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Stress analysis of flexible glass in a large deformation test setup

W. Langgemach

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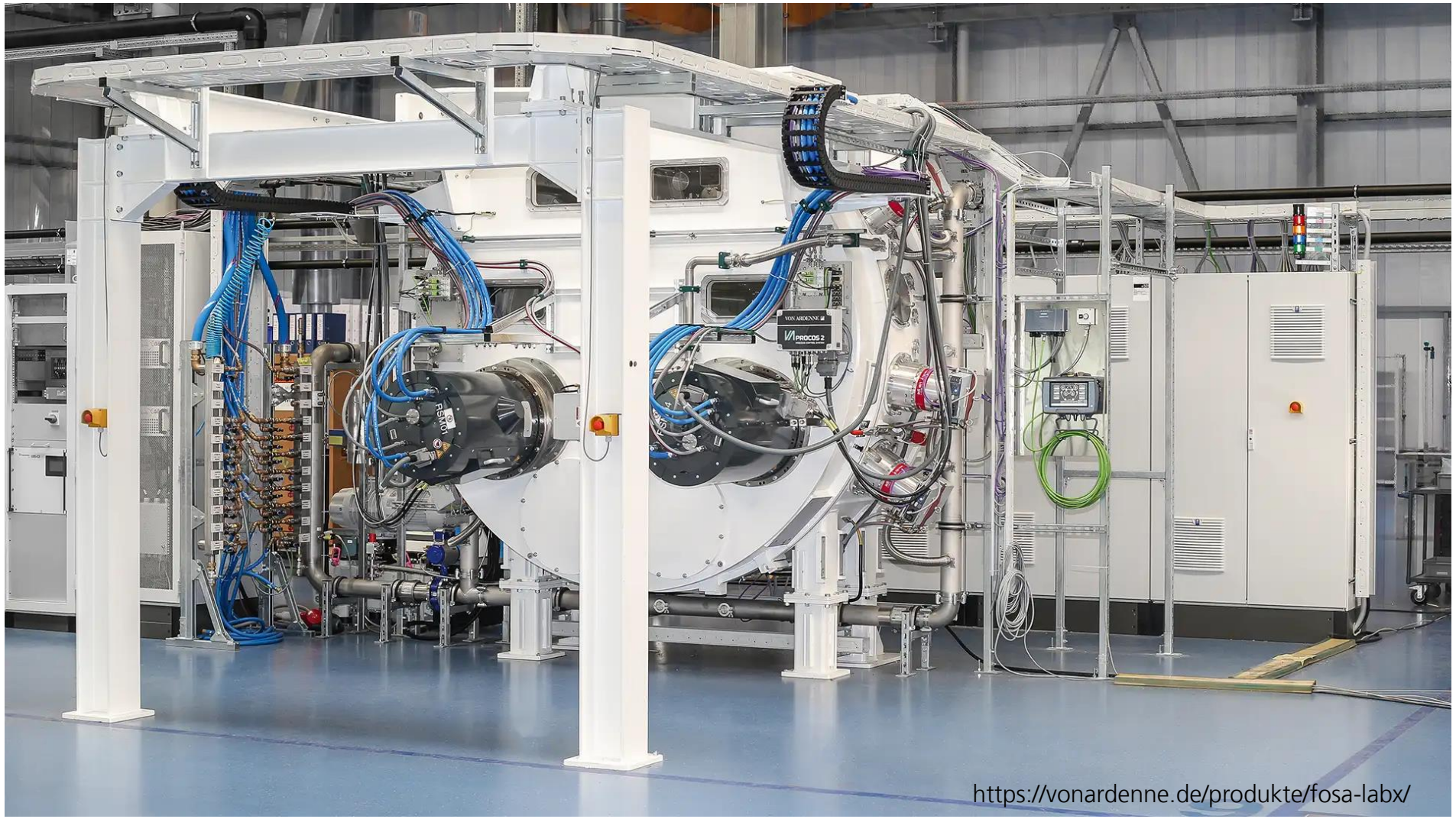
Flexible glass with thicknesses below 100 µm has outstanding properties:

- Low surface roughness
- Outstanding barrier properties
- …

… it is, however, still brittle.

Fosa LabX – Roll-to-roll pilot coating machine for flexible glass



https://vonardenne.de/produkte/fosa-labx/

VON ARDENNE

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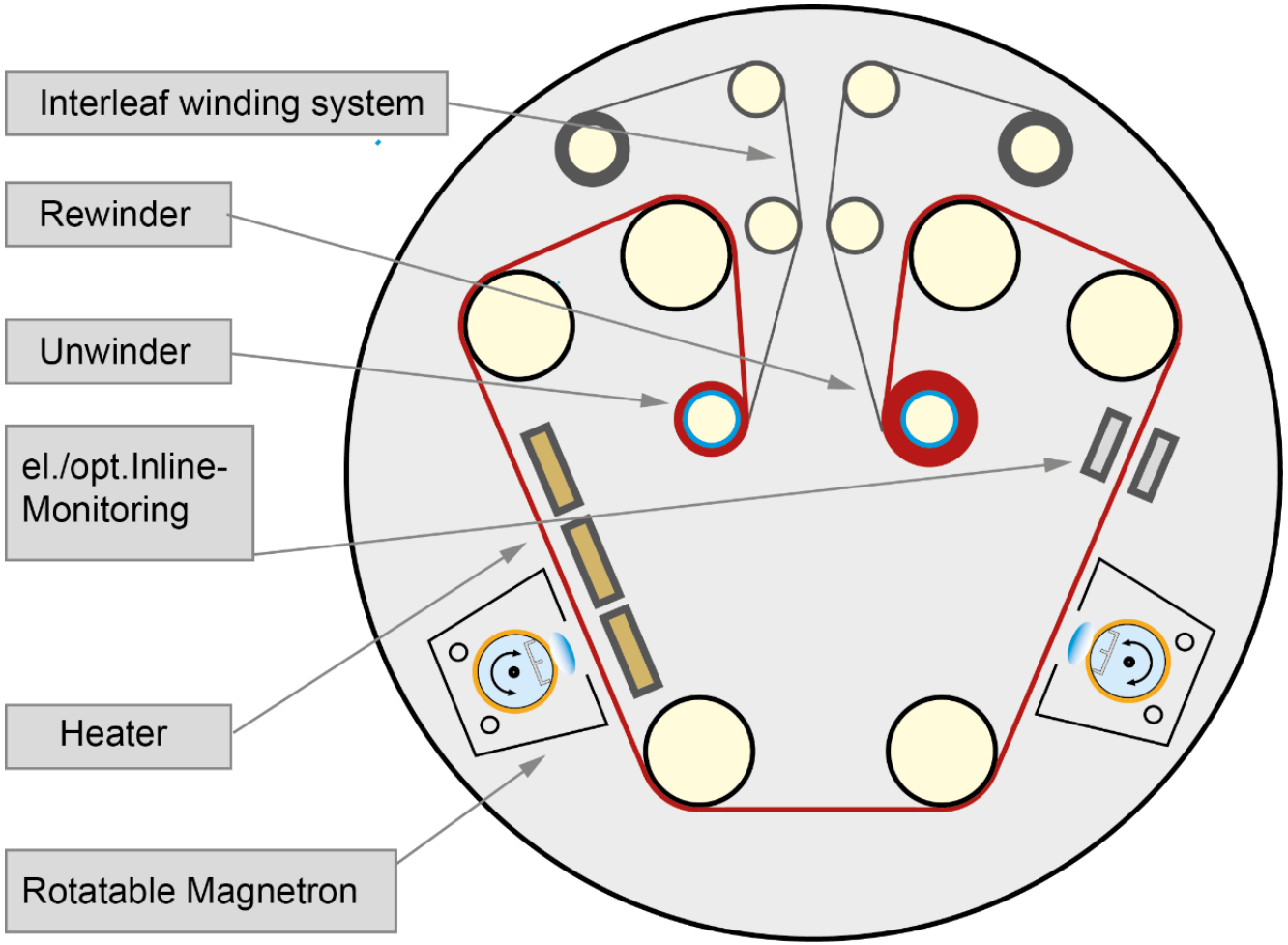
Fosa LabX – Roll-to-roll pilot coating machine for flexible glass



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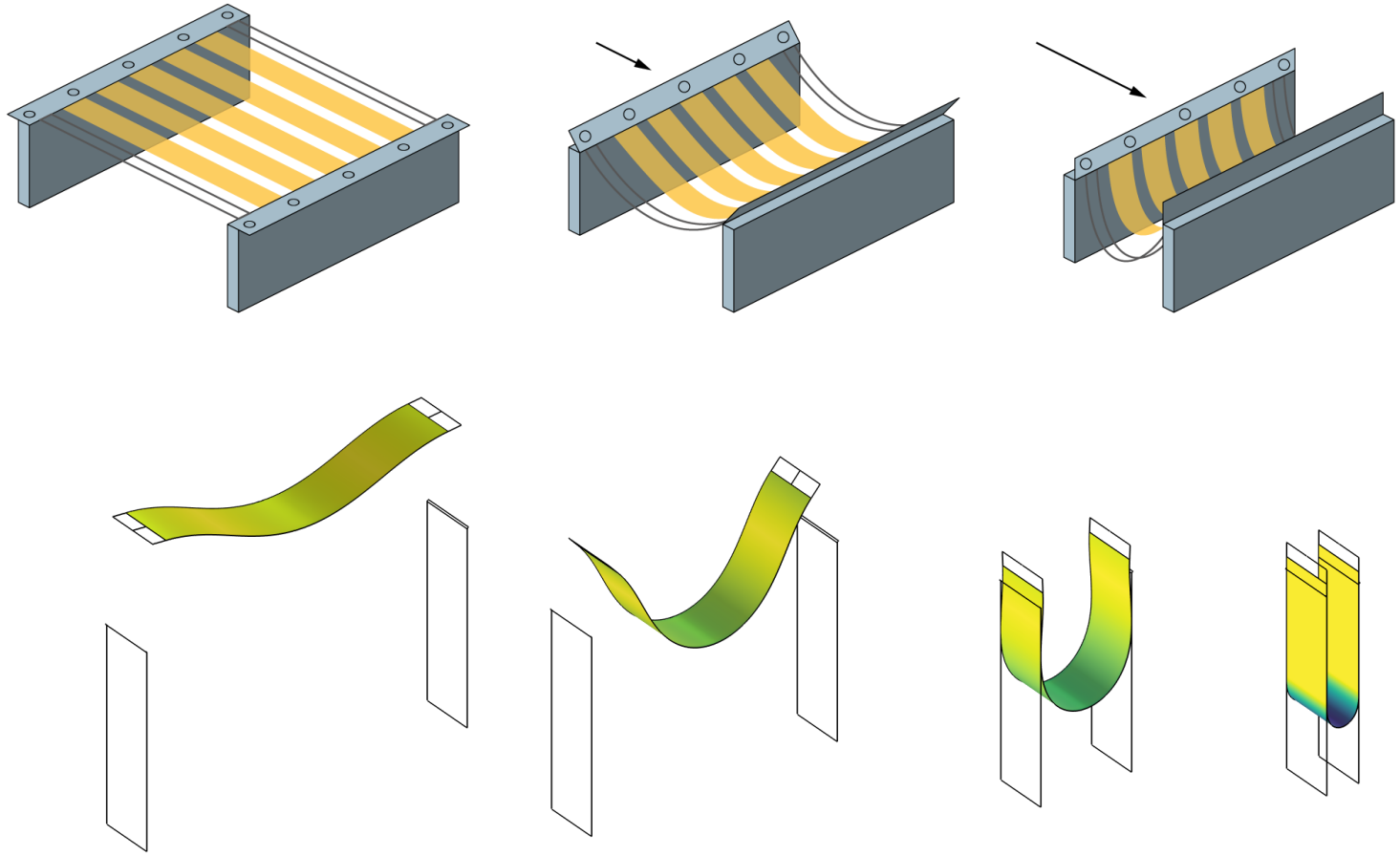
Newly developed fatigue test setup using a U-Shape Folding Tester by Bayflex solutions (endurance test machine).
→ Customized for flexible glass testing with 3D printed specimen holders

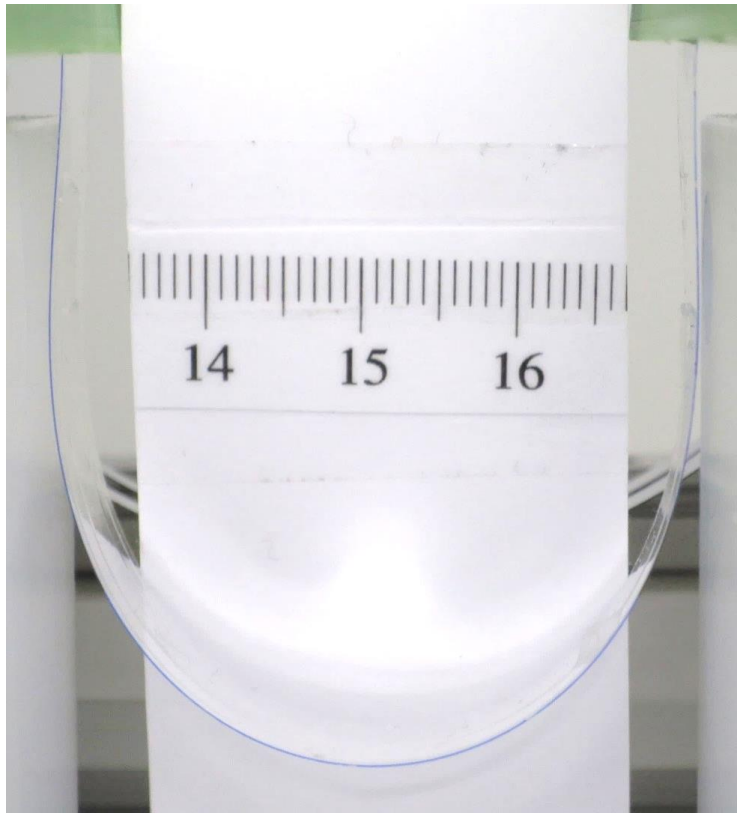
U-Shape folding test using an endurance testing machine

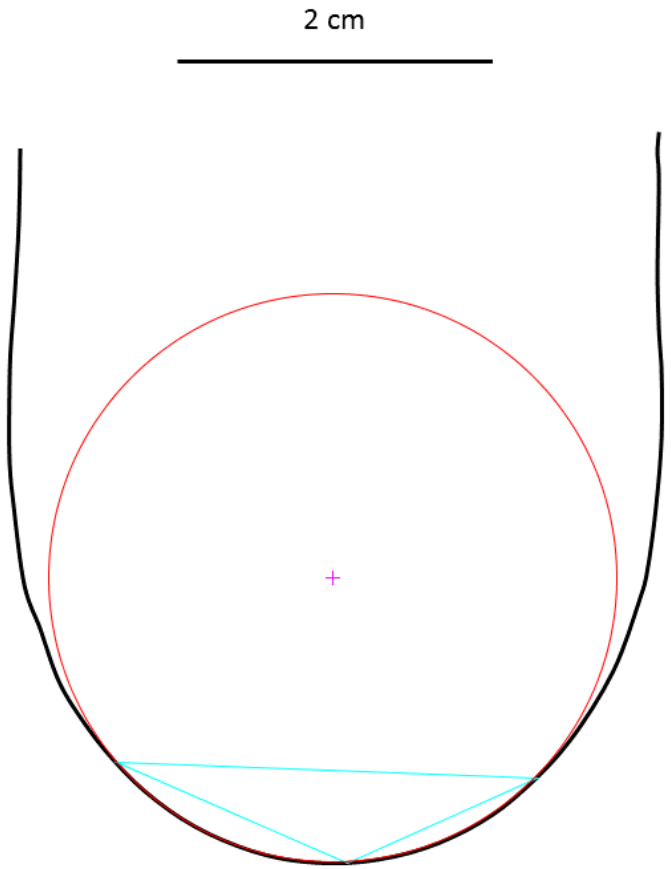


Two phases of deformation:

1. Horizontal state into drop-like form
2. U-Shape deformation with wall contact

Estimation of the bending radius from frontal photographs





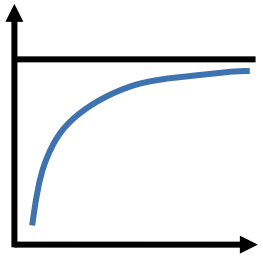
Assuming pure bending:

$$\sigma_{max} = \frac{E \cdot t}{2R}$$

σ_{max} … Maximum stress
E … Young's modulus
t … Glass thickness
R … bending radius

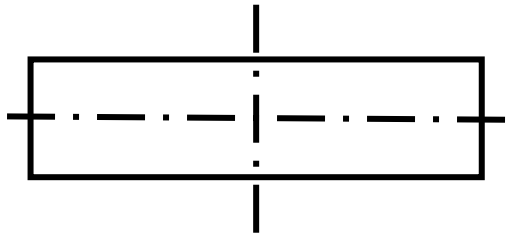
COMSOL Simulation of sample deformation

Structural mechanics module



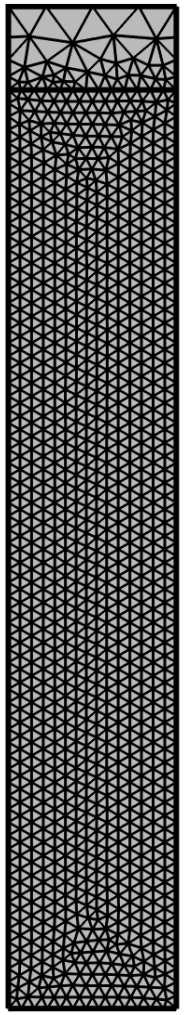
Stationary non-linear study

- Large geometric deformation
- Contact
- Evaluation of first principal stress



Simulation details

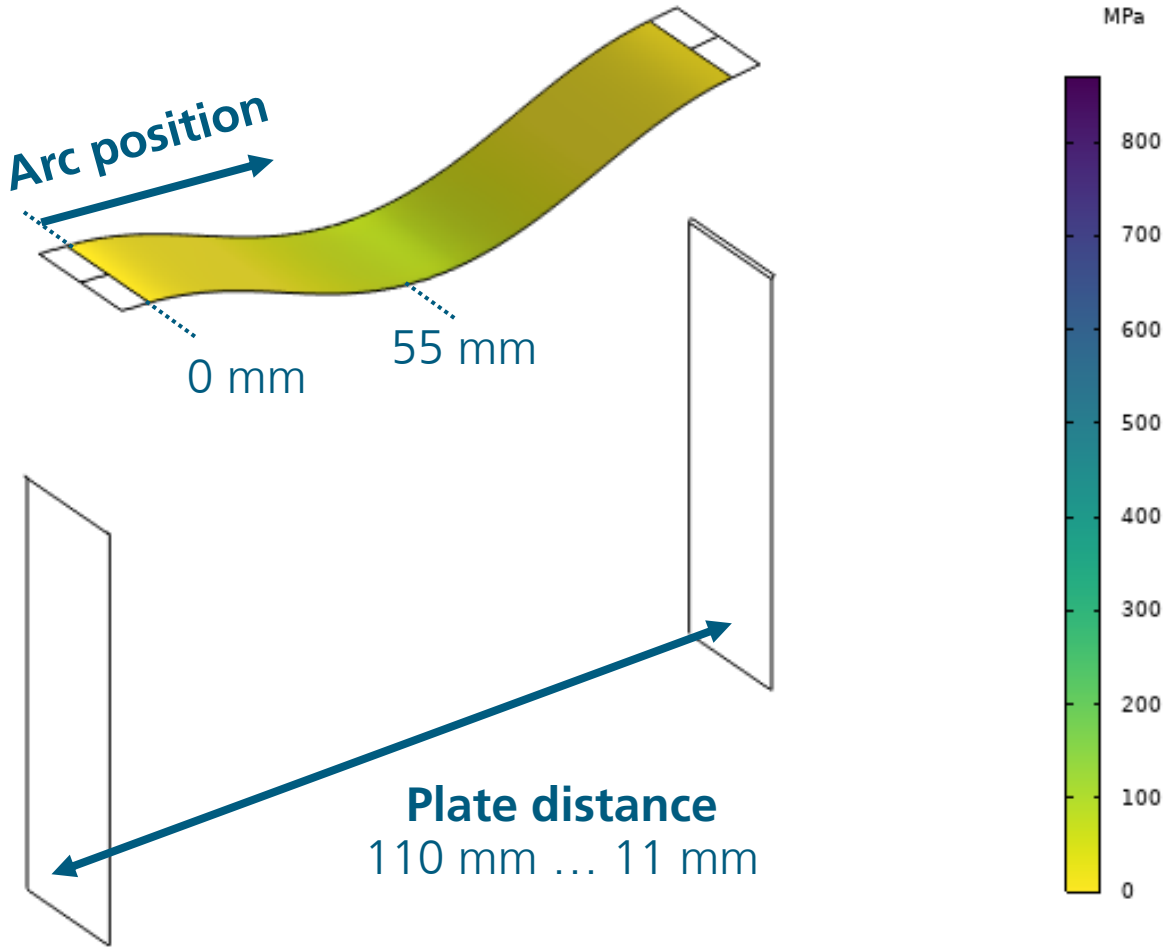
- Quarter of the sample
- Shell structure
- Triangular mesh elements



Clarification of terms

Sample dimensions
20 x 120 x 0.1 mm³

Deformed part
20 x 110 x 0.1 mm³



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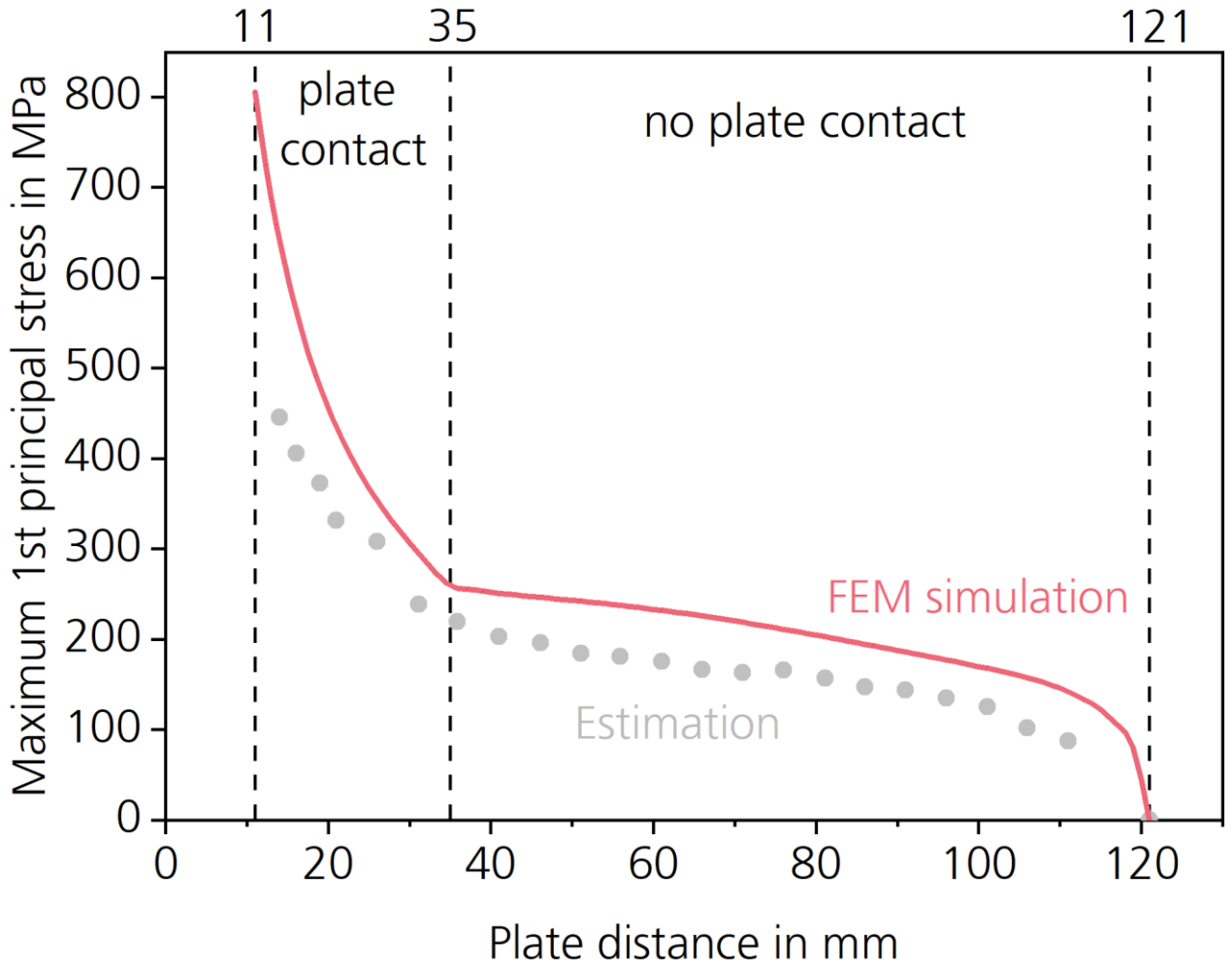
The maximum stress curve is non-linear and consists of two ranges

First principal stress



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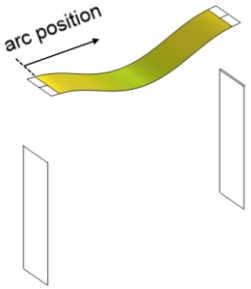
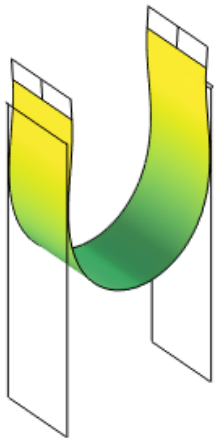
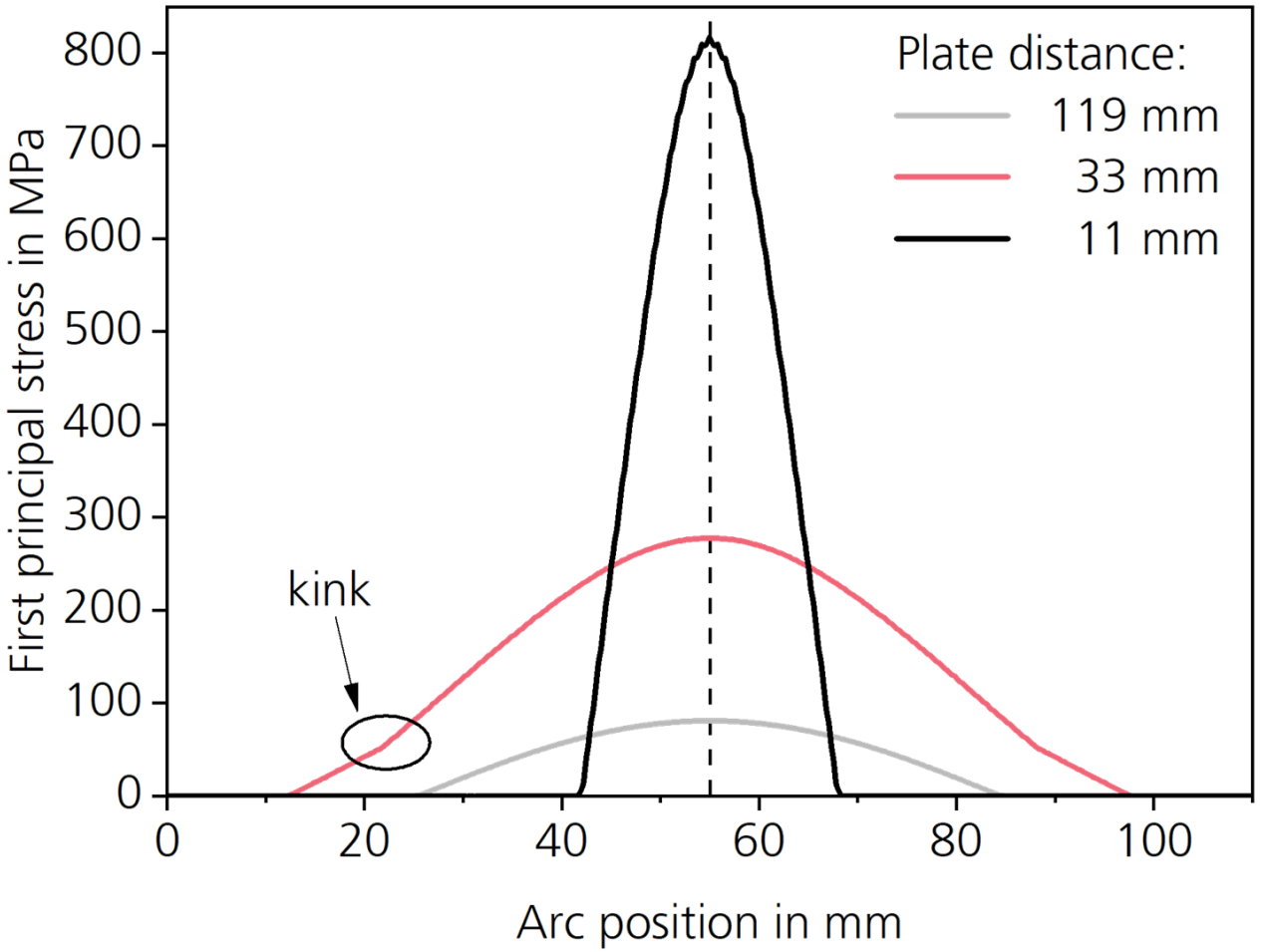
Analysis of the stress distribution in the sample

First principal stress







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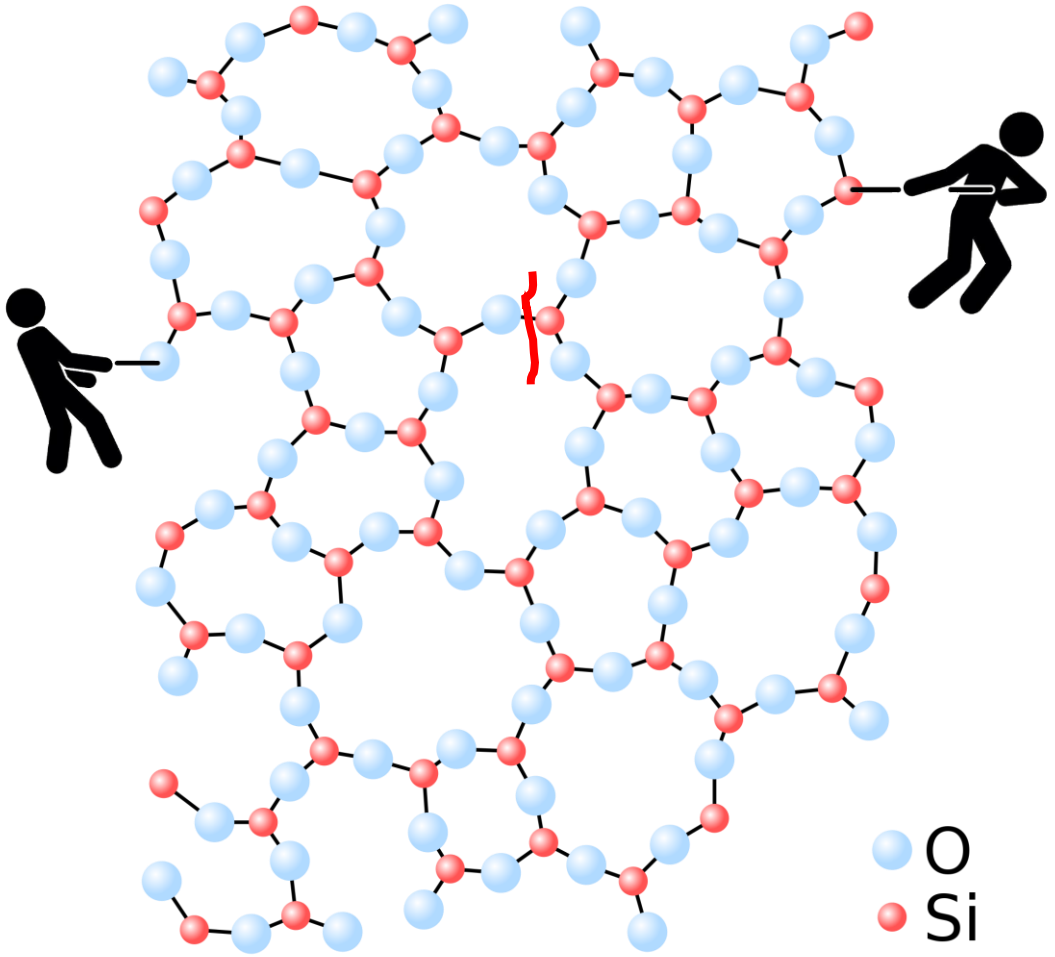
When glass breaks, atomic bonds are broken up



Glass network: Jdrewitt, Public domain, via Wikimedia Commons

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All you need to know about glass strength (today)

1. Failure at the weakest link
2. Glass strength is statistically distributed, following the Weibull distribution
3. Compressive strength is 10x higher than the tensile strength

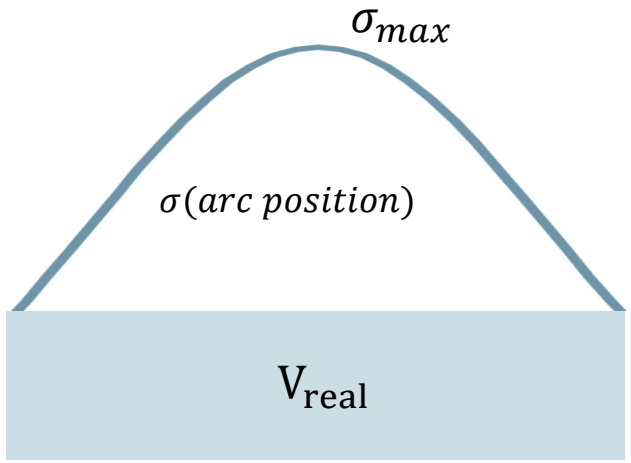
Icons by Vecteezy

Effective length of the sample

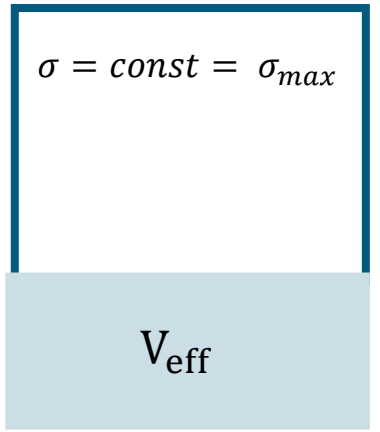
Fracture mechanics for professionals ☺

Weibull:

$$F(\sigma) = 1 - e^{-\left(\frac{\sigma}{\sigma_{crit}}\right)^{m}}$$



Equal failure probability



$$V_{eff} = \int_{\sigma>0} \left(\frac{\sigma(\vec{r})}{\sigma_r}\right)^{m} dV$$

constant cross-section

$$l_{eff} = \int_{\sigma>0} \left(\frac{\sigma(l)}{\sigma_{max}}\right)^{m} dl$$

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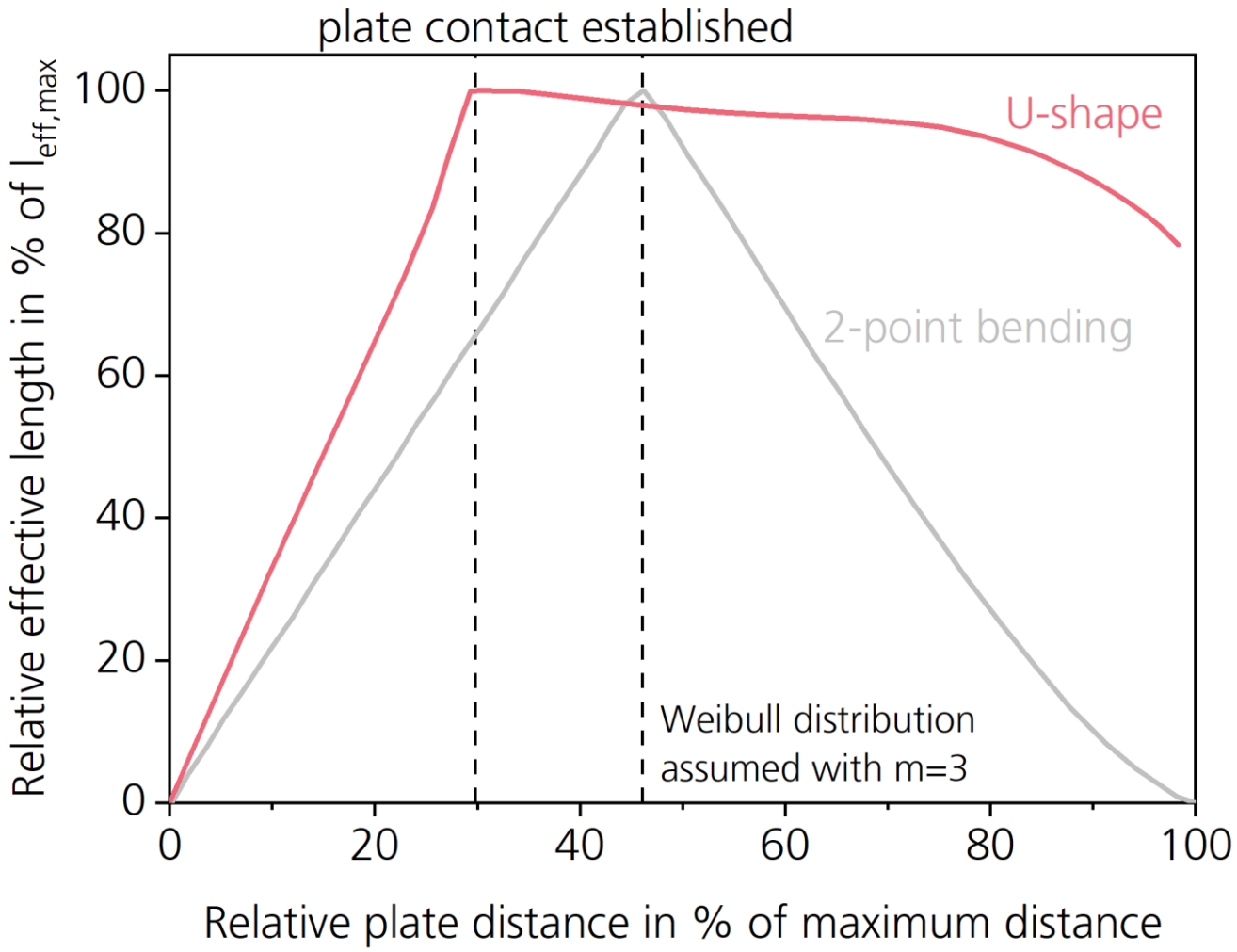
Effective length



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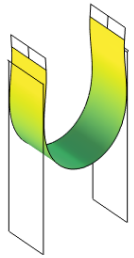
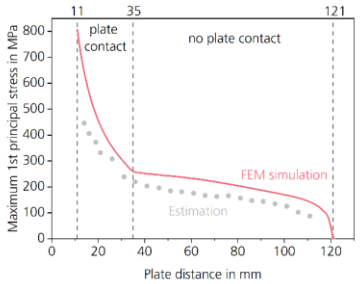
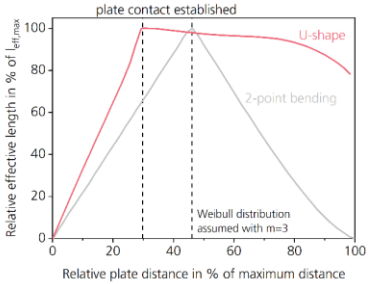
Summary



Successful non-linear simulation of the large-deformation test setup including mechanical contact



Maximum stress was underestimated when pure bending was assumed



Effective length of the new setup is advantageous compared to other existing setups

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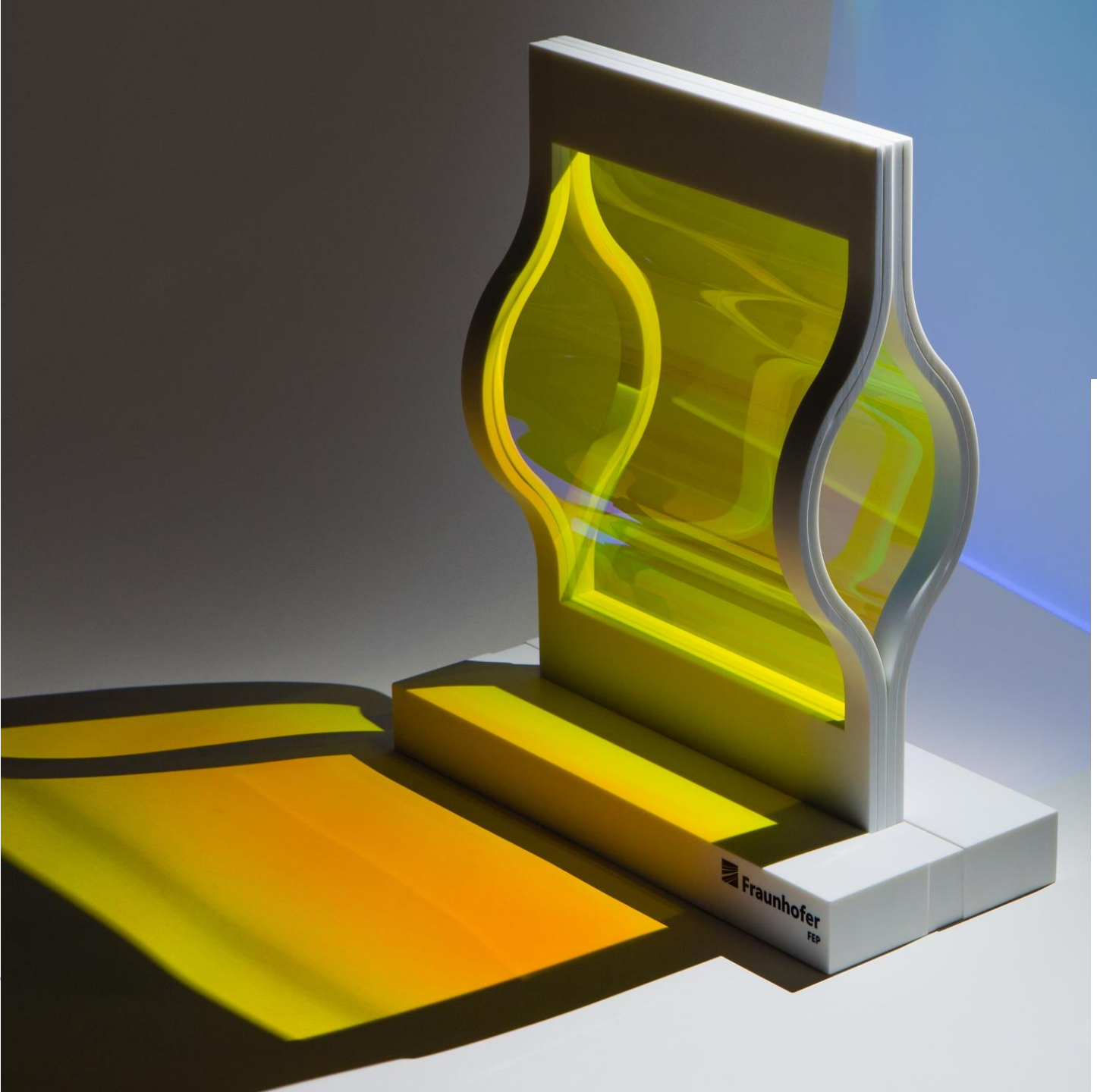

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Wiebke Langgemach

Fraunhofer FEP, Dresden

wiebke.langgemach@fep.fraunhofer.de