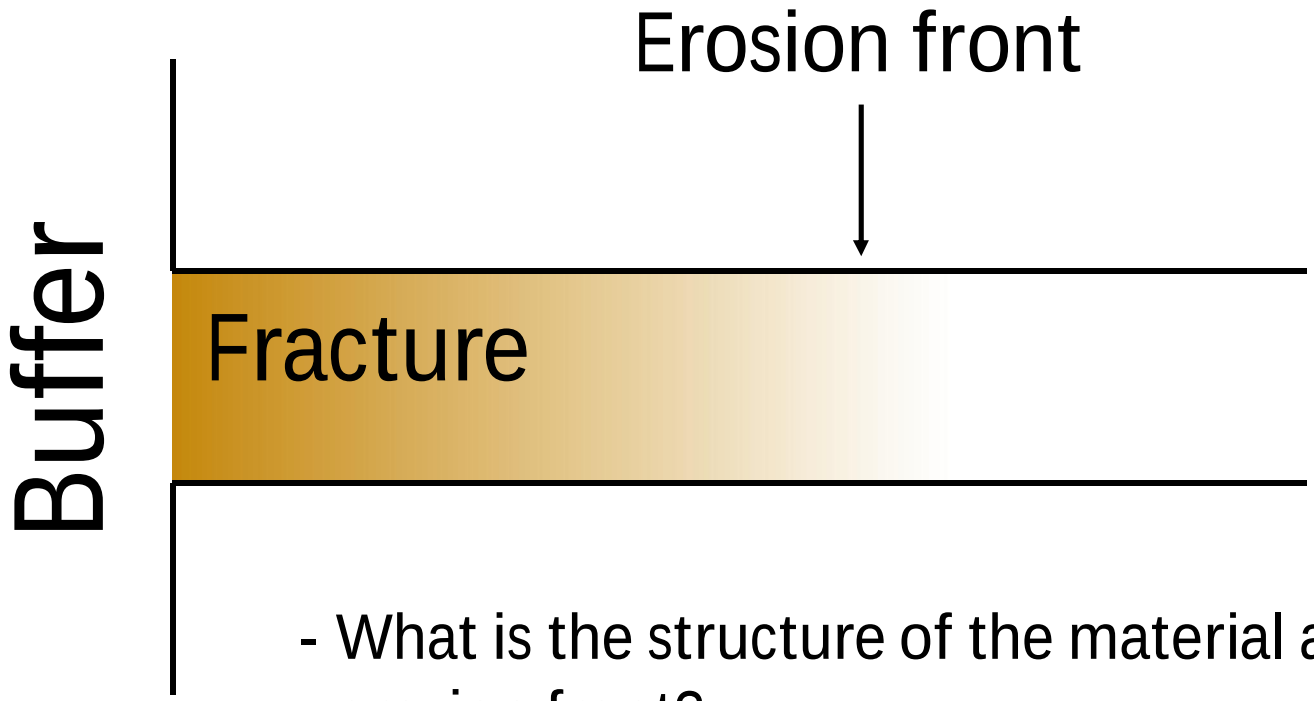
Application of Combined Optical Coherence Tomography and Rheometry to Montmorillonite Dispersions

Rasmus Eriksson, Tim Schatz and Seppo Kasa

B+Tech Oy
Posiva Oy

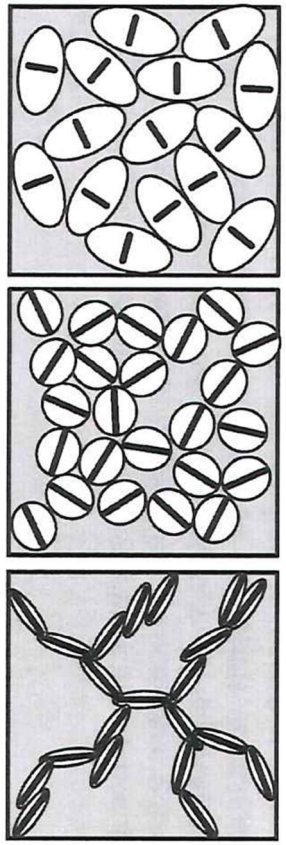
BELBaR 1st workshop
5-7.3.2013 HUT, Helsinki, Finland

Scenario

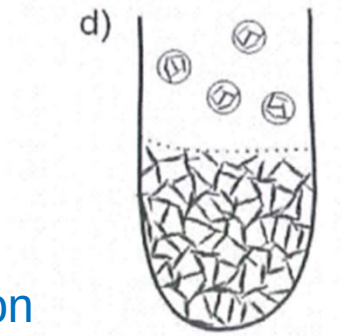


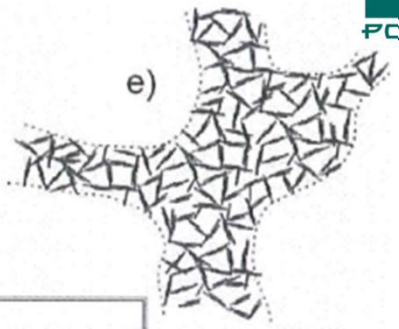
- What is the structure of the material at the erosion front?
- How strong is it?
- How do environmental factors affect the system (pH, pI, $\dot{\gamma}$)?

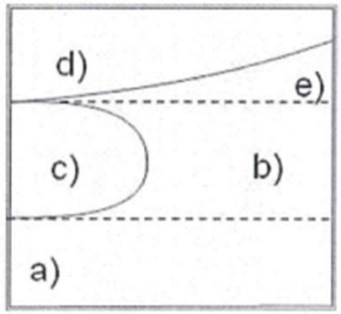
Configurations



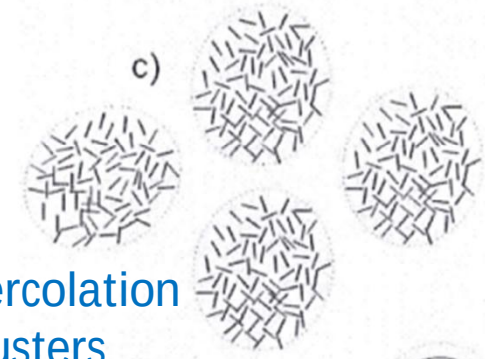
Increasing electrolyte concentration



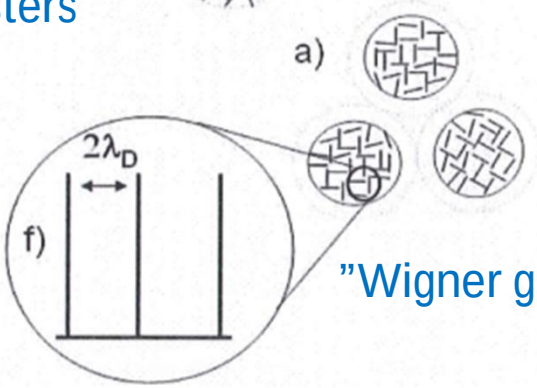




Percolation gels



Percolation clusters



"Wigner glass"

H. Tanaka *et. al.*, Phys. Rev. E 69 (2004)
A. Shalkevich *et. al.*, Langmuir 23 (2007)

Particle networks

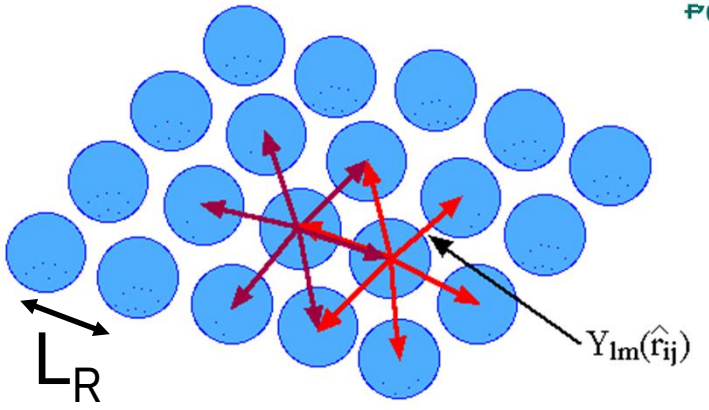
The elastic modulus is directly proportional to the network strength.

The characteristic length of the particle network can be probed by oscillatory shear.

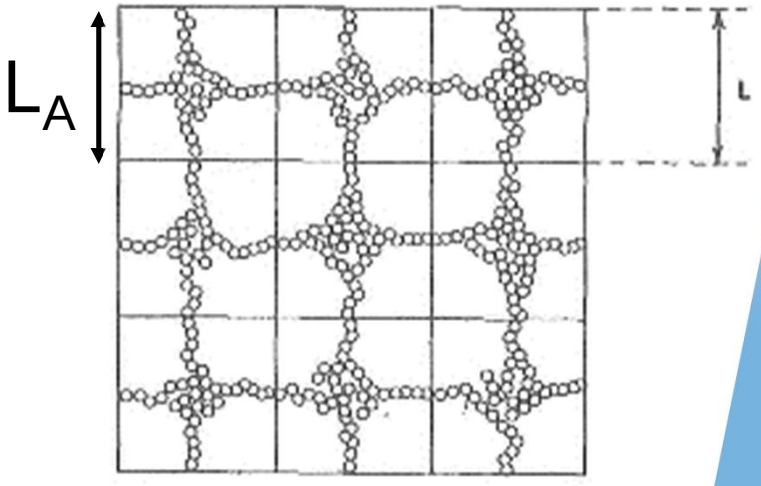
The characteristic length of a repulsive network (L_R) is proportional to the particle size and the characteristic length of an attractive network (L_A) is proportional to the average distance between clusters of particles, hence:

$$L_A > L_R\ (\sim d_p)$$

It should therefore be possible to distinguish between these two states by oscillatory shear.



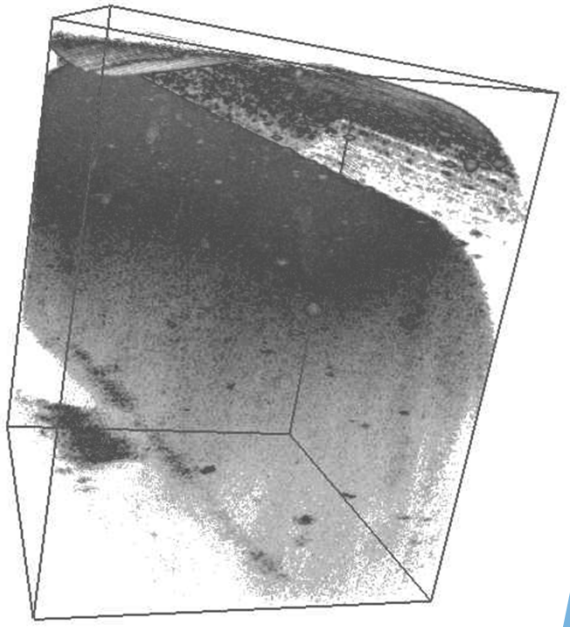
Repulsive network



Attractive network

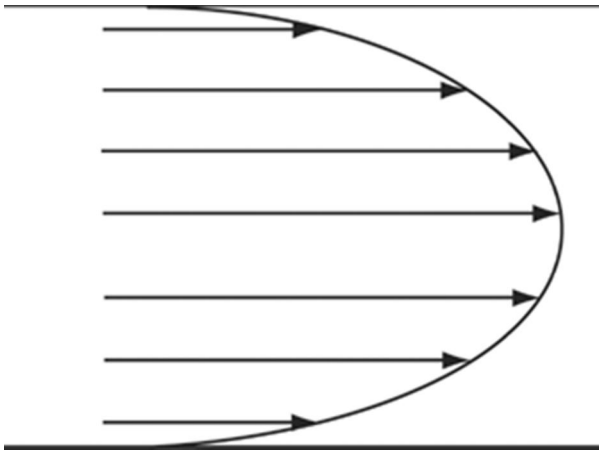
OCT overview

- Optical imaging technique for producing 3D images of semi-opaque samples
- Collects reflected light from the sample. An interferometer is used to filter out scattered light.
- Spatial resolution a few microns. Penetration depth 1 – 2 mm.



Capillary tubes

For laminar Newtonian flow in a straight tube:



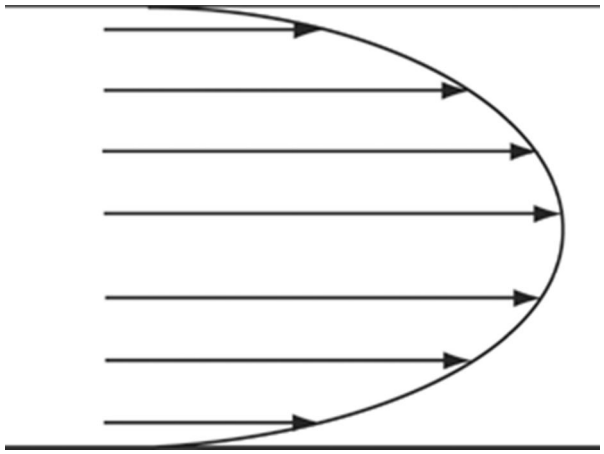
$$\dot{\gamma}_a = \frac{4Q}{\pi r^3}$$

$$\tau_w = \frac{\Delta P \cdot r}{2L}$$

Q = Volumetric flow rate
r = Radius of the tube

ΔP = Pressure drop across the tube
L = Length of the tube

Capillary tubes



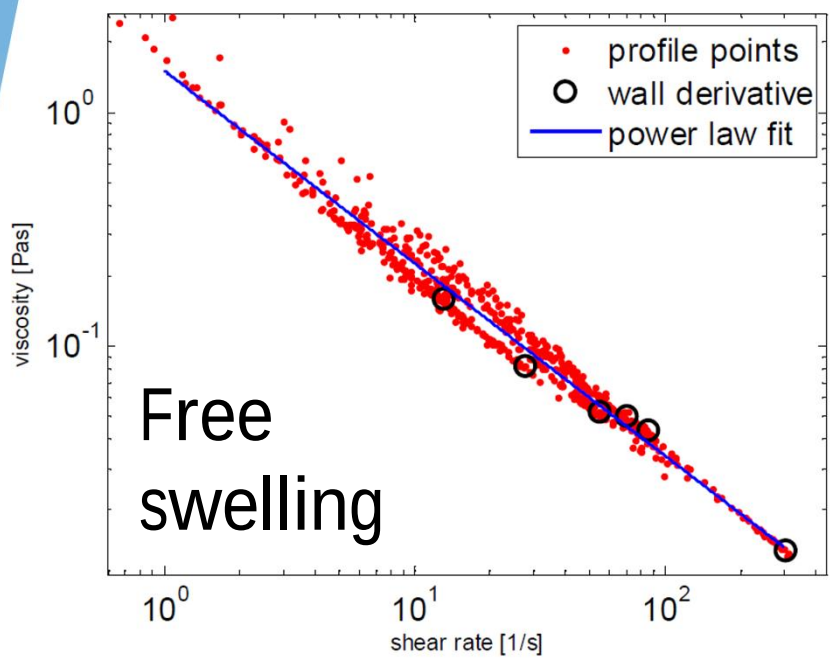
$$\dot{\gamma}(r') = -\frac{dv(r')}{dr'}$$

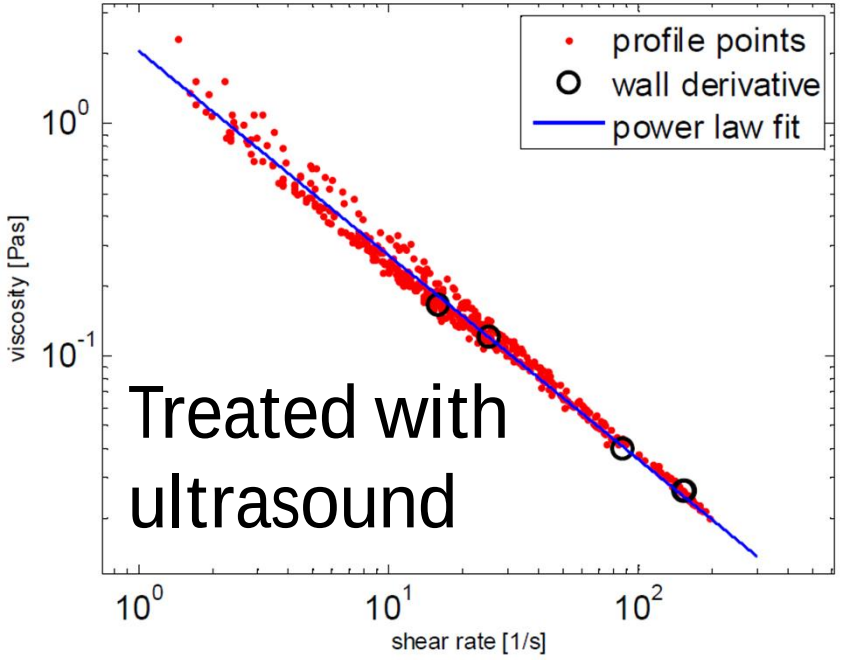
$$\tau(r') = \tau_w (1 - r'/r)$$

The radial velocity profile can be obtained by OCT, which makes it possible to calculate the viscosity locally anywhere along the flow field

Results, montmorillonite

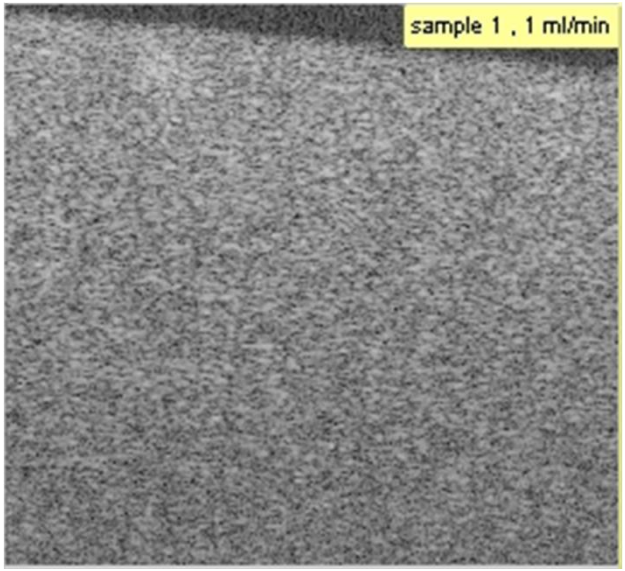
2 vol-%, 1 mM NaCl



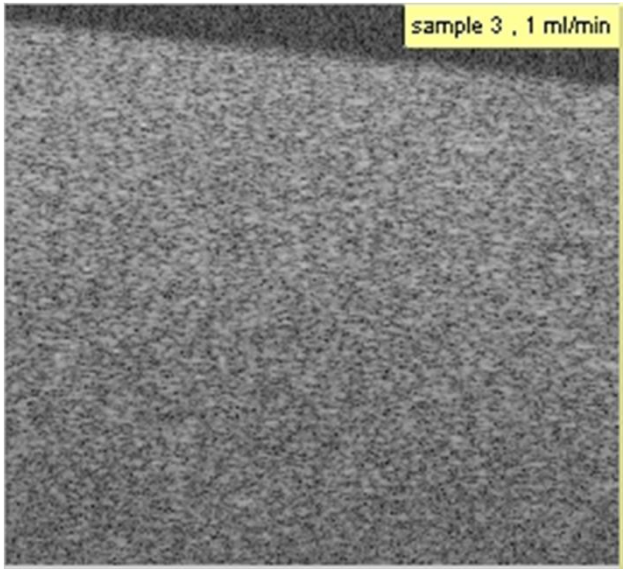


The nearly identical viscosity curves indicate that the sample preparation protocol has little impact on shear viscosity

Results, montmorillonite

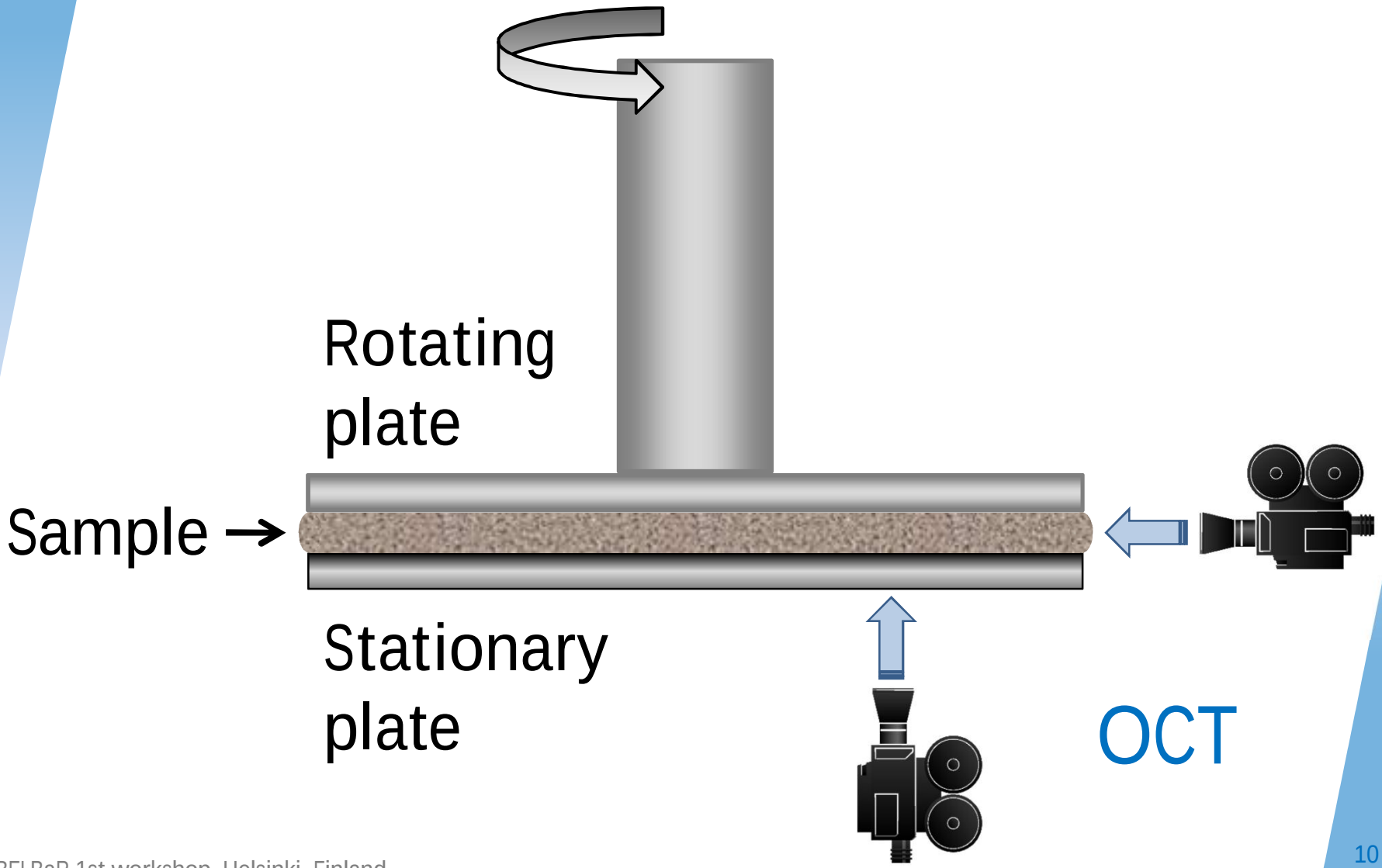


Free swelling



Treated with ultrasound

Possible experimental setup



Next steps

Collaboration with VTT Expert Services Oy (Jyväskylä)

- Acquire rheometer (Jyväskylä), 1 – 2 months
  - Start experiments