COST Action meeting Dublin

Herman Wijshoff

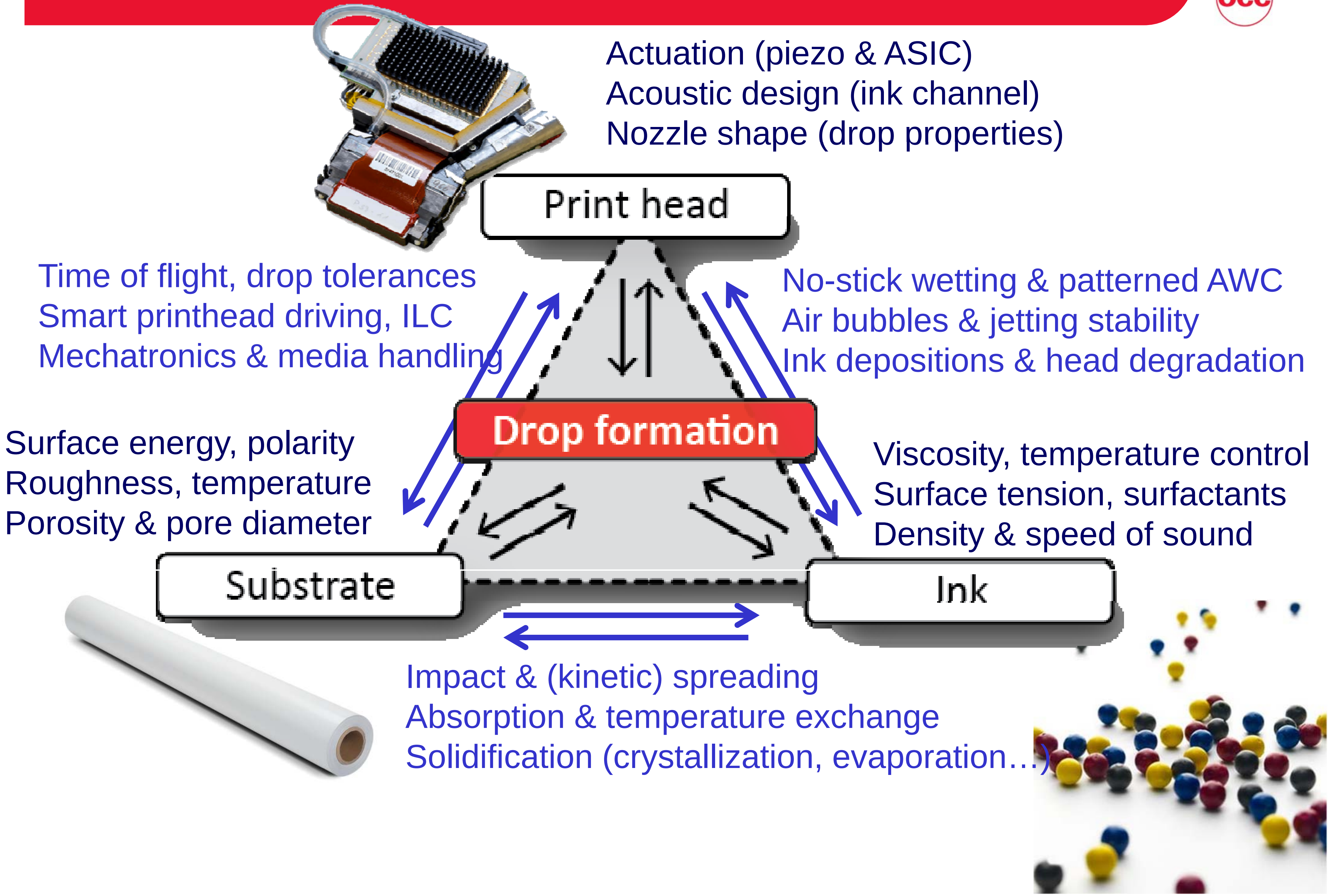
Océ Technologies B.V.

The Netherlands

Océ inkjet printers

Oce CrystalPoint technology: first introduction in ColorWave 600

Inkjet is complex



Our external network for printhead operation

- **From structure dynamics to narrow channel acoustics, drop formation and drop impact with wetting and air bubbles**
- **Research in a wide network**
  - Partner companies, universities, and organizations

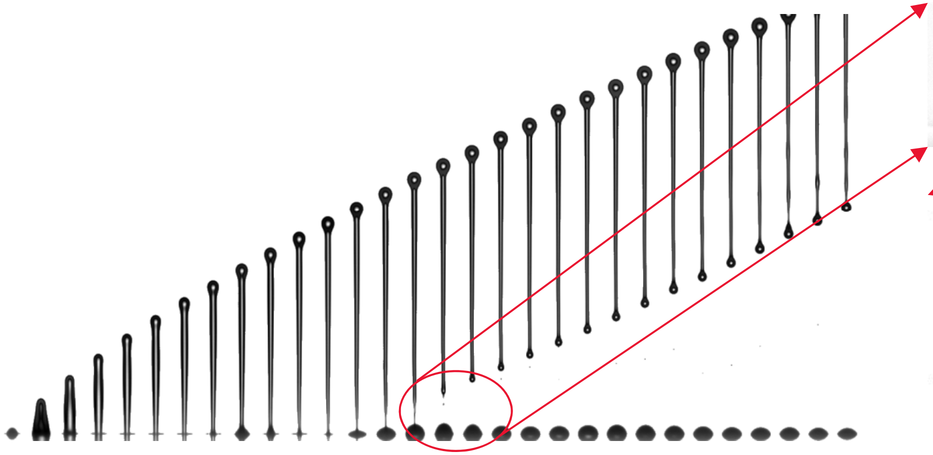
Mohamed Ezzeldin, "Performance improvement of professional printing systems", PhD Thesis TU/e (2012)
Agnieszka Lutowska, "Model order reduction for coupled systems using low-rank approximations", PhD Thesis TU/e (2012)
Wijnand Hoitinga, "Goal-adaptive discretization of a one-dimensional Boltzmann equation", PhD Thesis TUD (2011).
Olesya Bliznyuk, "Directional wetting on patterned surfaces", PhD Thesis UT (2011).
Anton Markesteijn, "Connecting molecular dynamics and computational fluid dynamics", PhD Thesis TUD (2011).
Wim van Hoeve, "Fluid dynamics at a pinch: droplet and bubble formation", PhD Thesis UT (2011).
Arjan van der Bos, "Air entrapment and drop formation in piezo inkjet printing", PhD Thesis UT (2011).
Jia Wei, "Silicon MEMS for detection of liquid and solid fronts", PhD Thesis TUD (2010).
Roger Jeurissen, "Bubbles in inkjet printheads: analytical and numerical models", PhD Thesis UT (2009).
Herman Wijshoff, "Structure and fluid dynamics in piezo inkjet printheads", PhD Thesis UT (2008).
Jos de Jong, "Air entrapment in piezo inkjet printing", PhD Thesis UT (2007).
Matthijs Groot Wassink, "Inkjet printhead performance enhancement by feedforward input design", PhD Thesis TUD (2007).
Vinayak Khatavkar, "Capillary and low inertia spreading of a microdroplet on a solid surface", PhD Thesis TU/e (2005).
Marco Beltman, "Viscothermal wave propagation including acousto-elastic interaction", PhD Thesis UT (1998).

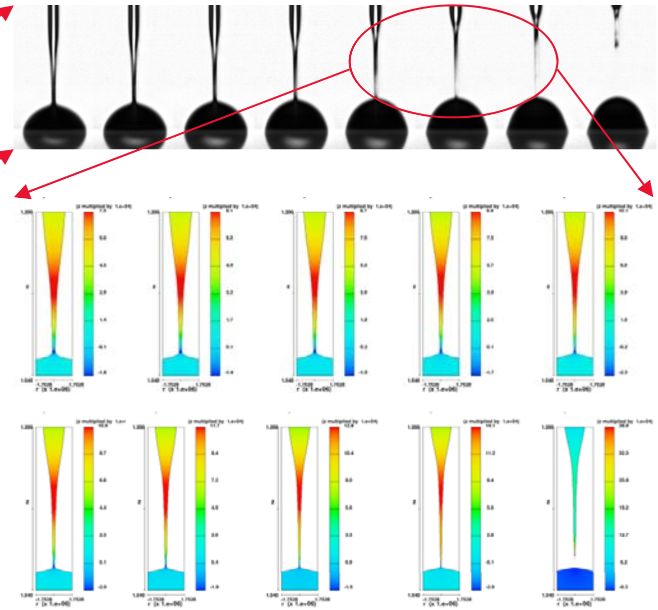
Modeling of the drop formation and impact

- Commercial VOF codes Flow3D and Fluent
- Efficient modeling with lubrication theory
  - PhD Theo Driessen (UT, Lohse) in Hiprins project
- Effect of soluble and insoluble surfactants
  - PhD Myra Hanyak (TU/e, Darhuber) in STW project
- Effect of evaporation and interaction with media
  - PhD Daniel Siregar (TU/e, Kuerten) in STW project
- Effect of wetting properties with lattice Boltzmann
  - PhD Sudhir Srivastava (TU/e, Toschi) in FOM/IPP project
- Theory of contact line movement
  - PhD Koen Winkels (UT, Snoeijer) in FOM/IPP project
  - PhD Wilco Bouwhuis (UT, Snoeijer) in STW project
  - PhD Patrick Jansen (UT, Kooij) in NanoNextNL project
- Effect of particle interactions with LB/MD
  - PhD Florian Günther (TU/e, Harting) in STW project
- Accurate modeling with FEM, level set
  - PhD Tatyana Medvedeva (UT, van der Vegt) in Hiprins project
- Interaction modeling with Cahn-Hilliard theory
  - PhD Görkem Simsek (TU/e, van Brummelen) in NanoNextNL project

Revealing the details of the drop formation process

- **State of the art visualization with UT, group prof. Detlef Lohse**
  - High speed camera recordings with Brandaris camera, up to 25 Mfps
  - Ultra short 4 ns laser flash strobe recordings without any motion blur

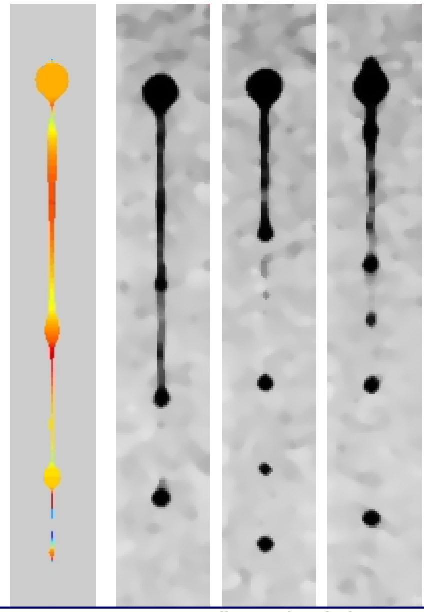


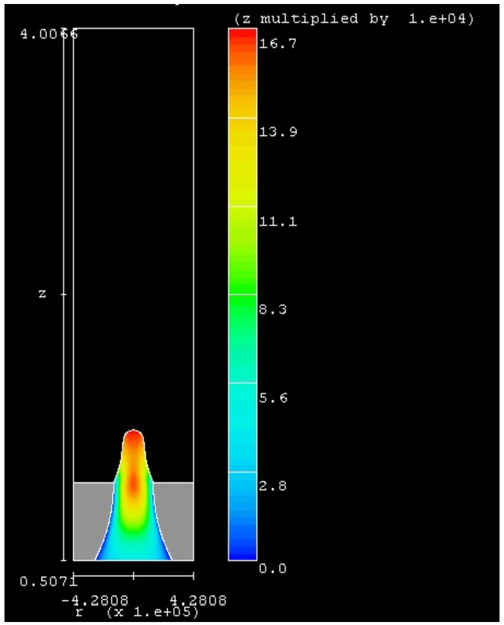


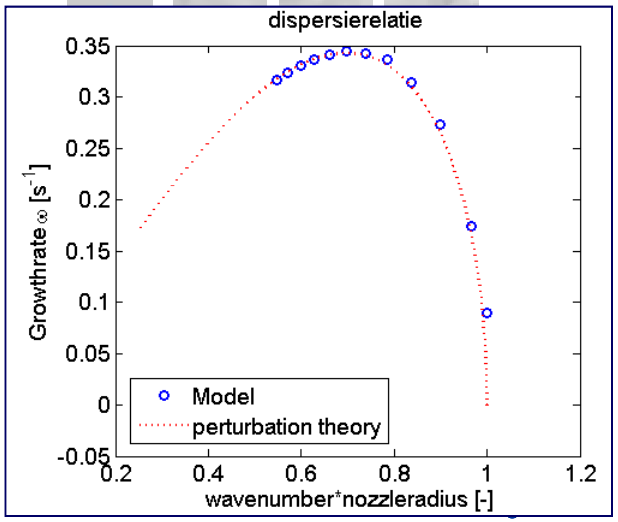
- **Simulation of the drop formation**
  - Use of commercial codes like Flow3D
  - Development of dedicated modeling tools with the academia
- **Understanding and controlling the drop formation**
  - Cope with high-level drop formation specs (e.g. velocity, volume)
  - Suppressing satellite drops, disturbances from air bubbles, dirt etc.

Satellite drops

- **Efficient modeling in Hiprins project and Flow3D simulations**
  - PhD work of Theo Driessen (UT)
- **Mist of droplets from secondary tail**
  - Not visible in graphical applications
- **Stream of drops from Rayleigh breakup**
- **Slow satellites from end-pinching**
  - Parameter space:
    aspect ratio a=L/R
    and Oh=$\eta^2/\rho\gamma R$



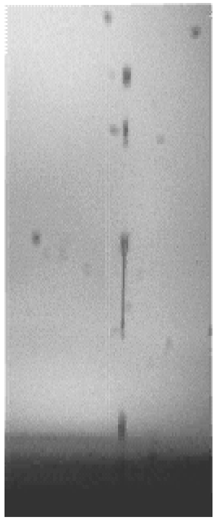


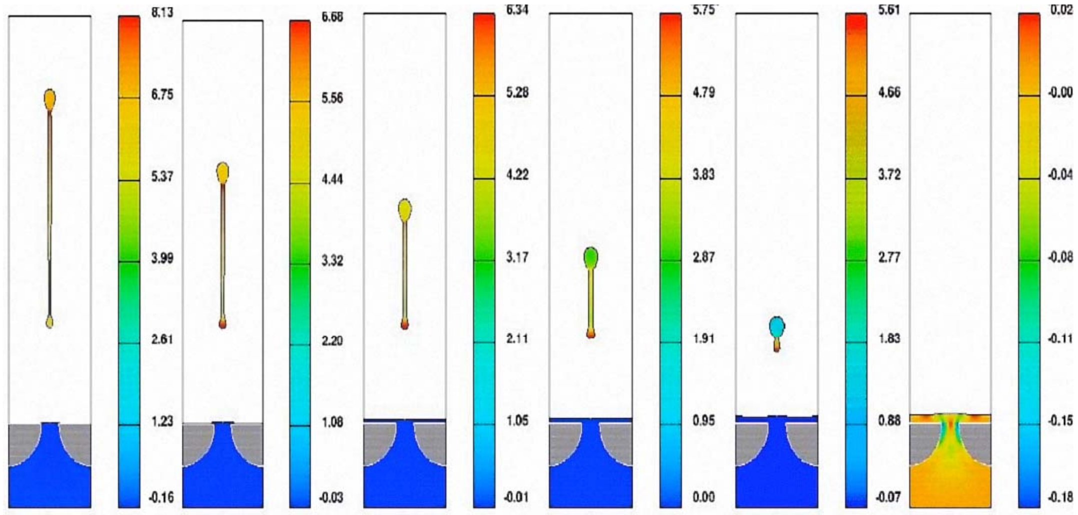


- **Fast satellite drops from initial acceleration**
  - Limits working range (drop size and speed)

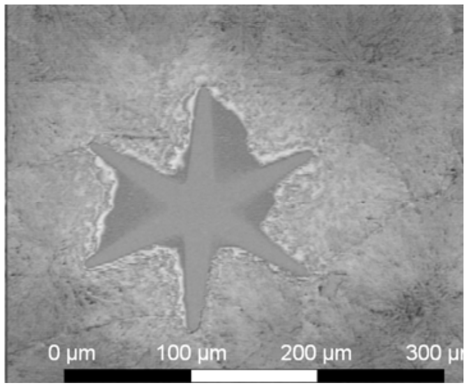
Wetting of the nozzleplate surface

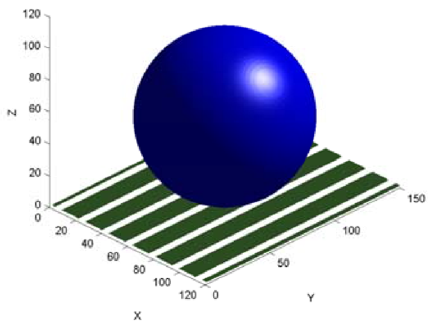
- **Drop formation cycle can result in overfilling**
  - Flow3D simulation and measurements with complete wetting NP

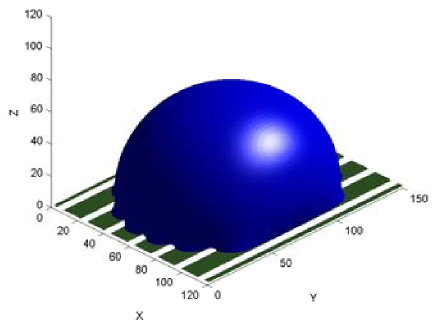




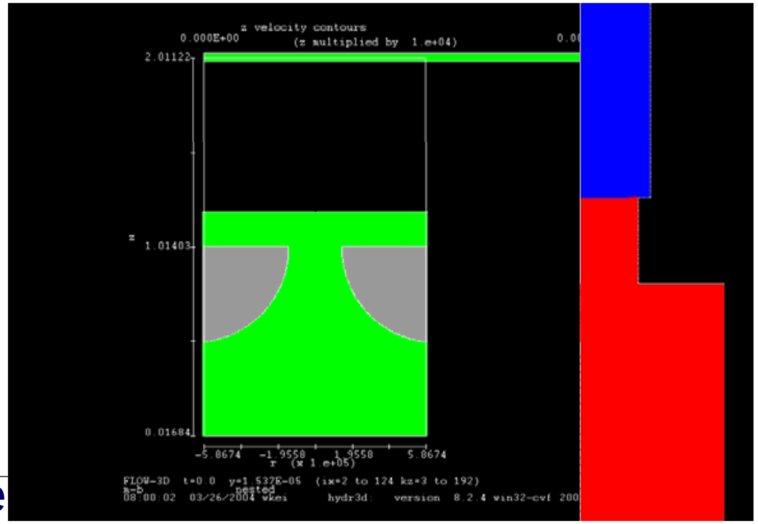
- **Patterned anti-wetting coatings: towards a self-cleaning NP**
  - Results MVDB and LB simulation (NanoNextNL project with UT)



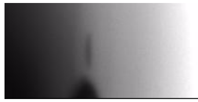




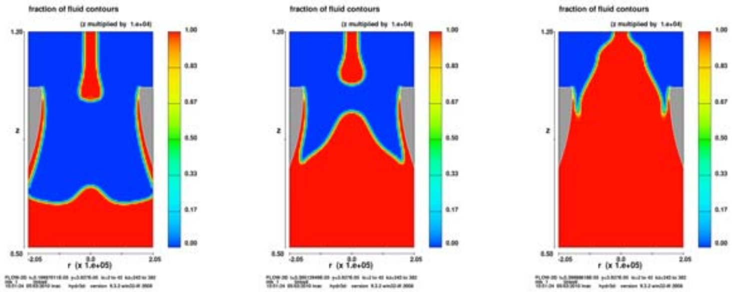
Air entrapment

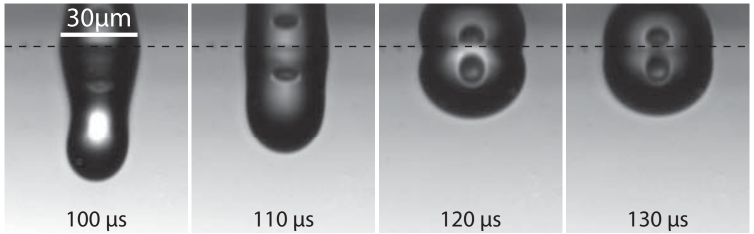


- **Cavitation as mechanism is ruled out**
- **Critical wetting layer**
- **Large meniscus retraction**
- **Collision of free surfaces**
  - Stroboscopic recording of surface collision

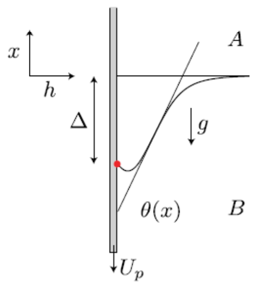


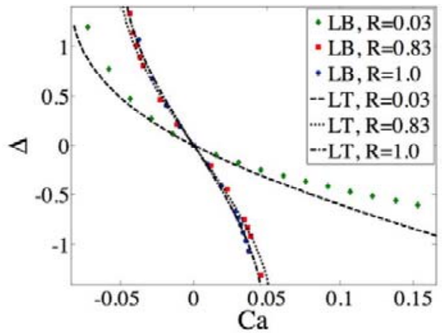
  - Air entrapment by collision inside the nozzle





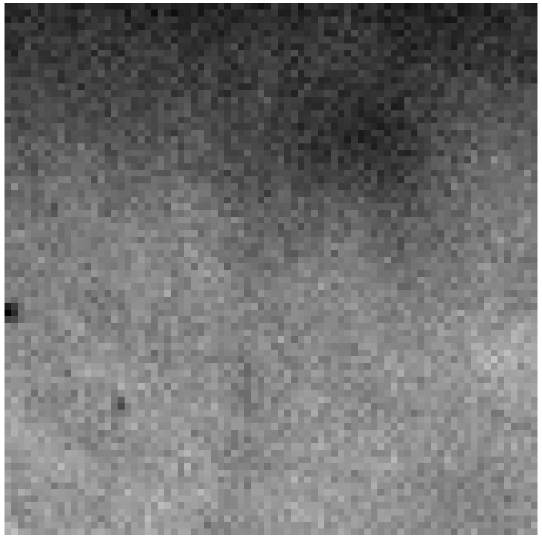
- **Contact line movement over air pockets at nozzle wall**
- **Instability of a fast moving contact line**
  - FOM/IPP project with TU/e and UT





Drop impact with Flow3D

- **High speed camera recording**
  - Impacting drop on plain paper
  - 30 pl with a viscosity of 10 mPa.s
  - Drop speed of 7 m/s
  - Phantom V7 camera @ 100 kfps
  - Recoil visible after 10 µs

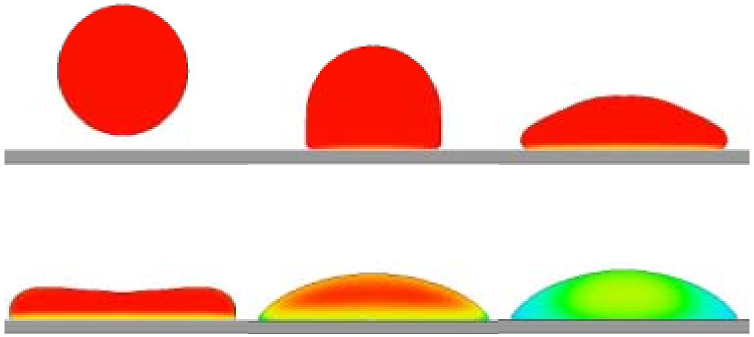


- **Impact on a rough glass plate**

Side view

Top view

- **Flow3D simulation**
  - recoil after 10 µs marks end of impact phase



Ink-media interaction challenges

- **Modeling interaction details**
  - Air cushioning upon impact with porosity and roughness
  - Coalescence between adjacent drops
  - Multiple thin layers of liquid
- **Modeling complex fluid behavior**
  - Multi-component bulk, e.g. water and glycerol
  - Multiple surfactants for each component and interface
  - Particles, e.g. pigments, latex, gelling components
  - Selective evaporation and absorption
  - Gelling, film formation, crystallization etc.
- **Modeling complex substrates**
  - Structures of same size as single drops
  - Structure changes upon contact with ink

Printing for Professionals