# Extensional Rheometry on a Chip

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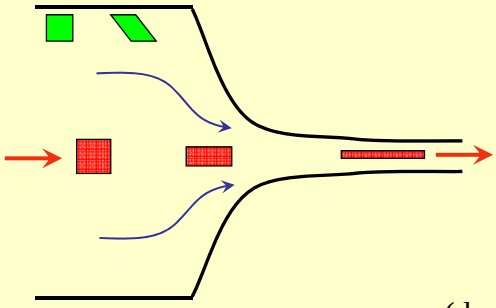
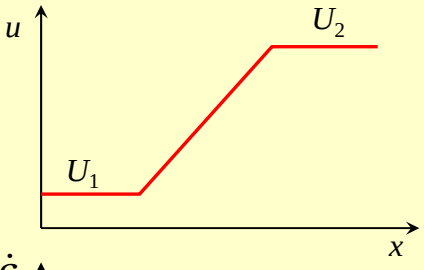
## Outline

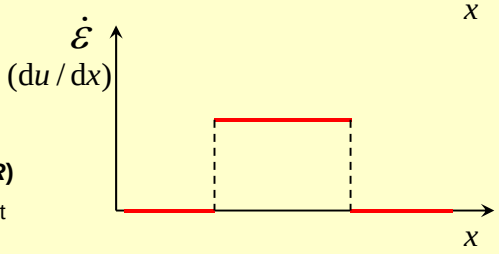
- Motivation
- Overview of microfluidic geometries where extensional effects are important
- Optimal Shape Design algorithm for viscoelastic fluid flow.
- Application of the optimization tool in strong extensional flows:
  (*i*) Flow in a cross-slot geometry;
  (*ii*) Flow in T-shaped geometries.
- Elastic instabilities in strong extensional flows
- Conclusions

## Motivation

**How can we achieve an ideal extensional flow?**






**Main limitation:**

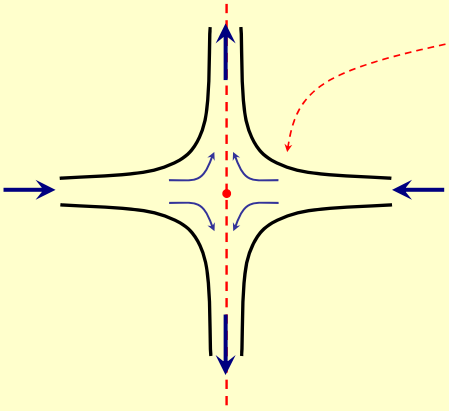
Finite total **Hencky strain**: $\varepsilon_H = \ln(CR)$

(steady-state extensional viscosity may not be attainable)

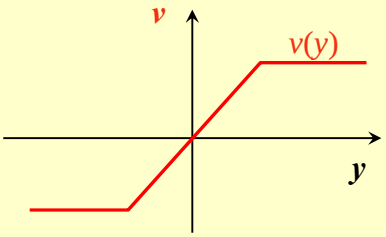


## Motivation

**An alternative**: **Stagnation flow**



**What is the proper shape of the geometry?**




**Cross-slot geometry**

Steady-state extensional viscosity can be measured

## Why Microfluidic Devices?

### Deborah number

$$De = \frac{\text{Relaxation time of material}}{\text{Characteristic time of flow}} = \frac{\lambda}{L/U}$$

↑↑↑

### Reynolds number

$$Re = \frac{\rho U L}{\eta}$$

↓↓↓

### Elasticity number

$$El = \frac{De}{Re} = \frac{\lambda \eta}{\rho L^2}$$

↑↑↑



## Goal

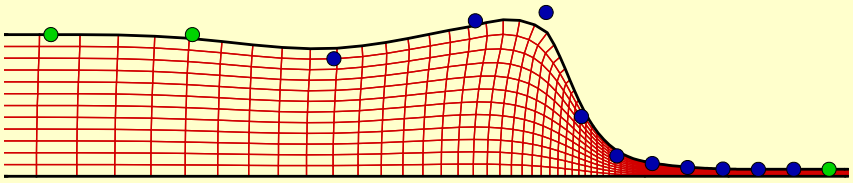
- Design microfluidic devices with optimal performance

**Ex:** Microfluidic extensional rheometer on a chip

Design a microfluidic nozzle which minimizes the pressure drop

(...)

## Conclusions

- Optimal shape design tools are suitable for design of microfluidic channels.
- The *ideal* flow in a Cross slot geometry *can* be achieved, and the 'optimal' geometry is *universal*.
- Other stagnation flows are also feasible for achieving ideal extensional flows (T geometries; Flow focusing devices; ...)
- Contraction flows are also an interesting alternative…
- 
- Strong extensional flows are prone to elastic instabilities (steady asymmetric and unsteady)



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