

Nonlinear Extensional Rheology of Soft Materials

Qian Huang

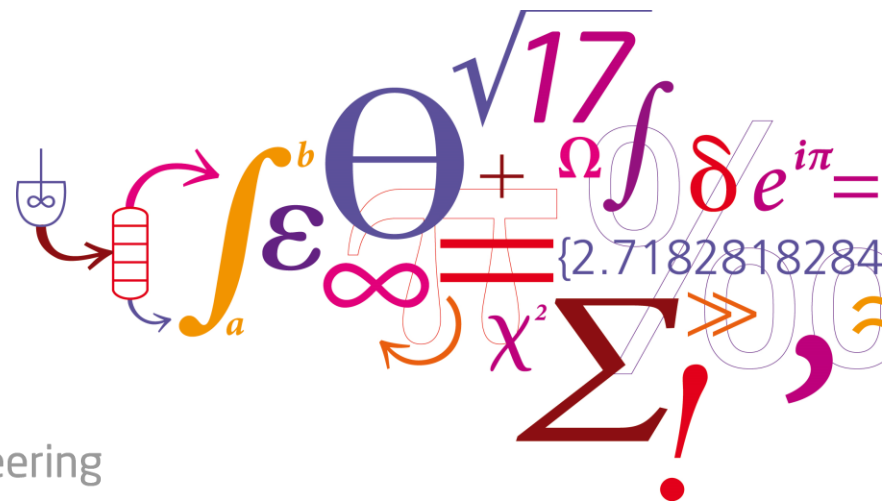
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DTU Chemical Engineering

Department of Chemical and Biochemical Engineering



Introduction

WP3 - Viscoelasticity, nonlinear rheology and mechanical properties

Nonlinear extensional rheology

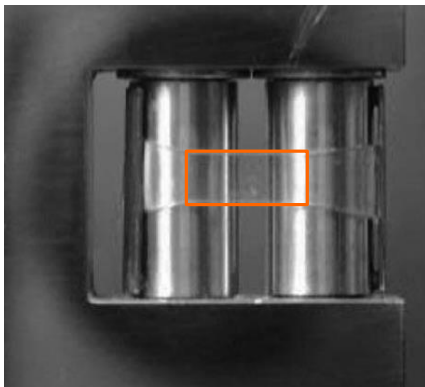
- Filament stretching rheometry
- Polymer melts and solutions
- Polymer networks

Mechanical properties

- Tensile tests
- High-speed imaging of fracture

Extensional rheology

Apparatus



Sentmanat Extensional Rheometer (**SER**)



Extensional Viscosity Fixture (**EVF**)



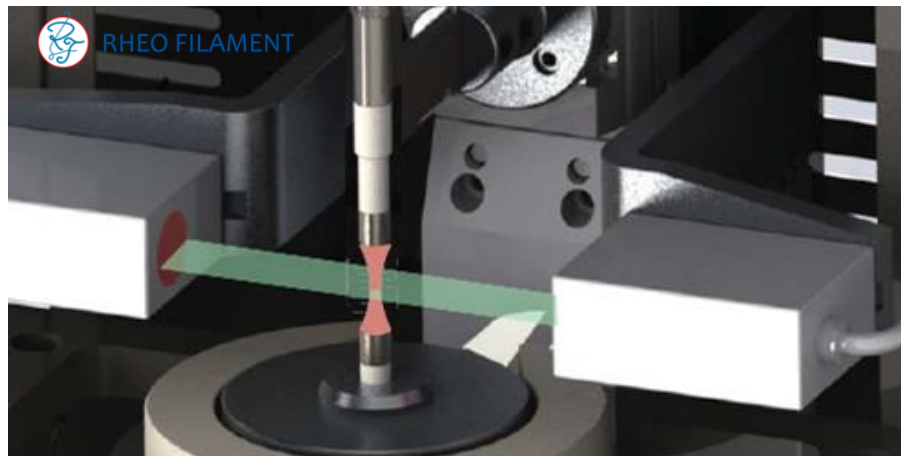
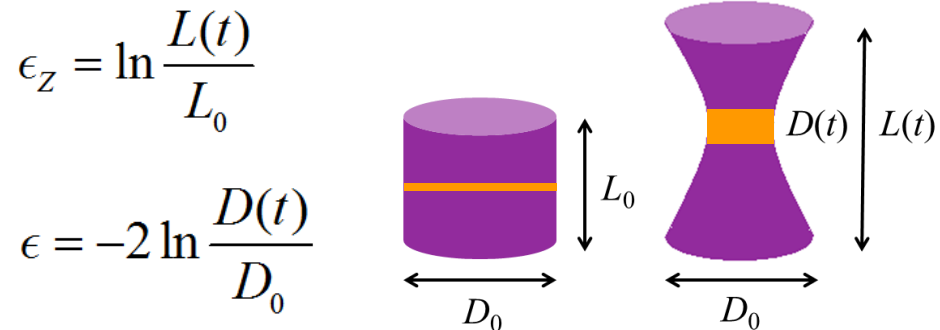
Filament Stretching Rheometer (**FSR**)



VADER-1000

Extensional rheology

Filament Stretching Rheometry

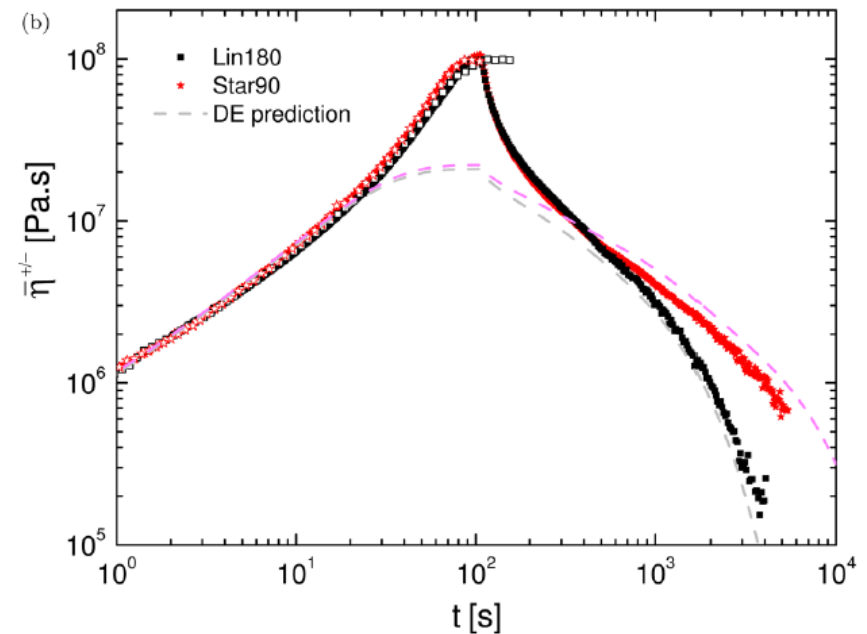
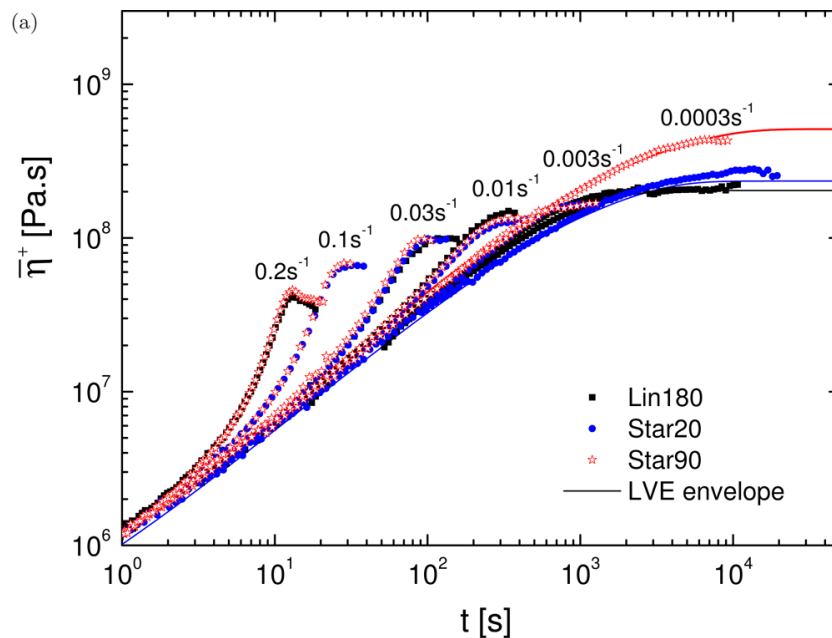
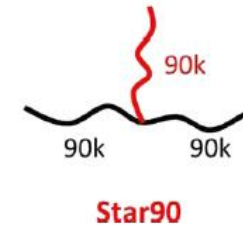
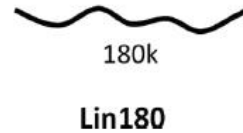


VADER-1000



Extensional rheology

Polymer melts

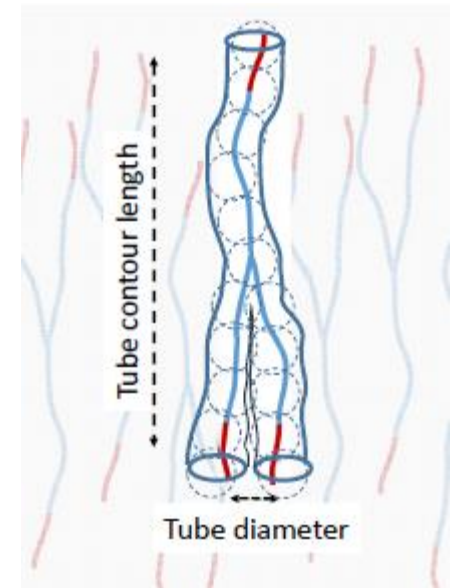
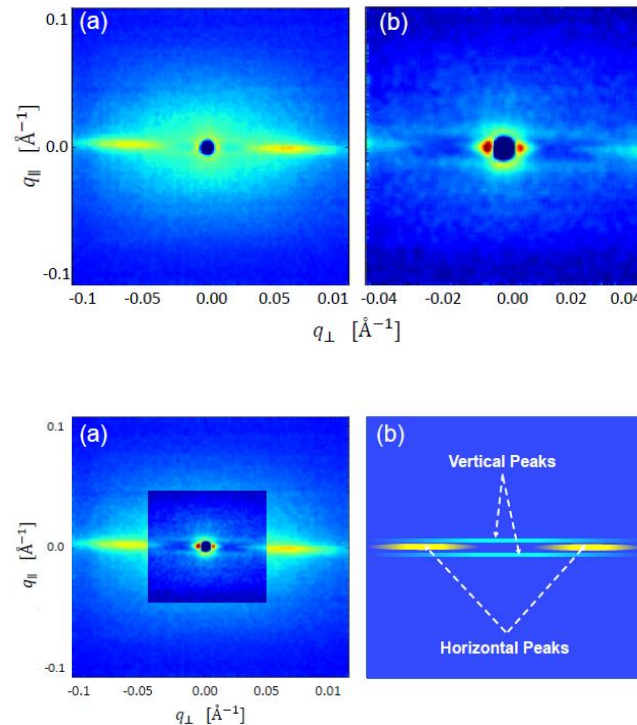
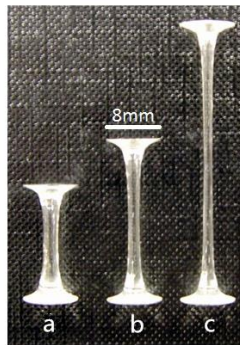
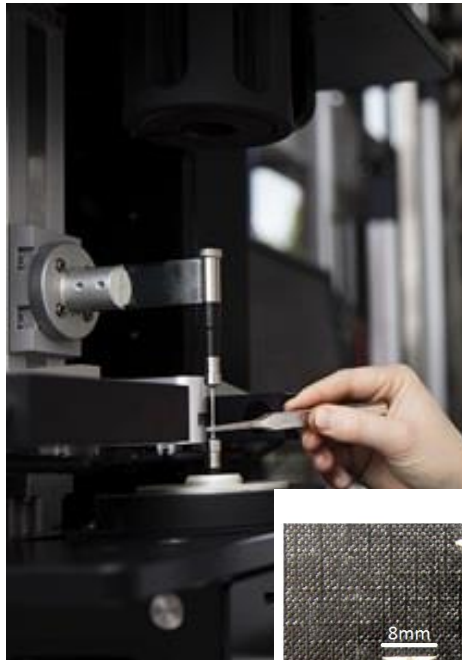


Extensional Stress growth Coefficient:

$$\bar{\eta}^+ = \langle \sigma_{zz} - \sigma_{rr} \rangle / \dot{\epsilon}$$

Extensional rheology

Polymer melts

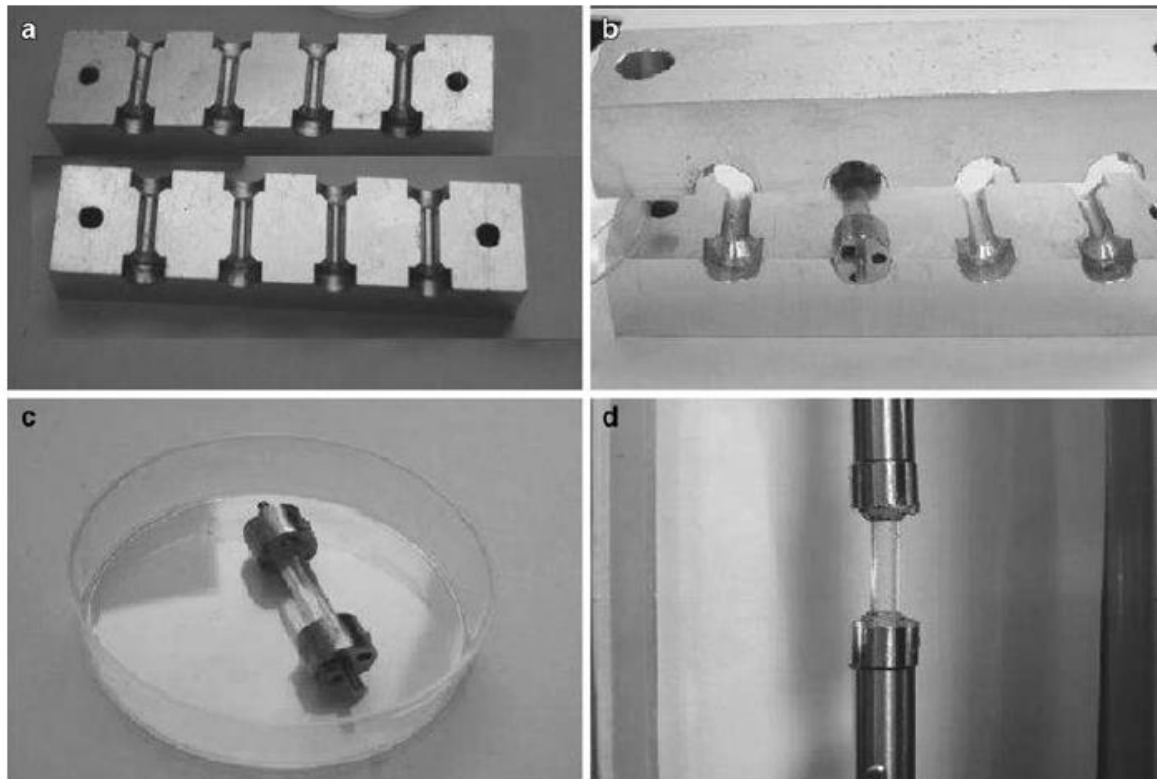


Mortensen et al., going to submit soon

Extensional rheology

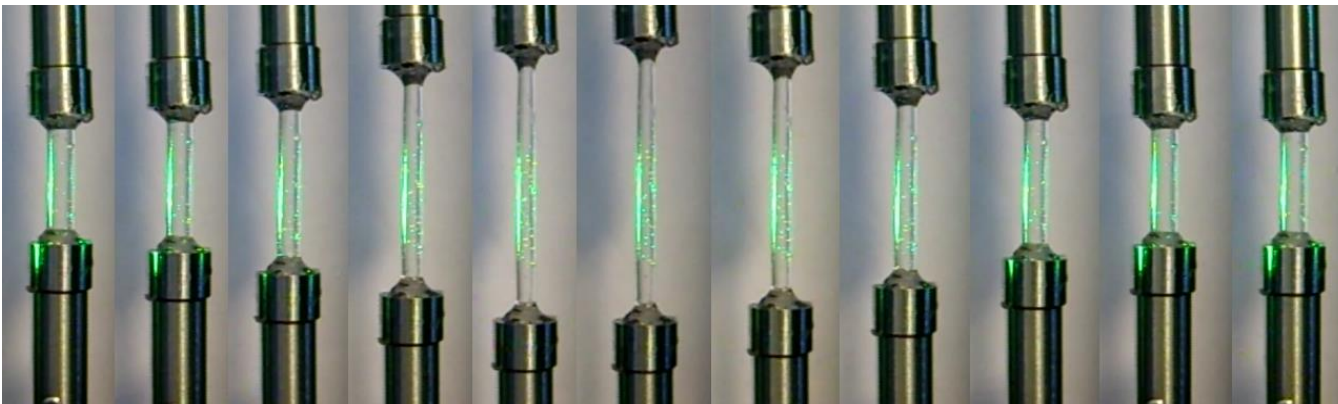
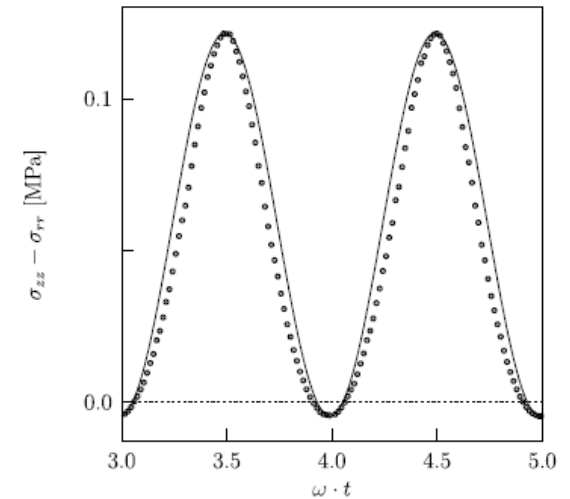
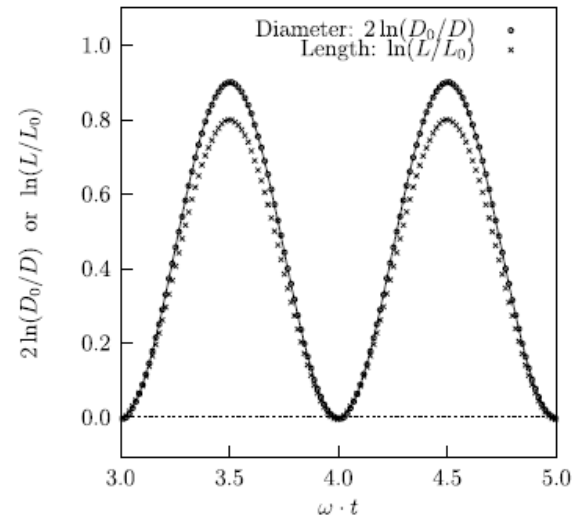
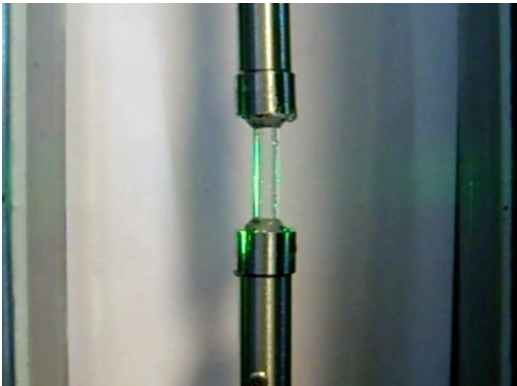
Polymer networks

PDMS soft network



Extensional rheology

Polymer networks



Mechanical properties

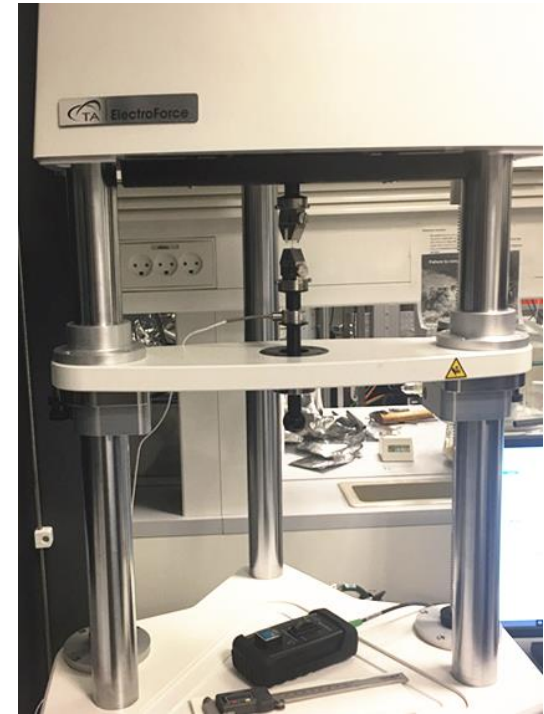
Apparatus



VADER-1000



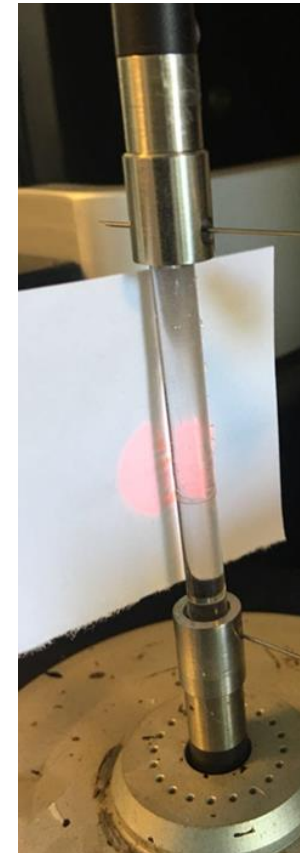
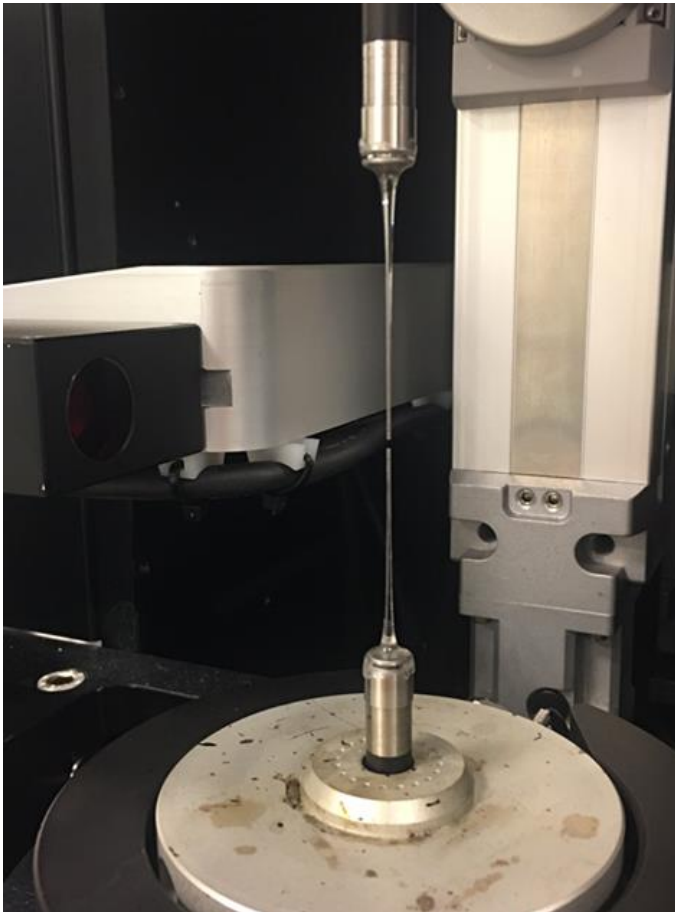
RSA3 Dynamic Mechanical Analyzer



ElectroForce 3200

Mechanical properties

Tensile tests



Mechanical properties

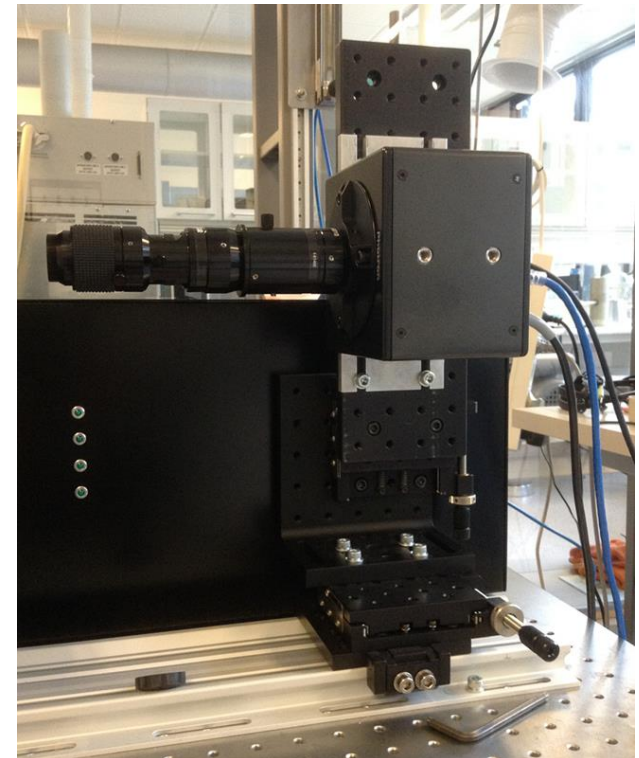
High-speed imaging of fracture

High speed camera FASTCAM Mini UX100

The camera is equipped with the NAVITOR Zoom 6000 Lens System (consists of a C-Mount Coupler 1-6010, a Mini Adapter 1-61400 and a Zoom Lens 1-60135).

Frame Rate Performance examples:

- 4,000 fps at 1,280 x 1,024 pixel resolution
- 5,000 fps at 1,280 x 1,000 pixel resolution
- 6,250 fps at 1,280 x 800 pixel resolution
- 10,000 fps at 896 x 488 pixel resolution
- 25,000 fps at 1,280 x 200 pixel resolution
- 200,000 fps at 1,280 x 24 pixel resolution
- 800,000 fps at 640 x 8 pixel resolution

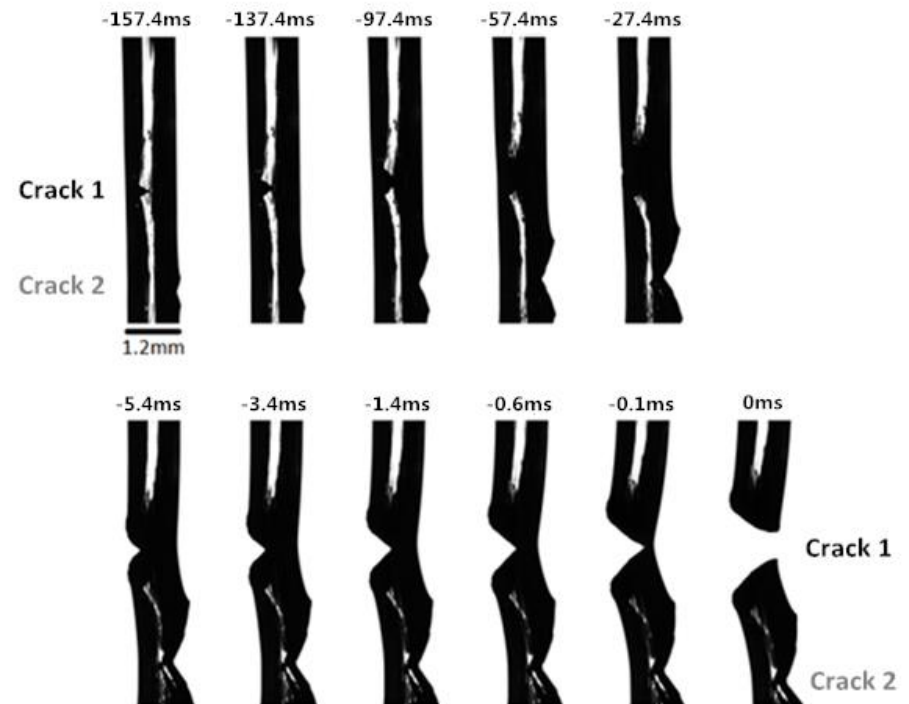


Mechanical properties

High-speed imaging of fracture

10,000 fps

(Crack propagation > 10ms)



Huang and Hassager, *Soft Matter*, 2017, 13, 3470-3474

Huang et al., *PRL* 2016, 117, 087801

Thank you

