Overview presentation-Internship in MPIE

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Department Microstructure Physics and Alloy Design

15-09-2014

Outline

- In-situ Tensile Stage (ITS)

1. Displacemnet sensor
2. Load sensor
3. ITS setup
4. Tensile Stage Control
5. The Control Software
6. Experiment I-BSE/SE movie

- DAMASK in (Experiment II)

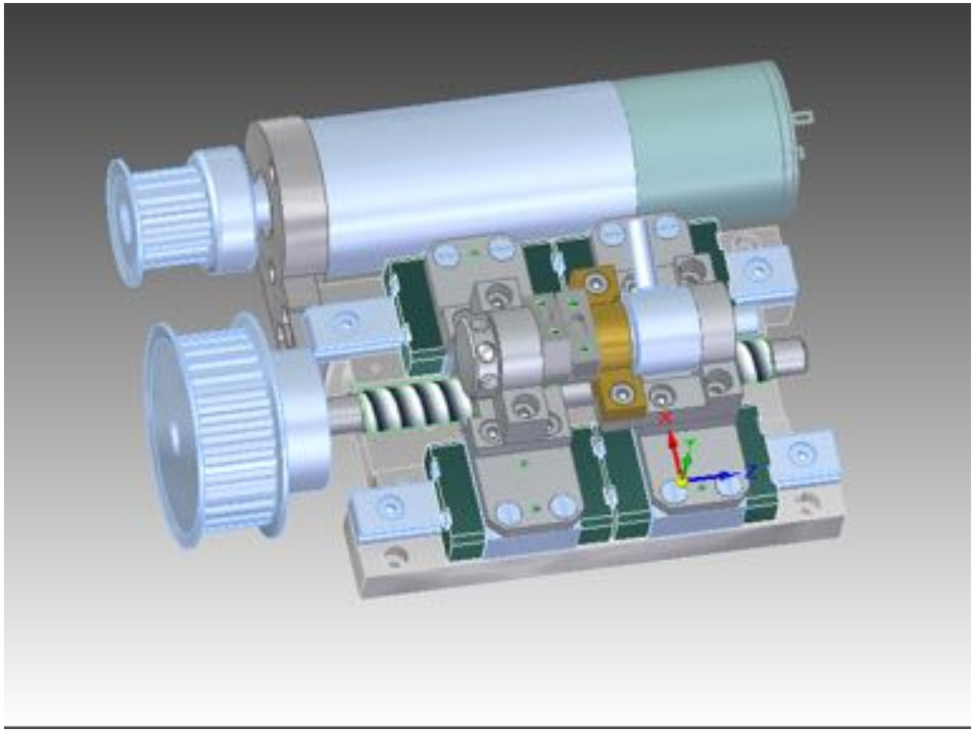
1. Introduction of DAMASK (CPFEM) / how it is used to solve the boundary value problems
2. Four files used in DAMASK
3. Process of DAMASK

- Results

1. Experiment II results obtained through DIC
2. Simulation Results obtained through DAMASK
3. Comparison of experimental results and simulation results

- Previous Work

Solid Edge ST6 animation (1000X)

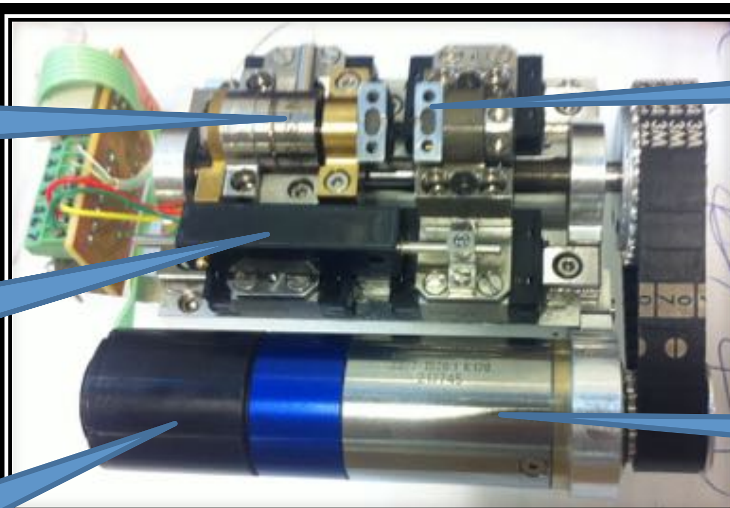


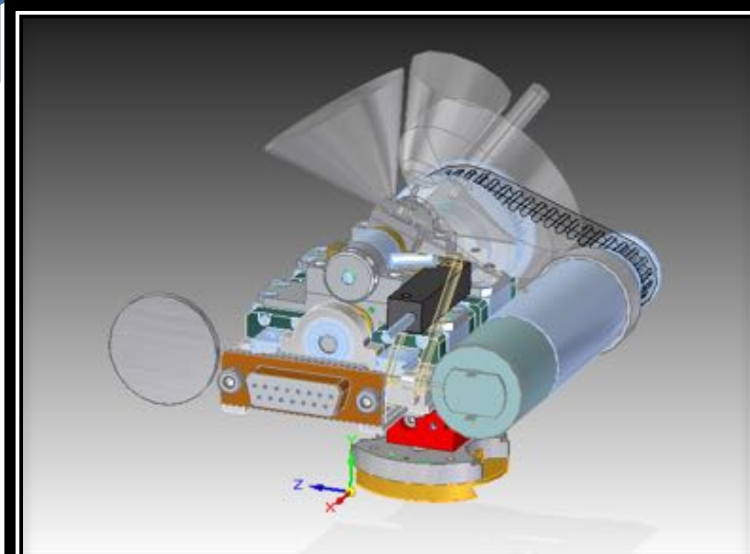
2 revolution of small gear
=1 revolution of large gear
=0.5mm linear movement of carriages
=1mm elongation of specimen

Specifications:

Teeth Ratio:15:30
Mass: 500g
| load |≤500N
Max Specimen Length ≤ 20mm
Motor: 5mNm
Small Gear:0.7Nm
Large Gear:1.4Nm

In-situ Tensile Stage-'ITS'





Specifications:

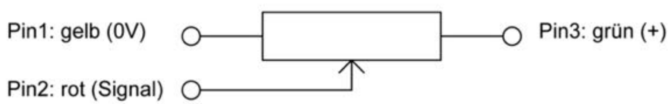
Teeth Ratio:15:30
Mass: 500g
| load | ≤500N
Max Specimen Length ≤ 20mm
Motor: 5mNm
Small Gear:0.7Nm
Large Gear:1.4Nm

Displacement Sensor

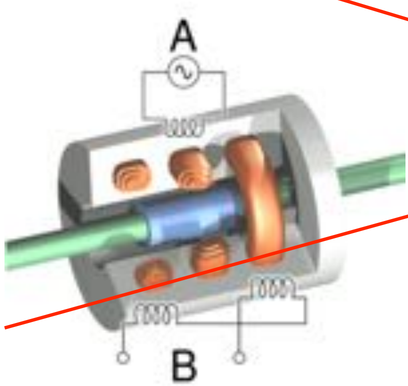
Weg Sensoren: Serie MM10 - Potentiomeric Linear Transducer

Electrical contact travels from 8 mm to 15 mm
Conductive plastic element

Cons: friction



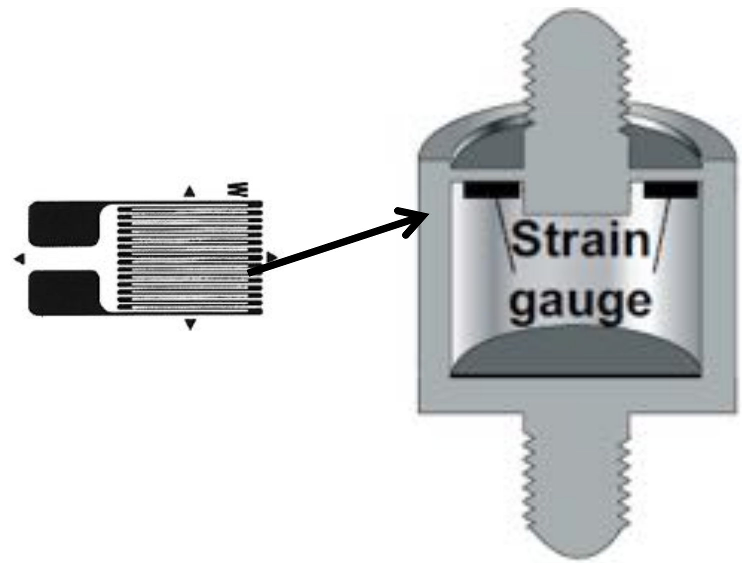
Linear variable differential transformer



Operation relies on electromagnetic coupling

Cons: magnetic field

Load Sensor: Model 8417



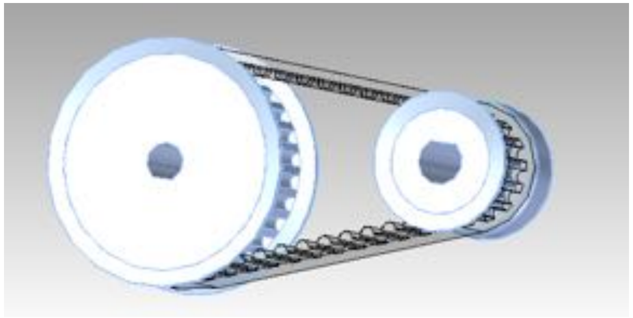
Force
-> deflection of elastic membrane
-> change of sensor's overall height
-> tension or compression in the spring element
-> resistance change in strain gauge

FAULHABER

DC-Micromotors (5mNm, steel, black coated**) + Planatery Gearhead (0.7Nm,** Metal housing)

Diameter (mm)	Length (mm)
22	24

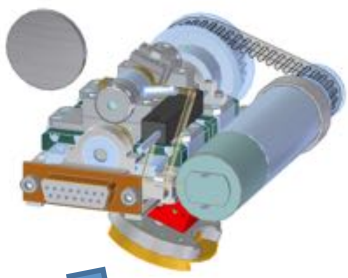
For high torque



1.4Nm 0.7Nm

ITS Setup

+



+ (

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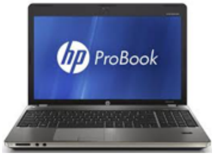
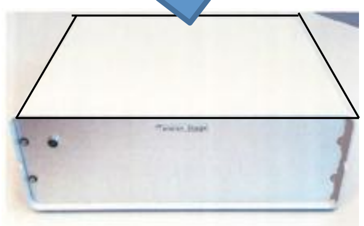
Zeiss 1540XB
Zeiss Merlin

Power

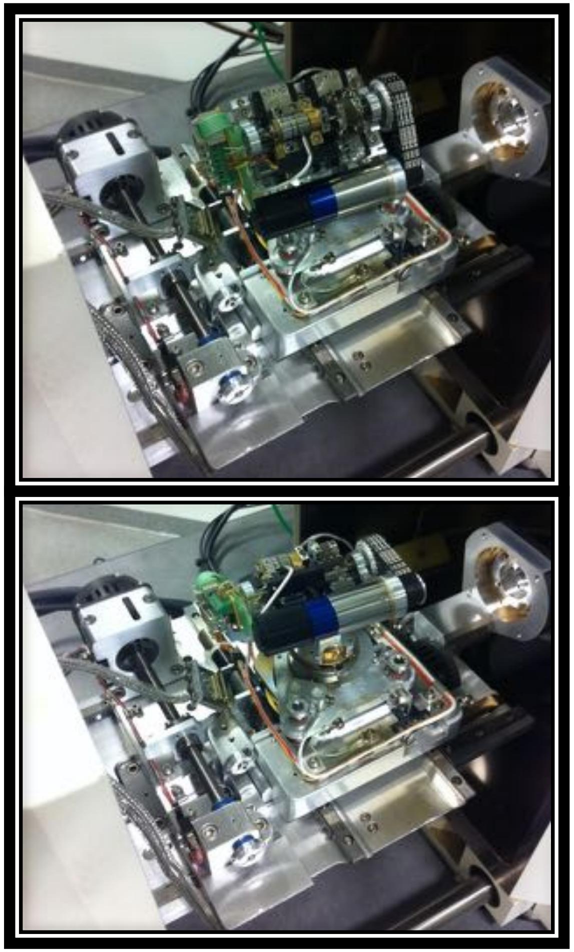
RS232 ->Stage



USB->Computer



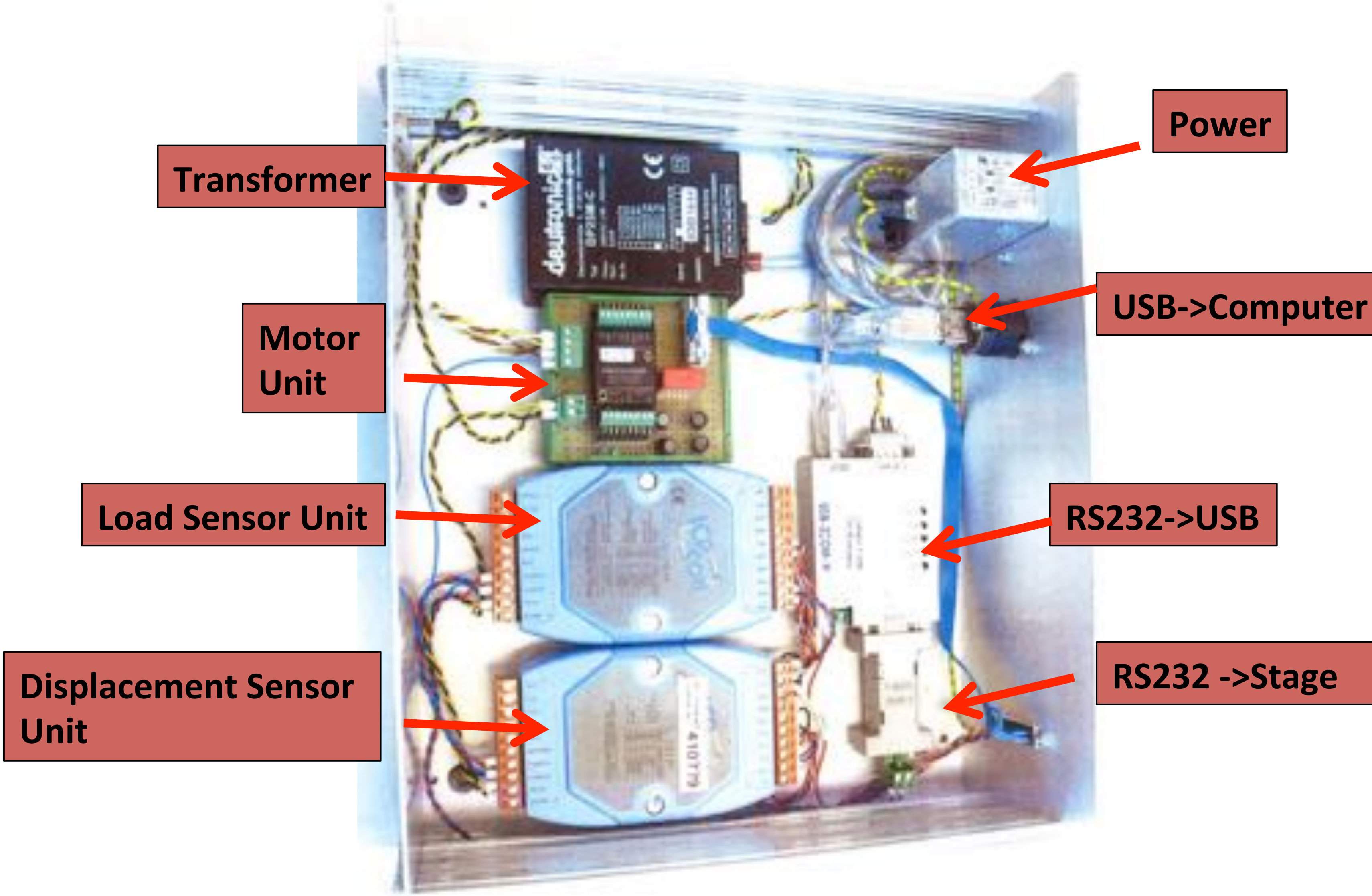
Tensile Stage Control



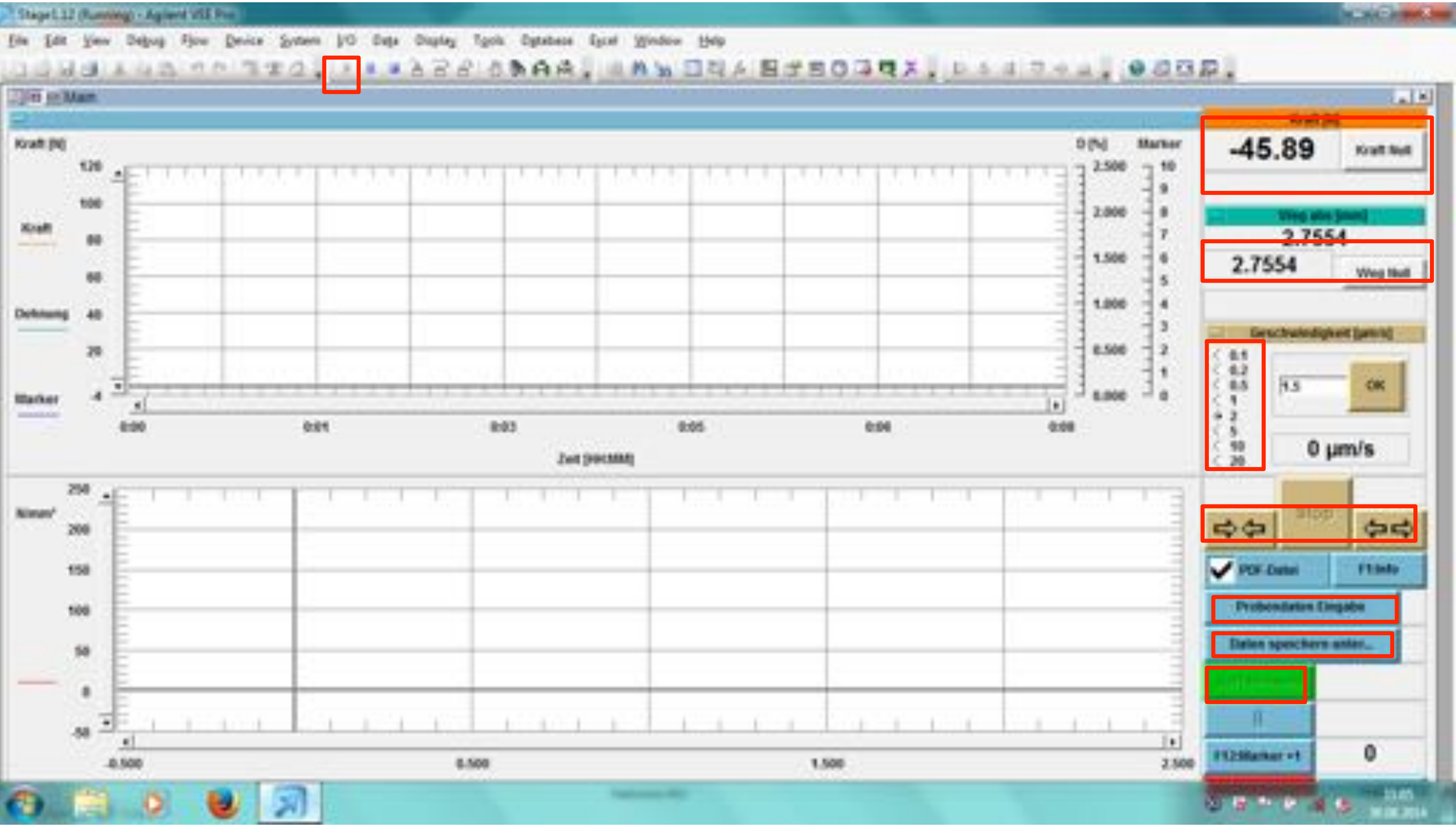
E B S D

S E

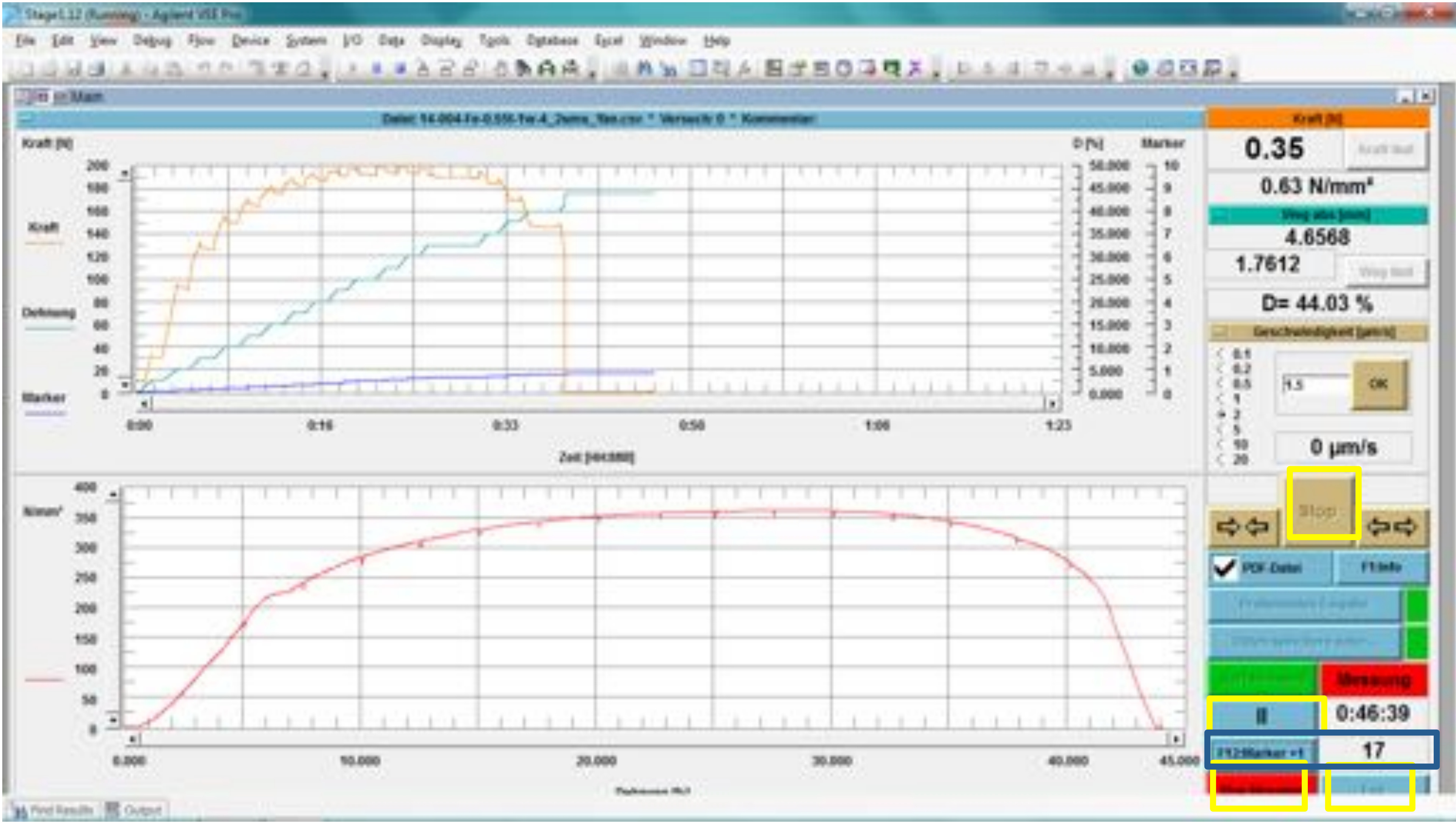
Tensile Stage Control



The Control Software



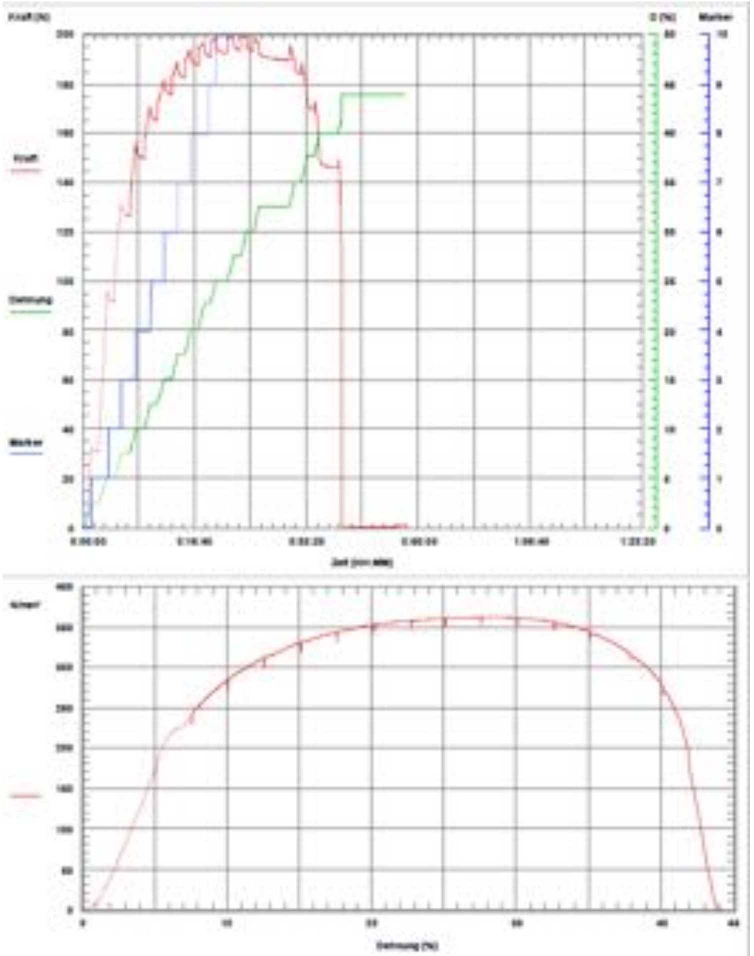
The Control Software



The Control Software

14-005-Fe-0.55t-1w-4_20ums_Yan.pdf
Adobe Acrobat Document

14-005-Fe-0.55t-1w-4_20ums_Yan.csv
Microsoft Excel Comma Separate...



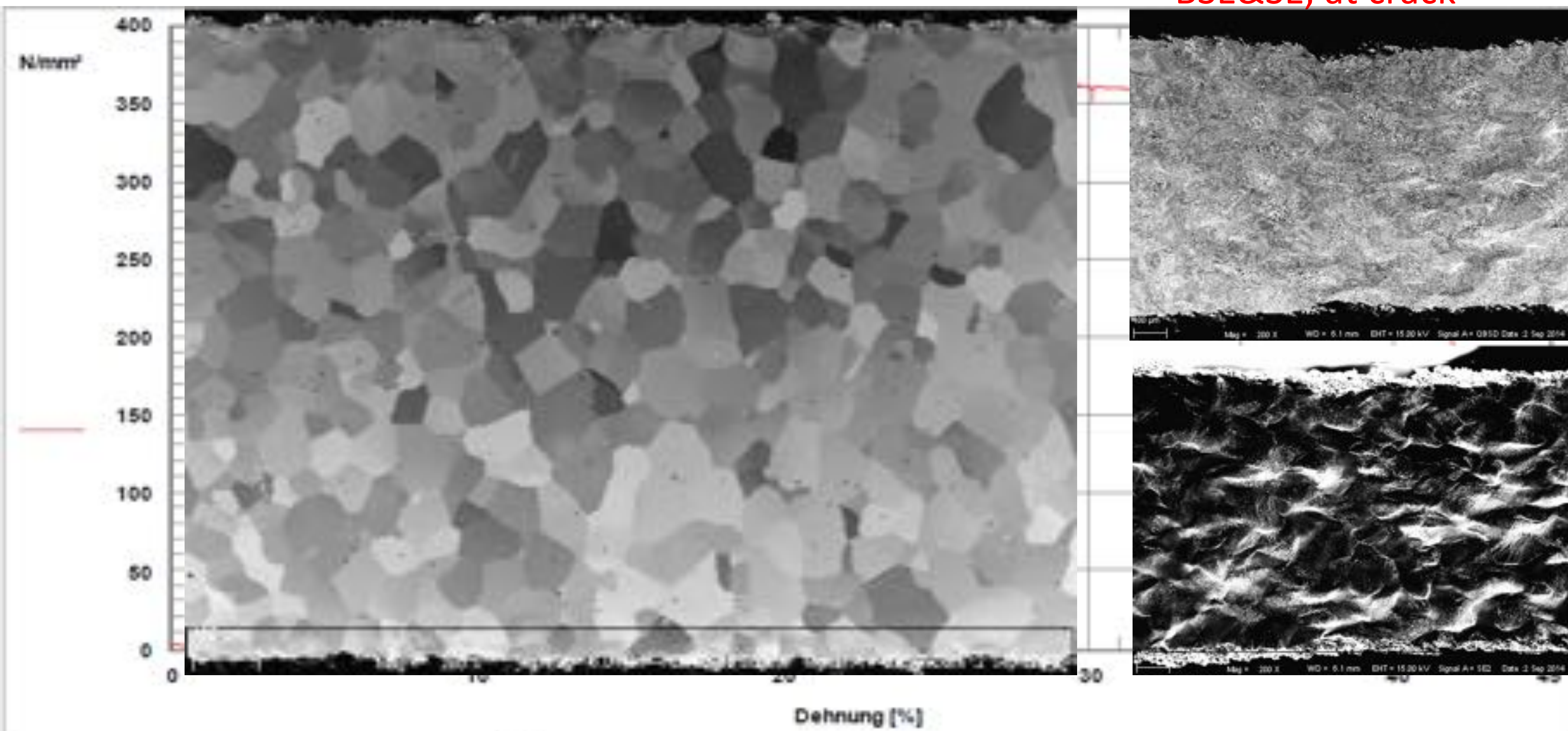
	A	B	C	D	E	F
1	Versuchsn	0				
2	Datum	########				
3	Zeit	21:48				
4	Probenbre	1				
5	Probendic 0,55					
6	akt. Probe	4				
7	Kommentar					
8						
9	Messzeit [	Marker	Kraft [N]	Weg [mm	Spannung	Dehnung [%]
10	0,0	0	-0,39	-0,0003	-0,72	0,000
11	0,4	0	-0,35	0,0000	-0,63	0,000
12	0,8	0	-0,30	0,0000	-0,54	0,000
13	1,2	0	-0,30	0,0000	-0,54	0,000
14	1,6	0	-0,30	0,0000	-0,54	0,000
15	2,0	0	-0,35	0,0000	-0,63	0,000
16	2,4	0	-0,39	0,0000	-0,72	0,000
17	2,8	0	-0,44	0,0000	-0,81	0,000
18	3,2	0	-0,44	0,0000	-0,81	0,000
19	3,6	0	-0,39	0,0000	-0,72	0,000
20	4,0	0	-0,35	0,0000	-0,63	0,000
21	4,4	0	-0,30	0,0000	-0,54	0,000
22	4,8	0	-0,35	0,0000	-0,63	0,000
23	5,2	0	-0,35	0,0000	-0,63	0,000
24	5,6	0	-0,10	0,0000	-0,18	0,000
25	6,0	0	1,43	0,0003	2,60	0,008
26	6,4	0	3,90	0,0007	7,09	0,017

Experiment I-BSE movie

RD Tensile

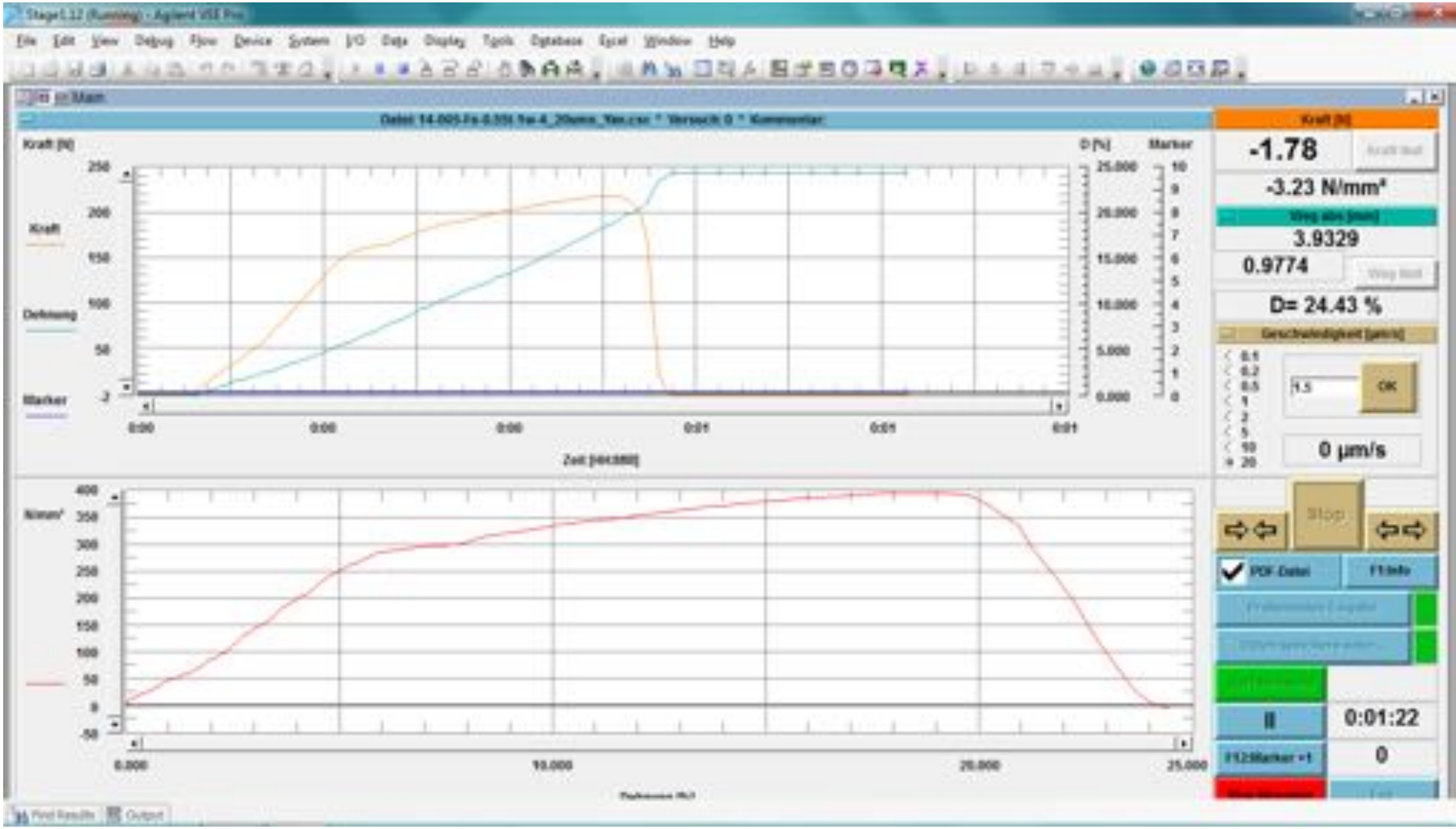
ε_{global} =0%-32.5%, BSE

ε_{global} =32.5%-44,3%, BSE&SE, at crack



Versuchsnummer:	0
Datum:	02/Sep/2014
Uhrzeit:	15:50
Probenbreite [mm]:	1
Probendicke [mm]:	0,55
akt. Probenlänge [mm]:	4
Kommentar:	

Experiment II- ε_{global} =0% to 19%

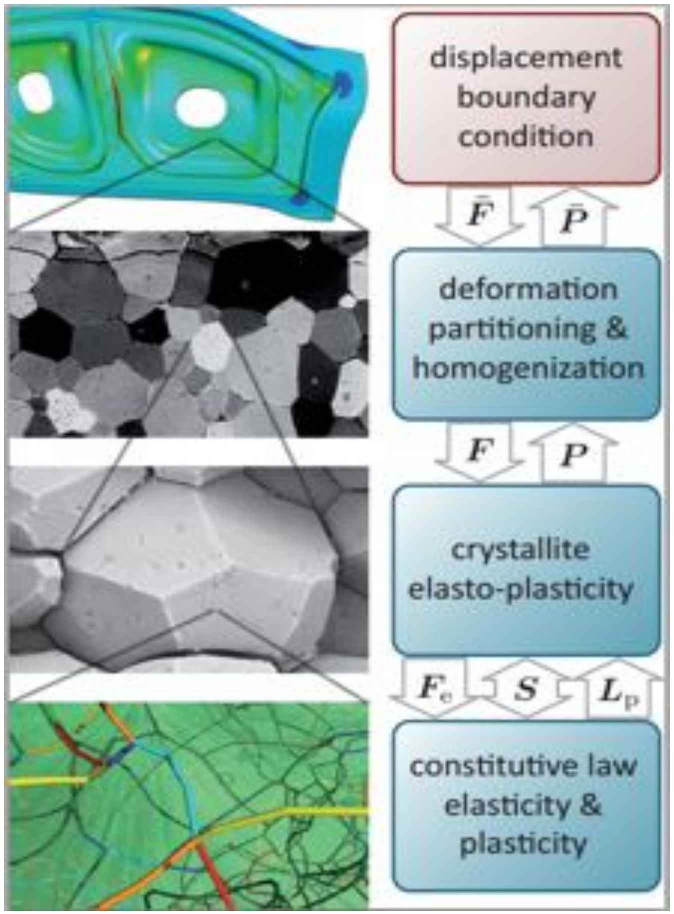


DAMASK simulation requirements (Franz Roters):

- arbitrary mechanical boundary value problems
- continuum mechanics
- accounting for crystal plasticity

→

Crystal Plasticity
Finite Element Method
(CPFEM)



DAMASK/boundary value problems solved by spectral solver

Solving with iteration through a convolution in Fourier space

Loop is finished when a given tolerance is reached (error stress BC, error F_{BC} , error P_{BC})

Phenomenological law: critical resolved shear stress

~~**Physics law: dislocation density**~~

http://damask.mpie.de/pub/About/WebHome/MPhierarchy.pdf

<u>tensionX-variant3.load</u> defines the loading conditions with deformation gradient rate $\dot{\boldsymbol{F}}_{BC}$ specified.

<u>tensionX-variant3.load :</u>

```
Fdot   5e-3 0 0   0 * 0   0 0 *   stress * * *   * 0 *   * * 0   time  50  incs   1000  freq 20
```

Strain tensor:

X: $\dot{\boldsymbol{F}}_{BC}$ (strain rate)

Y: arbitrary

Z: arbitrary

Stress Tensor:

Unknown

numerics.config defines the maximum and minimum iteration steps for the spectral solver.

numerics.config:

```
itmax 60
itmin 4
myspectralsolver basicPETSc
#myfilter cosine
```

material.config contains information about the material separated by five <part> (<output>, <phase>, <homogenization>, <microstructure>, <texture>) and phenomenological law used as the constitutive model for ferrite phase.

material.config:

```
#------------------#
<crystallite>
#------------------#
Output
#------------------#
<phase>
#------------------#
plasticity :phenopowerlaw/elasticity: hooke/slip systems/twin
#---
<homogenization>
#---
Ngrains 1
#---
<microstructure>
#---
[Grain00000001]
crystallite 1
(constituent) phase 1 texture 00000001 fraction 1.0
1 to 61401

#---
<texture>
#---
[Grain00000001](gauss) phi1 115.7272 Phi 154.8848 phi2 75.8287 scatter 0.0 fraction 1.0
1 to 61401
```

fe.geom maps the microstructure information of the model to the location in the volume element (VE). It also contains the resolution, dimension, origin coordinate, applied homogenization scheme and number of grains in the model.

fe.geom:

```
5 Header
resolution              a 291      b 211      c1
dimension               x 291      y 211      z1
origin         x 0      y 0        z0
homogenization 1
maxGrainCount 0
1 to 61401
```

Pure Iron Sample Preparation

Grinding
0.5m-1m
(1000 SiC)

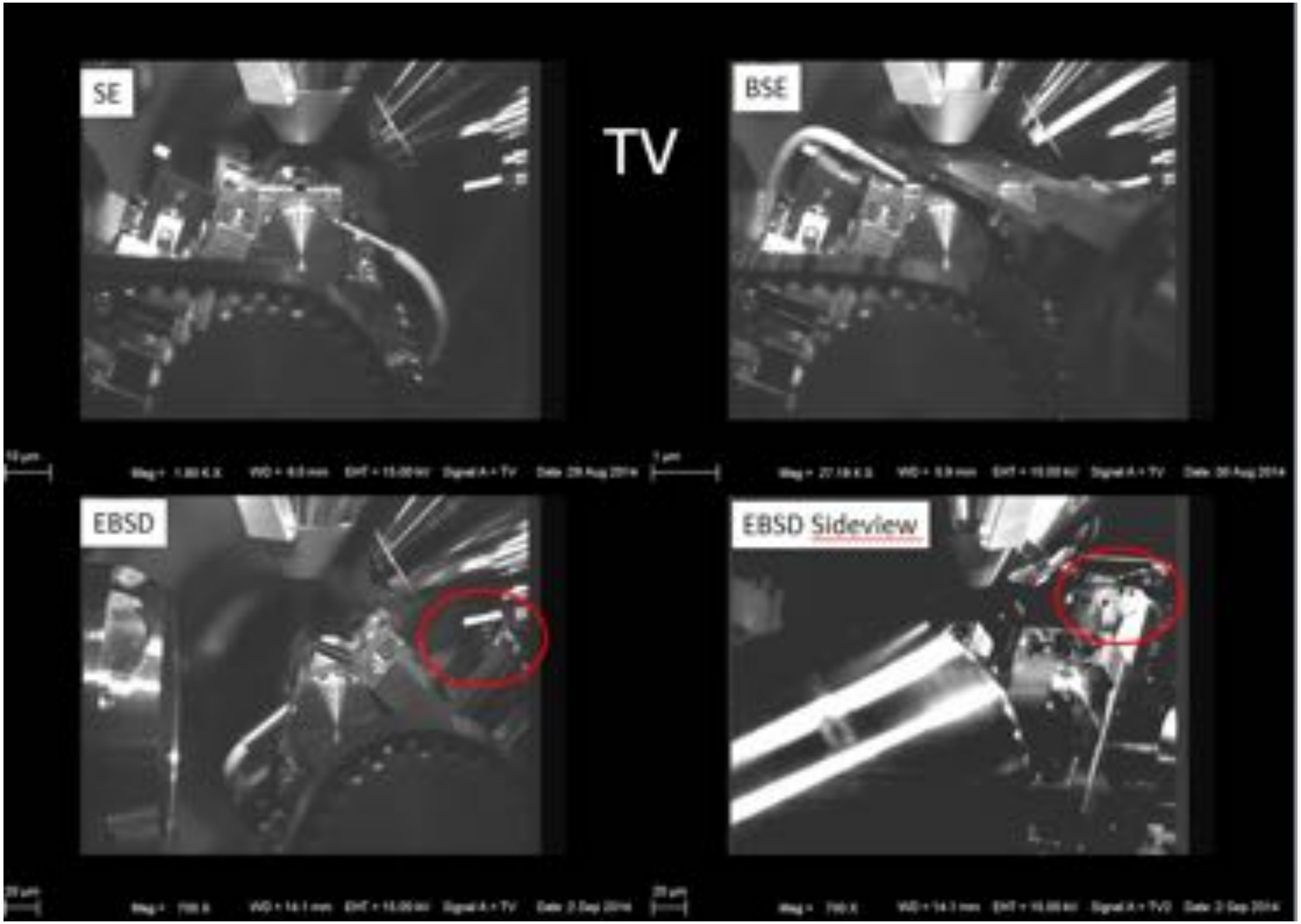
→

Polishing
（3 μm）
~10 m

→

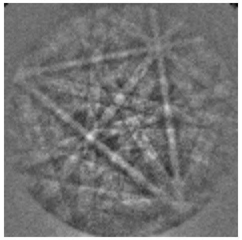
OPS
~10 m

Experiment I&II



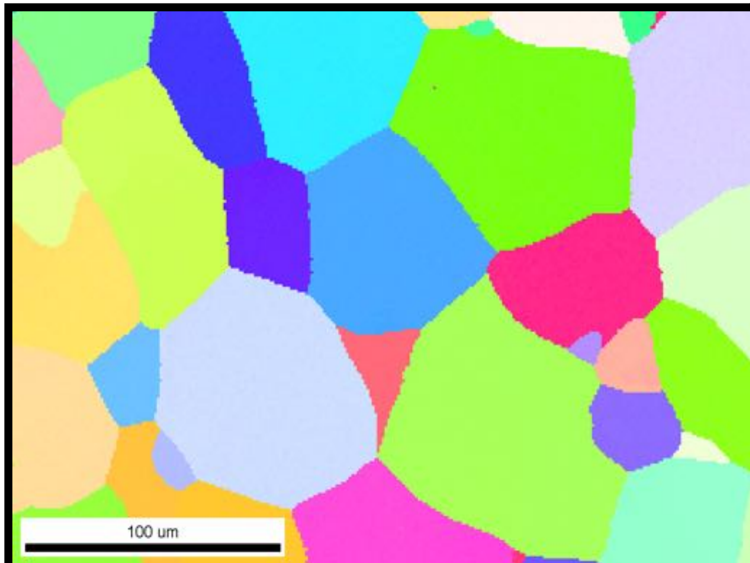
Experiment II- ε_{global} =0%

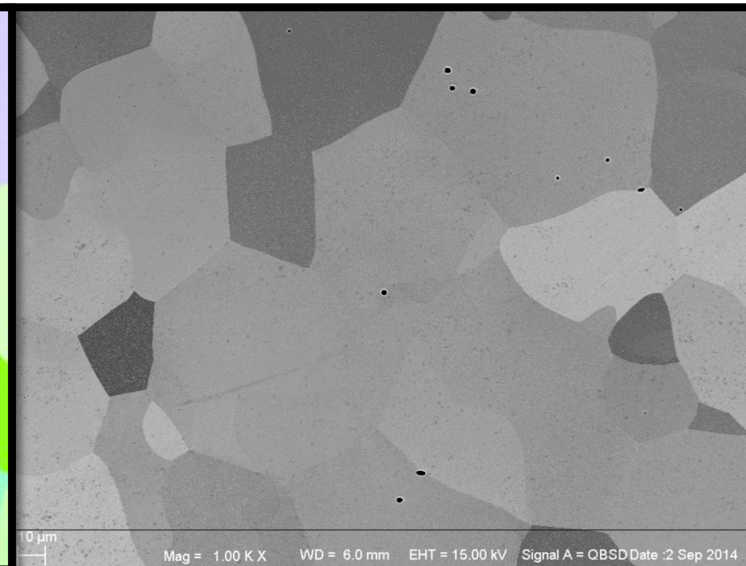
RD Tensile

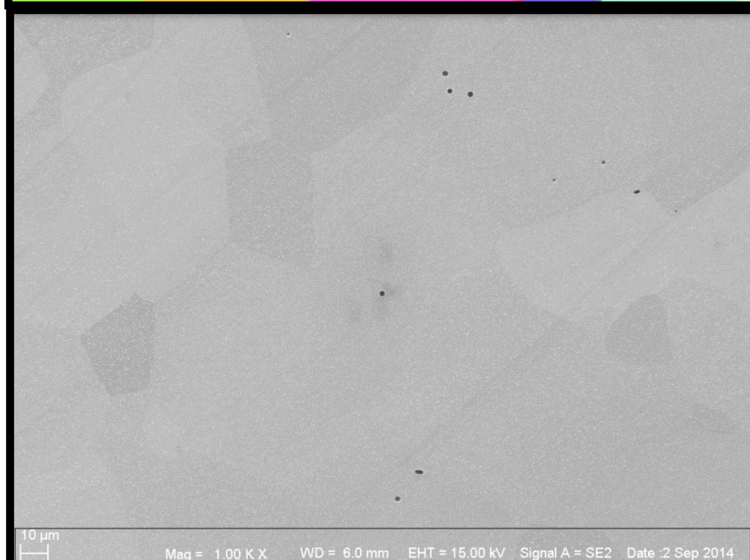


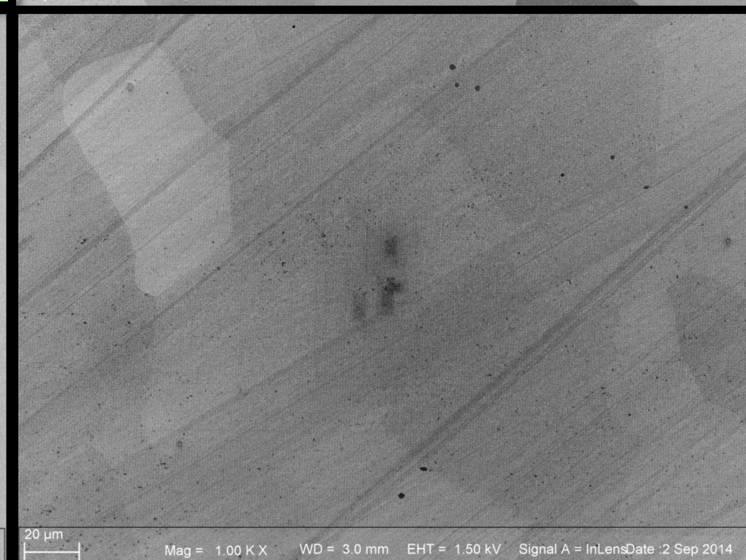
EBSD

Binning:4*4
Gain:21.27
Black:-0.28
Exposure:5.18



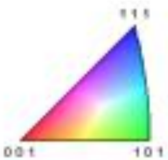


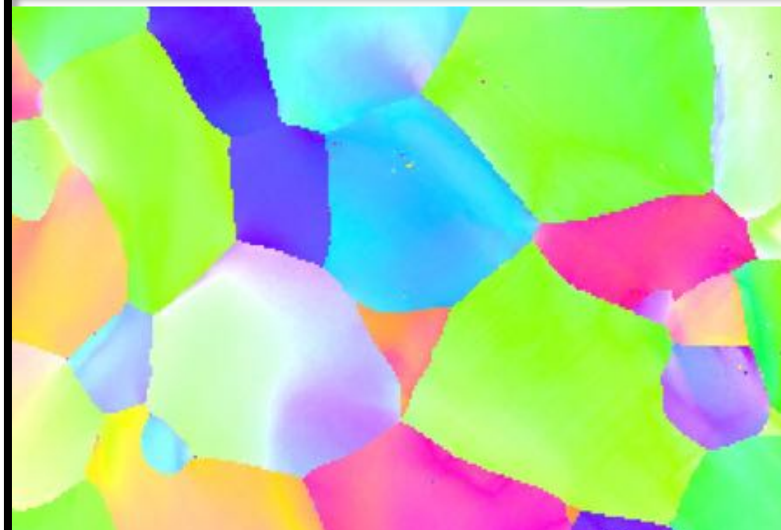


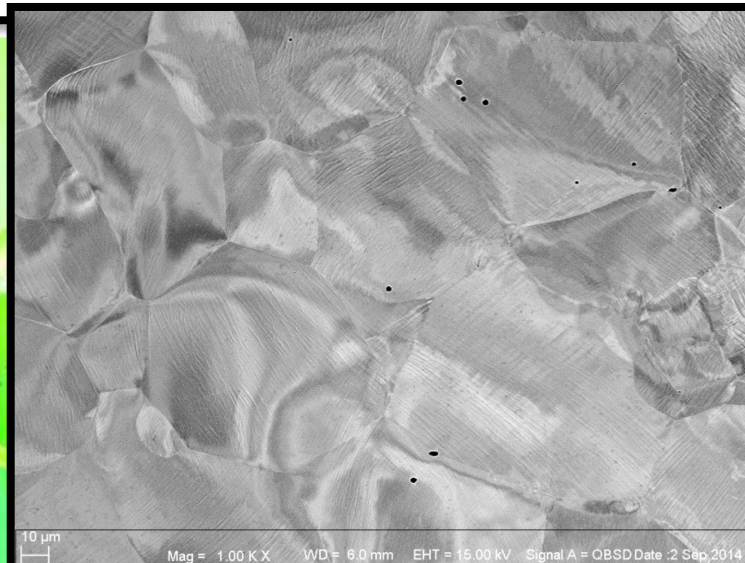


Experiment II- $\varepsilon \downarrow global$ =19%

RD Tensile

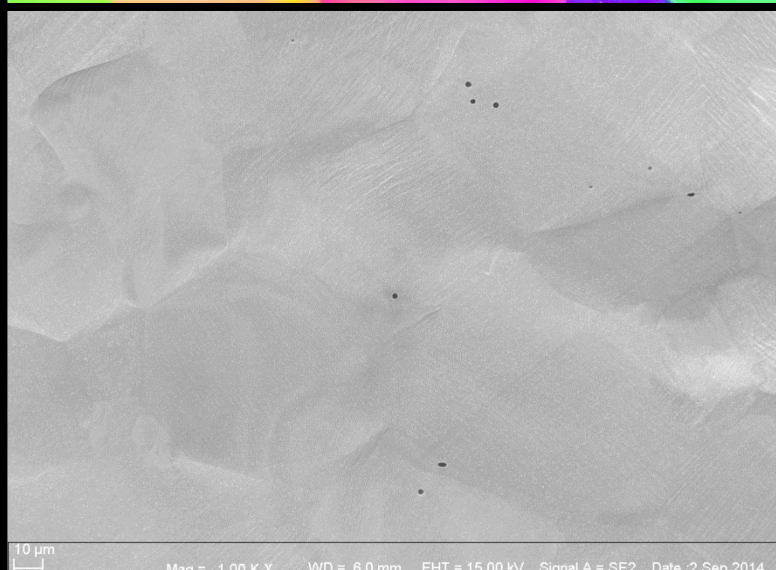


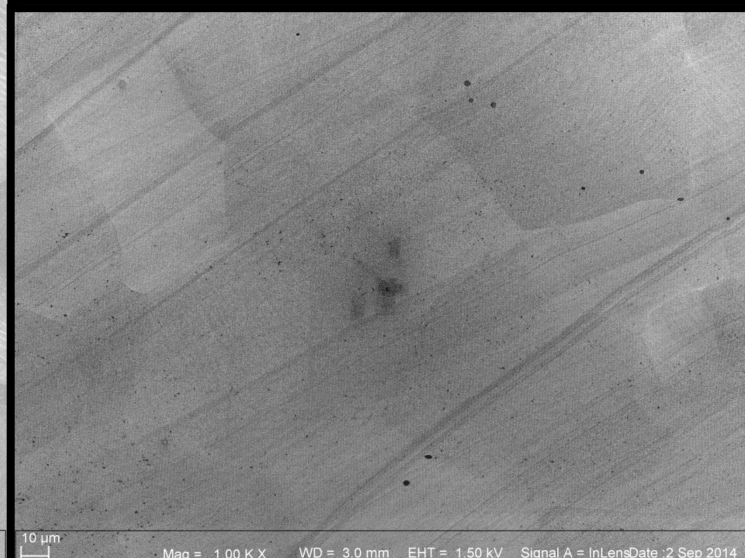




EBSD

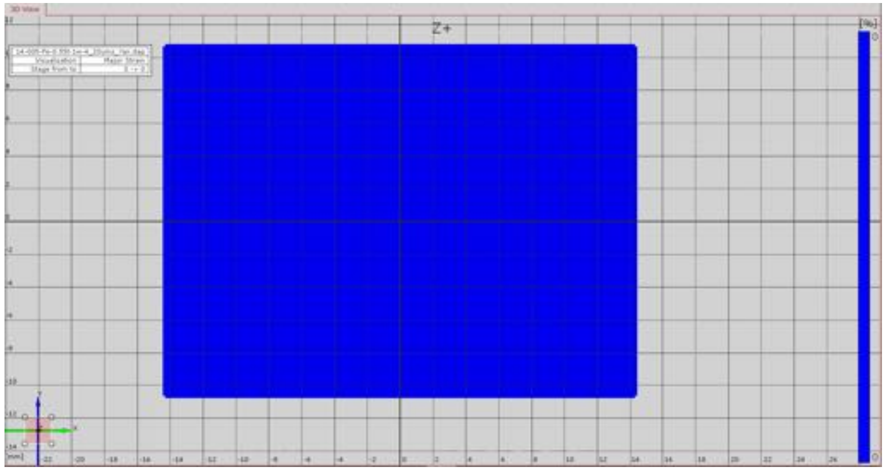
Binning:4*4
Gain:21.27
Black:-0.28
Exposure:5.18

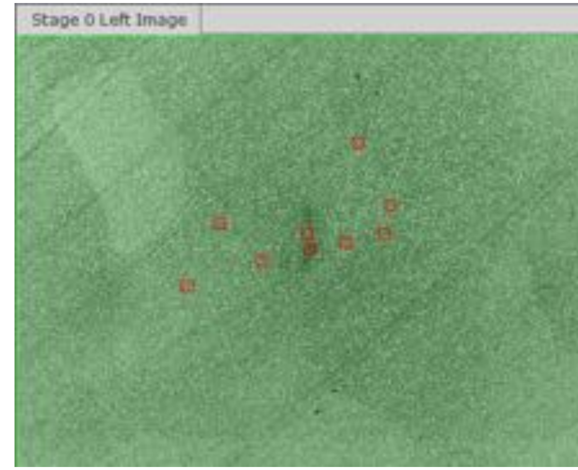




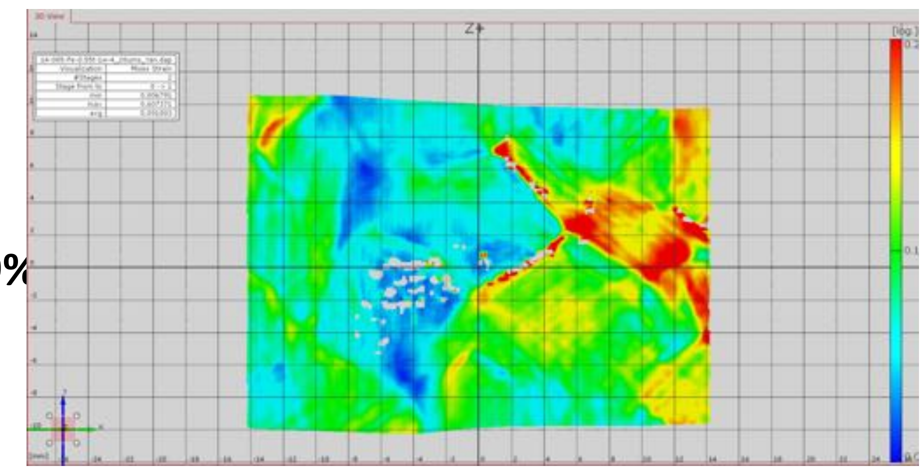
Experiment II-DIC calculation (Aramis)

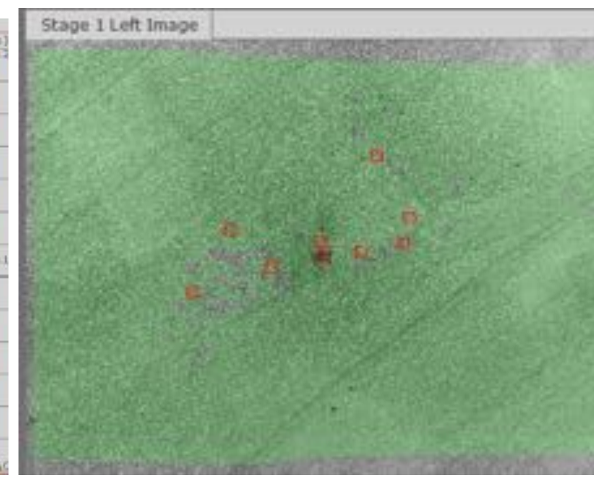
Stage 0
ε_{global}
=0%





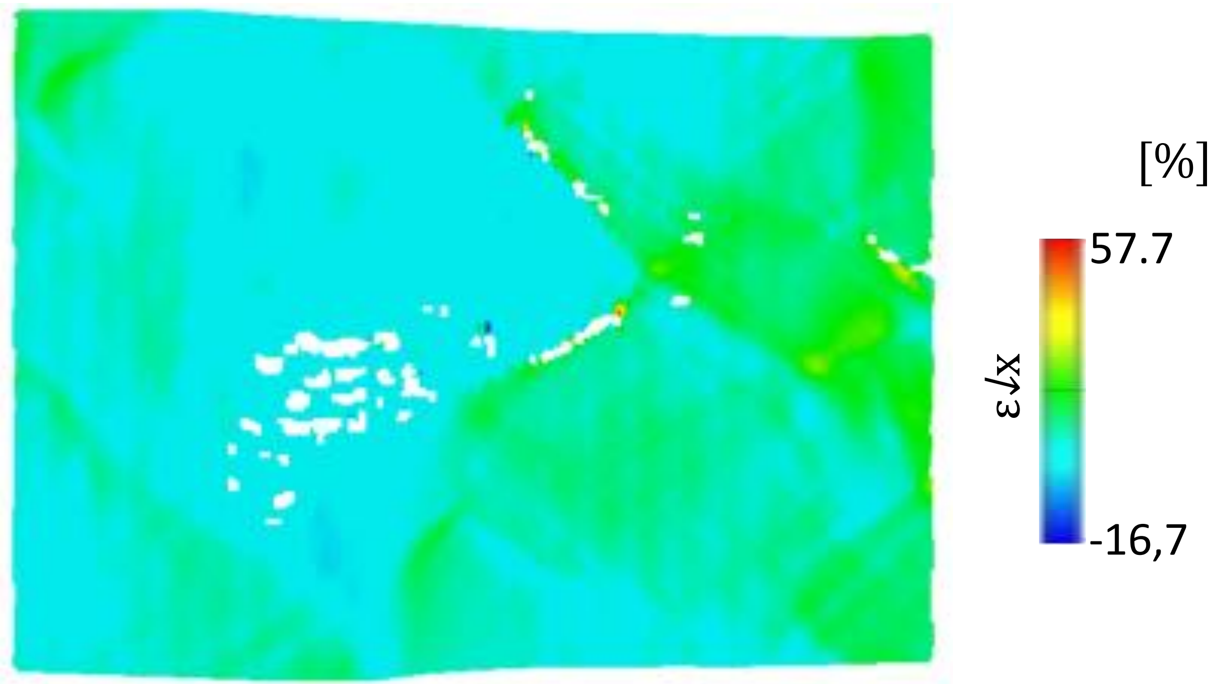
Stage 1
ε_{global} =19%





Experiment II Results-DIC

Visulisation: ε_x

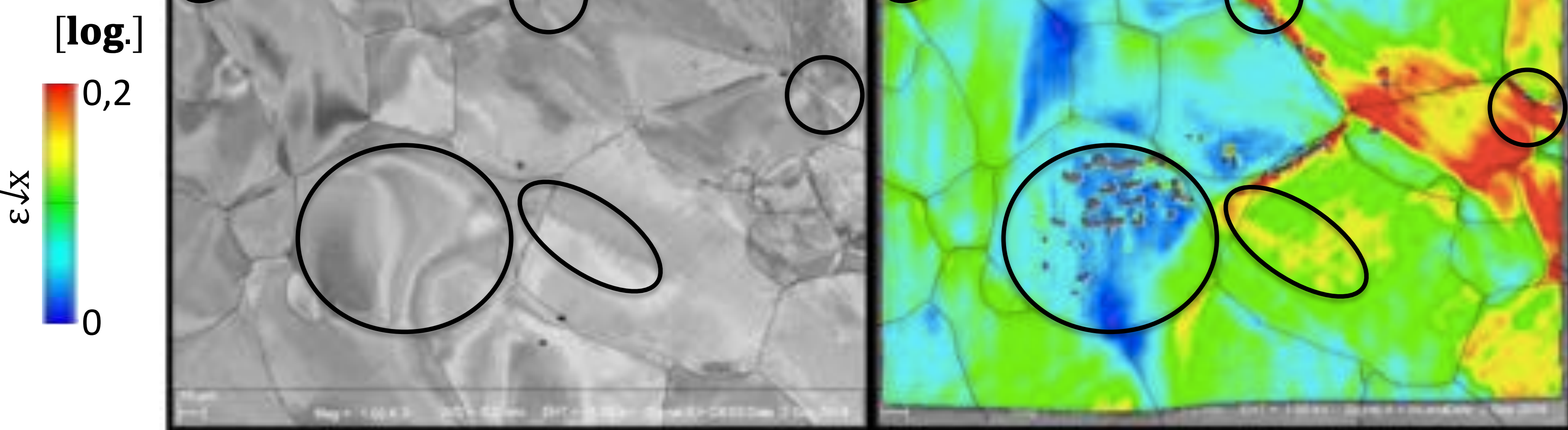


ε_{local}

min	-16.775
max	57.756
avg	8.568

Experiment II Results-DIC

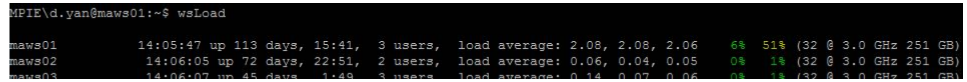
Visulisation: ε_x



Simulation Process- CPFEM

Start Simulation

- cd into /DAMASK, make spectral processing install
- wsLoad
- ssh maws02.mpie.de
- screen
- cd into working folder
- DAMASK_spectral –l xxx.load –g xxx.geom > monitor
- ctrl+A+D
- close window



Prepare Output

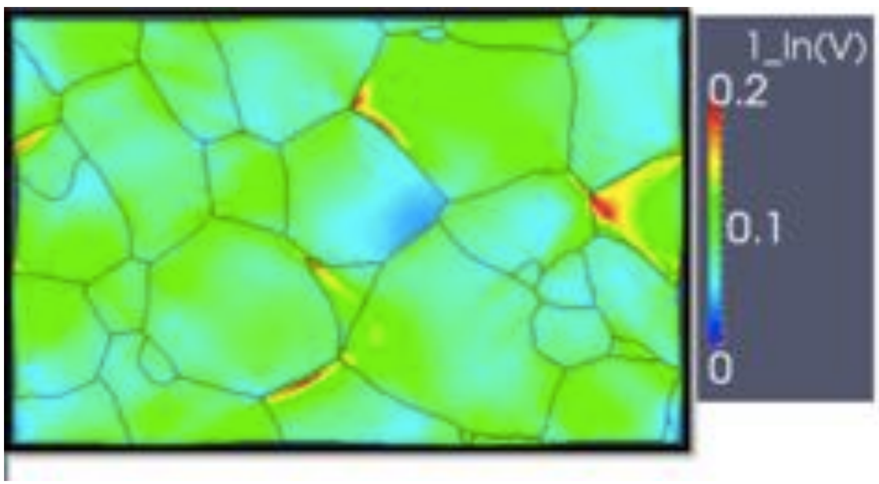
- postResults xxx.spectralOut --separation x,y,z --split -r 0 100 1 --increments --cr f,p,eulerangles
- cd into /postProc
- addStrainTensors -v -l xxx_inc*.txt [True strain]
- addCauchy xxx_inc*.txt [True stress]
- addMises -s Cauchy -e “ln(V)” xxx_inc*.txt [Equivalent stress/strain]
- addDeterminant -t f xxx_inc*.txt [Dilatation strain]
- addDeviator -t Cauchy -s Cauchy xxx_inc*.txt[Hydrostatic stress]
- For IPF, first Manually change degree to radius by excel and save as txt
- addIPFcolor -p 1 0 0 -e eulerangles xxx_inc*.txt [Inverse pole figure]

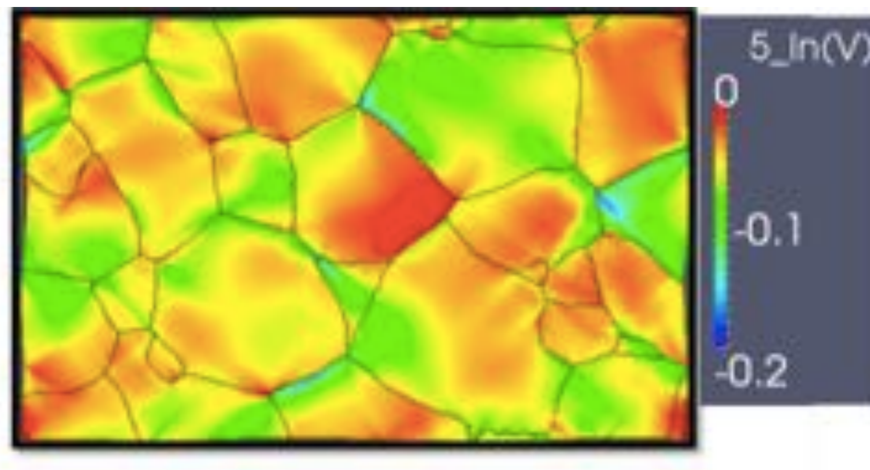
For Visualize in Paraview

- 3Dvisualize -s [1-9]_f,[1-9]_p,[1-9]_"ln(V)", [1-9]_Cauchy,"Mises(ln(V))","Mises(Cauchy)","det(f)","sph(Cauchy)",[1-3]_IPF_100 xxx_inc*.txt
- vtk_addVoxelgridData --vtk mesh_ xxx_inc*.vtk --color xxx_inc*.txt

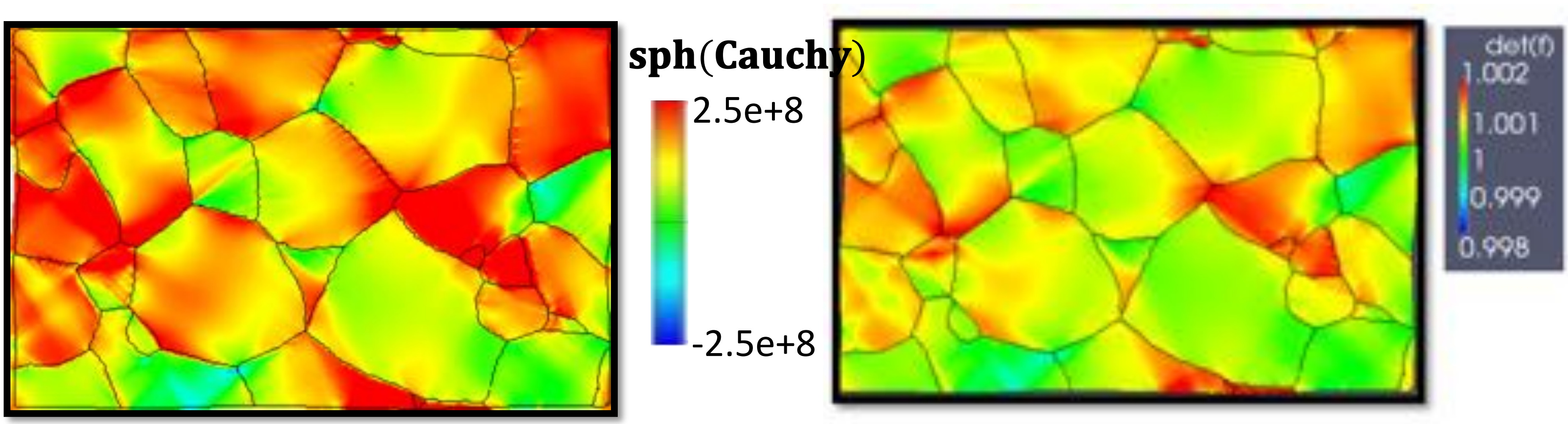
Simulation Results- CPFEM

DAMASK: True Local Strain Partitioning of Pure Fe sample in x and y directions



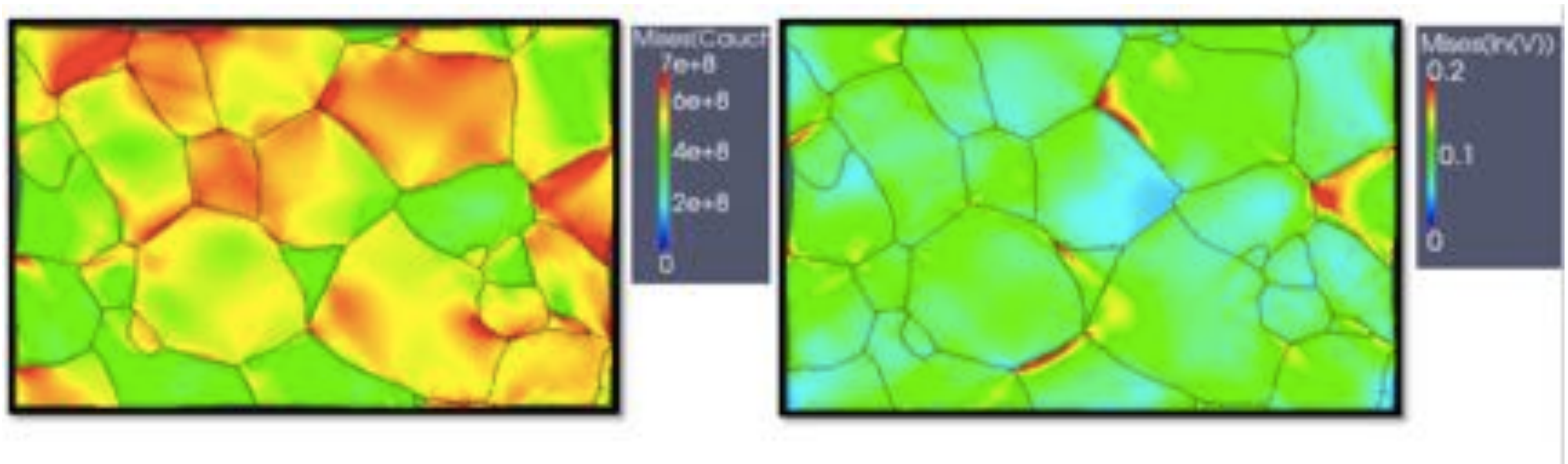


DAMASK: Hydrostatic Stress and Determinant of the Deformation Gradient in Pure Fe



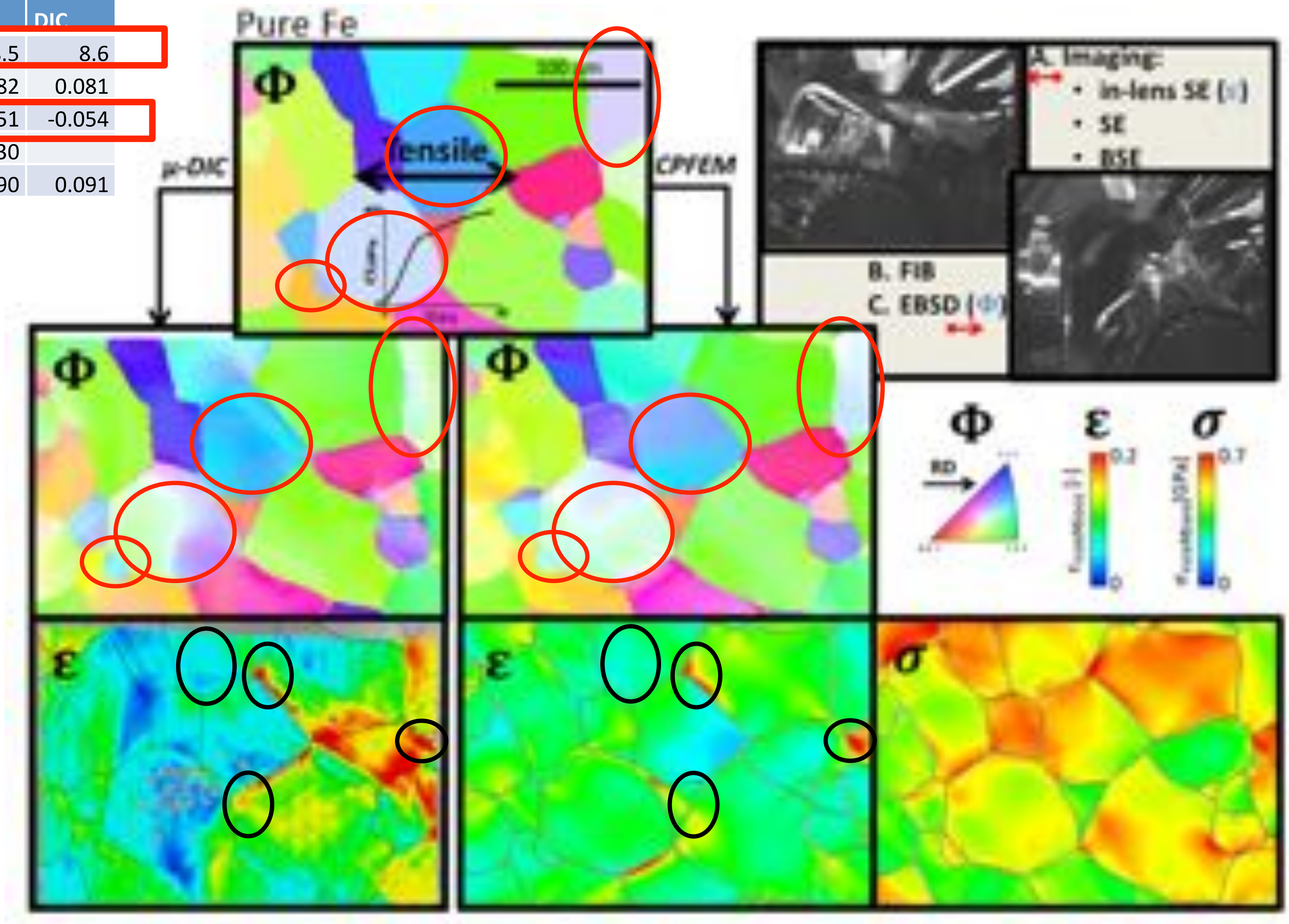
Simulation Results- CPFEM

DAMASK: Local Equivalent Stress and Strain Partitioning in Pure Fe

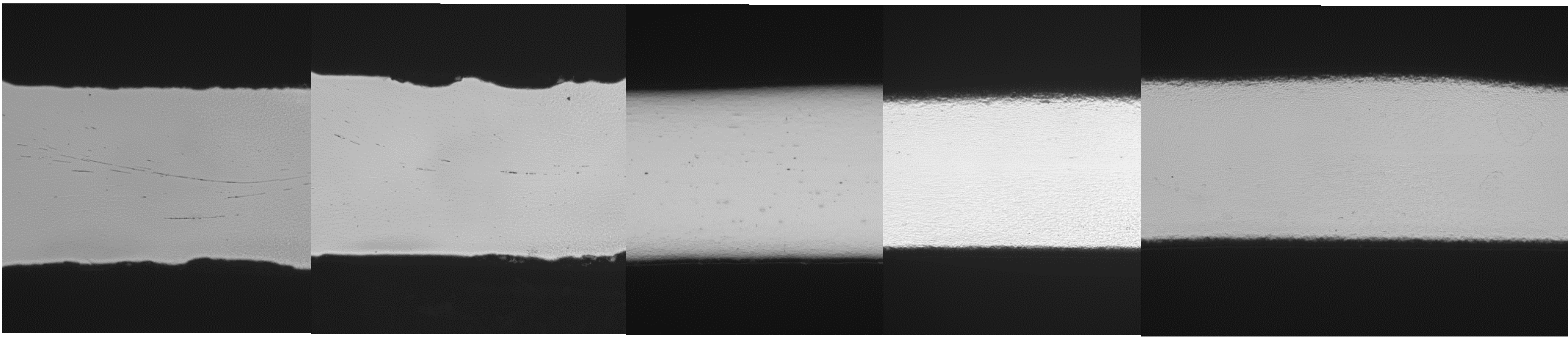


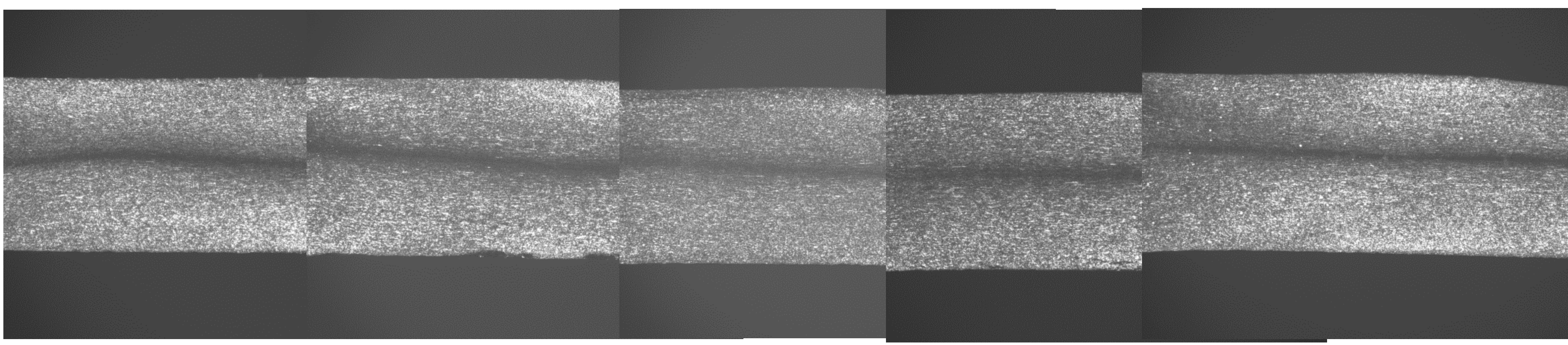
DIC and CPFEM Comparison

Ave.	Damask	DIC
x	8.5	8.6
lnx	0.082	0.081
lny	-0.051	-0.054
lnz	-0.030	
mises	0.090	0.091



Optimisation of the UFG steel sample





Summary

- Introduction to DAMASK and ITS
- Experimental Results from DIC
- Simulation Results from DAMASK
- Experiment and Simulation Comparison

1. Strain with a grain
2. Strain at triple points
3. slip transition across grain boundary

- Previous Work

End

- Thank you all!
- Questions?