Glass Chips

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Hard Lithography (the good)

SLAC

- Indestructible
- Multiple coating types
- Electrical contacts are straight forward
- Small channels
- High repeatability
- Multiple on-chip components are available (valves, pumps, mixers, etc.)

Hard Lithography (the bad)

Expensive?

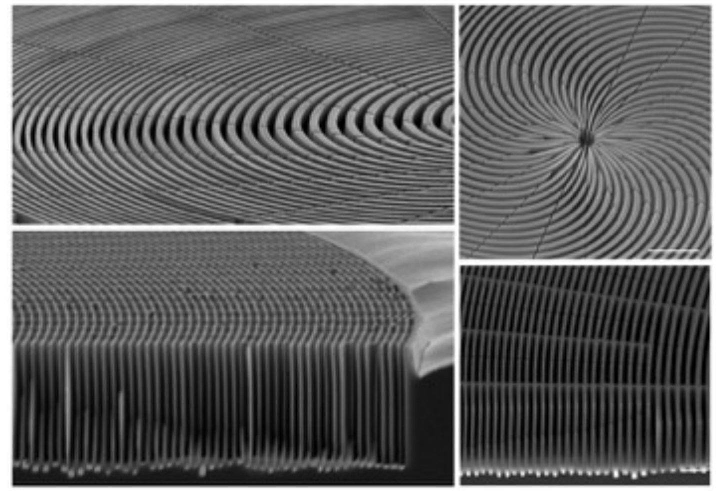
- Consider labor costs
- Consider detector costs

Long turn around time

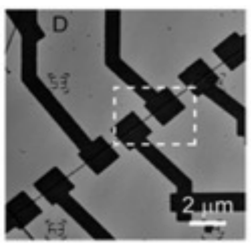
- We need 10’s not millions
- Most labs not done on-site
- NanoX

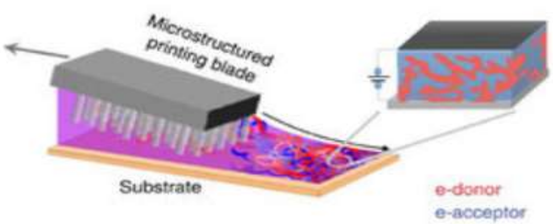
What is Nano-X ?

Nano-X is a 3100 sq. ft. class 100/10000 facility housing an advanced electron beam lithography tool and associated processing and metrology equipment. The toolset is aimed towards providing SLAC's scientific community with rapid nano-prototyping capabilities complementary to that of the current campus facilities.



Optics for spatial and temporal control of x-rays, injectors, collimators, beam metrology





On-chip in-situ and in-operando platforms for interface chemistry, advanced spectroscopy, theory-guided materials and nanosystems fabrication,

Nano-X is proposed to operate as a semi-shared facility with a percentage of time allocated for usage by trained personnel from the broad SLAC/Stanford community. Compared to the campus facilities, the equipment toolset will have a higher degree of oversight, quality control, and stability and a more rigorous training requirement.

Slide materials courtesy of Anne Sakdinawat

Why Nano-X at SLAC?

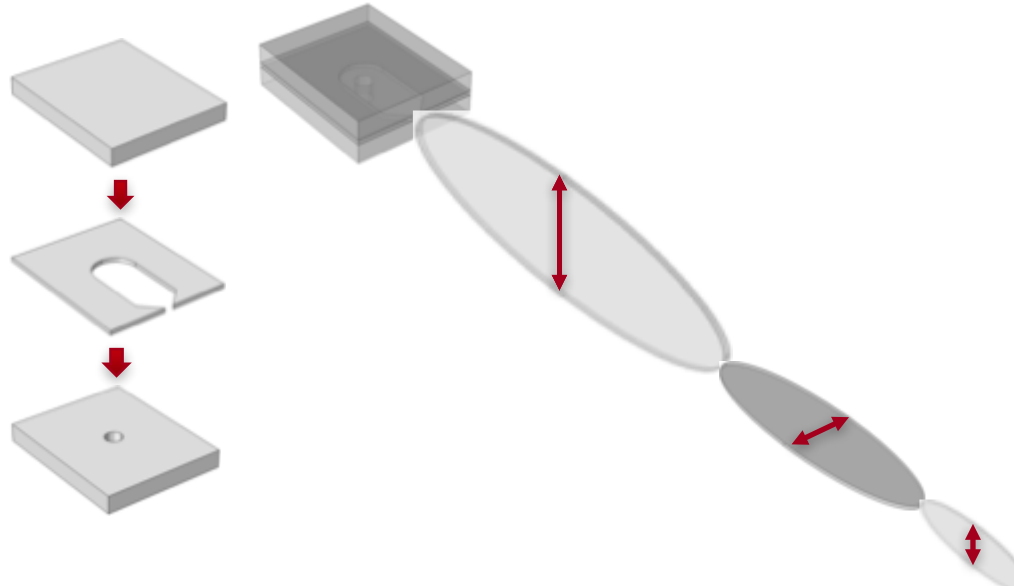
- **Right Place:** In-house nanofabrication facility will produce new scientific advances and support activities at LCLS, SSRL, and SLAC. A semi-shared facility provides much greater flexibility and freedom compared to primarily user facilities at other national labs.

- **Right Tools:** Nano-prototyping capabilities with direct-write tools efficiently increases scientific productivity and innovation leading to scientific/technological breakthroughs and future funding opportunities for SLAC.

- **Right People:** Builds community and teamwork among SLAC's directorates by integrating nanoscience and nanofabrication expertise across SLAC. In-house nanofabrication expertise allows for accountability and teamwork within SLAC. It also allows for efficient productivity in the unique operational environment of light sources.

Slide materials courtesy of Anne Sakdinawat

Single Fluid Nozzle

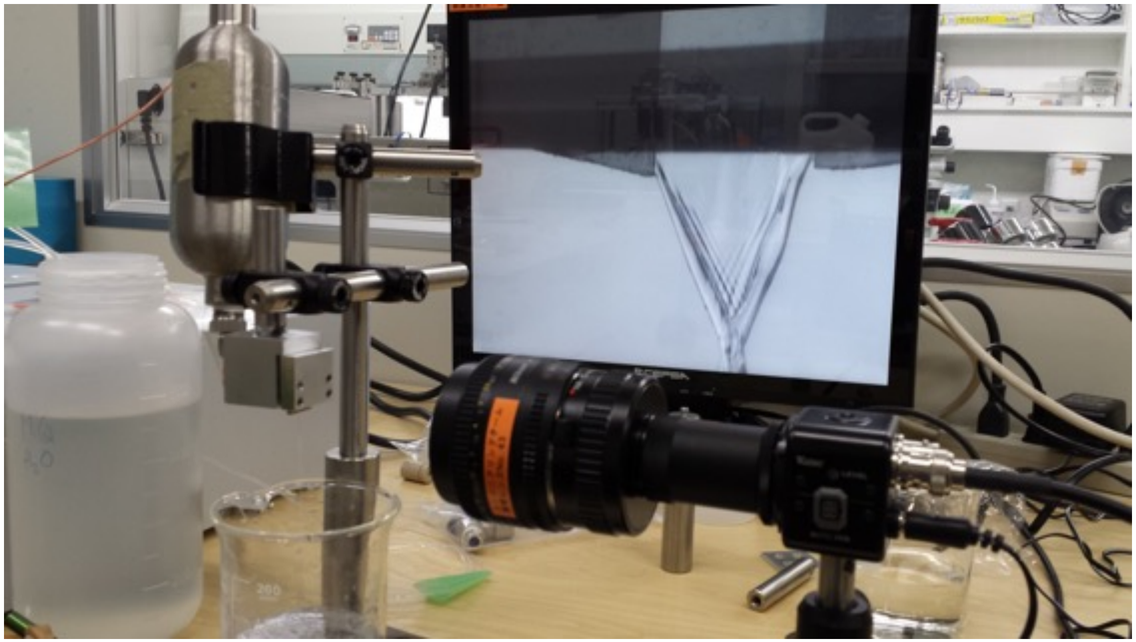


- Microchip: 1mm-thick glass slides + Kapton film
  - UV laser ablation
  - 20 - 30 μm beam diameter
- Grinding and polishing
  - Grinder w/ sample holder

Slide materials courtesy of Byunghang Ha

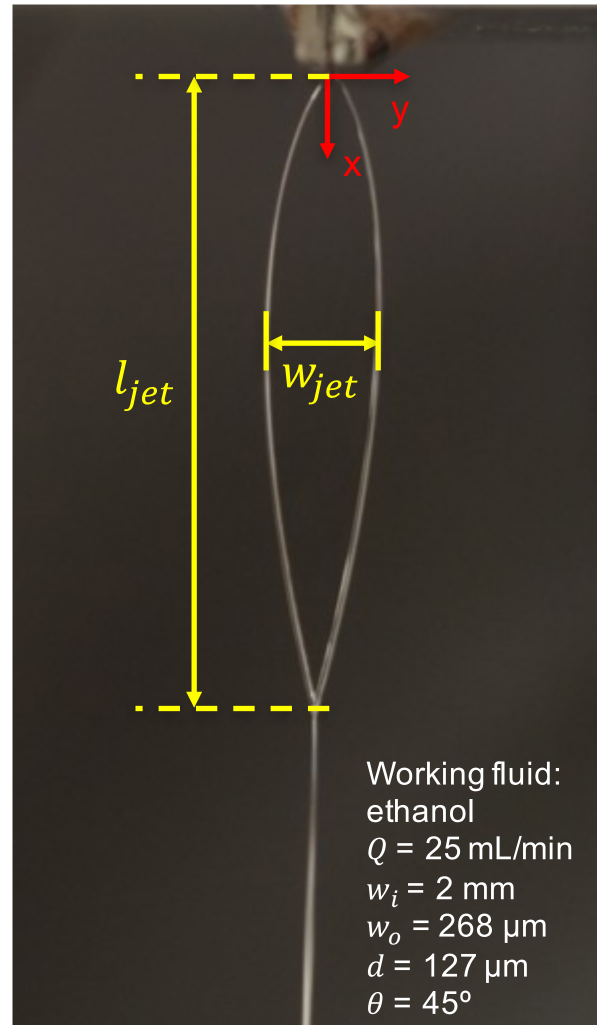
Single Fluid Nozzle

Straight Channel



13 micron thick by 2mm wide

Converging Channel



Slide materials courtesy of Foivos Perakis & Byunghang Ha

Converging Nozzle Sheets

- There are 2 competing things, inertia (transverse momentum) and surface tension.
- The center of the jet is all about the inertia and the edge is all about surface tension.
- The nozzle geometry completely determines the inertia part and therefore how fast the jet spreads.
- Sheet thickness/nozzle depth at a given length to exit spanwise width ratio is the same for any conditions for a given nozzle geometry.
- The center of the sheet doesn't know the edge exists – it spreads out as 1/r.
- The spreading stops at whatever distance the edges collapse back in.
- Higher flow rate means the edges collapse back in farther from the nozzle implying a smaller minimum jet thickness.
- Lower surface tension gives a longer & wider sheet with thinner minimum thickness.

2-Fluid Sheet Nozzles

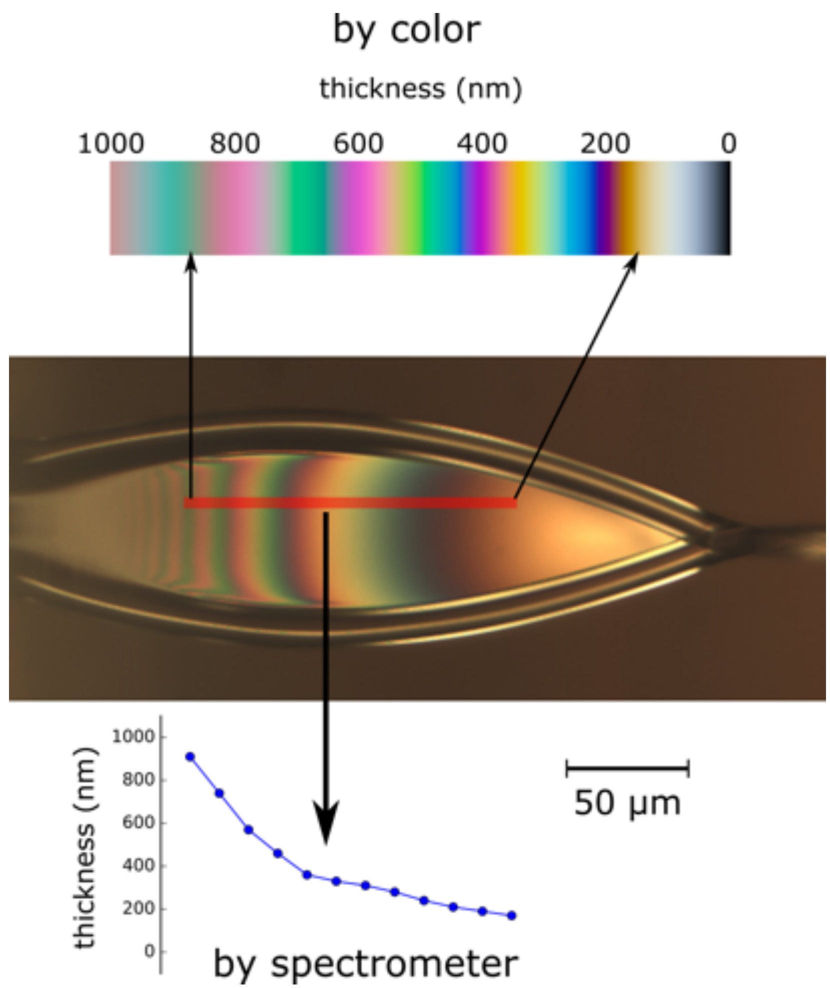
Nozzle edge

Liquid

Thin-film interference

Thickness by color camera and spectrometer agree pretty well.

During FEL experiments, often illuminate with monochromatic laser – also easy to get thickness.



Slide materials courtesy of Jongjin Kim and Jake Koralek

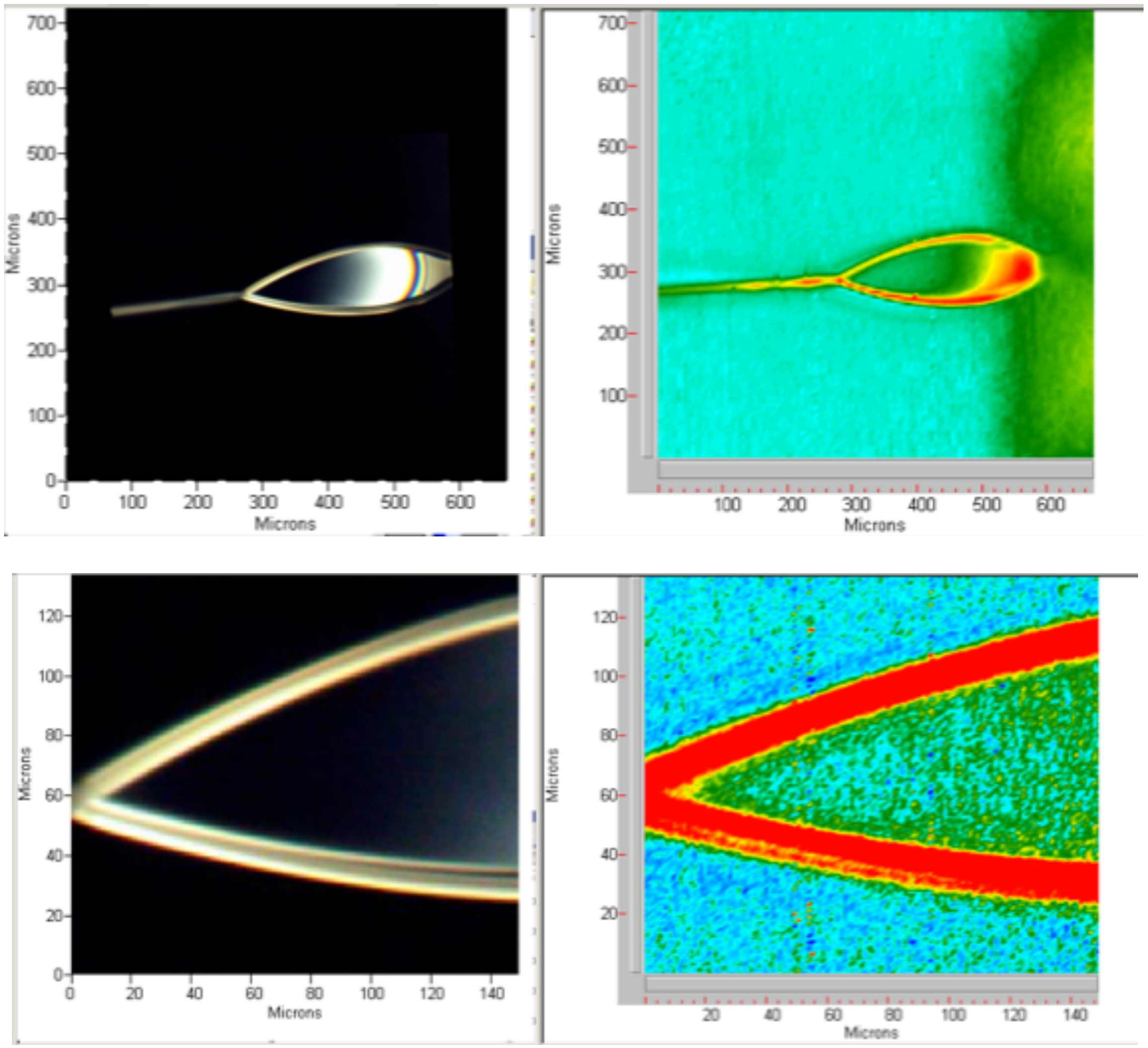
IR transmission spectromicroscopy

SLAC

Agilent Cary 620 FTIR microscope
15x objective, NA: 0.6
128 x 128 Pixel detector (16, 384 spectra simultaneously)
Low Magz: 720 x 720 μm^2 area with 5.5 µm pixel size
High Mag: 140 x 140 μm^2 area with 1.1 µm pixel size

Can adjust sheet thickness to achieve as low as 98% transmission at the O-H stretch mode…

Sheet ~10 nm thick!



Color scale is transmitted spectral weight of the O-H stretch mode

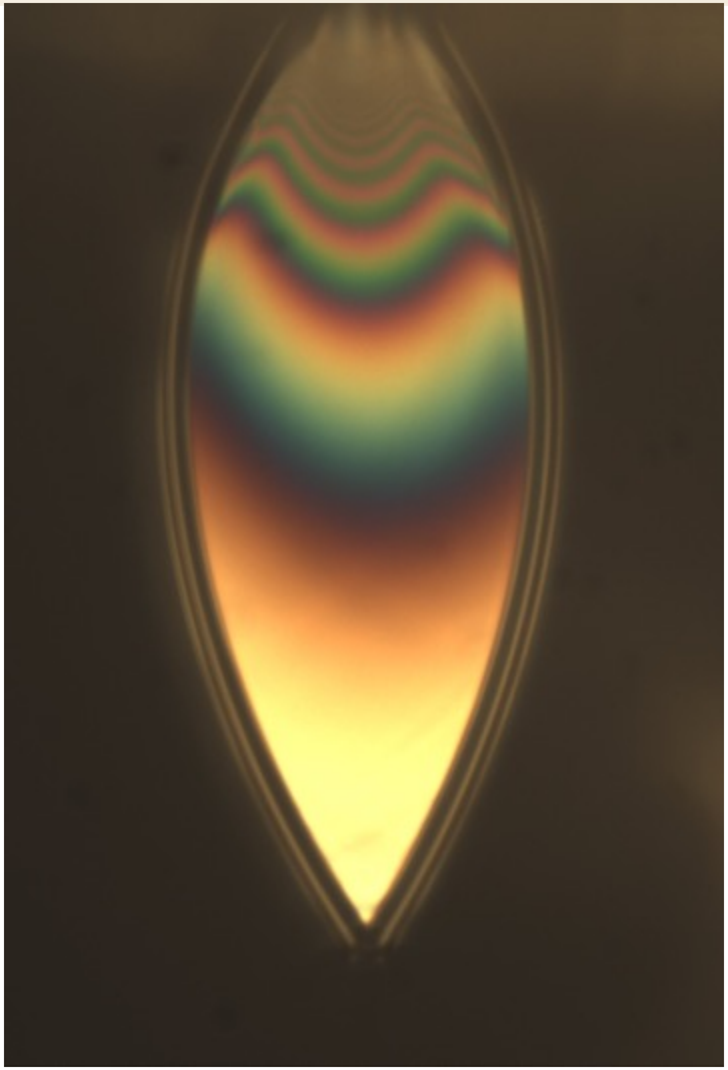
Slide materials courtesy of Jake Koralek

1-Fluid vs 2-Fluid Sheet Nozzles

SLAC

- ✓ There are 2 competing things, inertia (transverse momentum) and surface tension.
- ✓ The center of the jet is all about the inertia and the edge is all about surface tension.
- x The nozzle geometry completely determines the inertia part and therefore how fast the jet spreads.
- x Sheet thickness/nozzle depth at a given length to exit spanwise width ratio is the same for any conditions for a given nozzle geometry.
- x The center of the sheet doesn't know the edge exists – it spreads out as 1/r.
- ✓ The spreading stops at whatever distance the edges collapse back in.
- ? Higher flow rate means the edges collapse back in farther from the nozzle implying a smaller minimum jet thickness.
- ✓ Lower surface tension gives a longer & wider sheet with thinner minimum thickness.

Edge Effects



Microfluidic Nozzles Plan

Have them manufactured.

Manufacturer sells them to anyone.

Status

Single-fluid straight nozzle

- Decide on port layout
- Release to Fab

Single-fluid converging nozzle

- Decide on port layout
- Release to Fab

2-fluid nozzle

- Released to Fab (sold by Micronit, interface sold by Neptune fluid flow systems)

3-fluid nozzle

- Test Prototypes

SLAC

Design Guideline for Microfluidic Device and Component Interfaces (2 pubs)

Editors: Henne van Heeren (enablingMNT), Tim Atkins (Blacktrace/Dolomite), Nicolas Verplanck and Christine Peponnet (CEA-LETI), Peter Hewkin (CfBI), Marko Blom and Wilfred Beusink (Micronit), Jan-Eite Bullema (TNO), Stefan Dekker (University of Twente).

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Comments, suggestions and questions regarding this document can be addressed to:
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Standardization (outline)

Assume hardware has standard interface for standard instrument configurations.

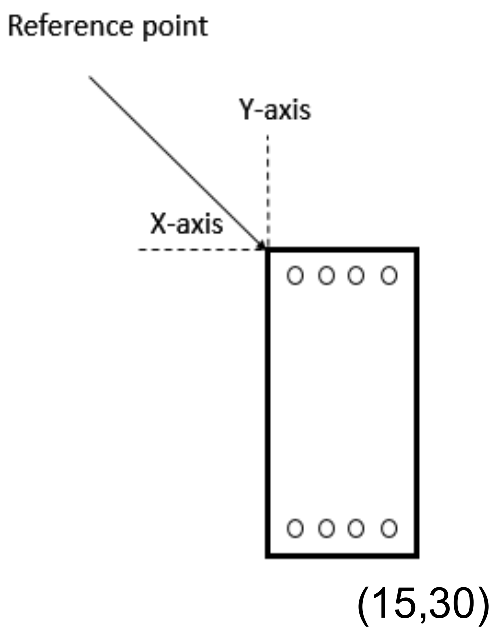
Assume high degree of automation.

In near term assume chip dimensions small in near term

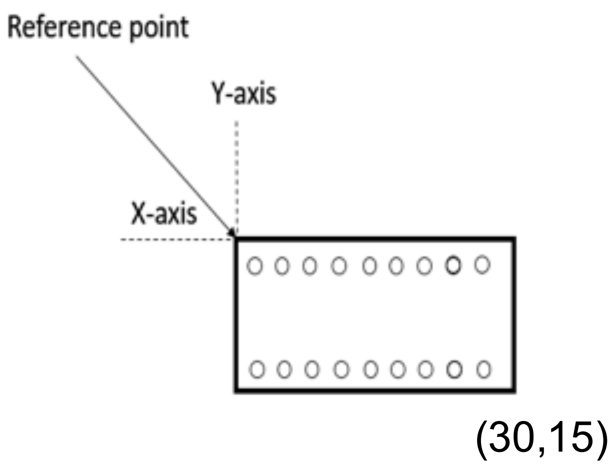
- Microtiter
- ”credit card” chip 85.60 × 53.986 mm
- microscope slide (75x25)
- Caliper chip 22.28 mm X 36.88 mm   (12.4,9) spacing
- None of the above

Assume we need half angle XXX(45?) for the scattered beam.

Standardization (naming)



15*30 mm chip with axes and reference point.



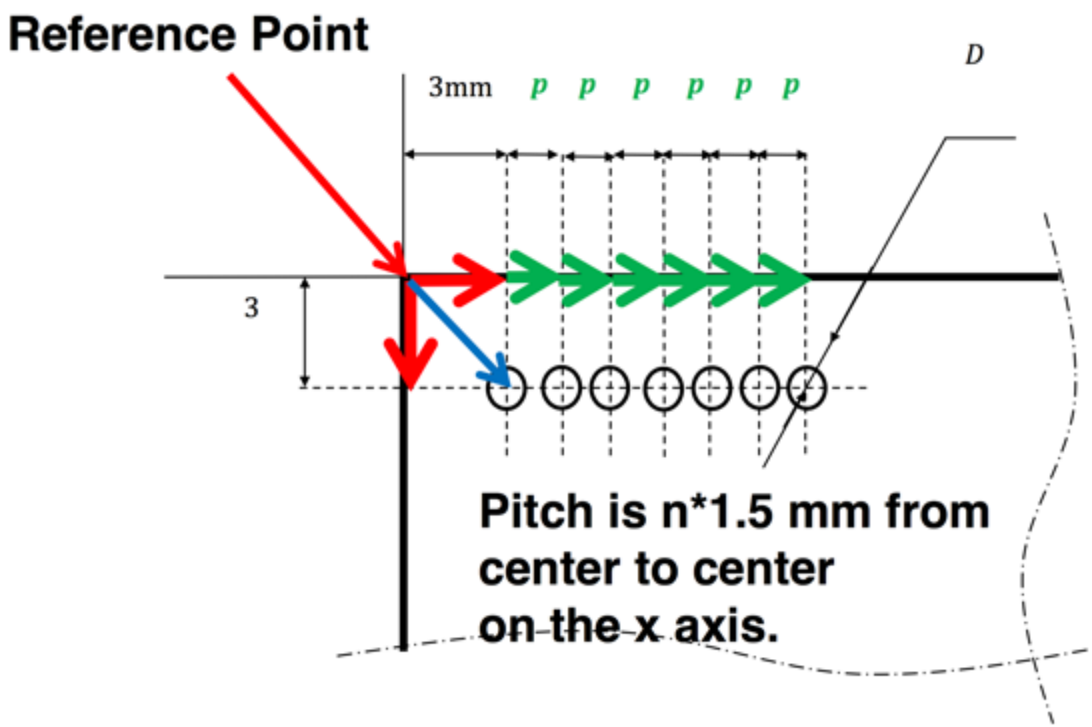
30*15 mm chip with axes and reference point.

From white paper "As a preference one should chose the naming (and with that the X axis) in such a way that (most of) the microfluidic connections are on the side of the X axis." What about for injectors?

From Design Guideline for Microfluidic Device and Component Interfaces

Standardization (pitch)

port pitch, i.e. the distance between the centres of two ports are to be based on a 1.5mm grid (or 0.75?)



Center of first hole is at (3 mm, 3 mm) from reference point

From Design Guideline for Microfluidic Device and Component Interfaces

Standardization (SLAC now)

Outline 17mm x 6mm

Ports (3,3) (6,3) (9,3)

Thickness 0.8mm