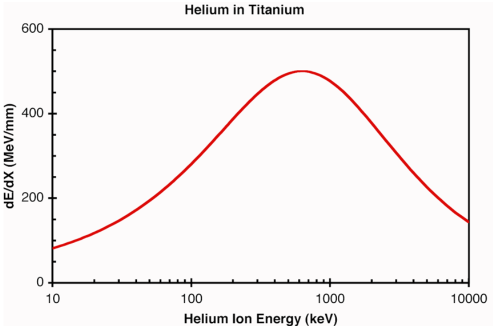
Virtual National Laboratory for Heavy Ion Fusion

March - April 2004

HIFNews

LBNL-PUB-844-04-03/04

Ion Beams for High Energy Density Physics



High Energy Density Physics (HEDP) studies require deposition of large amounts of power into small target volumes over a short time period with as much uniformity as possible across the target thickness. Lasers can supply high power densities, but with poor uniformity. A scoping study examined what sort of parameters might be achievable using ion beams in a modest cost (and therefore modest acceleration energy) facility.

Ideally we would like to maximize the energy deposited per unit volume (E/V in units of 10^{11} J/m^3 in table) and of energy deposition (ΔE) throughout the target. The rate of change of energy loss per unit distance within the target (dE/dX) as a function of velocity is smallest near the peak in dE/dX, see figure. We can achieve the ideal by choosing an incident beam energy which is near, but slightly above, the peak, along with choosing a target thickness δ thin enough that the beam exits before decelerating to an energy appreciably below the peak.

Reasonable Uniformity Can Be Achieved with 5-10 μm targets at voltages <10 MV. The He beam had 7 x 10^{12} ions, the others each had 2.5 x 10^{11} ions.

Beam Ion	Energy (MeV)	V_{acc} (MV)	δ (μ m)	E/V (10^{11} J/m^3)	ΔE (%)
He^+	1.6	1.6	3	1.4	15
Ne^{+8}	16	2	3	0.41	11
Ne^{+8}	20	2.5	3	0.43	3
Ne^{+8}	25	3.125	5	0.43	7
Kr^{+34}	269	7.91	10	1.8	4

Accelerator voltages, V_{acc}, of just 8 MV could allow compressed 1 ns pulses of helium-like heavy ions from electron cyclotron sources to deposit energy densities of 2 x 10^{11} joules per cubic meter (producing about 4 eV temperatures) across a 10 micron thick titanium target, with a power deposition variation of 4%, see table. These parameters are appropriate for HEDP studies, although further pulse compression might be needed to ensure that the energy is deposited within a time shorter than the hydrodynamic timescale for target disassembly.

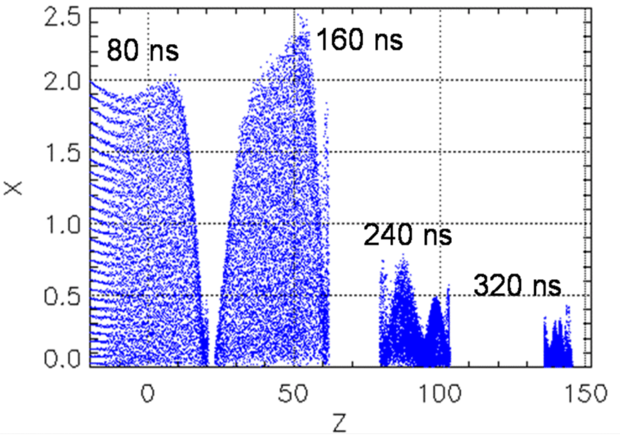
– Larry Grisham

Simulations Show 50,000x Increase in Heavy-Ion Power Density

A near-term application of ion beams is exploration of the high energy density physics (HEDP) regime requiring the deposition of 10^{11} J/m^3 in a time short compared with the hydrodynamic disassembly time (<1ns). The conventional scheme for temporal pulse compression uses an increasing ion velocity towards the tail to compress the beam length as it drifts in vacuum and uses beam space charge to stagnate the compression. Neutralized drift compression (NDC) in a plasma relies on ballistic beam transport, not stagnation, and can be a much more robust method. A final pulse shape at the target can be programmed by an applied energy tilt. To demonstrate the potential of beam pulse compression in a plasma to HEDP, we examine solenoidal transport for the proposed upgrade of the Neutralized Beam Experiment. We assume a 10-Amp, 100-ns He^+ beam emerges from the accelerator already given a head-to-tail 500-1000 keV energy ramp (linear in velocity). To achieve the required 100x compression, the applied beam energy must be accurate to 0.1%.

In the LSP simulation, the beam is injected in Brillouin flow equilibrium (BF) in vacuum. The full length transport simulation made use of a conductivity model (10^{14} s^{-1}) for the plasma in the NDC and discharge transport regions. Fully kinetic simulations of the transition region from BF through NDC (filled with 10^{11}-cm^{-3} plasma) were also performed to validate the model. Shown in the figure at various stages of transport, the beam transitions from a 3.5 T vacuum region into a 0.4 T NDC section at 0<z <92 cm. A 2-T final focus magnet is used to focus the beam into a 60-cm long 1-cm radius tapered discharge channel (z > 92 cm) that further compresses the beam to 1-mm radius. The beam longitudinally compresses to 750 Amps (1 ns pulse). The peak power density of the ion beam is increased by a factor 50,000.

– D. R. Welch and S. S. Yu



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This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48 and by Lawrence Berkeley National Laboratory under contract No. DE-AC03-76SF00098 (LBNL), and by Princeton Plasma Physics Laboratory performed under the auspices of the U.S. Department of Energy under contract No. DE-AC02-76CH-O3073.