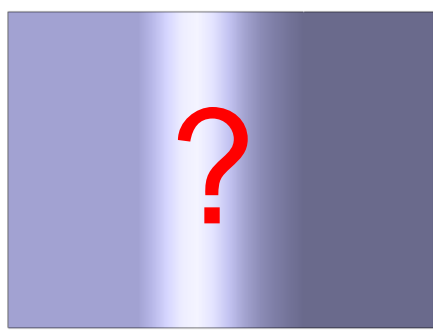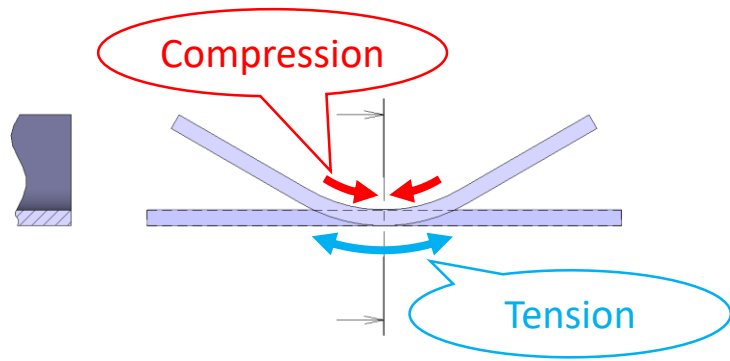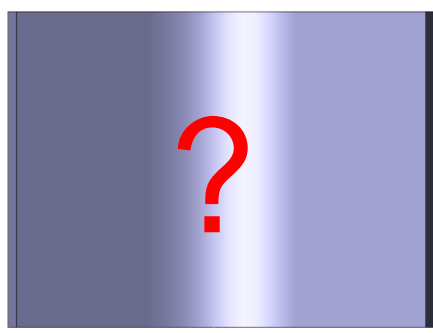# Analysis of Dynamic Strain on Foldable Devices
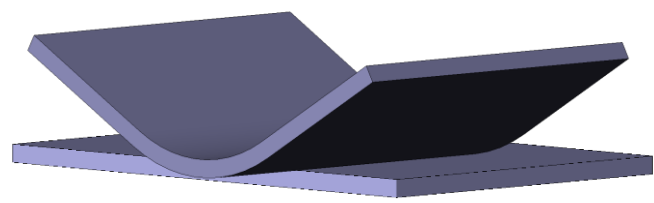
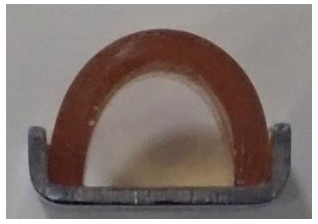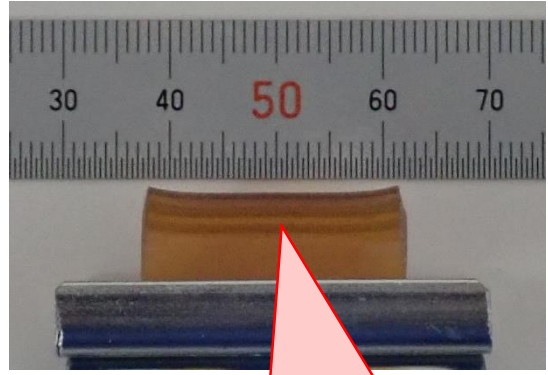Session 29-1

Aug. 5, 2020

Nao Ando, R&D, YUASA SYSTEM

Hybrid Relationship creates Wonderful Hybrid Future

What happens if a film bends?

Compression

Tension

Hybrid Relationship creates Wonderful Hybrid Future

What happens if an object bends?

Case of an urethane rubber sheet (t=3mm)

Repeatedly bending
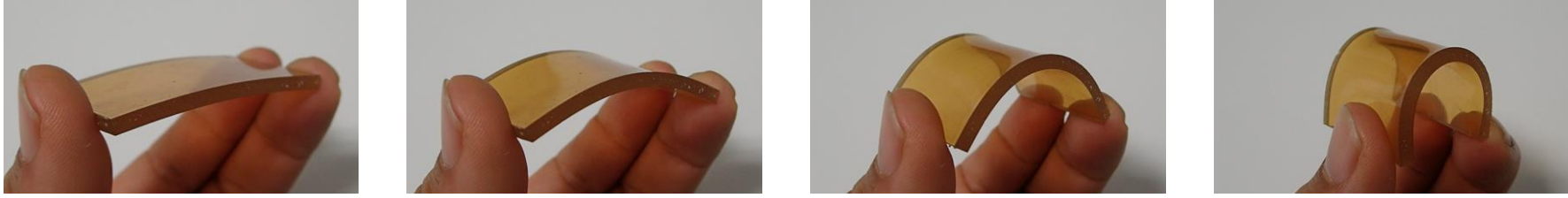
Top of arch is shaped strange shape!?

Hybrid Relationship creates Wonderful Hybrid Future

What happens if an object bends?

Case of a metallic plate (=3mm)

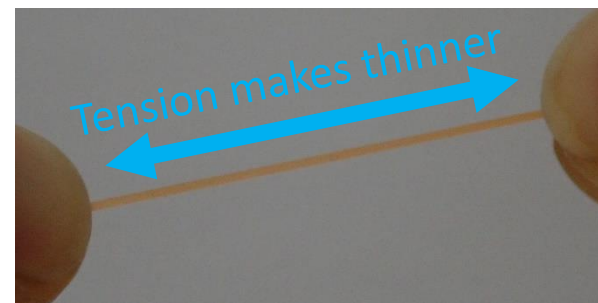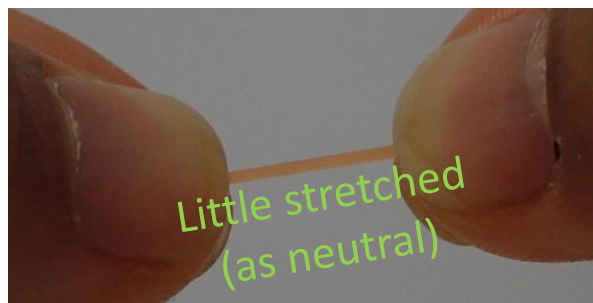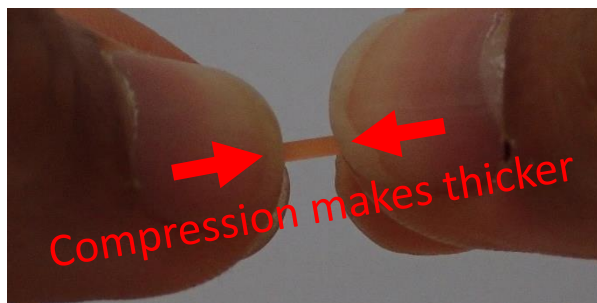General metallic bracket

Inside

Something is protruding!!

Side view

Looks like nothing is happening···
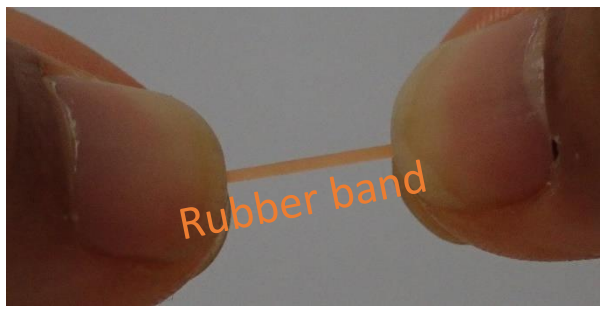
Outside

Complicated deformation!?

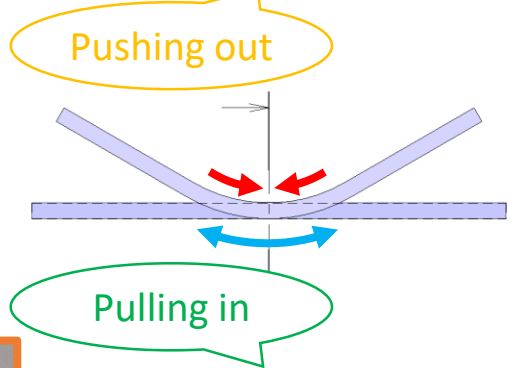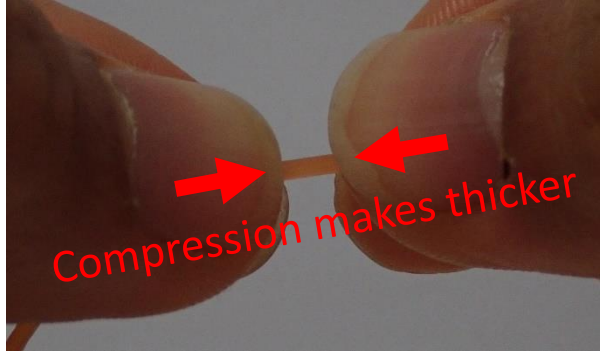Hybrid Relationship creates Wonderful Hybrid Future

What happens if an object bends?

Stretchable object "rubber band" has a hint to know that!

Compression makes thicker

Little stretched
(as neutral)

Tension makes thinner

Hybrid Relationship creates Wonderful Hybrid Future

What happens if an object bends?

Pushing out

Shear stress

That's why!!

Pulling in

Compression makes thicker

Rubber band

Tension makes thinner

Hybrid Relationship creates Wonderful Hybrid Future
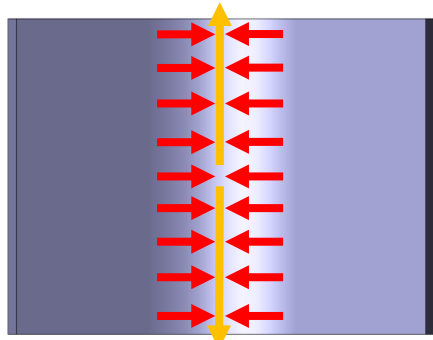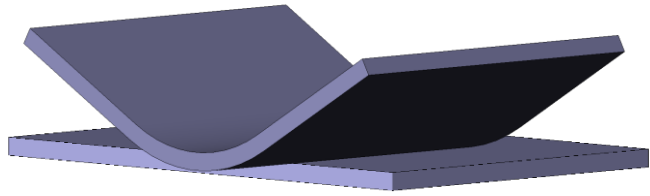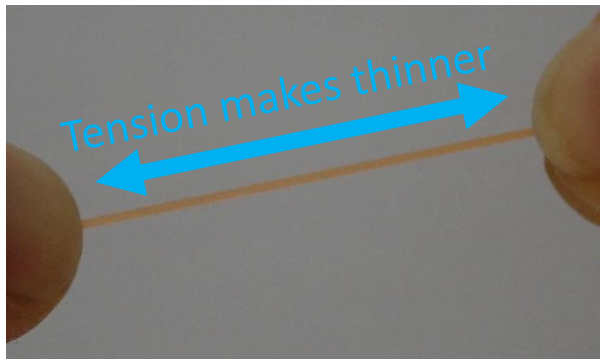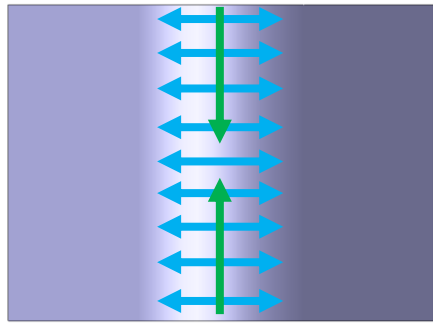
What happened on an object?

How much strain has occurred?

Hybrid Relationship creates Wonderful Hybrid Future

Contents

Hybrid Relationship creates Wonderful Hybrid Future

Mechanoluminescence [ML]

ML material (powder)
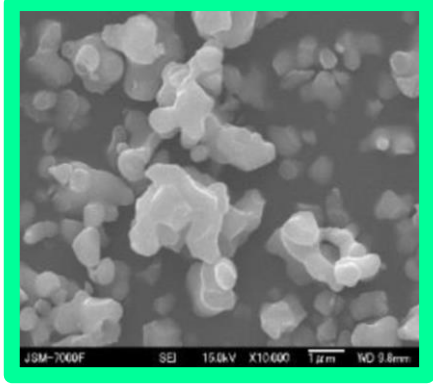
Mix in specimens

Paint on specimens

Proportion

ML intensity (a. u.)

Emission I

F

F

Strain Energy (μJ)

If stretch a holed plate...
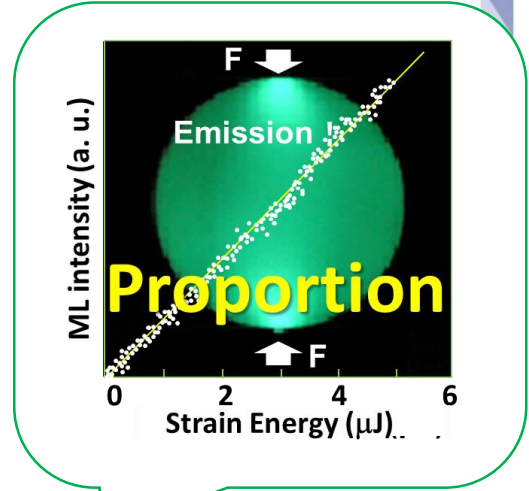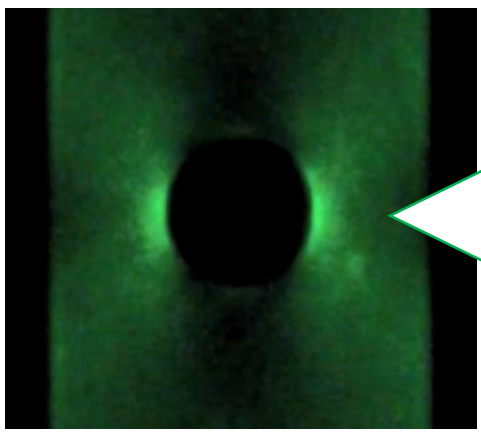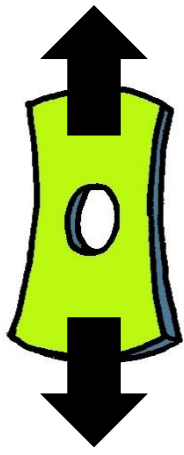
Visible green light (ML) shows
Dynamic Strain Energy
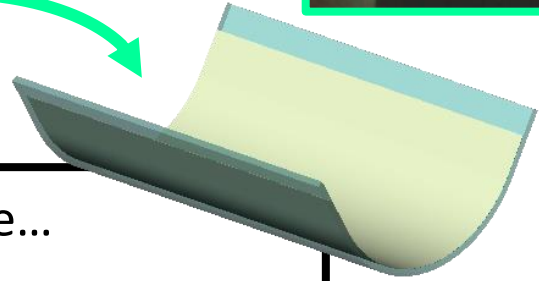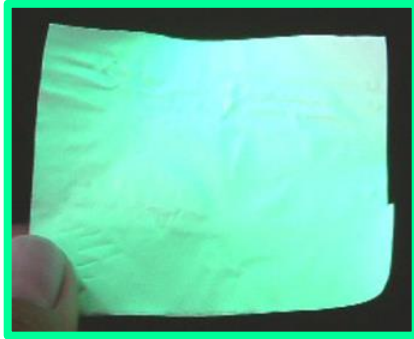(≒Painted surface strain changing amount per unit time)

If surface strain increases fast, ML becomes bright.
If surface strain not change, ML never emits.
*ML painted film never shows stresses of a specimen.

Provided from AIST

Hybrid Relationship creates Wonderful Hybrid Future

Result 2) Lighting Conditions on ML

Basic process

Absorb energy from light of the wavelengths below 600 nm

Wait for the afterglow to decrease... MUST keep dark!

Emit green light "ML"

Hybrid Relationship creates Wonderful Hybrid Future

Various Factors Affect ML Brightness
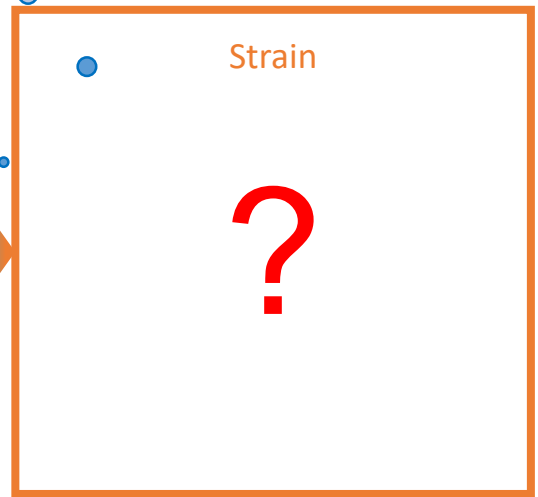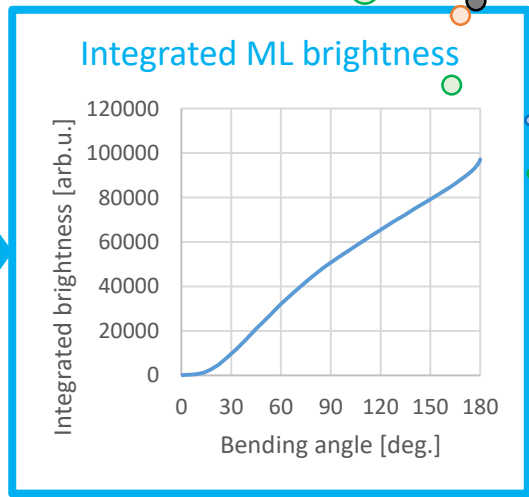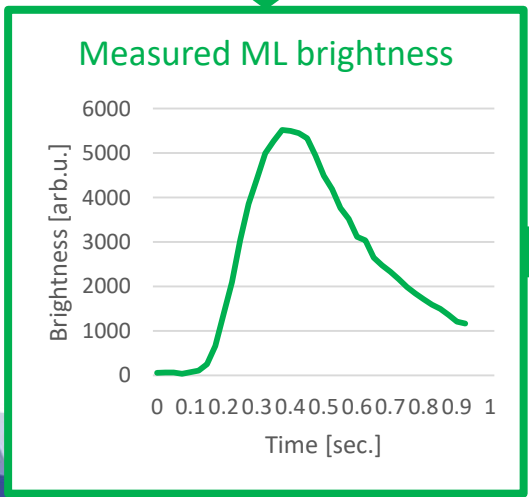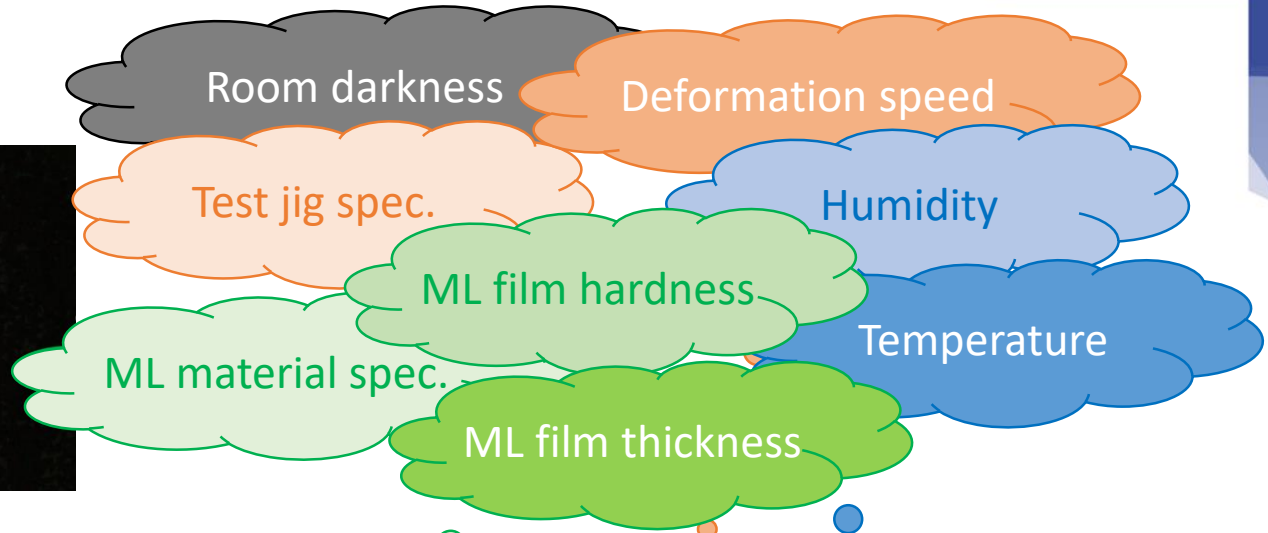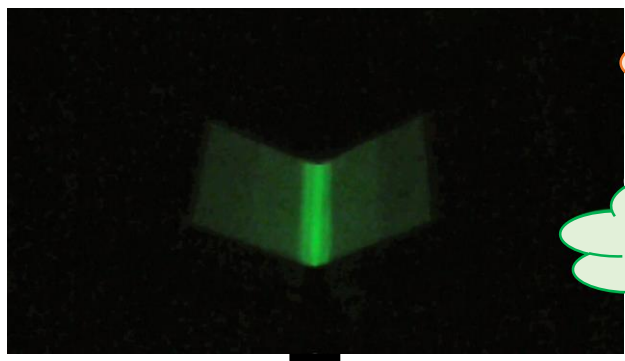
Various Factors Affect ML Brightness
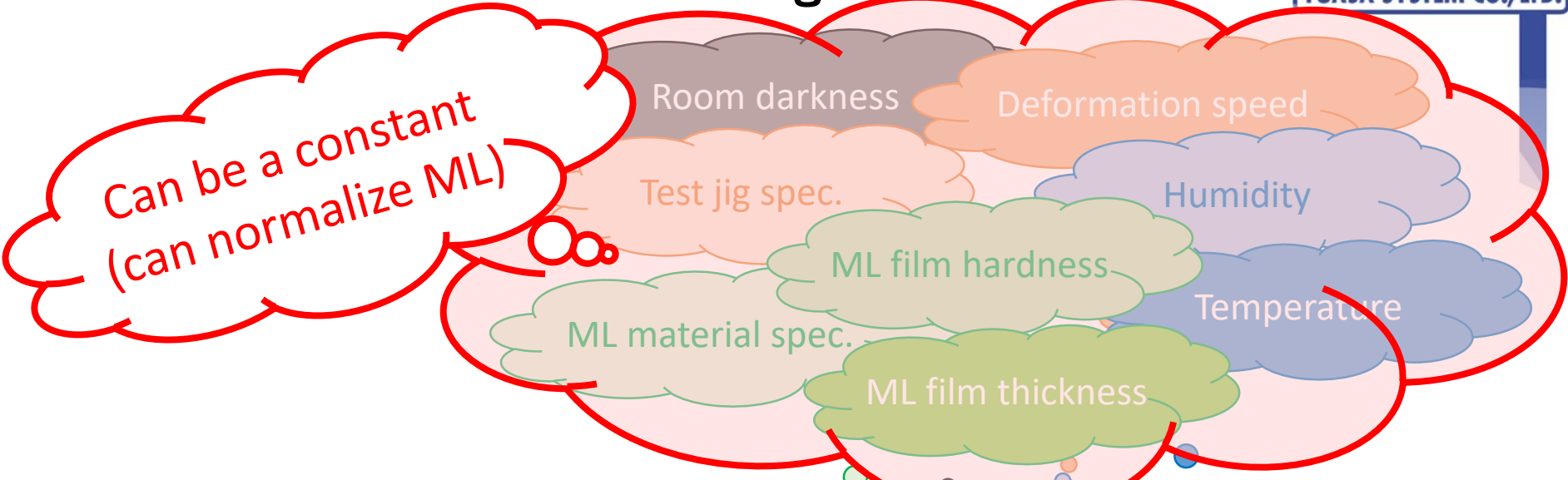
Can be a constant (can normalize ML)

Room darkness

Deformation speed

Test jig spec.

Humidity

ML film hardness

Temperature

ML material spec.

ML film thickness

Measured ML brightness

Brightness [arb.u.]

6000
5000
4000
3000
2000
1000
0

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Time [sec.]

Integrated ML brightness

Integrated brightness [arb.u.]

120000
100000
80000
60000
40000
20000
0

0   30   60   90   120   150   180

Bending angle [deg.]

Strain

?

Hybrid Relationship creates Wonderful Hybrid Future

Film Edge Profiler (Edge Shape Analysis)

Neutral plane
(center of thickness)

Inside surface strain:
(100-90)/100 = 10 % ・・・ Compressed

Outside surface strain:
(100-110)/100 = -10 % ・・・ Stretched
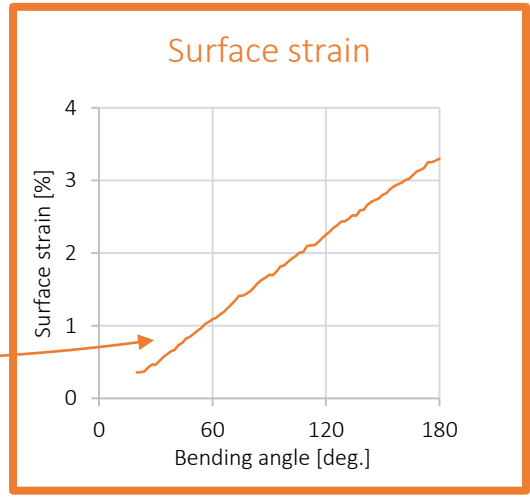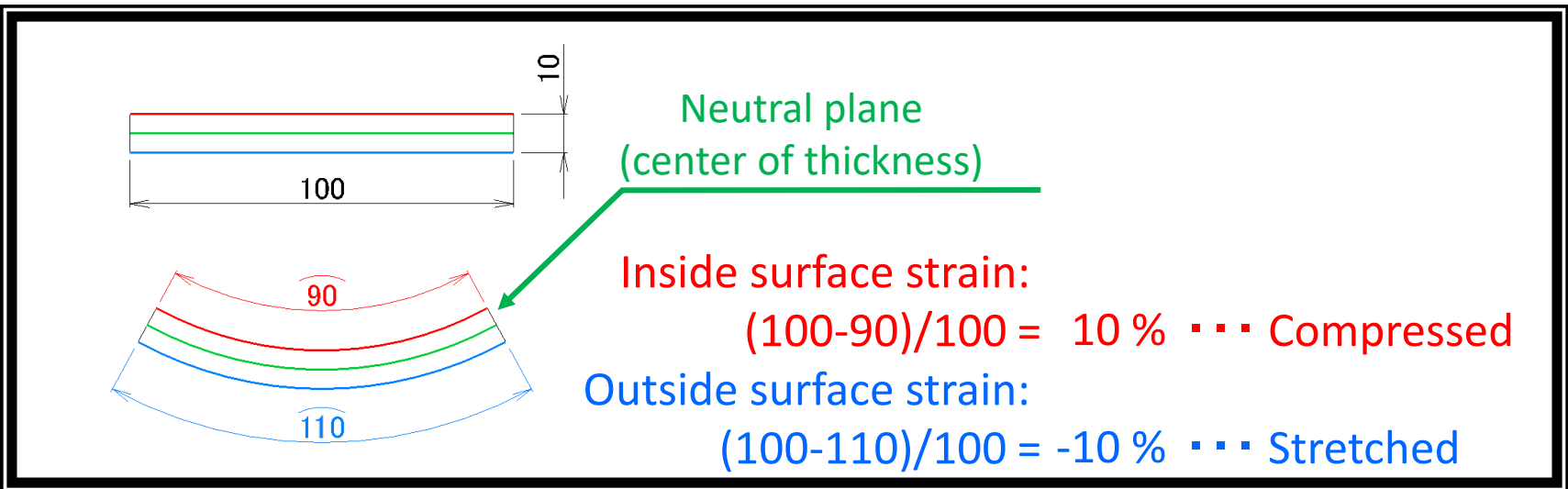
Surface strain

The system finds a neutral plane from shadow of specimen, then calculate its curvature to know surface strain.

Devised by Tokyo institute of technology

Hybrid Relationship creates Wonderful Hybrid Future

Simulation: ML meets Film Edge Profiler

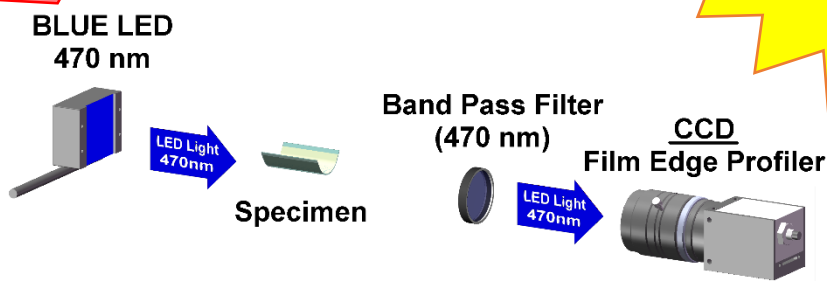|	ML	Film Edge Profiler
SAMPLING	Visible area *Good*	A point
OUTPUT	Surface strain changing rate	Surface strain *Good*
ENVIRONMENT	Dark or under red right (over 630 nm)	Anywhere *Blue LED backlight *Problem*

Combine

Blue LED is already used to excite ML materials, it affect to ML brightness.
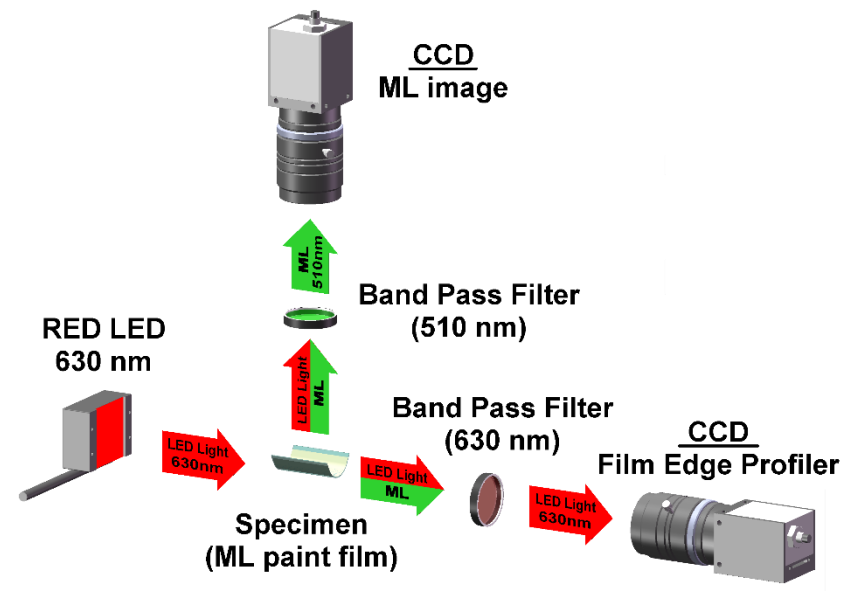
CCD ML image

BLUE LED 470 nm

LED Light 470nm

Specimen

Band Pass Filter (470 nm)

LED Light 470nm

CCD Film Edge Profiler

Cannot work together!?
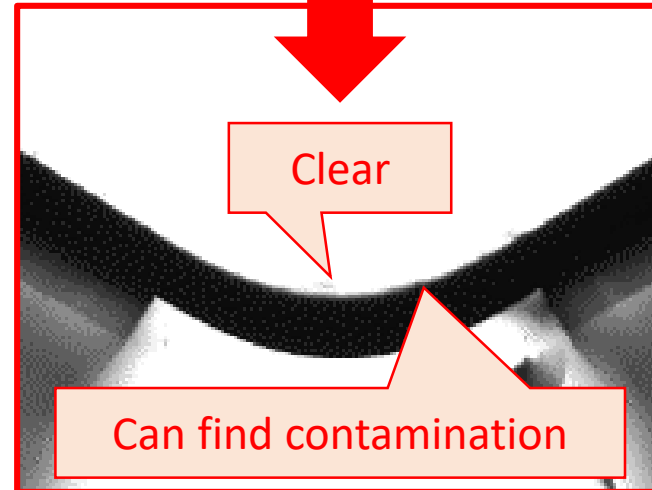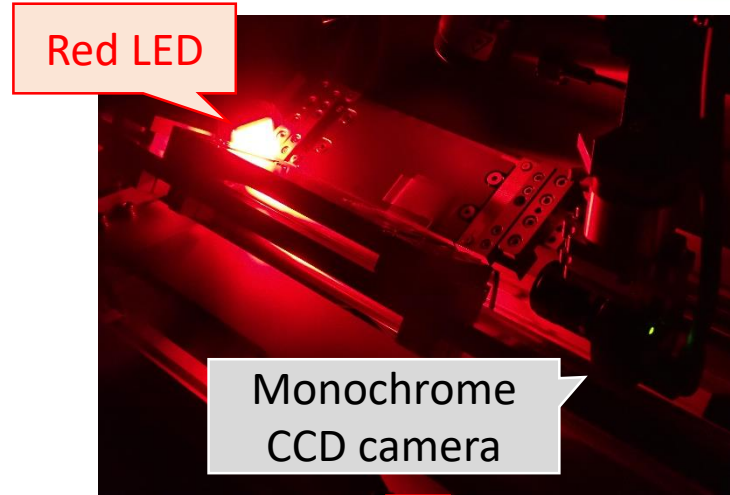
Hybrid Relationship creates Wonderful Hybrid Future

Evaluation System: ML meets Film Edge Profiler

	ML	Film Edge Profiler
SAMPLING	Visible area *(Good)*	A point
OUTPUT	Surface strain changing rate	Surface strain *(Good)*
ENVIRONMENT	Dark or under red right (over 630 nm)	Anywhere *Red LED backlight *(Solution)*

Combine

CCD
ML image

RED LED
630 nm

Band Pass Filter
(510 nm)

ML
510nm

LED Light
ML

Band Pass Filter
(630 nm)

CCD
Film Edge Profiler

LED Light
630nm

Specimen
(ML paint film)

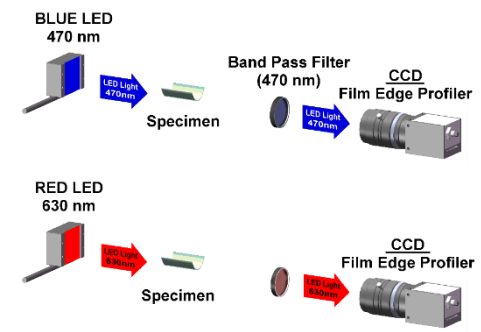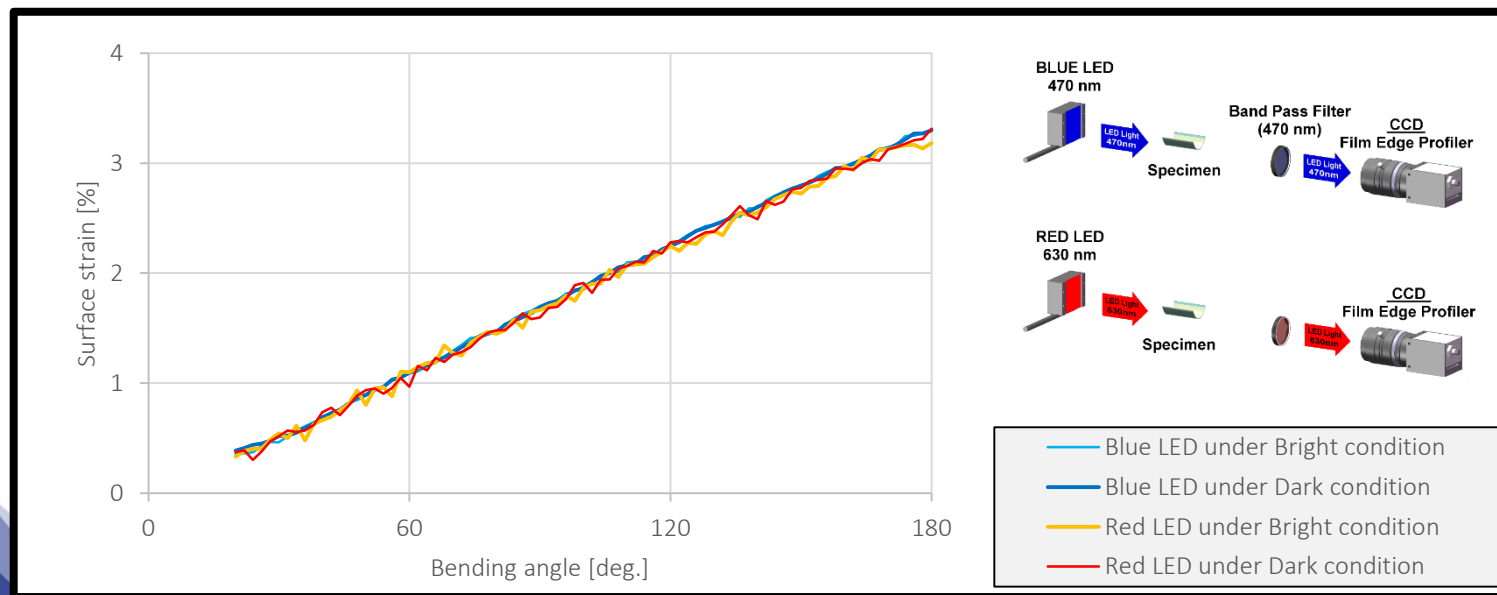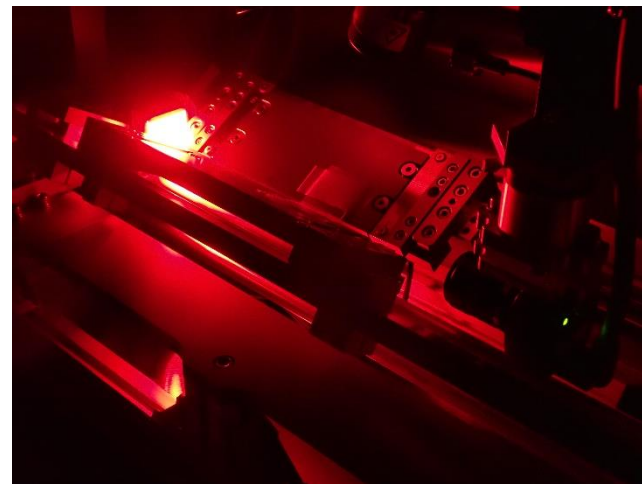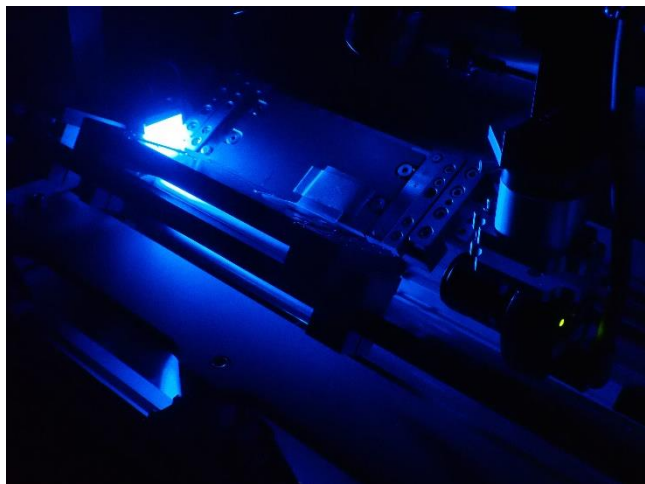LED Light
ML

LED Light
630nm

Hybrid Relationship creates Wonderful Hybrid Future

Result 1) Lighting Conditions on Film Edge Profiler

Blue LED

Monochrome
CCD camera

Red LED

Monochrome
CCD camera

Blurred

Clear

Can find contamination
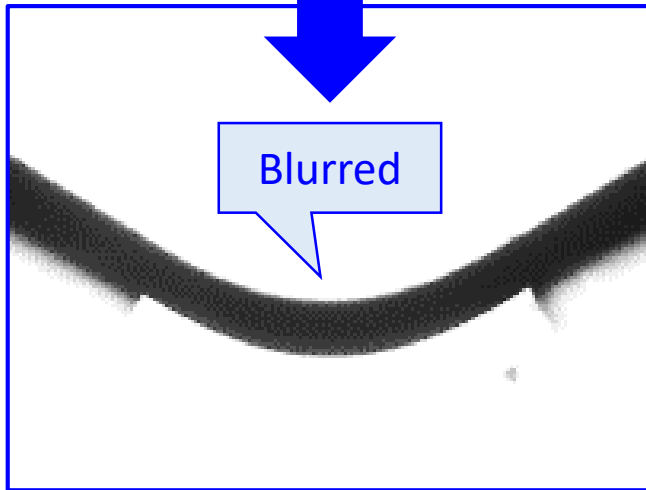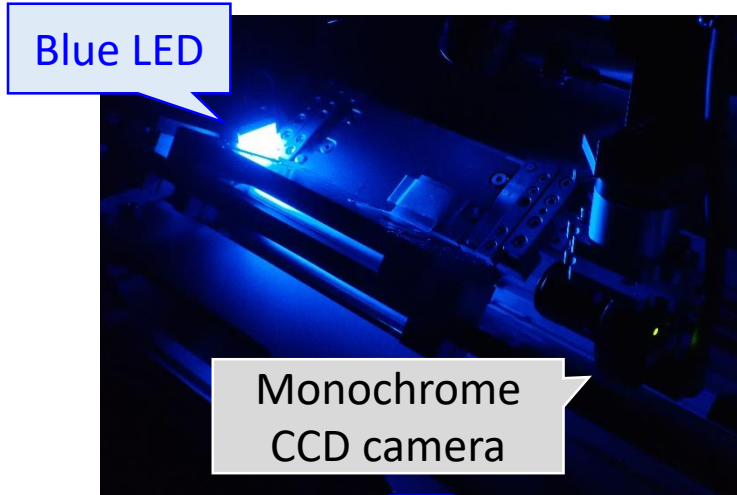
If 'electricity for LED' and 'lens aperture value' are same,
different colored LEDs make different shadow.

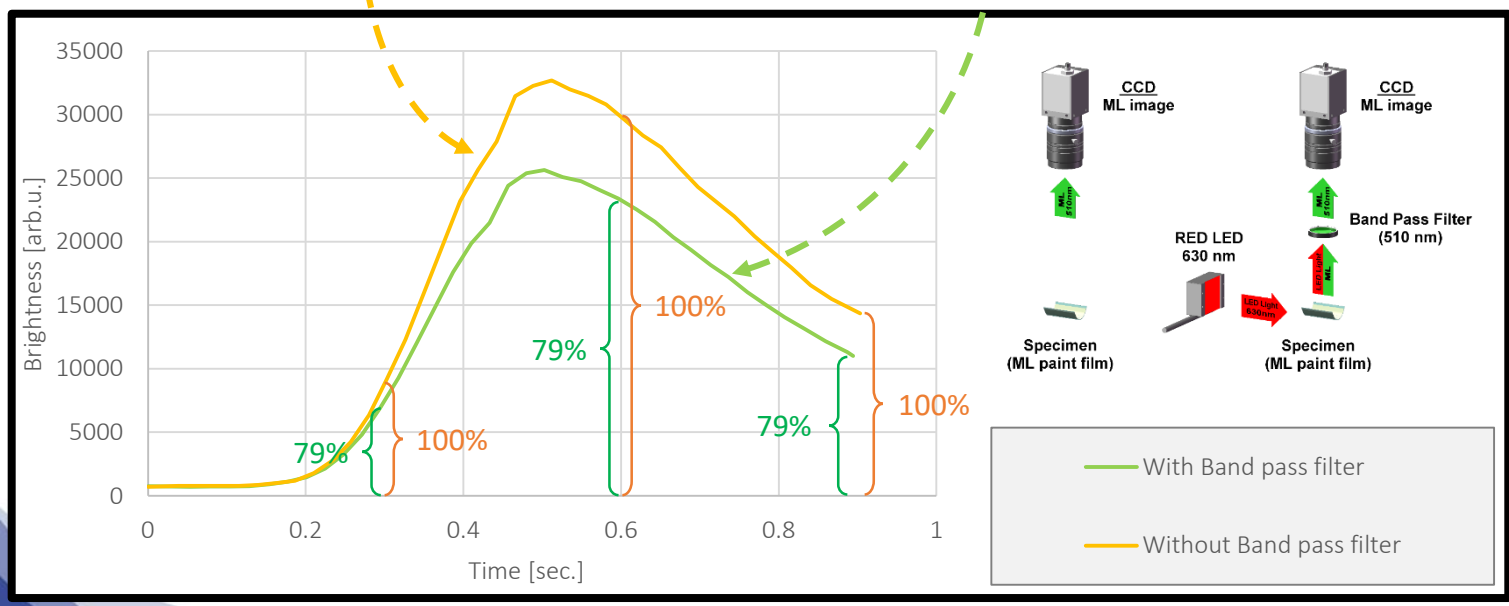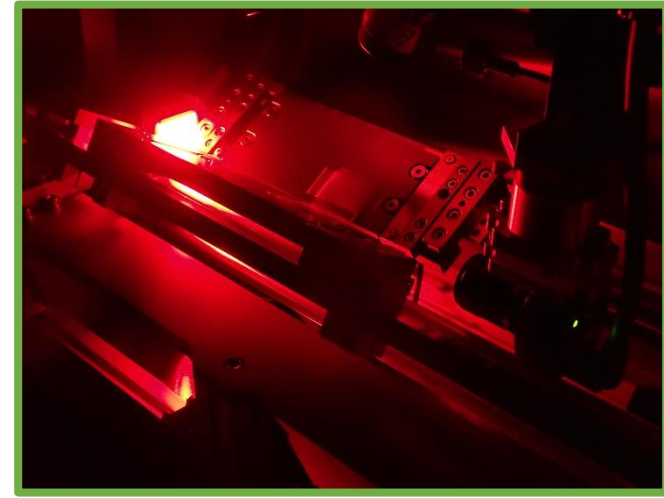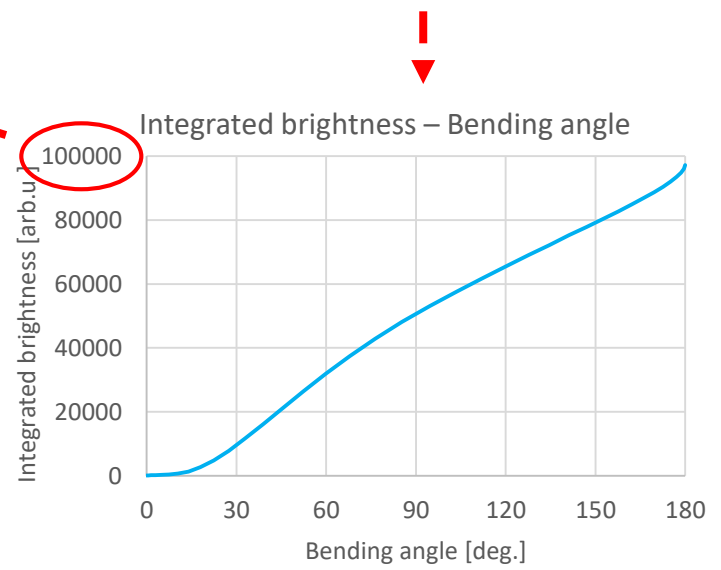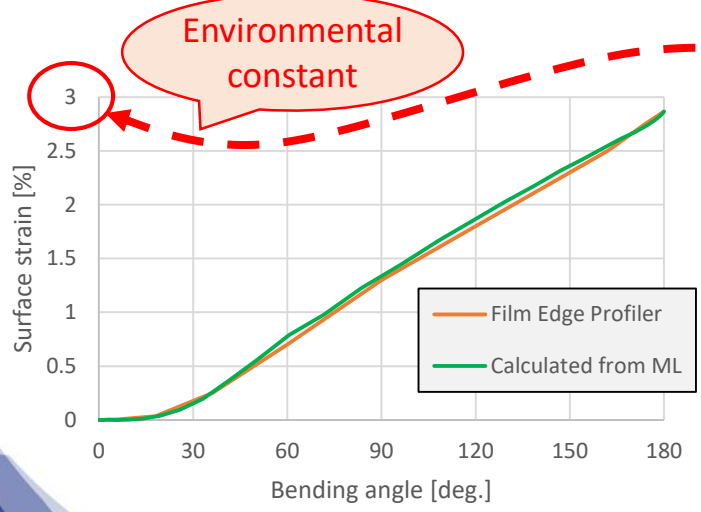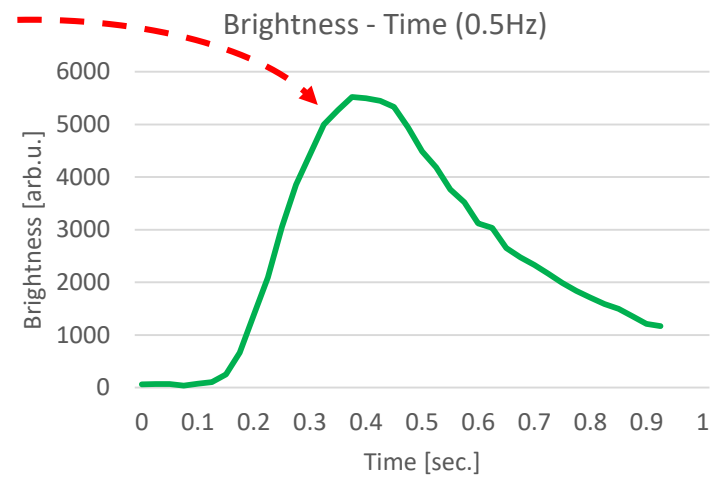Hybrid Relationship creates Wonderful Hybrid Future

Result 1) Lighting Conditions on Film Edge Profiler

Result 2) Lighting Conditions on ML

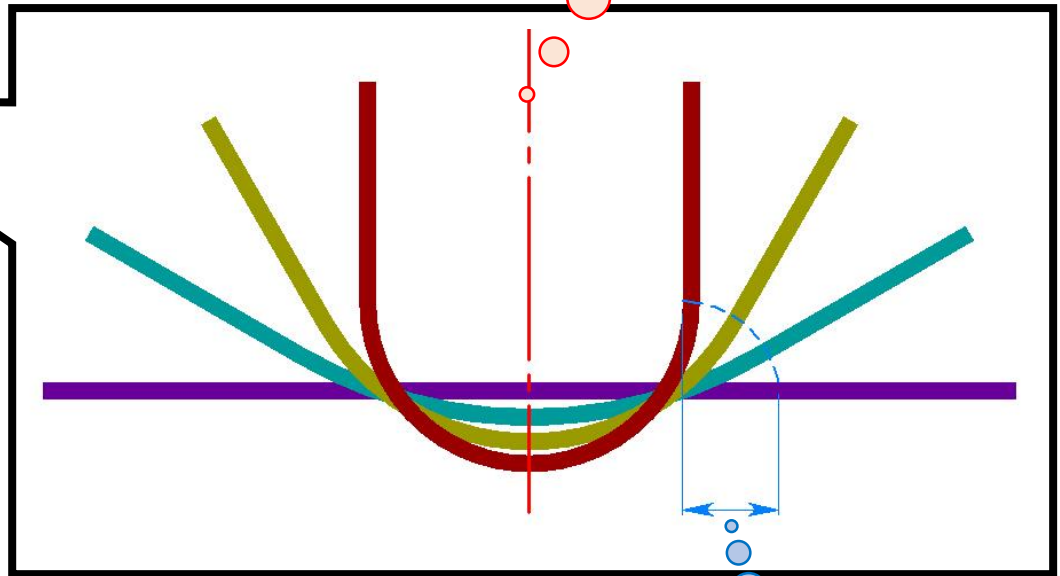Hybrid Relationship creates Wonderful Hybrid Future

Analysis: Convert ML brightness to Surface Strain

CCD
ML image

RED LED
630 nm

ML 510nm

Band Pass Filter
(510 nm)

LED Light ML

LED Light 630nm

LED Light ML

Specimen
(ML paint film)

Band Pass Filter
(630 nm)

LED Light ML

CCD
Film Edge Profiler

LED Light 630nm

Environmental constant

Brightness - Time (0.5Hz)

Brightness [arb.u.]

Time [sec.]

Integrated brightness – Bending angle

Integrated brightness [arb.u.]

Bending angle [deg.]

Surface strain [%]

Bending angle [deg.]

— Film Edge Profiler

— Calculated from ML

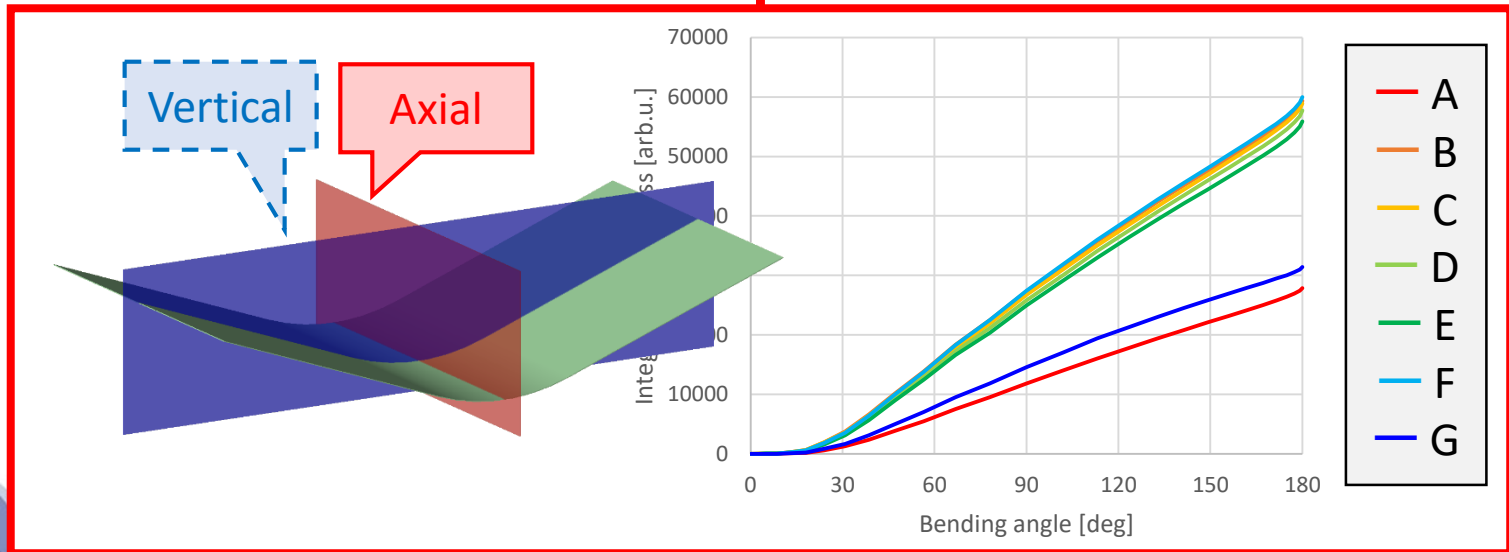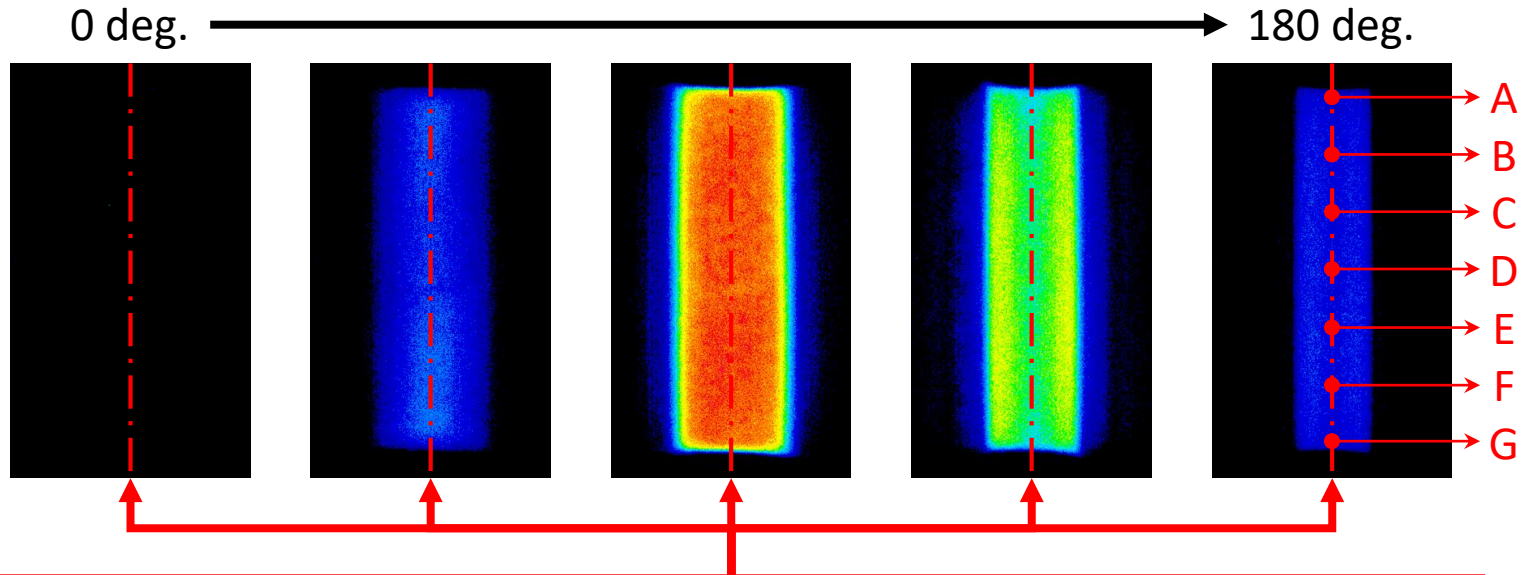Hybrid Relationship creates Wonderful Hybrid Future

Analysis: Surface Strain Distribution

Can observe a point on a same pixel

Cannot find a point

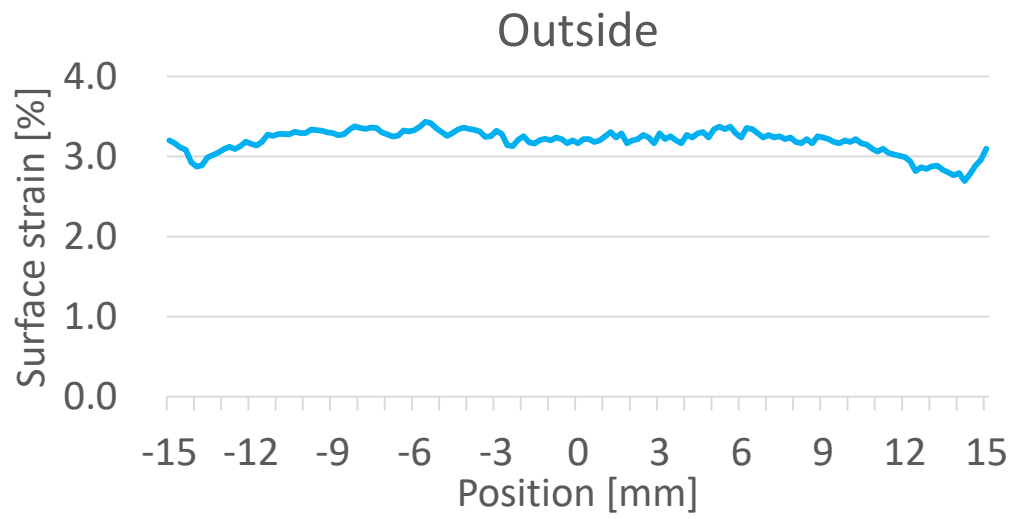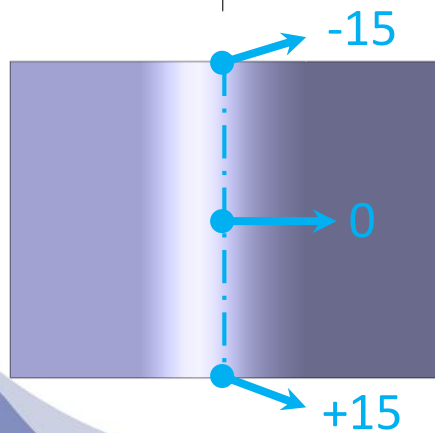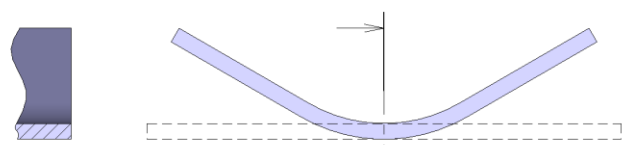Hybrid Relationship creates Wonderful Hybrid Future

Analysis: Surface Strain Distribution

Hybrid Relationship creates Wonderful Hybrid Future

Analysis: Surface Strain Distribution

PEN film
< 125 μm >

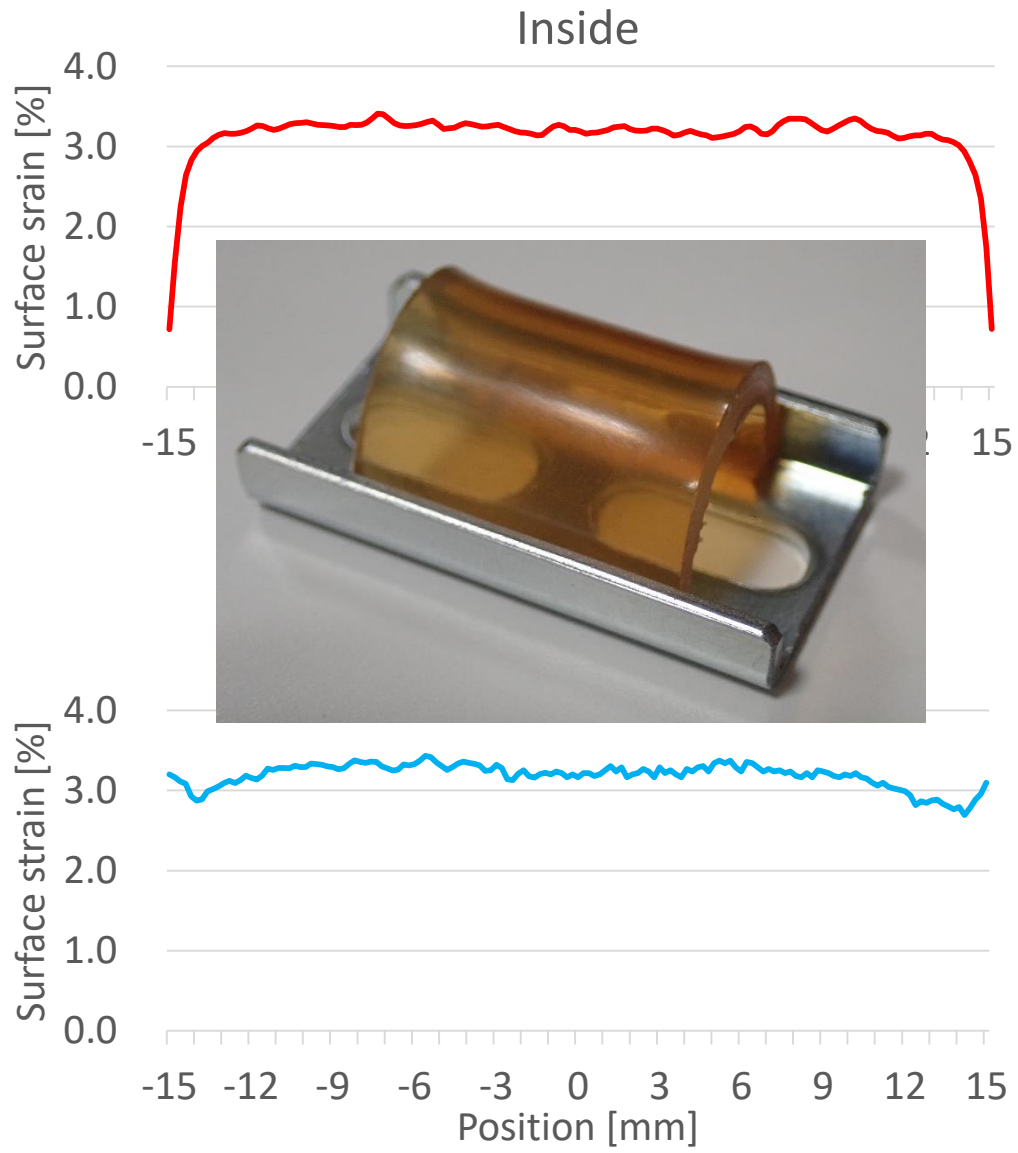Hybrid Relationship creates Wonderful Hybrid Future
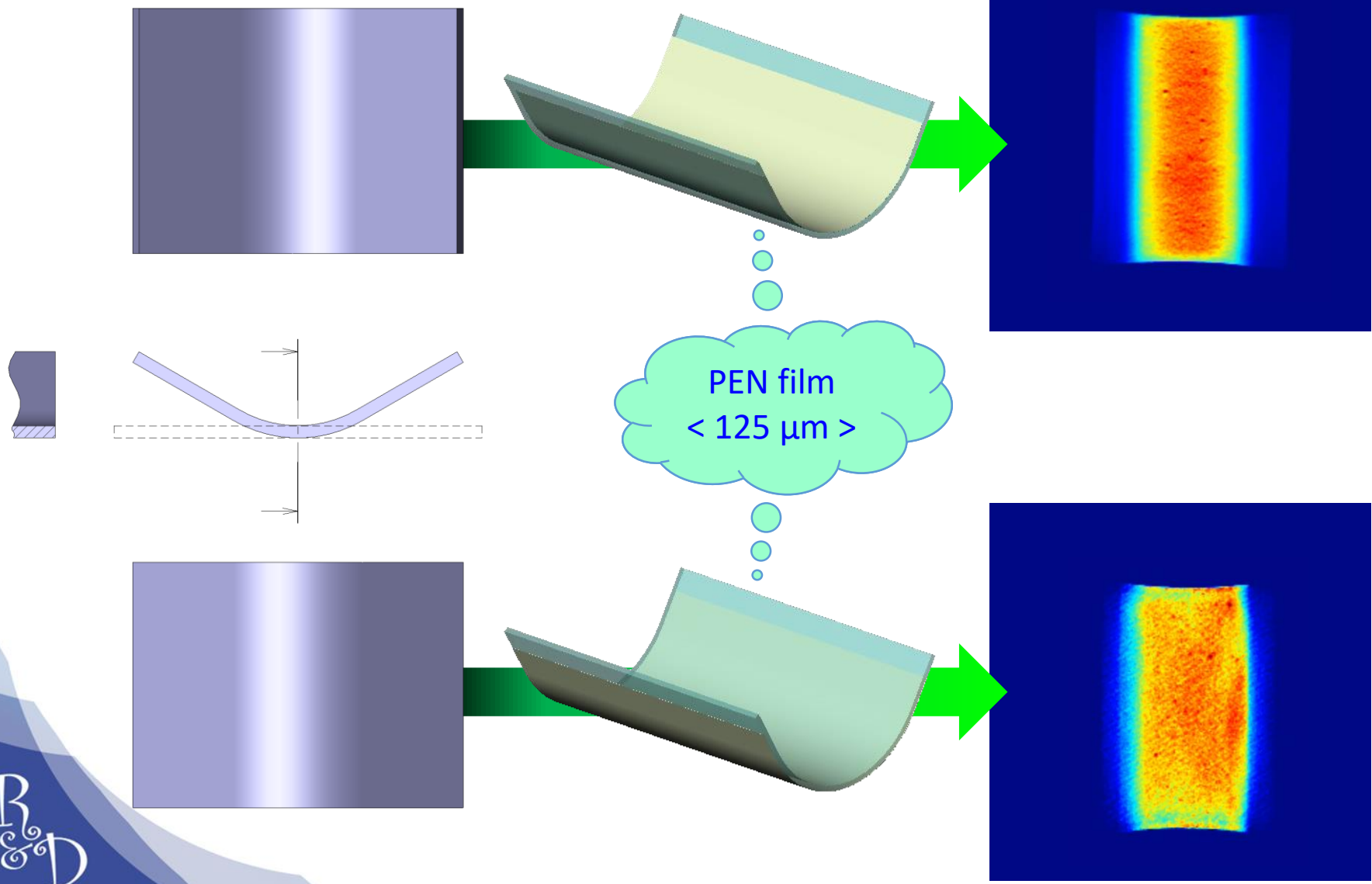
Analysis: Surface Strain Distribution on a PEN film

Analysis: Surface Strain Distribution on a PEN film

Hybrid Relationship creates Wonderful Hybrid Future
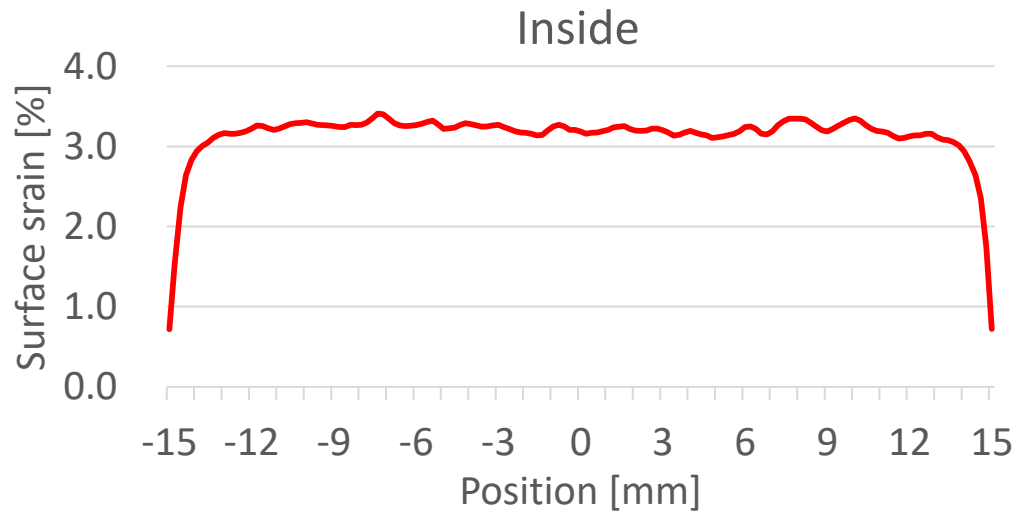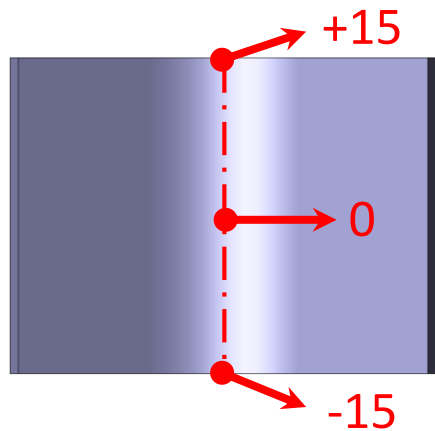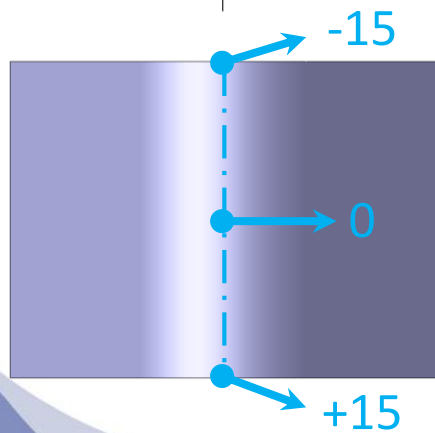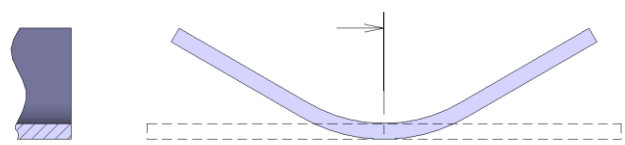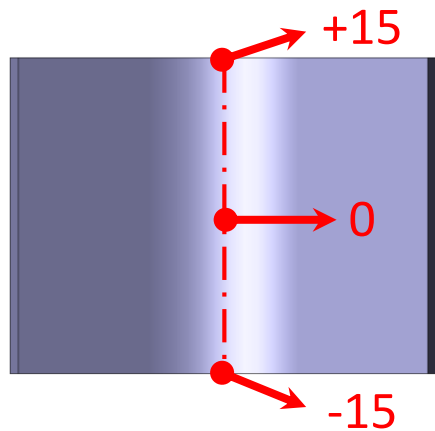
Future Challenge!!

Analyze surface strain distribution on a layered specimen. It is necessary to find a neutral layer in the layered specimen with the edge profiler, or find other method to analyze surface strain to normalize ML.

Study relationship between ML pattern and fatigue destructions to find a point where will be happened failure before conducting a long-tern endurance test.

Study ML characteristic to get more information from that.

Hybrid Relationship creates Wonderful Hybrid Future