will become unstable under typical operation conditions only for motion extending well outside the amplitude permitted by the physical aperture of the quadrupole lenses.

Fig. 2 Dependence of tune upon amplitude: A. Space-charge absent, small-amplitude $\sigma_0 = 80^\circ$; B. With space-charge tune depression, small-amplitude $\sigma = 16^\circ$. The departure of these log-log plots from linearity is chiefly ascribable to the dodecapole component of the field.

CONCEPTUAL DESIGN FOR THE ILSE ELECTROSTATIC FOCUSING ACCELERATOR SUPPORT AND ALIGNMENT

L. J. Hansen and R. L. Fulton

The mechanical design of the electrostatic-focusing accelerator section to meet the ILSE physics design¹ has been under study with the objective of developing a new concept for alignment of the focusing electrodes. The present four-beam accelerator, MBE-4,² is built in a "conventional" manner in that all its focusing electrodes are mounted and located with respect to the vacuum walls, which are in turn machined accurately and then assembled with the accelerating insulator and aligned to the accuracy required for the electrode assemblies. This method of construction for ILSE has several drawbacks: 1) it is not kinematic - vacuum loads, temperature variations and building motions can affect the electrode array positions, 2) it has more, and larger, components require precision machining tolerances, 3) its tolerance stackup leads to larger positional errors, and 4) there is no provision for realignment of the individual electrode arrays after installation.

The approach taken in the present ILSE design is to provide separate support for the electrode arrays, vacuum wall and induction cores, since they each have very different positional tolerance requirements. A schematic of the dynamic support concept is presented in Fig. 1. The focusing electrode arrays, installed in array rings inside the vacuum wall, are supported by constant force tension members incorporating positioning devices that can either manually or automatically adjust the arrays' position and alignment. Most of the 0.004 in positional tolerance¹ will be used within the electrode array itself, making the requirements on the support

and alignment system much more stringent than on previous systems. The array rings are in turn supported by tension members through bellows feedthrus in the vacuum wall to the precision positioning actuators on the support structure. The system of support tension members and actuators provides control of horizontal and vertical transverse position, along with pitch, roll and yaw rotation, of the array ring and electrode assemblies. Roll is the most critical rotation, translating into a transverse positional error for beams not on the axis. Position along the accelerator axis, which is not as critical, is controlled by having the tension members angled slightly along the z-axis, providing adequate stiffness and thus natural frequency of the array.

Measurement of the electrode array position is done by using offset rods of some stable, low coefficient of thermal expansion, material to accurately transfer the electrode position to the alignment system. Figure 2 shows conceptually a proposed scheme for a global-sectional-local alignment system. This allows the determination of transverse position and all three rotations of each electrode array.

Induction pulse cores for each accelerating gap will be mounted to an independent support structure, thus isolating the core weight from either the focus electrode arrays or the vacuum envelope. The cores will be insulated with a gaseous insulator, most likely sulphur hexafluoride, and connected electrically with the accelerating gap and insulator through a flexible connecting wall that can allow limited relative motion between the components. Further work on this aspect of the design will be done during the next half year.

Dynamic Support Concept for Focus Arrays

Achieves 0.1 nm Alignment Tolerance

Figure 1. Support and alignment concept for ILSE.

References

1. T.J. Fessenden, "Progress Toward...", this report.
2. R.T. Avery, "Program Plan for the MBE-4 Multiple Beam Experiment," LBL-19592, Feb. 1985.

Figure 2. Conceptual schematic of a method for establishing a global/sectional alignment coordinate system.

TRANSVERSE MIS-ALIGNMENTS IN A DRIVER

L. Smith

Transverse errors in quadrupole position stimulate a transverse coherent oscillation of the beam, the amplitude of which tends to increase as the beam encounters more and more mis-aligned lenses. In conventional accelerators this effect can be corrected quite well by observing the displacement of the beam and applying a transverse kick at an appropriate place to bring it back on axis. In an induction linac driver, this process is complicated by the fact that the head and tail of the bunch have substantially different velocities - as much as 3% at the low energy end - at a given quadrupole location. The induced amplitudes are different from head to tail but, more important, the phase advances per focusing period are different and coherent oscillations get out of phase with each other. At the point where it is desired to make a correction, one would observe, not a rigidly displaced bunch, but an object looking like a cork-screw during time of passage. The observation and correction would both have to be time-dependent; an experiment addressing this problem is being planned for MBE-4.

In view of the fact that this style of correction has never been done and the fact that toward the end of a driver the time scale approaches 100 ns and the required kicks would increase with increasing kinetic energy, it seemed useful to calculate the consequences of abandoning any attempt at correction. To this end the formalism developed in HIFAN note 251 (July, 1984) was applied to a sample driver supplied by E. Lee. This driver, for 4 MJ at charge state 3, is a distillation of the most economically appealing cases produced by the cost program, LACEP.

The result is shown in the accompanying figure, which gives the ratio of the expected amplitude, A , to the maximum, Δ , of an assumed uniform distribution of errors as a function of accumulated megavolts along the accelerator (kinetic energy in MeV equals 3 MV). In distance, the 60 MV point is at ~ 400 meters and the 3000 MV point at ~ 3.6 kilometers. There are about 1500 focusing periods in total. In a uniform channel with no acceleration, $A/\Delta \sim \sqrt{N}$, which

is clearly not the case in the figure. There are two reasons for the difference. With acceleration, the amplitudes are damped as the square root of the velocity. In the example used, acceleration begins slowly in favor of bunching the beam as rapidly as possible and the amplitude increases roughly as $\sqrt{N}$. Then acceleration builds up rapidly to a nominal maximum rate of 1 MV/m and in this portion the damping of the early contributions dominates the new contributions out to about 100 MV. Thereafter the lattice parameters are also changing, further upsetting the $\sqrt{N}$ rule. At the end, $2\sqrt{N} = 2\sqrt{1500} \sim 80$, which agrees with the figure, but the agreement must be a coincidence for the particular model.

Consideration of the final focusing system indicates $\Delta \approx 1$ mm. That calls for a 10 micron tolerance, which might not be entirely absurd considering the current rapid advances in alignment techniques. If such a precision were possible, the tolerance on the low energy end could be relaxed considerably because the acceleration damping greatly reduces the contribution of early errors to the amplitude at the end of the accelerator. In the meantime, an experiment on correcting orbits is certainly important.

TOLERANCE ON LONGITUDINAL POSITION OF QUADRUPOLES

L. Smith

INTRODUCTION

It has been assumed, rightly enough, that the tolerance on longitudinal placement of quadrupoles in a transport line is much less restrictive than the tolerance on transverse position. On the other hand, the procedure for longitudinal positioning might be inherently less precise than for transverse positioning and a quantitative estimate of the effect of longitudinal errors is needed. The qualitative effects are quite different; a transverse displacement induces a transverse coherent oscillation for which the motion of the centroid may be treated as single-particle motion, while a longitudinal displacement induces an envelope oscillation with the two transverse degrees of freedom coupled through the strong space charge force.

PROCEDURE

To good approximation for the HIFAR parameter range, the emittance term in the envelope equations may be neglected, leaving only the quadrupole and space charge terms to be considered. Also, the calculation is considerably simplified by treating the quadrupoles as δ -functions in the longitudinal directions, an approximation which does not affect the results significantly. The procedure is to consider a matched beam governed by the non-linear (due to the space charge term) envelope equations encountering a lens which is at the wrong longitudinal position and to calculate to first order in the displacement the resulting deviations in radii and slopes from the matched values. Then, using the linearized envelope equations, the contributions of each error are added linearly to obtain a final envelope oscillation amplitude. Finally, a statistical average is taken over the distribution of

errors and a tolerance set by requiring that the oscillation amplitude be reasonably small.

The propagation of the individual errors is complicated by the fact that both transverse degrees of freedom are involved. Mathematically that means that the eigen-vectors and eigen-frequencies of a 4x4 transfer matrix representing the linearized envelope equations must be obtained and used to propagate the disturbance. Fortunately, this calculation, for the δ -function quads assumed, is not insurmountable.

RESULTS

The result of this procedure is:

$$\left(\frac{\Delta a}{a}\right)_{\text{rms}} \sim 2\sqrt{\frac{2}{3}} \sqrt{N} \sin \frac{\sigma_o}{2} \frac{\Delta_m}{L},$$

where $\frac{\Delta a}{a}$ is the fractional amplitude of oscillation, N is the number of periods, L is the period half-length and Δ_m is the maximum of an assumed uniform distribution of errors between $\pm \Delta_m$. As an example for the electrostatic portion of ILSE, taking $\left(\frac{\Delta a}{a}\right) = 5\%$, $\sigma_o = 60^\circ$, $N = 12$ and $L = 40$ cm, $\Delta_m \sim 1/4$ inch. This is certainly much more forgiving than the specified¹ transverse tolerance of several mils, but as the construction of ILSE is presently conceived a specification of ~ 0.1 inches for Δ_m would have caused problems.

Reference

1. L. Smith, "Electrostatic Quadrupole Misalignments in ILSE," HIFAR Note 182, Feb. 1, 1988.

PUBLICATIONS AND INTERNAL NOTES

HIFAN-379
LBL-24272
Keefe

D. Keefe
"Induction Linac Drivers for Commercial Heavy-Ion Beam Fusion," presented at the The Third Inertial Confinement Fusion Systems and Applications Colloquium, Madison, Wisconsin, November 9-11, 1987, LBL-24272, HIFAN-379.

HIFAN-380
LBL-24519
Keefe

Heavy Ion Fusion Staff,
"Heavy Ion Fusion Accelerator Research (HIFAR) Year-End Report, April 1, 1987 - September 30, 1987," LBL-24519, HIFAN-380.

HIFAN-381
Warwick

A.I. Warwick,
"Range-Energy Relation for Au Ions, $E/A < 150$ MeV," Physical Review A October 15, 1987

HIFAN-382
LBL-24840
Lee

E.P. Lee,
"Heavy Ion Accelerator Driver for Commercial Inertial Confinement Fusion (ICF) Power," abstract submitted to the Spring Meeting of the American Physical Society, Baltimore, Maryland, April 18-21, 1988 (1/29/88).

HIFAN-383
Celata

C.M. Celata
"Some Thoughts on Beam Combining in ILSE," February 12, 1988.

HIFAN-386
Lee

E.P. Lee
"Cancellation of the Centrifugal Space Charge Force," Proceedings of the Wake-field Workshop held at Lawrence Berkeley Laboratory, Aug. 1987; LBID-1376, HIFAN-386.

HIFAN-387
LBL-24842
Fessenden

T. Fessenden,
"Physics Design of the Induction Linac Systems Experiment," Abstract submitted to the Spring Meeting of the American Physical Society, Baltimore, Maryland, April 18-21, 1988 (1/29/88).

HIFAN-388
LBL-25047
Lee

E.P. Lee,
"Heavy Ion Induction Linac Drivers for Inertial Confinement Fusion," Abstract
submitted to the 8th ANS Topical Meeting in Salt Lake City, October 9-13, 1988
(3/28/88).

HIFAR NOTES (Internal and Informal)

HIFAR NOTE-171

Meuth

H. Meuth and W. Ghiorso,
"A Small Energy Analyzer for MBE-4," October 1987.

HIFAR NOTE-172

Meuth

H. Meuth,
"Cs + Injector Modeling with the EGUN Code," October 1987.

HIFAR NOTE-173

Smith

L. Smith,
"Representation of Fields in Short Lenses or Dipoles," October 1987.

HIFAR NOTE 174

Warwick

T. Warwick,
"Linear Envelope Calculations for MBE-4," October 23, 1987.

HIFAR NOTE-175

Brady

V. Brady,
"Coil Misplacement Studies for ILSE," October 27, 1987.

HIFAR-NOTE-176

Smith

L. Smith,
"Recent HIFAR Notes Relating to ILSE Designs," November 5, 1987.

HIFAR NOTE-177

Lee

E.P. Lee,
"ILSE 180° Bend," Presented to HIFAR Group October 29, 1987. Preliminary Survey (11/87).

HIFAR Note-178

Faltens

A. Faltens,
"Voltage Rise and Fall Times." December 11, 1987.

HIFAR Note-179

Faltens

A. Faltens,
"Lambda," January 6, 1988.

HIFAR NOTE-180

Fessenden

T. Fessenden,
"A Straw Physics Design For ILSE," Viewgraphs presented
to the HIFAR Group January 14, 1988.

HIFAR NOTE-181

Smith

L. Smith,
"Emittance", February 1, 1988.

HIFAR NOTE-182

Smith

L. Smith,
"Electrostatic Quadrupole Misalignments in ILSE", February 1, 1988.

HIFAR NOTE-183

Celata

C.M. Celata,
"Matching from a Transverse Beam-Combiner into the Downstream Lattice,"
February 4, 1988.

HIFAR NOTE-184

Hovingh

J. Hovingh,
"LIACEP Versions - Update," February 9, 1988.

HIFAR NOTE-185

Warwick

T. Warwick,
"Transverse Emittance Measurement Techniques for
MBE-4," February 18, 1988.

HIFAR NOTE-186

Faltens

A. Faltens and B. Tiffany
"LANL Marx Tank Pumpdown," February 24, 1988.

HIFAR NOTE-187

Meyer

E. Meyer,
"Suggestions on Fabrication of Inductor Corona Rings with Input from Dave
Vanecek and Ralph Hipple," February 25, 1988.

HIFAR NOTE-188

Brady

V. Brady
"Single Particle Orbits in the Magnetic Field of the ILSE Current-Dominated
Quadrupole.," February 25, 1988.

HIFAR NOTE-189

Brodzik

D. Brodzik,
"Fiber Optics for the 2MV Source," March 7, 1988.

HIFAR NOTE-190

Fessenden

T. Fessenden,

"Progress on the ILSE Conceptual Engineering Design," March 3, 1988.

HIFAR NOTE-191

Lee

E.P. Lee,

"Achromatic Beam Combiner with Combined Function
Elements," March 14, 1988.

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D. Attwood, 80/101
R. Avery, 46/189
K. Berkner, 50/149
D. Brodzik, 46/125
C. Celata, 47/112
W.W. Chupp, 47/112
S. Chattopadhyay, 47/112
T. Elioff, 90/4040
A. Faltens, 47/112
T. Fessenden, 47/112
C. Fong, 47-112
R. Fulton, 90-2148
A. Garren, 90/4040
D. Gough, 47/112
R. Gough, 50/149
K. Hahn, 47-112
E. Hartwig, 47/112
L. Hanson, 90-2148
H. Heckman, 50/245
T. Henderson, 46/161
E. Hoyer, 46/187
R. Johnson, 50A/4119
D. Judd, 47/112
D. Keefe, 47/112
C. Kim, 47/112
M. Krebs, 50A/4112
W. Kunkel, 4/230
G. Lamberton, 47/112
L.J. Laslett, 47/112
E.P. Lee, 47/112
E. Lofgren, 47/112
J. Marx, 46/161
J. Meneghetti, 46/161
H. Meuth, 47/112
S. Mukherjee, 47-112
J. Peterson, 47/112
C. Pike, 47/112
G. Rosenblatt, 50A/4119

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H. Rutkowski, 47/112
A. Sessler, 4/230
D. Shirley, 50A/4133
L. Smith, 47/112
C. Taylor, 46/161
W. Thur, 47-112
D. Vanecek, 58/101
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