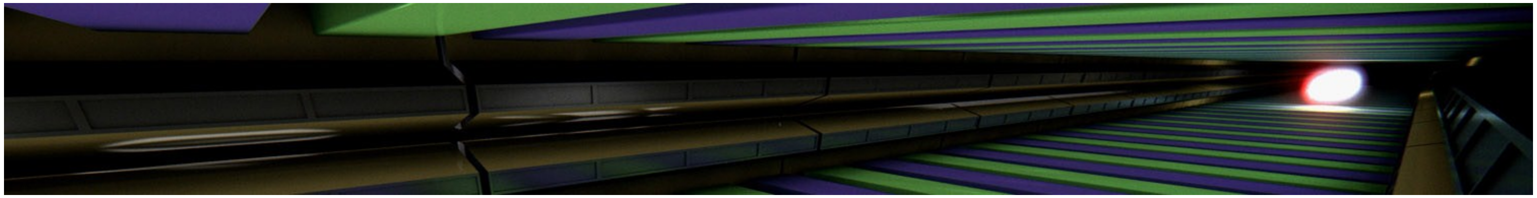
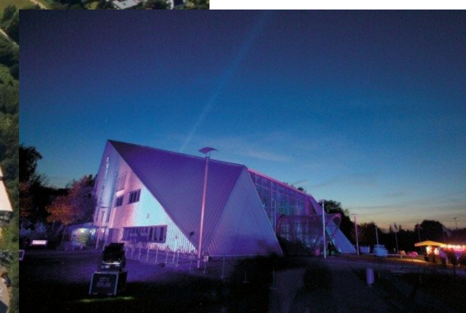


Challenges of Sample Delivery

for the European XFEL

Joachim Schulz

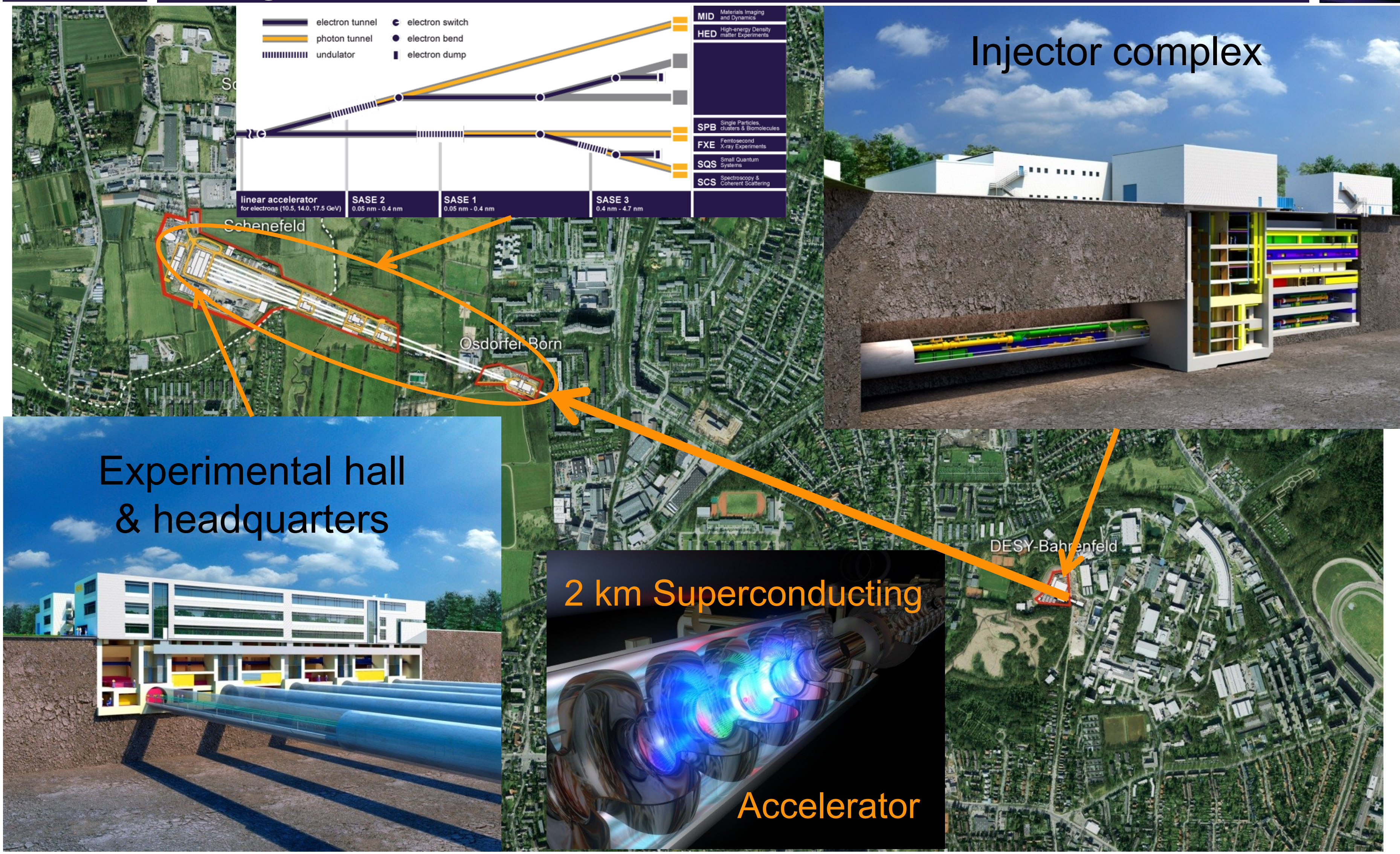
The DESY campus



- CSSB
- NanoLab

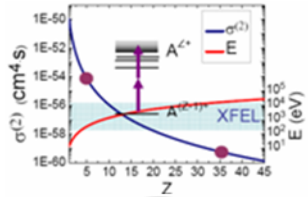
European XFEL

X-ray Free-Electron Laser



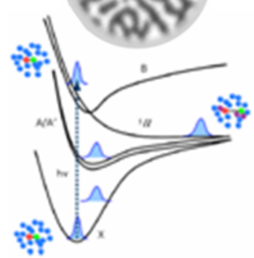
Six scientific instruments

SQS Small Quantum Systems

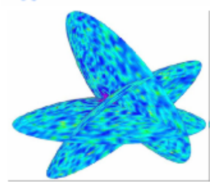


SCS Spectroscopy & Coherent Scattering

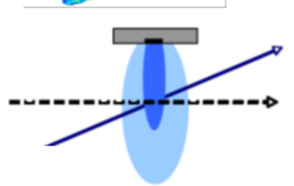
FXE Femtosecond X-ray Experiments



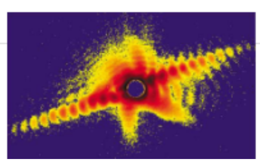
SPB Single Particle & Biomolecules

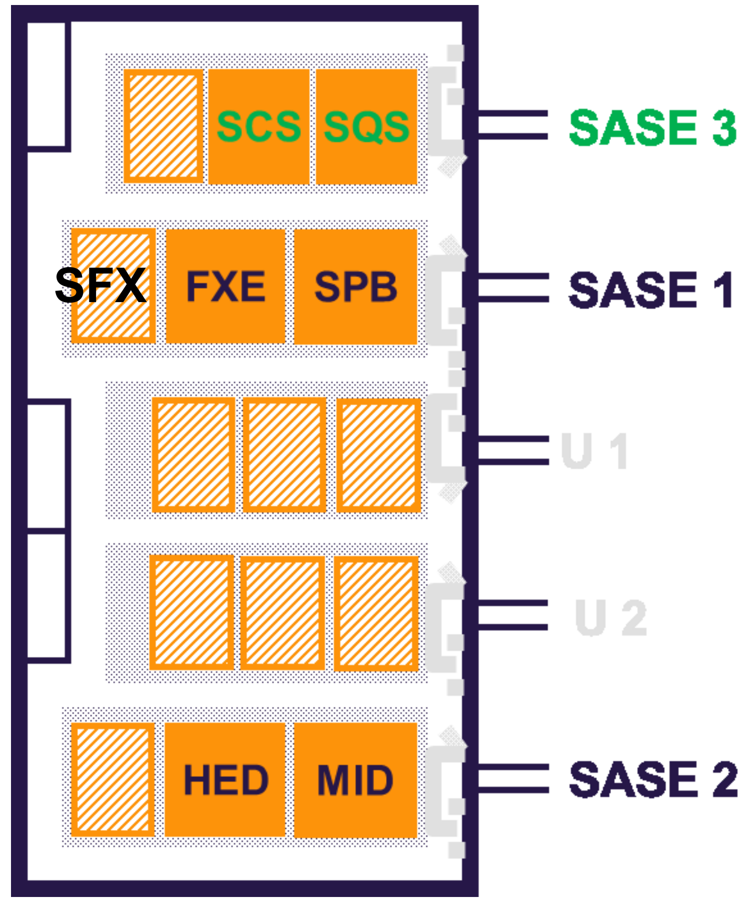


HED High Energy Density Science



MID Materials Imaging & Dynamics





Sample Environment Group

Sample environment for six instruments

- Setting standards for basic instrumentation
- Providing solutions for special sample handling (cold, hot, ambient)
- Clean preparation and transfer of surface samples
- Provide equipment for quality control

User support

- Provide lab space and equipment for sample preparation
- Support users in using XFEL equipment
- Help with integration of user equipment

In-house research

- Develop new methods for sample delivery
- Collaborate with European XFEL instrument groups
- Own research at synchrotrons and FELs

Overview over sample types

Gas phase
Liquid
Surface
Bulk

Samples	Pressure	Temperature	Fields
Free Atoms	UHV	Heating?	-
Molecules	UHV	Heated nozzle	Electric
Clusters	UHV	Controlled	-
Aerosols	HV	-	-
Living cells	Wet HV	-	-
Surfaces	XHV	Controlled/cryogenics	Magnetic
Surface chemistry	Ambient cell	Controlled	-
Liquid jets	Air/He/HV	Controlled	-
Liquid drops	Air/He/HV	Controlled	-
Microscopic solid samples	UHV	Controlled/cryogenics	-
Bulk material	Air/He/HV	Controlled	Magnetic

HV: ~10^{-5}mbar, UHV: ~10^{-8}mbar, XHV: ~10^{-11}mbar,

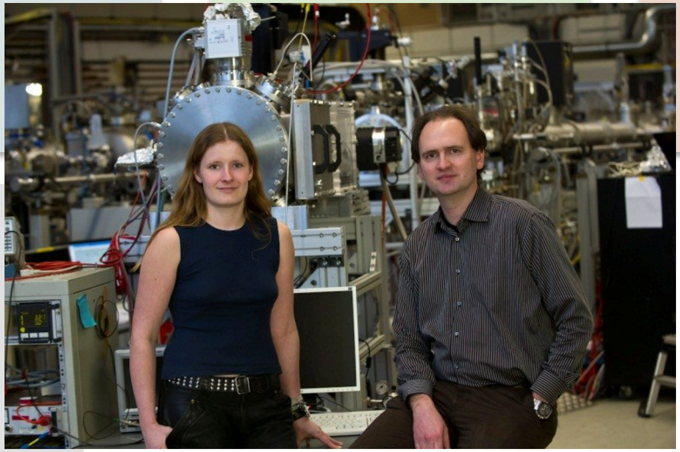
Sample environment group

Biology	Fixed targets	Gases	Liquids

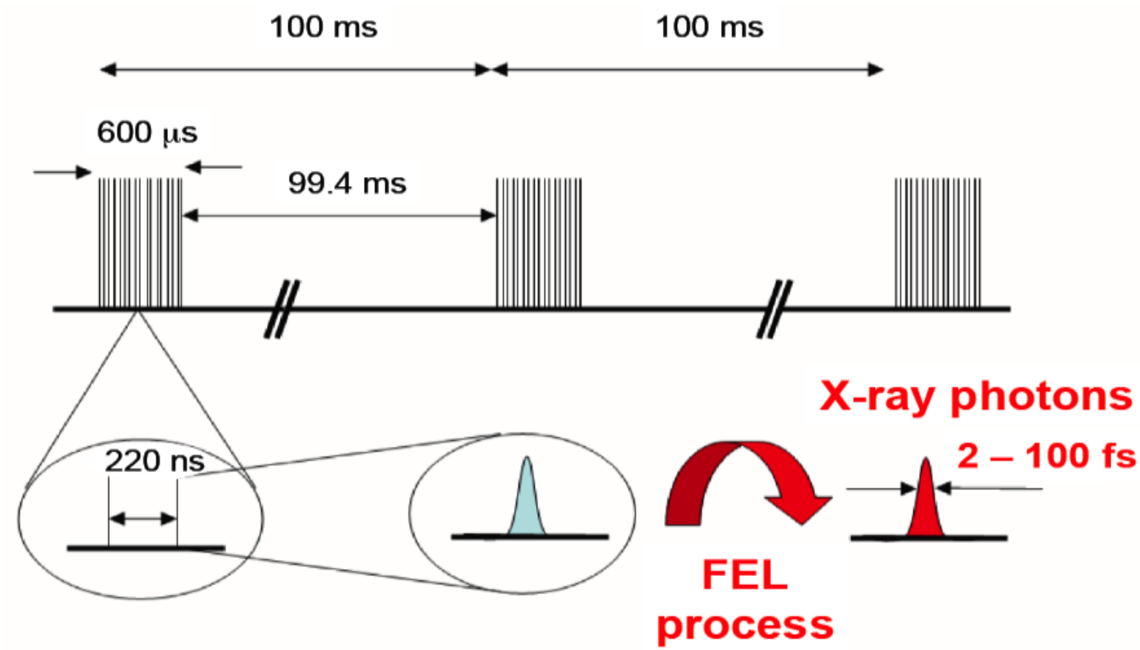
• Aerodynamic lens (Uppsala IKC)
• Bio-labs (together with UseXBI UC)
• Droplets
• Advanced preparation
	• Hexapod
	• Ultra-fast sample change
	• Sandwiches
	• Cryo samples
	• In gas cell
		• COMO UC
		• Ultrasonic beam
		• Cluster beam
		• Gas cell
			• Droplets in vacuum
			• Nano-droplets
			• Jets and sheets
			  • In air
			  • In vacuum

Scientists

- Sadia Bari
- Charlotte Uetrecht
- Two more to be hired



Unique time structure



- 2700 pulses in each train
- 220 ns between pulses
- 10 trains/sec
- Pulse length ~ 25 fs
- Flexibility in sending a given electron bunch down a given undulator

- Looking at trains we reach 0.6% duty cycle

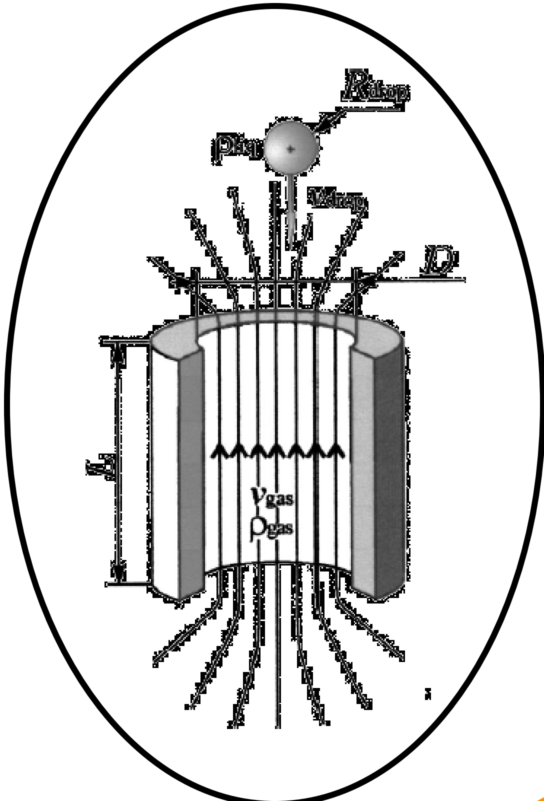
Pulsed liquid or aerosol sources

- 10 Hz with single shot trains
- 27 kHz with 4.5 MHz within the train (220ns separat
- 600 Hz with 100kHz within the train (10µs separatio

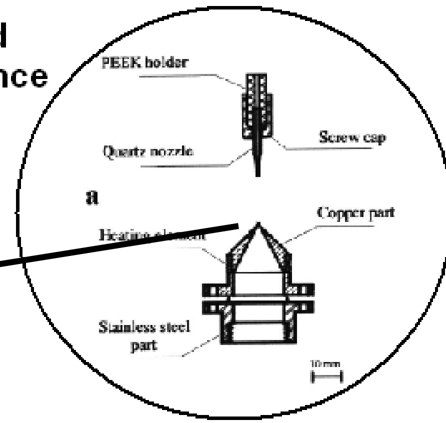
Fast fixed target change

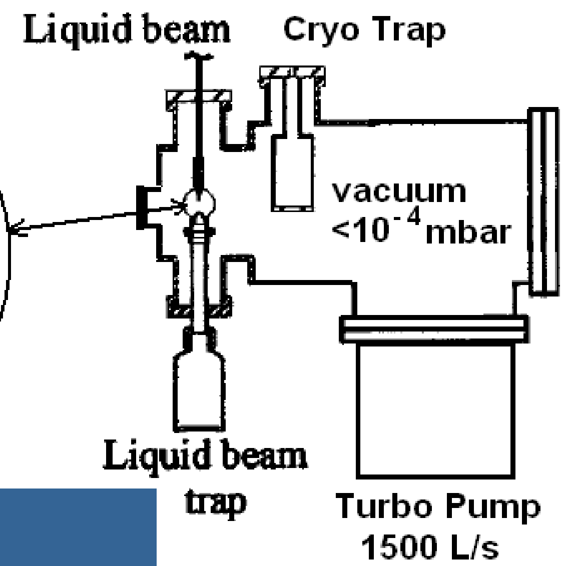
Liquids

Liquid jet concept

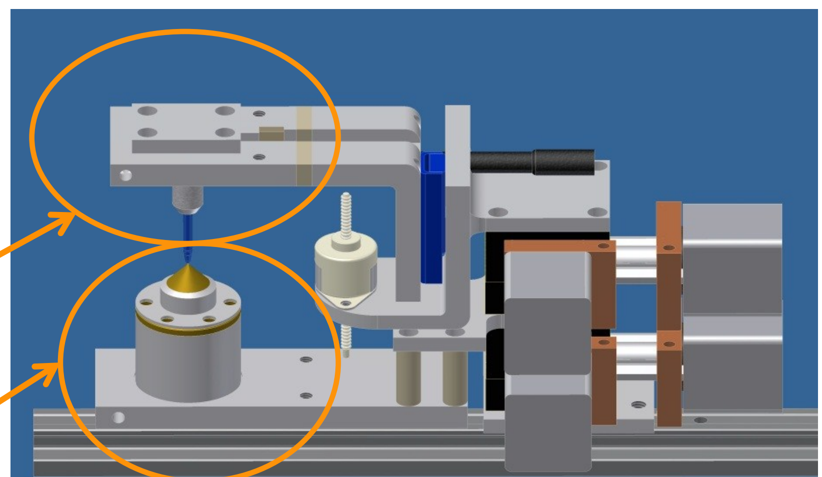


Detail:
Nozzle and
Trap Entance





Modular setup
Nozzle and catcher independently exchangeable



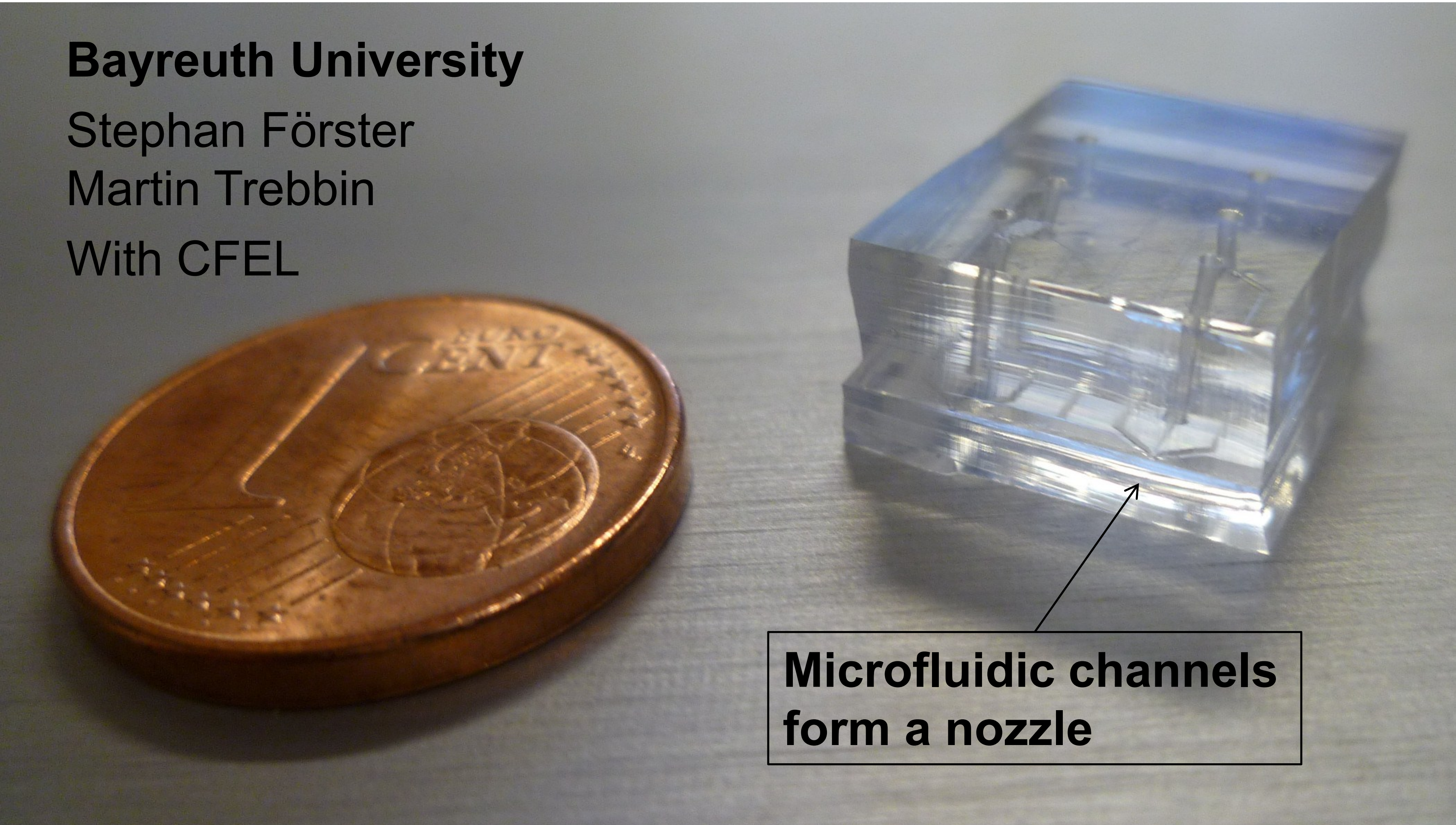
A compact liquid jet setup

Microfluidic devices

Bayreuth University

Stephan Förster
Martin Trebbin

With CFEL



Reasons for liquids

A few reasons to use liquid jets

- Study biological samples in natural environment
- Study liquids
  - Reaction dynamics
  - Phase transitions
- Fast exchange of the target by flow rate

Some experiments require flat sheets rather than round jets

- X-ray absorption spectroscopy
  - Well defined sample thickness
- Resonant x-ray scattering
  - Well defined scattering angle

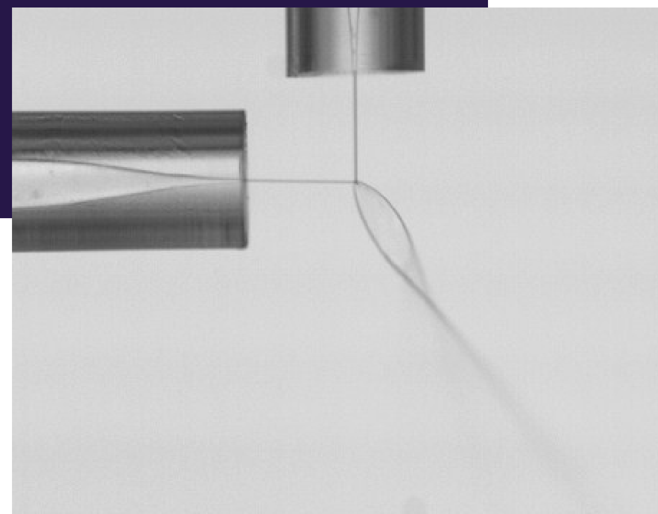
Flat sheet technology

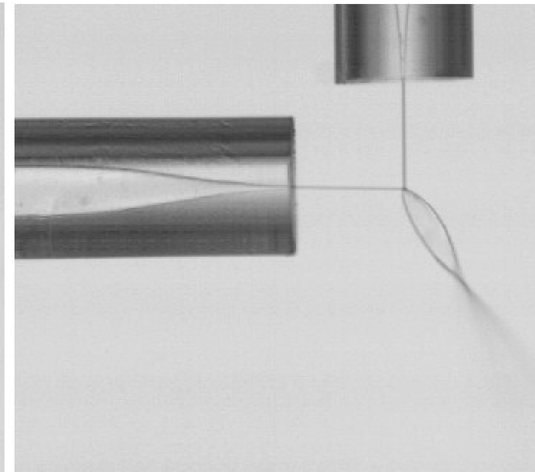
Ideas how to produce flat sheets

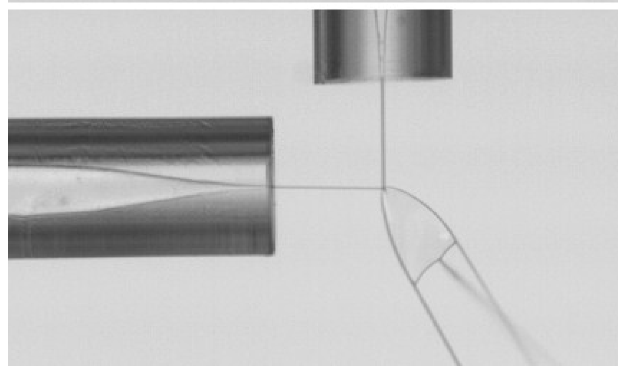
Flat nozzle

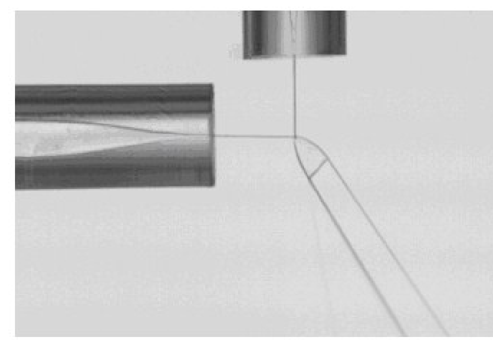
External shaper

Combine two round jets



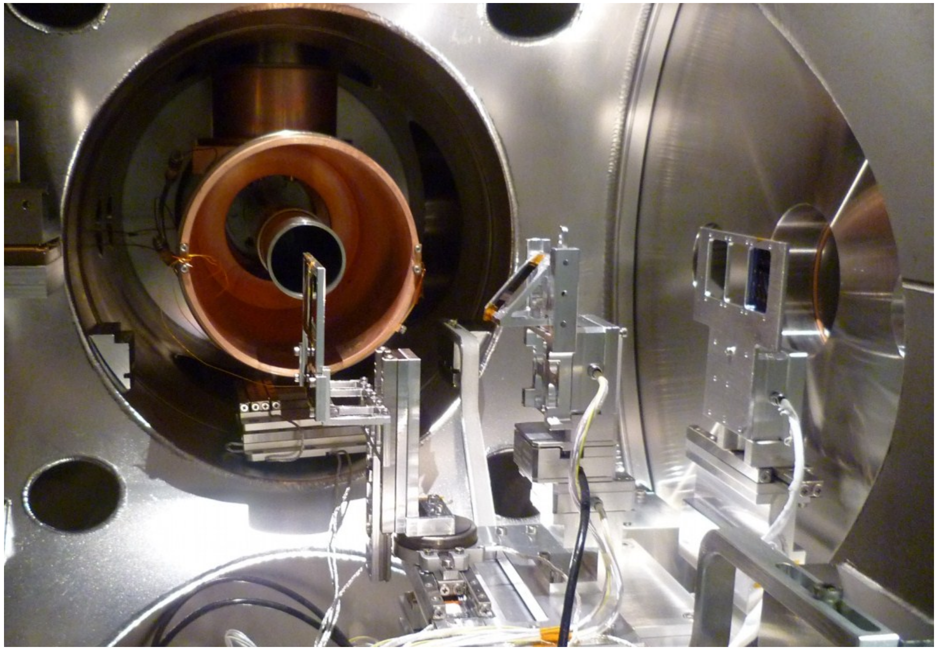






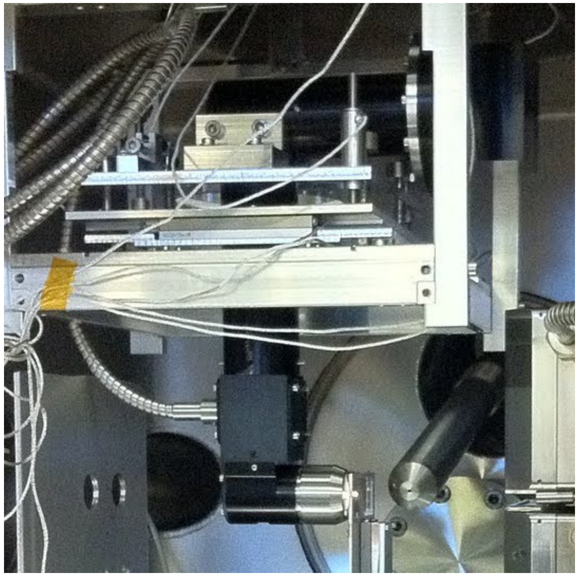
Solids

In-vacuum motorization (piezo motors)



- Compact and fast
- Modularity
- Pressures <10-7 mbar
- Established for
  - bio-imaging
  - gas phase spectroscopy
- Can be combined with cryogenics

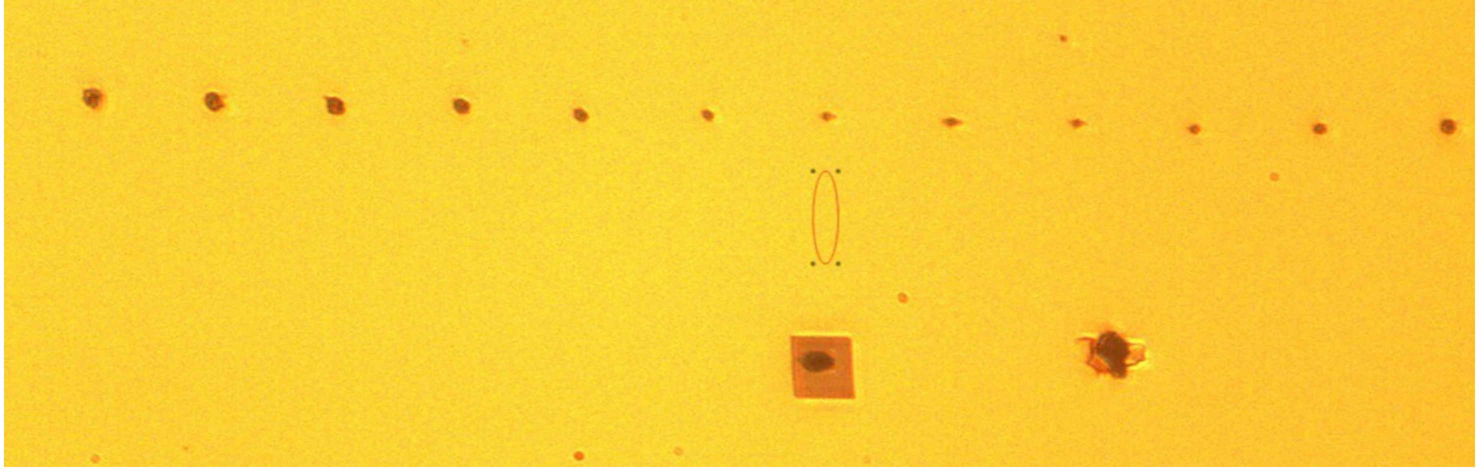
In-vacuum microscope for sample control



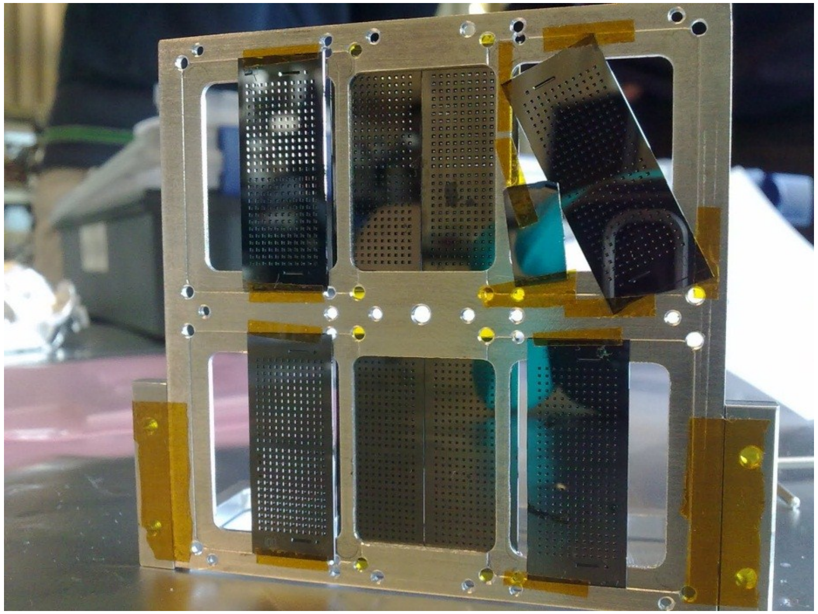
Specs

- 10x Mitutoyo Objective
- Black anodized tubus
- 3 mm holes in optics
- 1x imaging on ½" CCD
- 3 Megapixel detector
- Resolution <2 µm
- Field of view 480x640 µm

Build by Holger Fleckenstein following a design by Alke Meents & Bernd Reime (HASYLAB)



Demands on 10Hz sample change



Typical setup at FLASH

- 5x5 to 200x200µm² Si_3N_4 windows
- Window distance 750 to 1000µm

Samples for XFEL

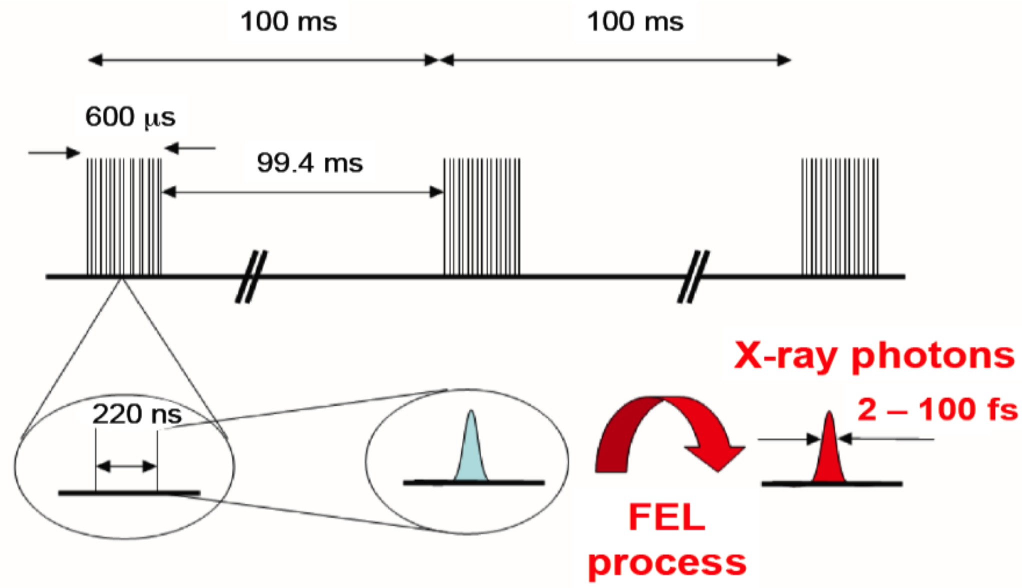
- small Si_3N_4 windows
- Other materials considered
- Small windows closer together

Possible solutions

- Synchronized sweep with constant speed >10mm/s
- Pre-programmed positioning with move-on trigger after shot
- Faster move-commanding with Beckhoff etherCAT

Software rather than hardware challenge

Really fast positioning (up to 4.5MHz)

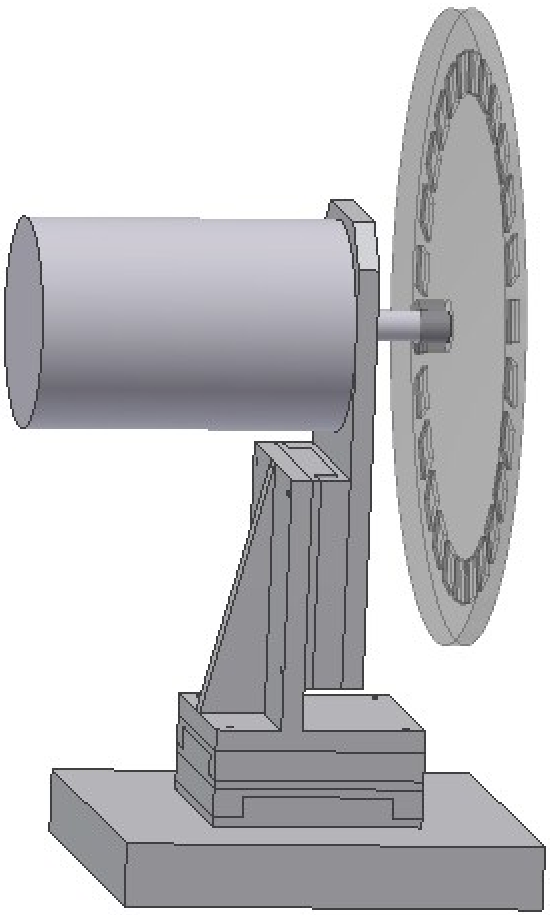


180km/h

$$\frac{10\mu m}{200ns} = 50\frac{m}{s} = 50.000\ \frac{mm}{s}$$

Cannot be reached with conventional linear stages

Idea: A fast spinning rotating wheel



Assuming

- Outer diameter 300mm
- Samples on 100 to 140mm radius
- Linear speed 50m/s
- 3400 to 4777 rpm

$$a_z = \frac{v^2}{r} = 17.900 - 25.000 \ \frac{m}{s^2}$$

To be considered

- What samples endure theses forces?
- Can structured windows hold droplets with biological samples?
- Tilted mounting of samples possible?

Conclusions

Sample Environment Group

Responsible for all sample env.

Gas / liquid / solid

Four scientists

Engineer

Technicians

Challenges and Chances

- High repetition rate
  - Chance for effective use of time and sample
  - Needs fast sample delivery
- High peak power
  - Space charge effects

Liquid samples

- Compact setup for jets in vacuum
- Modular setup
  - Replaceable nozzle
  - Recover liquids
- Liquid flat sheets desired
  - Concept ideas

Fast solid sample exchange

10 Hz sample exchange

Hardware available

Software to be developed

4.5 MHz sample exchange

High accelerations

Difficult to synchronize