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CLOSING SUMMARY FOR INERTIAL CONFINEMENT FUSION, DIODES, AND BEAM TRANSPORT

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The progress since BEAMS'83 has been very encouraging. The experiments and theories are of significantly higher quality than we have seen in the past. The problems that have been identified in our fields are now being solved. Scientific comradery is improving and more scientists from different countries are working to complement their associates on similar projects in other countries. The papers presented at this conference have been much more substantial scientifically than in the past and indicate the maturation of our discipline.

Since the BEAMS'83 meeting, advances in the light ion approach to fusion have increased the prospects for this approach. The beam divergence of intense ion beams has been shown to be adequate for fusion in the proof-of-principle experiment on the Applied-B ion diode. PBFA I experiments at Sandia National Laboratories have been completed and the lessons that were learned have been applied to PBFA II. The PBFA II accelerator has successfully completed its construction phase and the initial data on its pulsed power system is very encouraging. More work needs to be done on the plasma opening switch (POS) for voltage and power gain, the ion sources, and the beam focusing in the next two years.

The instabilities in the corona of a light ion fusion target have been examined with two-dimensional, electromagnetic computer simulations at the University of Madrid, and found to be benign. Even though the instabilities grow and heat the electrons in the corona, the energy of the electrons is insufficient to preheat the target. Preheat from proton contamination in the intense beam appears to be avoidable because conservation of canonical angular momentum prohibits the protons from approaching the target when the diode and transport system for the lithium beam is properly designed.

Theoretical studies on the various beam-plasma instabilities for high-current beam transport have shown that although many of these instabilities exist, their effect on beam transport appears to be benign.

In 1983, the need for lithium ion sources was identified and a major effort has produced five different approaches to the lithium ion source. At least four of those approaches show promise as being a satisfactory, high-performance, ion source for PBFA II and other high-current lithium accelerators.

The first repetitive ion diode was announced at the Tokyo Institute of Technology. Even though its pulse rate was only 0.2 Hz, it is a good beginning to a new phase of ion beam drivers.

The plasma opening switches that were introduced at BEAMS'83 have now spread to laboratories in Europe, Asia, and North America. The POS technology makes possible the PBFA II accelerator and its baseline design for ignition studies. Power gains of factors of 2 and voltage gains of up to 3.4 have now been observed. The conduction time has been extended from tens of nanoseconds to a microsecond in Novosibirsk and in Washington, DC, and is an important advance.

The theoretical tools and diagnostics with which we can examine the major issues have advanced considerably since BEAMS'83. Steady-state, particle-in-cell (PIC) computer simulations have become broadly available. Electromagnetic, PIC codes have advanced to engineering codes in at least one laboratory. The results from the electromagnetic codes indicate that the additional effort of making PIC codes fully electromagnetic are indeed worthwhile. Radiation-hydrodynamic simulations are becoming more widely available, and insights into the target coupling physics are beginning to emerge. The three-dimensional PIC approach to the simulation of hydrodynamic implosions offered a theoretical guide on the required symmetry of the drive. Additional experiments will have to be conducted to examine this theoretical result.

Diagnostics have always been a critical issue for light ion fusion and substantial advances in time-resolved and spatial-resolved, high-quality diagnostics were introduced in the BEAMS'86 meeting.

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Major issues still remain to be resolved. Proof-of-principle experiments need to be defined and conducted on the maximum power limits for beam transport in current carrying channels, on the self-magnetically confined, rotating-beam concept (for beam transport) on the radiation enhanced power gain in inertial confinement fusion (ICF) targets (on the efficient extractor ion diode theory in a focusing geometry) on imploding plasmas for ICF drivers, and the magnetically-insulated, confinement fusion concept. In addition, more and better ideas are needed for ion diode impedance control in high-current ICF ion beam diodes, and on stable formation of ion beam channels with a small radius.

Exploratory target experiments are good. The scaling of ablation pressure, with power density and the measurements of the stopping power of light ions in high-temperature plasmas, are good first steps towards the target physics relevant to ICF. We can expect more of these experiments to be done as intense beams in many laboratories are applied to these problems.

The major advances in laser fusion reported at the conference showed that the one-dimensional, hydrodynamic simulation of these experiments are consistent with the results. Apparently, increasing the laser energy from 1 kJ to 10-20 kJ and adapting pulse-shaped drive pulses was enough to permit the experiments to be adequately described by the theoretical simulations. If we have now reached a sufficiently large-scale target so that the subtle and deleterious physics not modeled by the simulations no longer dominate the implosions, we will have entered a new and very promising phase of inertial fusion research. These laser fusion targets are generally applicable to particle beam fusion and represent an opportunity for collaboration between lasers and ions.

In spite of the fact that so many new and good results were presented at BEAMS'86, authors of some important papers were absent. There was no report on the status of ANGARA V at the Kurchatov Institute or any results from those experiments, even though ANGARA V began operation in December 1984. New POS experiments have been done at Sandia, but were not reported. The experiments in plasma-filled ion diodes at Tomsk were included in the abstracts submitted for the meeting and could have provided important information on the impedance control in intense ion beam diodes, but were not described in the meeting. In addition, a major new experiment on the physics of the electron kinetics in magnetically-insulated structures has been done at Sandia, but was not presented at the conference. The implications of this experiment would be important for inertial fusion, magnetic insulation, microwave generation, and most high-current devices with magnetically-insulated sections. However, the author did not attend and the paper was not given. Since there is such a long time between BEAMS meetings and because the BEAMS meeting is the major forum in which this information can be presented, critiqued, and correspondingly advanced, the loss of these papers was a significant loss indeed.

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