Large Vortex Experiment

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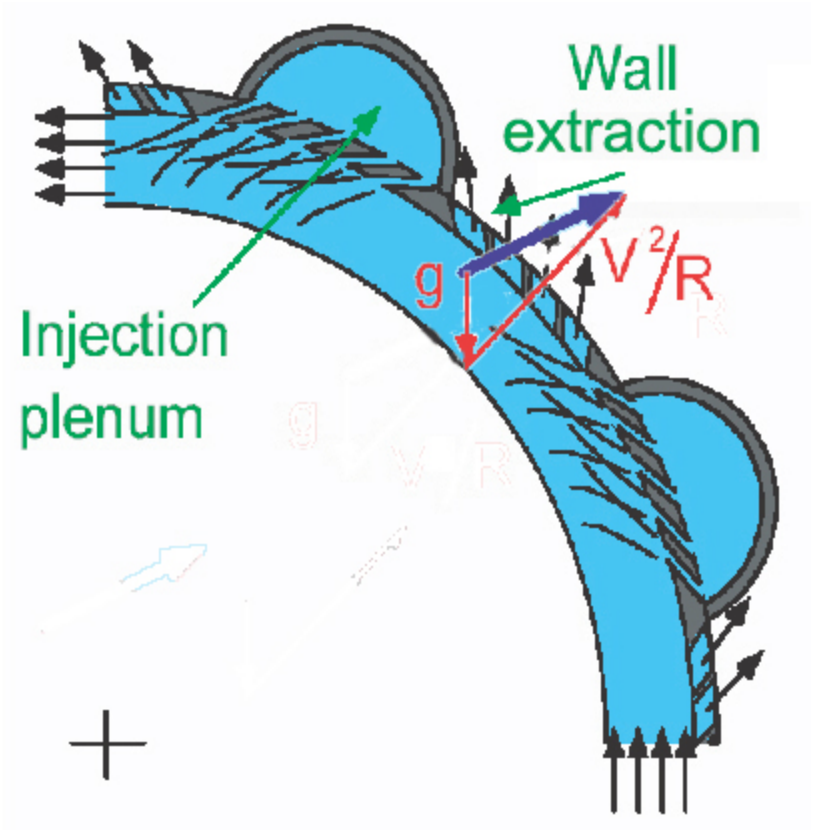
UCB has begun studies of combined blowing and extraction to keep liquid layers attached to large, concave surfaces

- Blowing is generated using patterns of small holes in the wall, supplied by a pressurized plenum
- Extraction rate depends on layer velocity, surface radius of curvature, and layer thickness
- Both injection and suction nozzles are protected by the liquid layer
- Want reasonable pumping power and large chamber radius:

$$\frac{U^2}{R \bullet g} = 3$$



Scaled model simulates incompressible vortex of HIF chamber

	Prototype	Model	Ratio Mod/Prot
Fluid	Flinabe (450°C)	Water (25°C)	
Radius, R (m)	3	0.127 (5-in)	0.085
Layer Thickness, δ/R	*0.2*	*0.2*	*1*
Velocity, U (m/s)	9.5	2.0	0.21
$Fr = U^2/Rg$	*3*	*3*	*1*
$Re = U\,\delta/\nu$	$1.2 \cdot 10^6$	$6.0 \cdot 10^4$	0.05
$We = \rho U^2 \delta/\sigma$	$1.0 \cdot 10^6$	$1.4 \cdot 10^3$	0.0014

δ/R and Fr are matched.

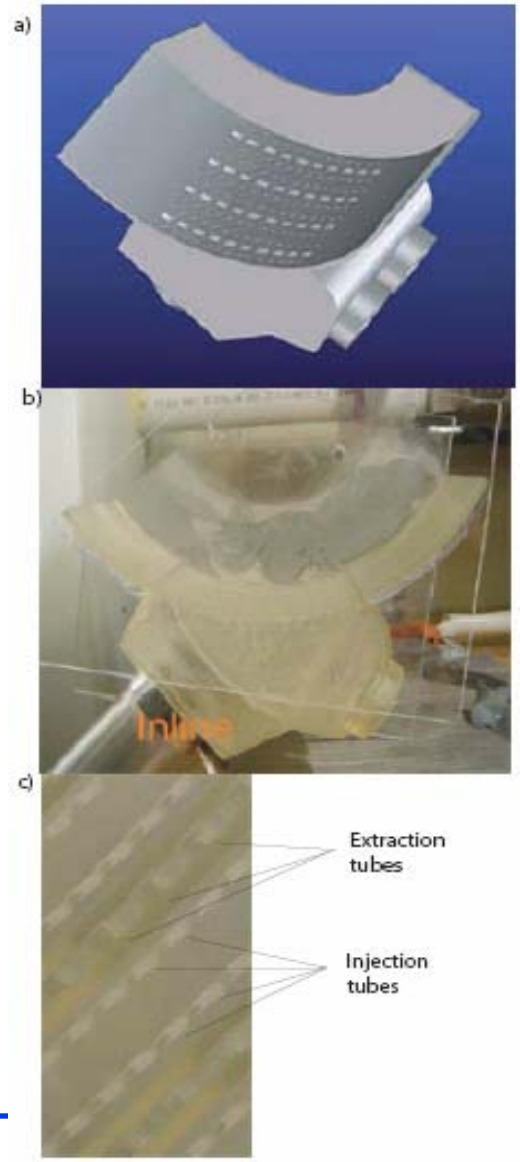
Turbulence intensity is lower in model. With T_{water} at 60°C, Re_m is multiplied by 2.

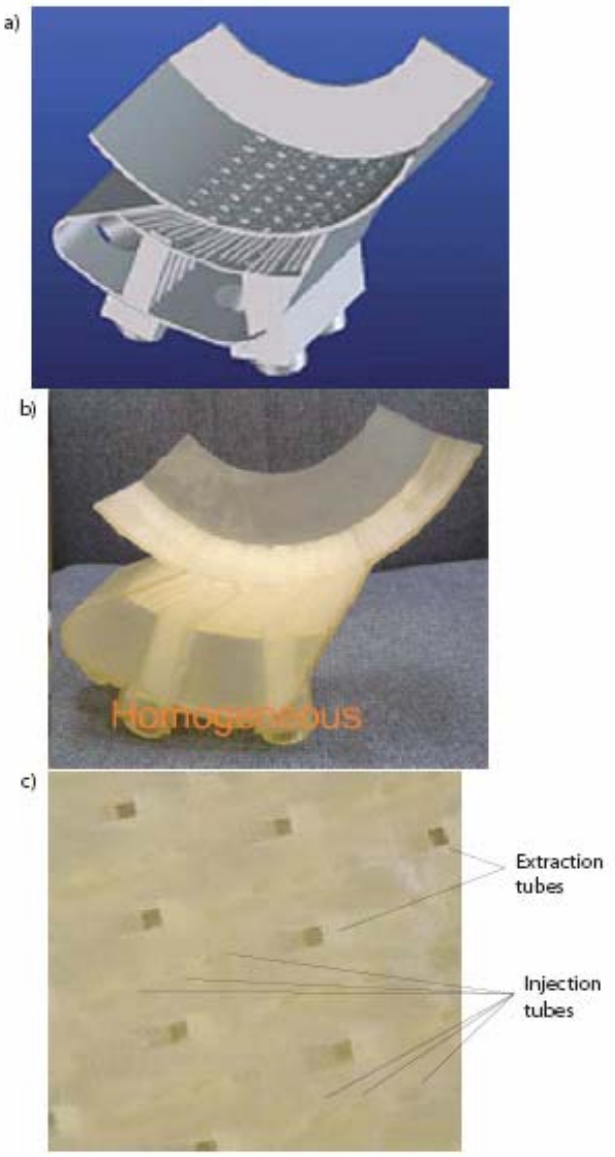
Model does not reproduce drop formation.

Compressibility effects are not simulated.

Prior to building complete cylindrical layer, UCB is testing curved nozzles in an inclined channel

- 2 existing nozzle geometries designed by Laura Chao, with different injection/extraction geometries:
  - In column
  - Homogeneous
- Nozzles were built by rapid-prototyping.
- Nozzles test:
  - ratio of injection to extraction areas
  - injection jets geometry
  - injection jets diameter

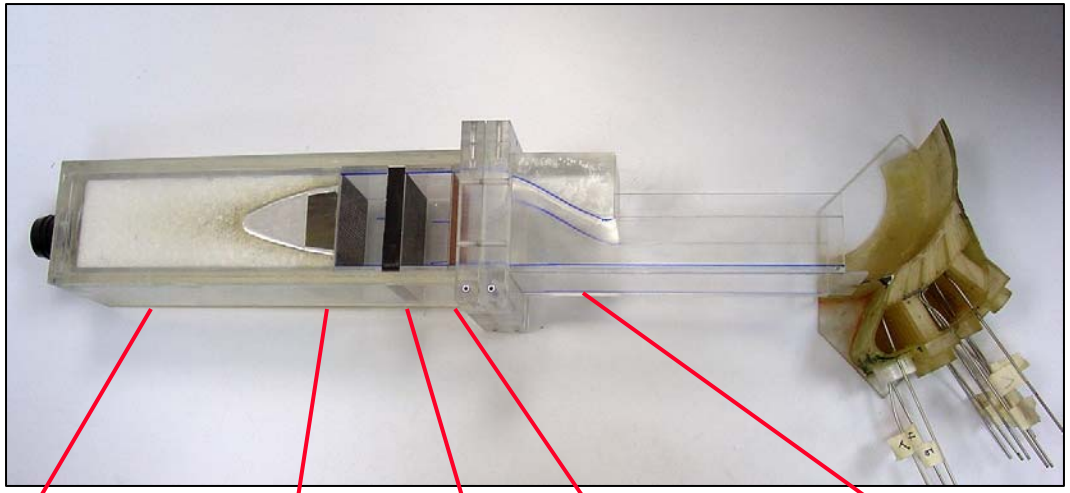


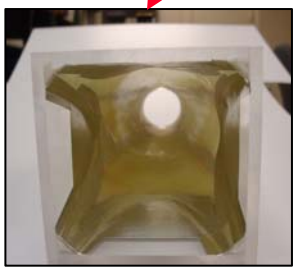


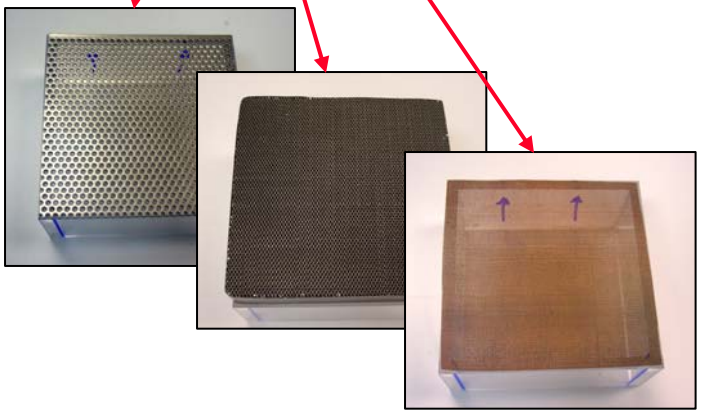
A new nozzle generates liquid layer in inclined channel

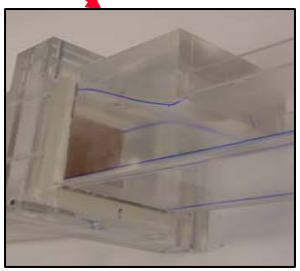
- **Precise machining allows accurate alignment of various flow conditioning elements.**

- **Modular design allows changing nozzle configuration to study various layer thicknesses and velocity.**









Conical Diffuser

Flow Conditioning

Contraction

Existing injection/extraction nozzles have been retrofitted with dye injection tubes

- Dye marks jets as they enter the liquid layer and allows understanding the flow geometry.
- 11 dye injection tubes are fixed adjacent to entrance of injection jet tubes.
- Dye is injected by compressed air for accurate and reproducible tests
- Dye visualizes jets:
  - Across the liquid layer width
  - Along the liquid layer path
  - Individual jets in injection group

Retrofitted homogeneous nozzle

Injection plenum

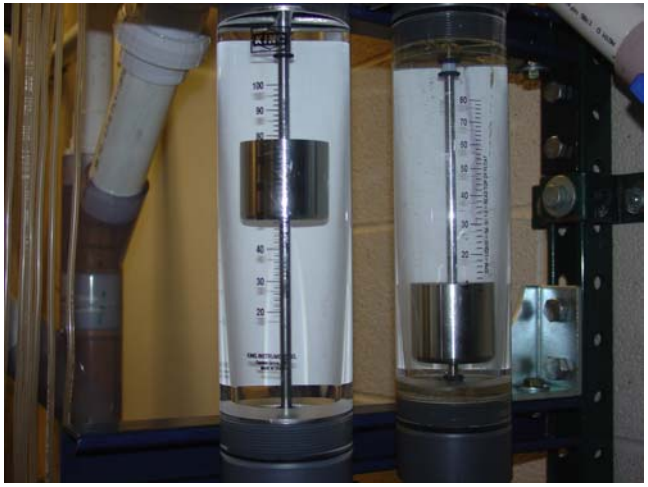
1-mm ID die injection tube

New ramp nozzle allows reaching desired scaled flow conditions

- **At the bottom of the ramp where the curved nozzle is inserted:**
  - **Layer thickness, δ = 2.5-cm (1")**
  - **Average velocity, U = 2-m/s (80gpm)**
- **The desired scaling parameters are reached in accordance with design:**
  - **$\delta/R = 0.2$**
  - **$Fr = U^2/Rg = 3$**

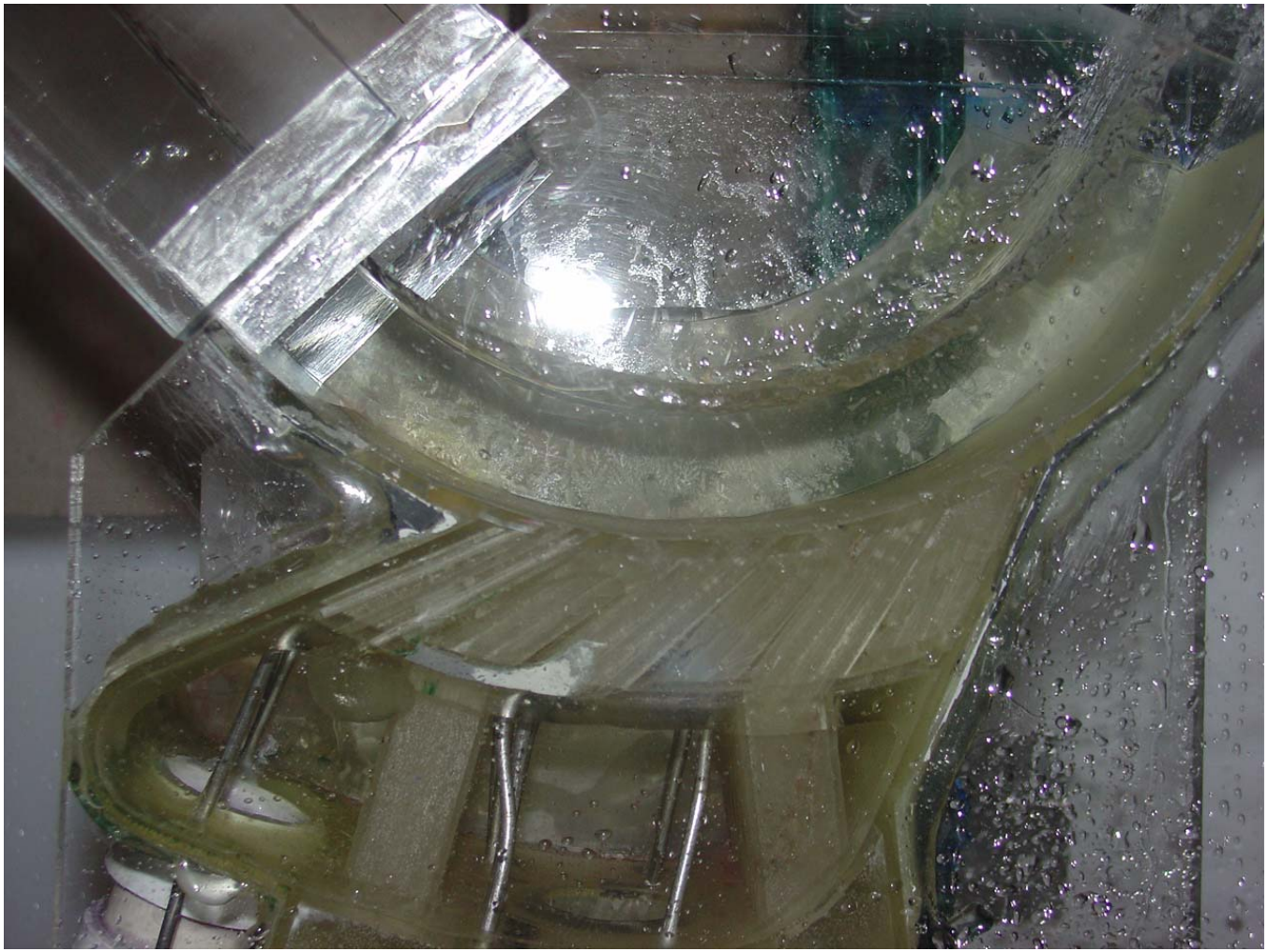
Ramp with nozzle connected with model flow conditions.

- **System is now leak free, which simplifies measurements.**

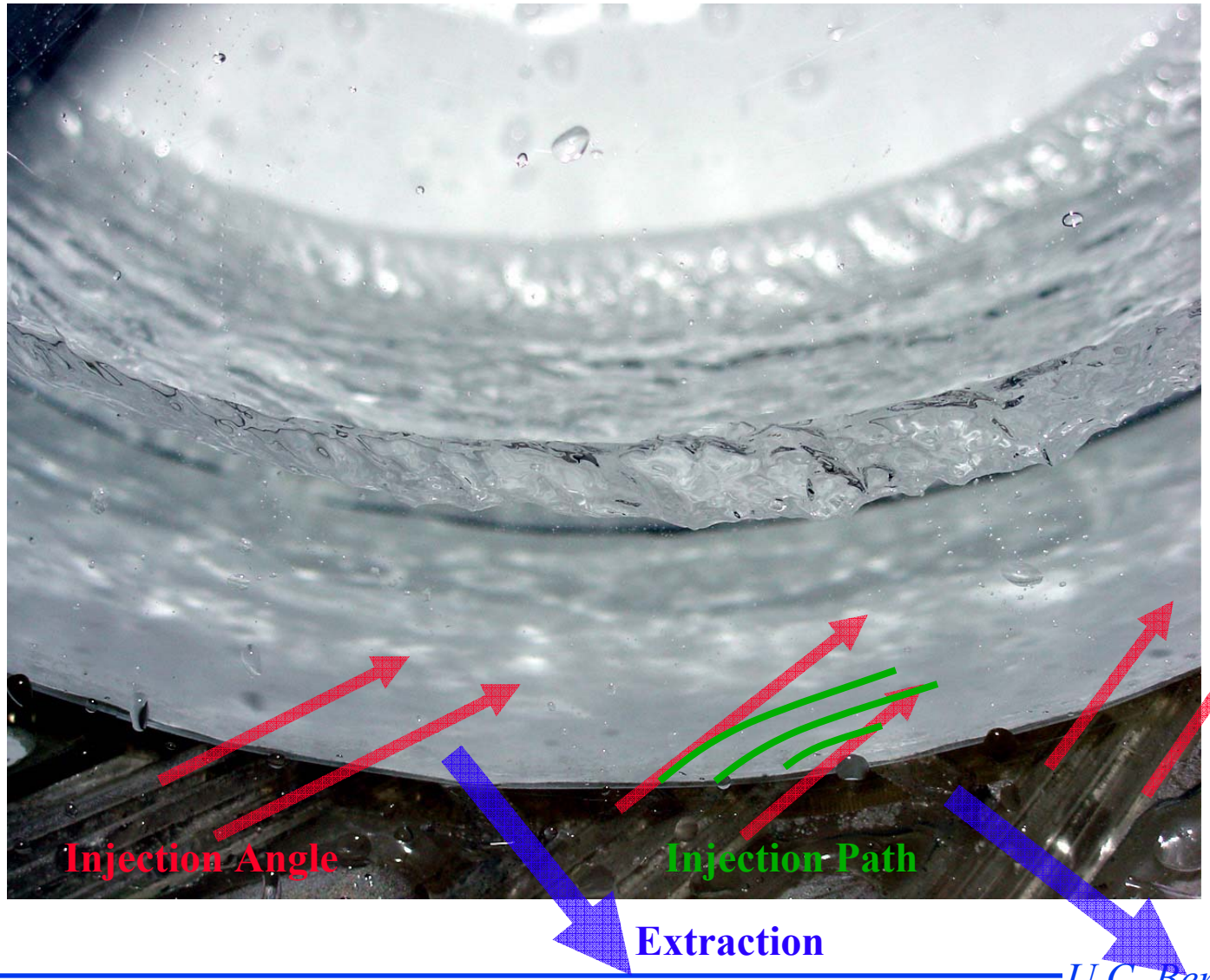


Rotameters

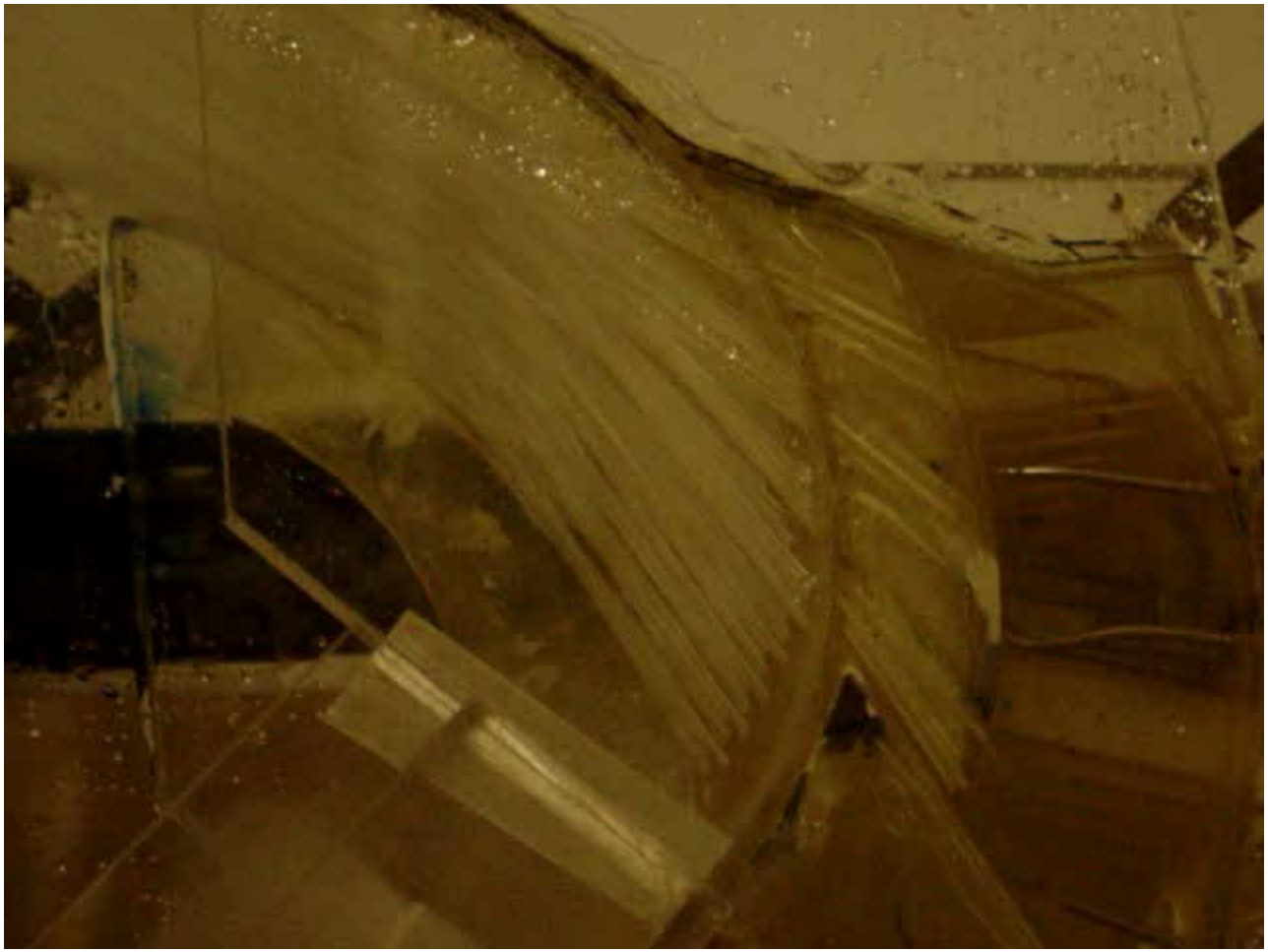
Close up view of liquid layer



Side walls effects have to be addressed



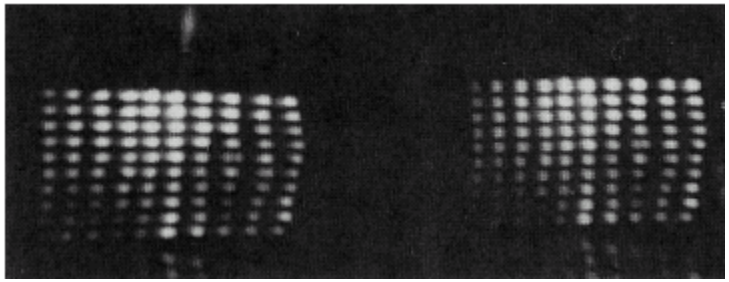
Momentum Injection



Conclusion and future work

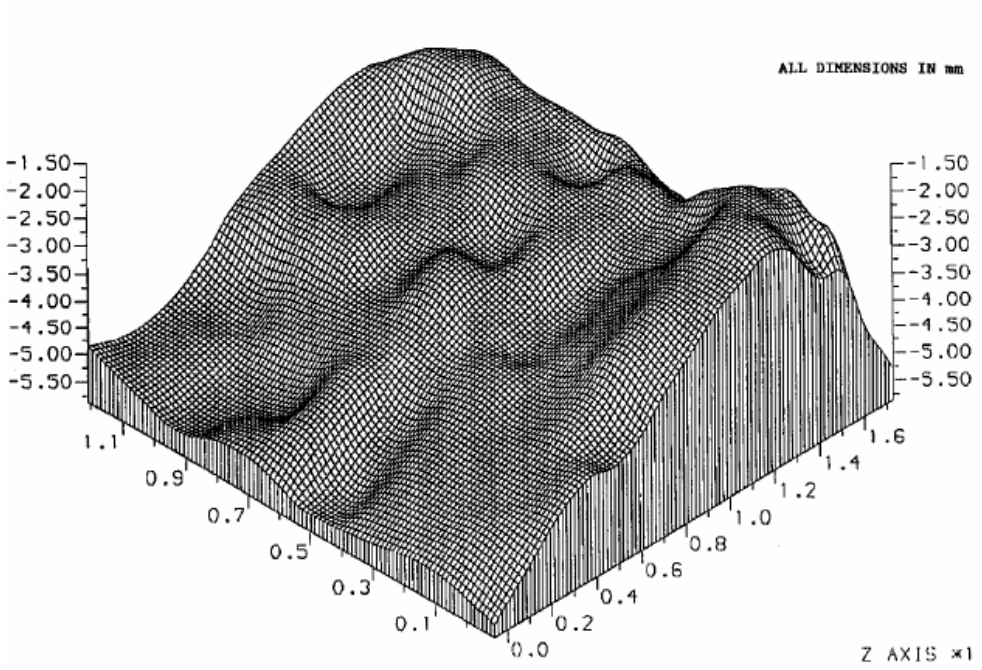
- **Conclusion**
  - **Developed new ramp nozzle that generates high quality liquid layer.**
  - **Conditions of scaled model have been reached.**
  - **Existing nozzles have been retrofitted for consistent and reproducible dye injection.**
- **Ongoing and future work**
  - **Proceed with dye injection to characterize injection geometry.**
  - **Measure extraction flow rate to confirm injection/extraction areas.**
  - **Develop liquid removal for side walls.**
  - **Design new nozzle and test new fabrication techniques (Acrylic casting).**
  - **Characterize free surface.**

Could use stereogrammetry diagnostic to measure waves shape



Project array of dots on surface of liquid and measure distortion.

If two views are available, then can do stereo-imaging and have 3D shape of waves



Could be a powerful diagnosis for surface shape characterization with sub mm accuracy

Will allow to quantify nozzle influence on Free Surface