Laser Speckle Imaging of heterogeneous dynamics in drying paint

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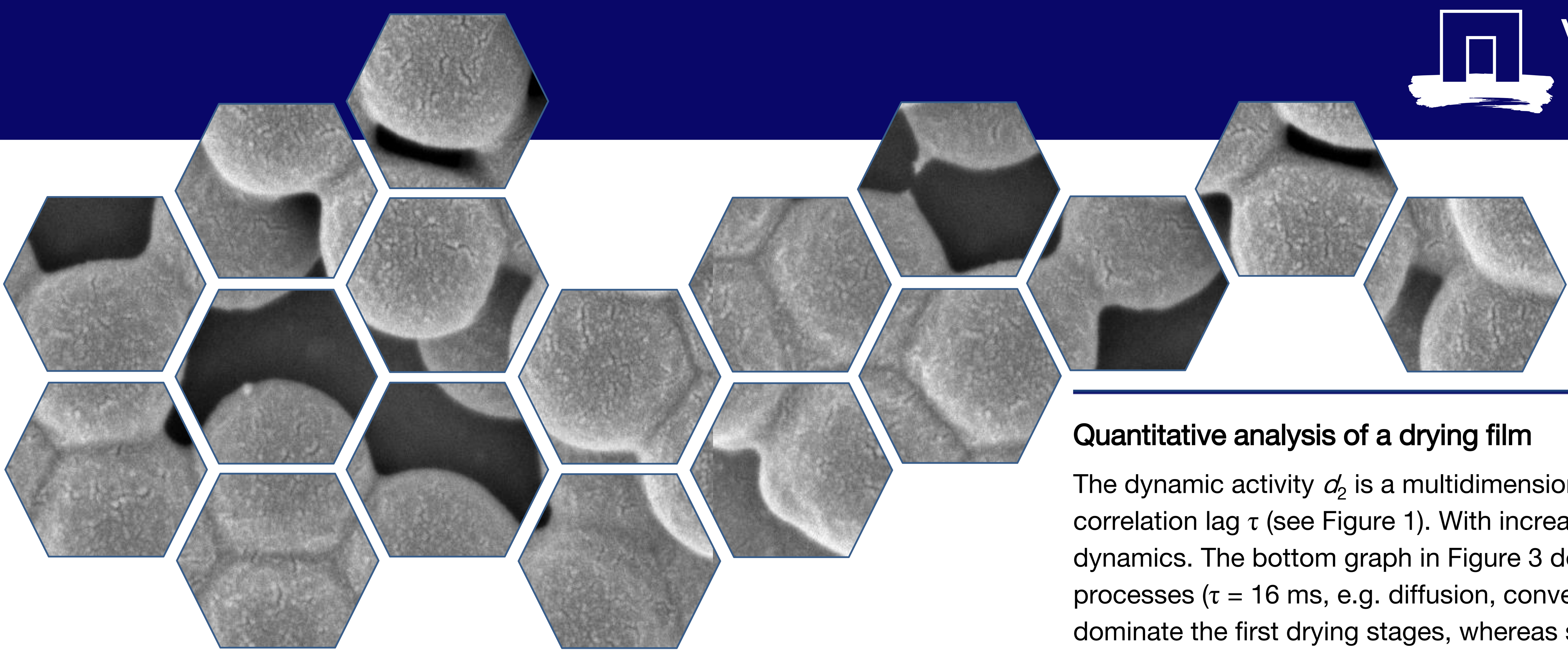
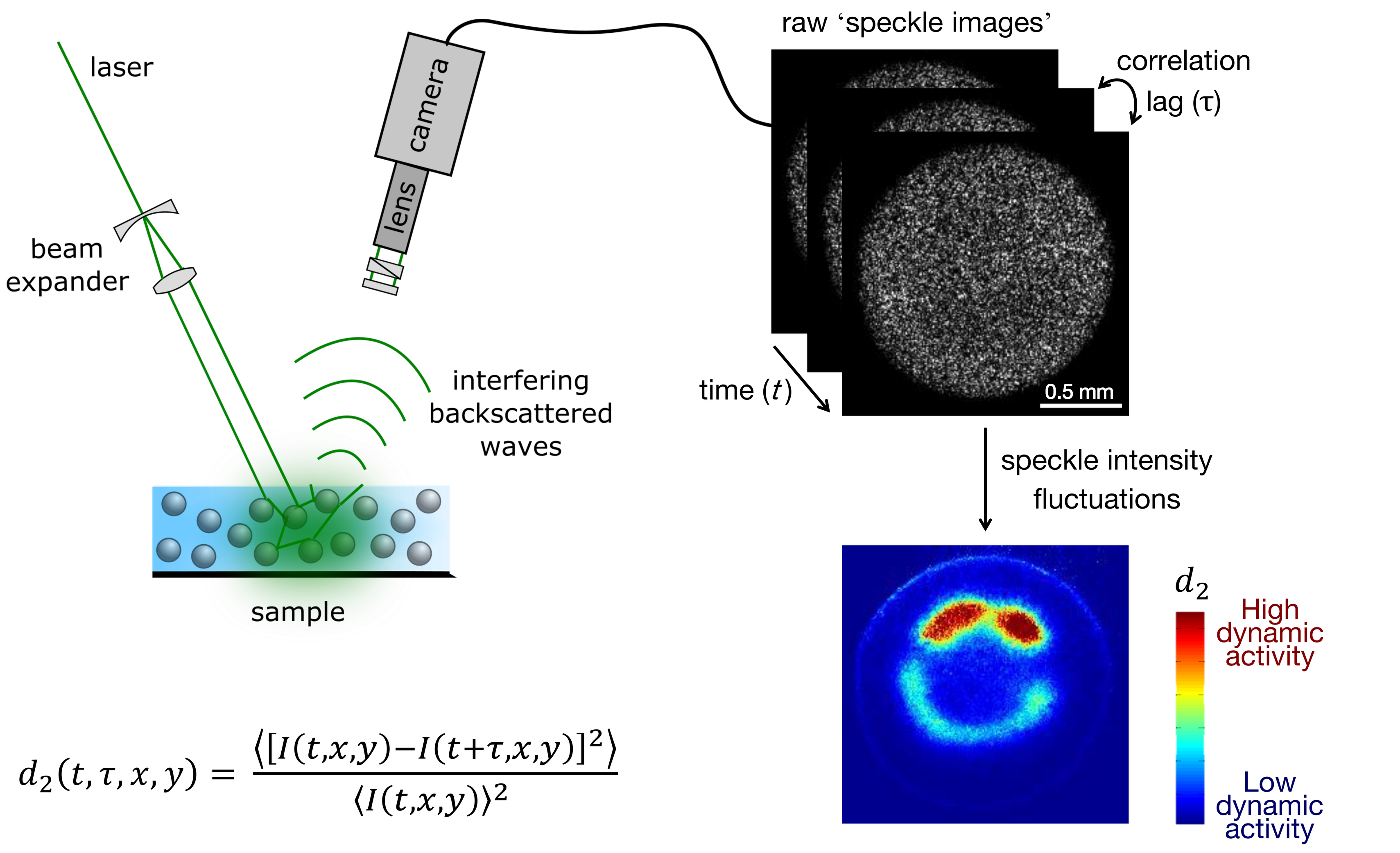
For quality of life



Introduction

The demand for sustainable, high-quality paints is growing. However, solvent-based paints still outperform their water-based counterparts, due to their fundamentally different drying process.[1] It is therefore essential to gain spatial insight into the dynamics of paint drying. To address this challenge, we are developing a novel imaging technique specifically targeted at turbid systems. This so-called Laser Speckle Imaging (LSI) method allows visualising the drying dynamics in virtually any turbid sample, over a wide range of time scales, on both sealed and porous substrates.[2] Here we explore the potential of LSI for elucidating the complex drying phenomena in water-based paints.

Laser Speckle Imaging (LSI) visualises motion



$$d_2(t,\tau,x,y) = \frac{\langle [I(t,x,y) - I(t+\tau,x,y)]^2 \rangle}{\langle I(t,x,y) \rangle^2}$$

Figure 1. Schematic of the LSI setup and data analysis. The sample is illuminated with a laser beam and the backscattered light is detected with a camera. This gives a speckled image of the sample, here a drying paint droplet. Any motion of scattering objects leads to fluctuations in the speckle intensity. These fluctuations are translated into dynamic information via the correlation function d_2, which encodes the local dynamic activity at a given time (t), position (x,y), and correlation lag (τ).

Heterogeneities in drying dispersion droplets

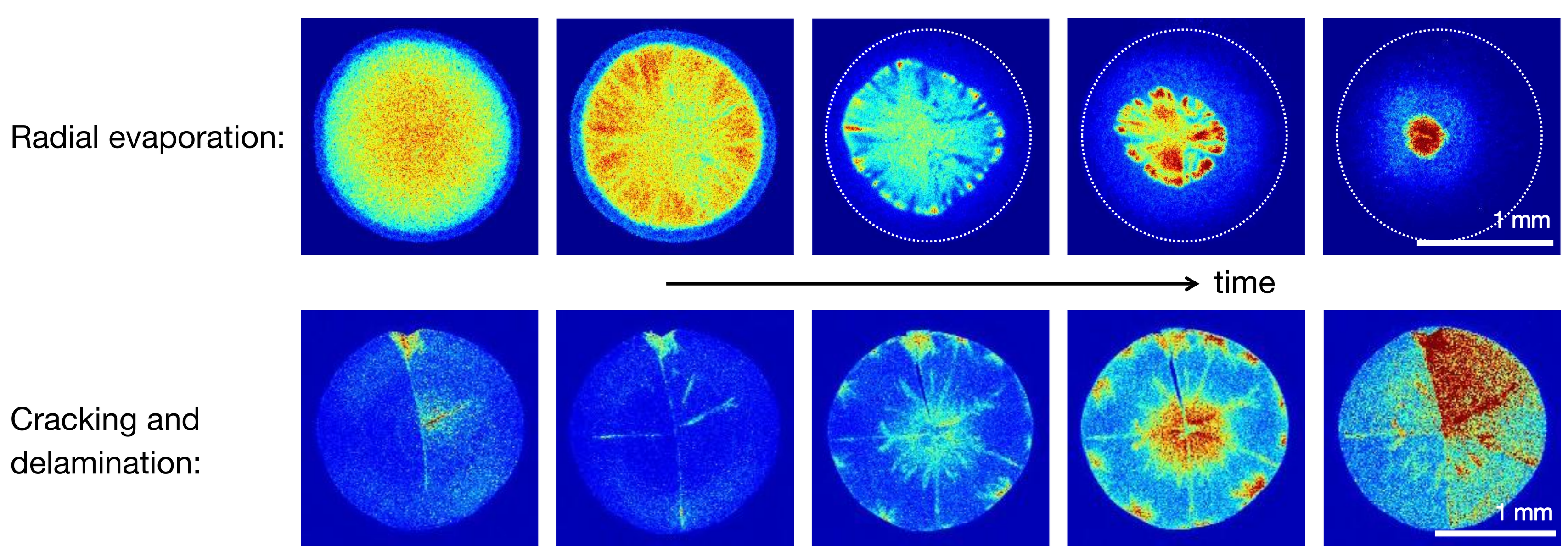


Figure 2. Evolution of evaporation, cracking and delamination in concentrated dispersion droplets on glass.

Quantitative analysis of a drying film

The dynamic activity d_2 is a multidimensional function of time, position, and the correlation lag τ (see Figure 1). With increasing τ, the focus shifts to slower dynamics. The bottom graph in Figure 3 demonstrates that fast dynamic processes (τ = 16 ms, e.g. diffusion, convection, cracking and delamination) dominate the first drying stages, whereas slow dynamic processes (τ = 1.6 s, e.g. particle deformation, relaxation and aging) dominate the last stages.

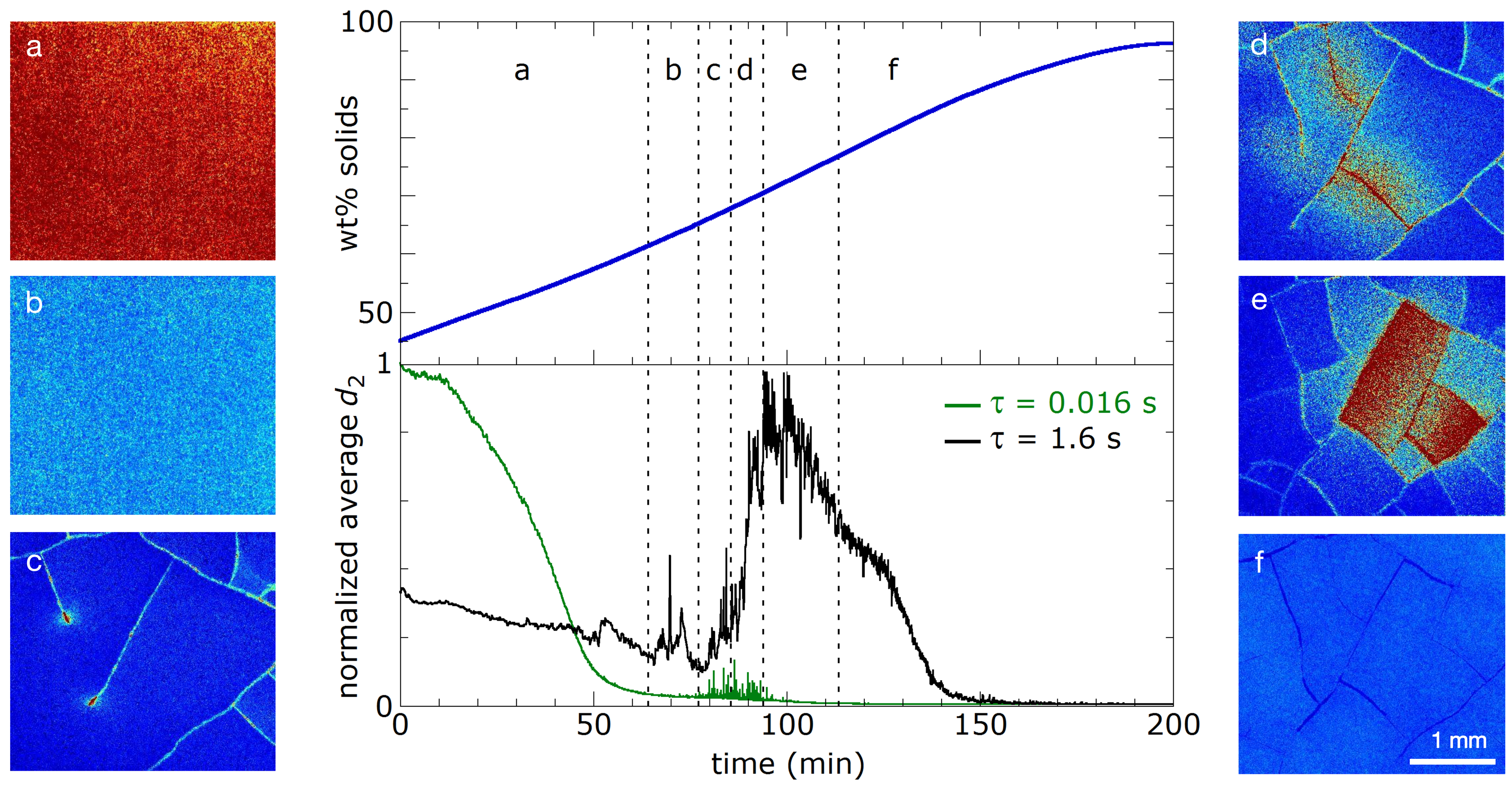


Figure 3. Drying of a 200 μm thick film of a polymer dispersion. Images (a) to (f) show the fast dynamic activity (τ = 0.016 s) in the centre of the film in different stages: (a) evaporation, (b) stress build-up, (c) primary cracking, (d) secondary cracking, (e) delamination, and (f) relaxation. The graphs show that the increase in wt% solids coincides with a shift from fast dynamics (τ = 0.016 s) to slow dynamics (τ = 1.6 s).

'Difficult' systems: porous substrates and pigmented samples

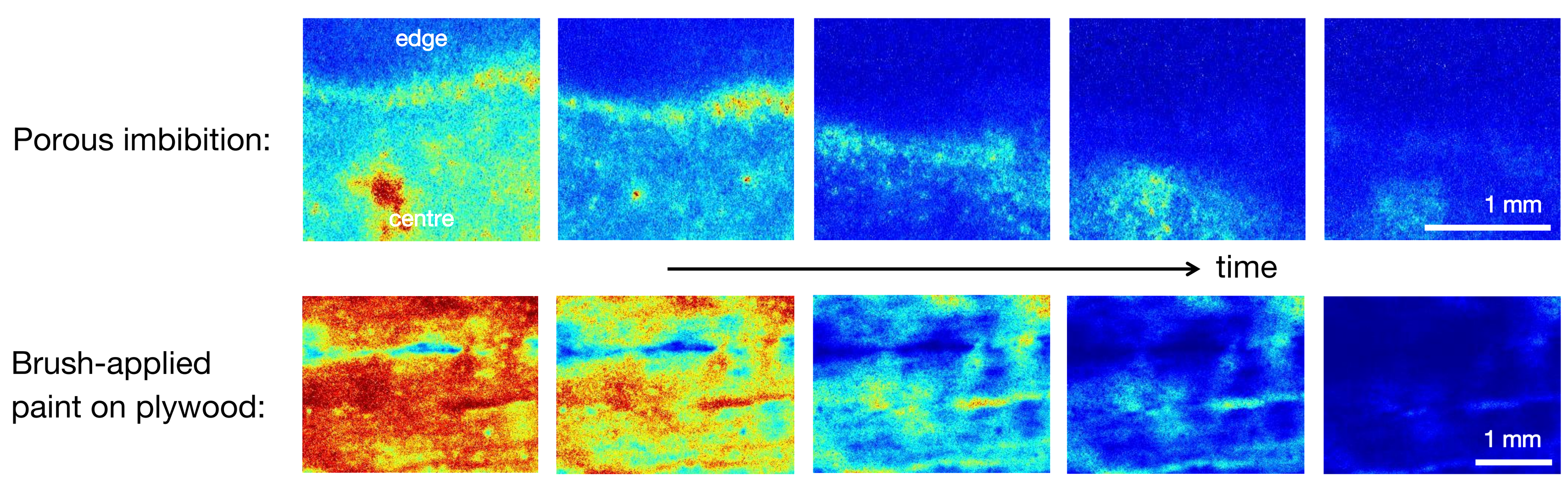


Figure 4. Top: wetting front propagation through paper. Bottom: drying of brush-applied woodtrim paint.

Conclusions

- LSI visualises dynamics in turbid systems, both spatially and temporally
  - Spatial resolution ~5 μm
  - Temporal resolution 1–20 ms, but processes can be followed over hours/days
- Applicable to a wide variety of complex systems:
  - Inhomogeneous, pigmented and light-absorbing, on porous substrates
- Quantitative imaging: differentiation between fast and slow dynamic processes
  - Evaporation, cracking and delamination vs. particle deformation, coalescence and aging

Future work

- Study effects of pigments, dispersants, wt%, substrate, drying conditions, ...
- ...on paint drying, film homogeneity, aging, ...
- Your input is highly appreciated!

References

(1) Van der Kooij and Sprakel, *Soft Matter* **11**, 2015 (2) Zakharov and Scheffold, *Light Scatt. Rev.* **4**, 2009

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