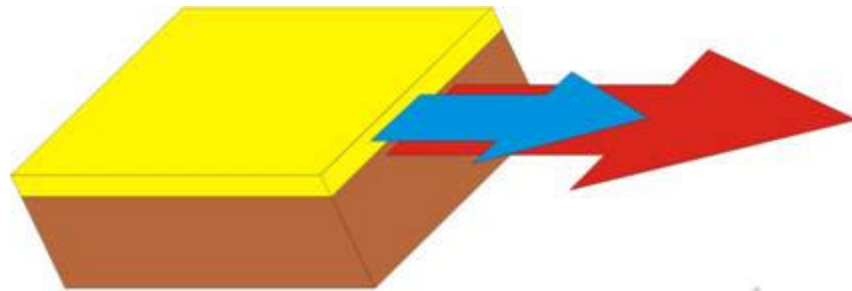


Fatigue fracture of paint layers from repeated cycles of humidity fluctuations

Michal Lukomski



Mechanical behaviour of painted wood – damage mechanism



The mismatch in dimensional response of wood and gesso to humidity variations

Mechanical behaviour of painted wood - questions

1. What is the **critical wood movement (strain)** above which damage in decorative layer appears?
2. How does the critical strain depend on the number of repeated cycles – the **fatigue** fracture?

The experimental approach

Stretching or compressing mechanically specimens of painted wood to **imitate large number of cycles** of climate-induced dimensional changes

Monitoring of the damage development at the micro-level

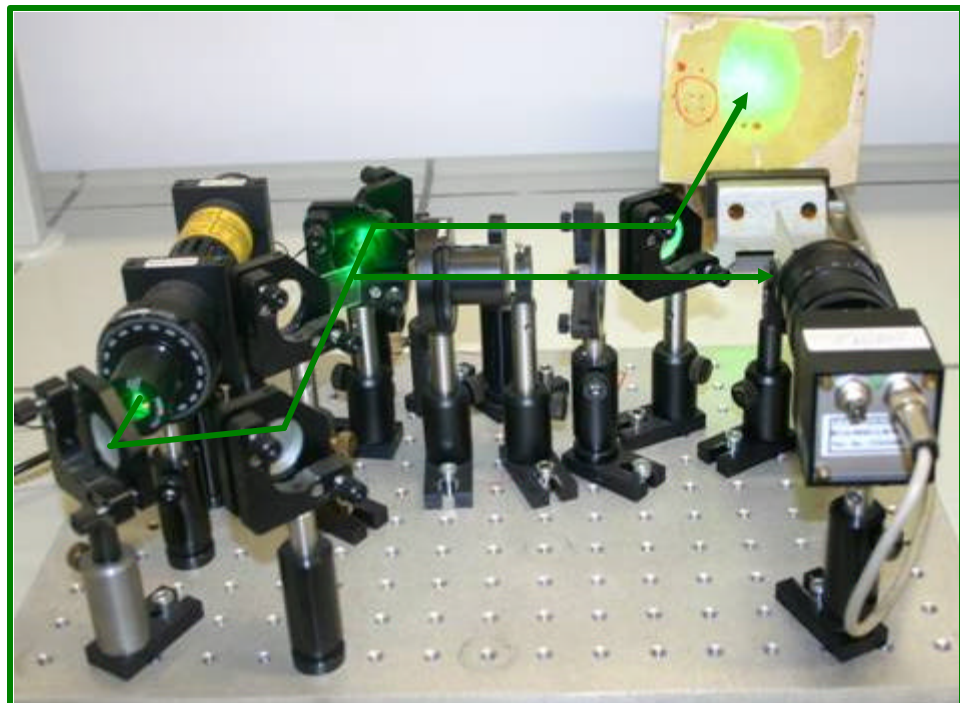
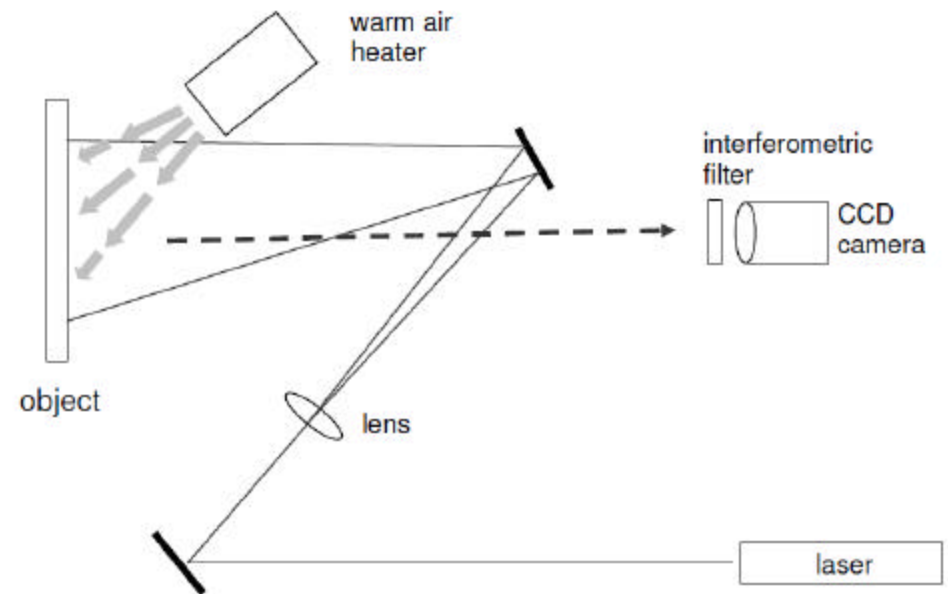
Specimens imitating panel paintings

- lime wood
- glue sizing
- gesso (white field)
- alkyd paint (red field)

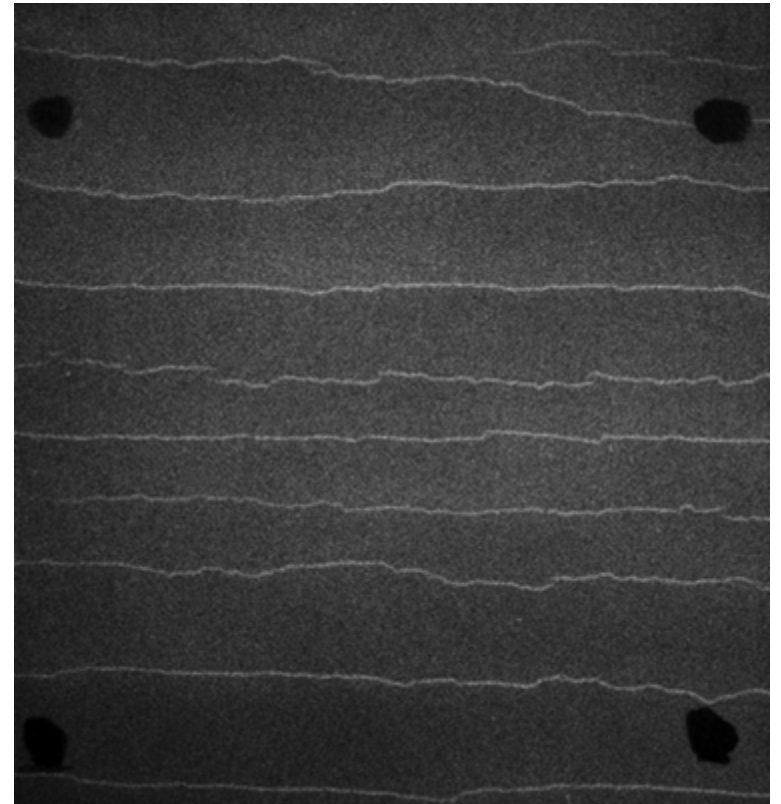
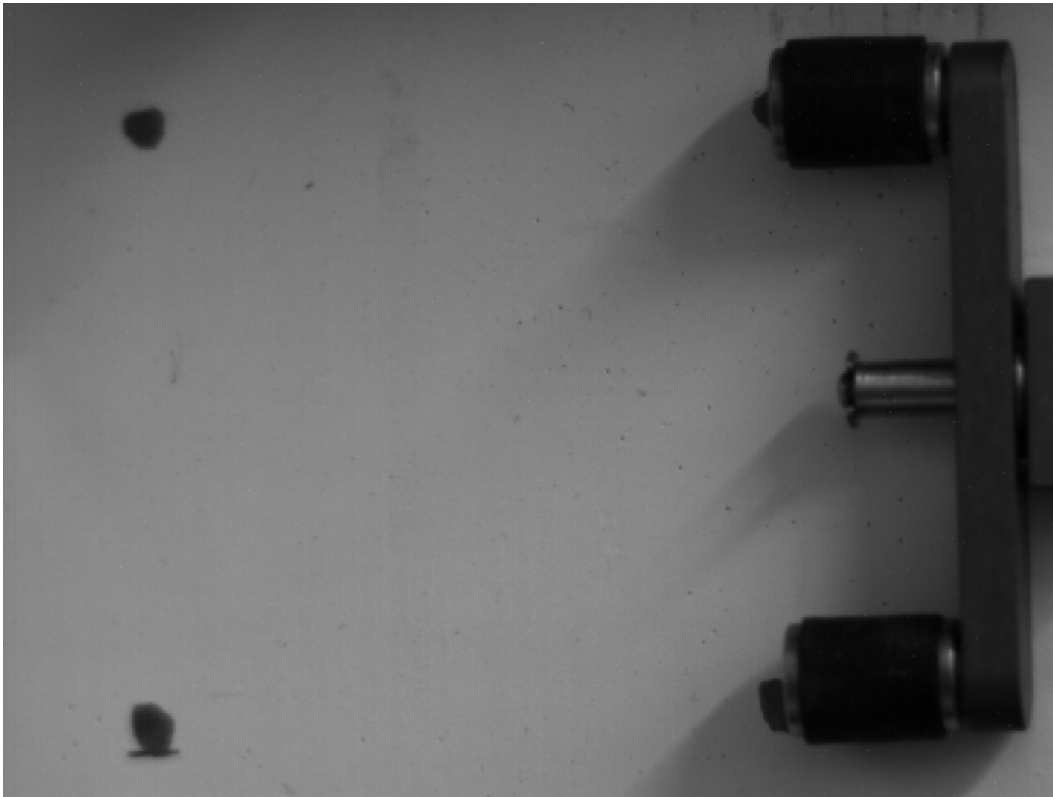


Direct tracing of damage development at the micro-level using ESPI (Electronic Speckle Pattern Interferometry):

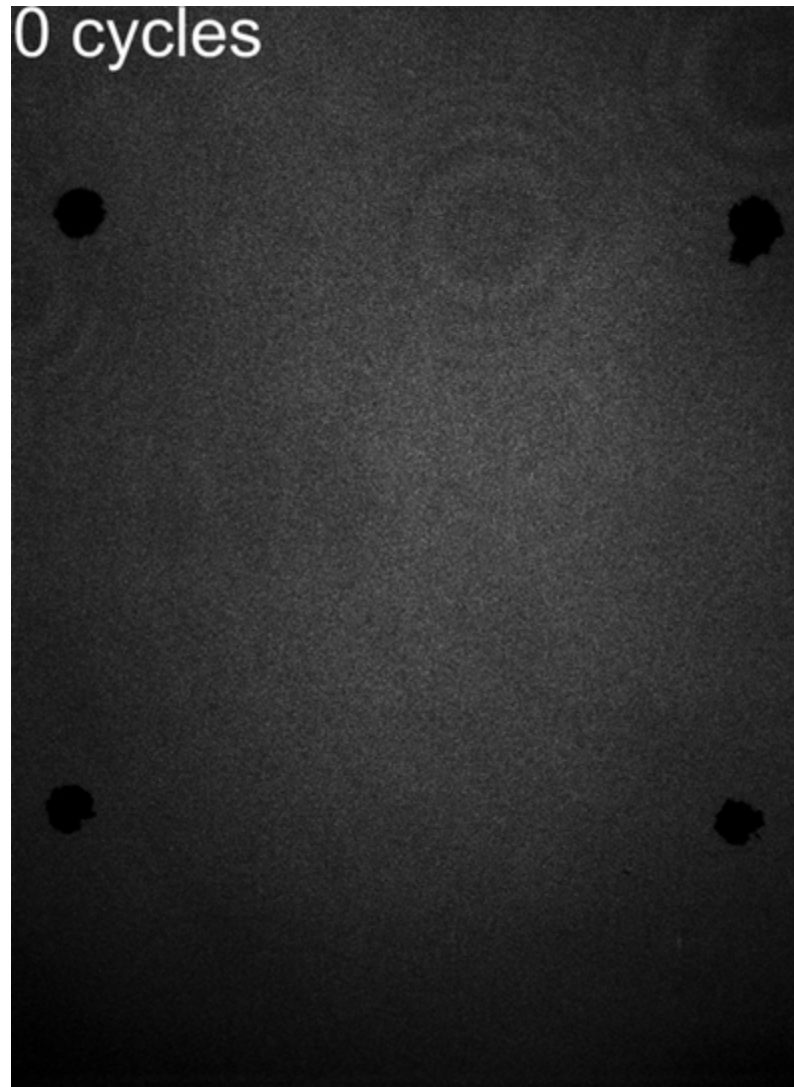
- fast
- accurate
- can be used in the field



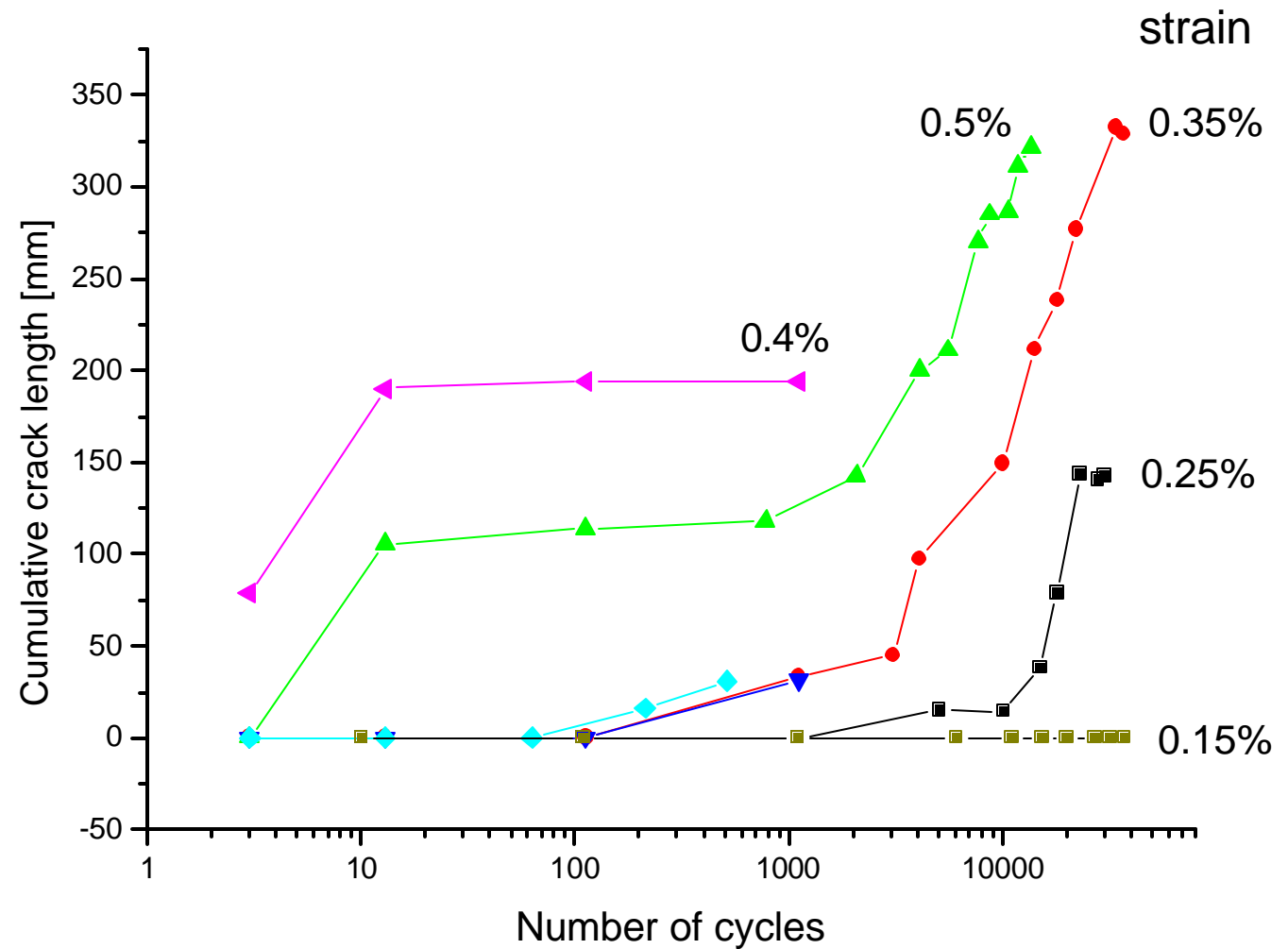
Specimens are **stretched** mechanically to imitate climate-induced dimensional changes (0.4%)



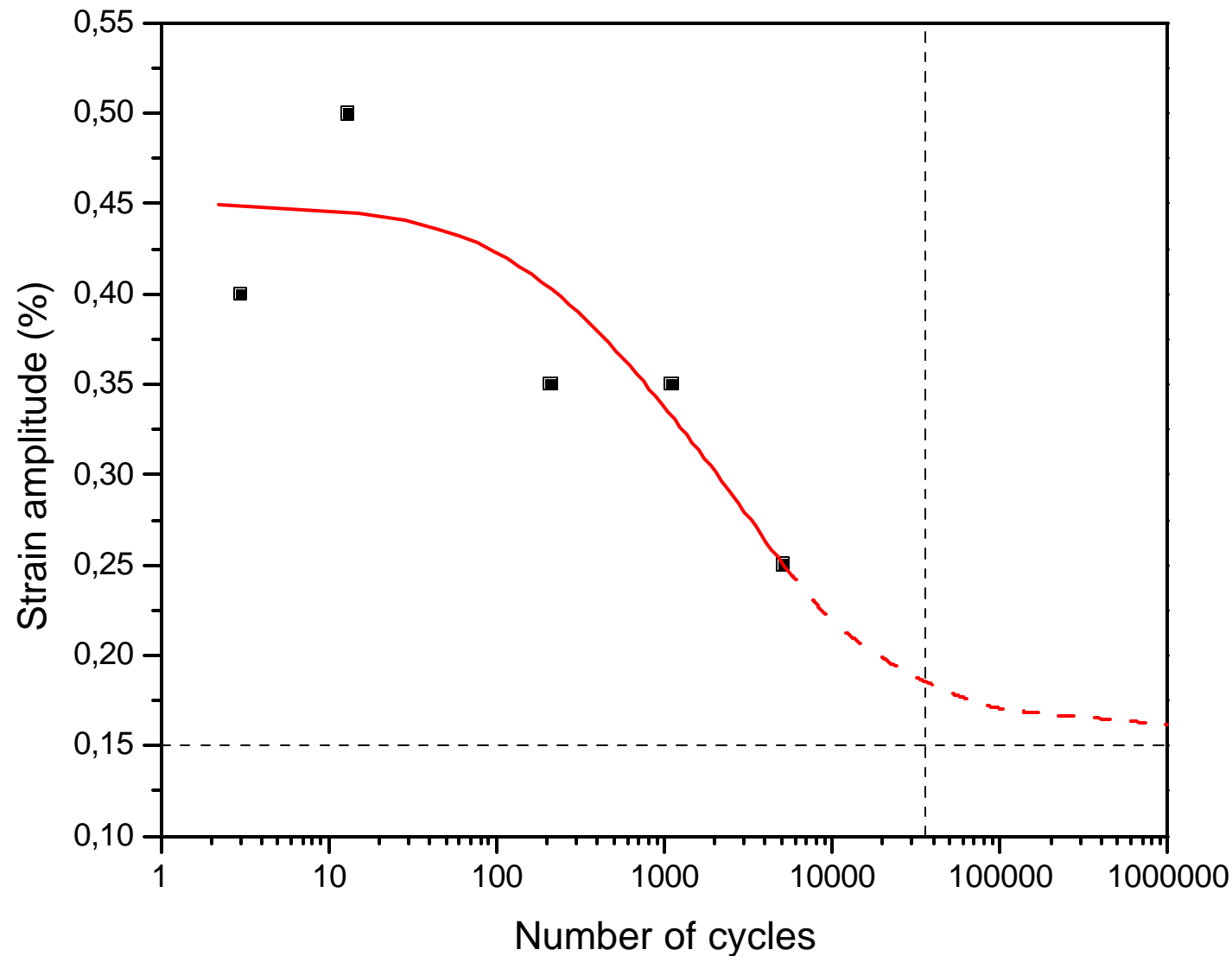
Development of **cracking** during cycling at a strain of 0.25 %



Cumulative crack length vs number of cycles (50% RH)



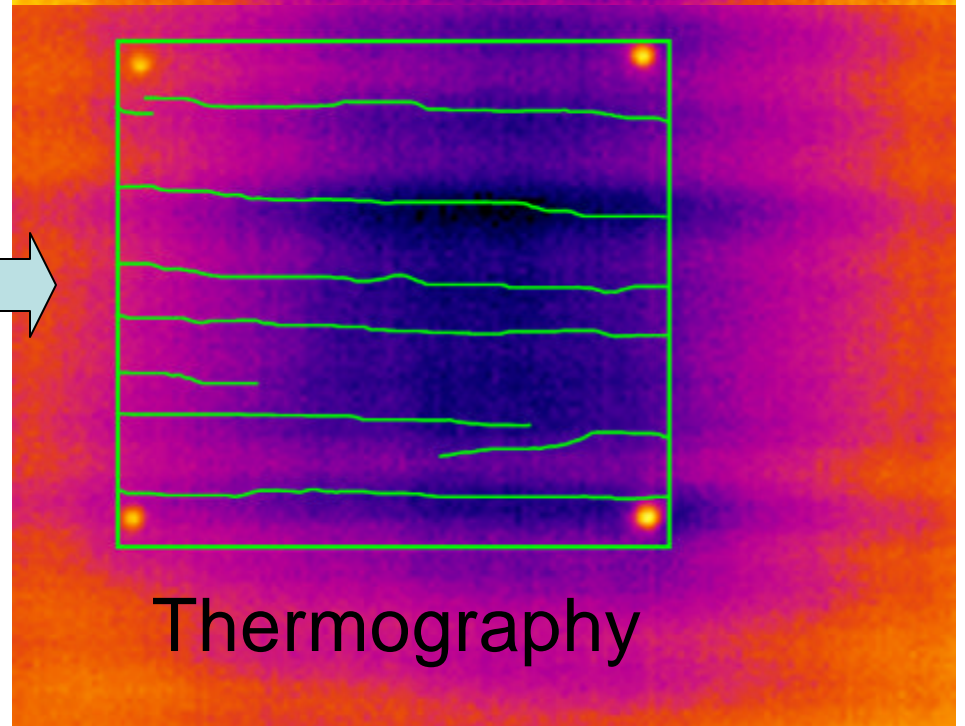
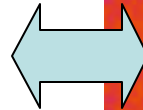
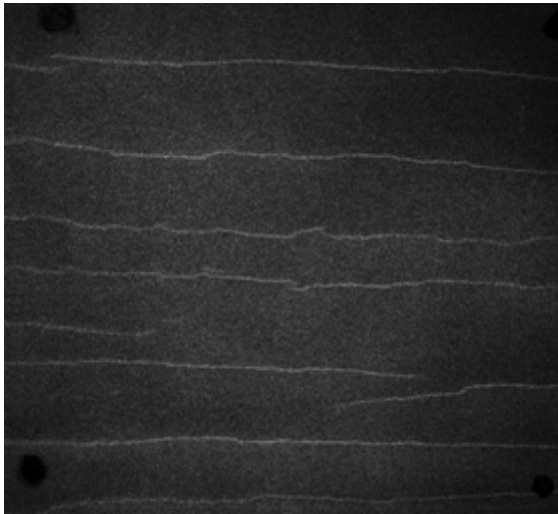
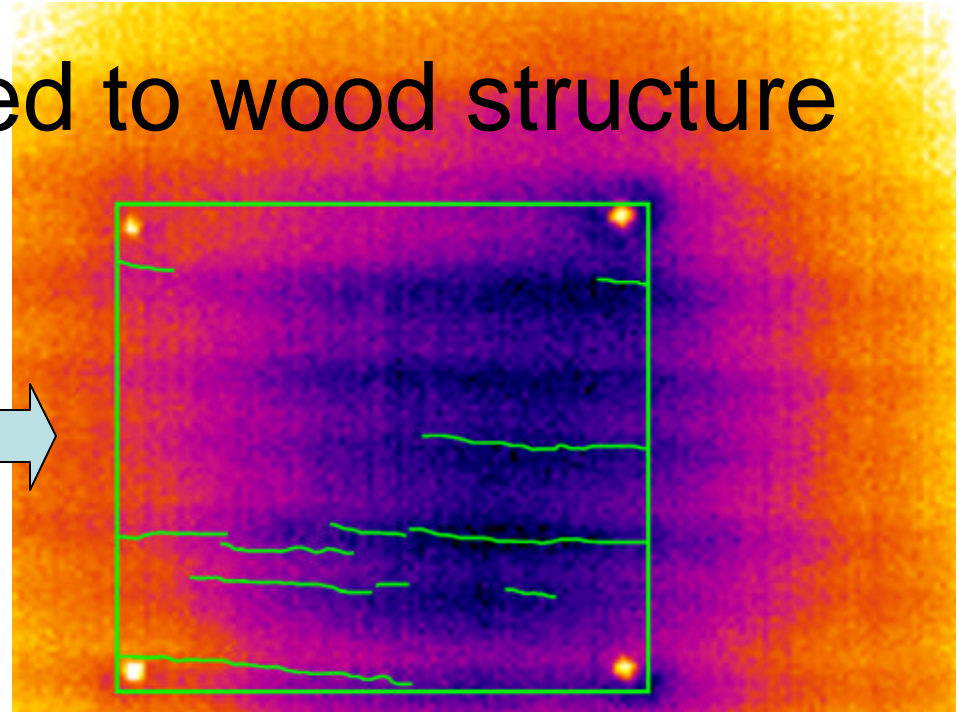
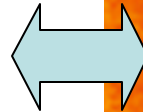
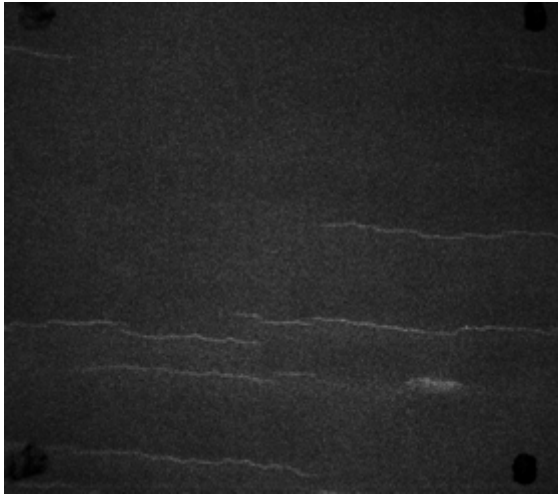
S-N relationship: strain to number of cycles after which damage appears



The **measured** critical strain

- around **0.2%** so the damage criterion for gesso (the yield point at 0.25%) was confirmed experimentally
- but the criterion remains **very conservative**: no fracture after 36.000 cycles equivalent to 100 years of diurnal variations

The damage is related to wood structure



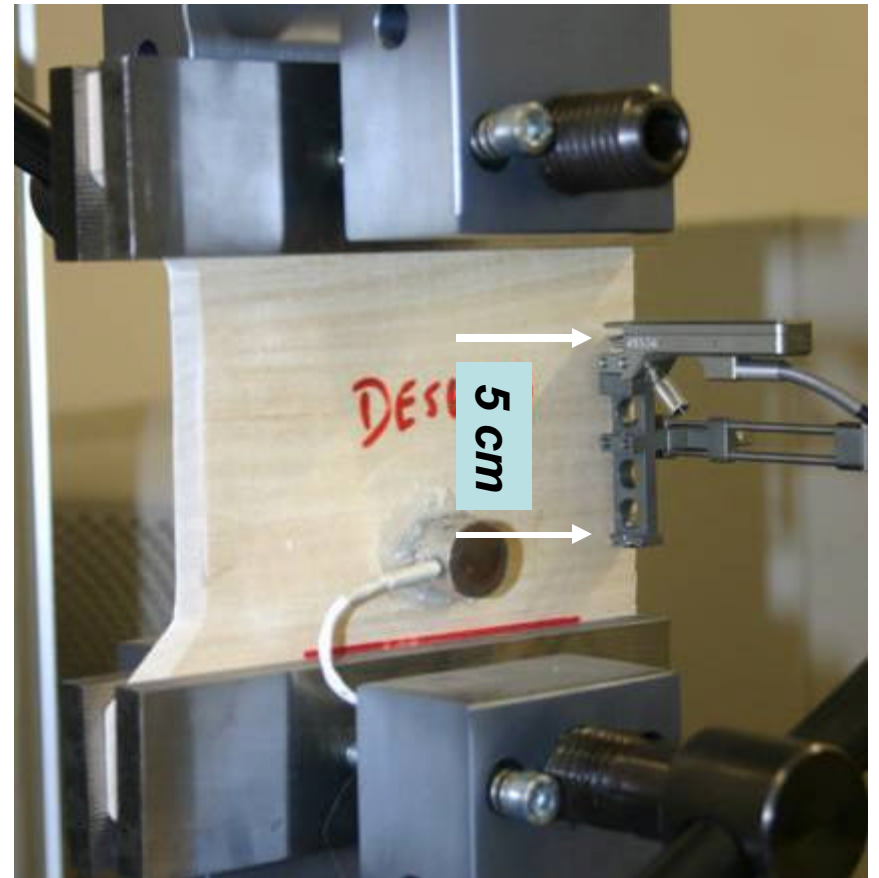
ESPI

Thermography

Next experimental problem

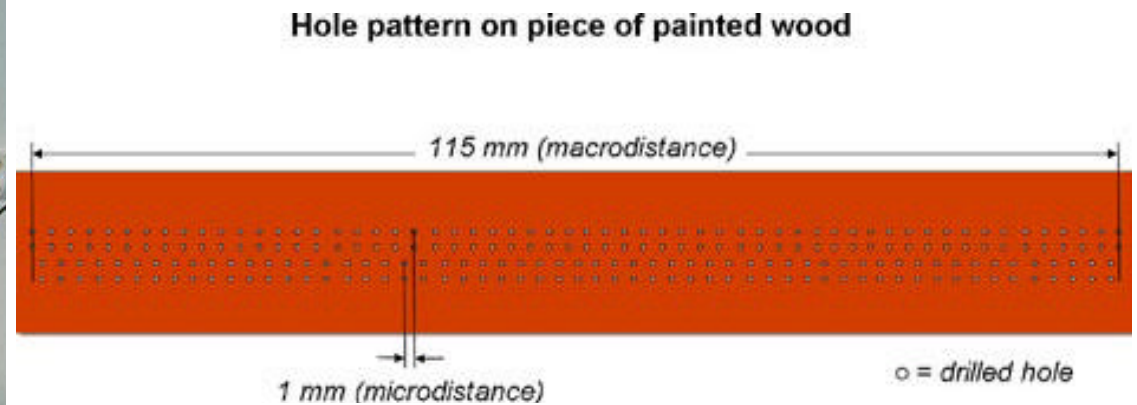
What is the **local movement of the wood** (strain pattern) during:

- mechanical stretching
- water vapour adsorption



‘Climate and dimensional changes in painted wood’ project

NIKU and Norwegian Building Research Institute, 1999-2001



Optical scanning of the painted surface revealed:

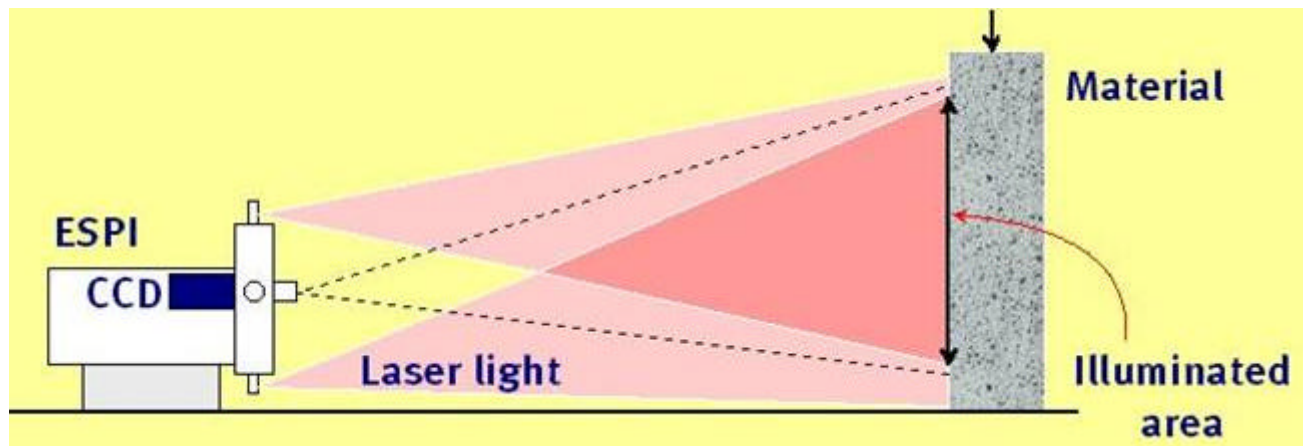
- fast response of the surface to climate variations
- large movements of the wood in micro areas

The present project – **in-plane ESPI** for monitoring the local strain pattern

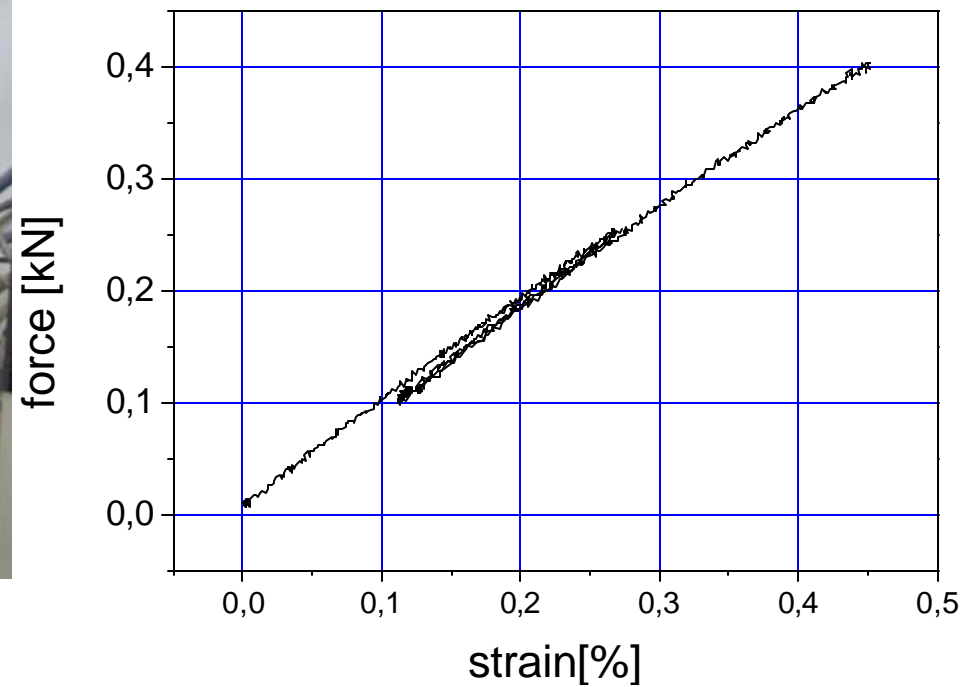
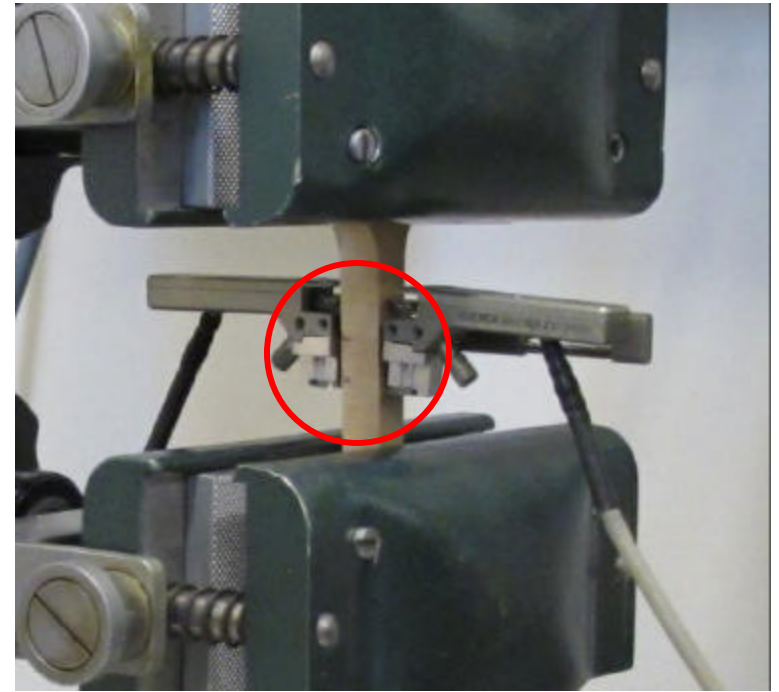
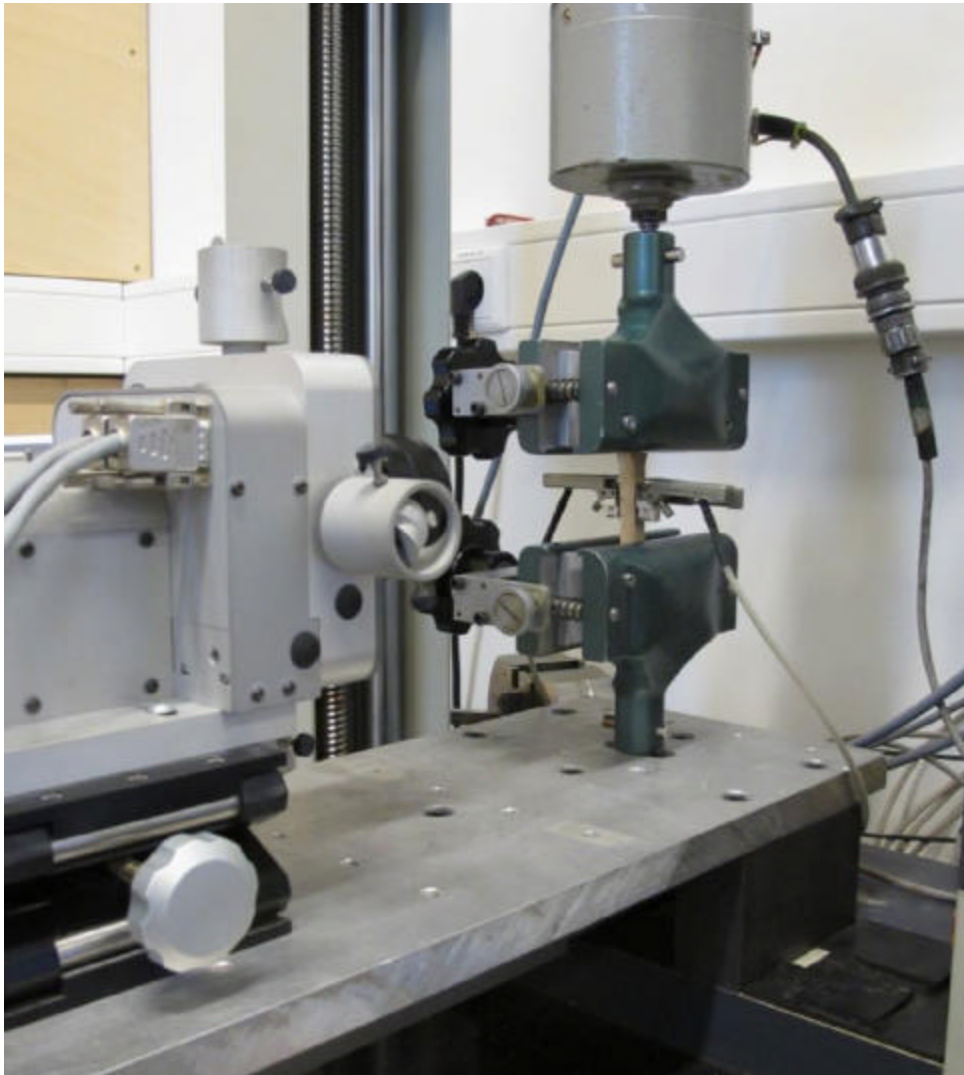


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Eric Wijen

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Building and Planning*



Tensile test (lime wood)



Displ. Y
(mm)

0.0410

0.0353

0.0295

0.0238

0.0180

0.0123

0.0065

0.0008

-0.0050

Strain Y
(Technical %)

0.5306

0.4745

0.4185

0.3624

0.3064

0.2503

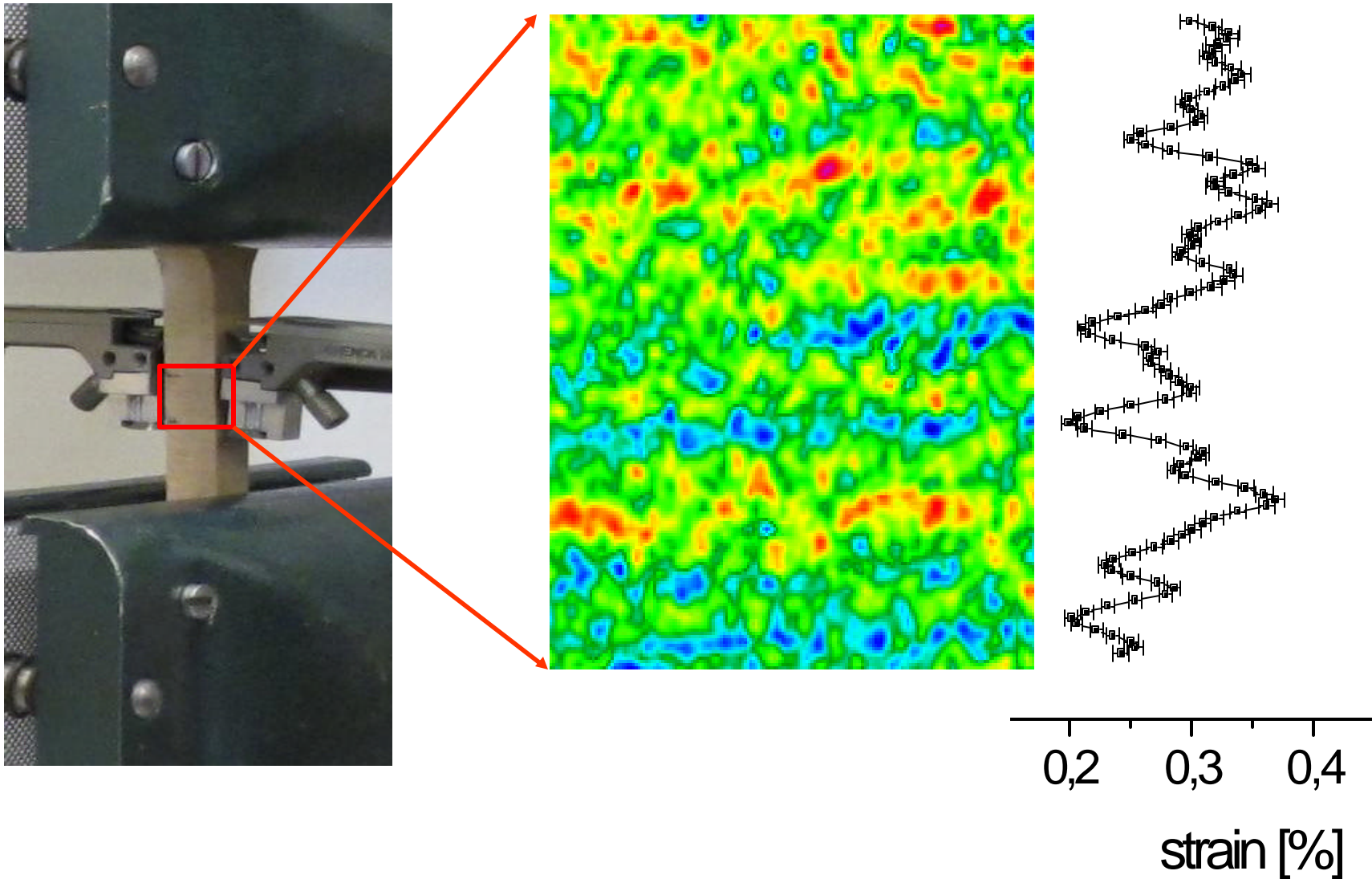
0.1942

0.1382

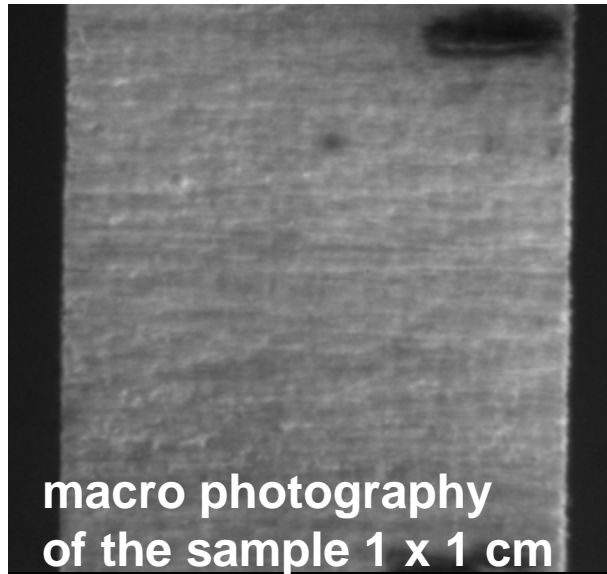
0.0821



Local strain field in the tensile test

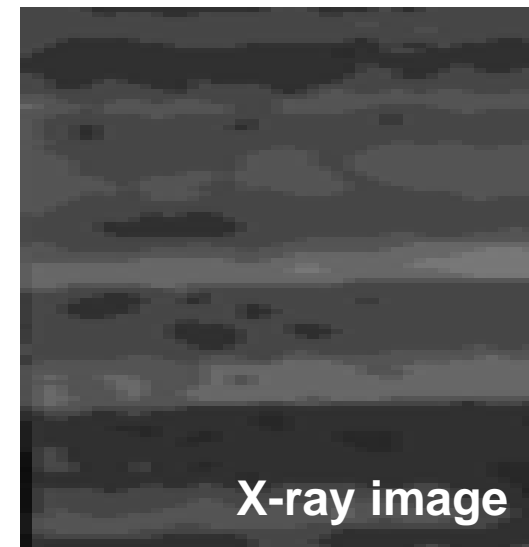
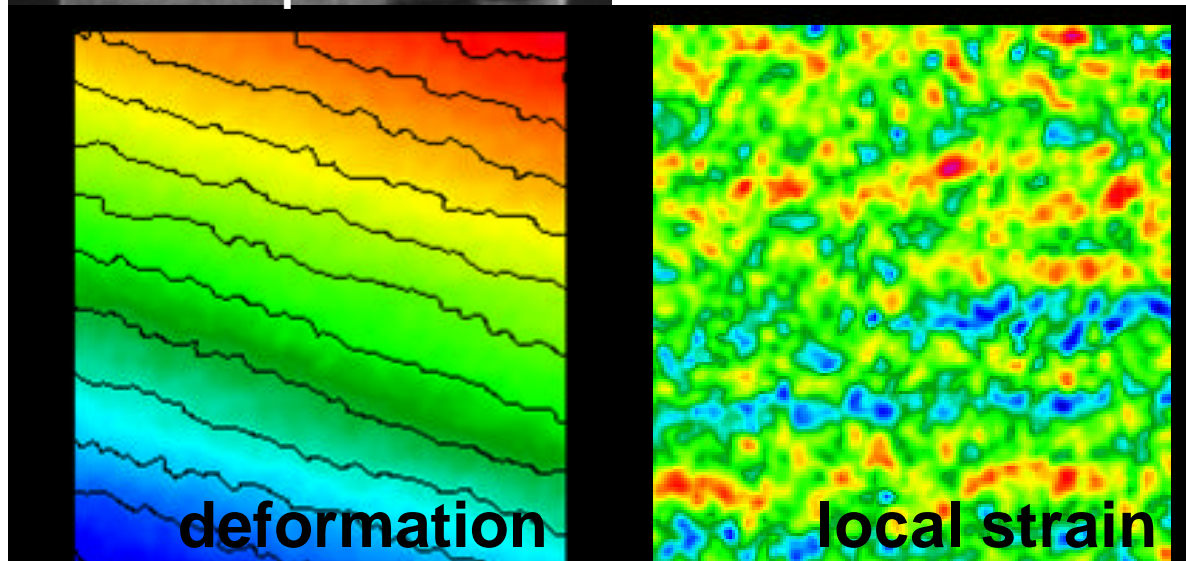


The tensile test - **conclusions**

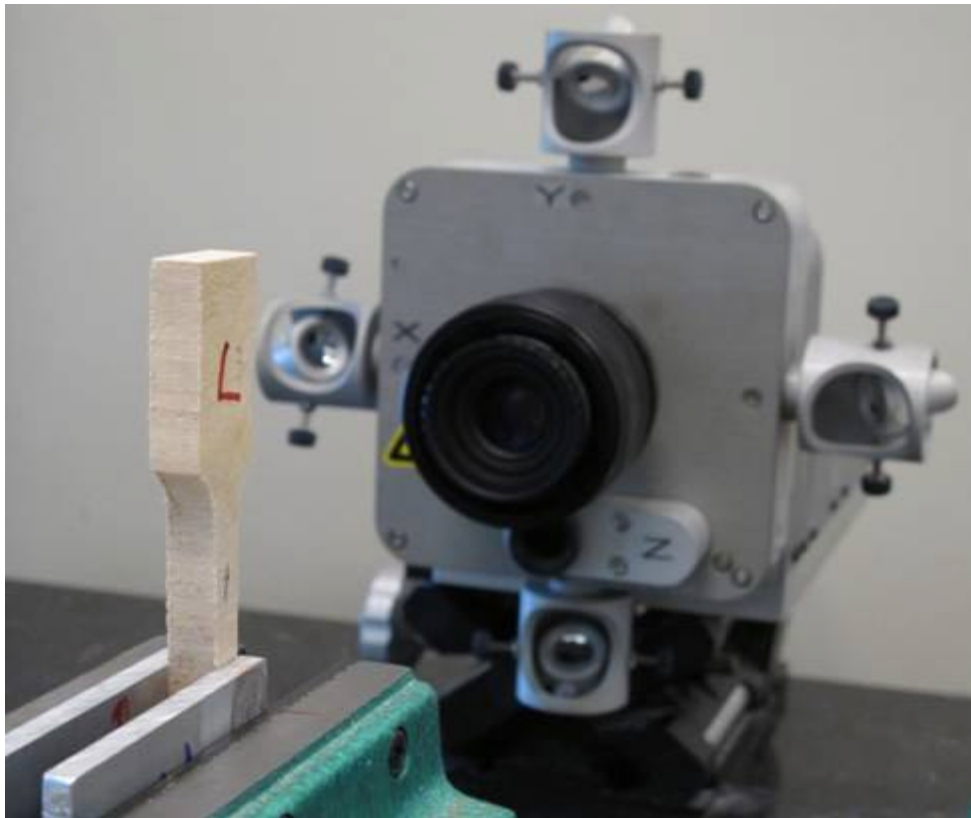


Sum of the local strains is equal to the total strain of the specimen

An excellent correlation between the local strain field and the growth ring structure of the wood is observed



Shrinkage test (lime wood)



The specimen was pre-conditioned for 24h at 80% RH, $T=20^{\circ}\text{C}$

Measuring conditions:
 $T = 20^{\circ}\text{C}$
RH = 20%

Shrinkage on drying of the specimen was monitored during 15 hours

Displ. γ
(mm)

0.0020

-0.0013

-0.0045

-0.0077

-0.0110

-0.0143

-0.0175

-0.0208

-0.0240

Strain γ
(Technical %)

-0.0500

-0.1005

-0.1510

-0.2015

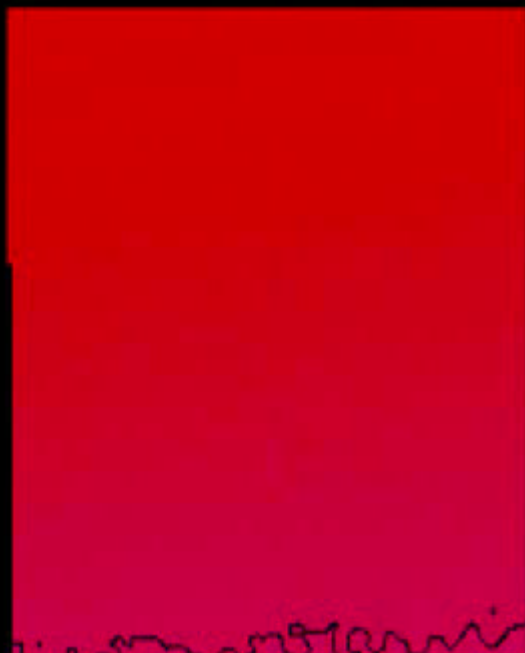
-0.2520

-0.3025

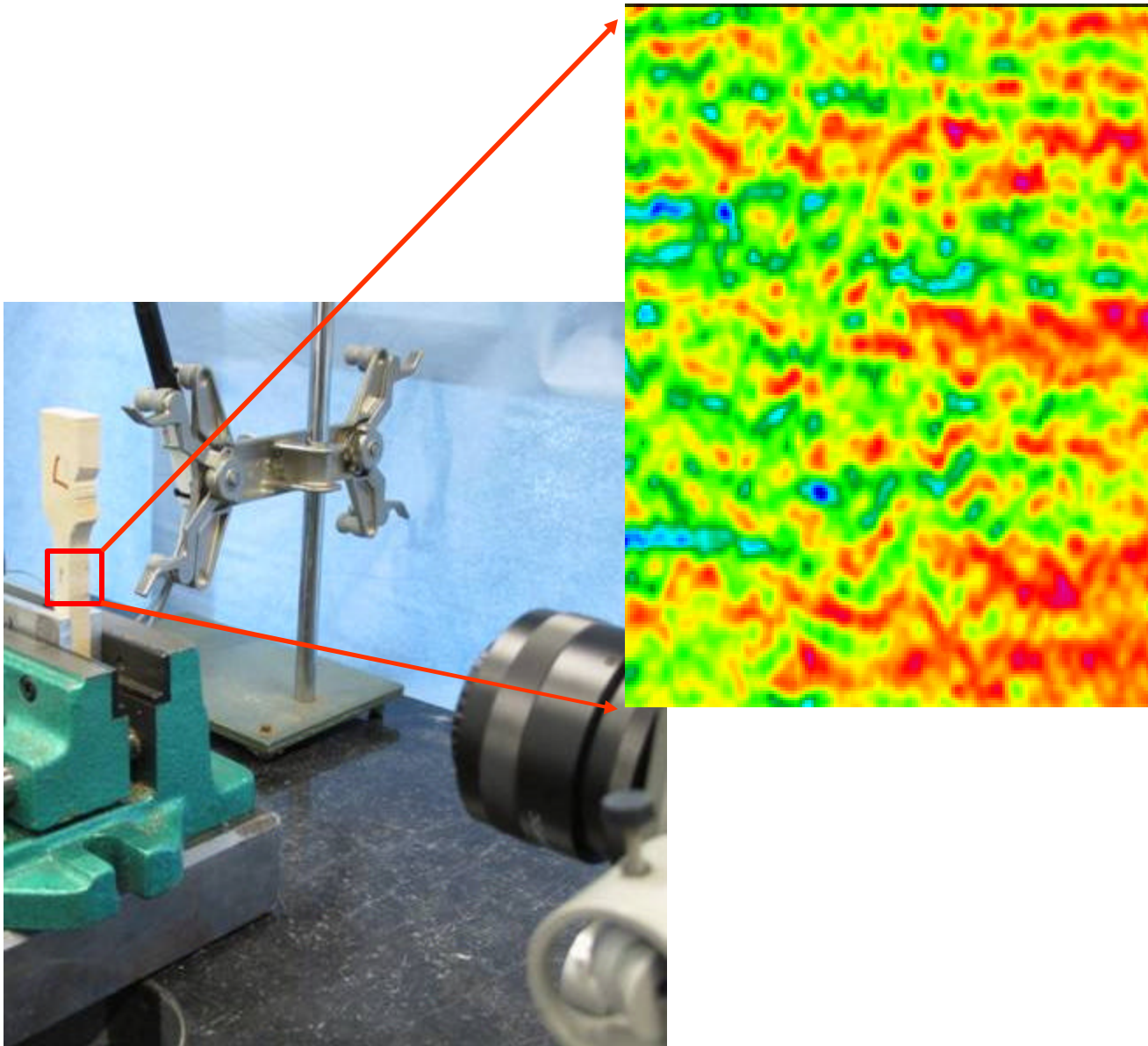
-0.3530

-0.4035

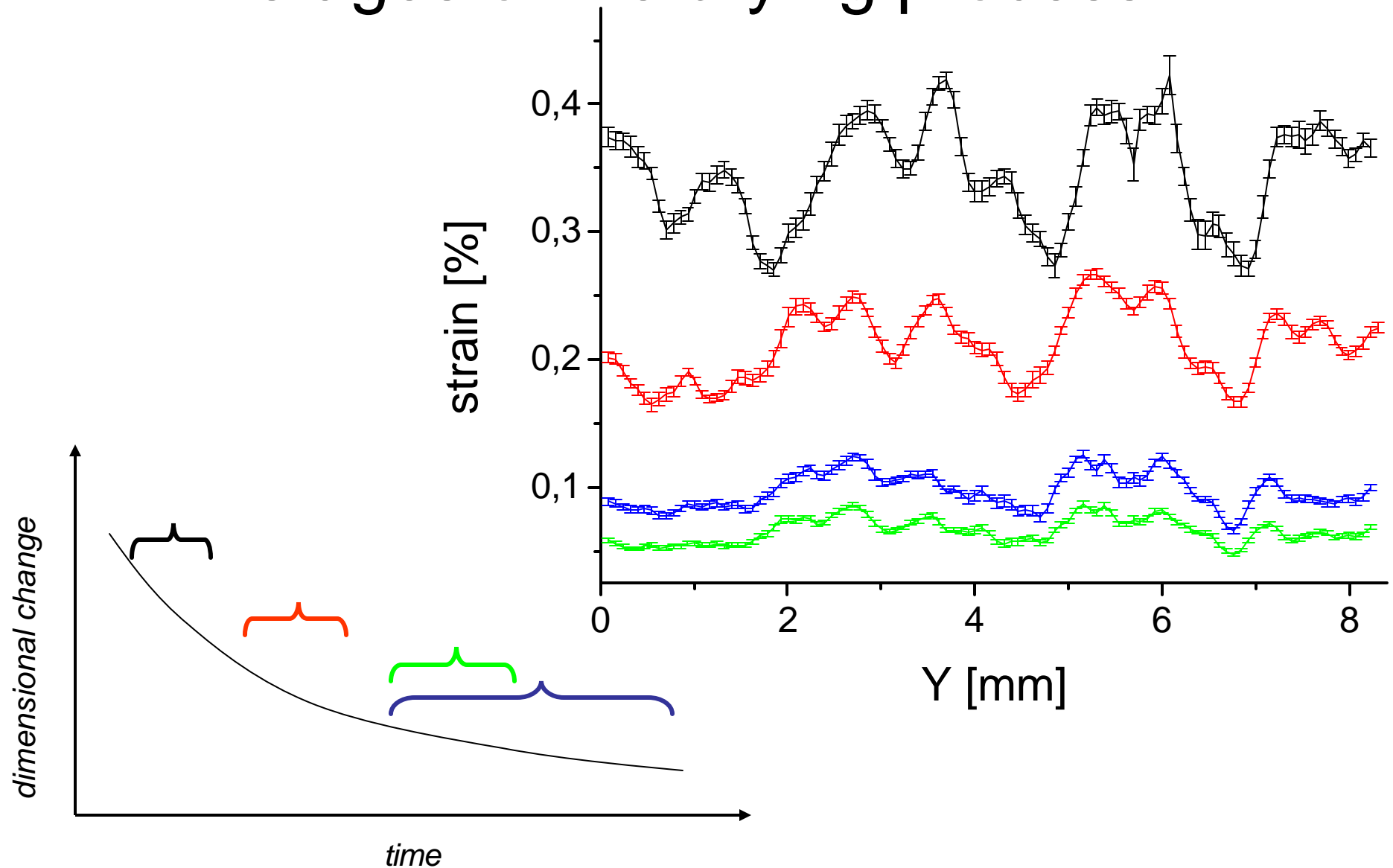
-0.4540



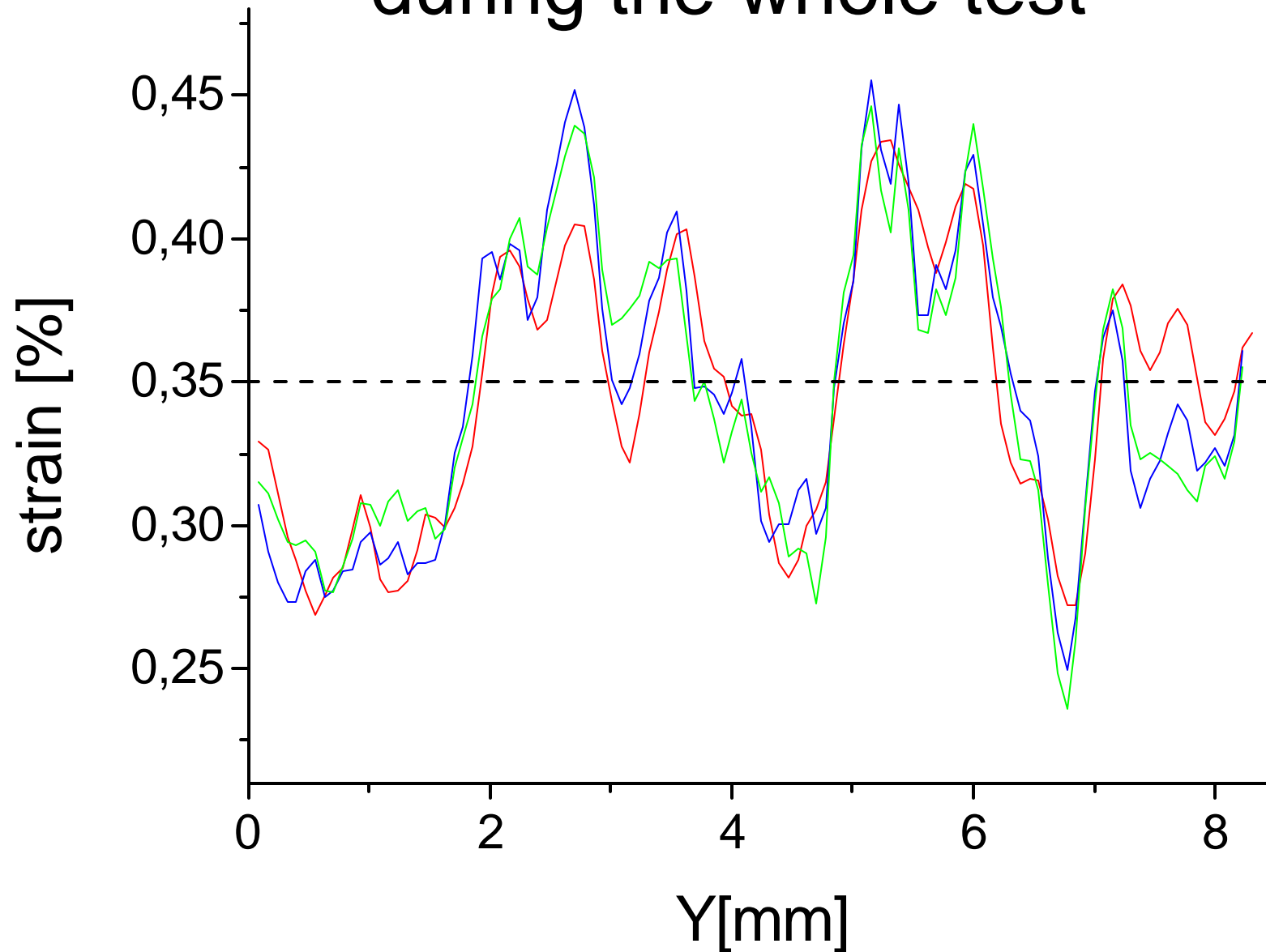
Local strain field in the shrinkage test



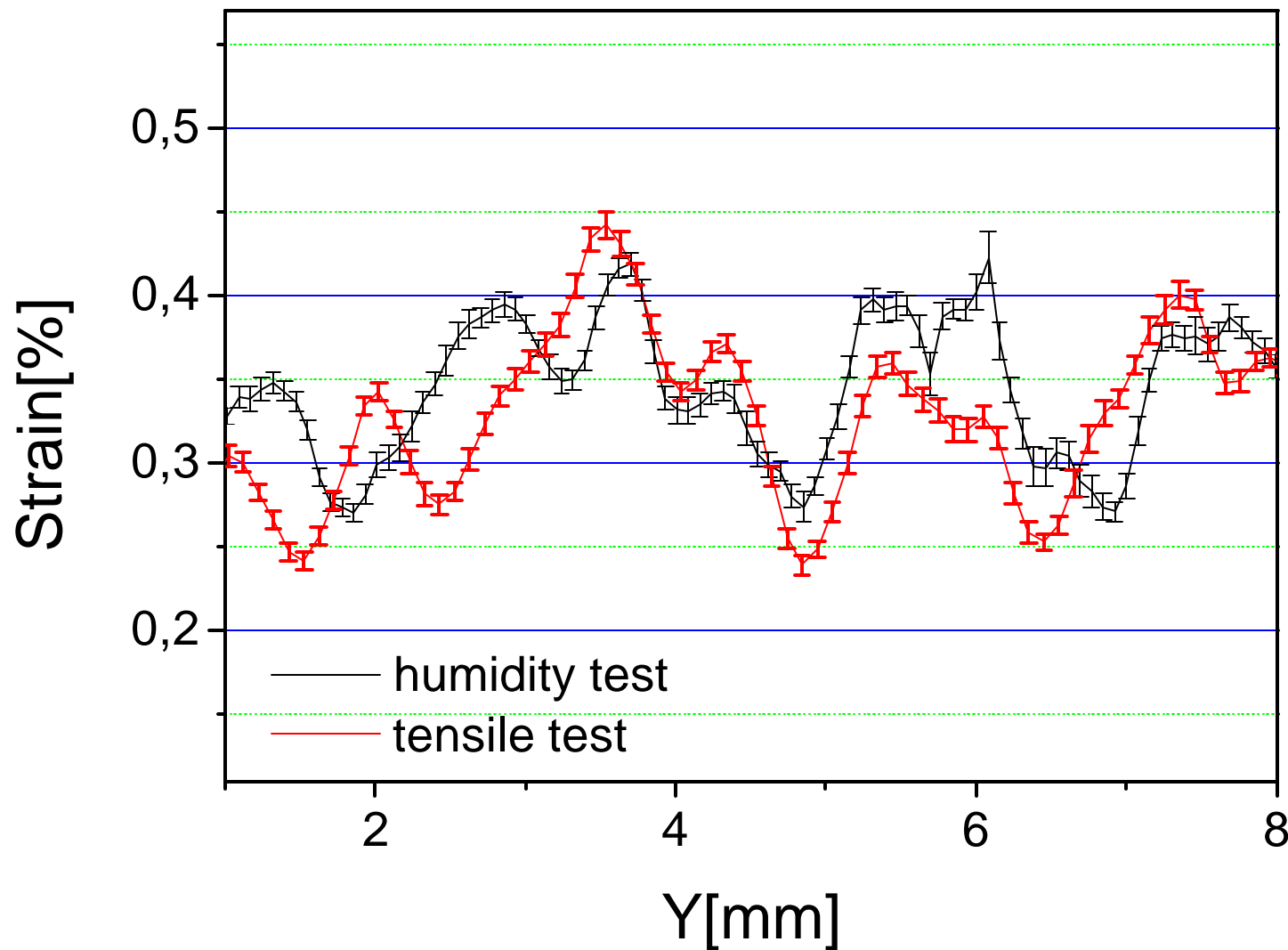
Local strain fields at consecutive stages of the drying process



Normalised strains across the wood during the whole test



Maximum local strain is critical value
accounting for damage



Monitoring the local strain patterns - conclusions

The maximal and minimal local strains **are equal** in mechanical and humidity tests

The mechanical fatigue testing is **suitable** for mimicking cyclic dimensional response of wood to humidity variations

The above observations need to be confirmed for wood supports **other than lime**, especially poplar and oak

Next step - the allowable RH variations

Starting point: RH-related wood movement of around 0.2%, averaged over many growth rings, is a critical value below which no microdamage in the decorative layer is observed up to 36.000 cycles

The question: how does this critical strain translates into the allowable RH variation?