

# Micro Fluidic System for the Investigation of the Synovial Liquid by X-ray Scattering Method



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Institute for metallic biomaterials

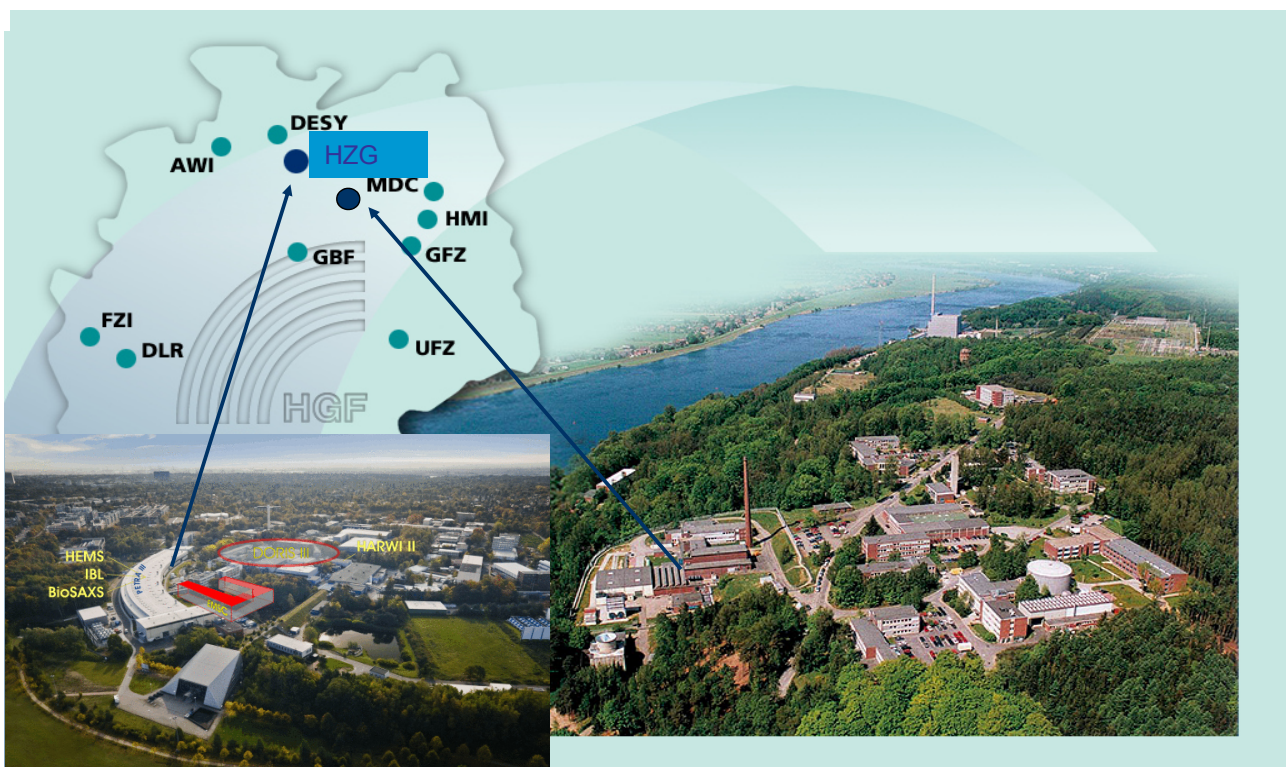
Lübeck, 4.7.2018

**Helmholtz-Zentrum  
Geesthacht**  
Zentrum für Material- und Küstenforschung

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## HELMHOLTZ ZENTRUM GEESTHACHT

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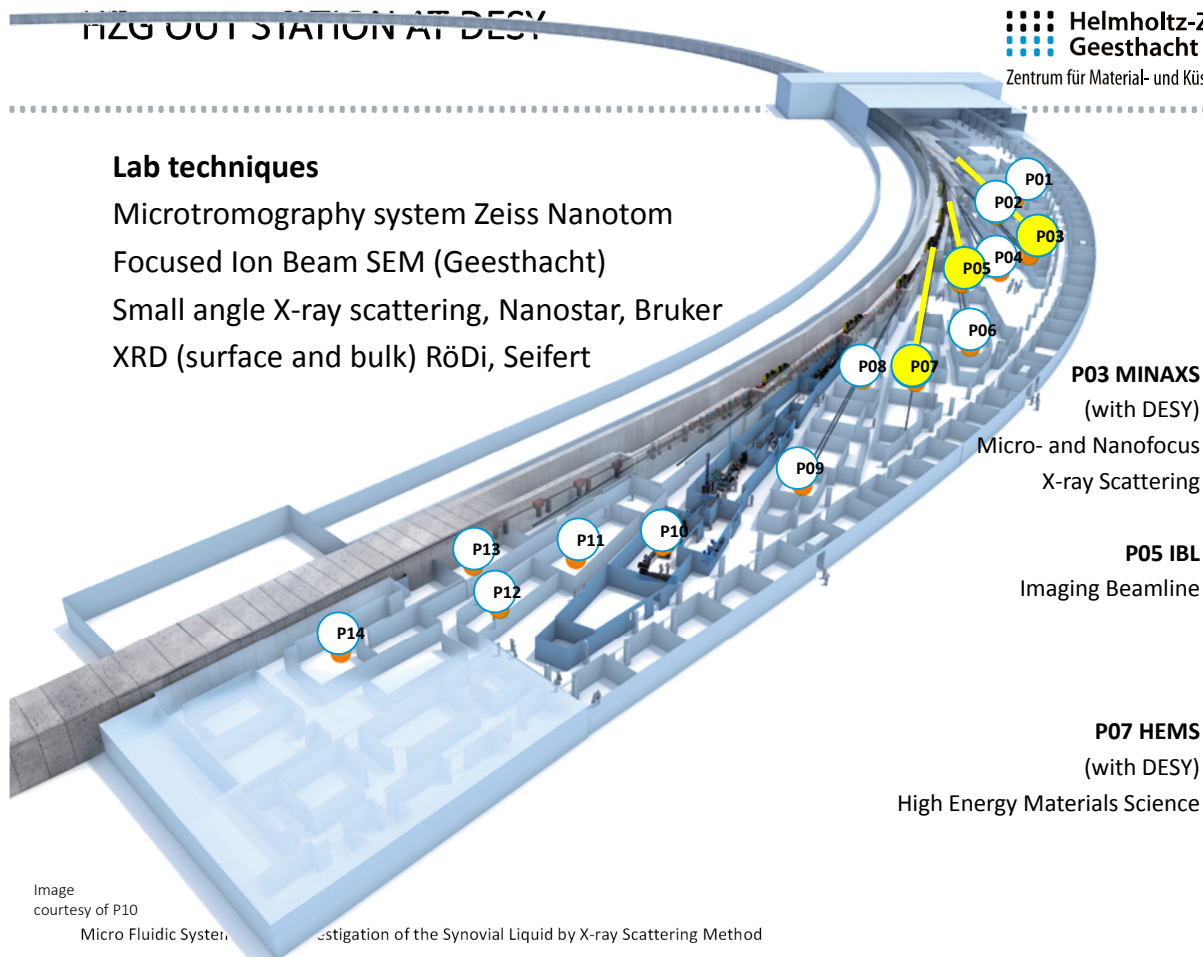
## Lab techniques

Microtomography system Zeiss Nanotom

Focused Ion Beam SEM (Geesthacht)

Small angle X-ray scattering, Nanostar, Bruker

XRD (surface and bulk) RDi, Seifert

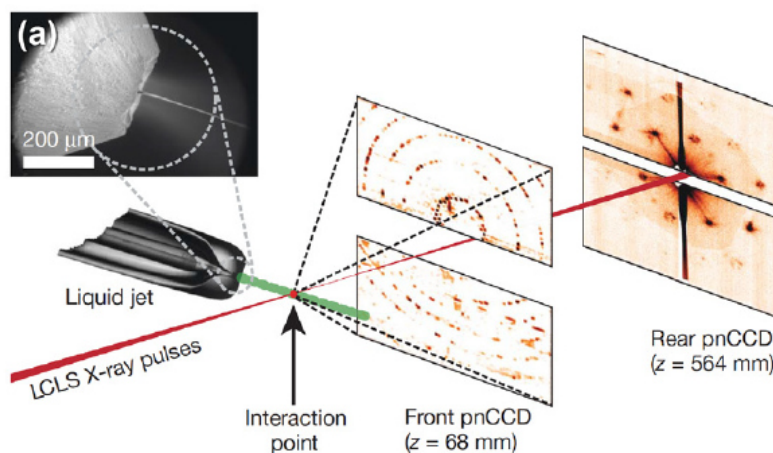


# USE OF MICRO FLUIDICS

## Sample delivery

Time resolved studies

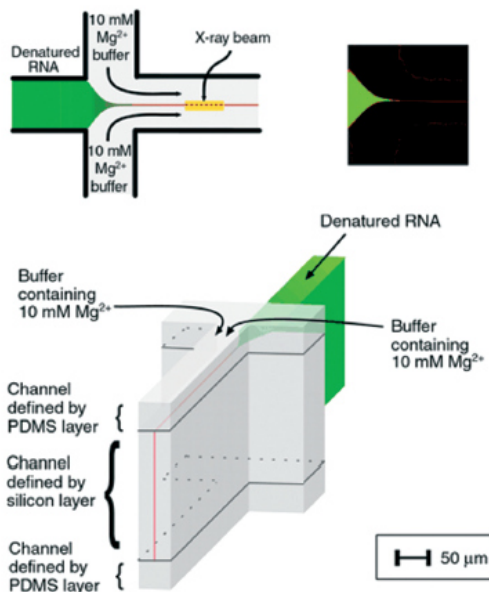
In-situ experiments



Sample delivery

Time resolved studies

In-situ experiments



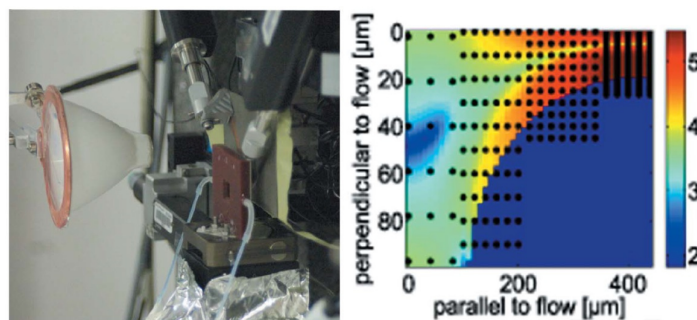
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Sample delivery

Time resolved studies

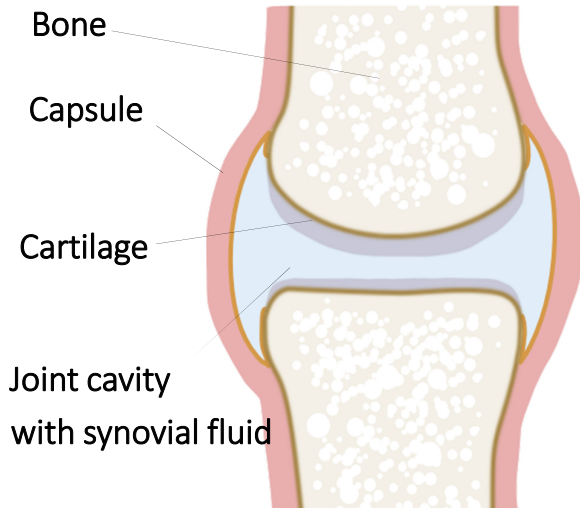
In-situ experiments



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Superior lubrication properties even under high shear and high load (high pressure)

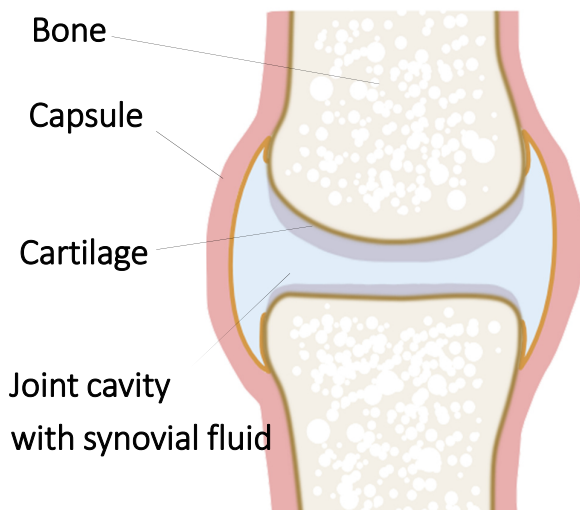


T. Zander, PhD Thesis, 2016

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Superior lubrication properties even under high shear and high load (high pressure)



## Properties of Joints

- very low friction
- high wear resistance
- high adaptability (jumping, running ...)

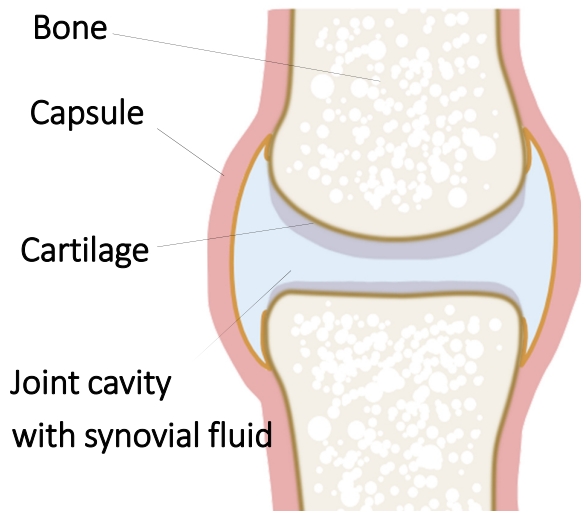
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Superior lubrication properties even under high shear and high load (high pressure)



## Properties of Joints

- very low friction
- high wear resistance
- high adaptability  
(jumping, running ...)

Pressures: 60MPa

Shear rates: 1 to 100kHz

Friction values: 0.01

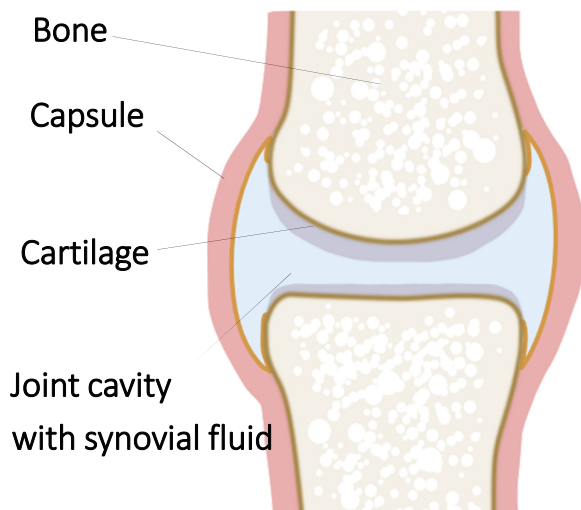
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Superior lubrication properties even under high shear and high load (high pressure)



## Important constituents of synovial fluid

- **lipids** (DPPC, DLPC, POPE ...)
- proteins (albumin, lubricin, aggrecan)
- **bio-polymers** (hyaluronan)

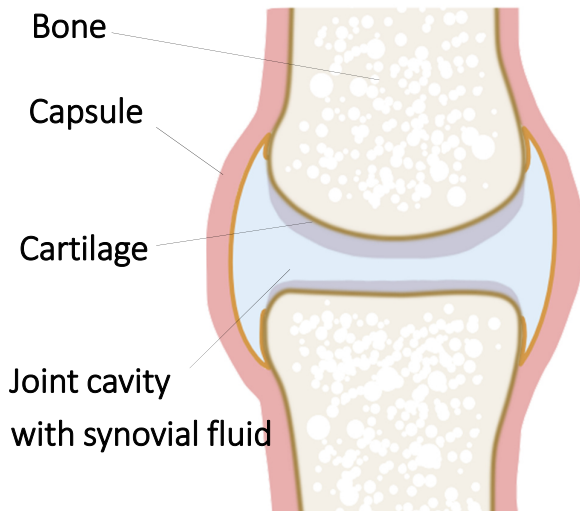
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Superior lubrication properties even under high shear and high load (high pressure)



Important constituents of synovial fluid

- **lipids** (DPPC, DLPC, POPE ...)
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HOW DO THEY INTERACT

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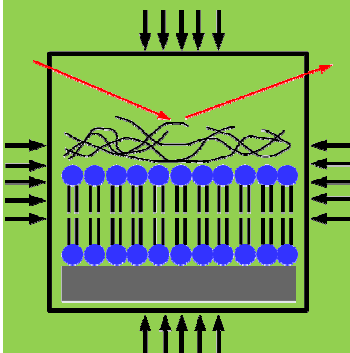
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## POLYMER AND PROTEIN SOLUTIONS UNDER NON EQUILIBRIUM AND NON STATIC CONDITIONS

Influence of pressure

Reflectivity  
measurements on  
surface with pressure up  
to 4000bar

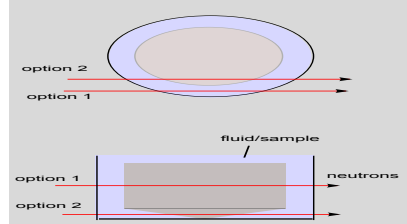


Interaction of  
polymer/lipid/protein  
mixtures under different  
shear rates

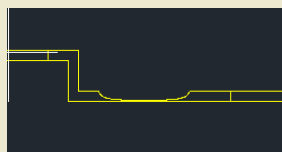
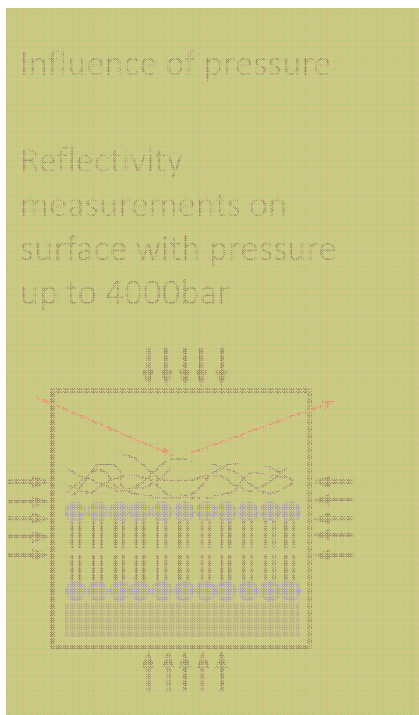
Small angle scattering on  
liquid solutions of model  
fluids of  
Synovial fluid

Interaction of  
polymer/lipid/protein  
mixtures under shear  
and pressure

Small angle  
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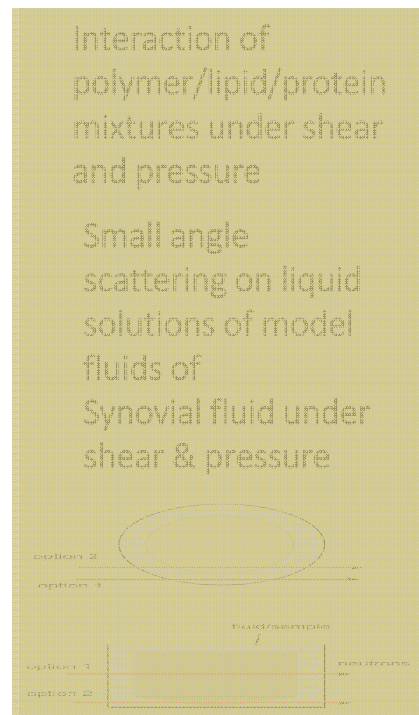


# POLYMER AND PROTEIN SOLUTIONS UNDER NON EQUILIBRIUM AND NON STATIC CONDITIONS

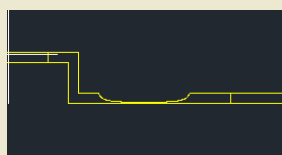
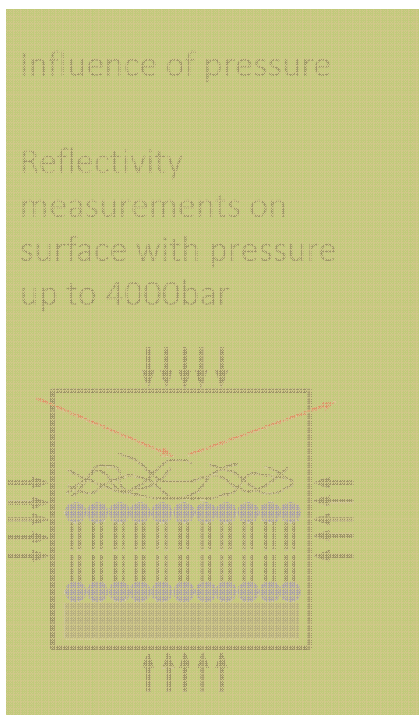


Interaction of polymer/lipid/protein mixtures under different shear rates

Small angle scattering on liquid solutions of model fluids of Synovial fluid

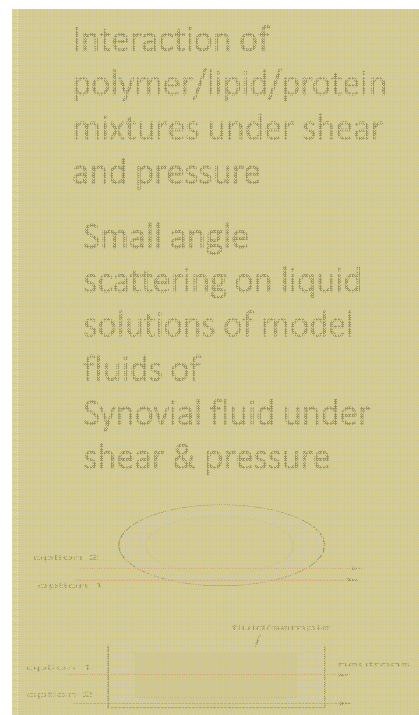


# POLYMER AND PROTEIN SOLUTIONS UNDER NON EQUILIBRIUM AND NON STATIC CONDITIONS



Interaction of polymer/lipid/protein mixtures under different shear rates

- low sample consumption
- high shear rates
- Easy handling



## HOW DOES SUCH A CHIP LOOK LIKE

- Channel with narrows from 100 $\mu$ m to 10 $\mu$ m
- Infinitely high aspect ratio
- No attenuation by the chip material
- Inert material
- Low cost

## HOW DOES SUCH A CHIP LOOK LIKE

- Channel with narrows from 100 $\mu$ m to 10 $\mu$ m
- **Infinitely high aspect ratio**  
maximum length in x-ray path length  
channel height from 100  $\mu$ m to 10 $\mu$ m



## HOW DOES SUCH A CHIP LOOK LIKE

- Channel with narrows from 100µm to 10µm
- Infinitely high aspect ratio
- **No attenuation by the chip material**
  - thin window materials
  - low scattering
  - not prone to radiation damage

## HOW DOES SUCH A CHIP LOOK LIKE

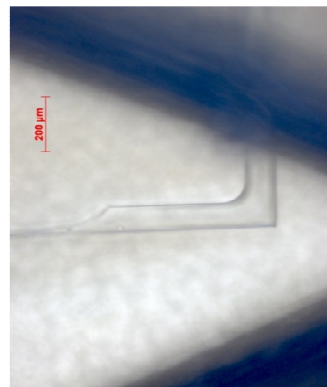
- Channel with narrows from 100µm to 10µm
- Infinitely high aspect ratio
- No attenuation by the chip material
- **Inert material**
- **Low cost**

## HOW DOES SUCH A CHIP LOOK LIKE

- channels 100µm from 100µm down to 10µm
- Channel depth of 200µm
- Moderate attenuation
- Made of polymer but not stable in the x-ray beam
- 30€ each

### Microfluidic Chips

- Width 100 µm – 10 µm
- Low volume
- High shear rates (100kHz)

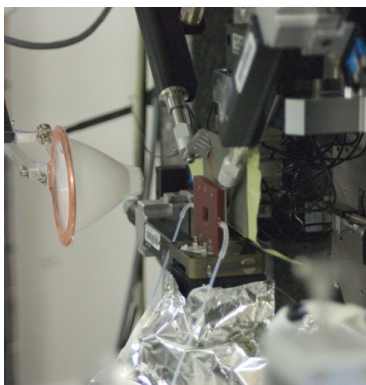


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## Macromolecules under shear



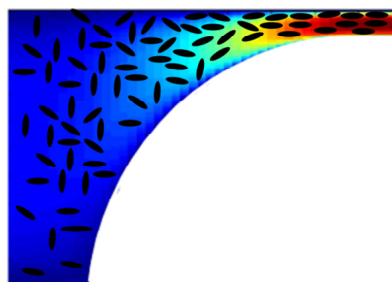
Microscope image of the microfluidic chip

- Beamsize of 250 nm x 250 nm
- Energy 15 keV
- Volume speed 0.1 µl/s, 5 mm/s
- Shear rates probed from 100 s<sup>-1</sup> to 300000 s<sup>-1</sup>
- Lysozyme, reported to form clusters at high concentrations

### Microfluidic Chips

- Width 300 µm – 10 µm
- Low volume
- High shear rates (100kHz)

Shear profile in the microfluidic channel

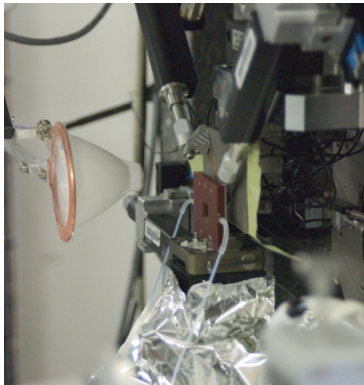


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# Macromolecules under shear



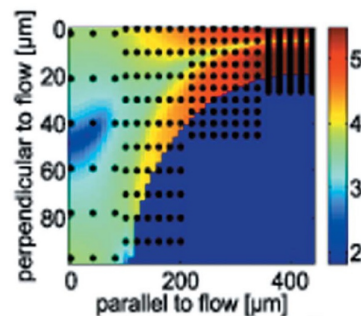
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Microscope image of the microfluidic chip

Shear profile in the microfluidic channel

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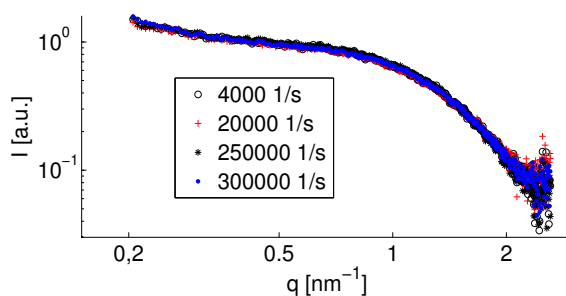


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## PROTEIN SOLUTIONS UNDER SHEAR



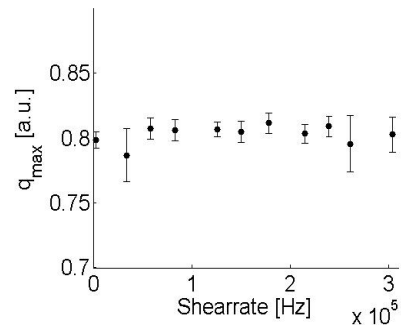
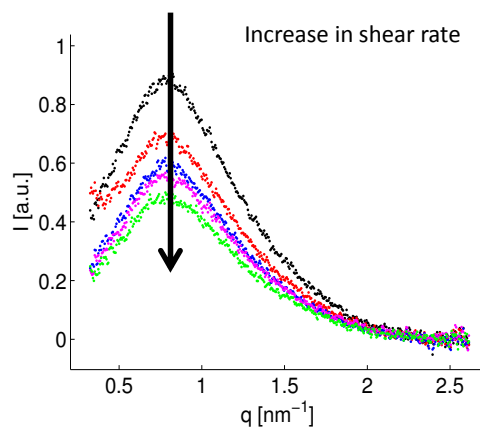
- Structure lysozyme is not changing due to shear

- Lysozyme c = 50 mg/ml, 150 mM NaCl
- Flow rate 0.1  $\mu\text{l/s}$
- Shear rates from 200  $\text{ks}^{-1}$  up to 30  $\text{ks}^{-1}$



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# PROTEIN SOLUTIONS UNDER SHEAR



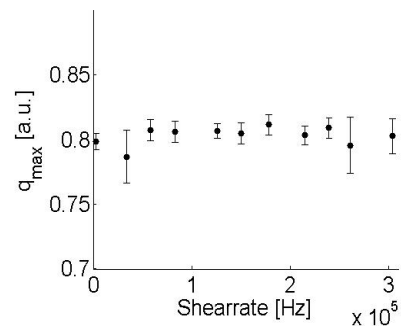
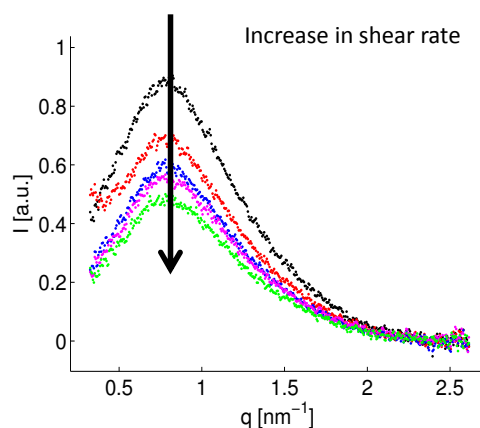
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Wieland et al., J. Syn. Rad. 2014

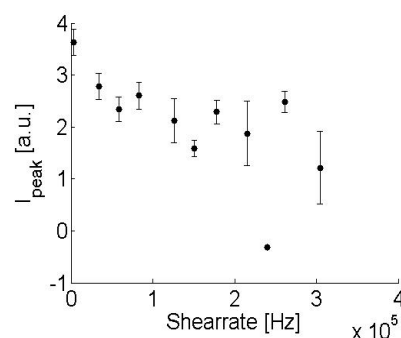
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# Acknowledgements

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