FastGrid

EUCAS 2017

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A new EC project: FASTGRID

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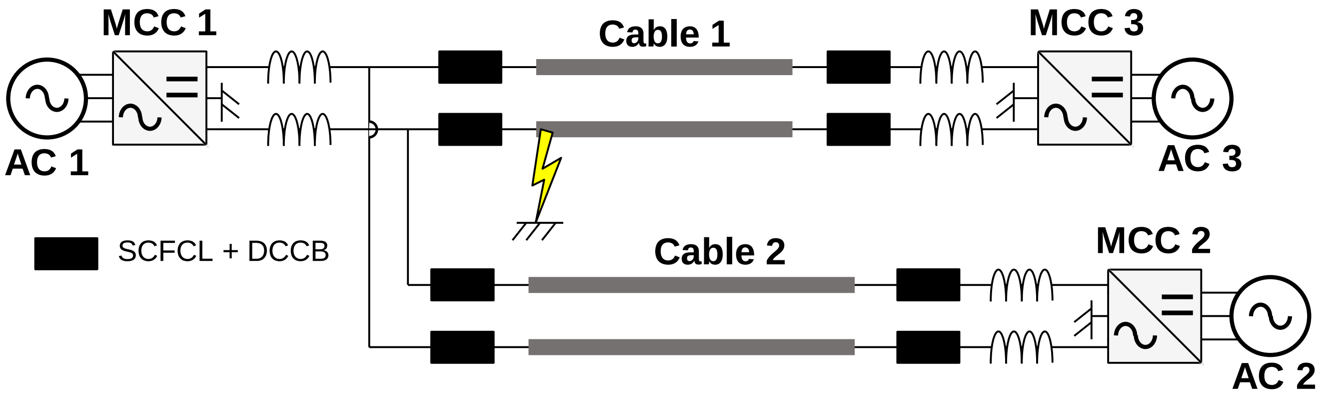
Cost effective FCL using advanced superconducting tapes for future HVDC grids

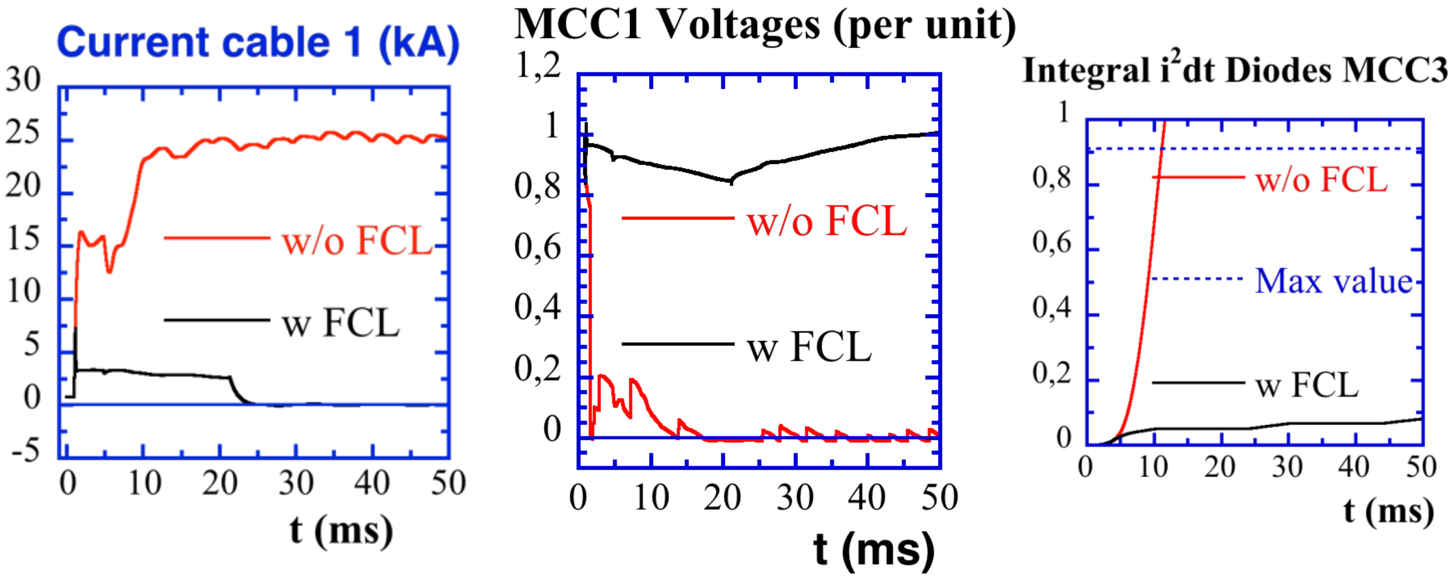
Started January 1st 2017 (42 months)

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No 721019

HVDC supergrids

HVDC circuit breaker
SGRI (200 kV)
(7 x 7 m^2)
Footprint & cost





Strong interest of R-SCFCL

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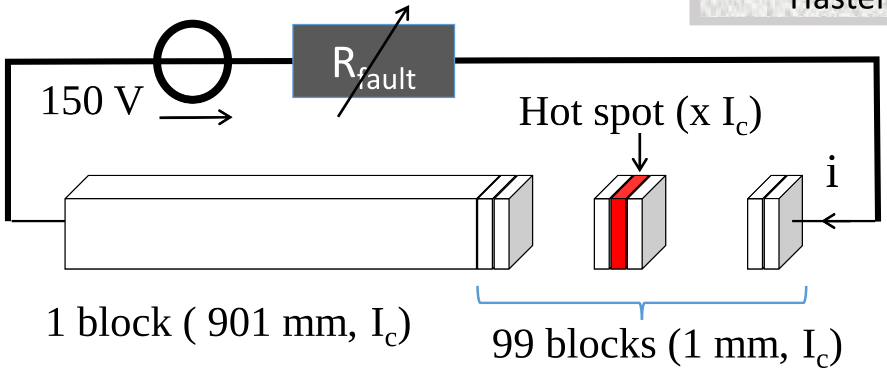
Cost of the Superconductor in a R-SCFCL: $Cost_{SC} \gg \frac{C_{SC}}{E_{\lim}} k_a \, I_a \, V_{SC\text{-}Lim}$

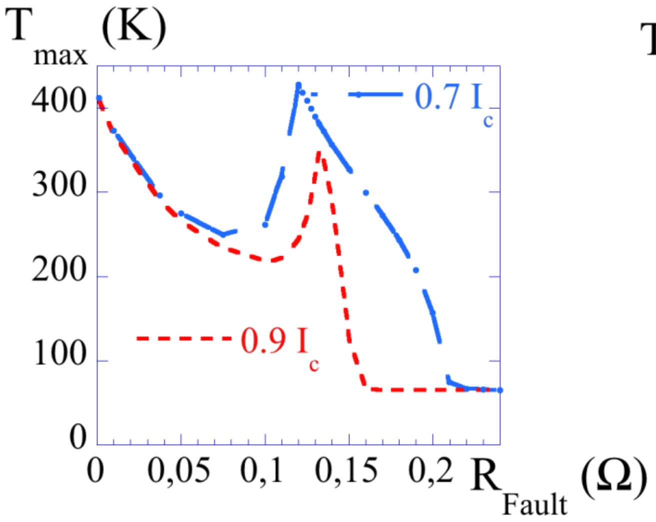
⇒ **Reduction of C_{SC}**

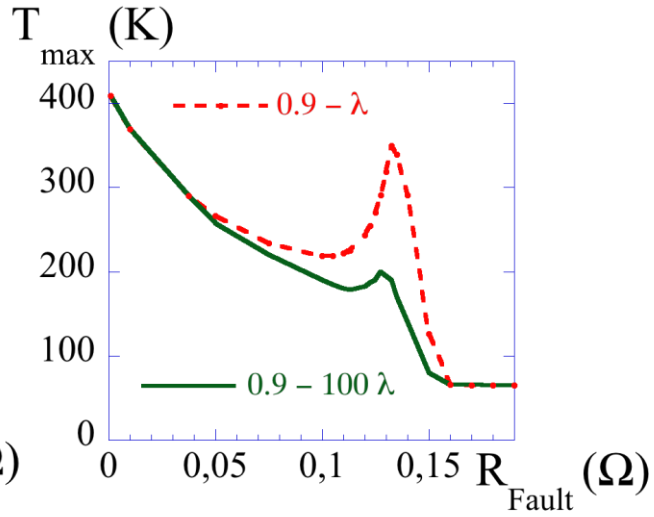
- Material & Larbor
- $I_{c\text{-}w}$ Perf. & operating temp. => 65 K



⇒ **Enhancement of E_{lim}**

- Conductor design (shunt)
- Hot spot issue for low prospective faults
  - Homogeneity
  - NZPV
- New route

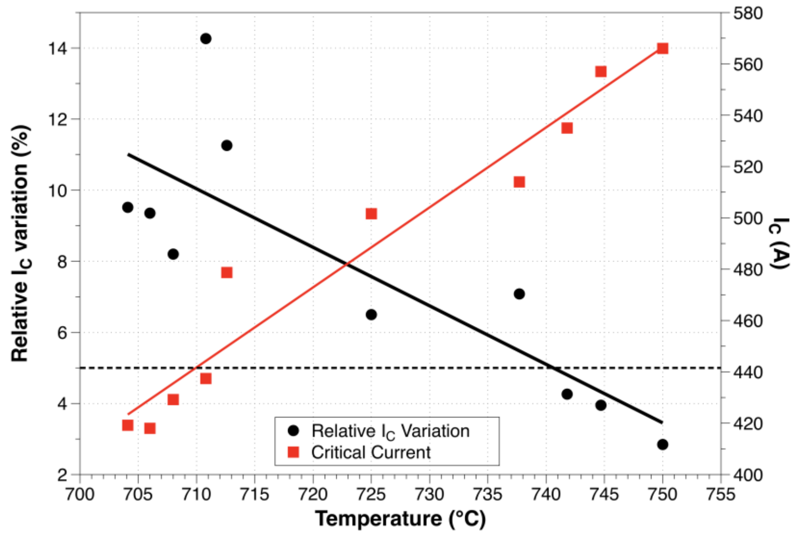




FASTGRID deliveries

- **Advanced REBCO tape**
  - Low standard deviation in term of critical current over the tape length
  - Critical current higher than 1000 A/cm-w at 65 K (self-field)
  - Electric field higher than 100 V/m (50 ms)
- **Emerging REBCO tape**
  - Tape with enhanced propagation velocity (CFD concept)
  - Sapphire substrate REBCO tape with ultra high electric fields
- **Smart module of a HVDC apparatus**
  - Current and voltage in the range of 0.5/1 kA and 30/50 kV
  - New functionality such as quench detection through optical fiber
  - Extensive testing of the module in relevant operating conditions

Low standard deviation in term of I_c over the tape length and high I_c

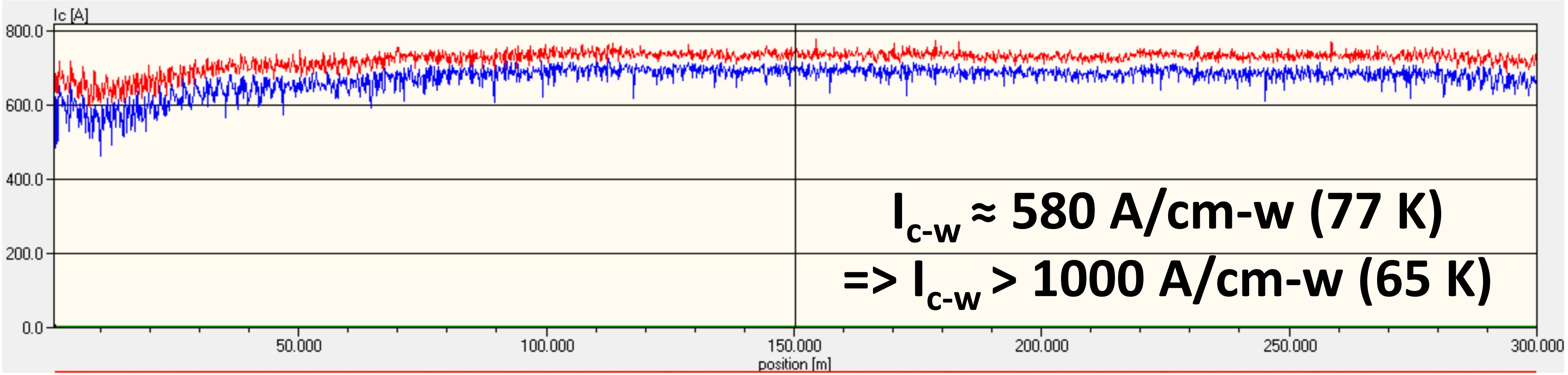


THEVA

After optimization of process parameters:

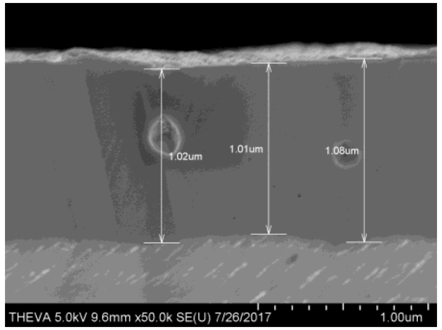
- $I_C > 500A$
- $\Delta I_C < 5\%$

can be produced with high yield



$I_{c\text{-}w} \approx$ **580 A/cm-w (77 K)**

=> $I_{c\text{-}w} >$ 1000 A/cm-w (65 K)



Example:
Ag thickness

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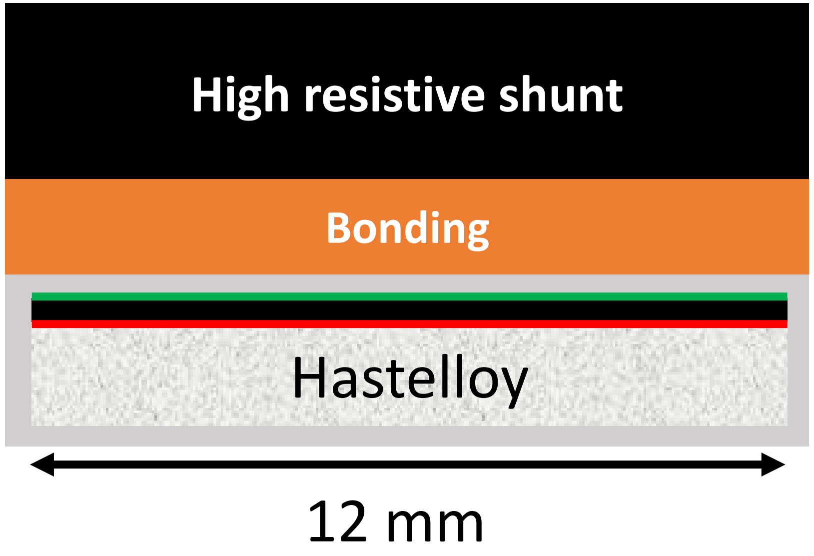
- A numerical model in COMSOL has been developed
- Various configurations of shunt tested in different scenarios (limitation, hot spot) with soldered or adhesive bonding
- Two architectures to test
    - CuproNickel shunt ($Cu_{60}Ni_{40}$) 150 µm- 300 µm
        - 5 µm solder PbSn
    - Hastelloy shunt 500 µm - 800 µm
        - 5 µm solder PbSn



Validations tests and first tests are undergoing

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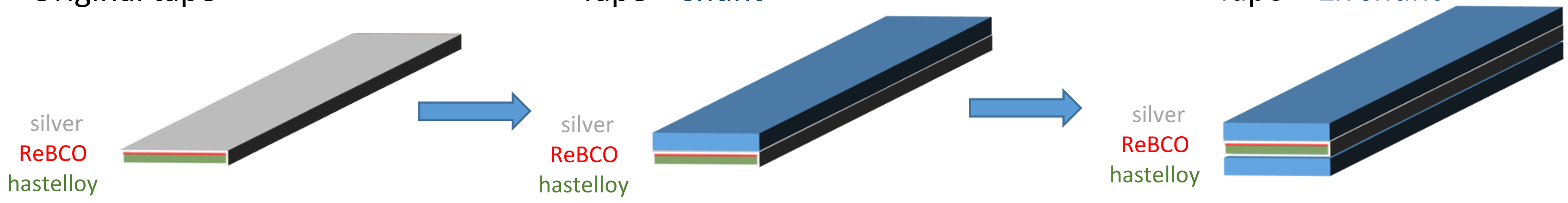
Conductor with high electric fields (> 100 V/m) – other approach

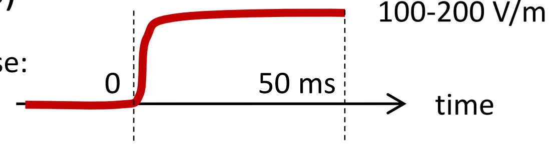
Original tape | Tape + shunt | Tape + 2x shunt



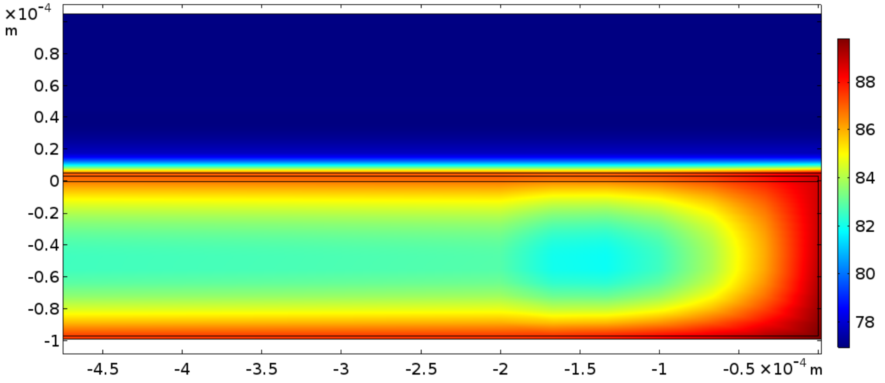
- High thermal capacity,
- Electrically insulating layer

FEM simulations, Comsol 5.2 model developed by EPM (Ch. Lacroix, F. Sirois)

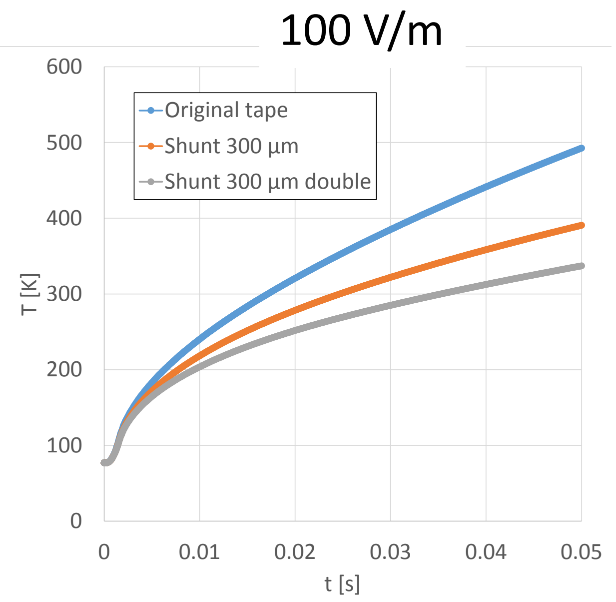
voltage pulse:

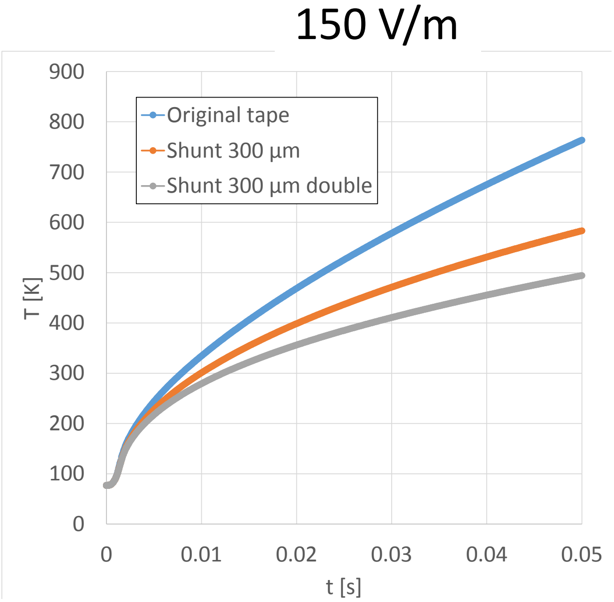


t = 1 ms



Shunt properties: C_p = 900 J/(kg.K) at 77 K
λ = 1 W/(m.K)





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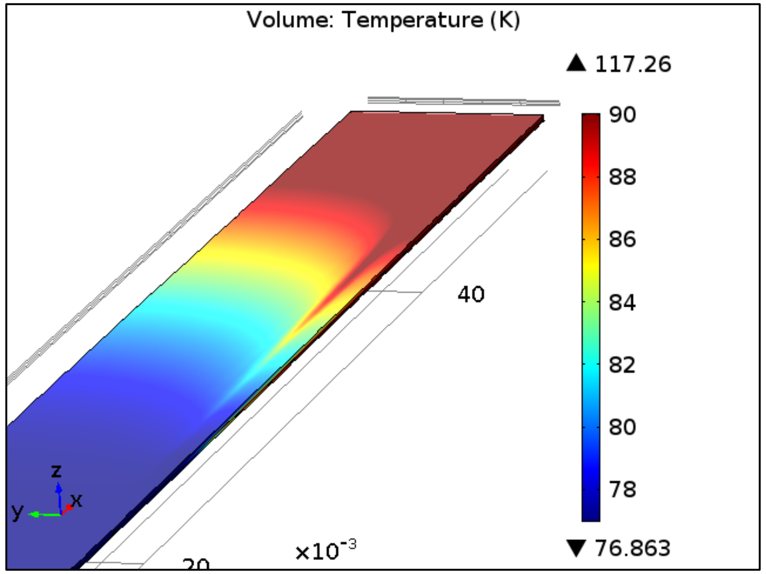
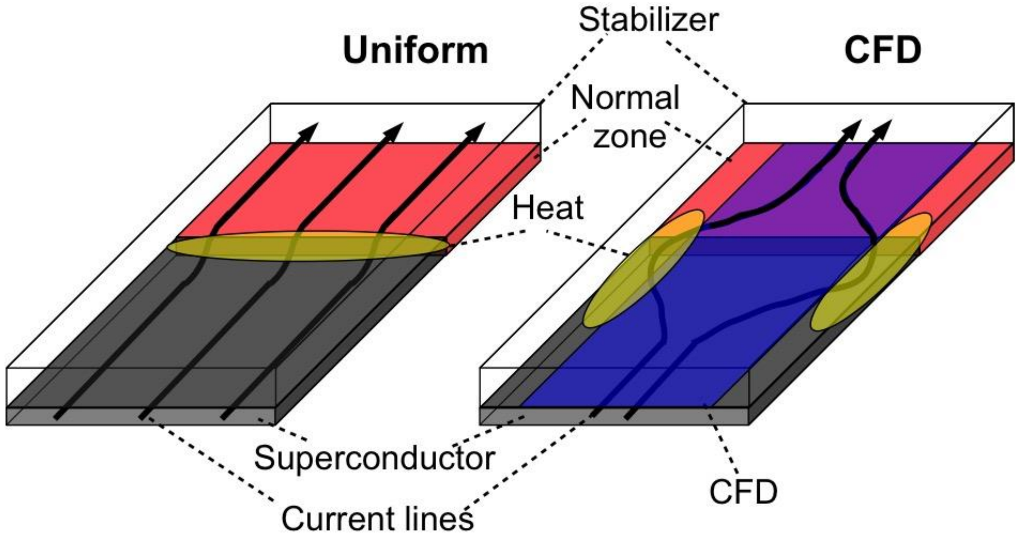
NZPV enhancement: Current Flow Diverter (CFD) concept

- Full 3D numerical simulations of 2G HTS CCs including the « Current flow diverter » (CFD) concept
- Types of shunt investigated:
  - Hastelloy, Stainless Steel, Composite, CuproNickel, etc.
  - Shunt thickness: 0 - 200 microns
- Calculations also realized for tapes based on a sapphire substrate

Quench simulation of a CFD-2G HTS CC with a 100-microns-thick Hastelloy shunt





The NZPV can be increased from
0.5 m/s to 15 m/s (x 30)
using the CFD even with a thick shunt

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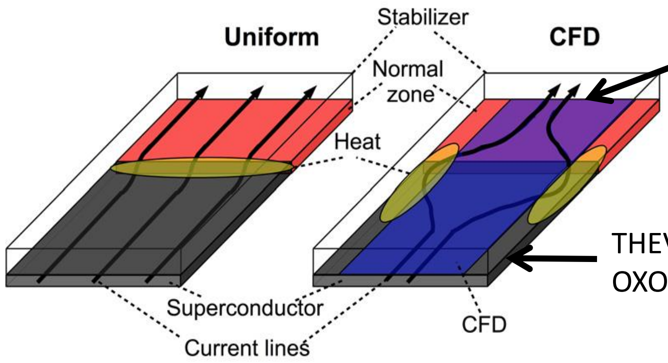
CFD realization through Ink Jet Printing (IJP): customization of conductors

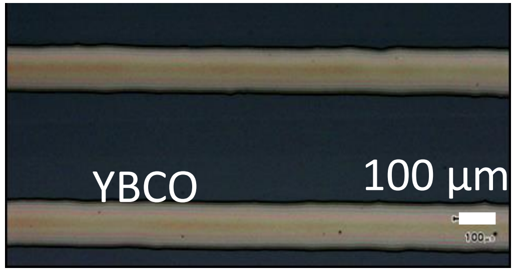


IJP insulating layer

THEVA CC (ISD)
OXO CC (CSD/ABAD)

THEVA tapes are coated by IJP with amorphous Y_2O_3 layers tracks: CVD

IJP can be used to pattern customized tracks



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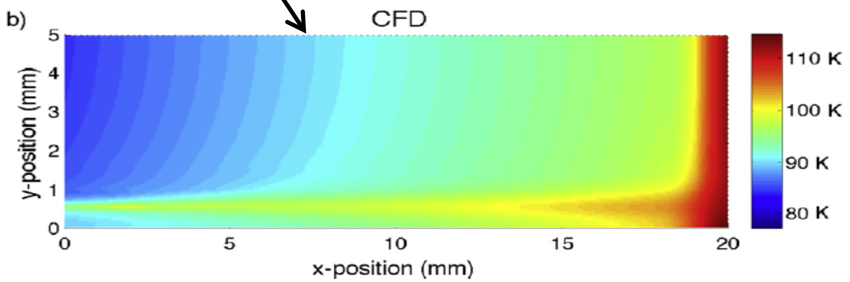
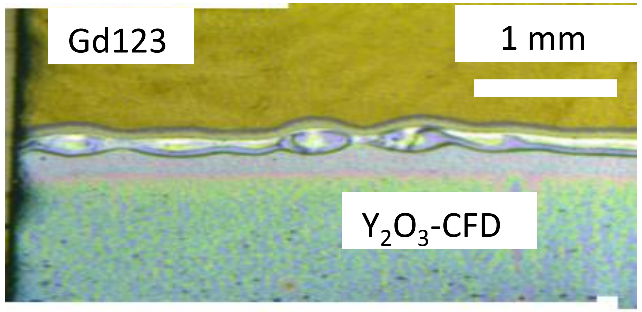
Center of the tape



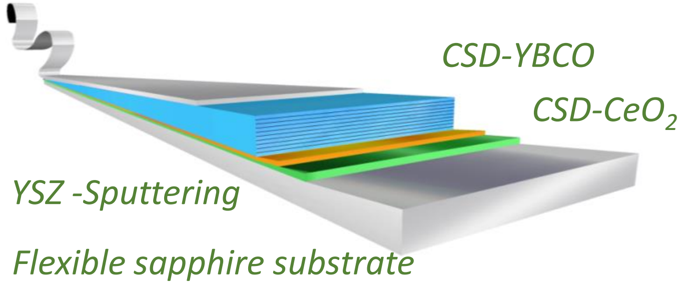
Surface temperature distribution

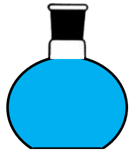


IJP nanometric coatings of insulating layers customized

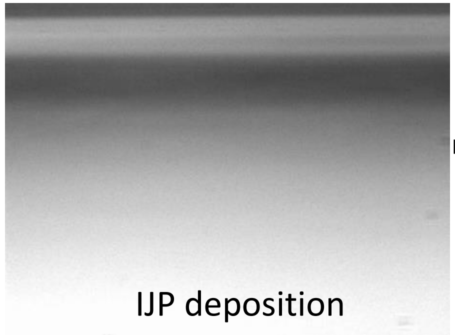
- IJP metalorganic precursors (~ 100 nm)
- High deposition speed (>20 m/h)
- Long lengths demonstarted (> 100 m)
- Low temperature annealing (T ~400-500 ºC)
- SC performances CC stable
- Test of limitation properties underway

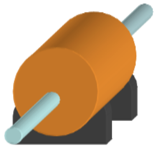
Ink Jet Printing: customization of conductors for FCL





Metalorganic solutions





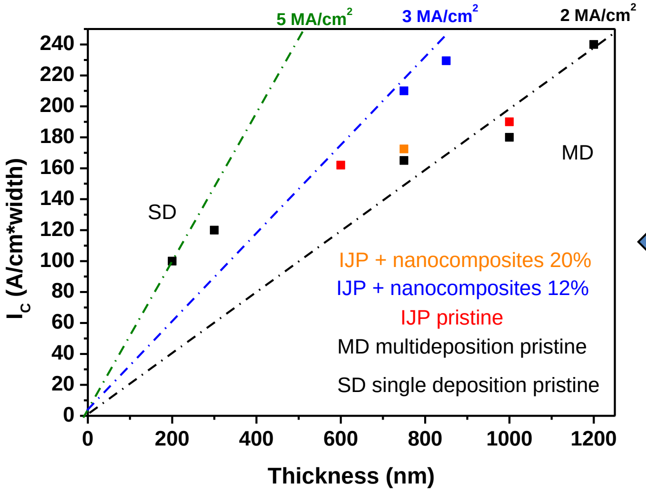
Epitaxial growth

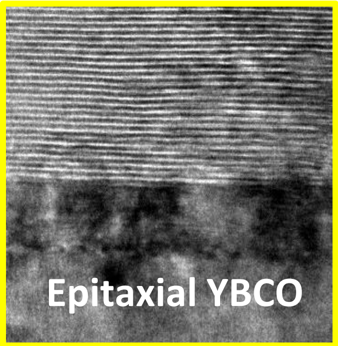
TEL AVIV UNIVERSITY
אוניברסיטת תל-אביב

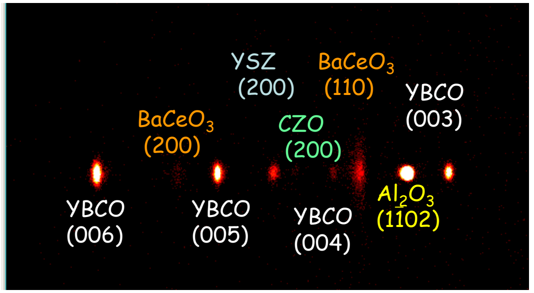
ICMAB

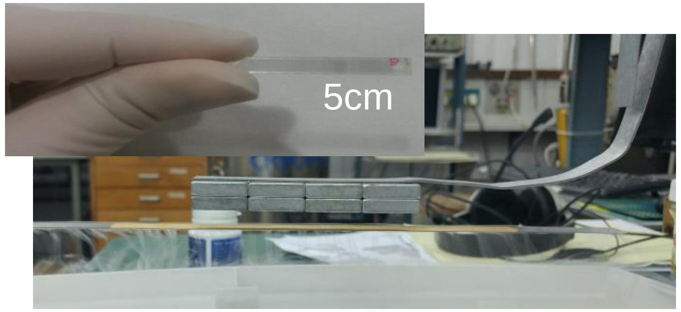
OXOLUTIA

CSD growth of thick YBCO layers on Sapphire









Thick YBCO layers can be grown after IJP deposition (I_c > 220 A/cm-w on LAO): implementation on sapphire substrates under way.

Ultra high electric field tapes (>1000 V/m) expected.

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Coated Sapphire substrates

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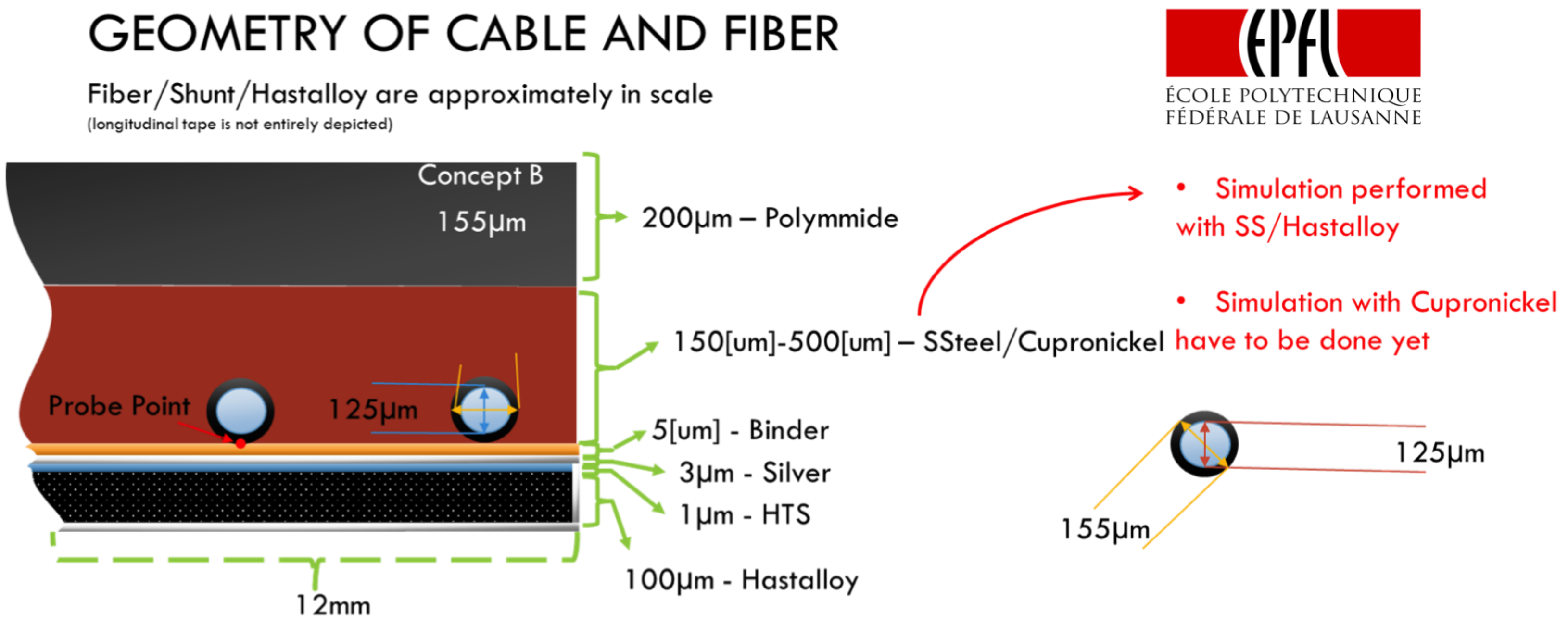
Smart module of a HVDC apparatus

- ➢ Current and voltage in the range of 0.5/1 kA and 30/50 kV
- ➢ New functionality such as quench detection through optical fiber
- ➢ Extensive testing of the module in relevant operating conditions



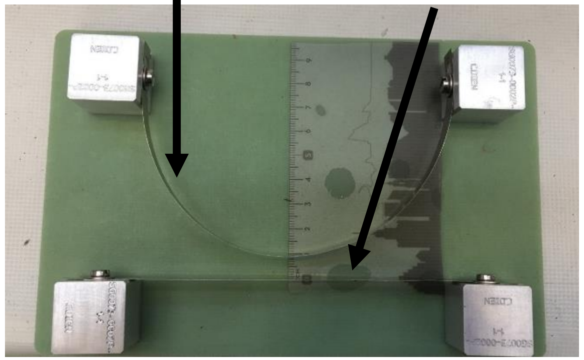
- Preliminary Electro-thermal simulations on HTS tapes, show the feasibility of a system which can detect quickly and with good spatial resolution.
- Further investigations with Optical Fiber implementation in the model
  - ➢ Mesh issues and computational time.
- Study of feasibility for the integration
  - ➢ Which is the shunt? Which is the geometry? Is it feasible integrate a fiber in the shunt?
- Test samples with Optical Fiber integrated

- Two studies are undergoing to validate the FCL design with pancake

Voltage breakdown

Positive Electrode 4-50 kV

Ground



Imposition of High voltage in DC in LN2 with or without bubbles

CNRS G2Elab Grenoble Génie Electrique Grenoble Electrical Engineering

SuperGrid Institute

Dielectric studies of liquid Nitrogen at 77 K, 65 K with or whitout pressure
Impact on a Superconducting FCL

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THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION HORIZON 2020

High-speed thermal imaging of quench propagation in HTS tapes using temperature-sensitive fluorescent films

Karlsruher Institut für Technologie

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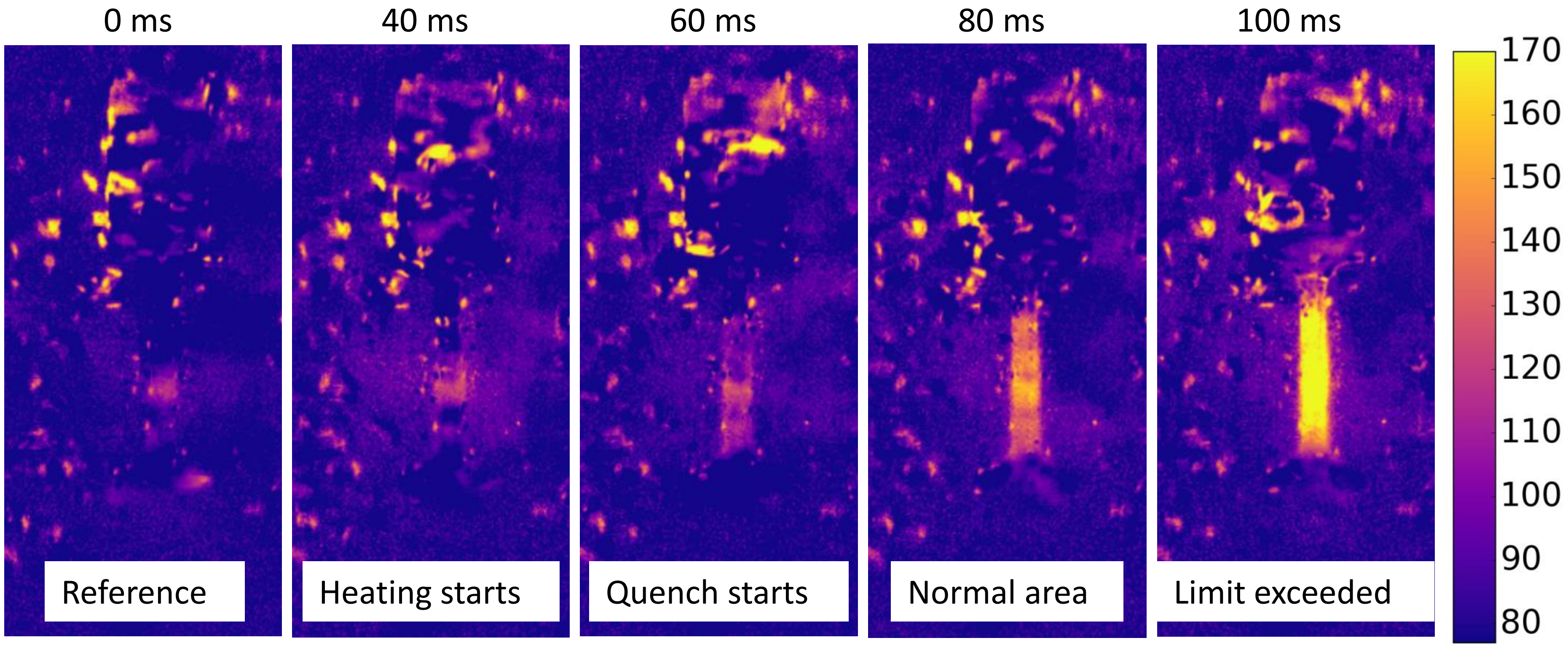

Conclusions

H2020 FASTGRID project started January 1st 2017 with objective to reduce the cost of the REBCO tapes

- High I_c tapes & operation at 65 K (1000 A/cm-w)
  - Hot spot issue to be carefully studied
- High Electric field under limitation (> 100 V/m)
  - High I_c homogeneity (5 % already reached by THEVA)
  - Enhancement of NZPV
    - Current flow diverter (realization through Ink Jet Printing)
- New route: sapphire substrate based tapes
  - Successful short tapes
- 50 kV – 1 kA module
  - Quench detection and temperature through fiber glass
  - Works on electric insulation & winding configurations
- New investigation tools
  - High-speed thermal imaging using temperature-sensitive fluorescent films

Thank you !

http://fastgrid-h2020.eu