Mechanical studies of Twisted stacks

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ICMAB/CSIC-CIEMAT

WP MAG 2019 Final Meeting

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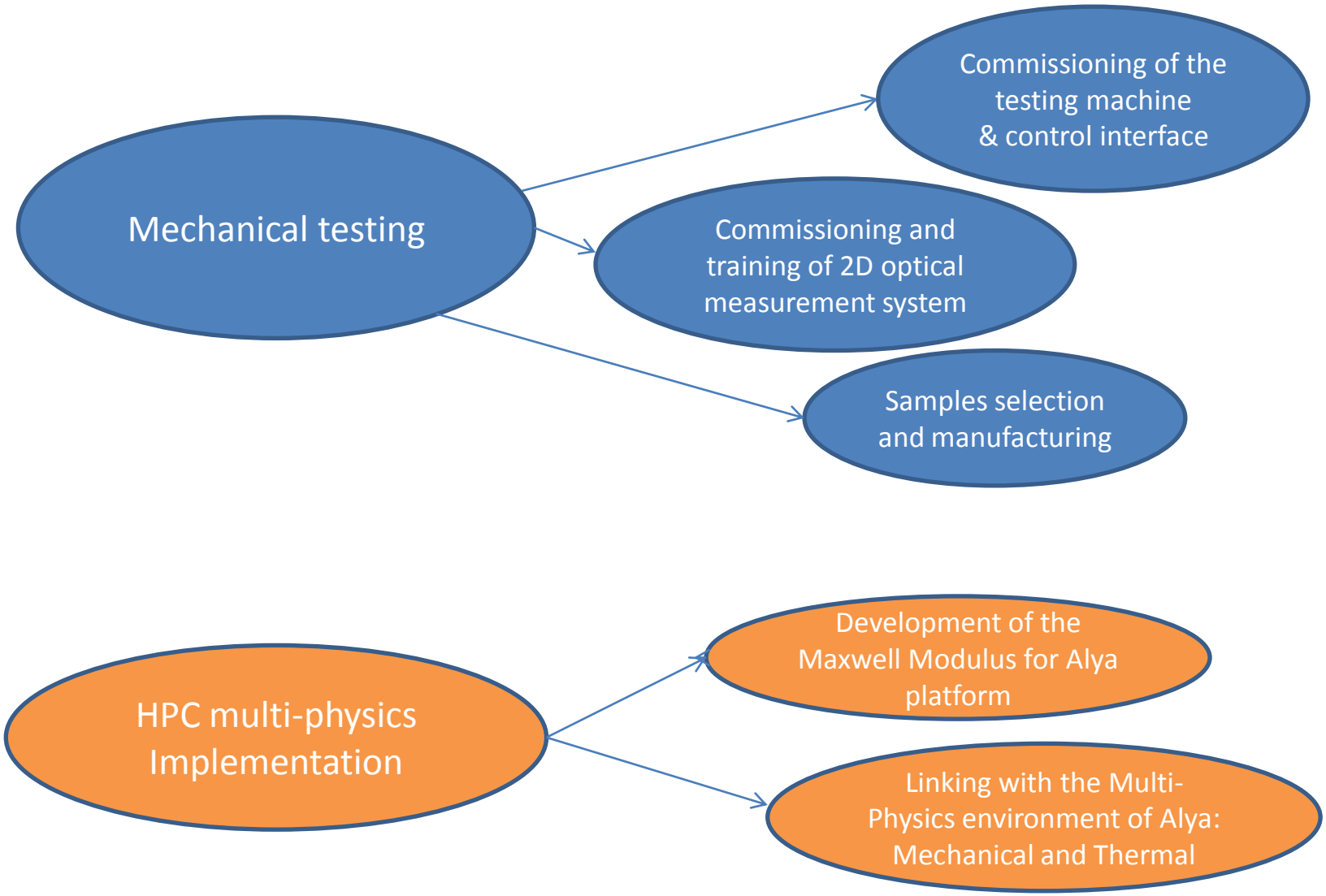
2019 Proposal

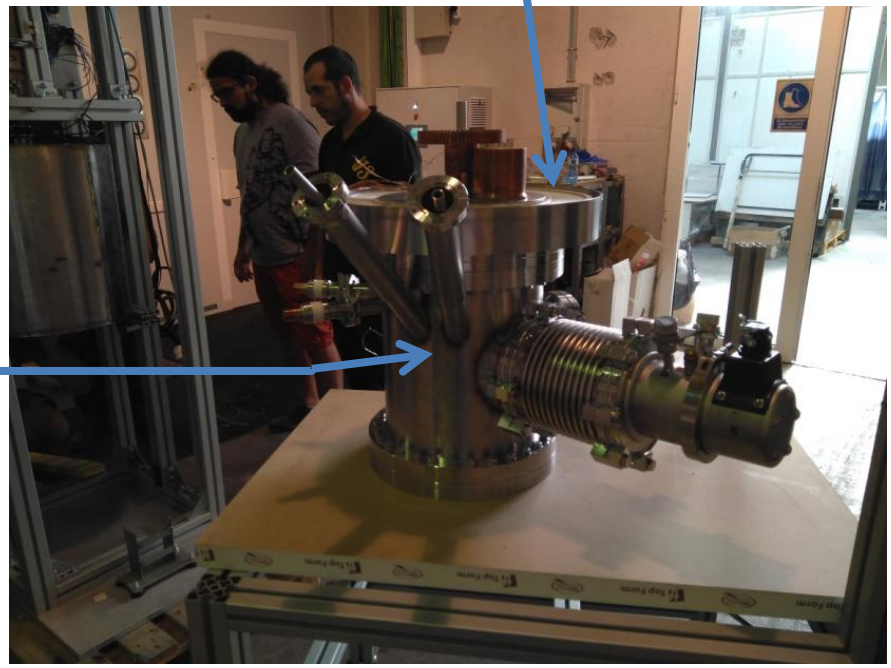


Mechanical testing

By May 2019 the machine was ready for testing

At room temperature
- Isolation vacuum : OK
- Displacement mechanics :OK
- Thermal sensors: OK

At Low temperature
- A thermal expansion problem was detected when cooling at the bottom PEEK isolation plate: a crack appears
- A leak of N2 was appreciated at the LN2 medium temperature reservoir .

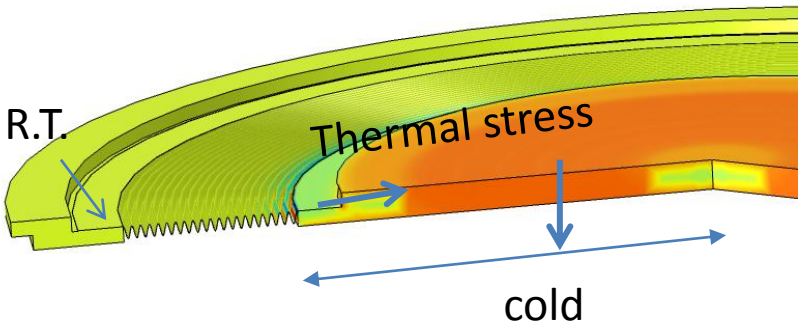


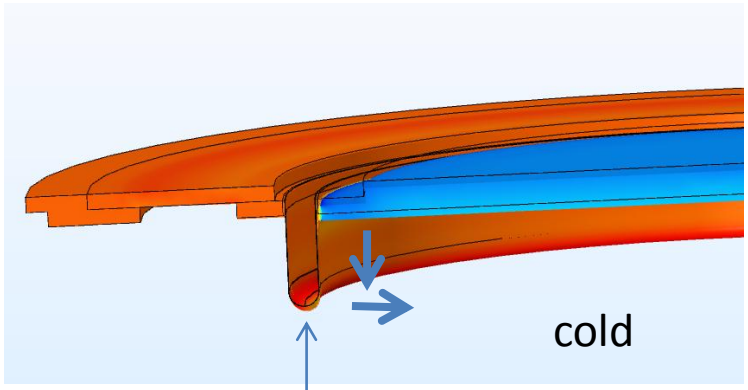
Bottom plate Options

Change of material: PEEK to Polyimide

Corrugated Stainless steel:

Stainless steel expansion damper:





Thermal expansion elastic damper

Supports :vertical displacement due to the thermal contraction and mechanical loads

horizontal thermal contraction of the cold bottom support

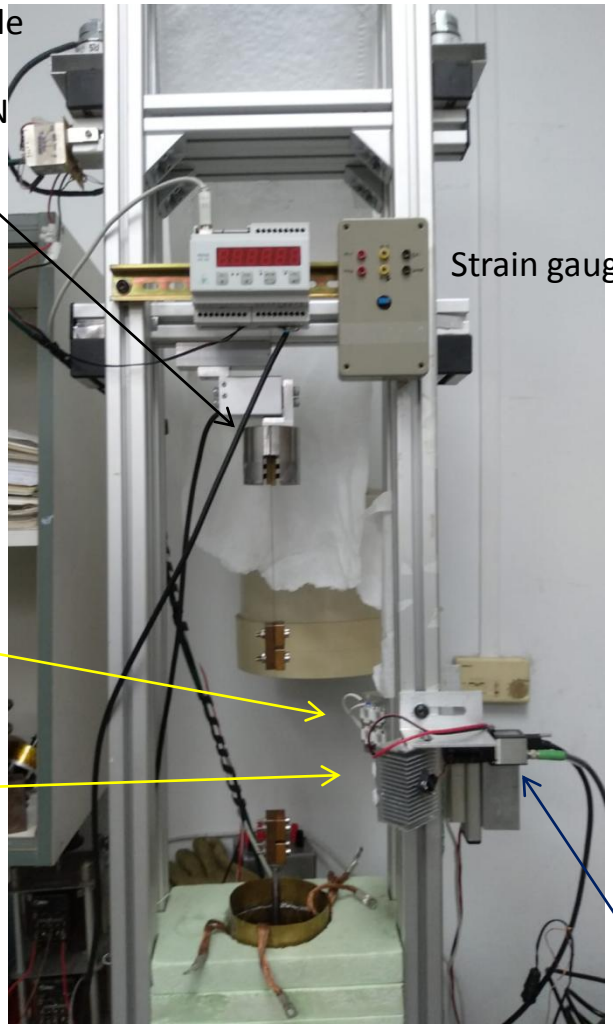
Mechanical simulations of both have been made and manufacturing is under the scope consideration

No other problem has been detected but the full system is under revision

Commissioning is expected for June 2020

The LN2 leak has been detected, localized, welded and tested for vacuum

R.T. Mechanical testing: Optics

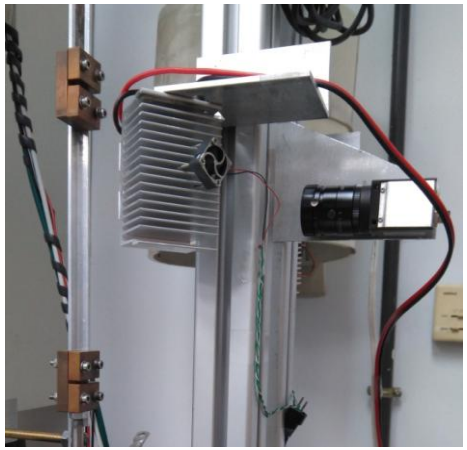


In the mid-time a testing machine for low loads has been arranged for optics testing and training

It allows for

- testing up to a load of 750N
- LN2 Temp is allowed but only for Strain gauges
- Electrical current can be applied to the sample
- Camera allows 77 fps with full field (5Mpx)
- The rate can be enhanced up to a rate of 1kfps by reducing the field
- Data acquisition and analysis has been included in a “labview” platform and can be directly transferred to the larger machine

Mechanical testing: 2D Optics



Testing machine control
Force and motor displacement
Pack (Labview)

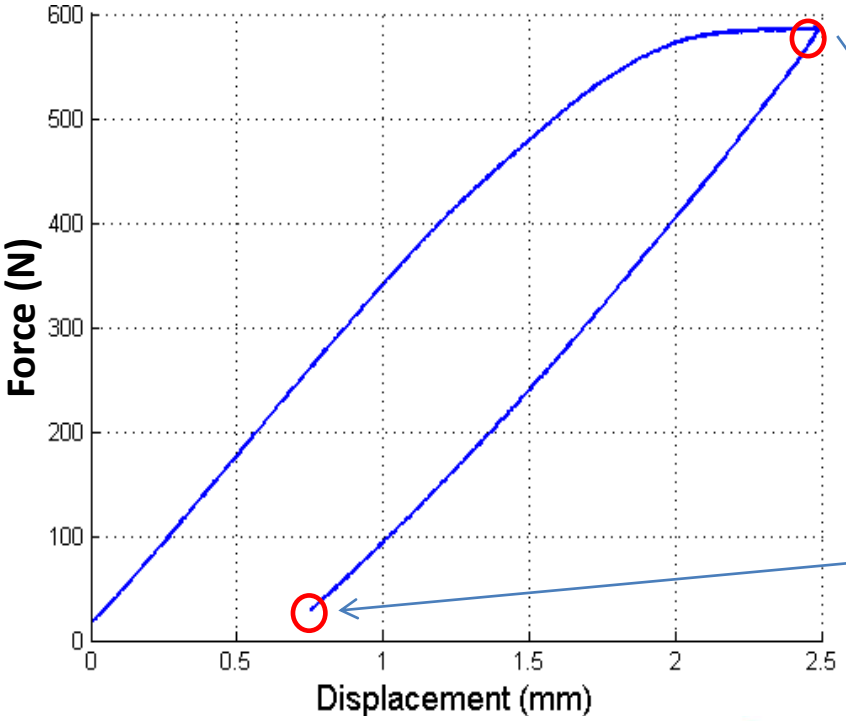
DIC image Capture
Pack (Instra 4D)

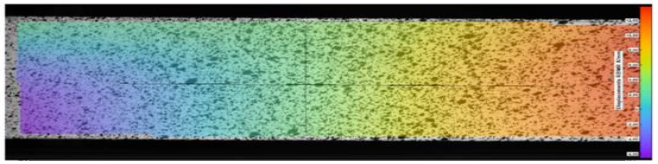
Temperature control,
Current supply &
Measurement data

Experiment control and Post processing

Instra4D+ Matlab

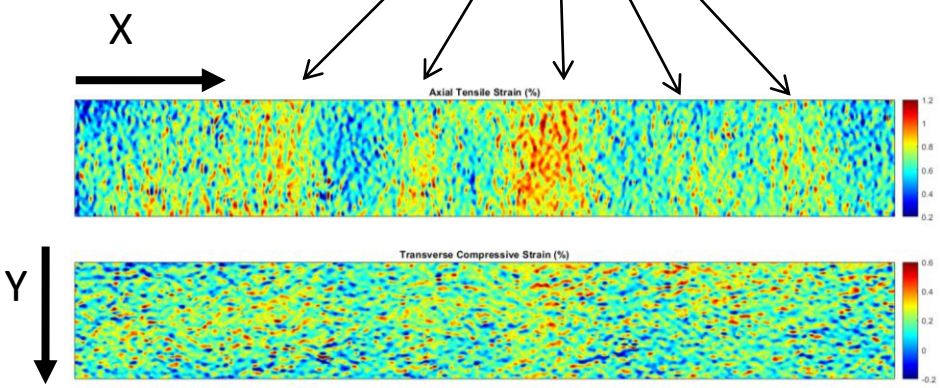
Bare SuperPower sample with 50 µm susbtrate



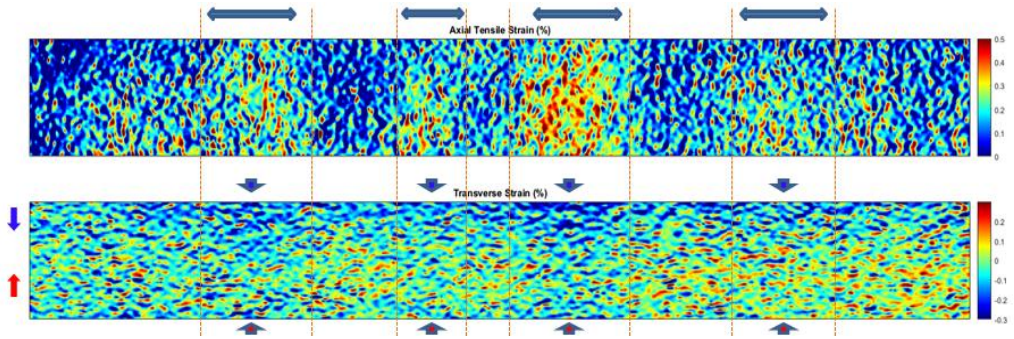


Max strain point

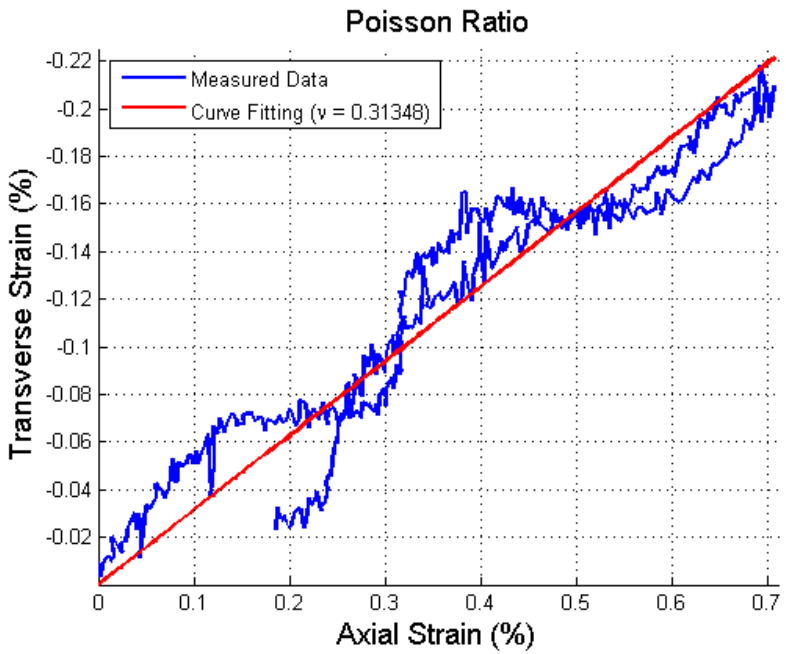
Fluence bands

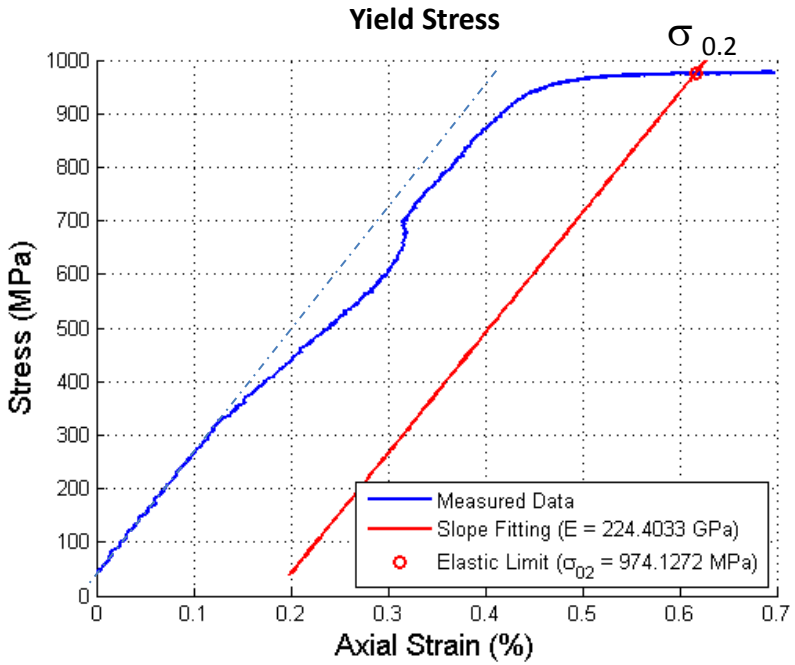


Relaxed point



Mechanical testing: Averaged parameters

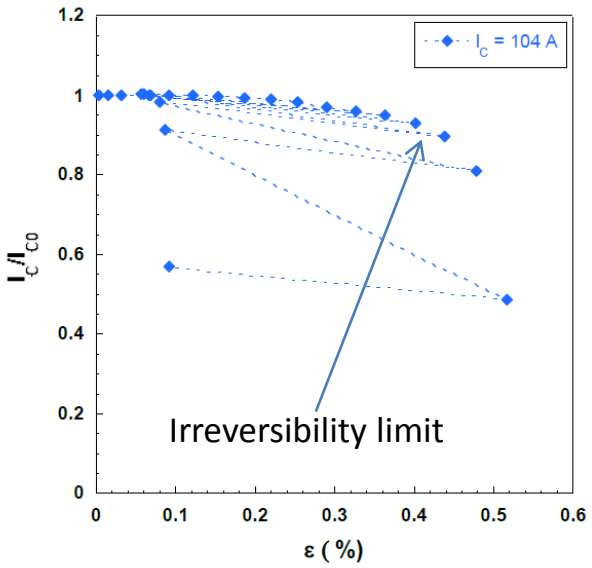




@ RT	Poisson's Ratio	Young's Modulus (GPa)	Yield Stress (MPa)
* For Ag stabilized CCwith 50 µm Hastelloy susbtrate [1]			
Measured Values	0.31	224	974
Reference Values*	0.31	200	970

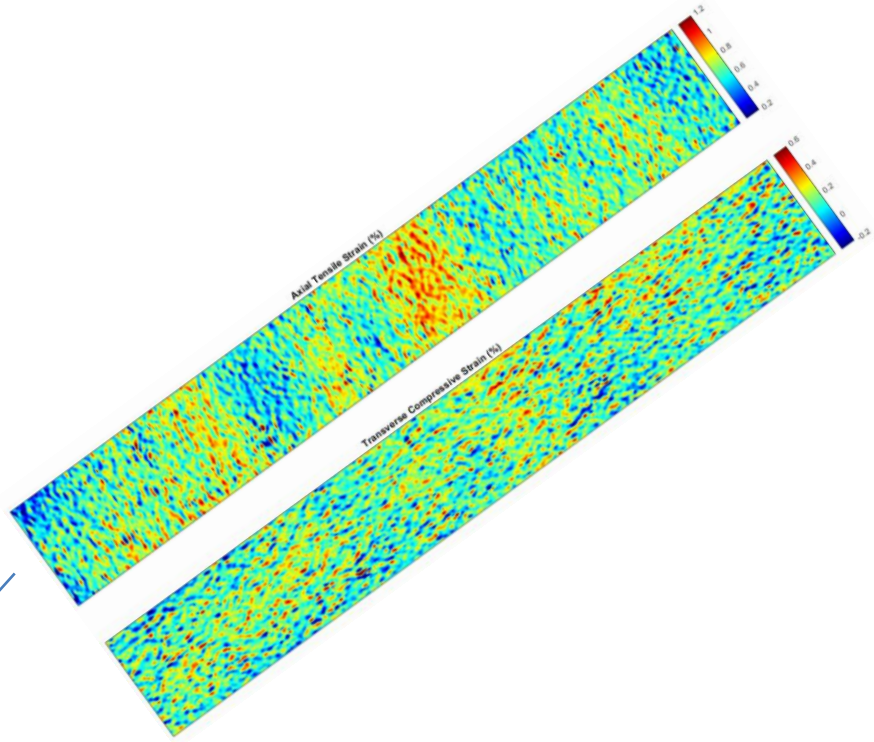
[1] M. J. Dedicatoria and H. S. Shin, *Analysis on Stress/Strain Tolerances of Ic in Externally Laminated GdBCO CC Tapes,* IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 23, NO. 3, JUNE 2013

From Strain Field to Ic distribution?



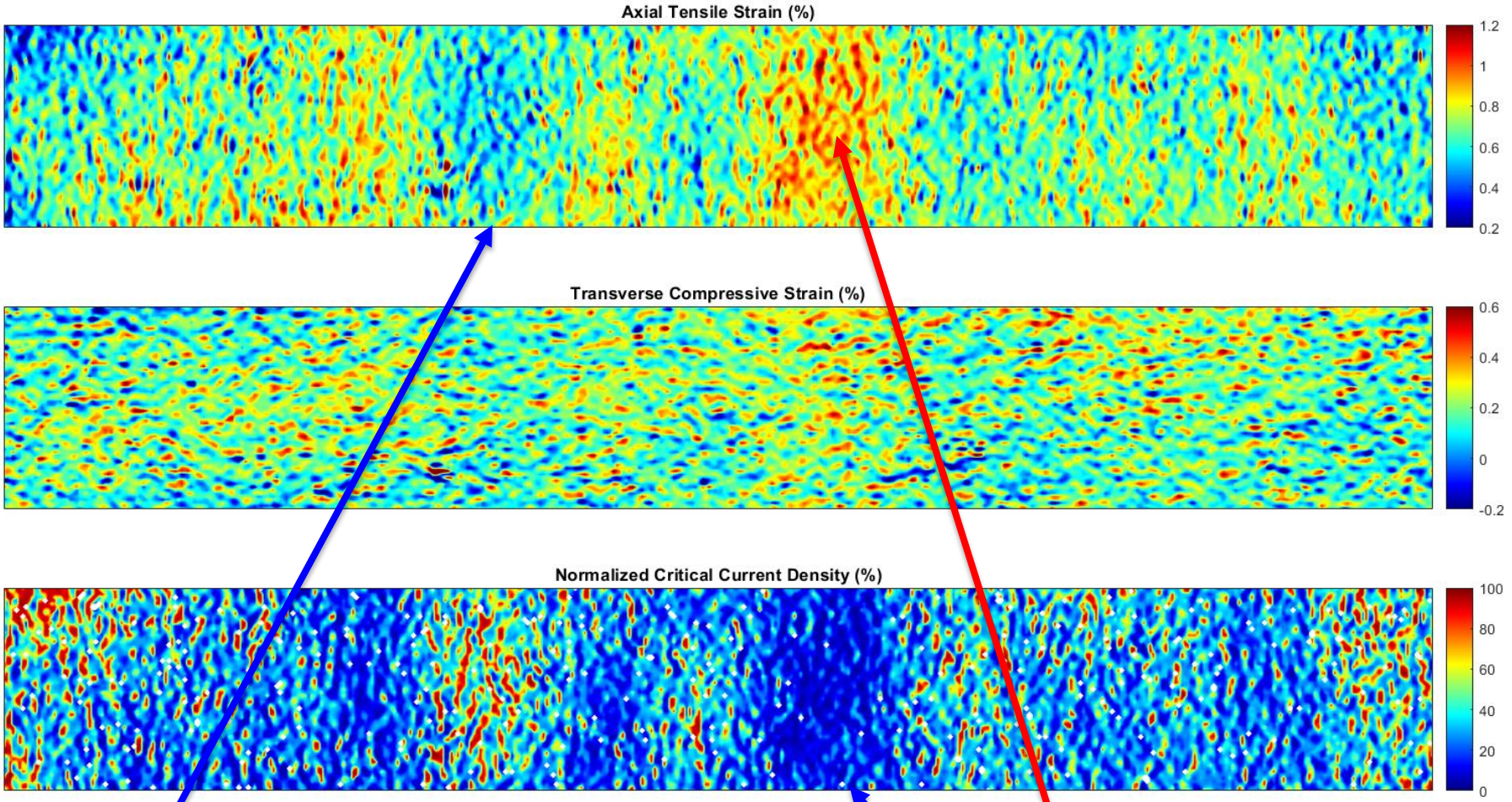
Measured Ic factor

K. Konstantopoulou, X. Granados et al. (ICMAB/CSIC)



Ic map?

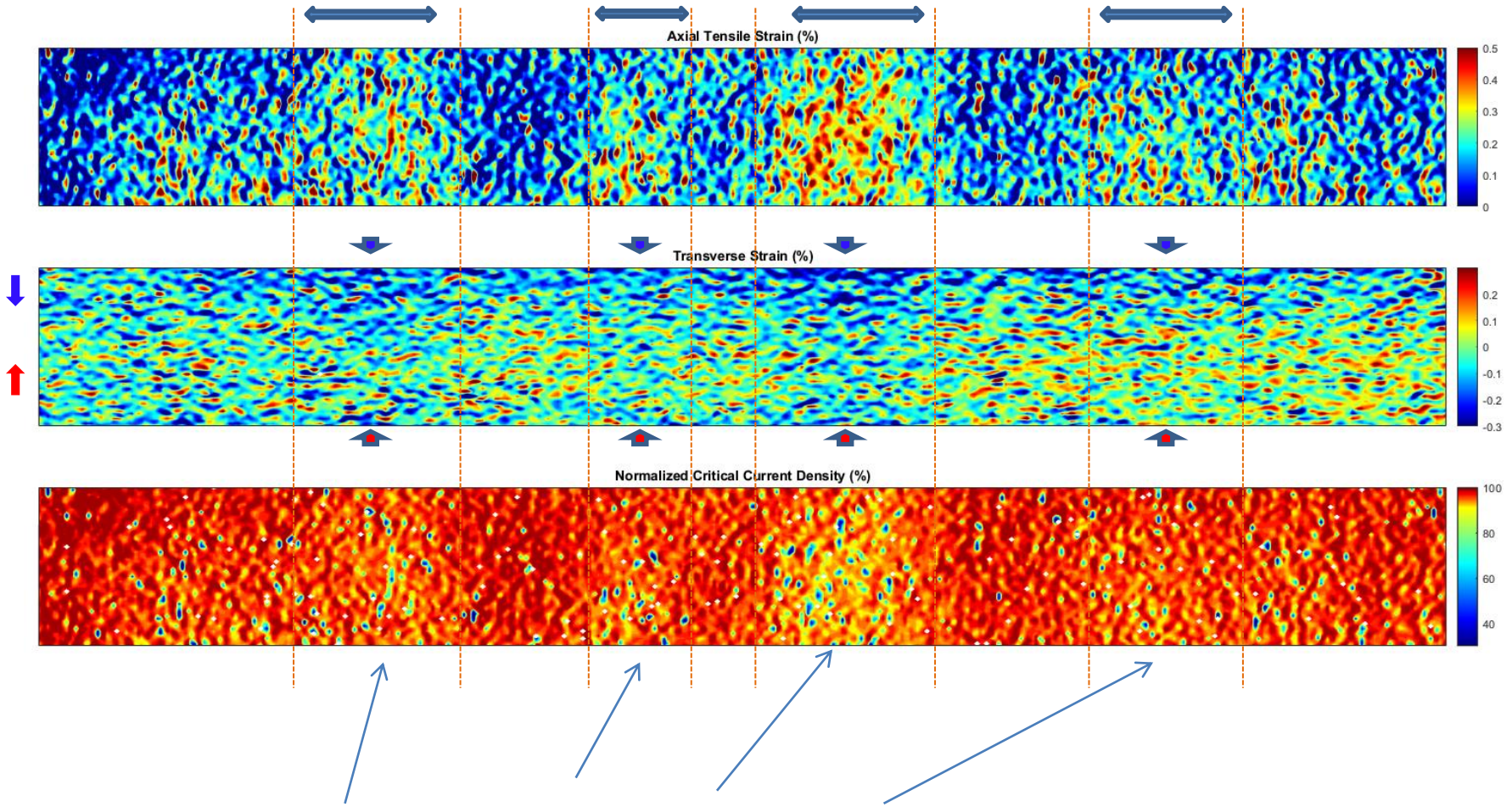
Ic map: Max ε step



Low strain,
Low degradation
(Jc near 100%)

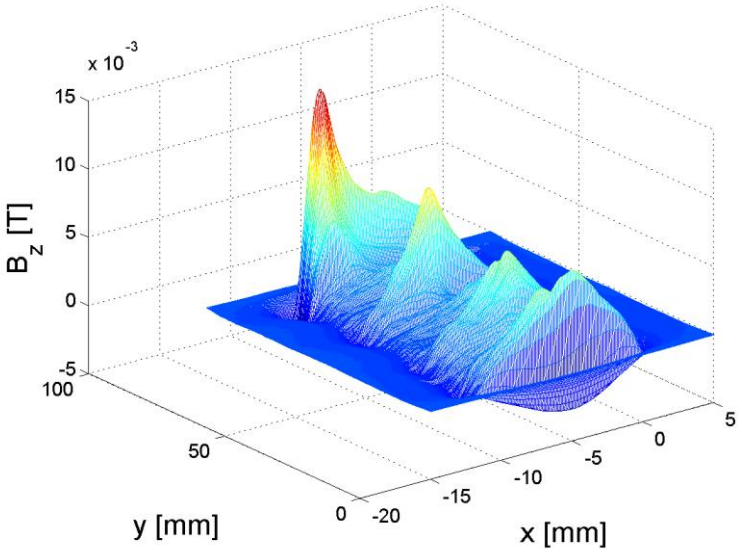
High strain,
High degradation
(Jc near zero)

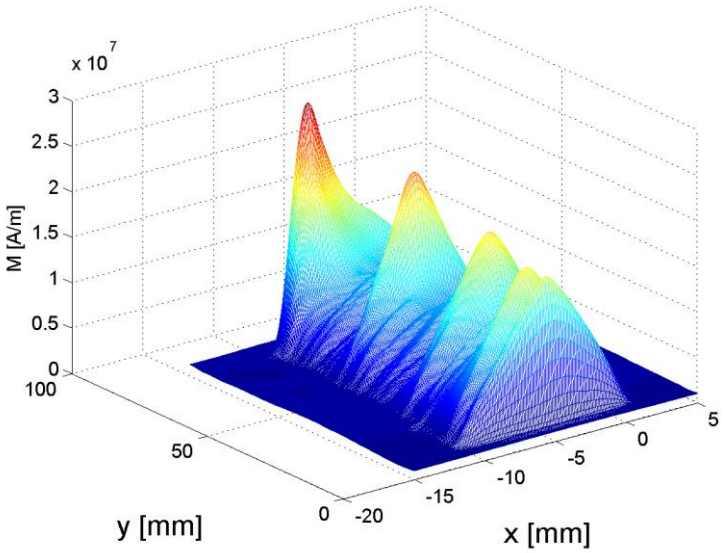
Ic map: Relaxed point (hysteresis)

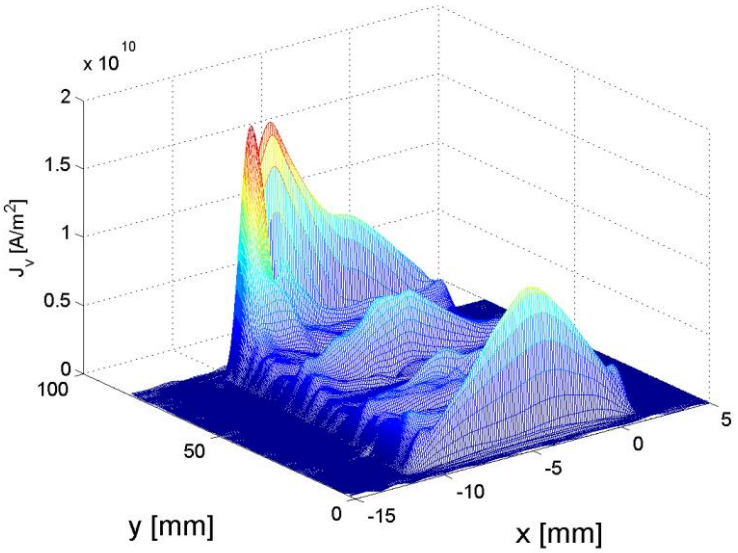


Predicted critical current decay bands

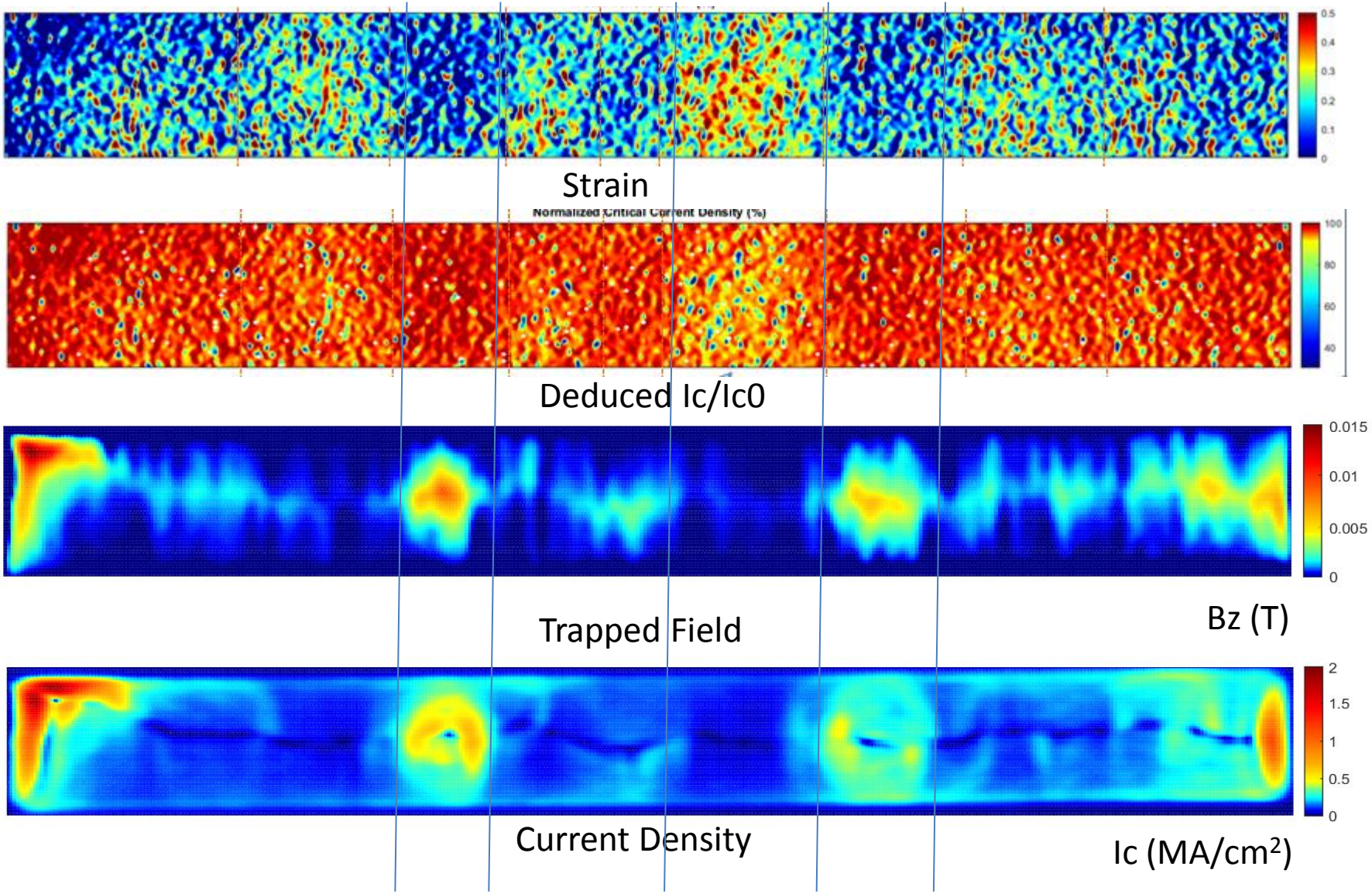
Hall map : Experimental testing







Measured Ic map: Relaxed point

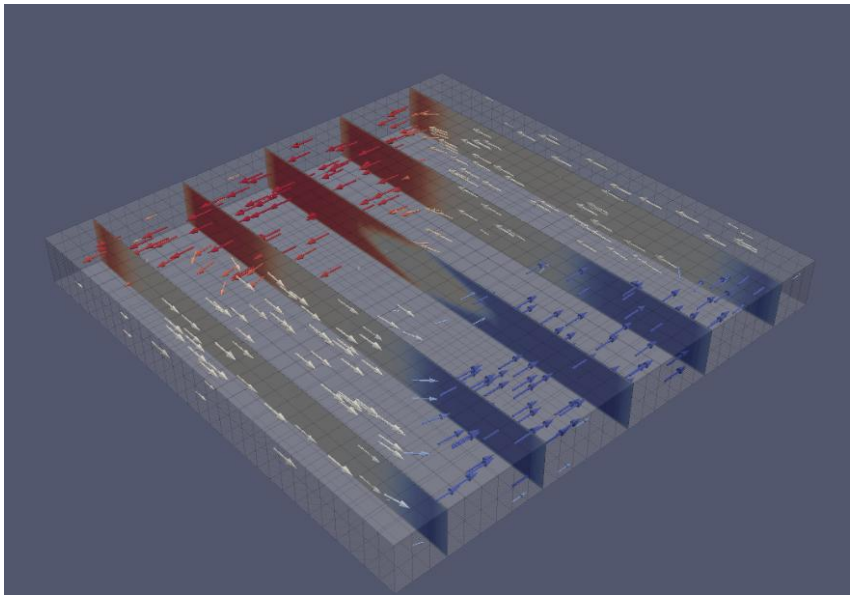


- 2D DIC system has been developed, installed and tested showing its performances for detecting the in-plane deformation
- Results confirm the validity of Digital Image Correlation for precise measurement of local strain including
  - ✓Strain (ε) and temperature (T) dependence of Ic(T, ε)
  - ✓Strain-Stress
  - ✓Hard and soft bending radii
  - ✓Twisting
  - ✓Thermal expansion
  - ✓Validation of computed results
  - ✓Deformation of subsystems (max 110 mm)
  - ✓Ic correlates well with local strain
- The implementation of the system in the new cryostat for mechanical properties will alow the simultaneous measurement of mechanical, thermal and critical current and allows also including a second camera for 3D DIC measurements. It allows also including compresive & thermal stress ,the possible induced buckling and their correlation with the critical current. In such a case quench propagation experiments for NZPV measurements will be also possible.
- Correlation with FEM computation could be also implemented.

Simulation: Mechanics

✓Isotropic and orthotropic approaches can work with stack Twisting and Bending
✓Orthotropic approaches better the behavior and suggest manufacturing process without bonding between layers
✓Bending problems without twisting the stacks have been detected due to the difference between inner and outer radius that leads to a cummulative displacement each turn.
✓Twisting corrects the difference if the turn length is multiple of the twisting pitch
✓Very soft shear between layers can allow stress in the turn if done during manufacturing of the cable

✓Col·laboration with BSC's Prof. M. Mantsinen group (Dr. J. Lorenzo) has allowed the development of a 3D HPC-Alya support now available for testing .



HTS Current flow distribution induced in a stack by an external field, computed in by J. Lorenzo et al. (BSC)

Conclusions

Both task are running on time with the exception of the large test machine.

Samples for testing will be available on time
Room Temperature testing will be also done
Mechanical models (approx) are available
Maxwell 2D and 3D have been demonstrated and is under
Validation against experimental results
New problems for testing are ready
Multiphysics will be developed along the following period: 2020

Next steps

Simulation and experimental validation of a coil winded by twisted stacks

- ✓Feasibility study of the measurement of the current distribution
- ✓Estimate of losses in loading, unloading , transients or ripple when using stacks with shorted or isolated layers
- ✓Quench: thermal and mechanical concerns

Acknowledgments

I would like to acknowledge the contributions of G. Telles (ICMAB), P. Barusco (ICMAB) & J. Lorenzo (BSC)