Virtual National Laboratory for Heavy Ion Fusion

**July - August 2004**

# HIFNews

LBNL-PUB-844-07-08 /04

## Rough surface mitigates electron and gas emission

Heavy-ion beams impinging on surfaces near grazing incidence (to simulate the loss of halo ions) generate copious amounts of electrons and gas that can degrade the beam. We measure ~100 electrons and ~10,000 gas molecules, emitted for each 1 MeV $K^+$ incident on stainless steel. Electron emission scales as $1/\cos(\theta)$, where $\theta$ is the ion angle of incidence relative to normal. If we were to roughen a surface by blasting it with glass beads, then ions that were near grazing incidence (90°) on smooth surface would strike the rims of the micro-craters at angles closer to normal incidence. As expected, this reduced the electron emission: the factor of 10 reduction in Fig. 1(a), implies an average angle of incidence of 62°. Gas desorption, which varies more slowly with $\theta$ (Fig. 1(b)), decreased a factor of ~2, and along with the electron emission became independent of the angle of incidence on a rough surface.

In a quadrupole magnet, electrons emitted by lost primary ions are trapped near the wall by the magnetic field, but grazing incidence ions can backscatter and strike the wall again at an azimuth where magnetic field lines intercept the beam. These generate electrons throughout the beam (R. Cohen, HIF News 1-2/04). The SRIM Monte Carlo code predicts that ~75% of 1 MeV $K^+$ ions backscatter when incident at 88-89° from normal on a smooth surface.

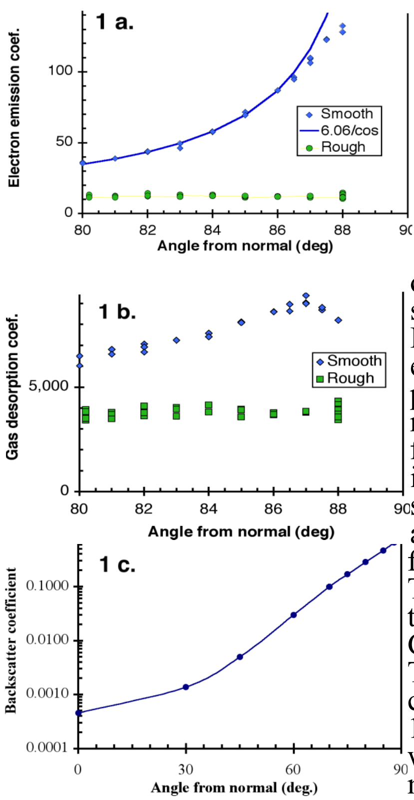


**Fig. 1. (a) Measured electron emission coefficient, and (b) Gas desorption coefficient; (c) Ion backscatter from a smooth surface, as predicted**

Most scattered ions are within ~10° of the initial direction but a few scatter to ~90°. Ion scattering decreases rapidly away from grazing incidence, Fig. 1(c). At 62 deg. the predicted ion backscattering (from a rough surface) is 3%, down a factor of 25 from the peak, which should significantly reduce electrons in the beam from lost halo ions. These results are published in Phys. Rev. ST – Accelerators and Beams. ***– Art Molvik***

## High fill-factor transport experiments on the HCX

Heavy-ion induction linacs have application as drivers for high energy density physics studies and ultimately as drivers for inertial fusion energy. Experiments on the High-Current Experiment (HCX) at LBNL explore heavy-ion beam transport at high fill factors (*i.e.*, the ratio of the maximum transverse extent of the beam to the physical aperture). The fill factor has a large impact on the cost of multi-beam induction accelerators, the 80% fill factor compared with 60% would reduce the cost of an HIF driver by about 1/3.

With a coasting low-emittance 1 MeV $K^+$ beam, transport through ten electrostatic quadrupoles was achieved at high beam fill factor (80%) without observed emittance growth and with little beam loss ( 1%), even though the initial beam distribution is neither ideal nor in thermal equilibrium, see Figure. While 10 quadrupoles are too few for settling questions of emittance evolution in a long system, they are very relevant for studying the rapid initial evolution of the emittance and beam profile that is expected in the front end of an accelerator. Studies at higher fill factors are planned, so that the failure mode can be established.

Agreement was reached between an improved envelope model and the data. Improvements to the model are: realistic quadrupole fringe fields based on 3D field calculations; quadrupole $E_z$ from the 3D lattice structure and corresponding radial focusing force; and corrections due to the grounded slit plates of the intercepting diagnostics that short out the self-field of the beam near those plates. We also find that understanding and controlling the time dependence of the envelope parameters is critical to achieving high fill factors, notably because of the injector and matching section dynamics.

***– L.R. Prost, P.A. Seidl, and S.M. Lund***

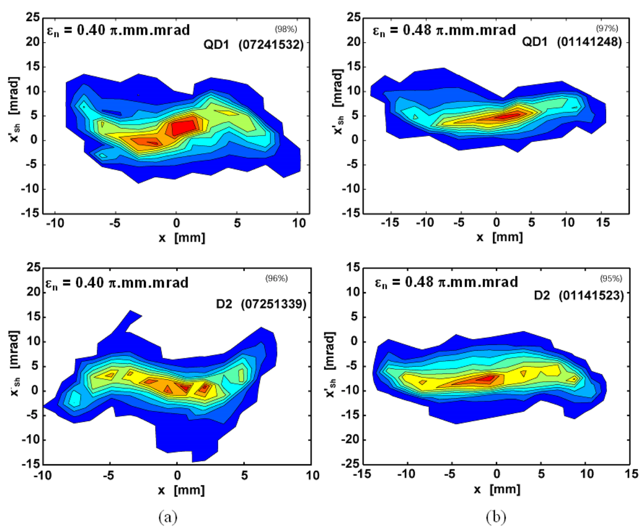


**Figure: Horizontal phase-space diagrams measured before (top) and after (bottom) the electrostatic transport section for (a) 60% fill factor; (b) 80% fill factor, for a single time slice at mid-pulse.**

For comments about the content of the HIF News, contact Art Molvik (925)422-9817, or molvik1@llnl.gov.
To get on the mailing list of the HIF News, send a request to WWTabler@lbl.gov

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.