
INSTITUTE FOR RESEARCH IN
ELECTRONICS
& APPLIED PHYSICS

# Flow Birefringence of Aqueous Polyacrylamide Solutions

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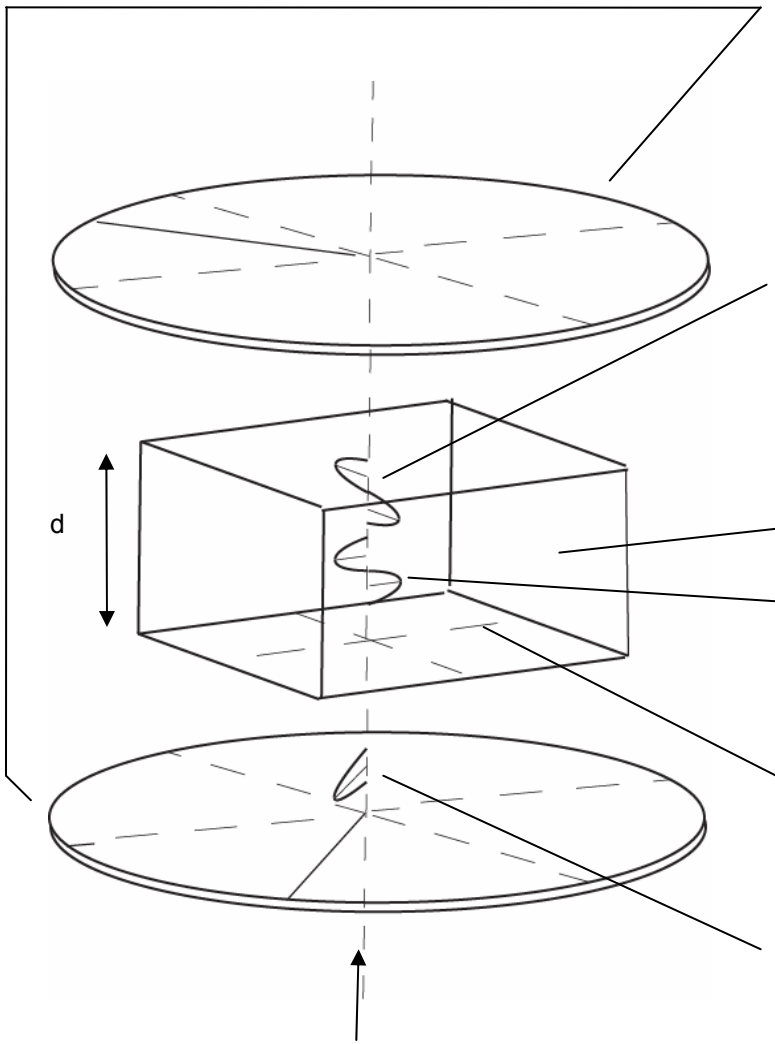
# *Birefringence*




Crossed polarizers oriented 45° to axis of anisotropy

Light traveling along fast axis (o-ray) *(for positive Δn)*

Birefringent material

Light traveling along slow axis (e-ray) *(for positive Δn)*

Optical axis (axis of anisotropy)

Incoming linearly polarized light

$$\Delta n = n_e - n_o$$

$$\Lambda = d(n_e - n_o)$$

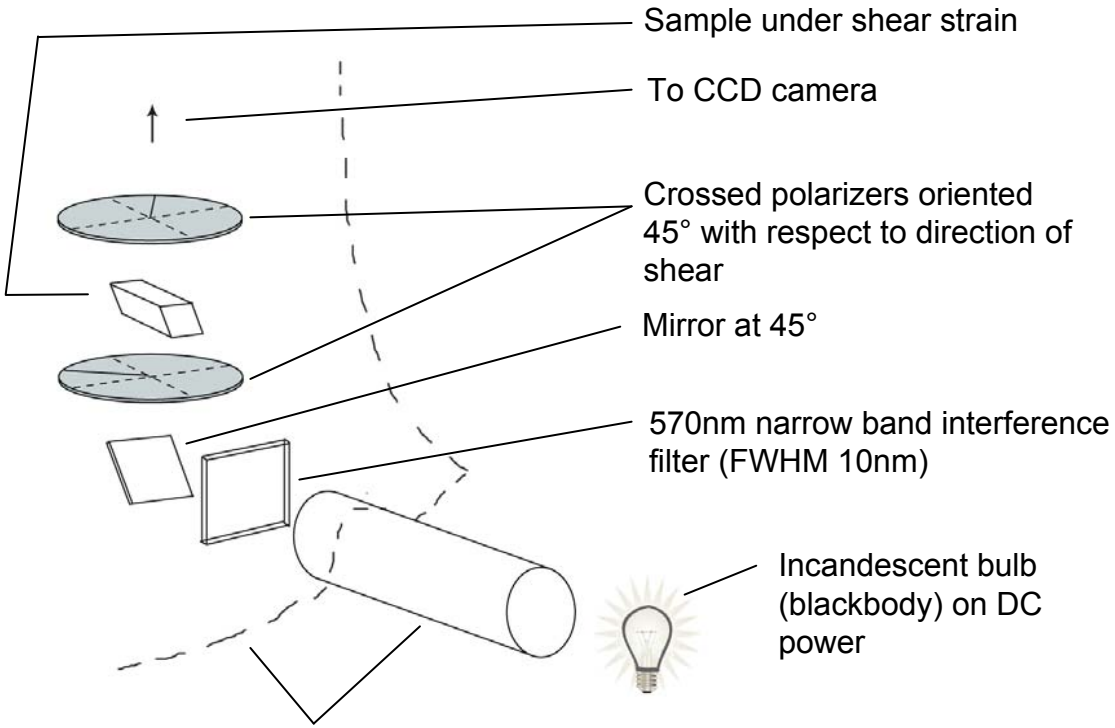
$$\Delta\varphi = k_0 \Lambda$$

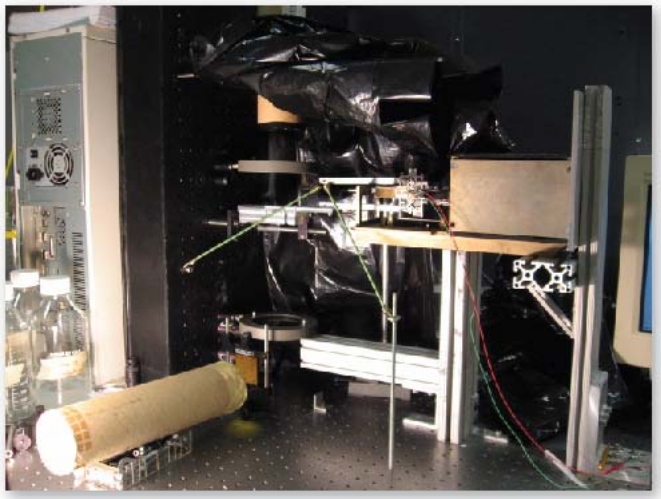
$$\Delta\varphi = \frac{2\pi}{\lambda}(n_e - n_o)$$

- Many polymeric liquids exhibit birefringence under shear strain due to anisotropies introduced as the polymer chains become aligned with the direction of shear

# Overview of Project

- Objective was to validate anecdotal reports of birefringence of polyacrylamide (PAAm) under controlled shear
- Two setups designed, constructed, and tested with PAAm ($M_w$= 18Mg/mol)
  - Many modifications
  - No birefringence of PAAm observed
  - Also tested with PEO, a known birefringent polymer ($M_w$= 4Mg/mol)
- Sensitivity to flow conditions and detection method more significant than initially expected

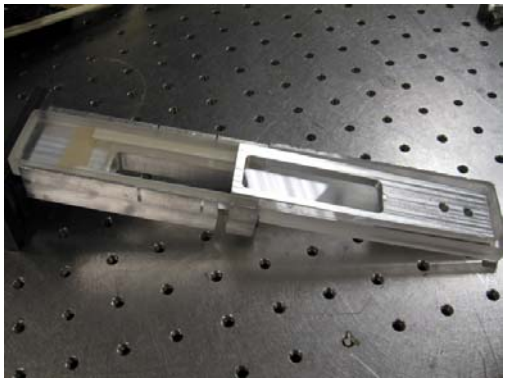


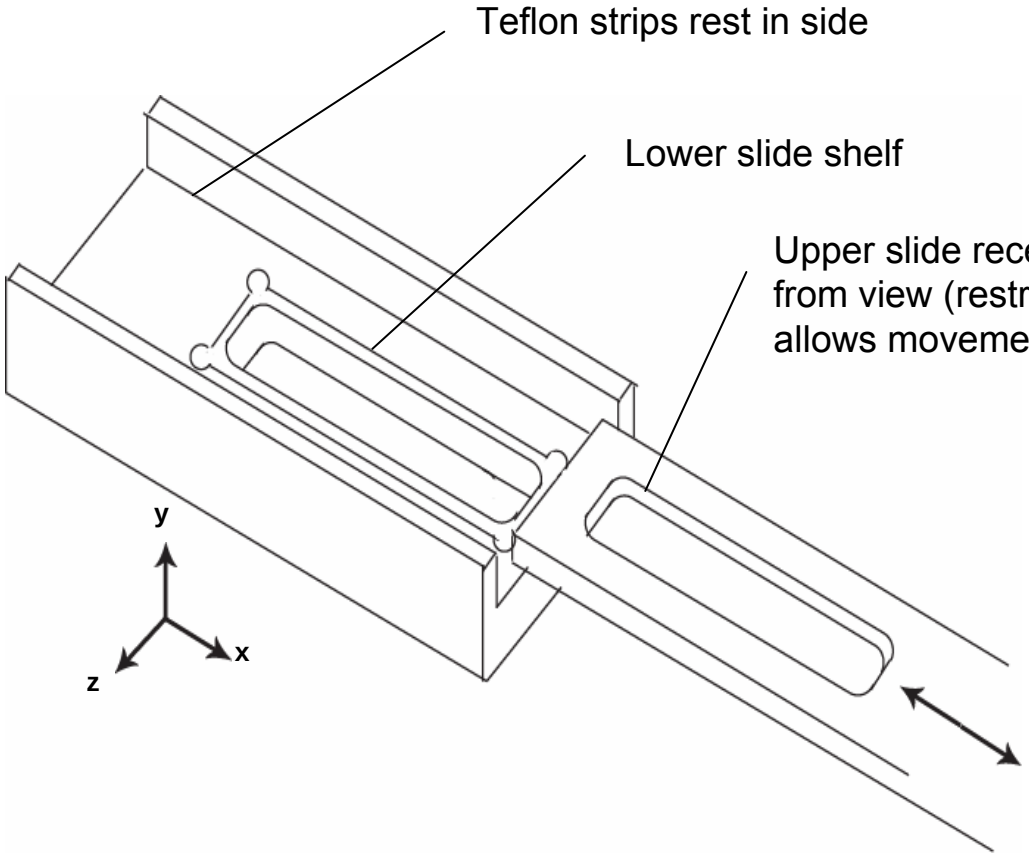



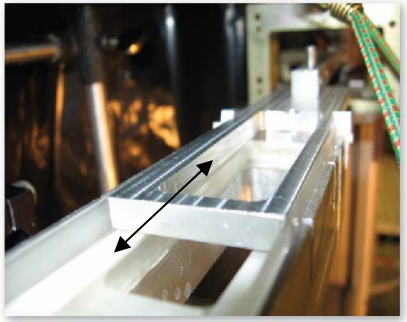
# Oscillatory Shear

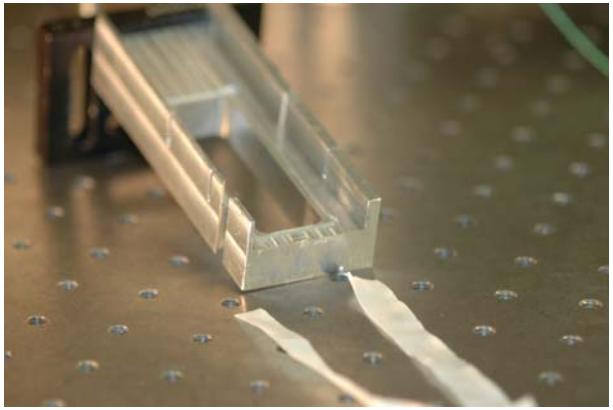
- Birefringence would appear as a cyclical change in the amount of light transmitted through the sample over the course of the oscillation of the top slide.

- No birefringence observed for PAAm







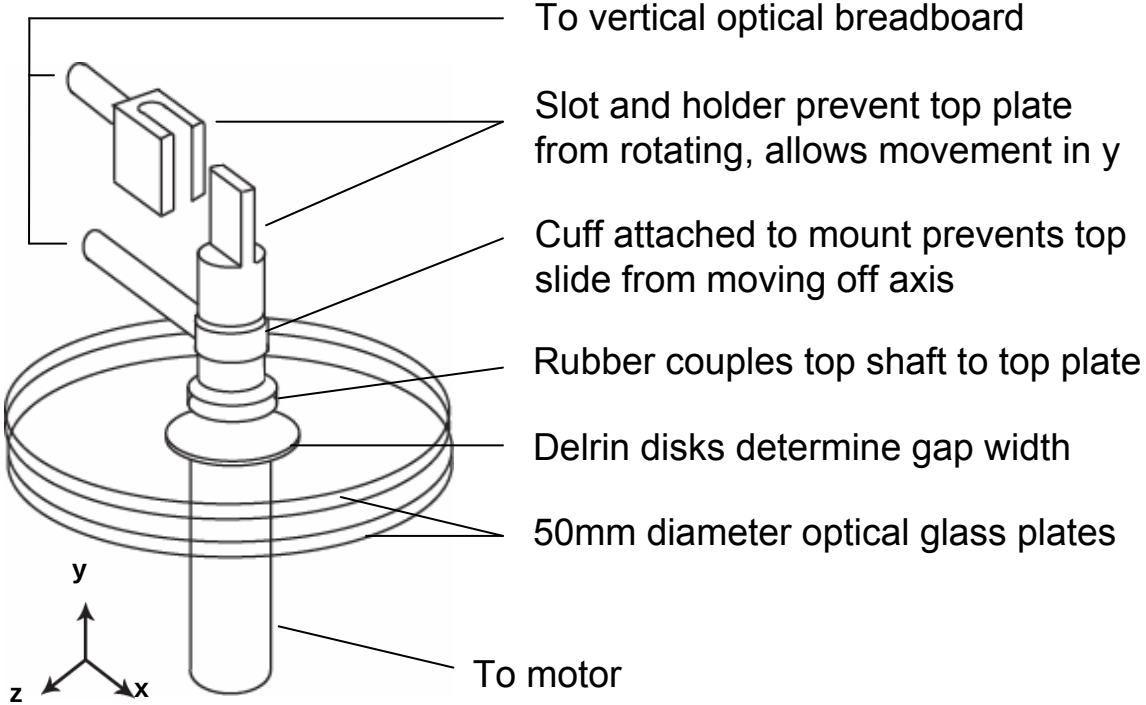
# Continuous Shear

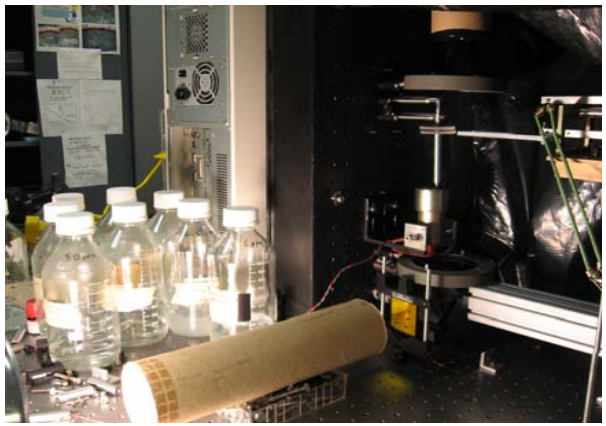
- Thinking that oscillatory shear might not allow the polymer chains to elongate enough for the fluid to display birefringence, a setup which employed continuous shear was constructed.

- In this case, birefringence would:
  - appear as a bright line along the radius of the plates
  - become more pronounced toward the plate edges
  - fade as polymer relaxes when rotation is stopped

- No birefringence observed for PAAm

- Some PEO data suggestive of weak birefringence



## Conclusions

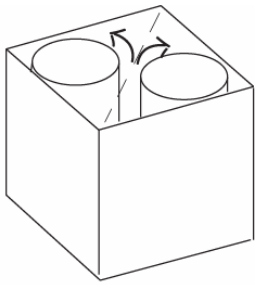
Lack of observed birefringence in these setups could be due to:

- Insufficient path length through fluid (problem with detection)
- Instabilities in flow (no longer pure shear; problem with chain elongation)
- Insufficient time in flow for full extension of polymer chains (in oscillatory setup)
- Insufficient molecular weight of polymer samples (chain length)
- Chain scissions from excessive agitation- for example under high oscillatory shear- or expected time dependent decay (chain length)
- Insufficient shear rate to induce elongation (unlikely)

## Future Work

- Test with shear setups which allow longer path length (more significant phase change) and more stable, continuous flows (polymer chains more likely to align in the first place).

  →Fluid filled mill with two counter-rotating rollers (line of shear in between)



- Use polymers with higher molecular weights (increased chain length)
- Use a more sensitive CCD camera (> 8 bit pixel depth) or a photodiode