Proton beam on lithium film experiment for the FRIB stripper

Argonne National Laboratory has developed a liquid lithium charge stripper for use in the Facility for Rare Isotope Beams (FRIB) located at Michigan State University. FRIB will provide intense beams of rare isotopes that cannot be handled by ordinary means, creating a challenge to find a workable concept for the charge stripper and to test it in a beamline environment. The advantages of liquid lithium are: a) the heat deposited on the medium is carried away by the fast moving fluid, b) the heat capacity of the lithium is high, c) the vapor pressure is low. The expected energy deposition in the film from a typical uranium beam is about 700 W.

The goal of the experiment was to simulate the power deposition of the FRIB beam on the liquid lithium film with a proton beam and determine whether the film breaks up or not. As substantial power is deposited on the film, the risk exists of forming bubbles in the thin film and disturbing the flow. Simple approximations had shown that it was not likely that bubbles would form and that the momentum transfer from the beam to the film was very small compared to the flow momentum. Another possible breakup mechanism is thermal stress induced by the large temperature jump at the point where the beam crosses the film.

The experiment was to deposit a power density comparable to 30% of the maximum power density expected at FRIB when accelerating 400 kW of U at 200 MeV/u. We should remember that the protons only penetrate the first 1.5 µm of the film compared to the 10 µm film thickness. This could be interpreted as increasing the power density by a factor 6 if we neglect the heat conductivity of the lithium. The net effect would be a power density higher than FRIB by a factor 2.

The width of the lithium film was ~14 mm at ~50 m/s. When the beam hit the liquid film, no significant effects on the film were observed at the impact point. The power deposited by the proton beam heats the lithium film above its incoming temperature of ~200 °C. Turning off the light makes it possible to see the heated flow lines moving away from the impact point. By moving the beam in the horizontal direction we can visualize the lithium stream line. Note that the heated trails do not propagate beyond the film edge, implying that it is not produced by overheated gas that moves away from the fluid surface. Note that there is a small-scale fluctuating brightness within the beam while the film is flowing. We assume that this is due to beam hitting small droplets of lithium that splash from the liquid reservoir in the bottom of the tank.

This experiment showed for the first time the operation of a liquid lithium stripper under realistic conditions of beam deposited power. The proton beam deposits its full energy in the first 2 microns of the lithium film, creating approximately 200% of the maximum power density deposition expected at FRIB. At this power density the liquid film did not show any indication of being disrupted by the beam at the point of impact.

View the film video here:
http://www.ne.anl.gov/capabilities/high-power-accelerator-components/beam-on/

Table: Summary of beam and power parameters of the experiment compared to the FRIB values.

	FRIB	Experiment	Ratio (Exp/FRIB)
Beam power (W)	700	260	0.37
Beam σ (mm)	0.62	0.70	1.17
Beam power/σ^2 (W/mm^2)	1821	531	0.29
Beam power/σ (W/mm)	1129	371	0.33

CONTACT > Claude B. Reed | fax: 630-252-3296 | CBReed@anl.gov | Nuclear Engineering Division | www.ne.anl.gov