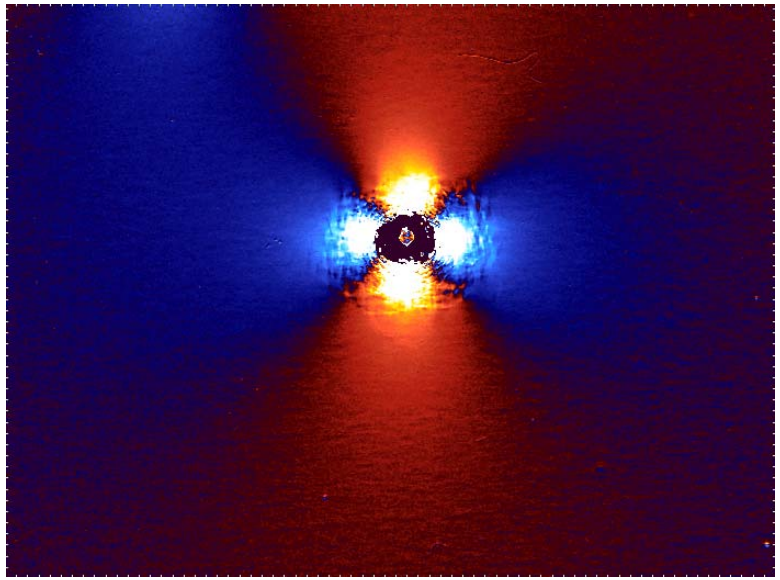
Direct Stress Of Windows

Integrated Window Inspection Technology (IWIT)



Jon R Lesniak
Feb. 29 2012

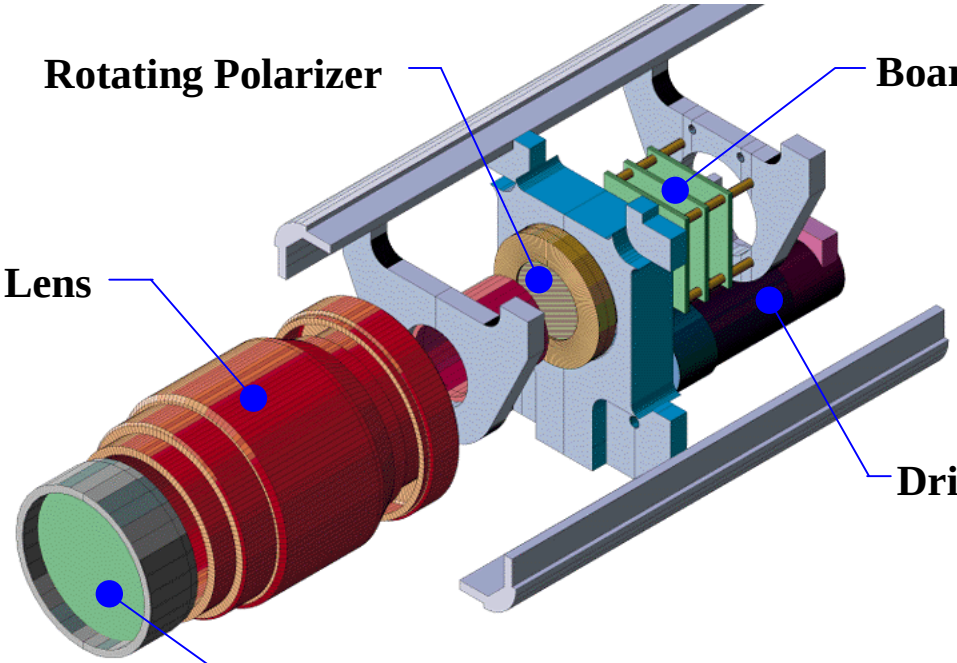
Stress Photonics

Stress Photonics

3002 Progress Road
Madison, Wisconsin 53716
Phone: (1) 608-224-1230 Fax: (1) 608-224-1233
email: info@stressphotonics.com
Web site: www.stressphotonics.com

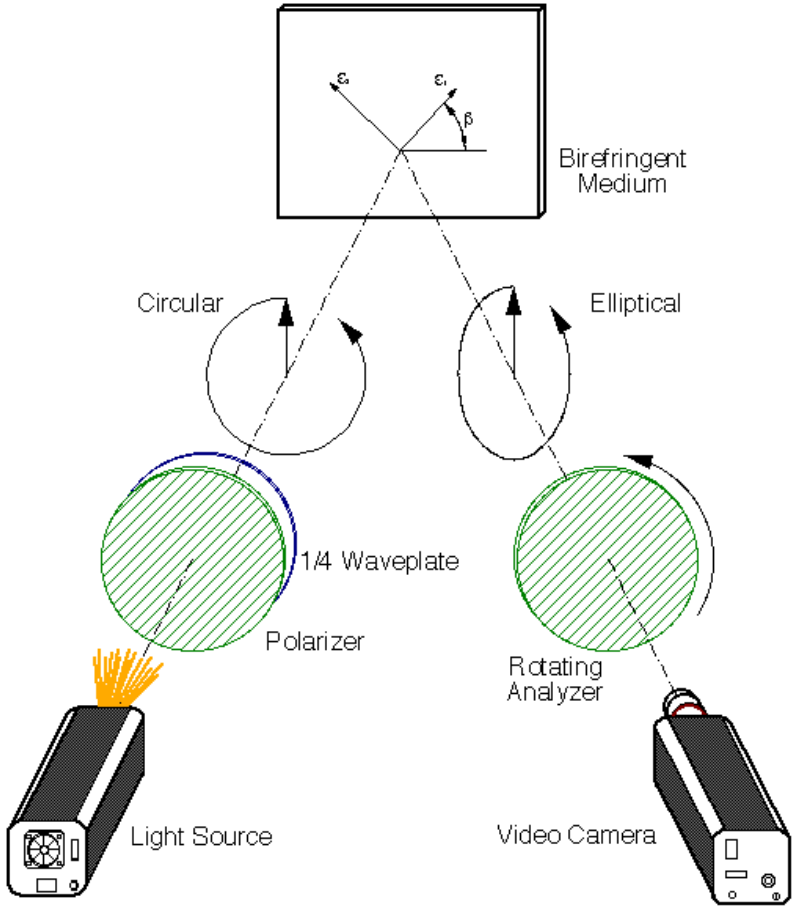
Stress Photonics

NASA LaRC Funded GFP 1000



Stress Photonics

GFP Fundamentals



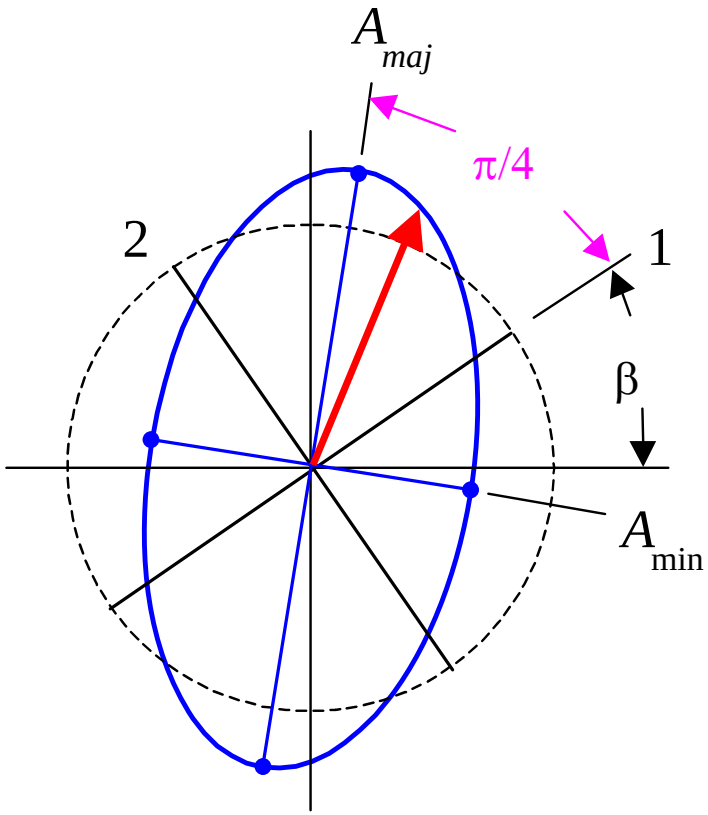
Stress Photonics

GFP1200c

General purpose lab tool

Stress Photonics

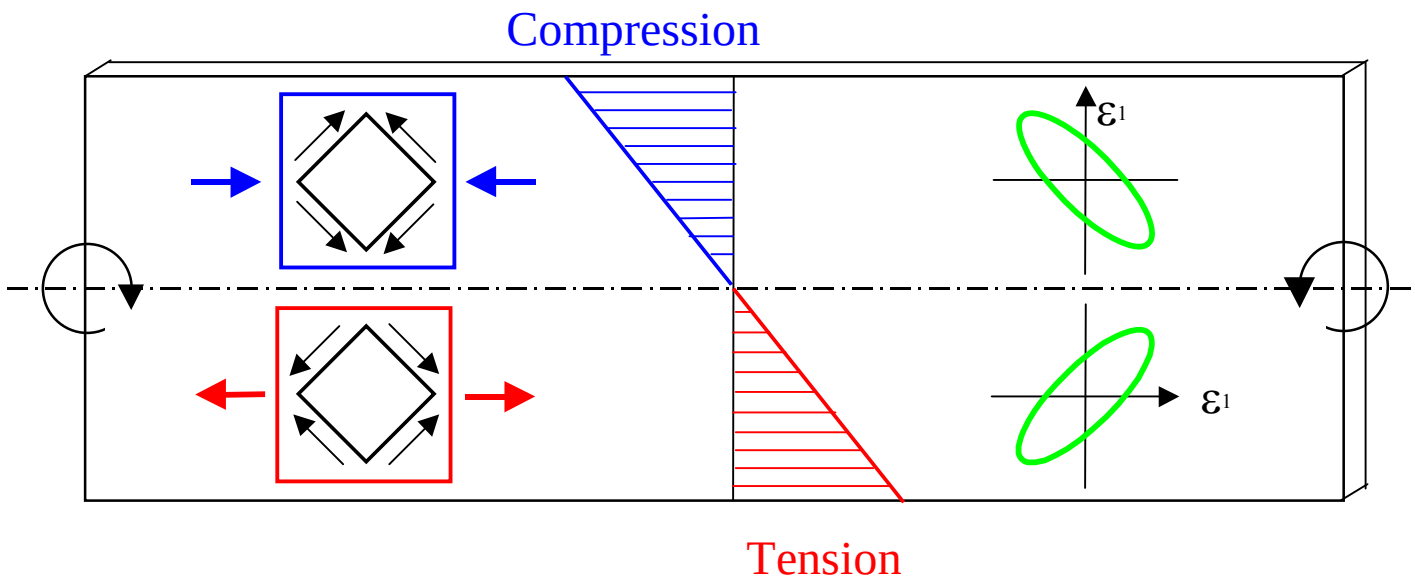
Elliptically Polarized Light



$$A_{maj} = a\cos\left(\frac{\pi}{4} - \frac{\Delta}{2}\right)\cos\left(\eta t + \frac{\pi}{4} + \beta\right)$$

$$A_{min} = a\cos\left(\frac{\pi}{4} + \frac{\Delta}{2}\right)\sin\left(\eta t + \frac{\pi}{4} + \beta\right)$$

Beam in Bending

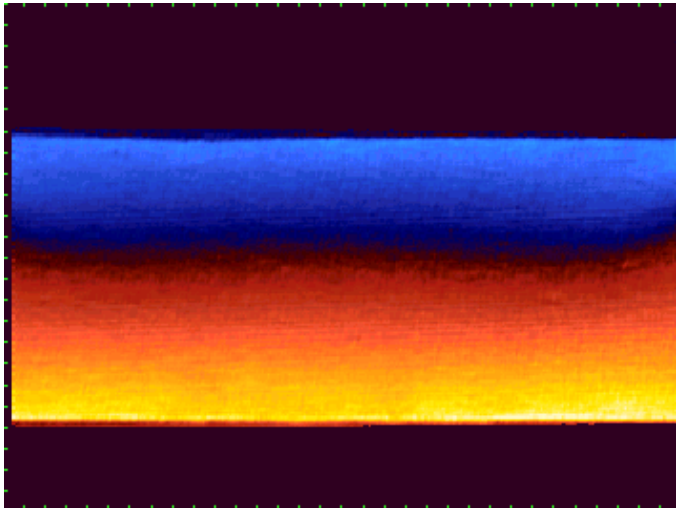


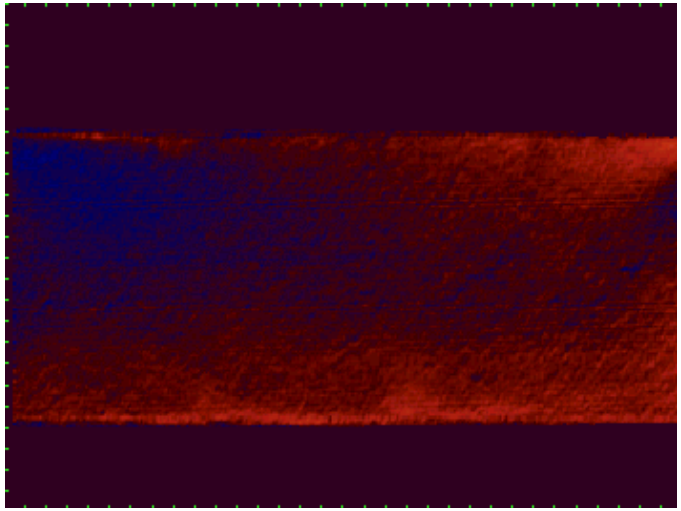
Stress Photonics

Shear Planes

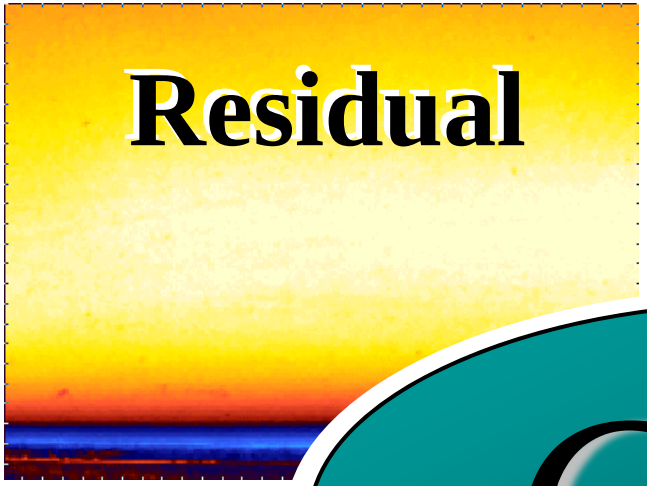
$$\bar{I}_{\sin} \rightarrow \gamma_{45}$$

$$\bar{I}_{\cos} \rightarrow \gamma_{0}$$





Stress Photonics

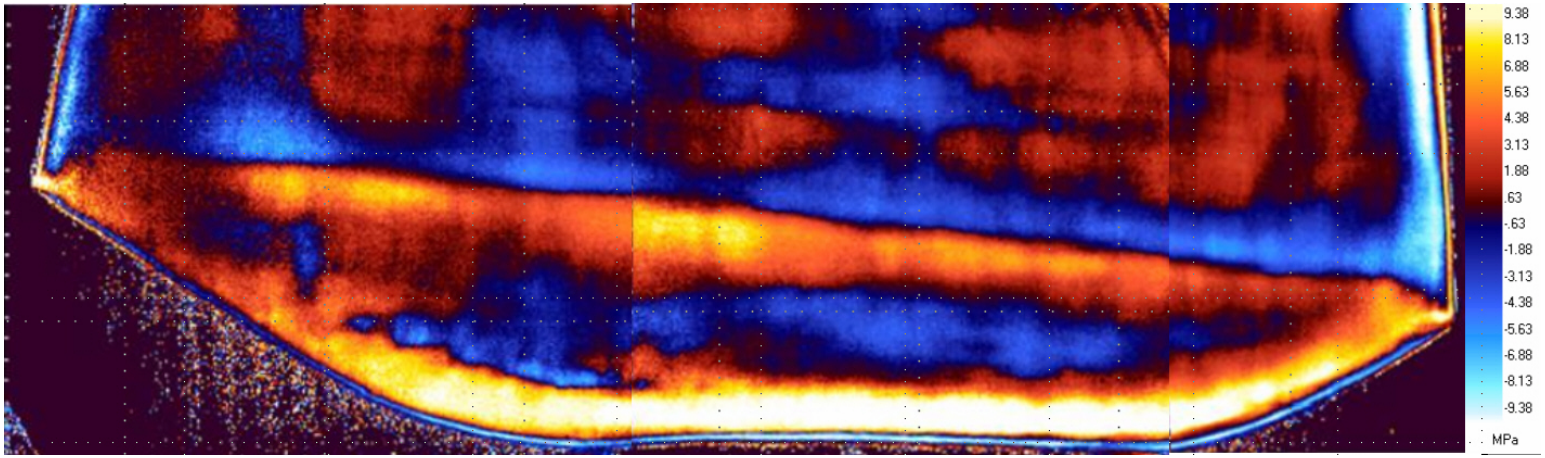


GFP

Grey-Field Polariscopes

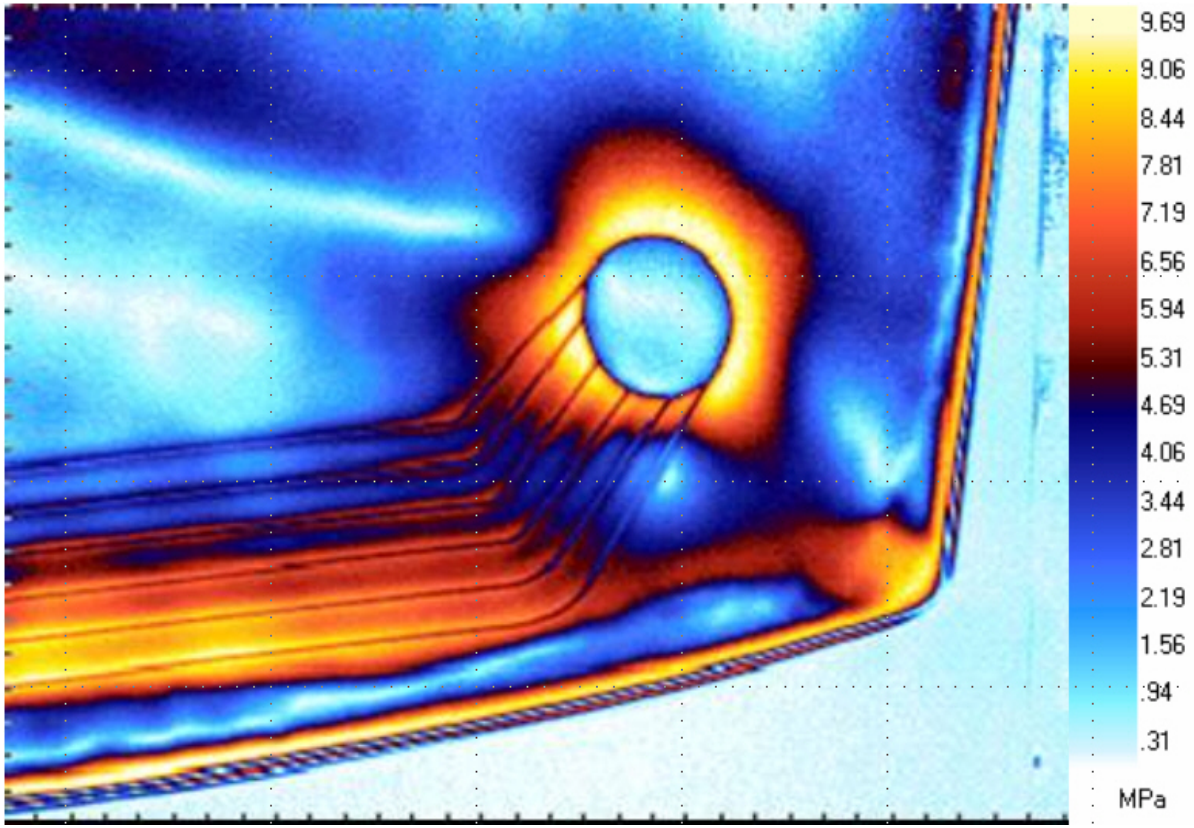
Stress Photonics

Press form - Fold Line



Stress Photonics

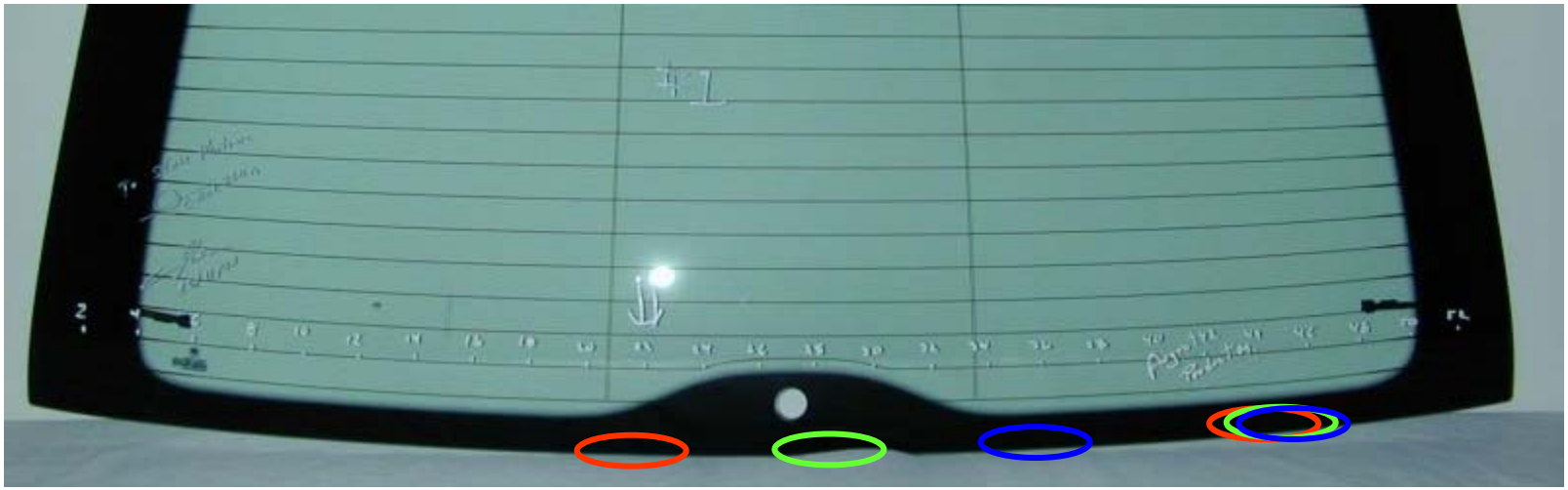
Effects of silver patterns



Stress Photonics

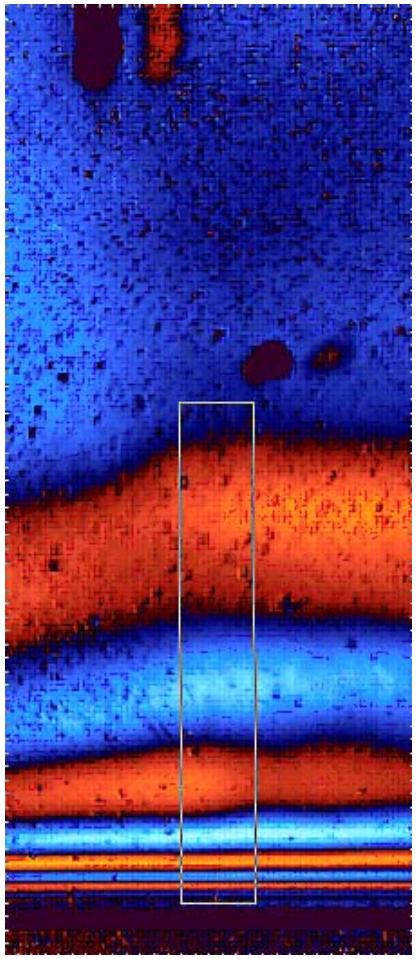
Flaw Locations

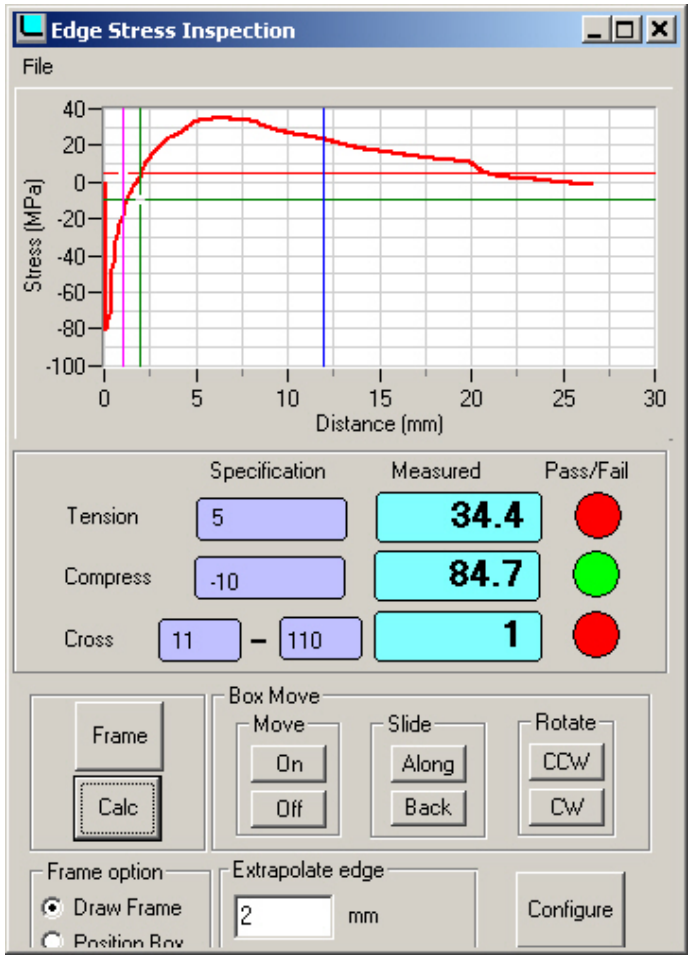
- August Production Hot Spots
- September Production Hot Spots
- Dec. ‘02 Production Hot Spots



Stress Photonics

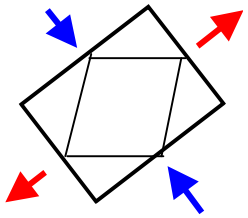
Defects



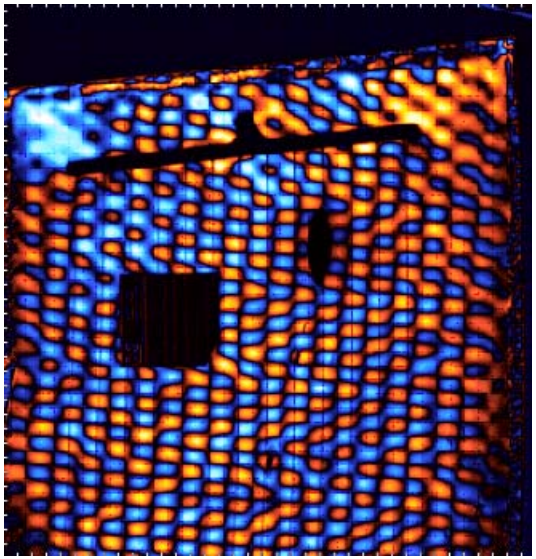


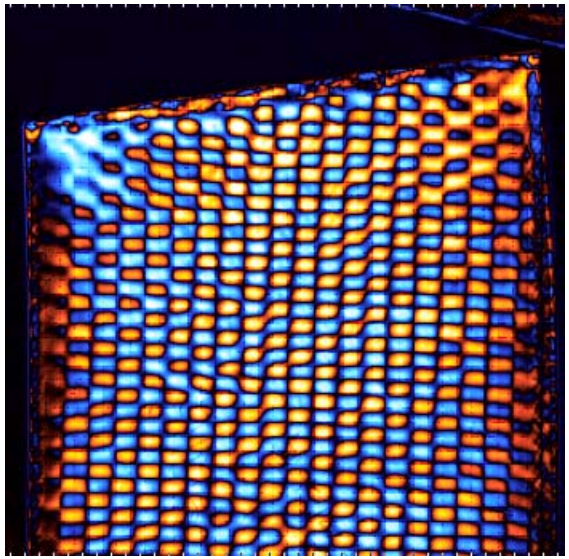
Stress Photonics

Temper Patterns



σ_{45}-σ_{-45}

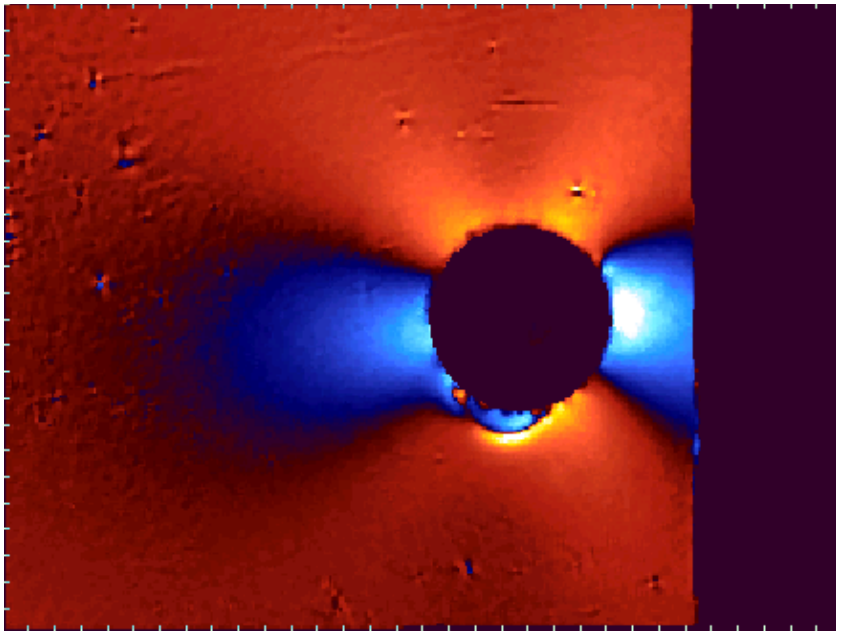




Reverse Assembly Strain

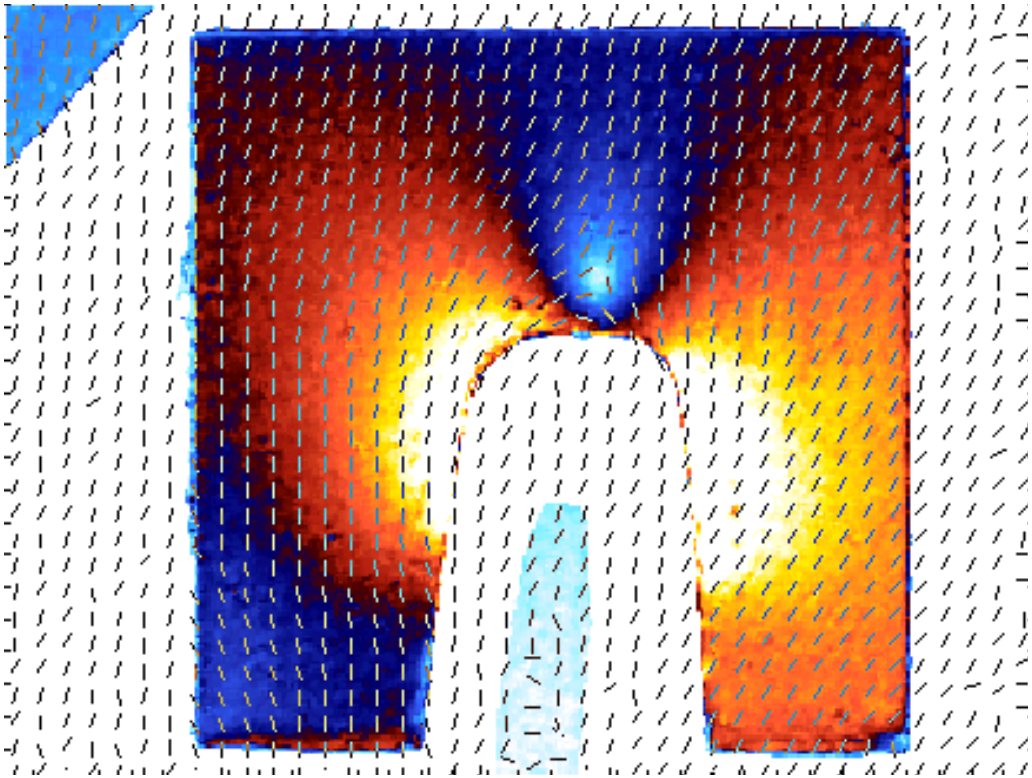
Stress Photonics

Stresses Around Button



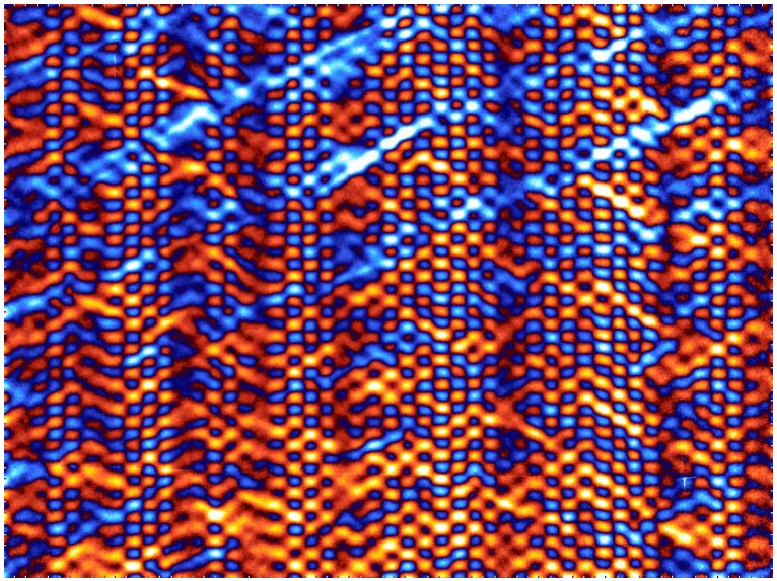
Stress Photonics

Hinge Assembly Stress

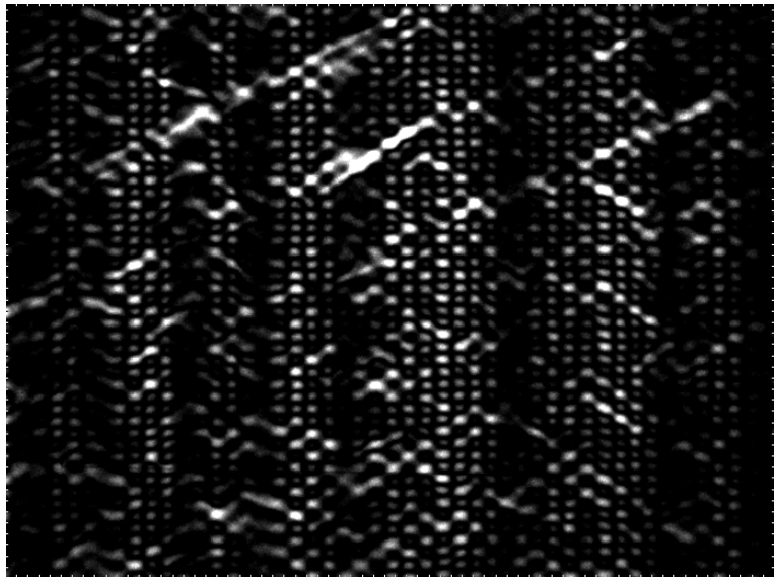


Stress Photonics

Predicting iridescence – online



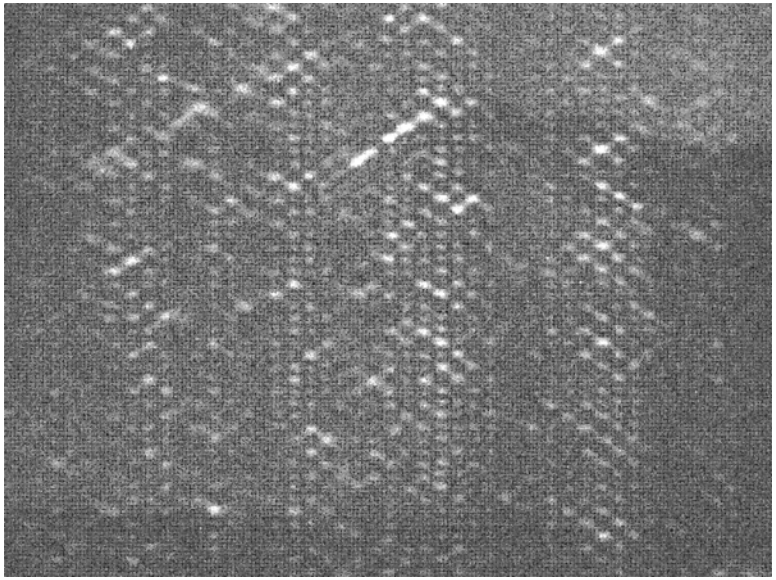
Stress Photonics GFP
Stress Map σ_{45}



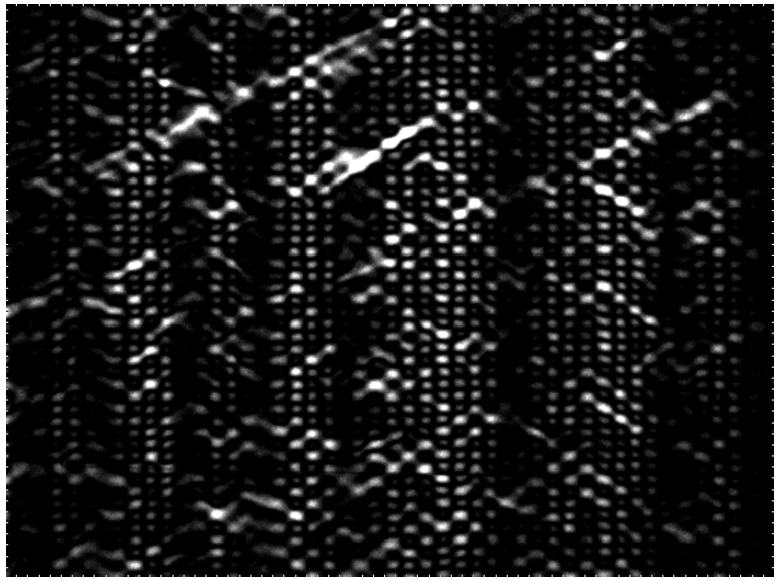
Predicted iridescence – calculated from stress map

Stress Photonics

Iridescence prediction vs. actual



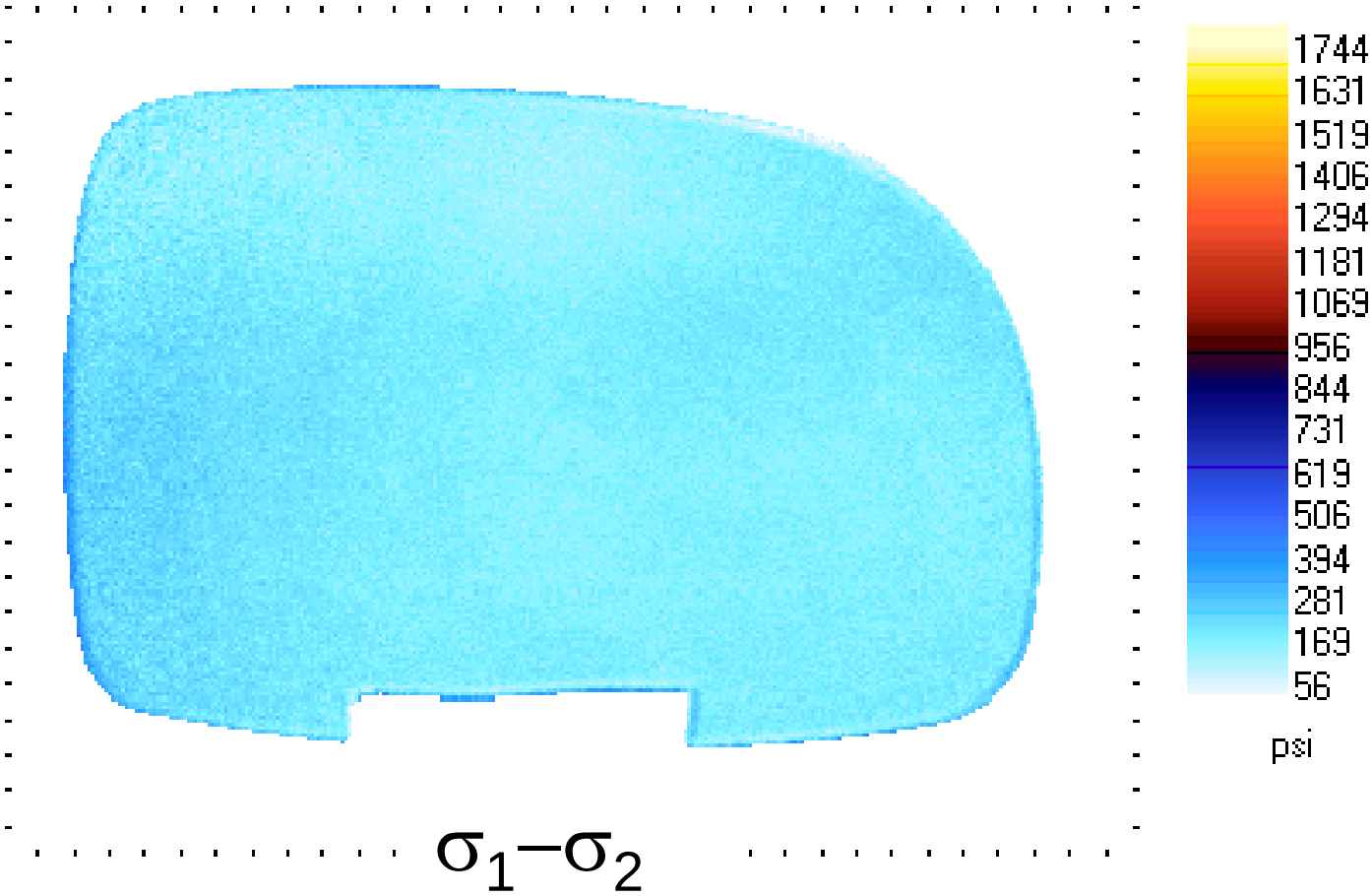
Actual Iridescence



Predicted iridescence

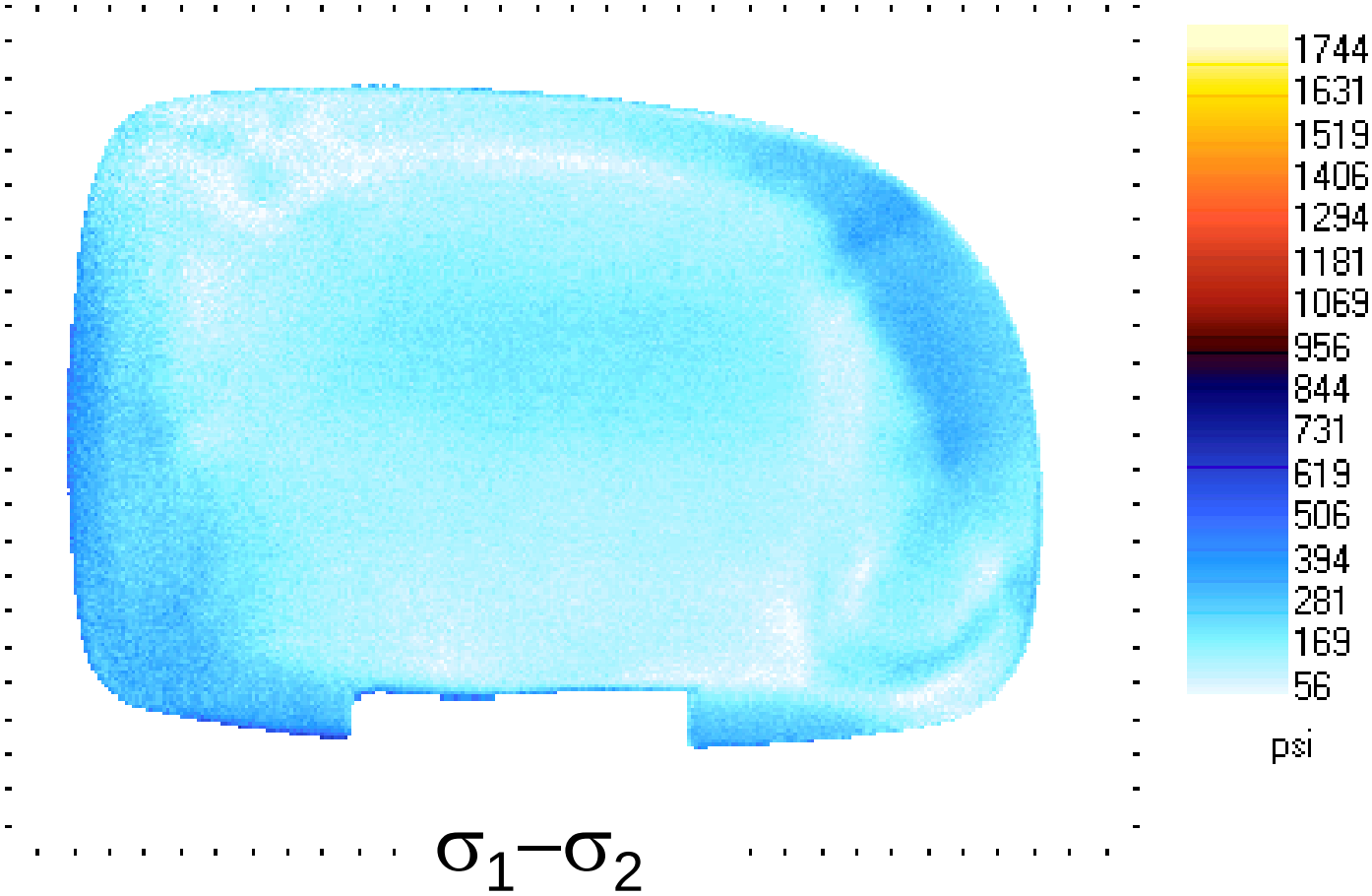
Stress Photonics

T=0



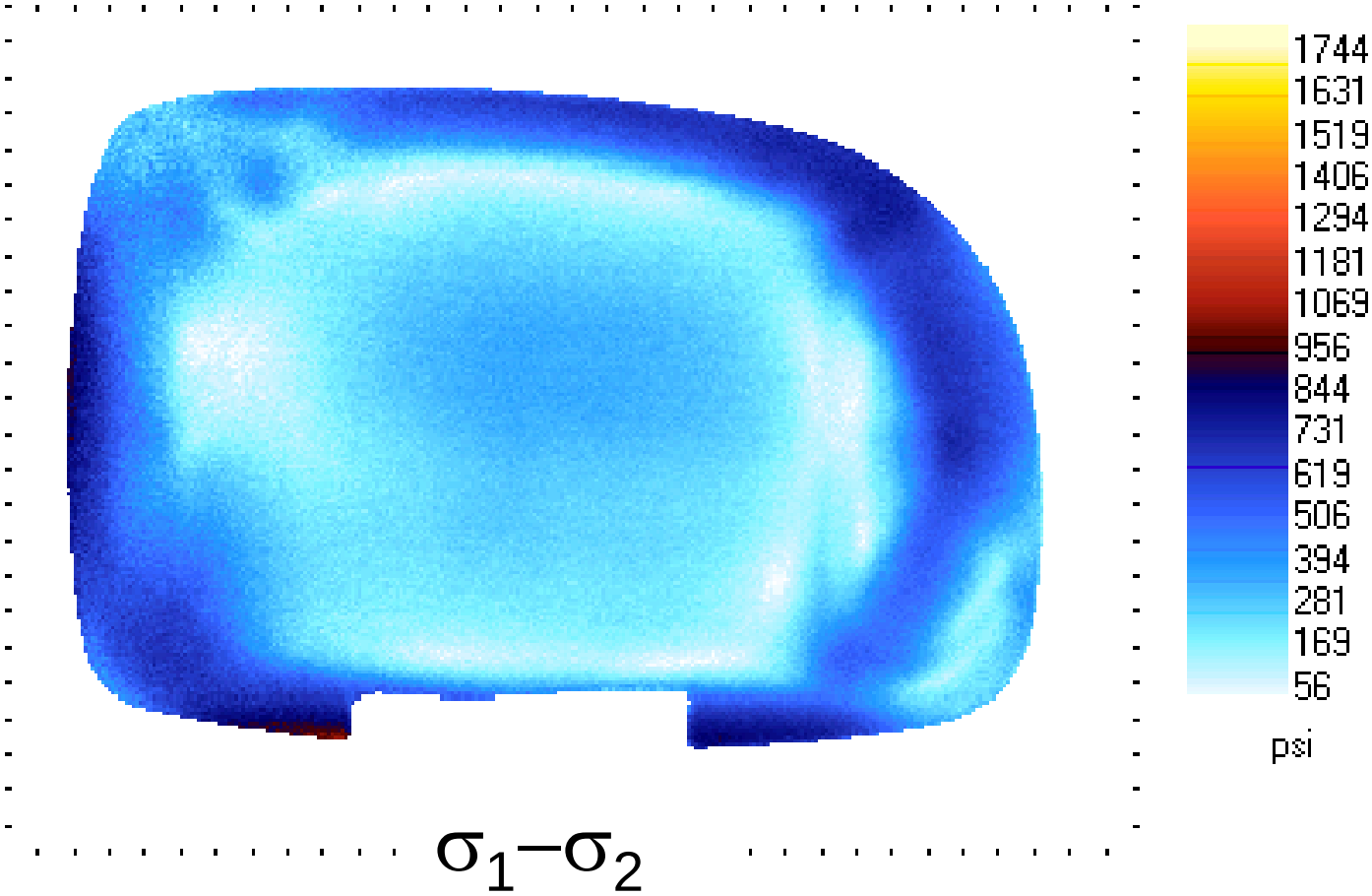
Stress Photonics

T= 0^+



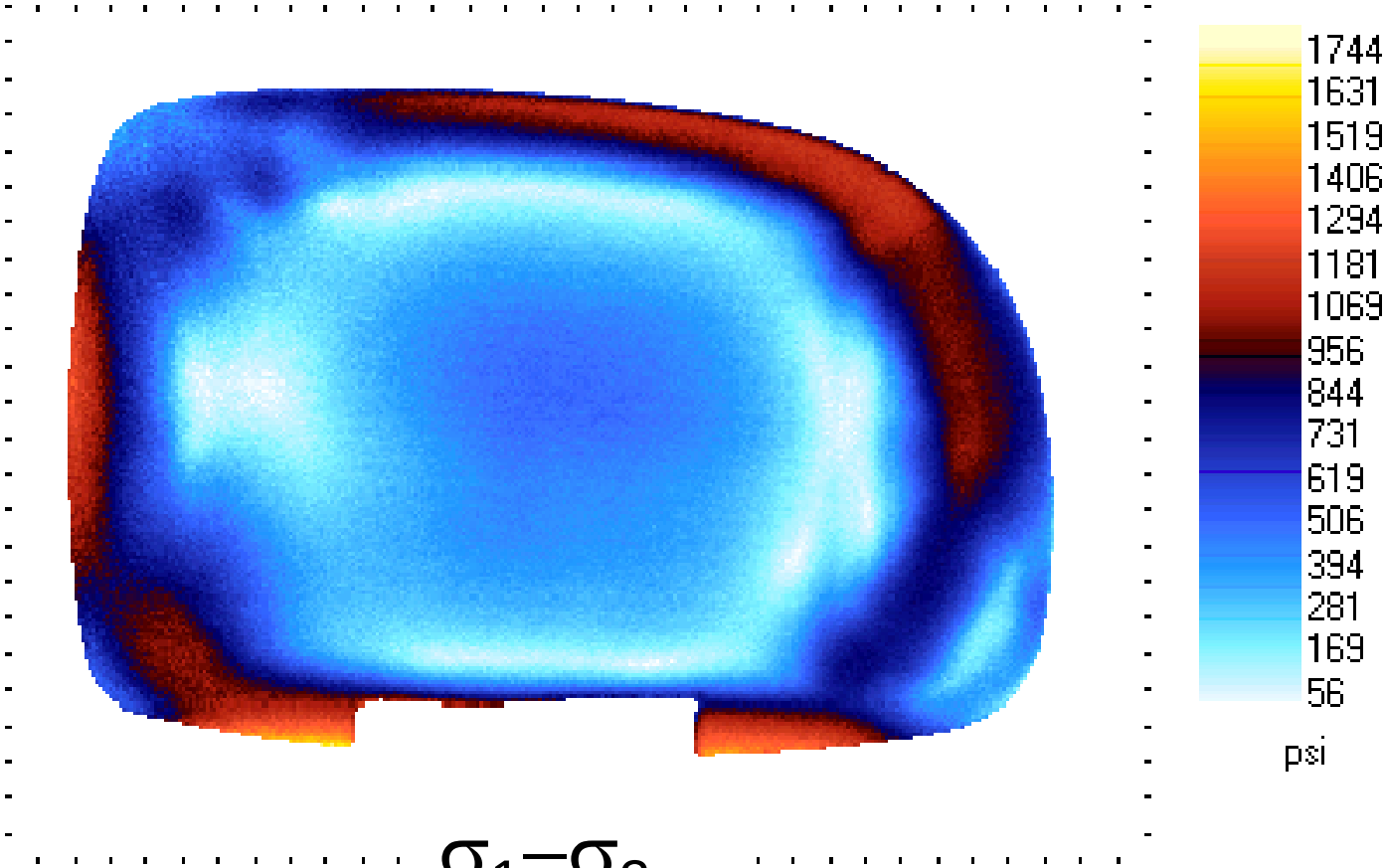
Stress Photonics

T= 1 min.



Stress Photonics

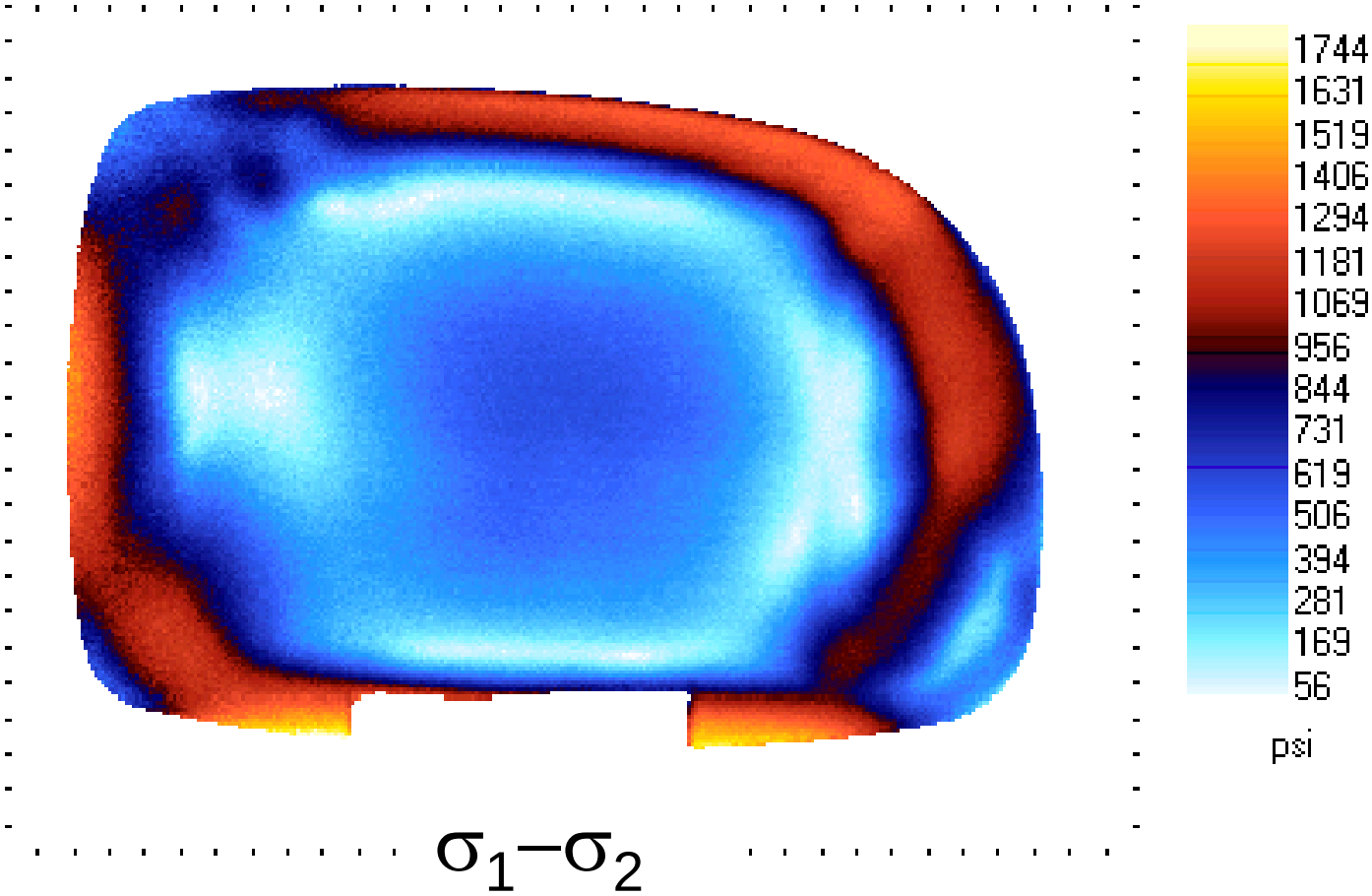
T= 2 min.



$\sigma_1 - \sigma_2$

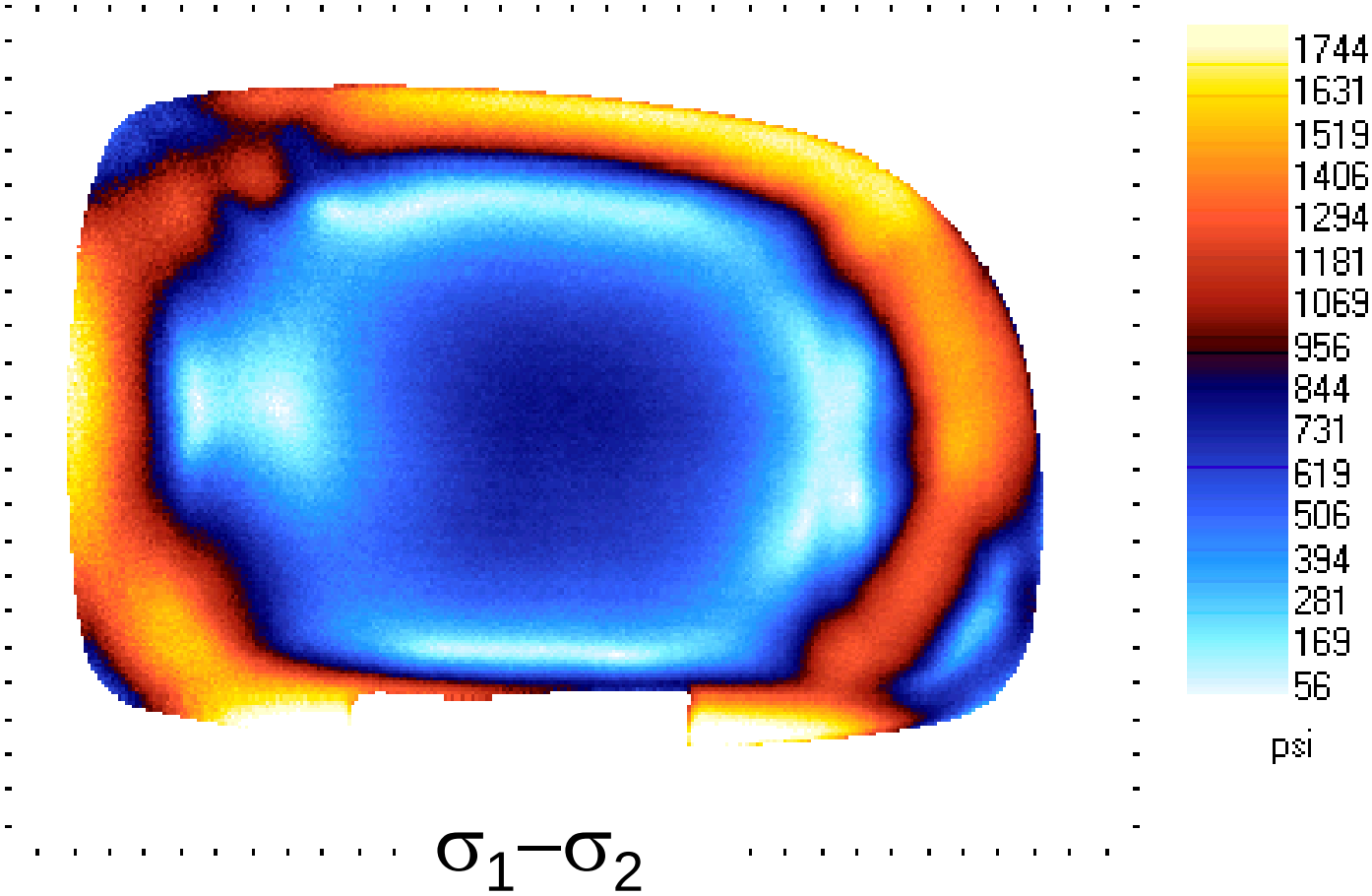
Stress Photonics

T= 3 min.



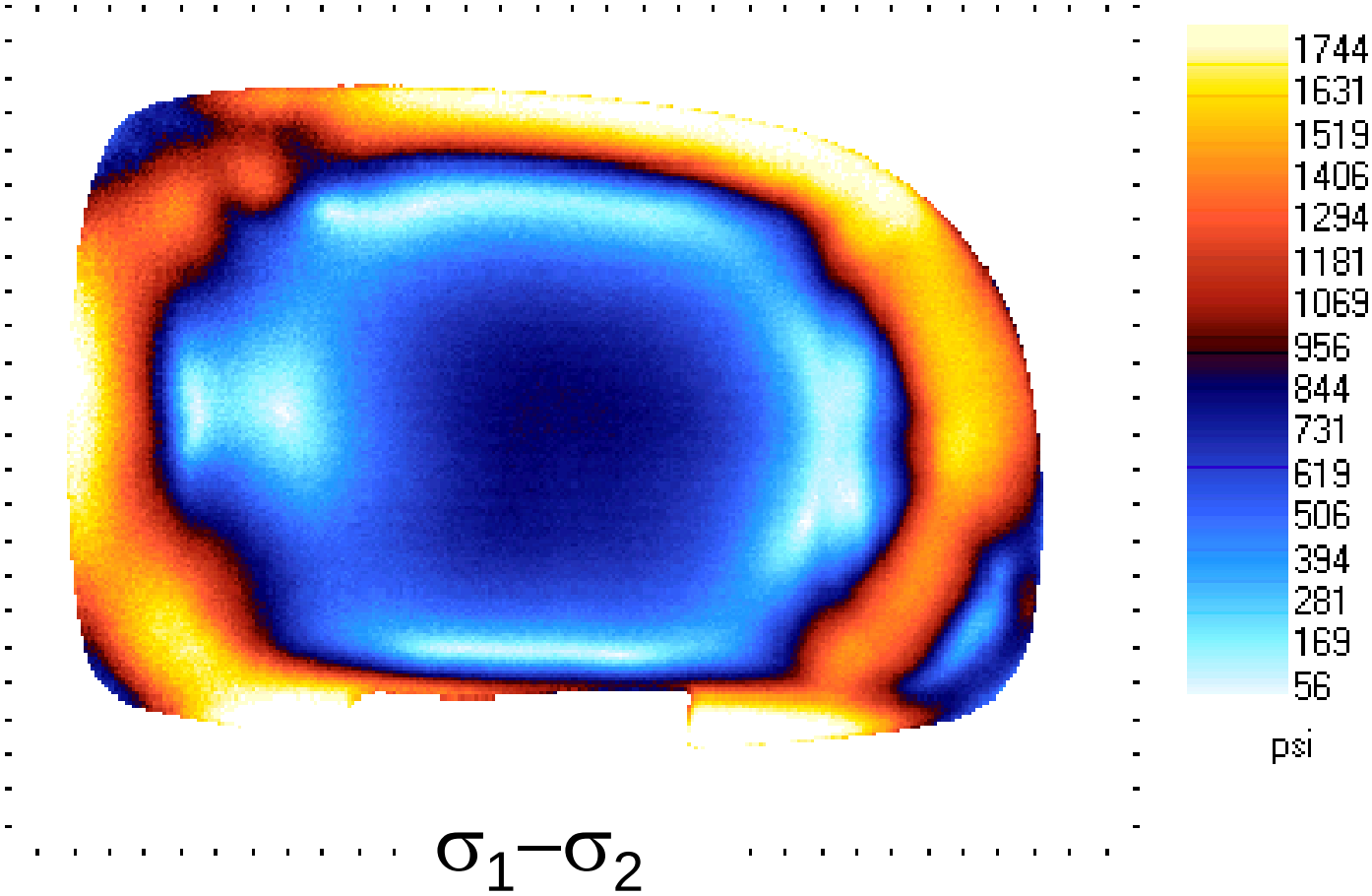
Stress Photonics

T= 4 min



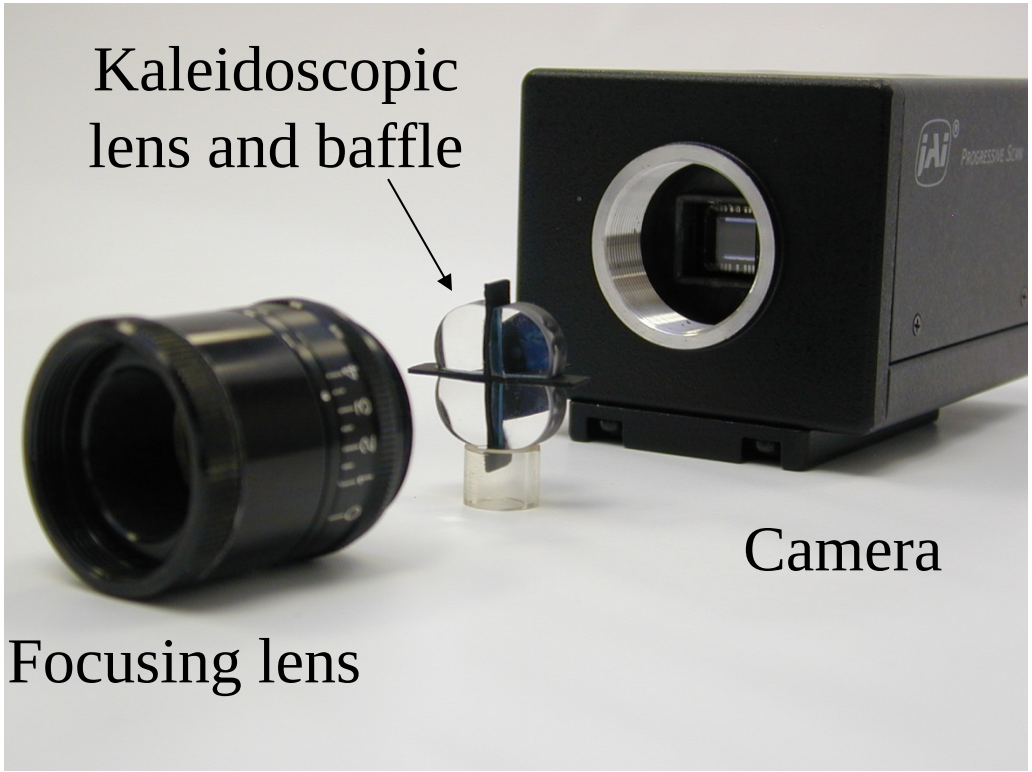
Stress Photonics

T= 5 min



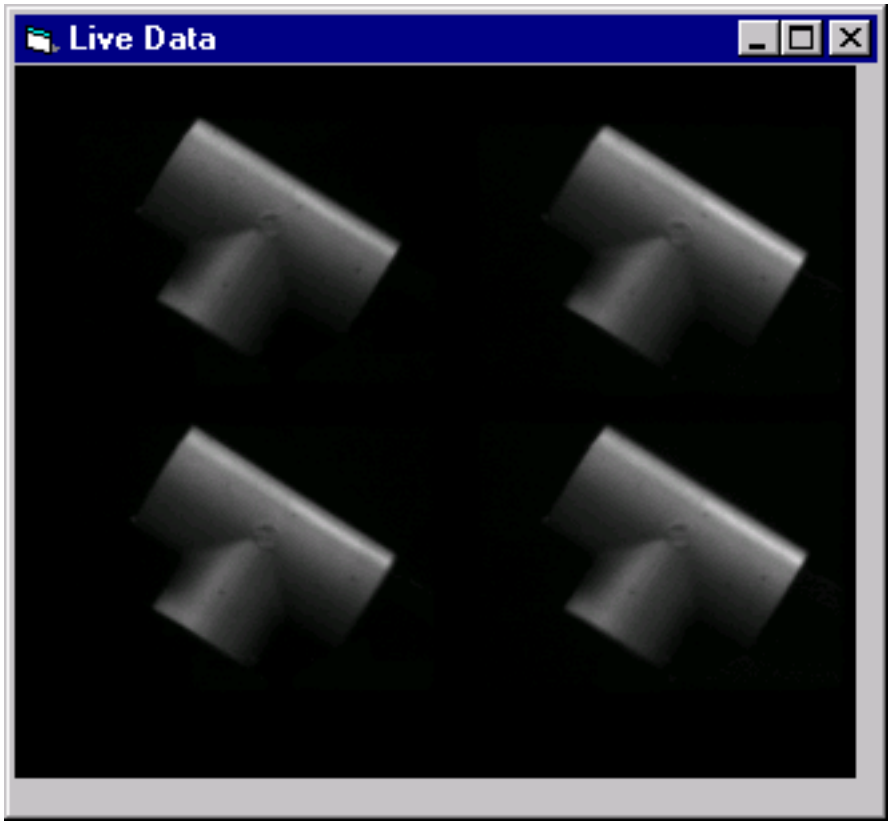
Stress Photonics

Poleidoscope construction



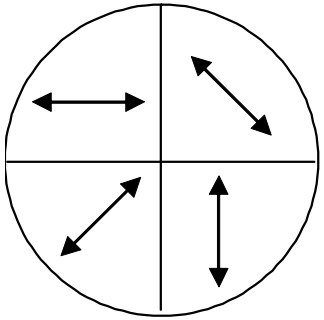
Stress Photonics

Video Image

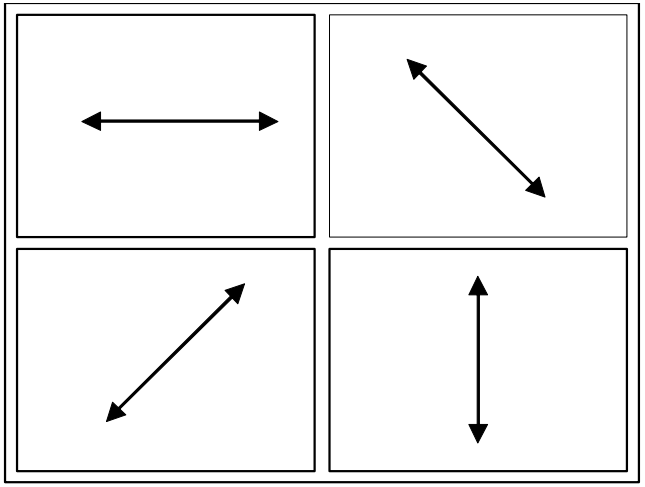


Stress Photonics

Simple Polarizer Set



Filters on lens



Result on Detector

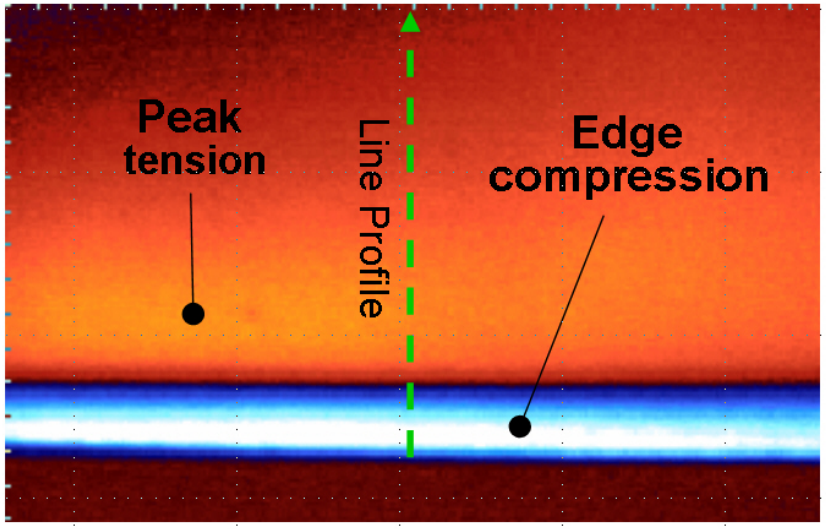
Stress Photonics

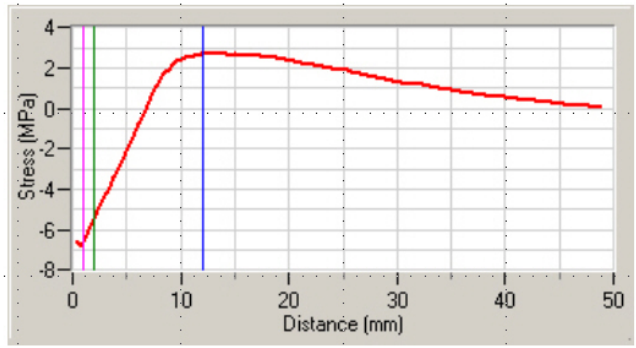
Glass Inspection

Edge Master

Stress Photonics

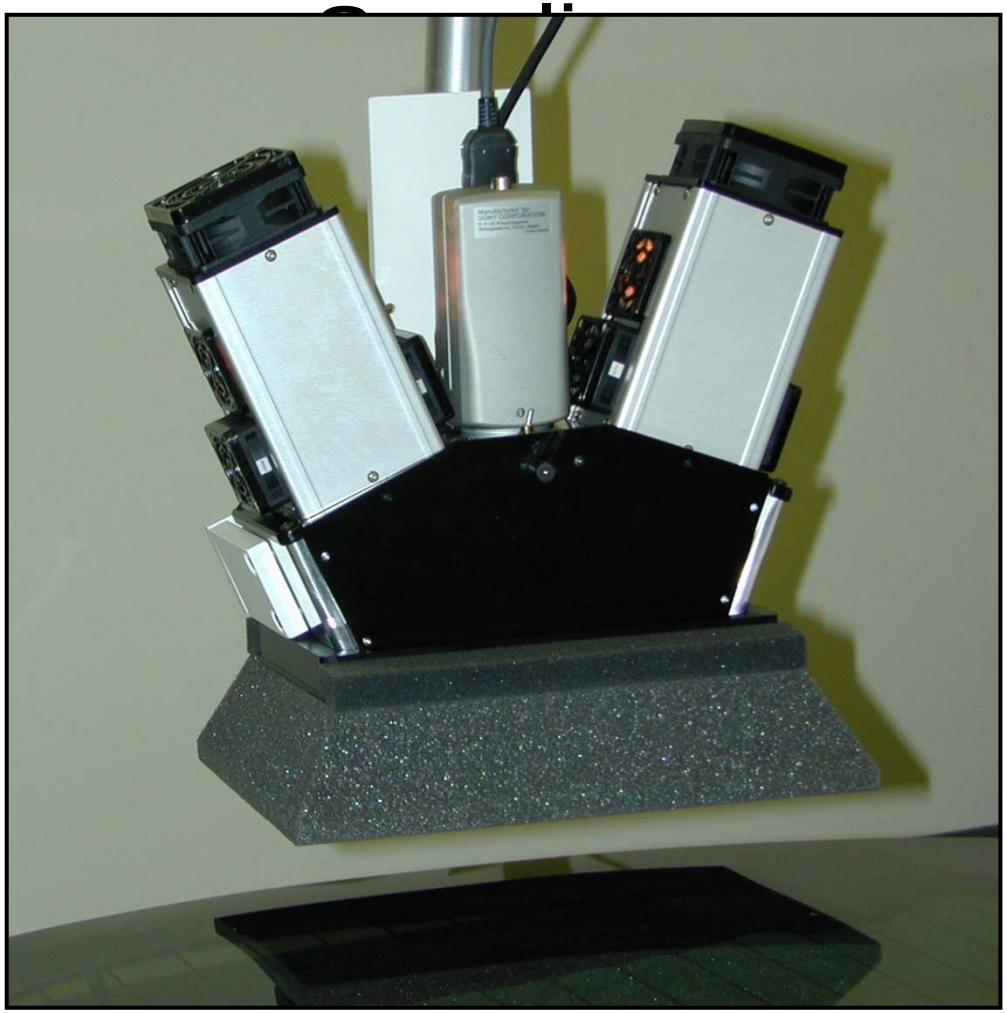
Edge Stress





Stress Photonics

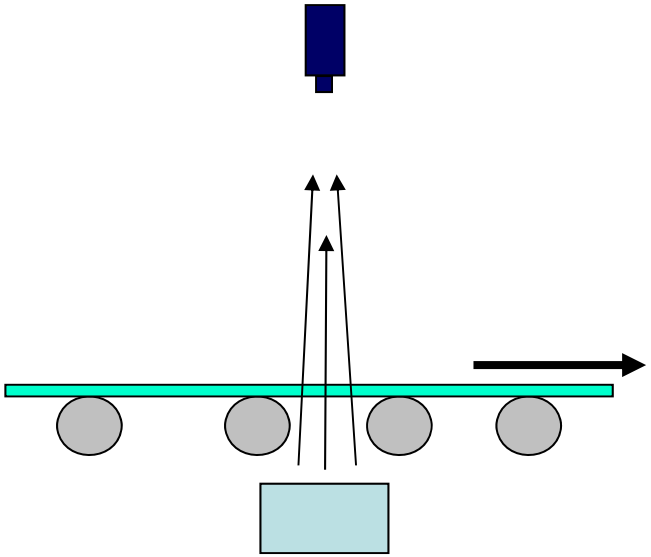
Quality Control – Responsible



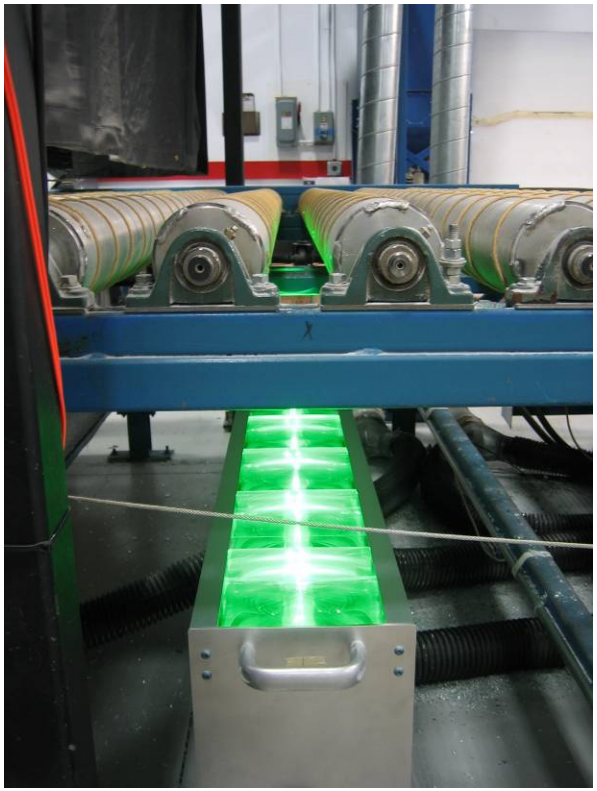
Stress Photonics

Transmission Illuminator

GFP2400m Camera

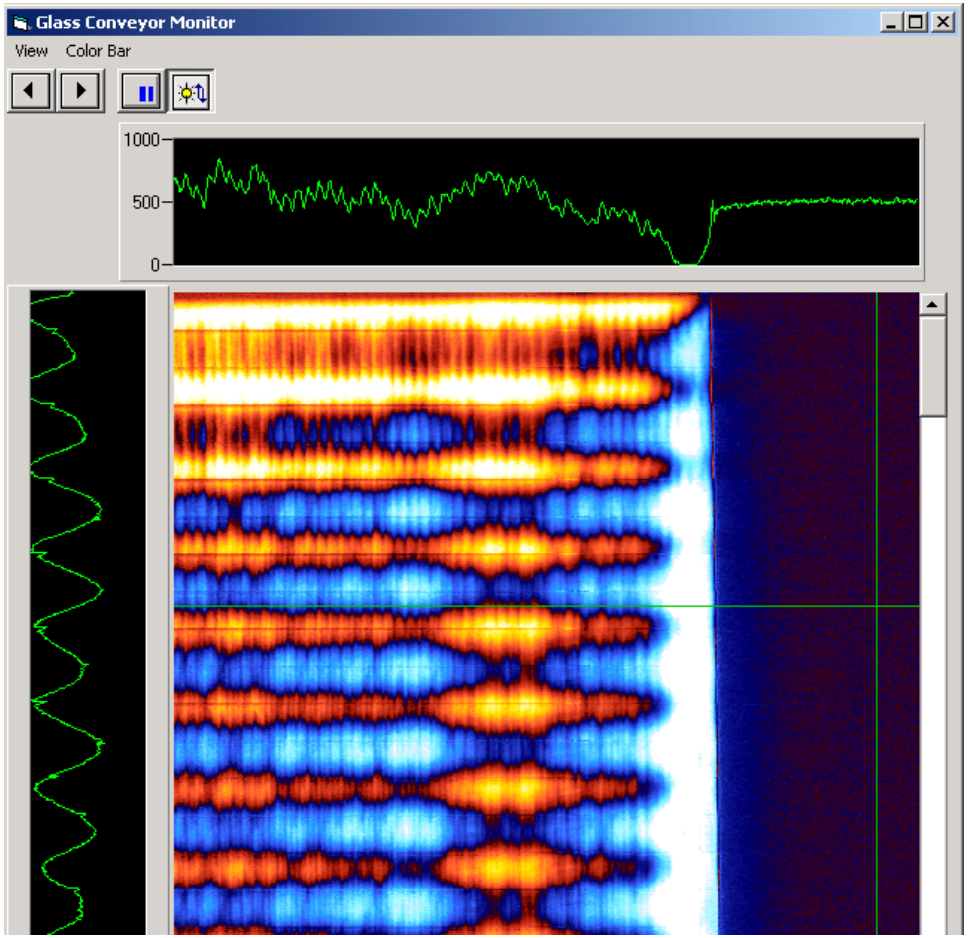


Illuminator Box



Stress Photonics

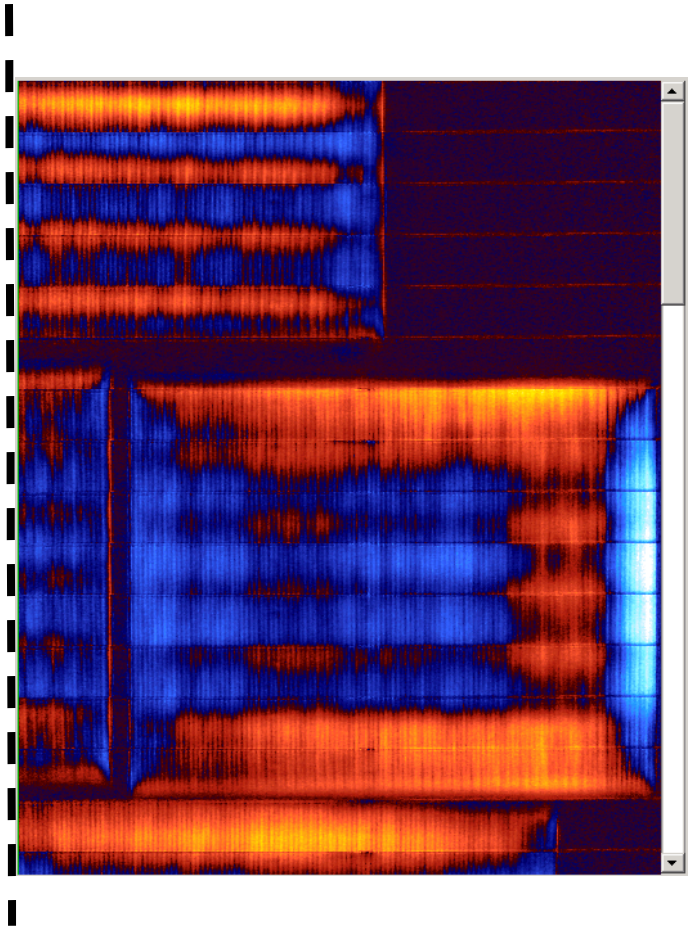
Roll Stress



This image collected with GFP 2000 Online. Also typical example of result from GFP 1200 or GFP 2000

Stress Photonics

10. Heat Treating



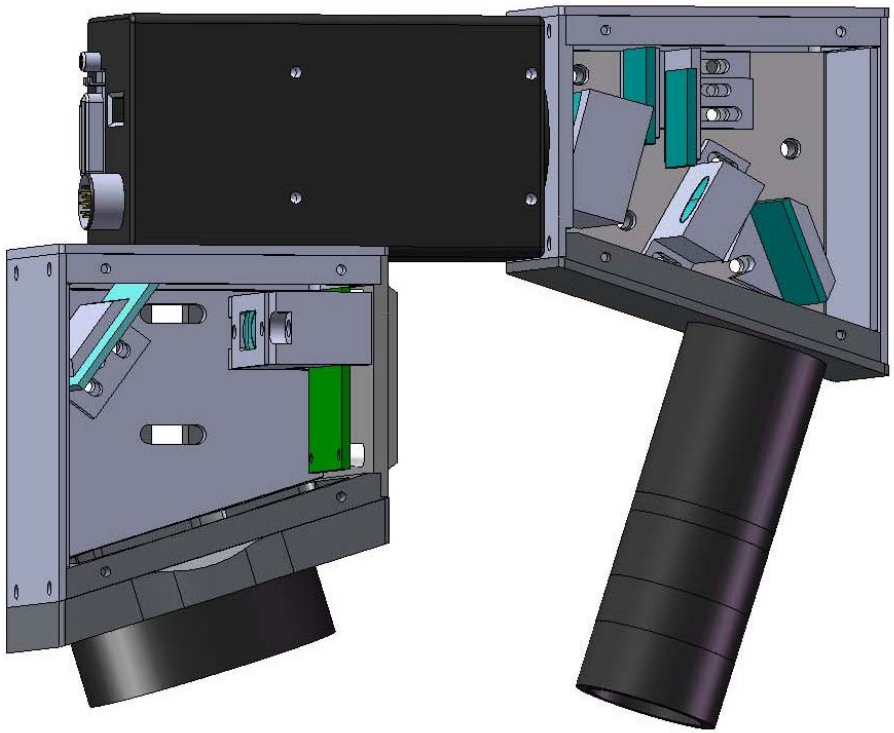
Far right

Center of conveyor

This image collected with GFP 2000 Online. Also typical example of result from GFP 1200 or GFP 2000

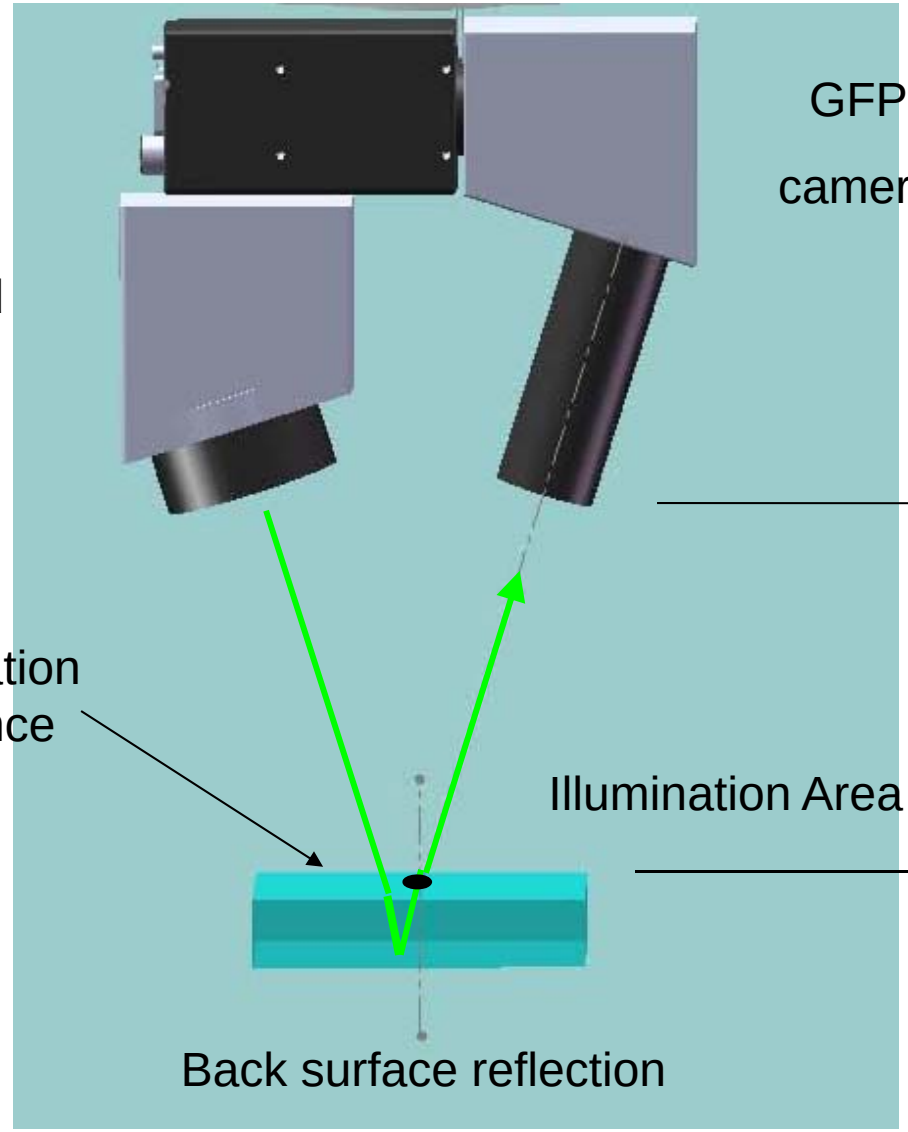
Stress Photonics

Orbiter Window Inspection System - Guts

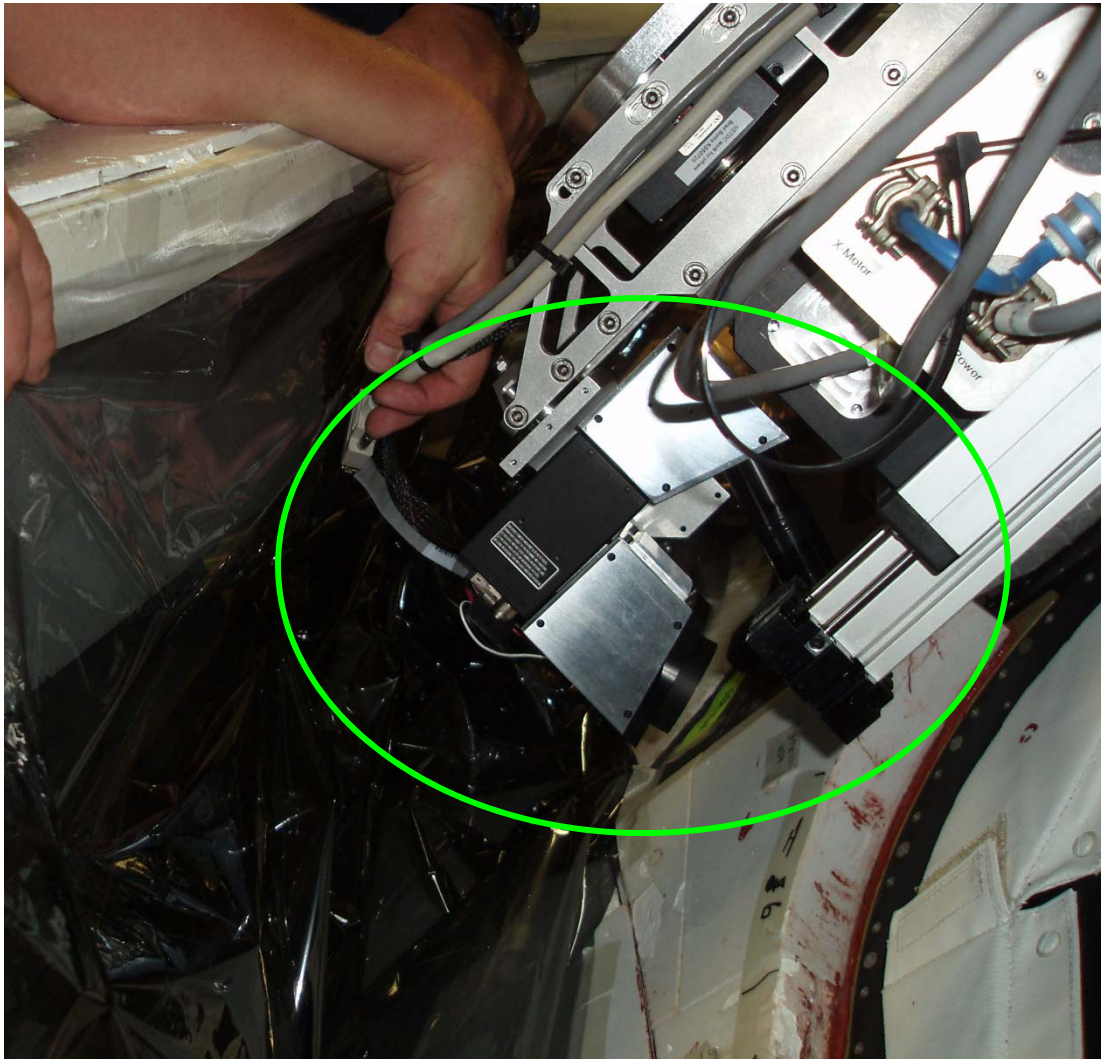


Stress Photonics

Stress Photonics - Orbiter Window Inspection System



Stress Photonics



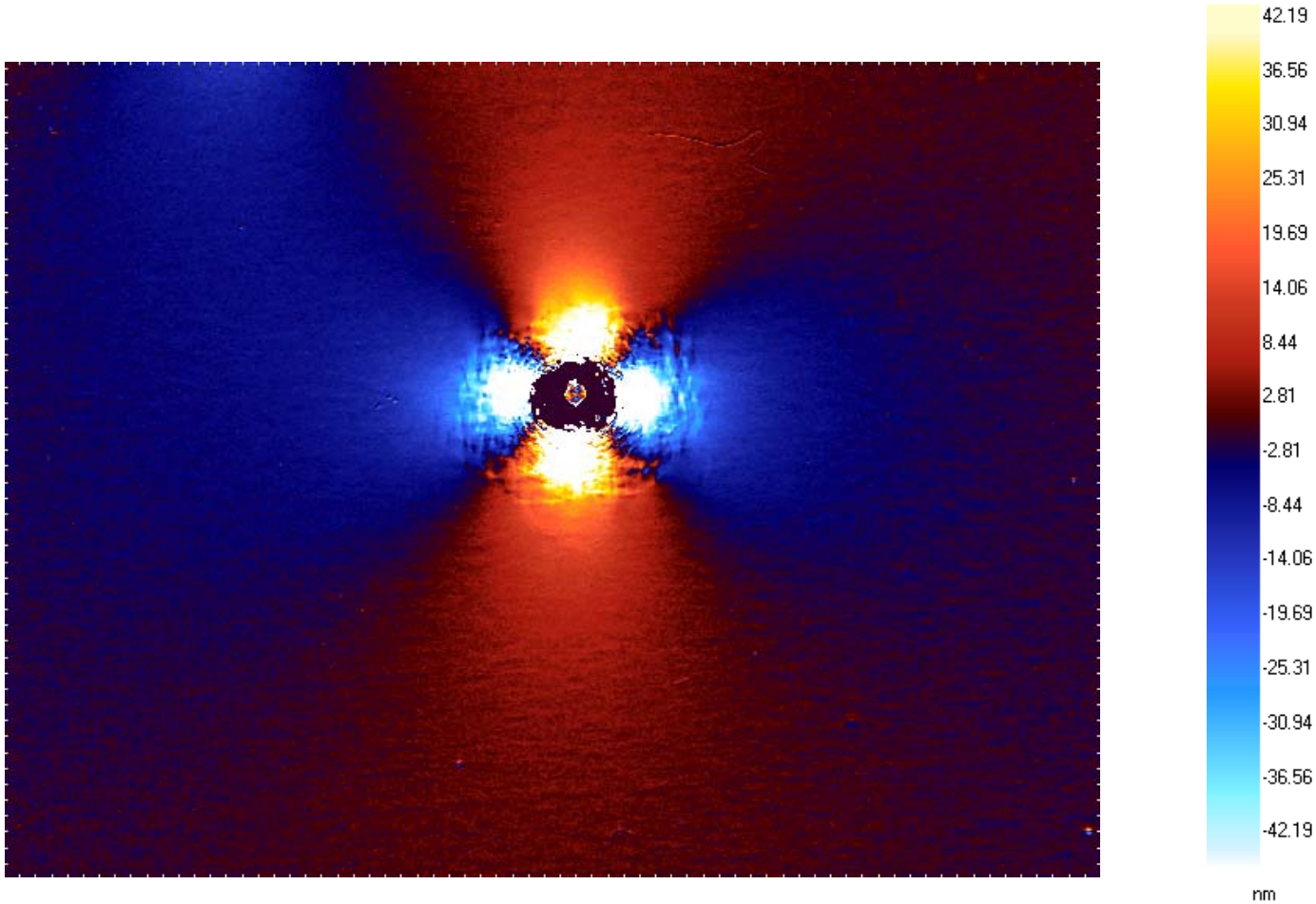
Stress Photonics

Defect stress profiles

- HVI
- LVI / Digs
- Bruise
- Chatter Check

Stress Photonics

27-135-1 HVI

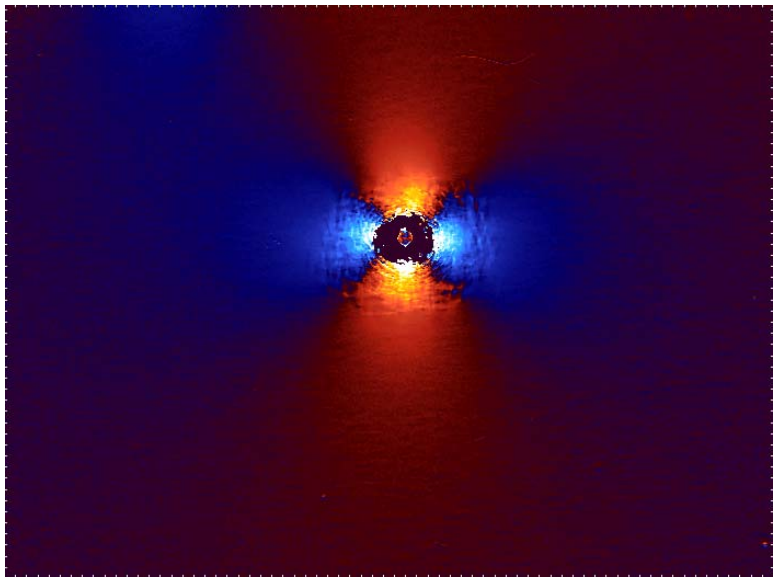


σ_x-σ_y

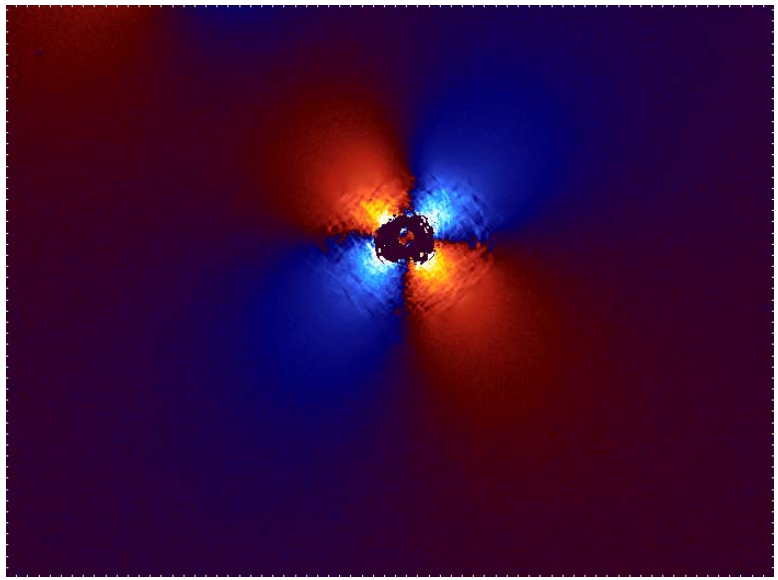
Stress Photonics

GFP 2400 Stress data

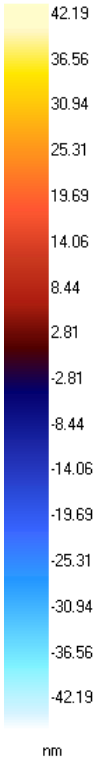
(captured and stored)



$\sigma_x - \sigma_y$



$\sigma_{45} - \sigma_{-45}$

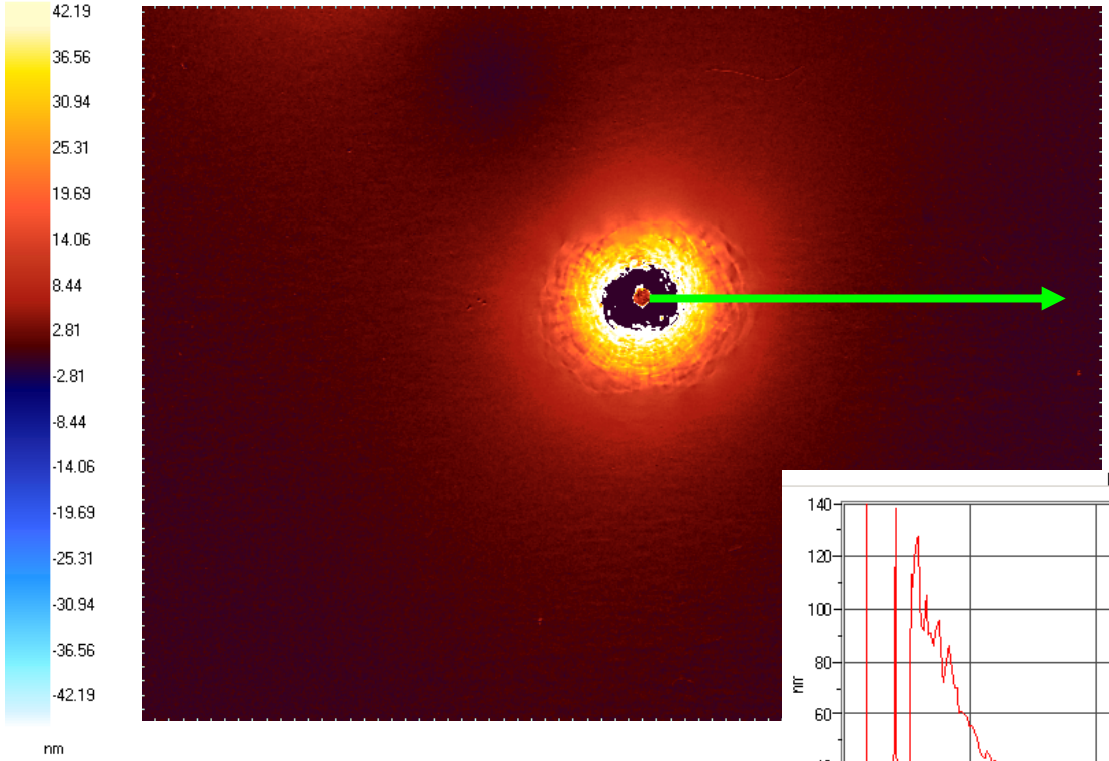


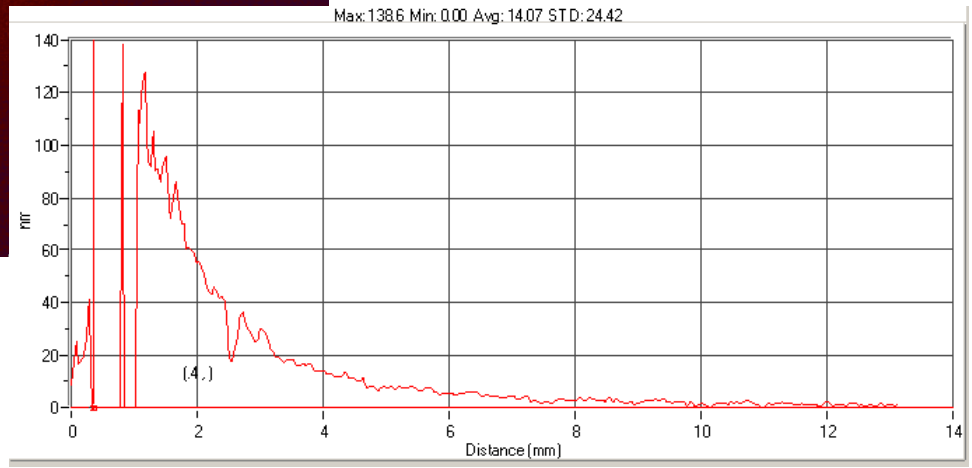
27-135-1 HVI

Stress Photonics

Max in-plane shear (σ_1-σ_2)

(Calculated)





27-135-1 HVI

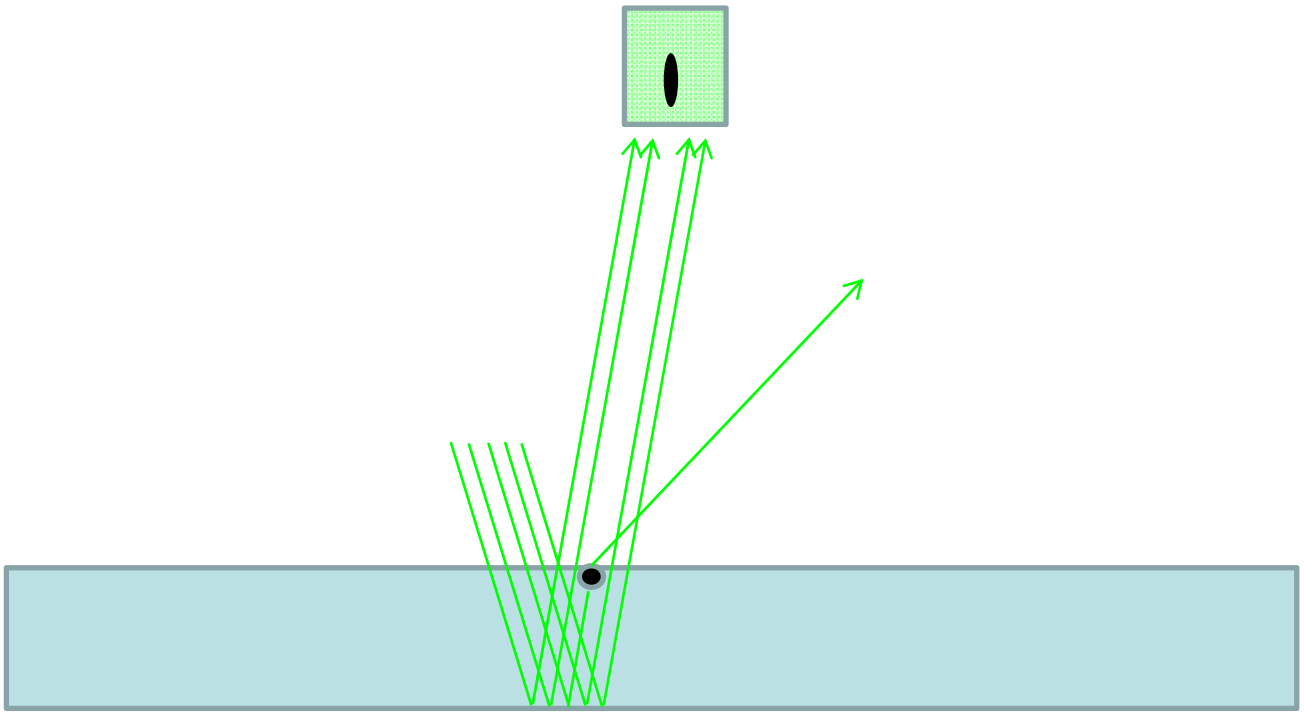
Stress Photonics

Modes of operation

- Stress
- Shadow
- Schlieren
- Refractive polarization

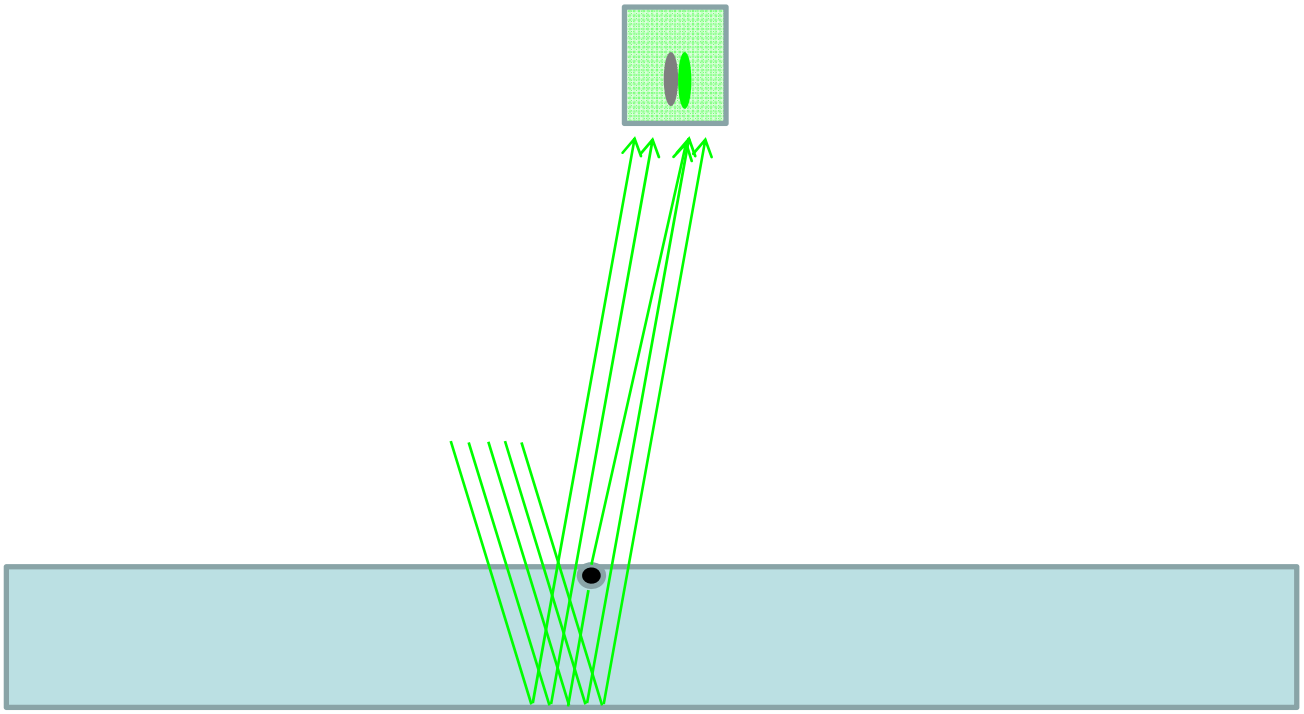
Stress Photonics

Shadow



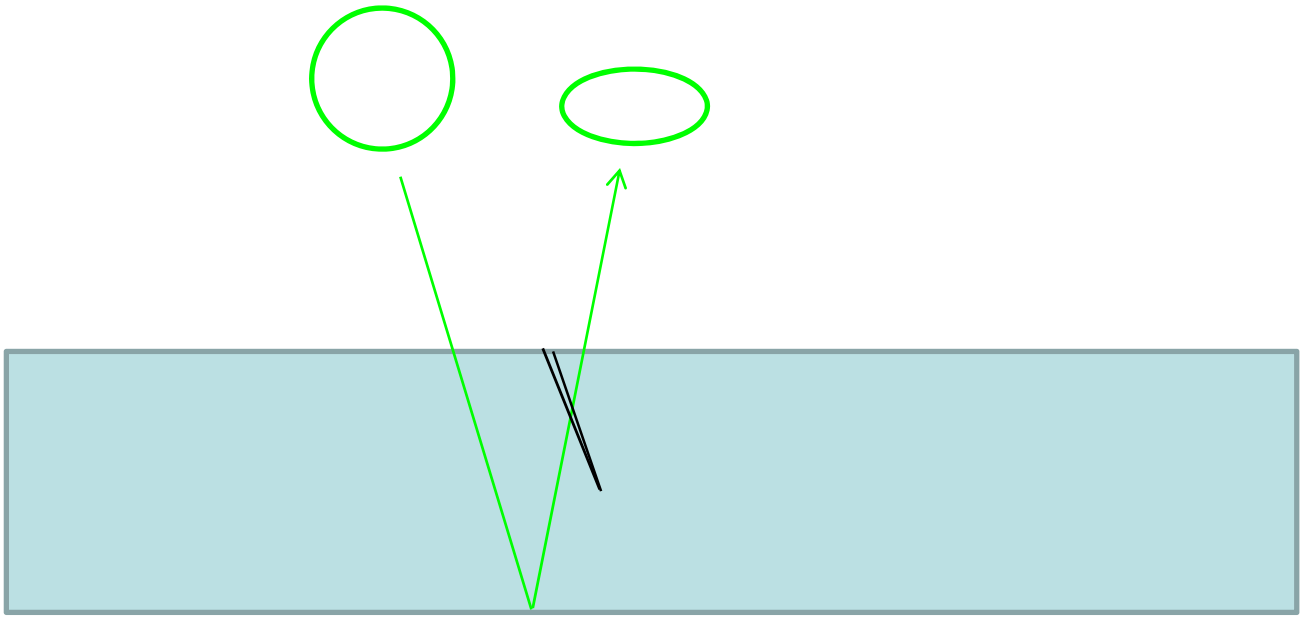
Stress Photonics

Schlieren



Stress Photonics

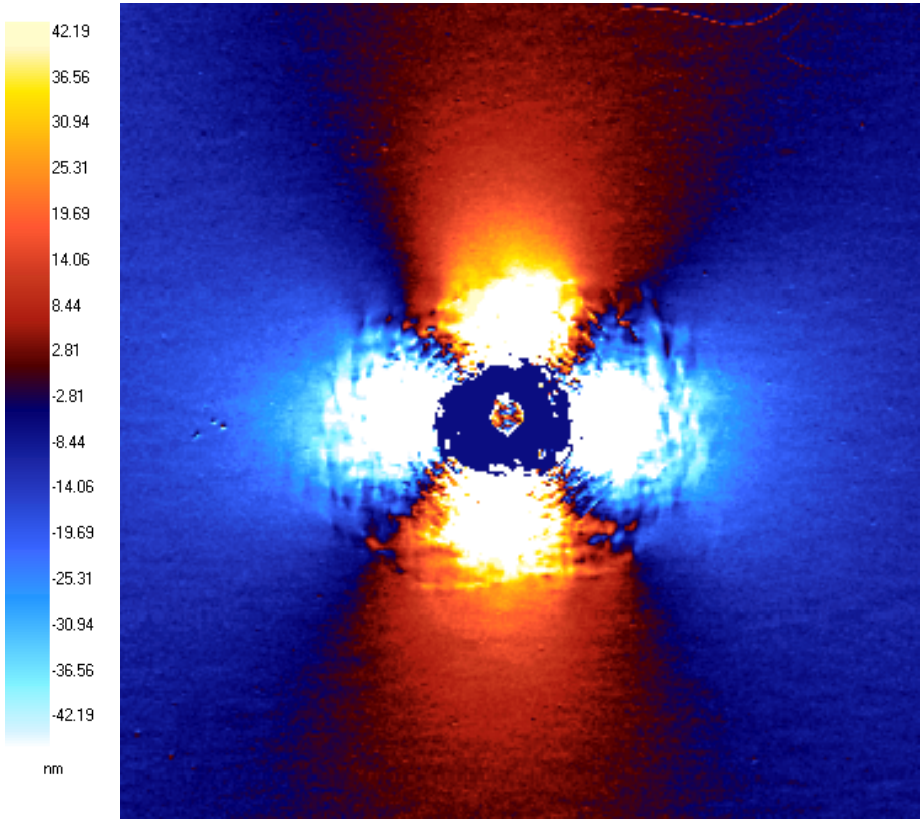
Refractive Polarization



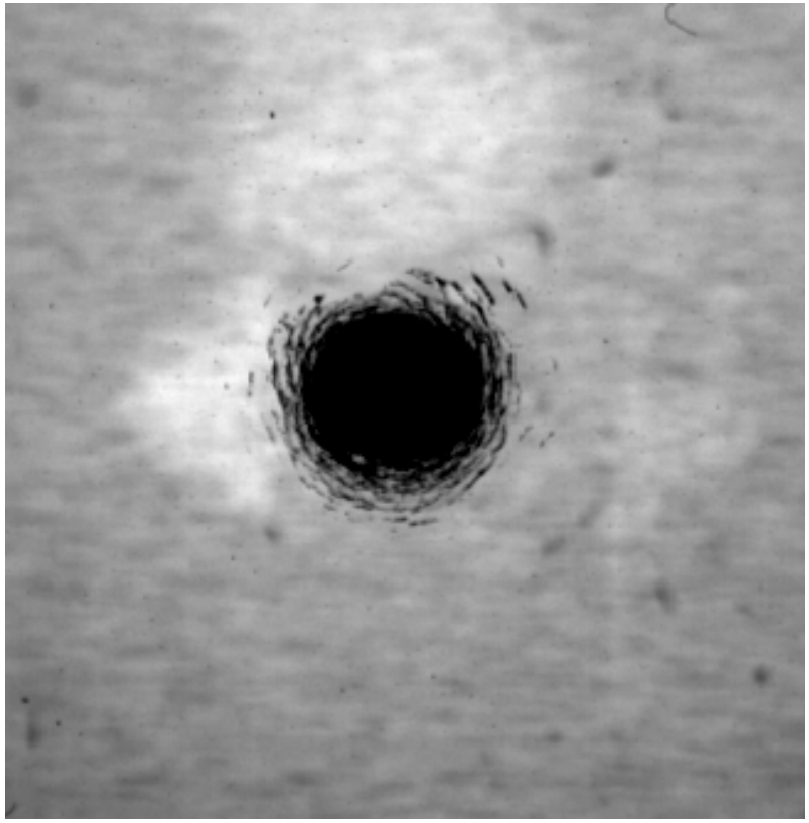
Shadow and Polarization match

Stress Photonics

HVI Stress Profile



σ_x-σ_y

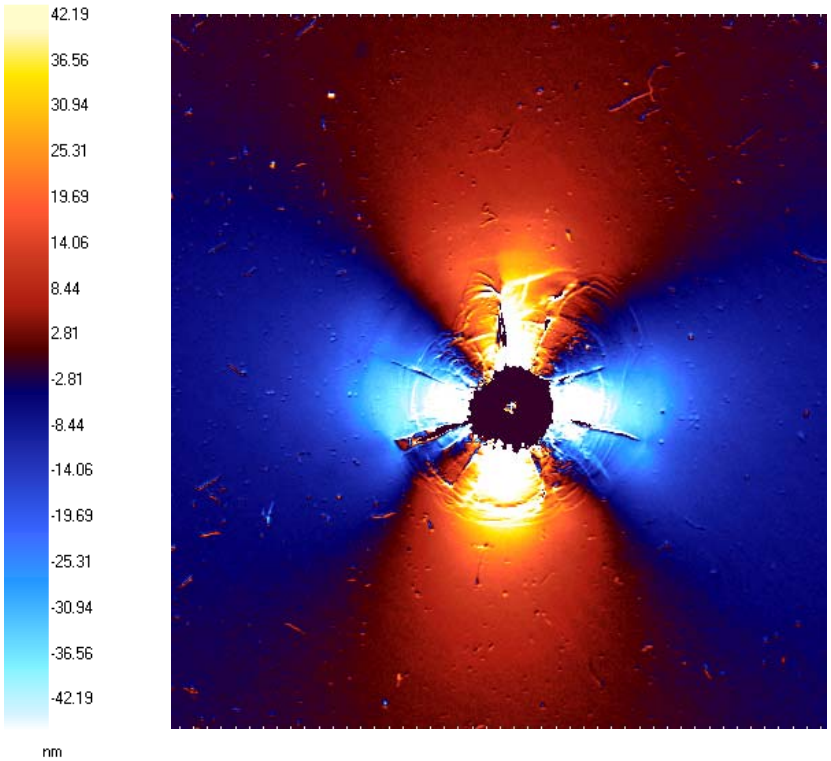


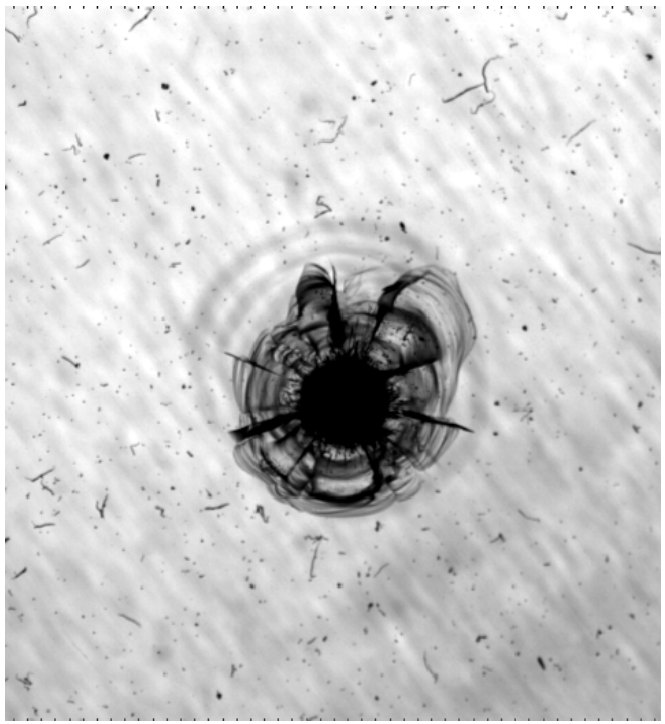
Light Image

27-135-1 HVI

Stress Photonics

Stress Fields

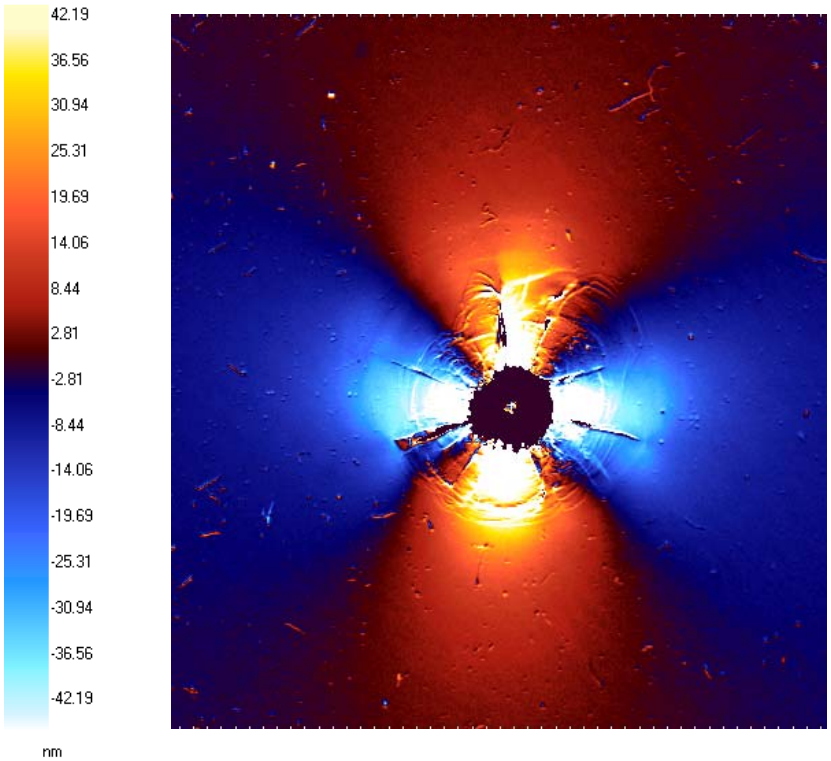


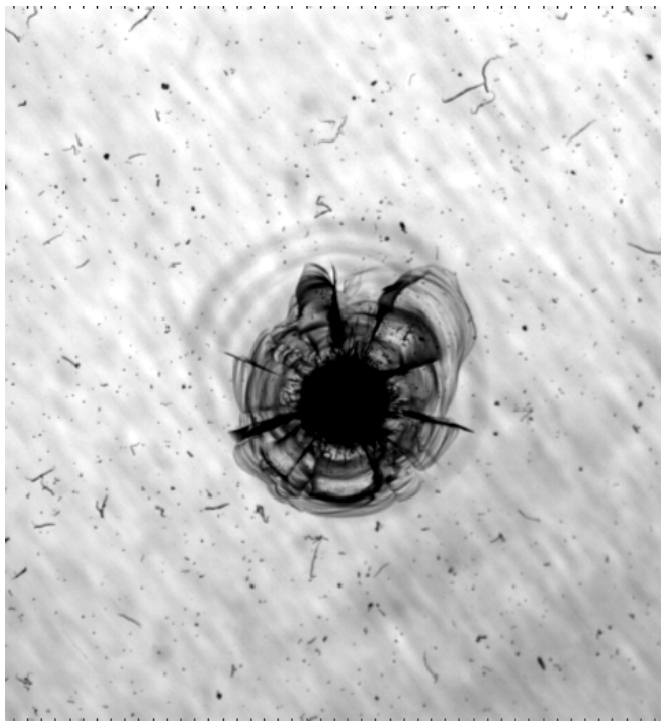


Stress Fields extend outside of shadow

Stress Photonics

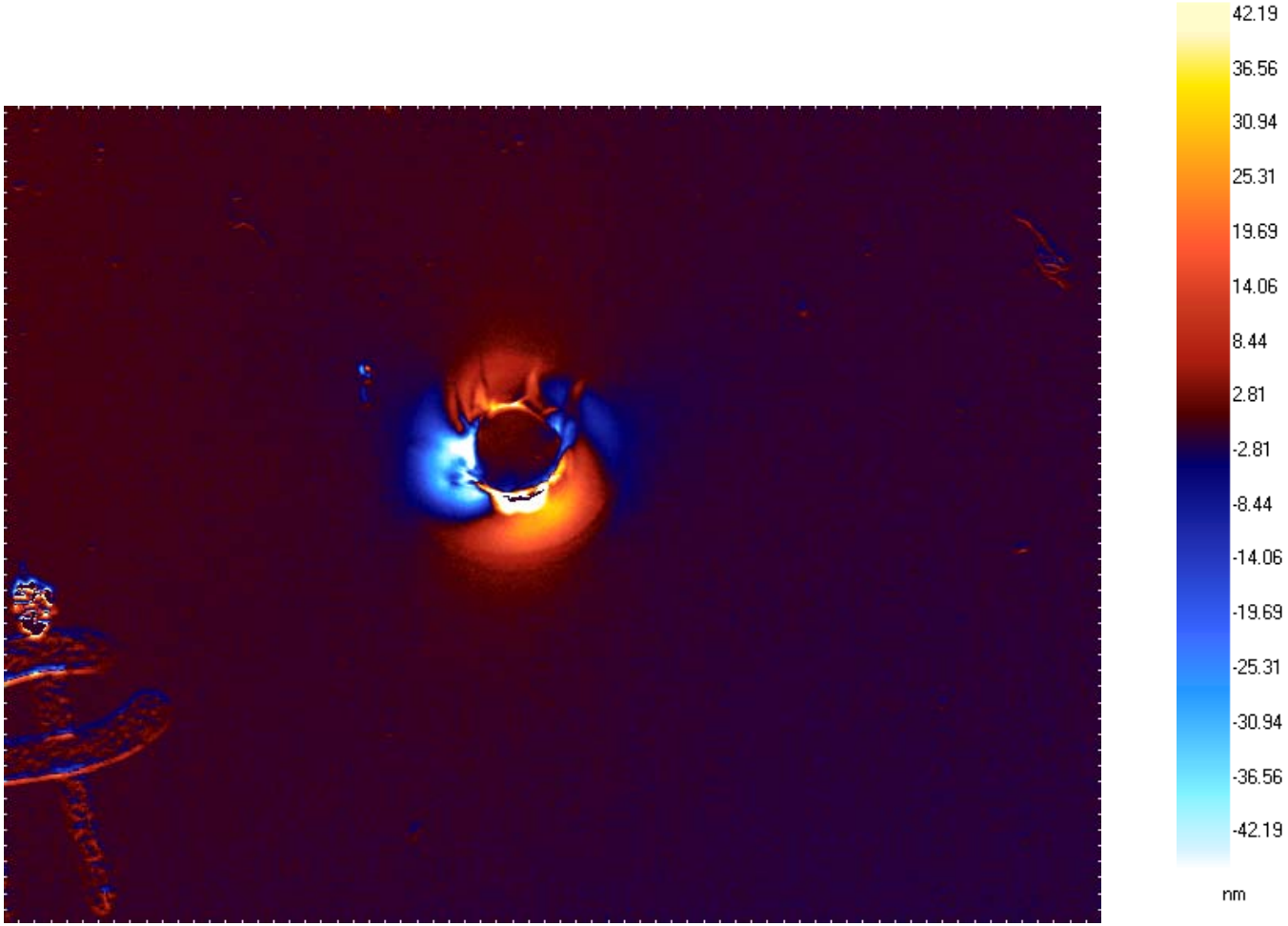
HITF 05305





Stress Photonics

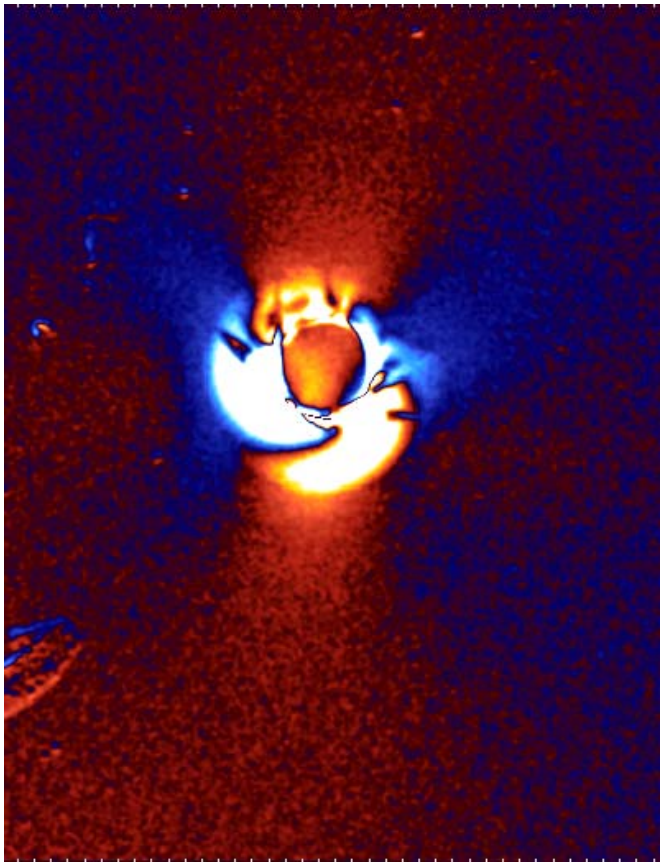
27-139-18 Bruise



Stress Photonics

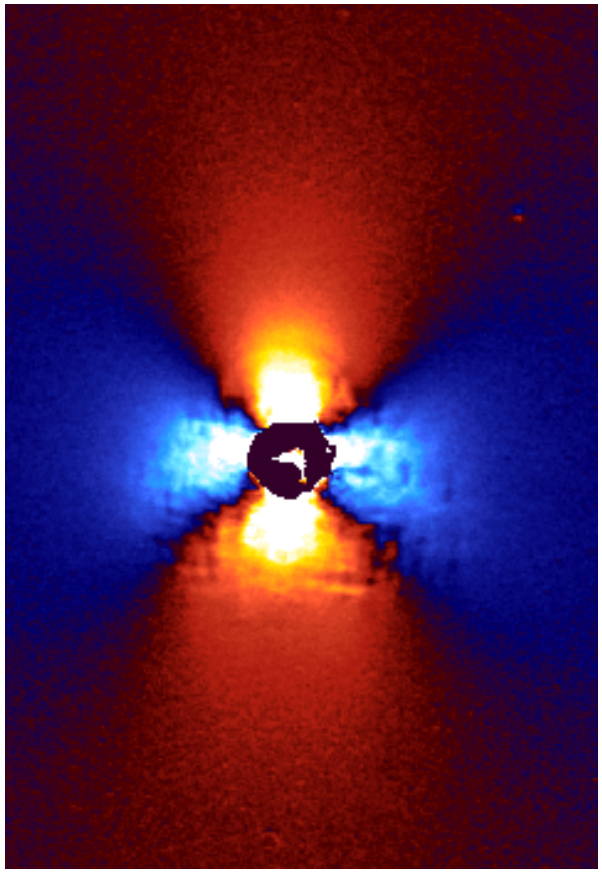
Stress Profile differentiation

Bruise



27-139-15

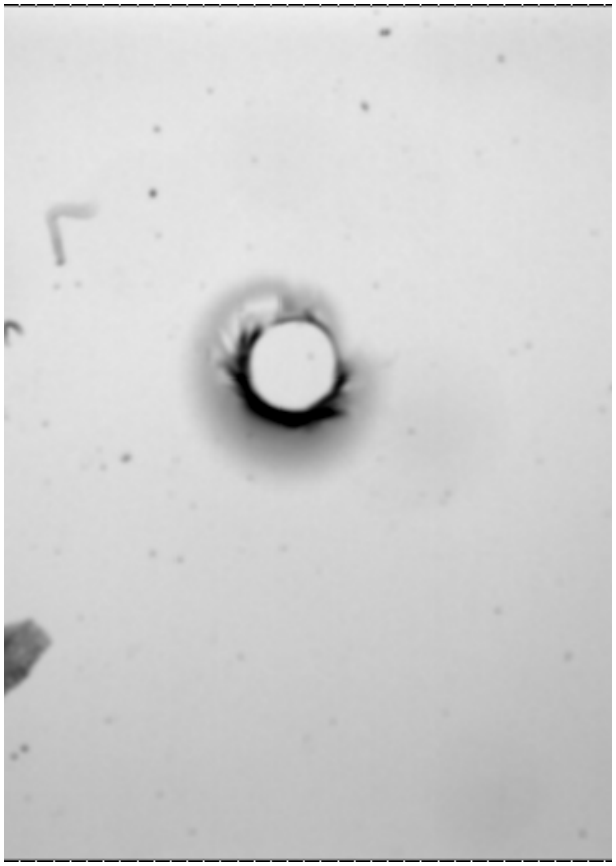
HVI



27-116-1

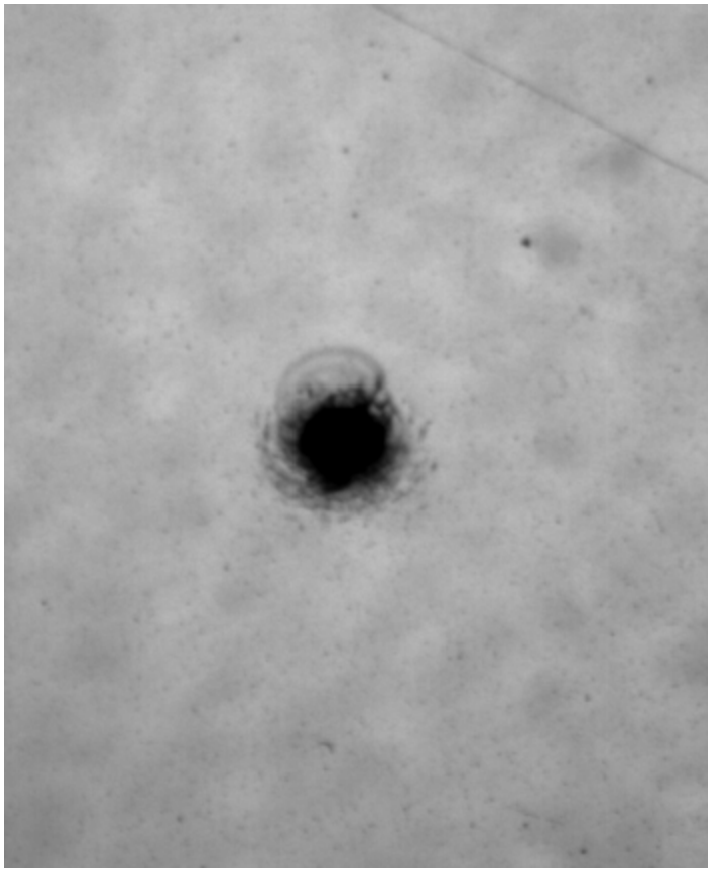
Stress Photonics

Bruise



27-139-15

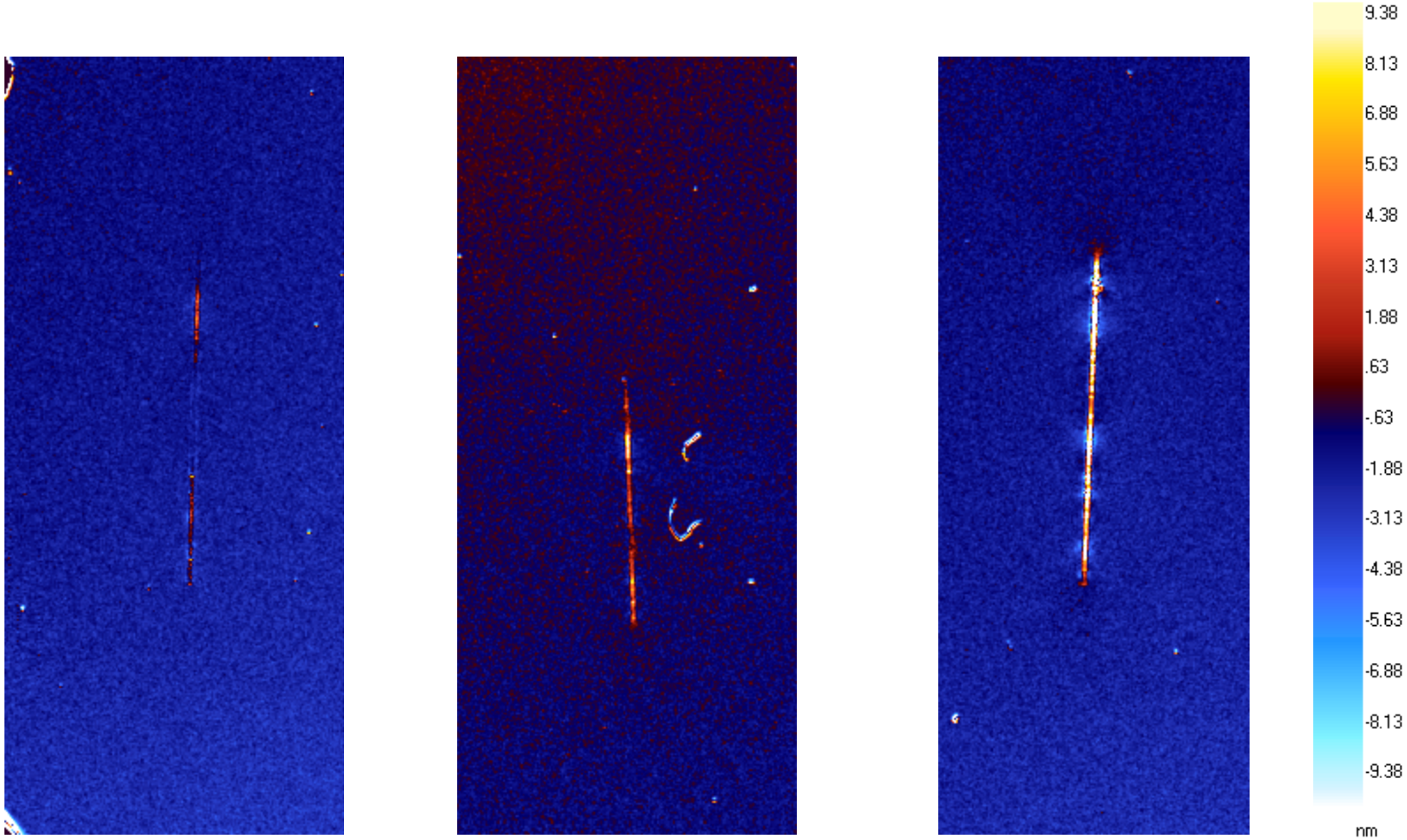
HVI



27-116-1

Stress Photonics

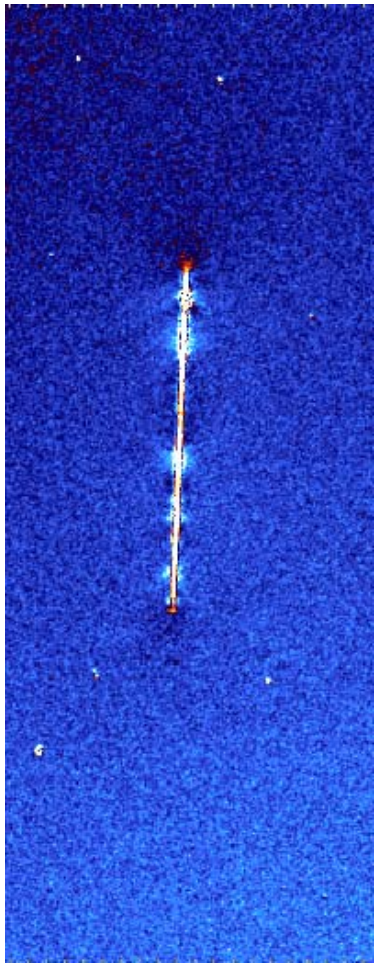
Chatter Checks



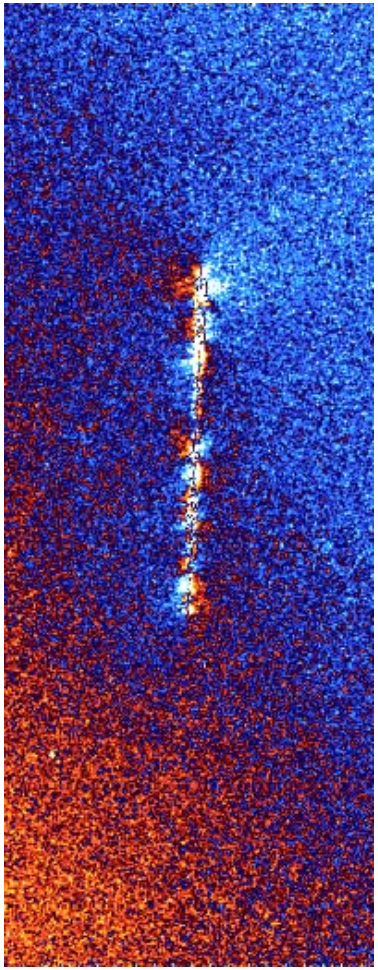
26-210-31 26-210-25 26-210-30

Stress Photonics

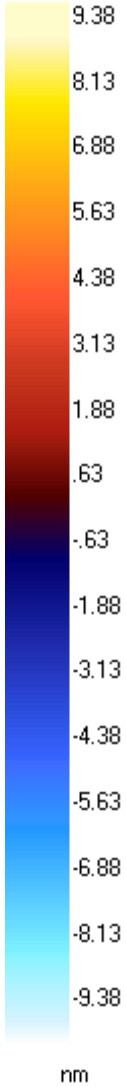
26-210-30 CC



σ_x-σ_y

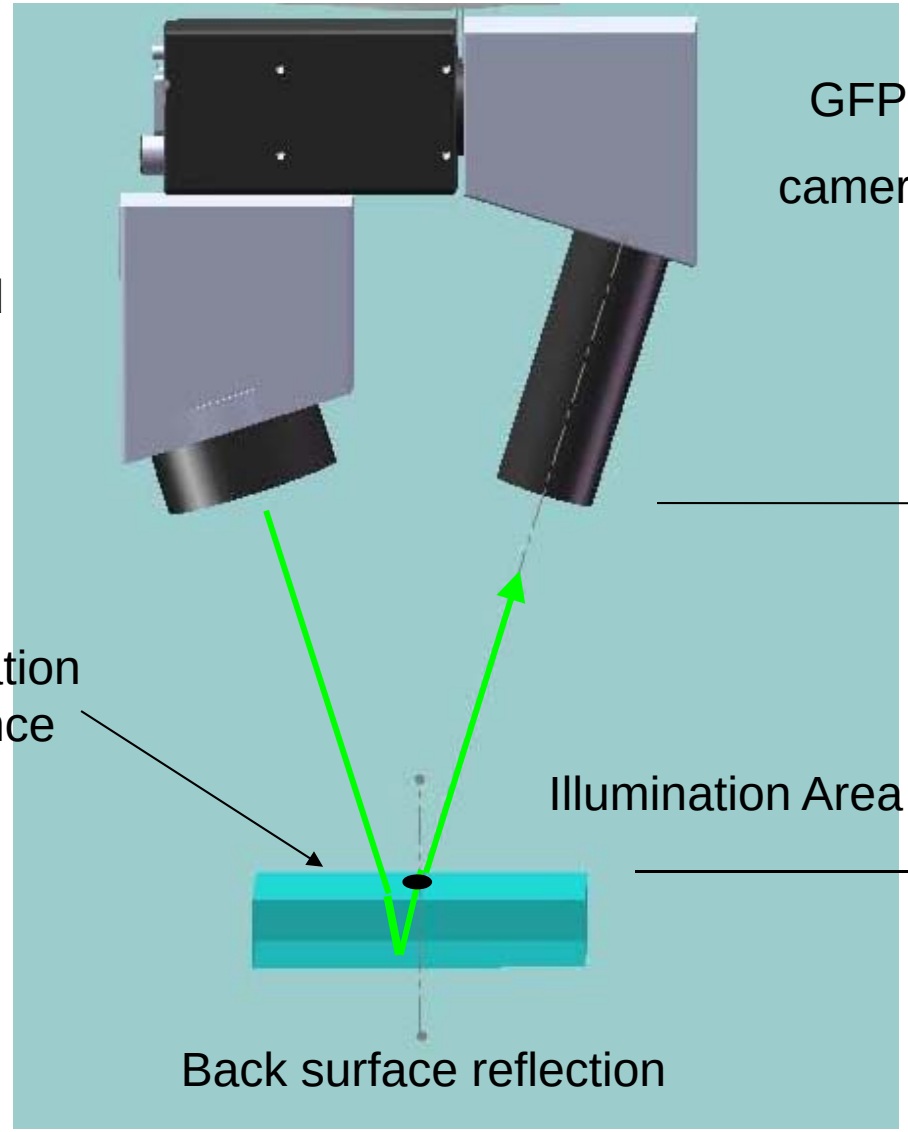


σ_{45}-σ_{-45}



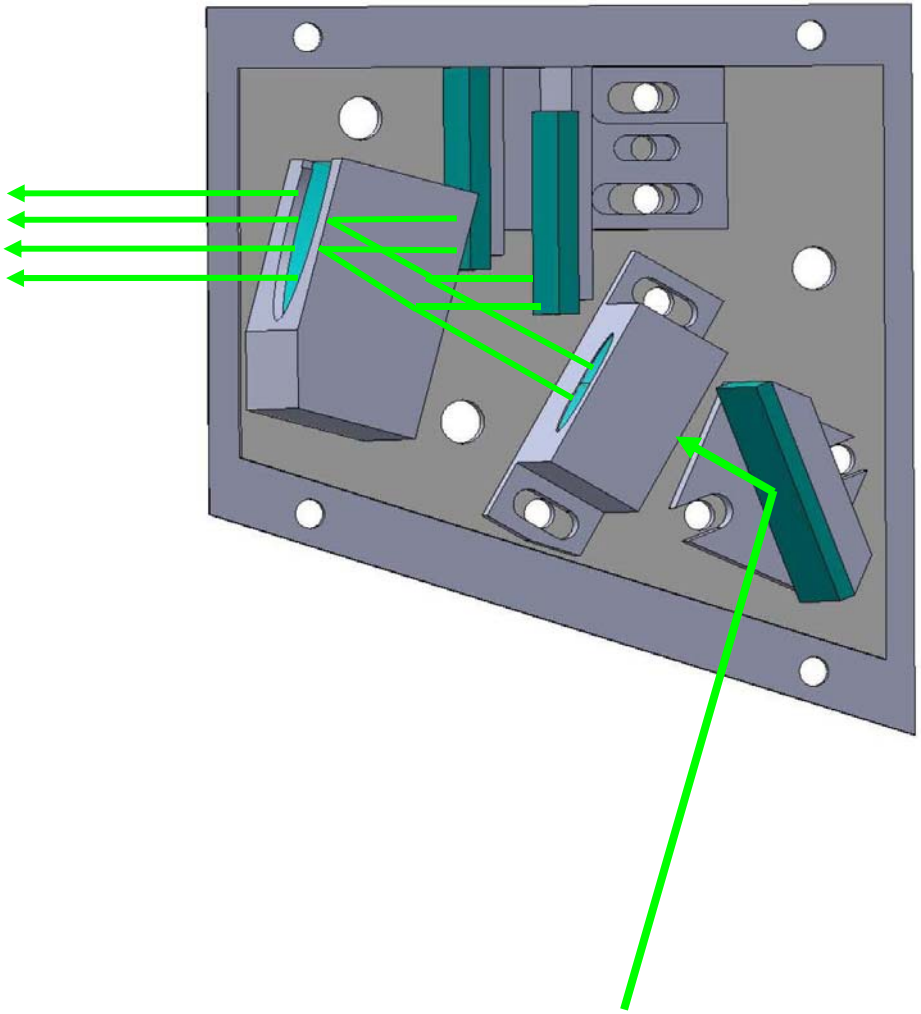
Stress Photonics

Stress Photonics - Orbiter Window Inspection System



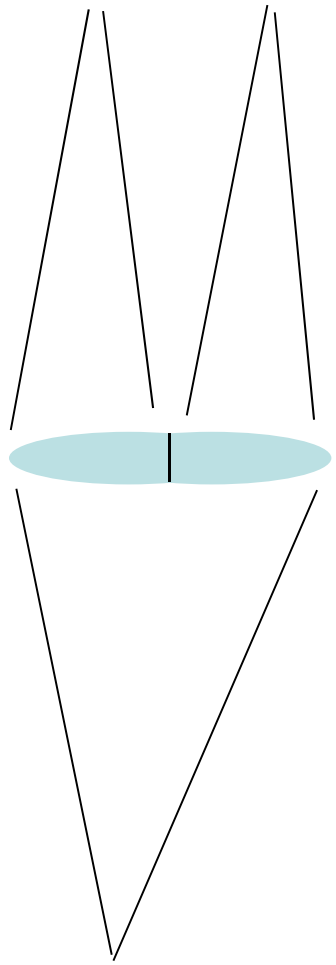
Stress Photonics

Image Separation



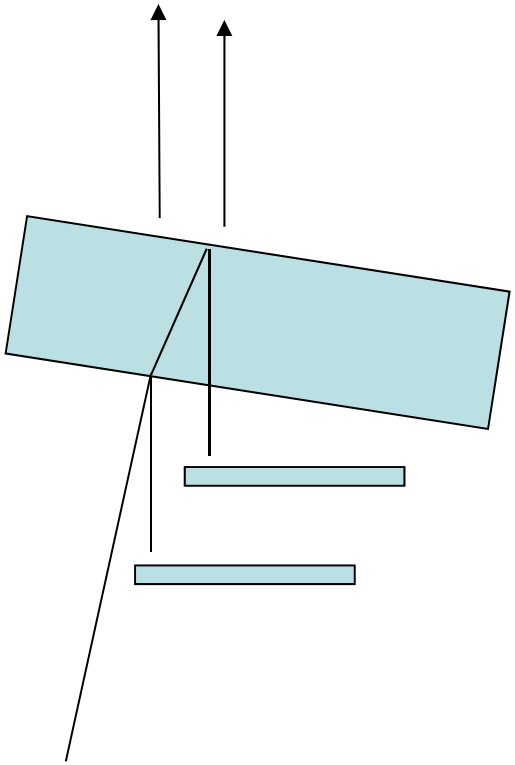
Stress Photonics

Stereoscopic Copies



Stress Photonics

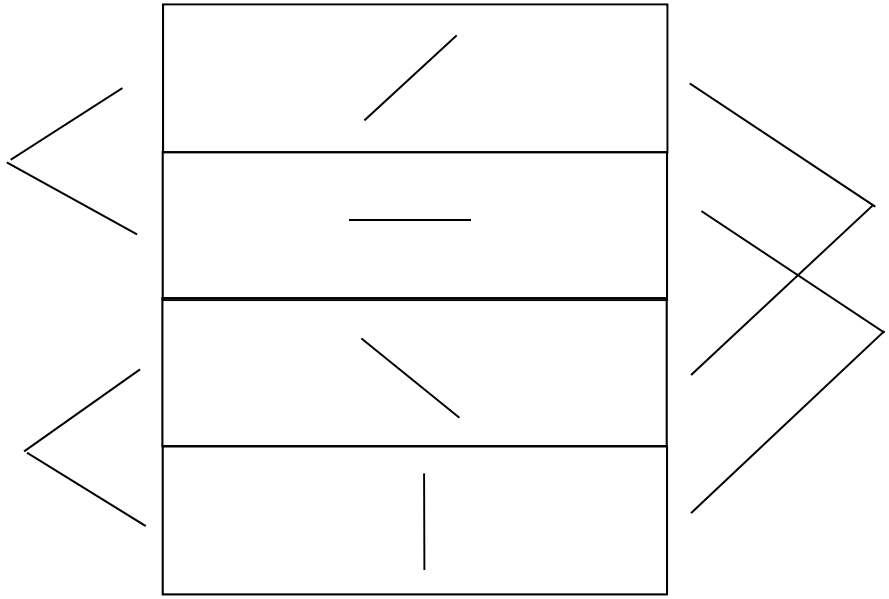
Exact Copies



Stress Photonics

Stereoscopic

Copies



Exact

Copies

Stress Photonics

Assessment

- Automated
- Fast
- Very high detection
- Good defect differentiation

Stress Photonics

Qualifying remarks

- This primary goal of this method is to detect and identify types of defects.

- The geometric stress concentration and the service loads dictate failure, not the presence of residual stress in a parked state.