Virtual National Laboratory for Heavy Ion Fusion

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HIF News

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Scaled beam merging experiment

A cost-saving beam manipulation employed in some designs for HIF drivers is the transverse merging of four beams (from separate beamlines) into a single beamline. It is of interest in accelerators with initial electrostatic quadrupole transport, followed by magnetic quadrupoles that can transport higher current than a single electrostatic quadrupole. However, the resultant phase space dilution and emittance increase from space charge, must be minimized so as not to sacrifice focusability at the target.

At LBNL, a prototype combining experiment merged four 3-mA Cs^+ beams injected at 160 keV (Fig 1). The focusing elements upstream of the merge consist of four electrostatic quadrupoles and a final combined-function element (quadrupole and dipole). The combined-function element worked as designed, with the beam edge only ~2 mm from the field defining electrodes.

Following the merge, the resultant single beam is transported in a single alternating gradient channel where the subsequent evolution of the distribution function was diagnosed. In the transverse beam merging process, the free space-charge energy of the configuration of beams in the initial state of the merge leads to emittance growth. This is a significant effect, since the generalized perveance of the beams before the merge is considerable, $K = qI/2\pi\varepsilon_o mv^3 \approx 10^{-4}$, and the initial state charge distribution is highly non-uniform

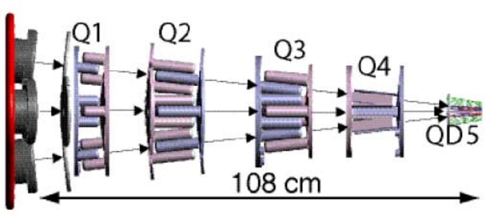

Figure 1 – A CAD view of the lattice elements of the Combiner apparatus. The first four elements (Q1-Q4) are electrostatic quadrupoles. QD5 is the combined function dipole and quadrupole, for which the electrostatic field-defining rods around each beam converge as z increases.

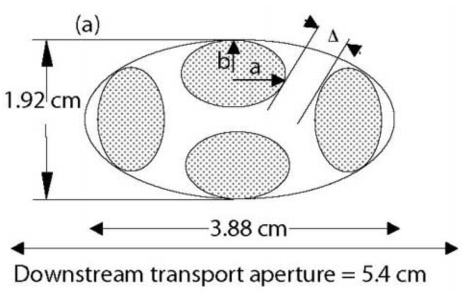

Figure 2 – Schematic of the beam footprints at the exit of QD5. The individual beams size is a=3.7 x b=3.7 mm. The beam-edge to beam-edge clearance is = 4 mm.

(Fig. 2). Analytical and particle-in-cell models predicted the final emittance of the merged beam has a dominant contribution from conversion of the free space-charge field energy of the initial merged beam distribution. This was confirmed by the experimental results, recently published in PRST-AB, indicating that for some HIF driver designs, the phase space dilution from merging is acceptable.

–P. Seidl

NTX beam transport in vacuum

Ions from a poorly matched beam head and halo ions in the main pulse of a beam can strike the outer wall of the transport tube producing secondary electrons that can neutralize the beam. Figure 1 shows images of a beam transported through a meter long drift tube with a tube diameter of (a) 15 cm and (b) 7.6 cm. A smaller spot size, roughly 50% less in diameter, was measured for transport in the 7.6 cm diameter tube, due to the capture by the beam of electrons from the wall that partially neutralized the beam. In both cases, the current transmission through the drift section was nearly 100%. A cylindrical metal mesh 2.2 mm thick, and 58.2 cm long with 90% transparency, was inserted into the 7.6 cm beam tube to control partial neutralization. The outer diameter of the mesh tube was 6.3 cm, providing >5 mm radial gap from the beam tube wall. At a bias potential of 250 V, the beam through the 7.6 cm pipe became larger. At the same time, we measured significant electron current collected in the mesh. Figure 2 shows a pattern of beam profiles corresponding as the energy is varied for vacuum transport in (a) WARP calculation, the (b) 15 cm diameter tube and (c) 7.6 cm diameter tube using the mesh bias. Using a mesh bias in the smaller pipe or the larger pipe with out mesh, the measured beam profile was in general agreement with WARP for vacuum transport

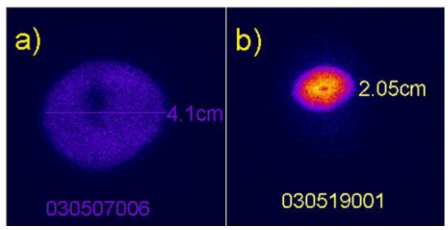

FIG. 1. Beam images for a 255 keV beam measured 1m downstream as transported through a tube of diameter (a) 15 cm and (b) 7.6 cm.

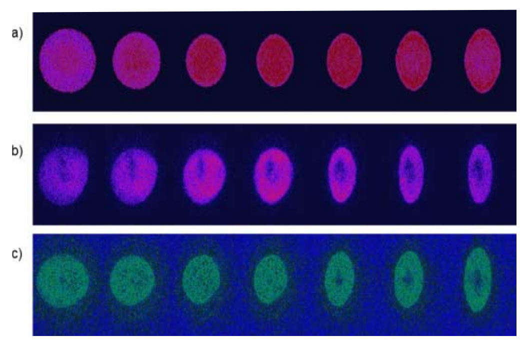

FIG. 2. Vacuum transport beam profile for 240-310 keV energies in (a) WARP calculations, (b) for transport through a 15 cm diameter tube and (c) for transport through a 7.6 cm diameter tube using the biased mesh.

We have demonstrated experimentally that a biased cylindrical mesh inside a drift tube can prevent uncontrolled neutralization of a space-charge-dominated ion beam.

– Simon S. Yu, S. Eylon, E. Henestroza and P.K. Roy

For comments about the content of the HIF News, contact Art Molvik (925)422-9817, or molvik1@llnl.gov.
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