

# **SIO X-Ray: View inside your material with contact experiments**

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# SIO AntMan technology

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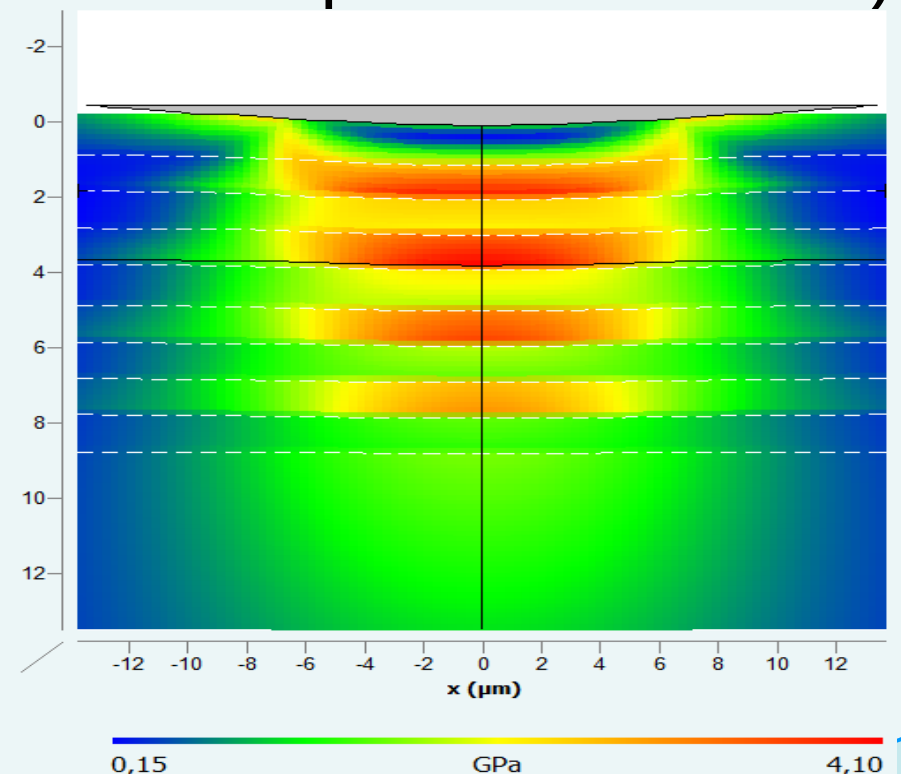
## Goal

Optimize the materials and material combinations to increase application performance to reach certain goals (e.g. longer application life time of our composite structures)

but structures are more and more complex nowadays

need computers and models,  
personal experience and rules of thumb are no longer enough

generic material parameters needed



## Goal

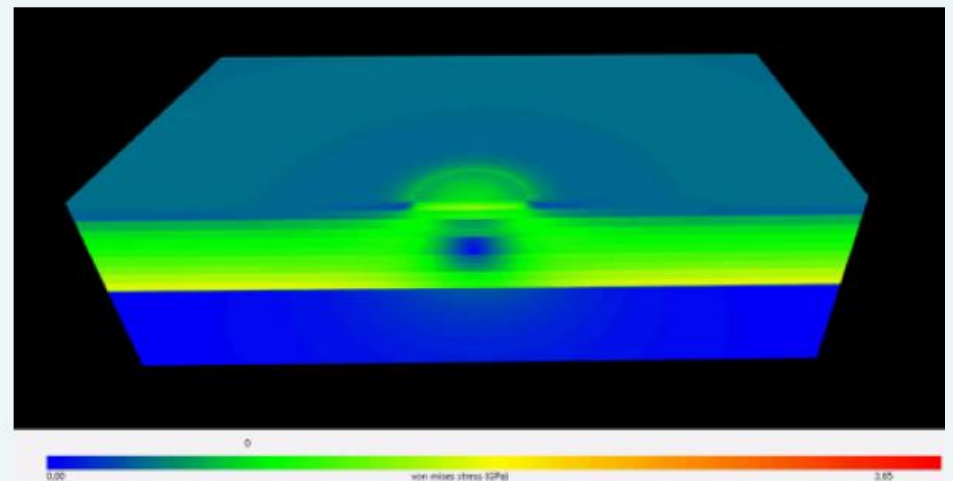
Optimize the materials and material combinations to increase application performance to reach certain goals (e.g. longer application life time of our composite structures)

**No FEM system** – closed formula calculations

but structures are more and more complex nowadays

need computers and models, personal experience and rules of thumb are no longer enough

generic material parameters needed



## Analytical models

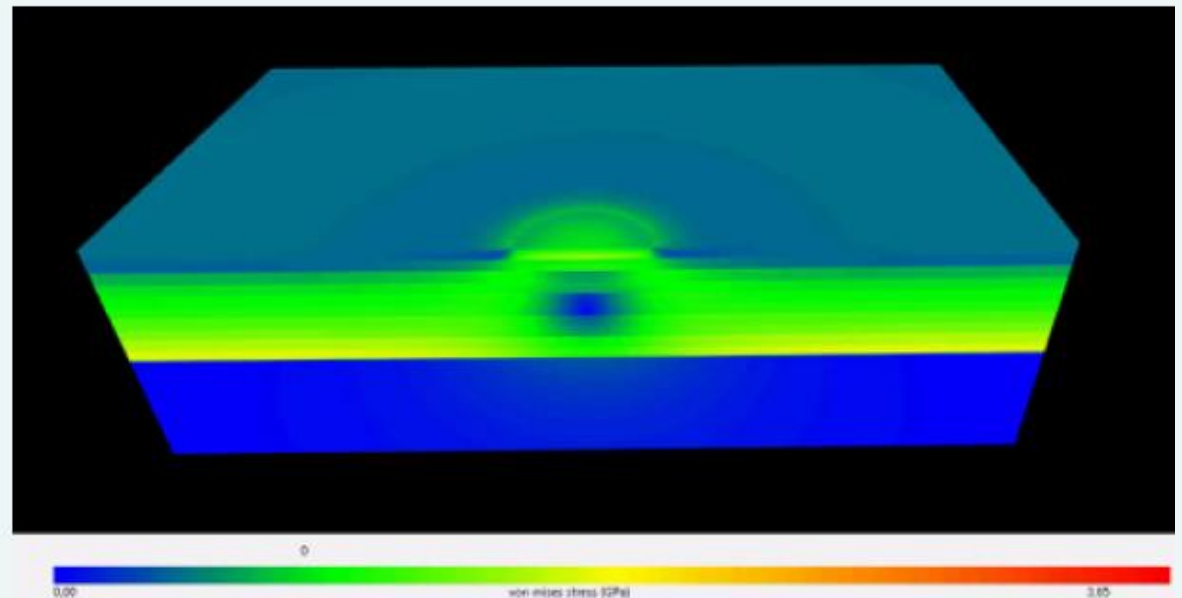
Much faster calculations possible

→ thus allows software for

experimental analysis

simulation

optimization





# Complex structures



# Complex structures



Local project with Naish International  
(<http://www.naish.com>) from 11/21/15 to 2/18/16

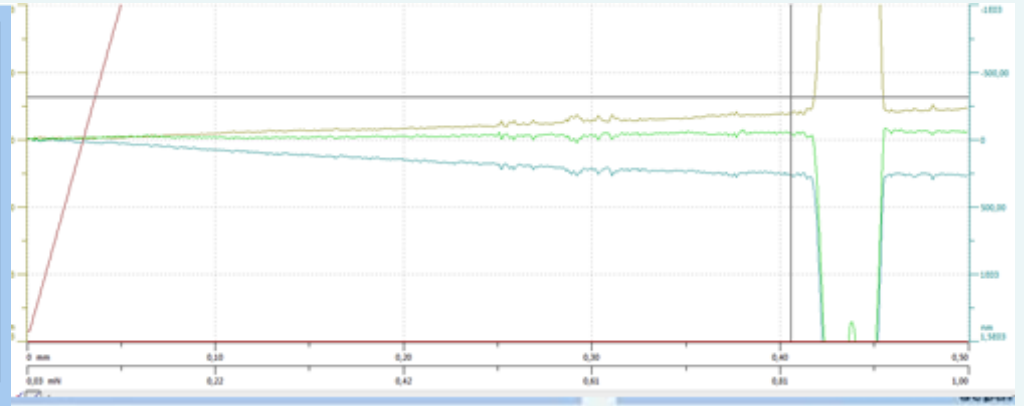
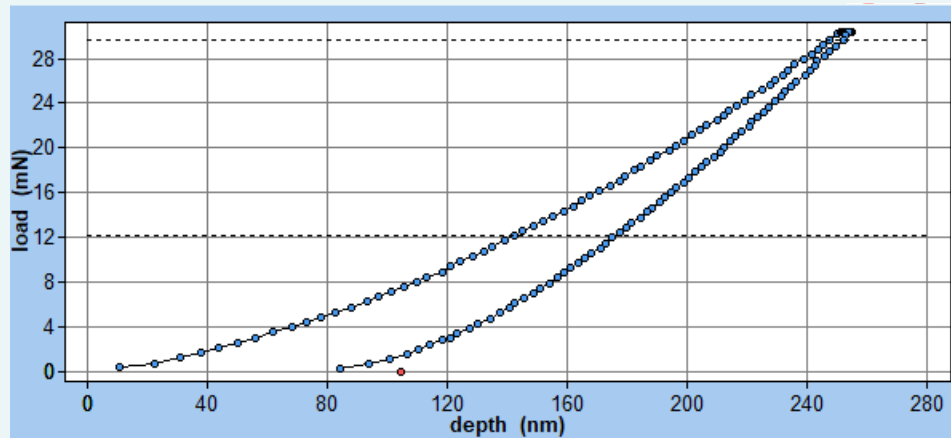


# Complex structures



# Complex structures

- use nanoindentation to get generic material parameters
- analyze more complex experiments with these parameters





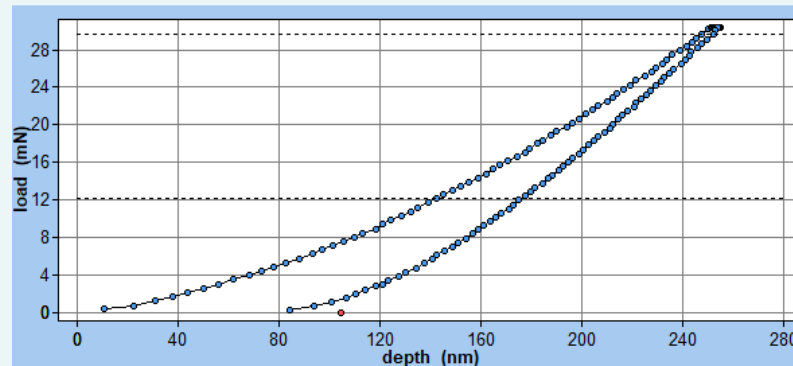
# Determination of material parameters

## Determination of physical parameters by nanoindentation

Standard analysis method (Oliver & Pharr) gives you only effective values for Young's modulus and Hardness

For measurement analysis needed:

- physical parameters like e.g. Yield Strength
- true material parameters for inhomogeneous materials

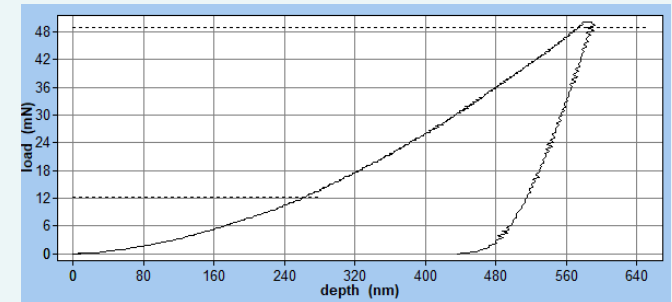


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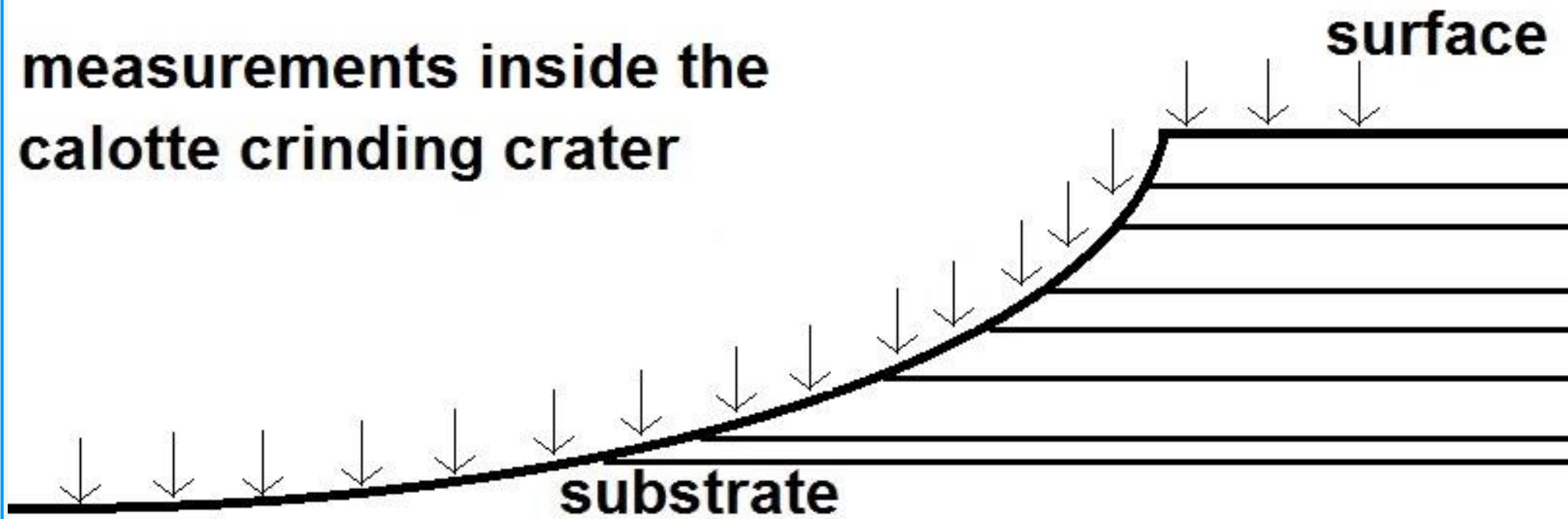
Therefore SIO has extended the standard method → Oliver & Pharr for Coatings

- for inhomogeneous materials (layered, gradients, ...)
- for time depending material behaviour (viscose, creep (HT))



Now perform a series of indentation measurements inside and outside of the crater

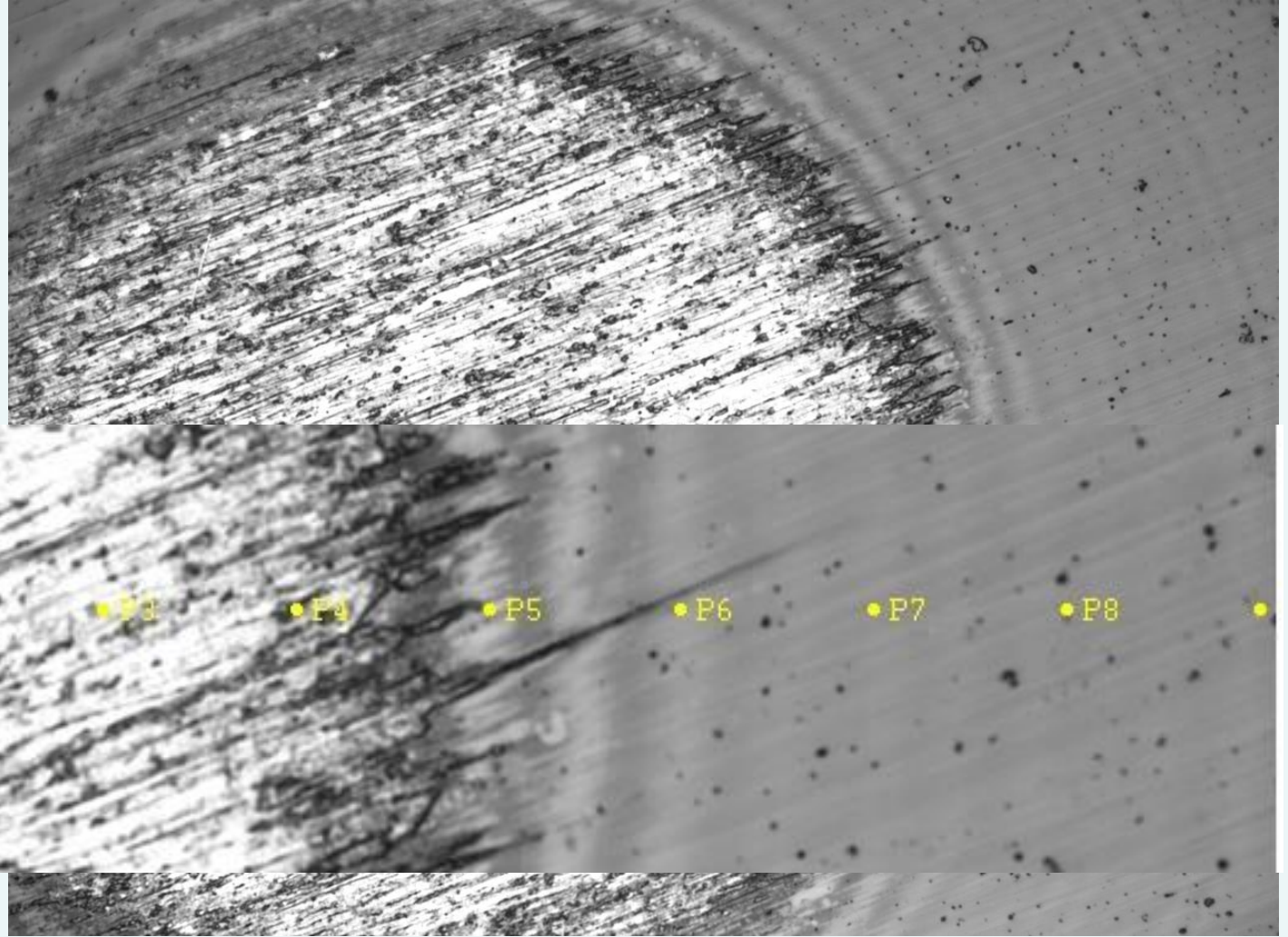
**measurements inside the  
calotte crinding crater**





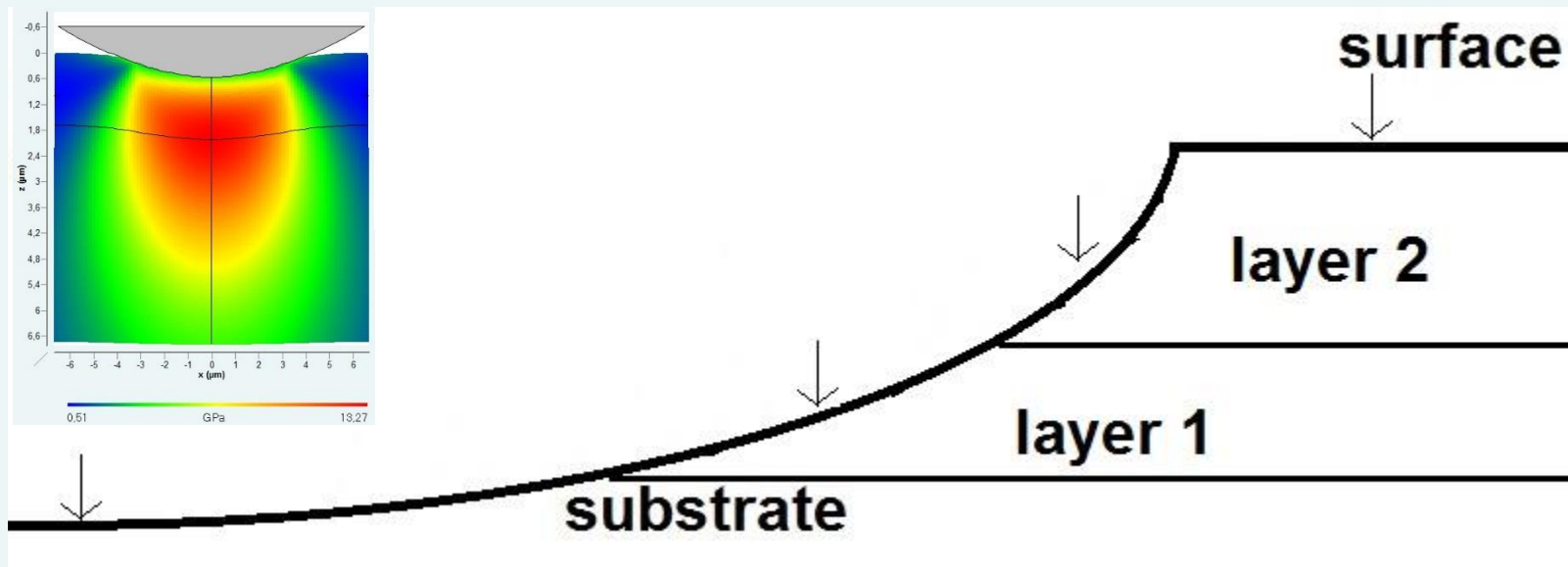
# SIO Calotte Module

Can be easily  
programmed  
in modern  
indentation  
devices



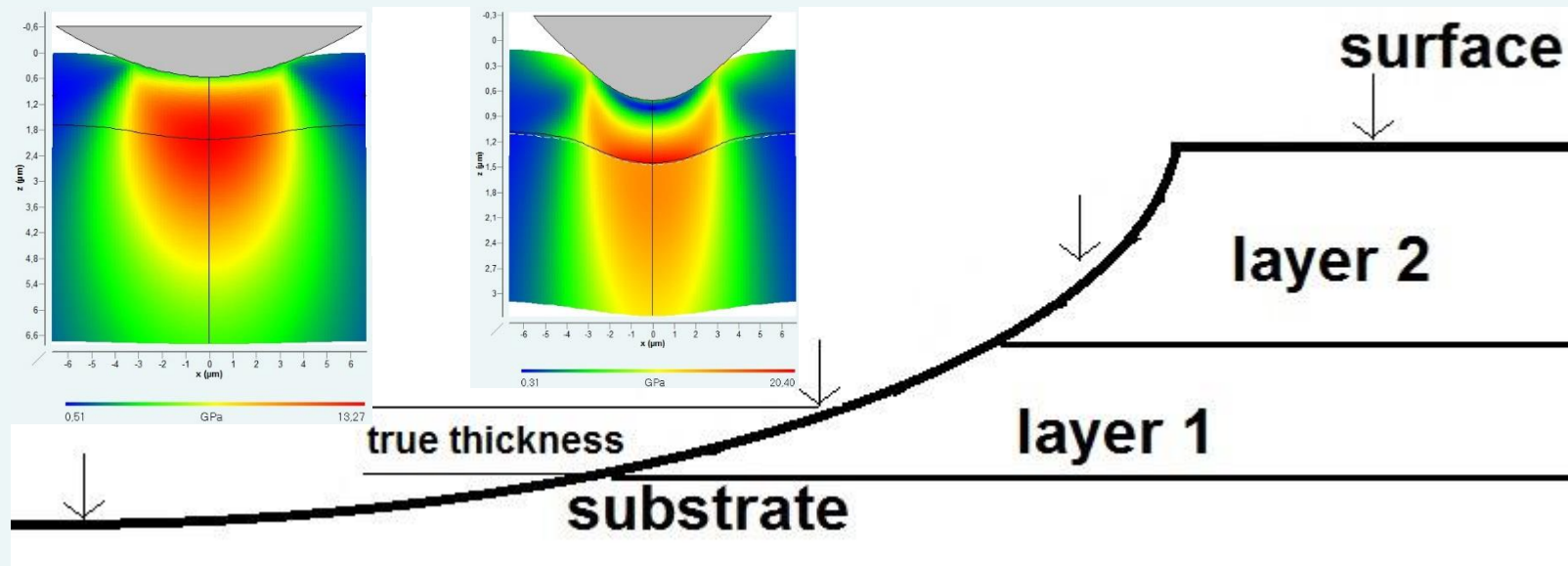
## How it works in detail

- Analysis I: substrate measurement →  $E_s$



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- Analysis II: 1  $\mu\text{m}$  thick layer 1 →  $E_1$

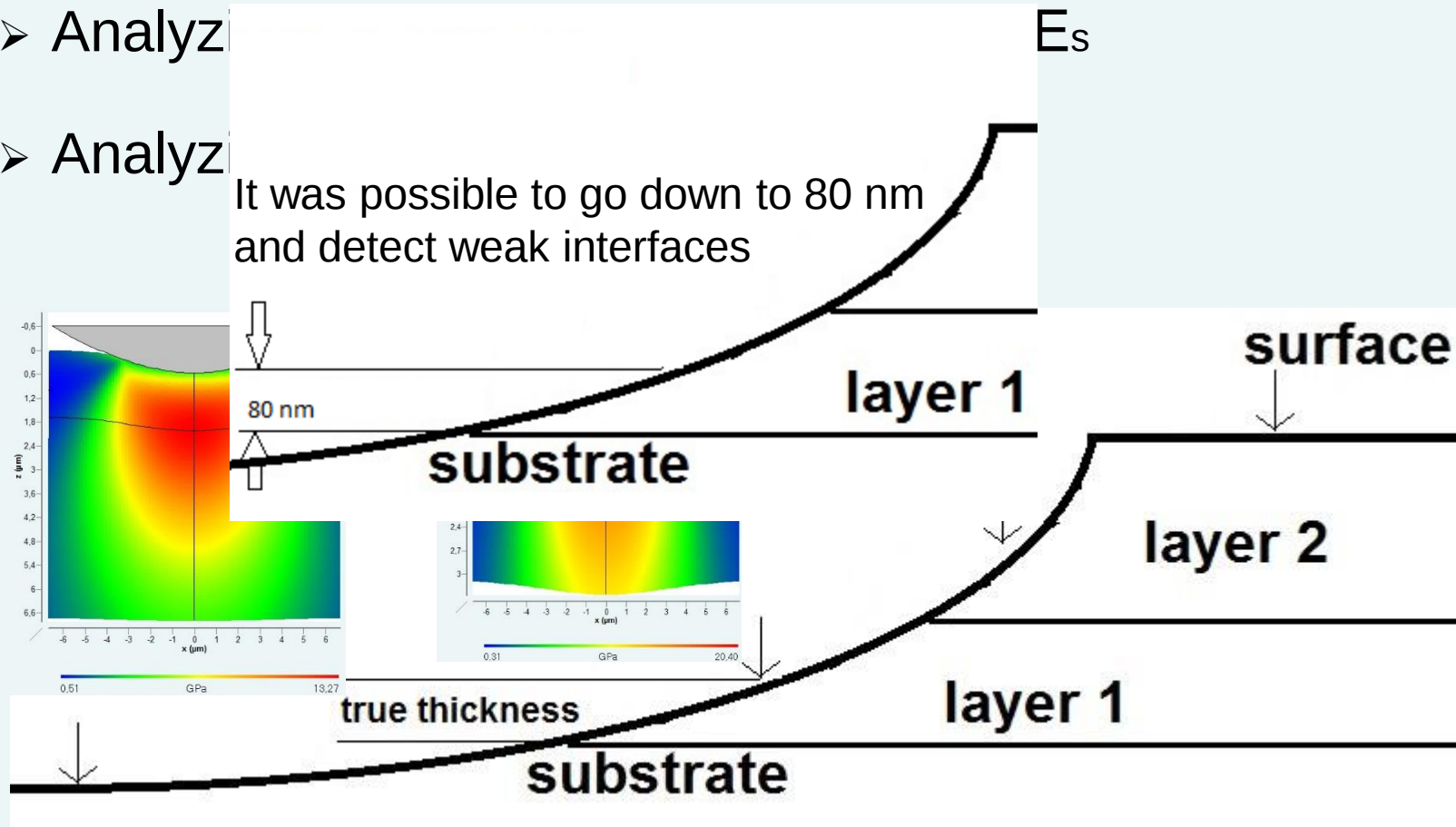


## How it works in detail

➤ Analyz

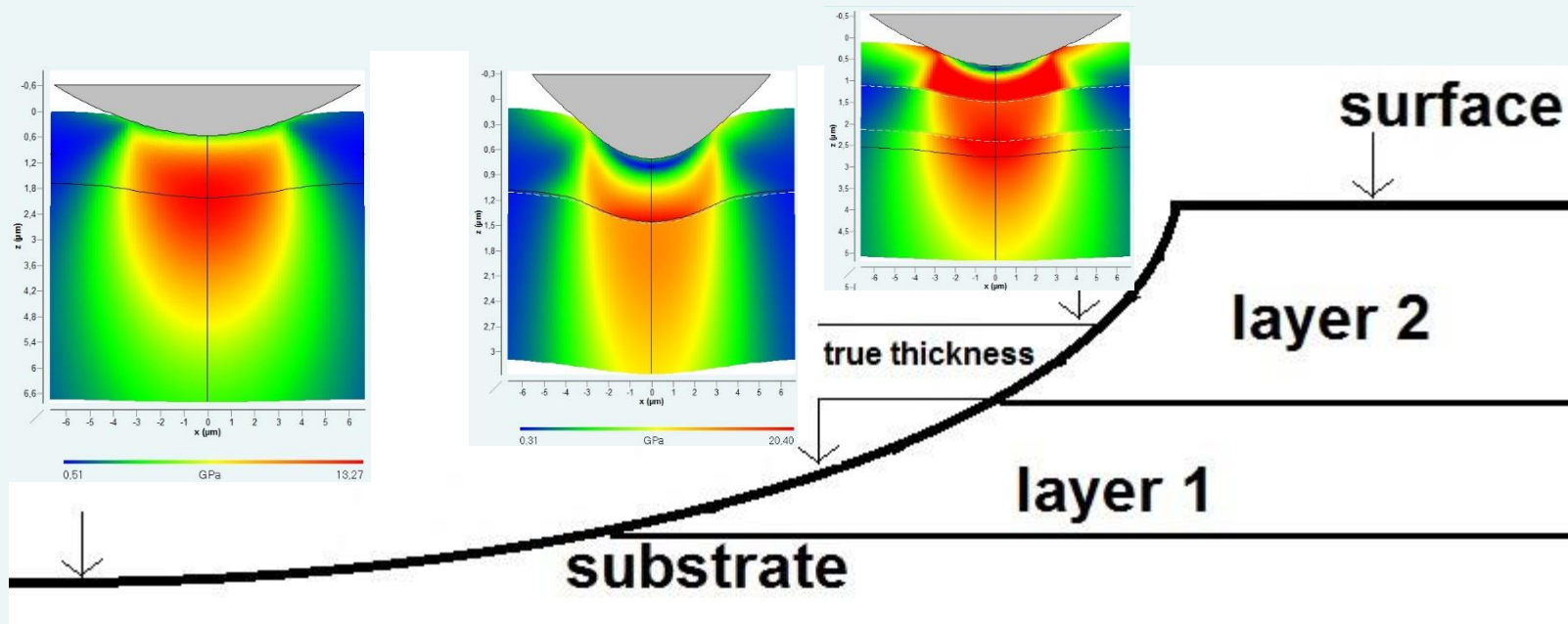
➤ Analyz

It was possible to go down to 80 nm and detect weak interfaces



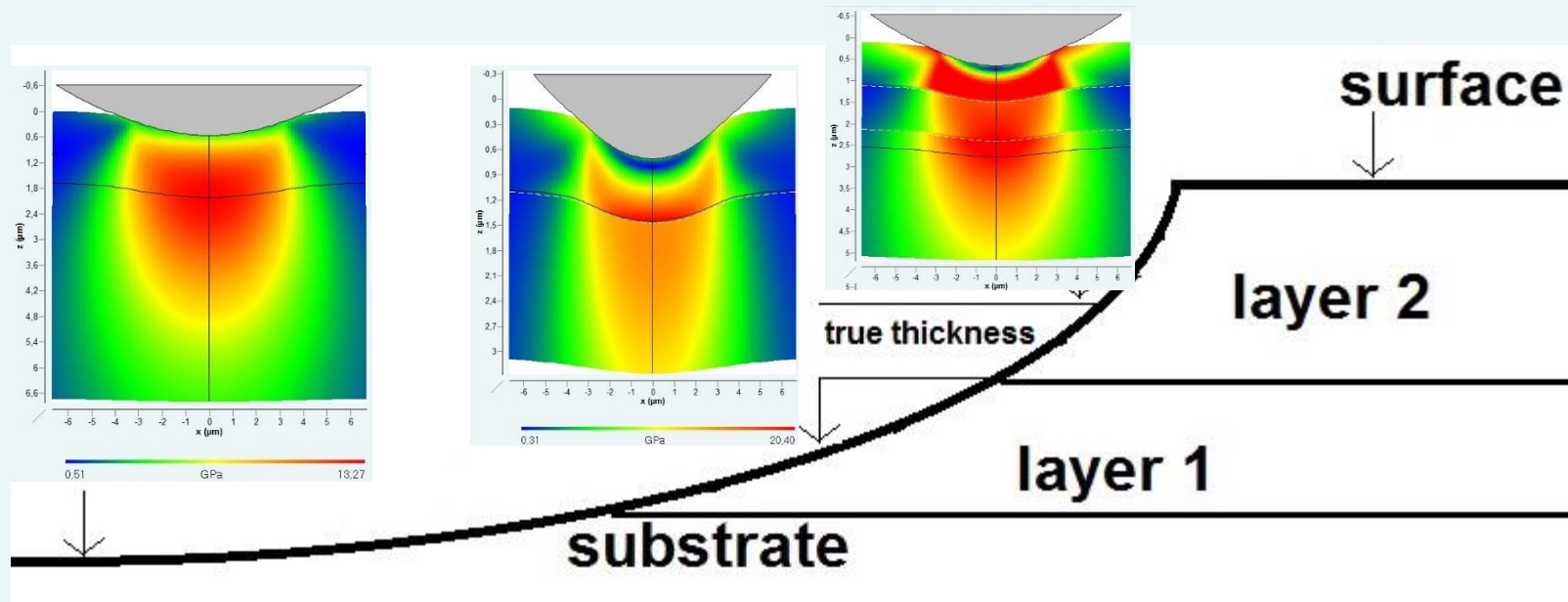
## How it works in detail

- Analysis III: 1  $\mu\text{m}$  thick layer 2  $\rightarrow E_{21}$



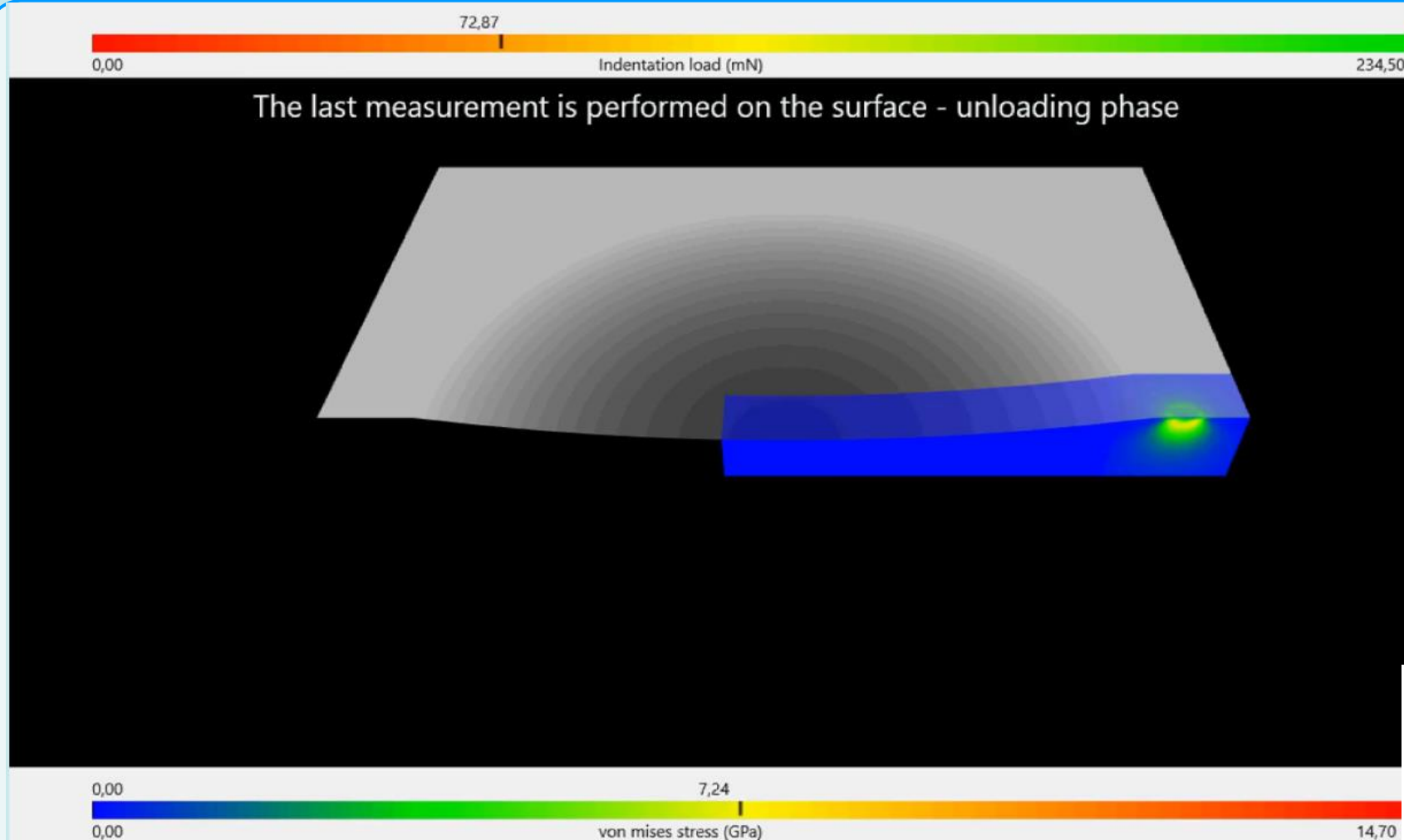
## How it works in detail

- Analysis III: 1  $\mu\text{m}$  thick layer 2  $\rightarrow E_{21}$
- Analysis IV: 3  $\mu\text{m}$  thick layer 2  $\rightarrow E_{22}$
- If  $E_{21}$  and  $E_{22}$  differs significantly check homogeneity!





# SIO Calotte Module



<http://worldformulaapps.com/videos/calotteindentationanalyzis>





# IStress module

[www.stm.uniroma3.it/iSTRESS](http://www.stm.uniroma3.it/iSTRESS)





# IStress module

F.D. FilmDoctor Studio IStress v 0.9.6.2 - time-limited edition - 14 days left - project: istress eggshell example 08\_06\_15

Project Tools Help

material load result close iStress module

**step 1: select your material**

|                                              | Poisson's ratio | Young's modulus                                | select from database | layer thickness    | intrinsic stresses |   |
|----------------------------------------------|-----------------|------------------------------------------------|----------------------|--------------------|--------------------|---|
| <input checked="" type="checkbox"/> layer 1: | $\nu$ : 0,25    | <input checked="" type="checkbox"/> E: 590 GPa | user defined         | h: 2 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 2:            | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 3:            | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 4:            | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 5:            | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 6:            | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 7:            | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 8:            | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 9:            | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 10:           | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 11:           | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 12:           | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 13:           | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 14:           | $\nu$ : 0,22    | <input type="checkbox"/> E: 450 GPa            | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |
| <input type="checkbox"/> layer 15:           | $\nu$ : 0,321   | <input type="checkbox"/> E: 115,7 GPa          | user defined         | h: 1 $\mu\text{m}$ | 0 GPa              | ↓ |

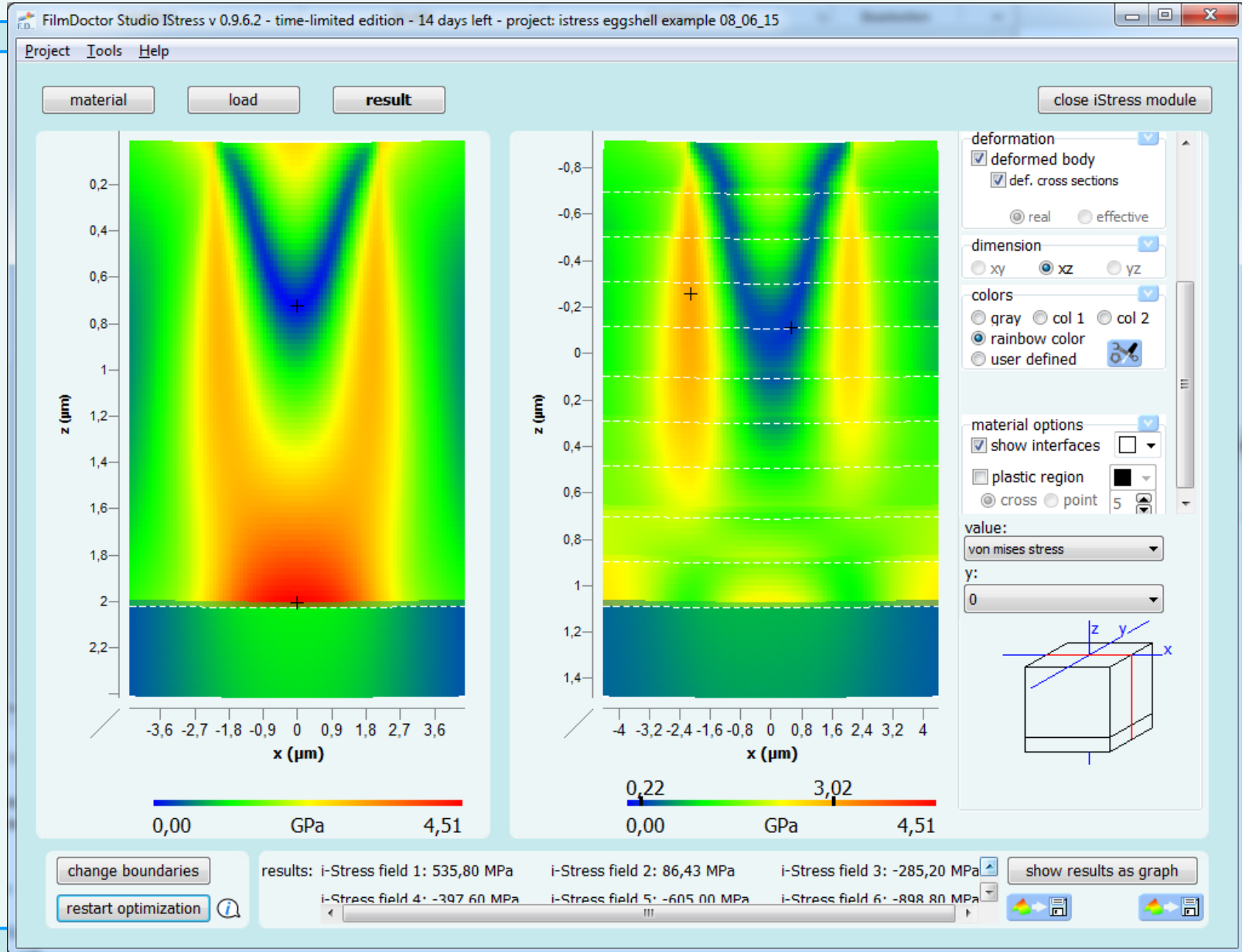
upgrade to more layers

substrate:  $\nu$ : 0,345 ☐ E: 70,3 GPa user defined 0 GPa ↓

edit database use 5 iStress fields ☐ define istress field thicknesses OK

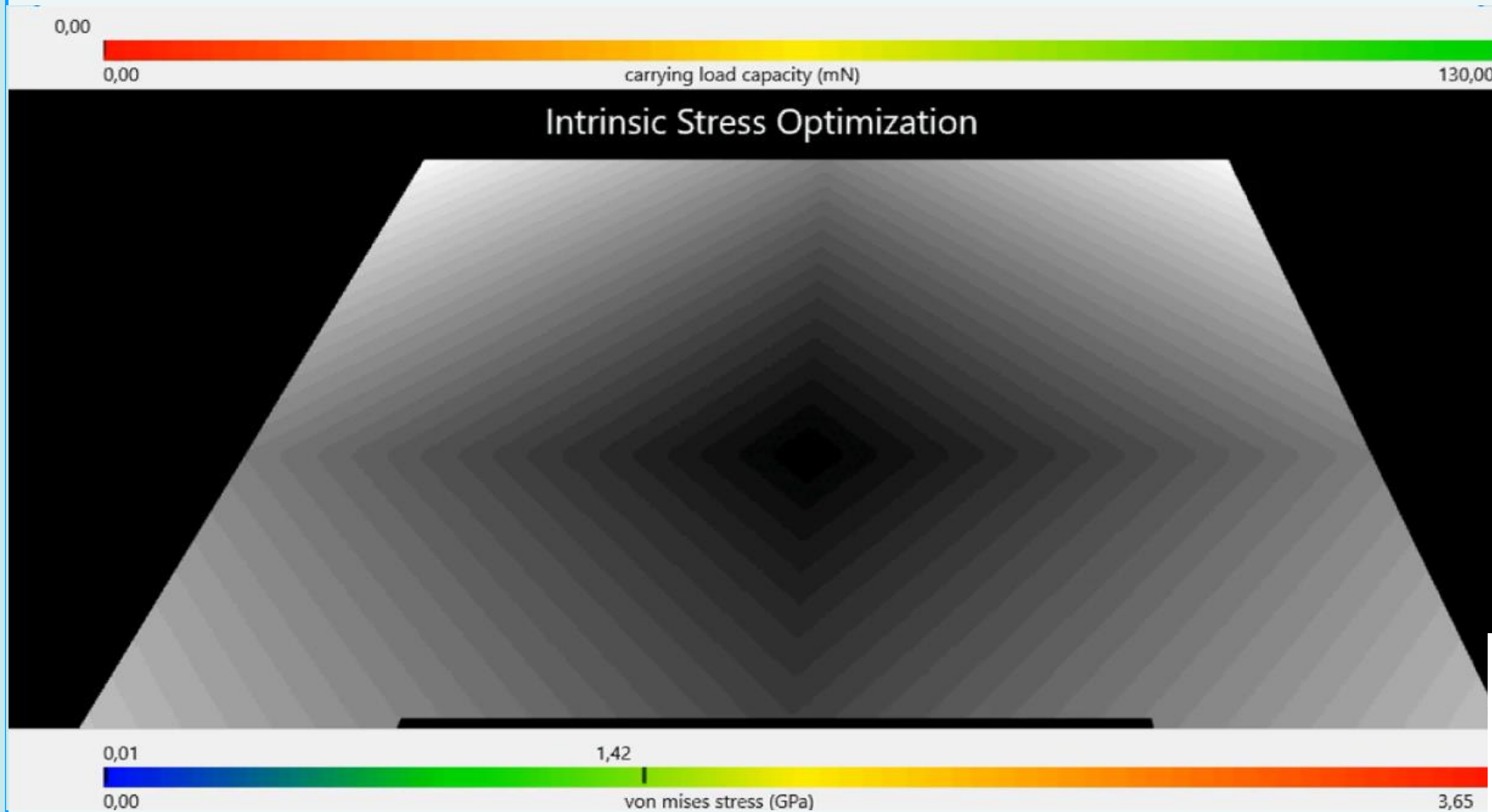


# IStress module



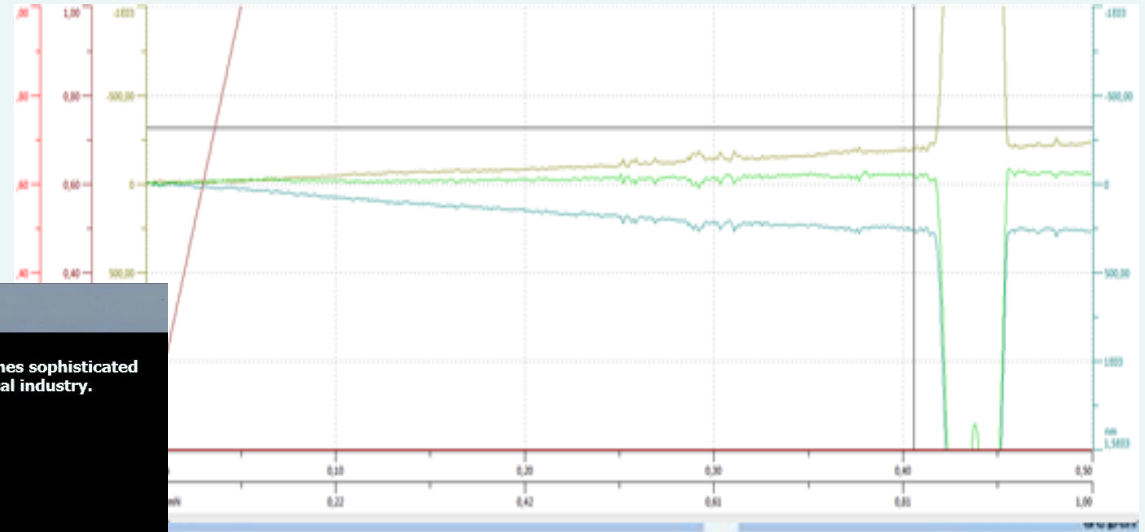
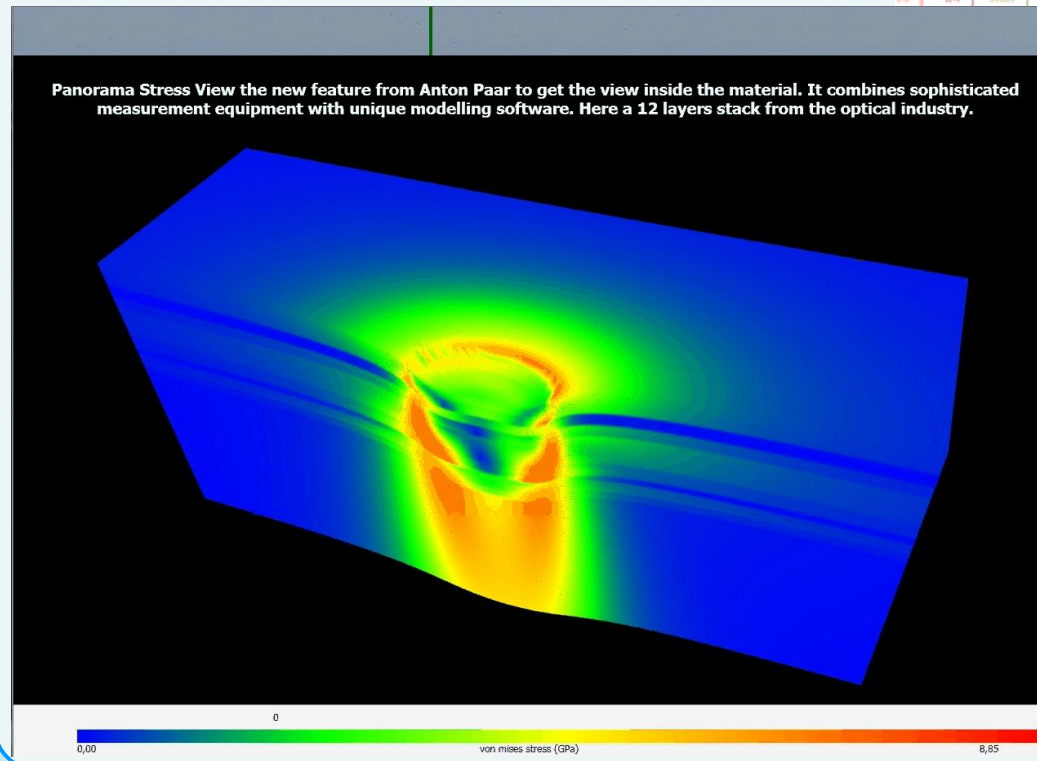


# IStress module



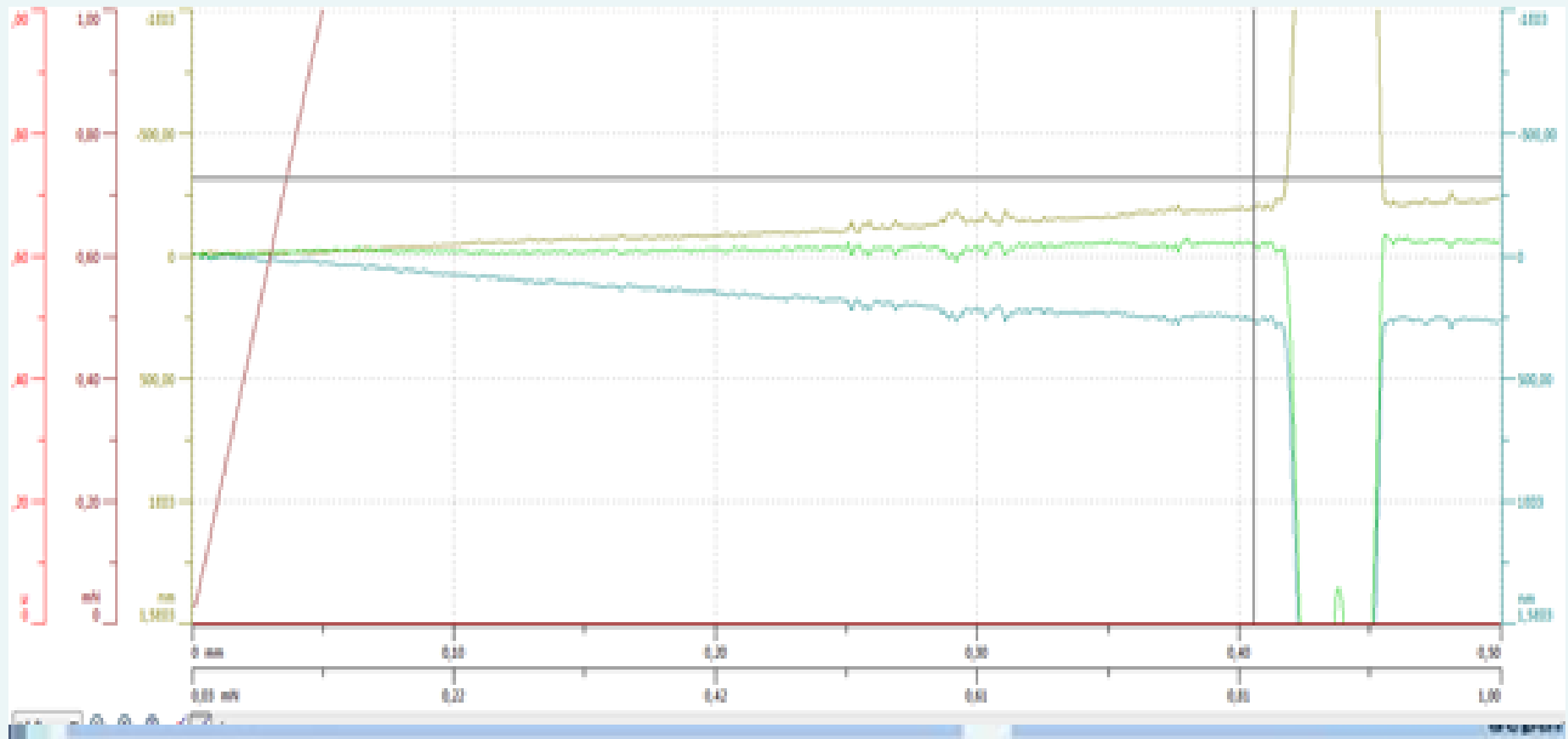
<http://worldformulaapps.com/videos/intrinsicstressoptimization>

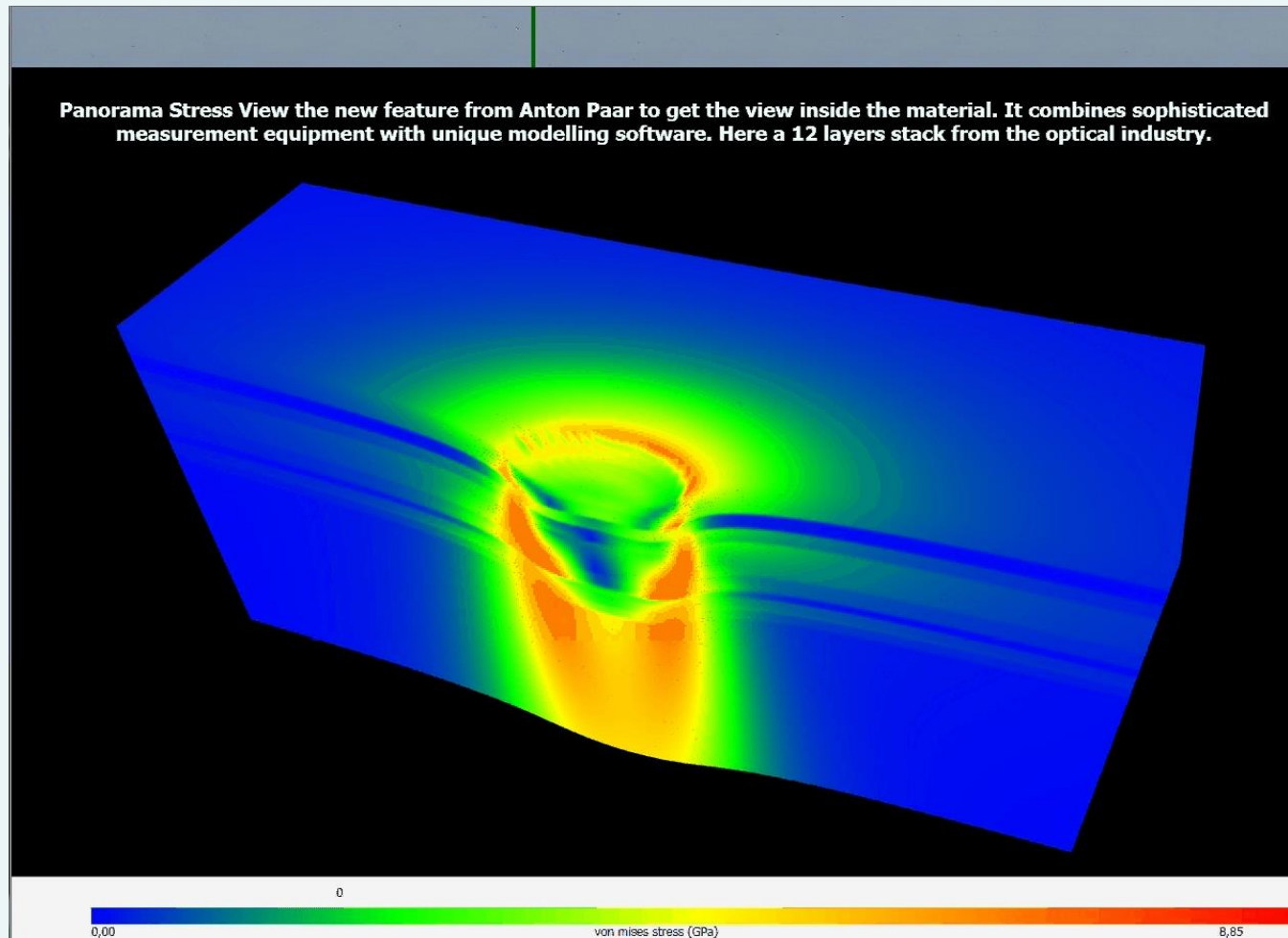
Combining measurements  
with modelling made easy.



Example today: 12 layers  
stack with total  
thickness below 400 nm.

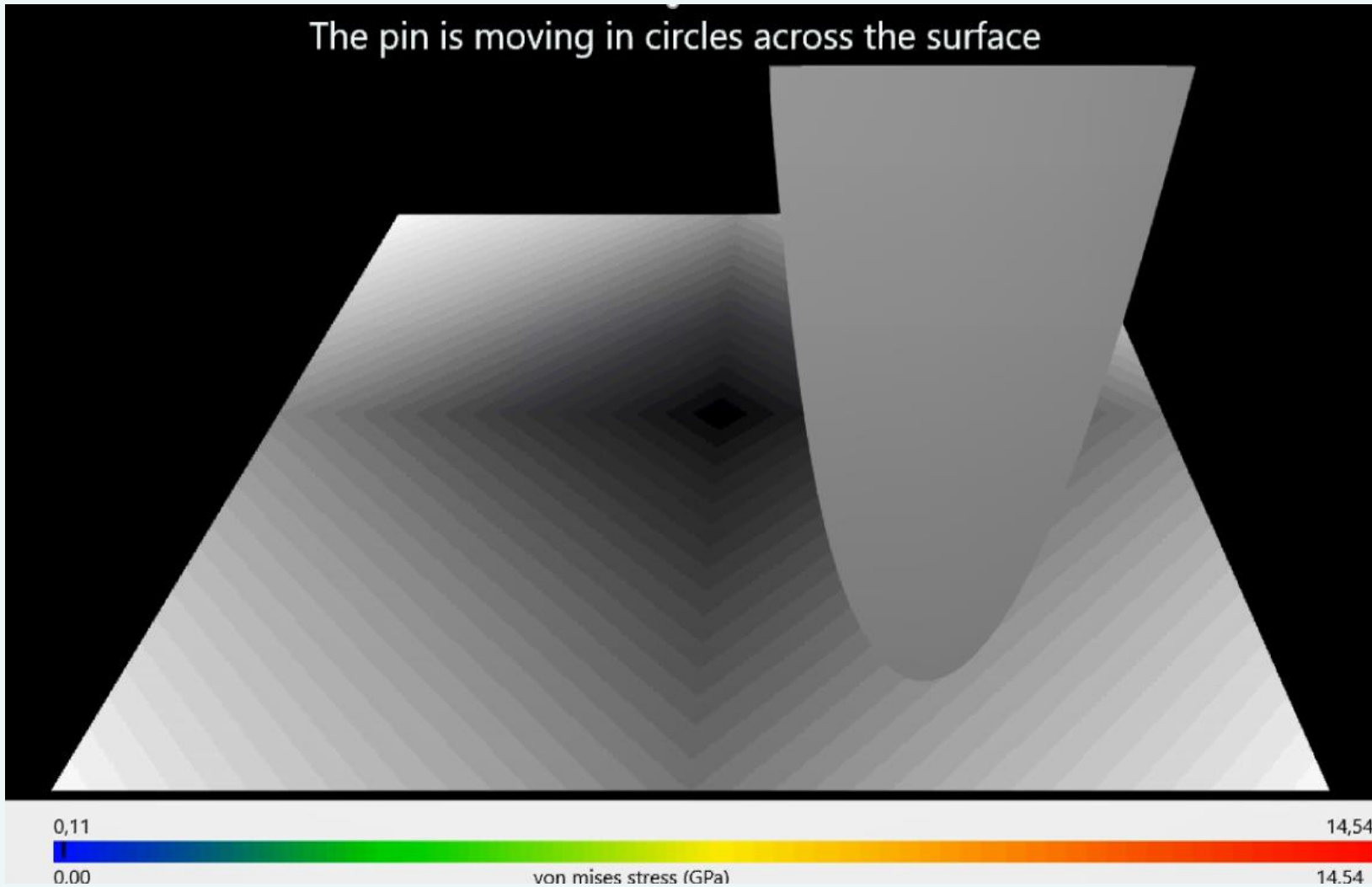
**Analyzing a scratch test from 1 to 8 mN on a multi layer stack.**





**No FEM system – closed formula calculations**

The pin is moving in circles across the surface



<http://worldformulaapps.com/videos/wearanalyzis>





# Summary

**Analytical models allow to analyze contact experiments very easily and quickly.**

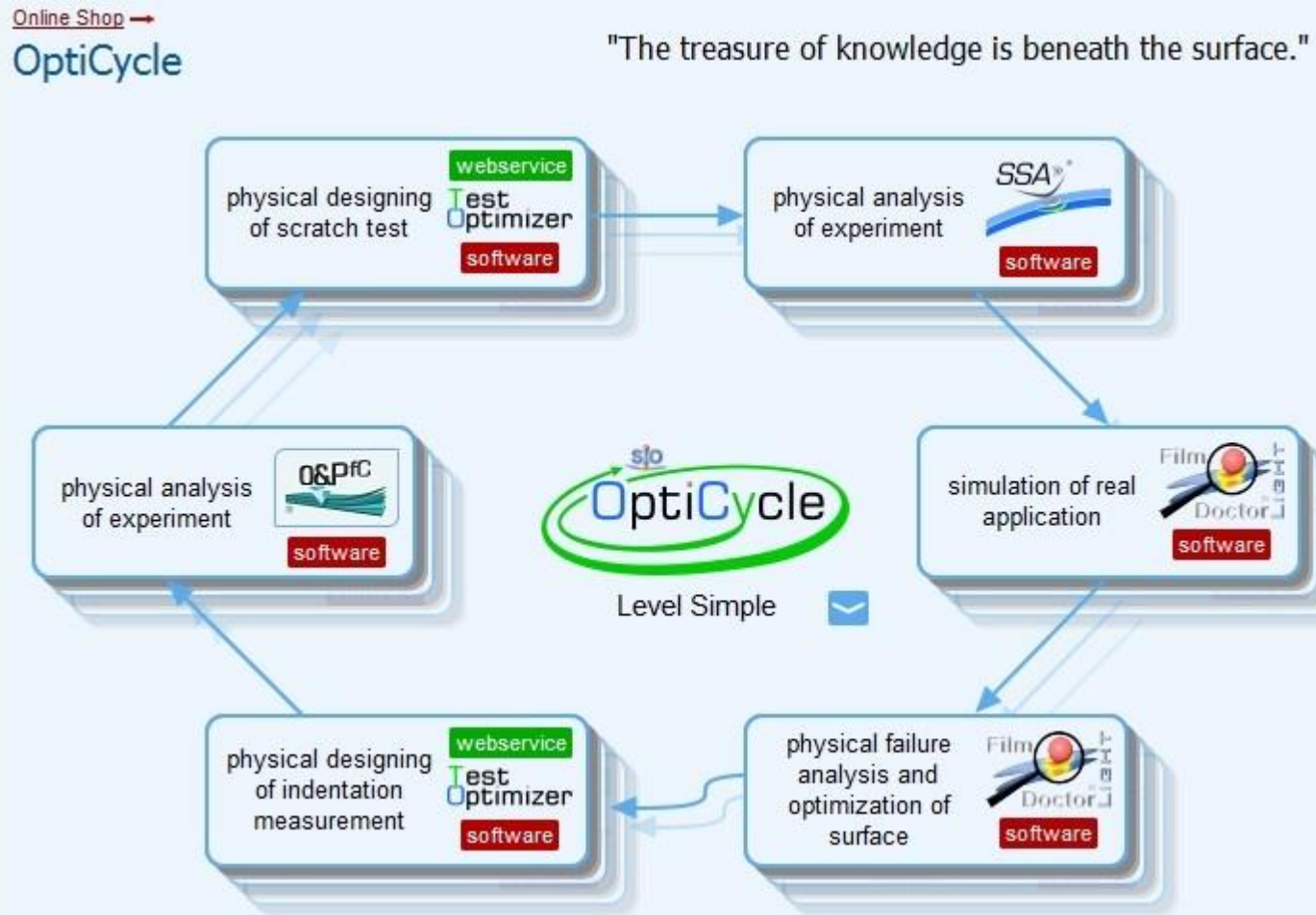
**With specialized software packages simulations and optimizations are possible.**

**Residual stresses can be determined and optimized very easy and fast with the new modules developed within the EU and german research projects.**

## **Indentation, Scratch AND Tribo-Tests**

**No FEM system – closed formula calculations**

# The flow chart of the Plan



<http://siomec.de/en/119/OptiCycle>



**Actual project with  
technical university of munich**



[www.spp2013.tum.de](http://www.spp2013.tum.de)