Virtual National Laboratory for Heavy Ion Fusion

January - February 2005

HIF News

LBNL-PUB-844-01-02 /05

New measurement of gas density within beam

Beam-induced pressure rises have been observed to limit the beam quality and intensity in high intensity accelerators for high-energy physics, and are also a concern for heavy-ion inertial fusion. We have developed a gridded ion-collector (GIC) diagnostic that measures the time-dependent gas density in a quadrupole magnet and within the beam. A gas molecule has a ~1% probability of being ionized by the High Current Experiment (HCX) 1 MeV, 0.18 A, K^+ ion beam. The resulting cold ions are expelled radially across the quadrupole magnetic field (B ~ 8 T/m) by the 2 kV beam potential. The ions are expelled in ~0.5 µs after ionization, providing a time-dependent current collected by the GIC during the 5 µs beam duration.

The GICs are located on the minor axis of the octagonal diagnostics beam-tube, Fig. 1, where the quadrupole magnetic field is tangent to the electrode surface, which suppresses electron emission or collection by the electrodes. A GIC diagnostic consists a collector that is shielded from the beam potential by a pair of grounded grids. Without the grids, the capacitive signal at the beam head and tail would exceed the expelled ion current by a factor of ~500. We tested the GIC by injecting argon gas, which increased the density by up to an order of magnitude above the base density, measured with an ion gauge. As shown in Fig. 2, the measured current increased linearly with gas density, demonstrating that the GIC measures gas density within a quadrupole magnet. These data also enable determination of fractional neutralization of the beam by ionization of gas, and will constrain simulations.

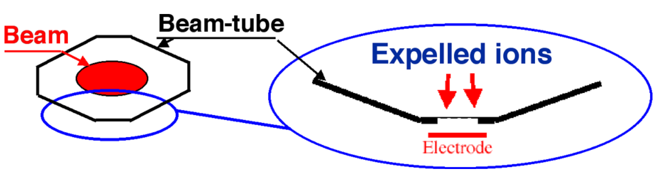


Figure 1. Diagnostics are mounted on an octagonal tube, that fits within an elliptical quadrupole magnet tube. The Gridded-ion-collector (GIC) is shown.

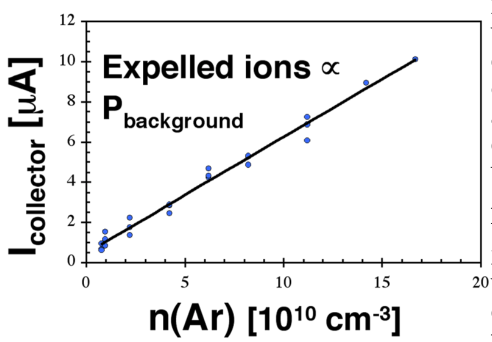


Fig. 2. The expelled ion current increases linearly with the background pressure, indicating that it provides a measurement of gas density within a magnetic quadrupole.

– Art Molvik

First observations of ~50x longitudinal compression

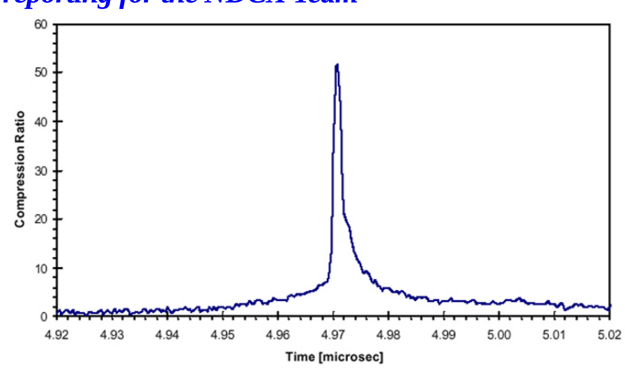
Heavy-ion drivers for high-energy-density physics applications and inertial-fusion energy use space-charge-dominated beams, which require longitudinal bunch compression in order to achieve high beam current. The Neutralized Drift Compression Experiment-1A (NDCX-1A) at Lawrence Berkeley National Laboratory (LBNL) is currently studying the issues, which determine the effective limits of neutralized drift compression, and is comparing results with theory and particle-in-cell simulations.

Neutralized-drift compression is achieved by imposing an initial velocity tilt on a drifting beam immediately before passing it through background plasma that can neutralize the beam space-charge. The velocity tilt causes the tail of the ion beam to catch up with the head, which longitudinally compresses or focuses the beam. Unneutralized compression is limited by beam space-charge; neutralization of the beam by a plasma has been predicted to enable compression to high current densities with short pulse widths at a focal plane about one meter beyond the applied velocity tilt (HIF News 3,4/04).

Fast diagnostics are currently in development to measure the longitudinal bunch compression factor and current density of the ion beam at the focal plane with high resolution (sub-mm and sub-ns) and accuracy. Knowledge of the current density of the compressed heavy ion beam is important for determining the magnitude of power that can be delivered to a target.

We have injected a low-emittance 300-keV K+ beam, with a 50% velocity tilt, through a neutralizing plasma of roughly 10^{11} cm^{-3} density and 3-eV temperature. Preliminary optical measurements with a scintillator and photomultiplier tube (see figure) indicate that NDCX-1A has achieved longitudinal current compression of up to 50 times the original injected current with a FWHM signal of about 2 to 3 ns, in good agreement with particle-in-cell simulations. (See P. K. Roy, et al., submitted to Phys. Rev. Lett., for more complete and recent results.)

– Adam Sefkow
reporting for the NDCX Team



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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.