Virtual National Laboratory for Heavy Ion Fusion

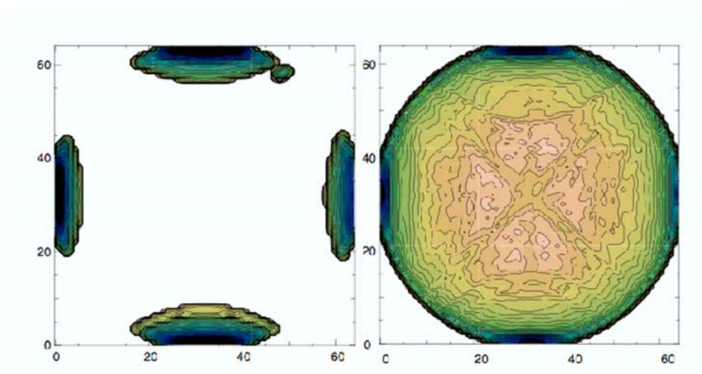
January - February 2004

HIFNews

LBNL-PUB-844-04-01/02

Simulating Secondary Electron Clouds in Quadrupole Magnets

We are implementing in WARP a self-consistent calculation of electron clouds in magnetically focused IFE accelerators. A capability now in place allows calculation of electron clouds produced by emission of secondary electrons when halo ions strike the wall. The calculation starts with an ion beam simulation. For each lost ion, the resulting secondaries are characterized by their number and mean velocity; this defines a macro-electron whose subsequent dynamics is followed. The figure on the left shows the electron density, in a plane transverse to the beam propagation, for a calculation that assumes that all ions striking the wall are lost. Since virtually all halo-ion wall impact occurs well within a quadrupole magnet at azimuthal positions where magnetic field lines are nearly tangent to the beam pipe, the resulting electron cloud is confined to the vicinity of the impact points where it has little effect on the beam. The picture is significantly changed



Electron cloud produced from secondary electrons with (right) and without (left) reflected ions in quadrupoles

if account is taken of ion scattering off the beam pipe; there is then a non-negligible probability of electron emission onto field lines that penetrate deep into the ion beam. This is shown in the right-hand figure for a very simple (straight-line orbit, single generation) model of the scattered ions. An interesting feature of this plot is a (small) local maximum of electron density near the beam center, indicative of a collisionless trapping phenomenon associated with passage through a magnetic-field minimum.

– Ron Cohen, Tony Azeveo, Art Molvik, Jean-Luc Vay

Vortex Tube Jets: Turbulence Aids Heat Removal

Isolating the high pressures in an HIF chamber from the high-vacuum driver is challenging. A promising invention from UCB uses the renewable-swirling-liquid inner walls of vortex tubes for absorbing the chamber energy and particles that get past the free-liquid jets while transmitting the heavy-ion beams. The liquid must be turbulent to enhance surface heat transfer, while keeping a sufficiently smooth surface.

The test vortex tube, Fig. 1, has a diameter of 37.8 mm. Water is injected through small holes, tangent to the inner surface at the center of the tube, and removed centrifugally at both ends. A plenum around the nozzle is used to supply the flow. The resulting water layer occupies ~25% of the pipe radius.

With Professor O. Savas of the UCB Fluid Dynamics lab, we recently conducted flow visualization experiments. Reflective particles of ~10 µm diameter are added to the liquid, illuminated by an Ar laser sheet, and recorded by a CMOS video camera. The displaced reflective particles leave streaklines, so the flow patterns can be visualized.
Fig. 2 shows two images captured using this method. The average flow velocity is 5m/s. In image (a) the exposure time is 200 µs. We notice that the “blue” streaklines have a different orientation than the “red.” This indicates that the flow is turbulent. In image (b), the

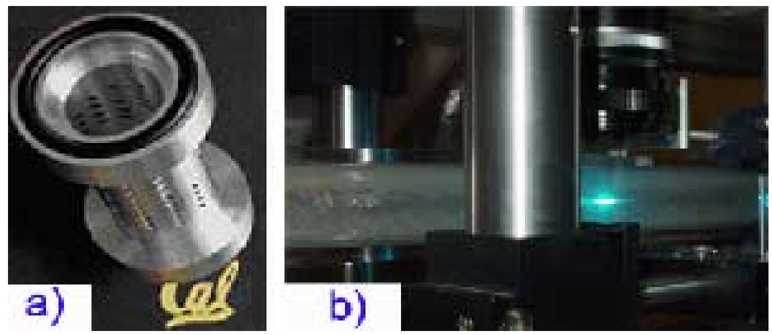
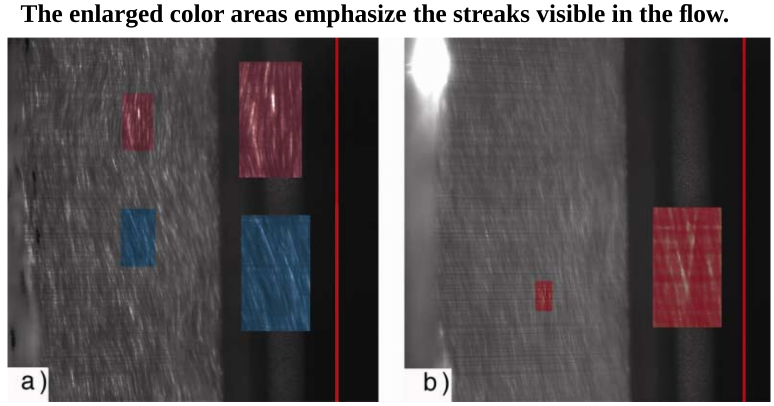


Fig. 1. UCB Vortex Tube: (a) the vortex nozzle, (b) laser sheet set up.

exposure time has been extended to 1000 µs. In the highlighted section, some streaklines cross each other, indicating that the turbulent eddies have a frequency in the kHz range! This shows that the vortex injection method creates intense turbulence in eddies with very small length scales, a phenomena which is not observed in normal turbulent film flows and which suggests the potential for substantial enhancement of heat and mass transfer to occur at the layer surface while maintaining a smooth surface.

– Phillippe M. Bardet, P.S. Peterson, O. Savas

Fig. 2. Flow Visualization images of the vortex tube. The red vertical line marks the wall. The exposure time is 200 µs (a) and 1000 µs (b). The enlarged color areas emphasize the streaks visible in the flow.



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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.