An Interferometric Study of Moving Contact Line Dynamics

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Spreading of Fluids and Precursor Layer

- Fluidy (1919) reported the existence of a very thin film in front of moving wetting line.
- Centurioni et al. (2011) used ellipsometry to observe precursor film.
- Cottington et al. (1964) used ellipsometry to observe precursor film.

Gravity Current on an Inclined Plate

- Hardy (1919) reported the existence of a very thin film in front of moving wetting line.
- Local slope is calculated by numerical differentiation of drop profile.
- Measure droplet profile and compare with self-similar profile predicted by Huppert (1982).

Power-laws for Spreading Drops on Inclined Plates

- For small inclination angle γ → 0, lubrication theory remains valid.
- For γ → 0,ρ α σCa 1/3.
- Spreading driven by quasi-steady static balance, hence, Ca 1/3.

Conclusions

- Non-invasive optical technique has been used to investigate dynamical evolution at the vicinity of the dynamic contact line of spreading droplets.
- Existence of an “inflection point” close to the contact line is confirmed.
- Microscopic spreading is of form predicted by “Tanner’s Law” $\theta_a \sim |\text{Ca}|^{-1/3}$.
- Length of precursor layer $L_P$ is determined by comparing spatial variation of visibility and drop heights.
- Shape of spreading drop on inclined plate close to the contact line follows the similarity solution given by Huppert (1982).

Project Goal: Develop a non-invasive optical technique that has sufficient spatial and temporal resolution to investigate contact line evolution.

Power-laws for Spreading Drops on Inclined Plates

- For small inclination angle $\gamma \to 0$, lubrication theory remains valid.
- For $\gamma \to 0$, $\rho \alpha \sigma \text{Ca}^{1/3}$.
- Spreading driven by quasi-steady static balance, hence, $\text{Ca}^{1/3}$.

Phase-shifted Laser Feedback Interferometer (psLFI)

- Feedback into the laser eliminates the need for a beam splitter and separate reference arm.
- Electro-optical modulator (EOM) is used to impose a series of controlled phase changes.
- Vertical spatial resolution of 50 nm is achieved using phase-shifting algorithms.
- Diffraction-limited lateral resolution achieved using high N.A. objectives.

Precursor Layer Length, $L_P$

- $L_P$ is determined by comparing spatial variation of visibility and drop heights.
- Theoretical prediction $L_P \propto \rho \alpha \sigma \text{Ca}^{1/3}$ (De Gennes, 1985).

Confirmation of Tanner’s Law

- Vary spreading velocity by using several different silicone oils.
- Dynamic contact angle is proportional to the capillary number, $\text{Ca}^{1/3}$ (Tanner, 1979).

Dynamic Contact Angle, $\theta_a$

- Local slope is calculated by numerical differentiation of drop profile.
- Dynamic contact angle, $\theta_a$, corresponds to maximum value of slope.

Gravity Current on an Inclined Plate

- Spreading of viscous drops on an inclined plate under gravitational body force.
- Measure droplet profile and compare with self-similar profile predicted by Huppert (1982).
- Shift data so that $\xi = 0$ corresponds to inflection point of profile.

- For $\text{Ca} \ll 1$, $\text{Bo} \ll 1$, regardless of the slope of plate, $\theta_a \sim \text{Bo}^{-1/6}$.