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Computing Implementation of stabilized HTS tape Model based on distribution of currents between the tape layers

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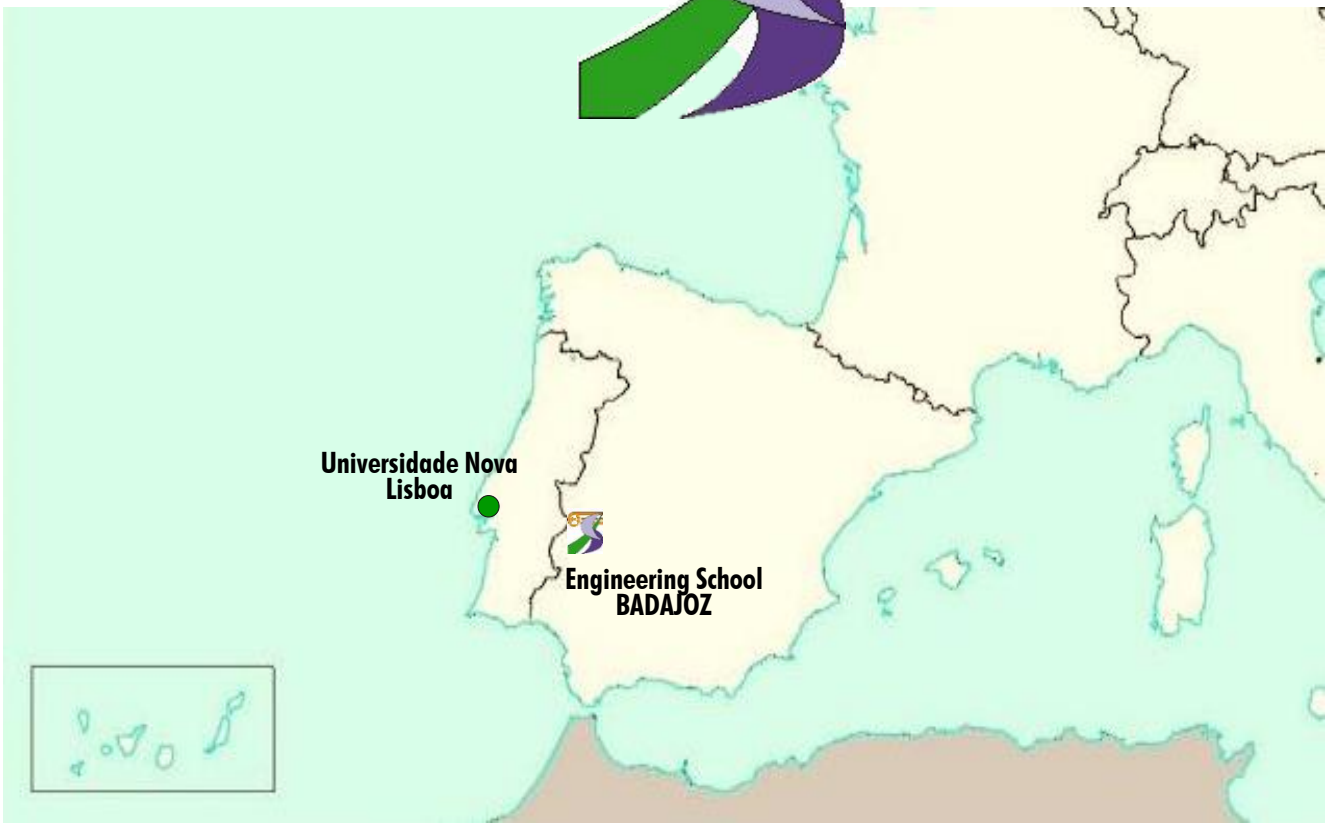

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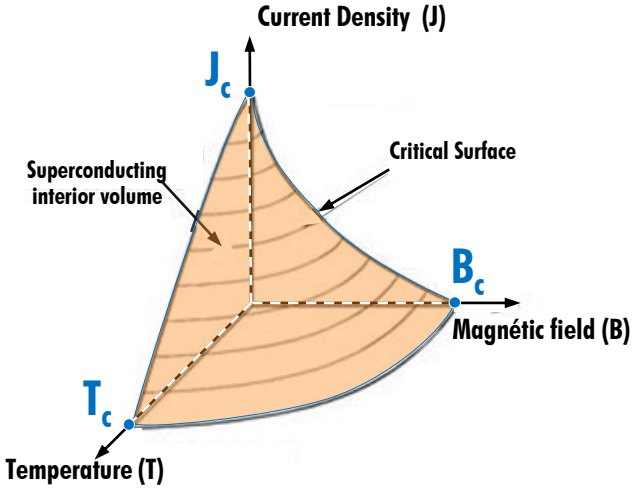
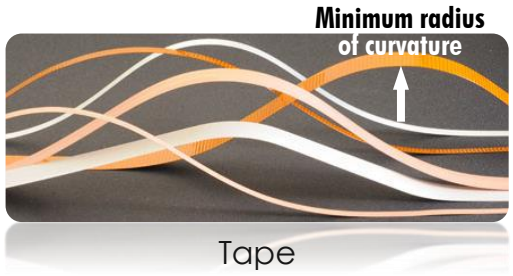
The problem of superconducting elements to be modeled is the nonlinearity of their response, due to the nonlinearity of the superconductor which the elements are made of.





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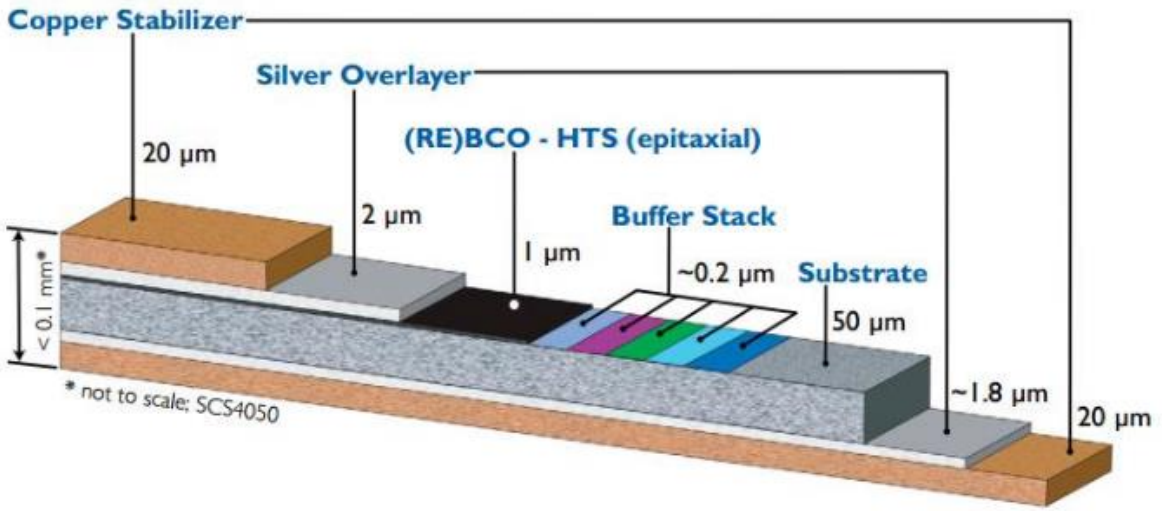
Hypothesis for an Engineering model of the superconducting tape

1. Current peak values, *Ip*, can exceed the critical current *Ic*.
2. The excess current over *Ic* flows through the stabilizing layers.
3. The superconducting layer maintains the current at its critical value.
4. When *Ip* < *Ic*, the whole current flows through the superconducting layer.



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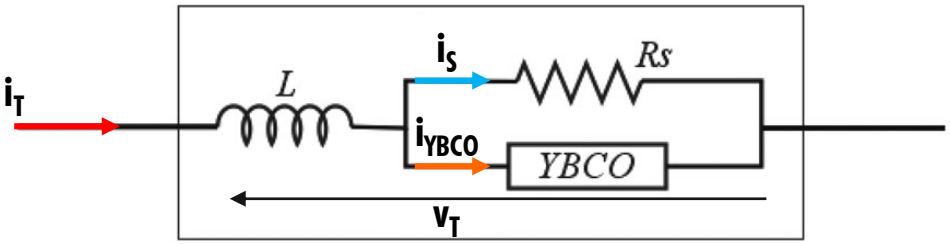
Engineering model of the superconducting tape



Equivalent circuit for the proposed hypothesis

i_T : Whole current in the tape

i_{YBCO} : Superconducting layer current

i_S : Resistive stabilizer layer current

$$i_T = i_{YBCO} + i_S$$

$$v_T = i_S R_S + L\,(di/dt)$$

$$i_S R_S = v_{YBCO}(i_{YBCO})$$

R_S L I_c n

Parameters of the tape

Non-linear part of the model

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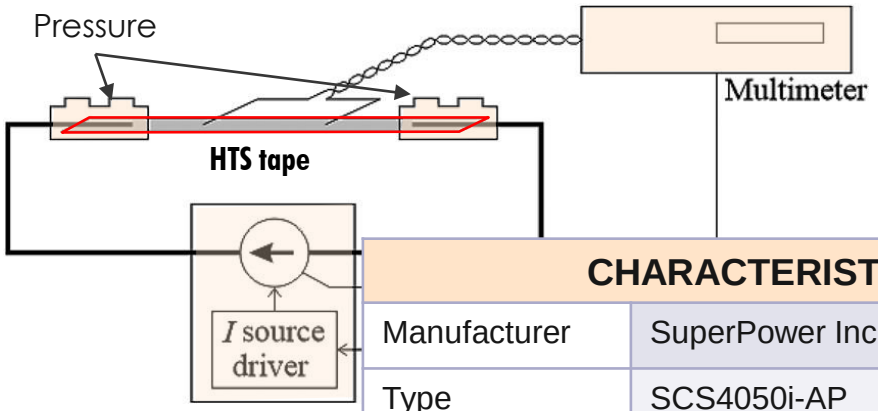
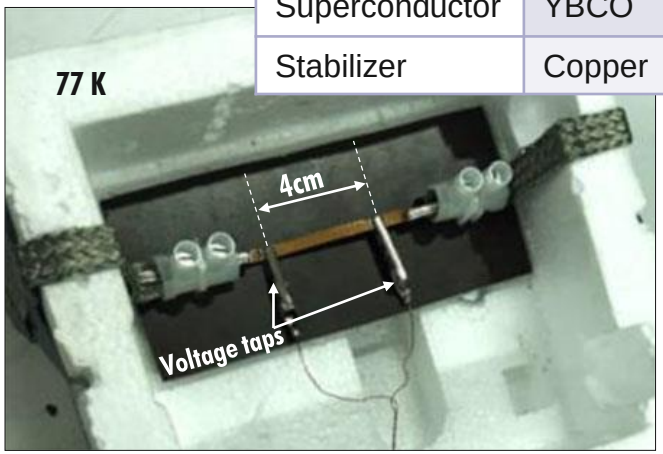
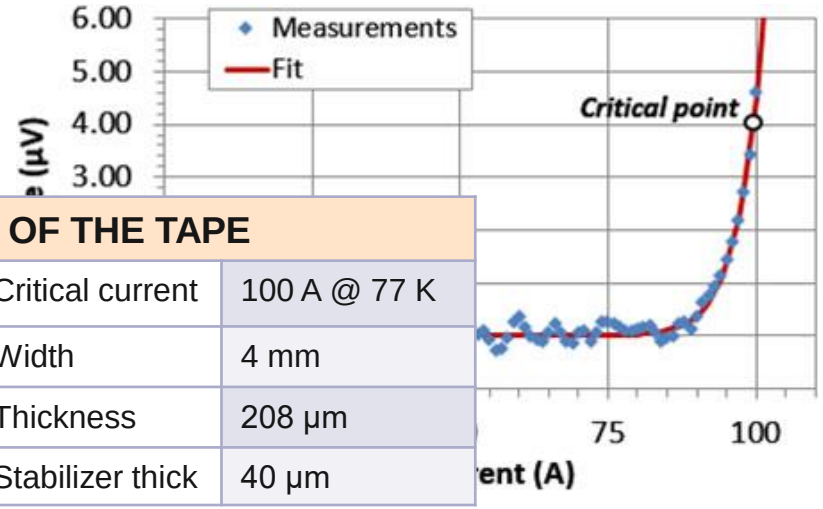
Experimental tests





A. DC Characteristic

$I_c = 99.5A \quad n = 23.5$



CHARACTERISTICS OF THE TAPE			
Manufacturer	SuperPower Inc.	Critical current	100 A @ 77 K
Type	SCS4050i-AP	Width	4 mm
Superconductor	YBCO	Thickness	208 μm
Stabilizer	Copper	Stabilizer thick	40 μm

$$V = V_c \left(\frac{I}{I_c} \right)^n$$

V : Voltage in the tape
I : Current in the tape
I_c : Critical current

V_c : Criteria for critical current $(1\mu V / cm)$

$$V_c = 4\mu V$$

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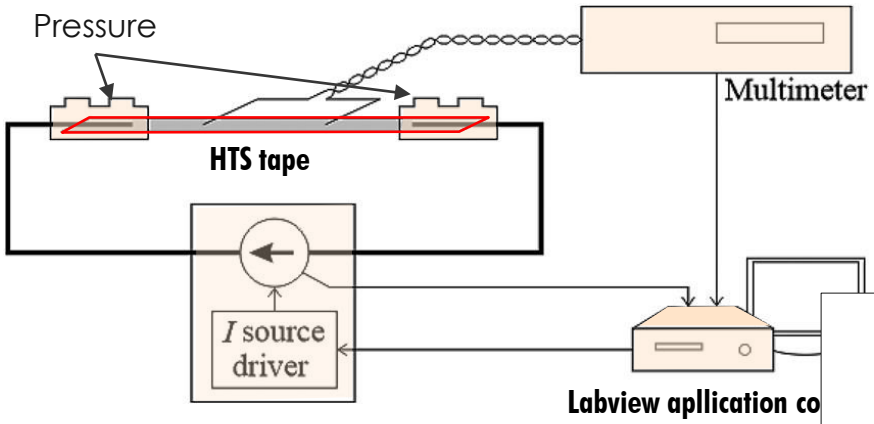
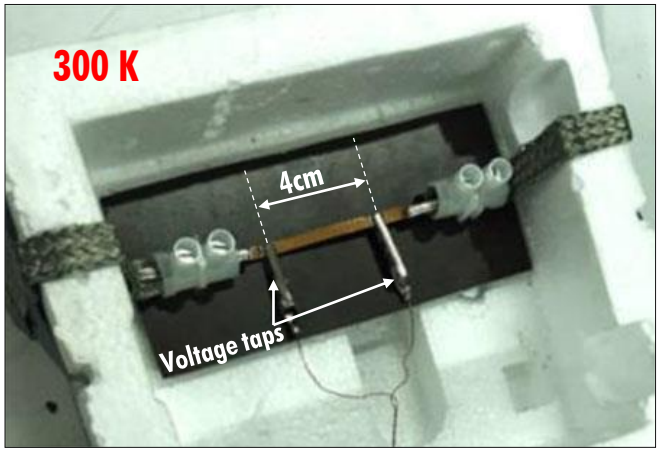
Experimental tests





B. Stabilizer Resistance

Copper layer

$$R_S(77K) = R_S(300K)\left[1+\alpha(77-300)\right]$$

α : Copper temperature coefficient of resistance (typically equal to $0.0039\,K^{-1}$)

Rest of the non-superconducting layers in the tape can be neglected

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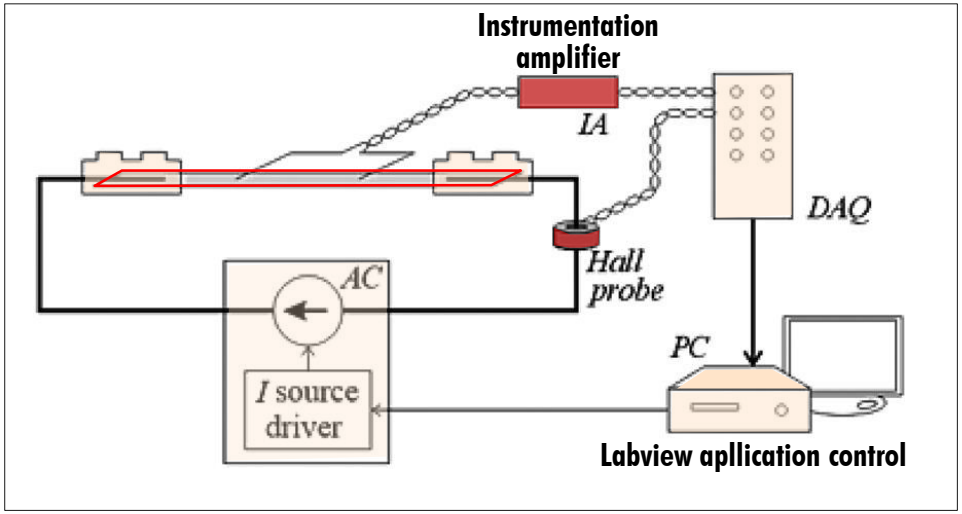
Experimental tests



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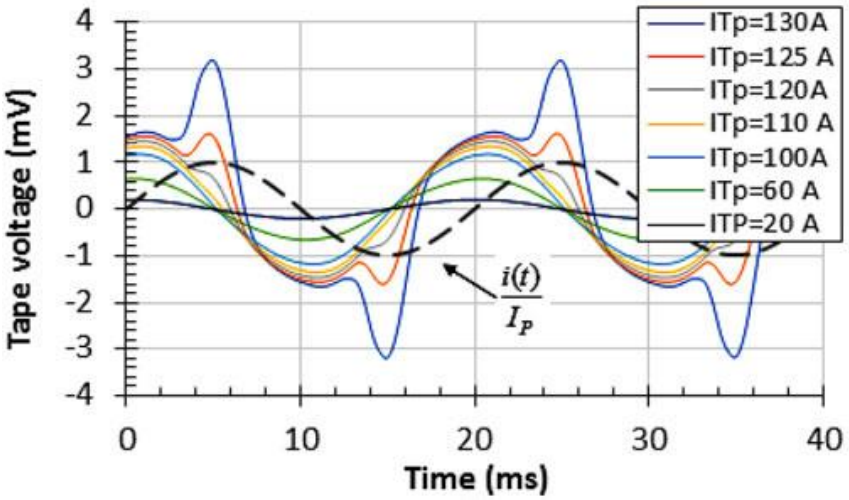
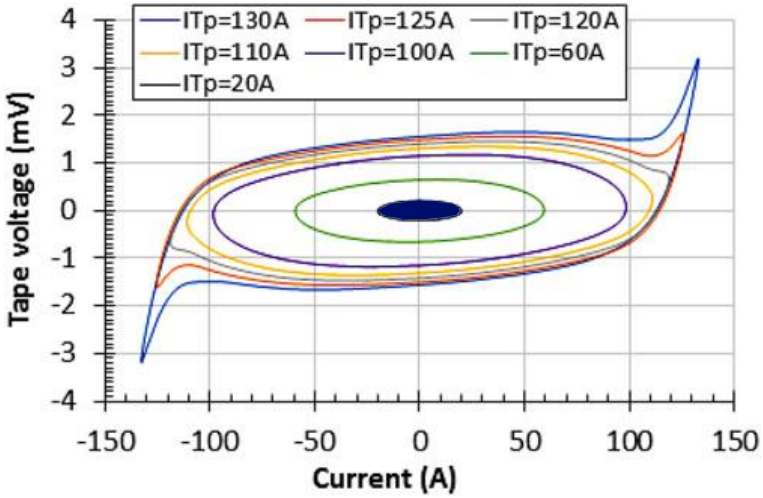
Experimental tests

C. AC Characteristic

i-v characteristics of the tape, transporting 50 Hz sinusoidal current with amplitude increasing from 20 A-peak to 130 A-peak.





D. Induction Coefficient

$$L = \frac{1}{2\pi f}\left(\frac{V_p}{I_p}\right)$$

$$L = 3.28 \cdot 10^{-8}\, H$$

$$L = 8.21 \cdot 10^{-7}\, H/m$$

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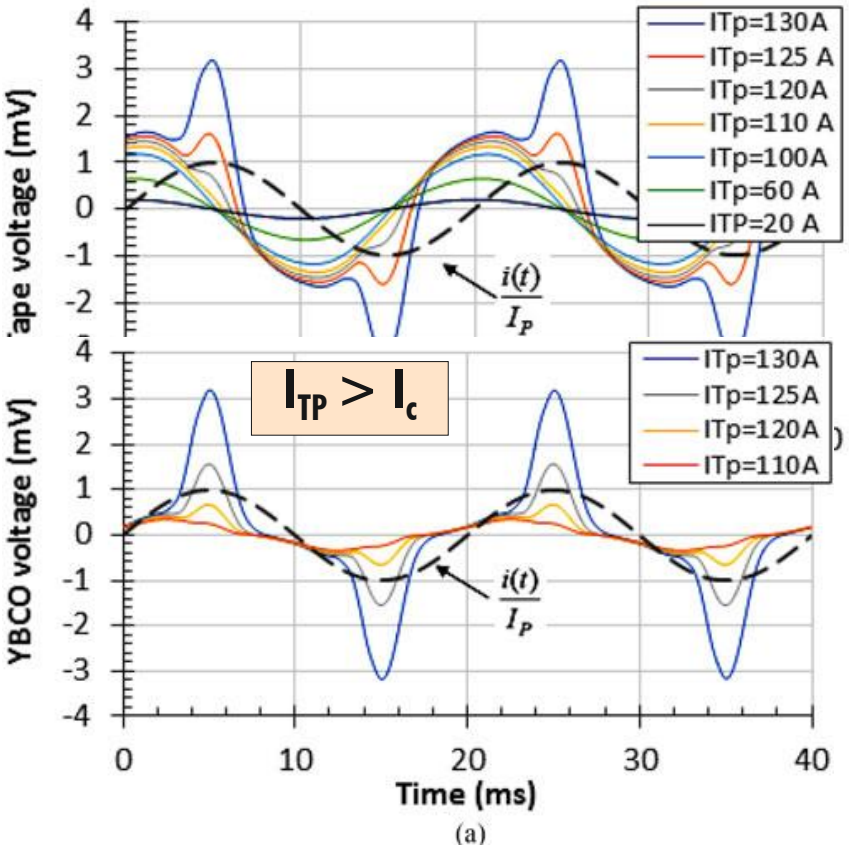
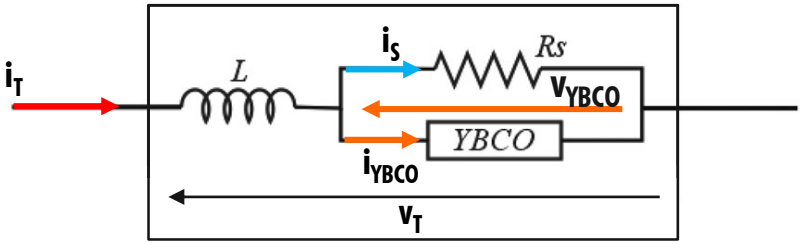
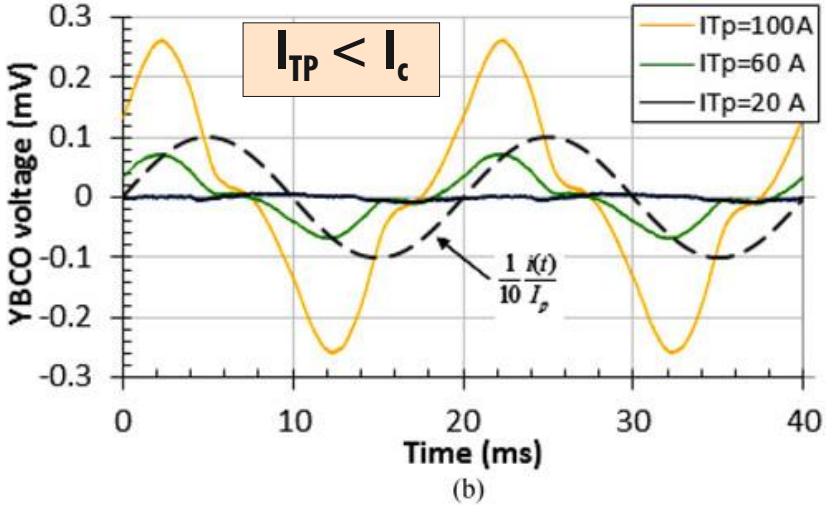
Model

D. Superconductor Nonlinear Drop Voltage





$$v_{YBCO} = v_T - L\,(di/dt)$$



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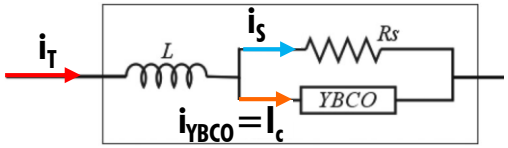
Model

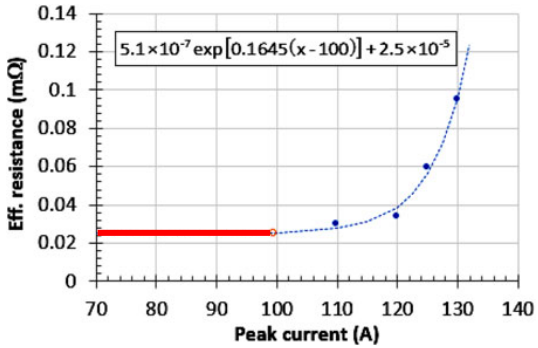
E. Stabilizer Layer Current

Effective resistance R_S

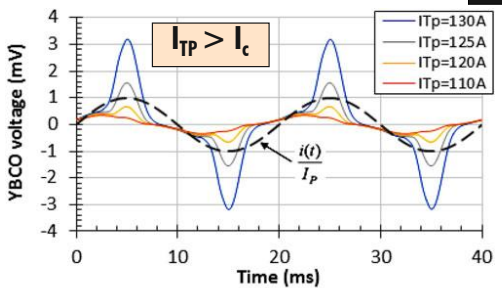
$I_{TP} > I_c$

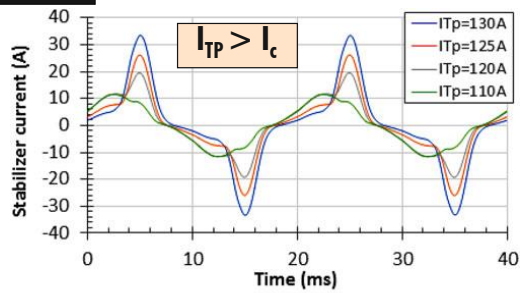
$$|i_S| = |i_T(t)| - Ic > 0$$





In phase





$$R_S = V_{YBCOp}/I_{Sp}$$

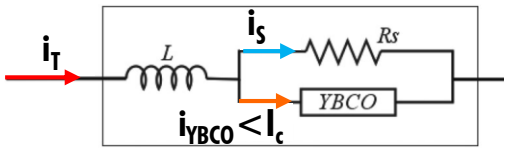
$$I_{Sp} = I_{Tp} - Ic$$

CHARACTERISTICS OF THE STABILIZER LAYER					
Reference quantity	130 A	125 A	120 A	110 A	$I_{Tp} \le Ic$
Excess current (A)	33.4	26.2	19.6	11.6	~0
Peak voltage (mV)	3.19	1.57	0.67	0.34	—
Eff. resistance (μΩ)	95.2	59.7	34.1	29.6	25.0

$I_{TP} < I_c$

i_S just the necessary for verifying

$$i_S R_S = v_{YBCO}$$



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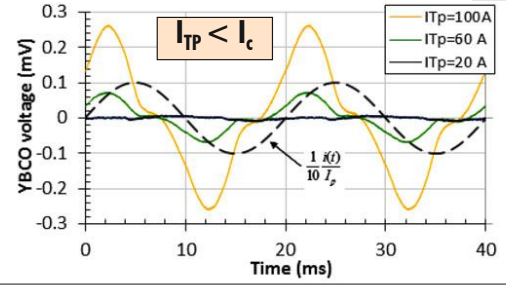

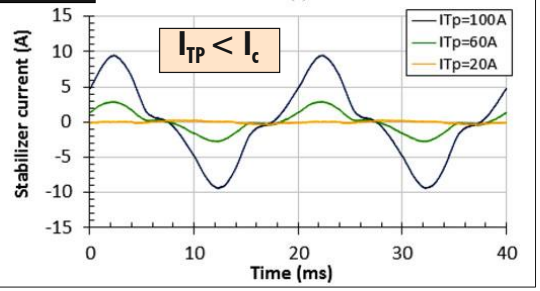

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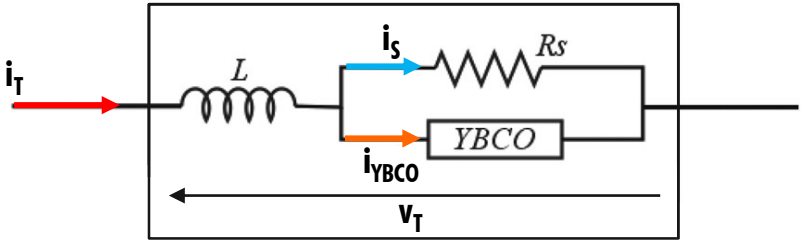
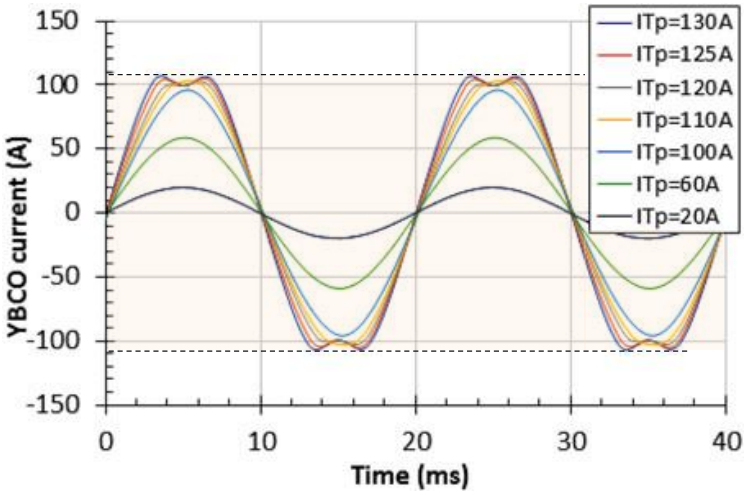
Model

G. YBCO Layer Current



Equivalent circuit for the proposed hypothesis

$$i_{YBCO} = i_T - i_S$$



Sinusoidal current in the tape is Somehow limited in the YBCO layer at the critical current value

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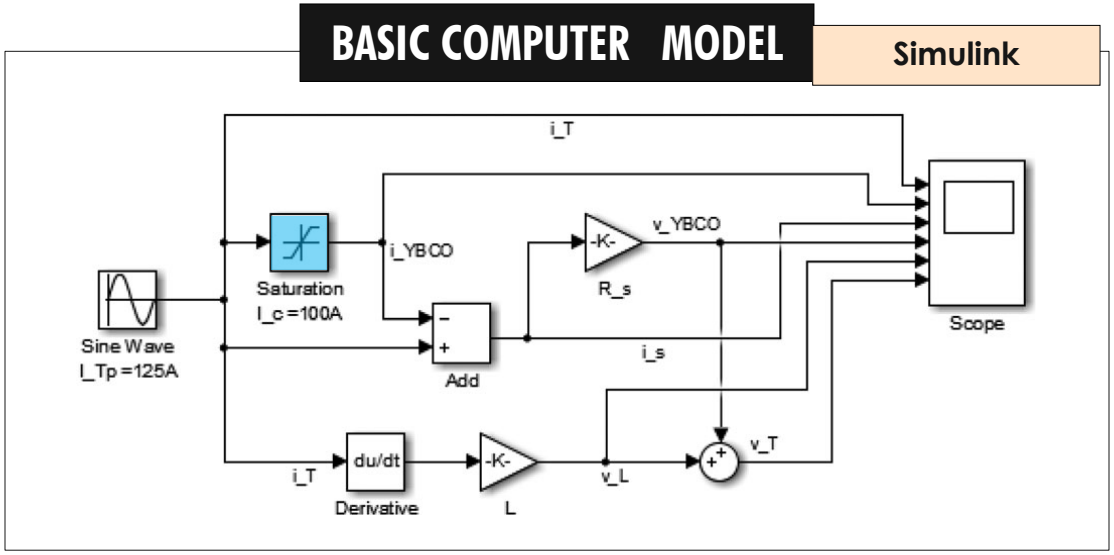
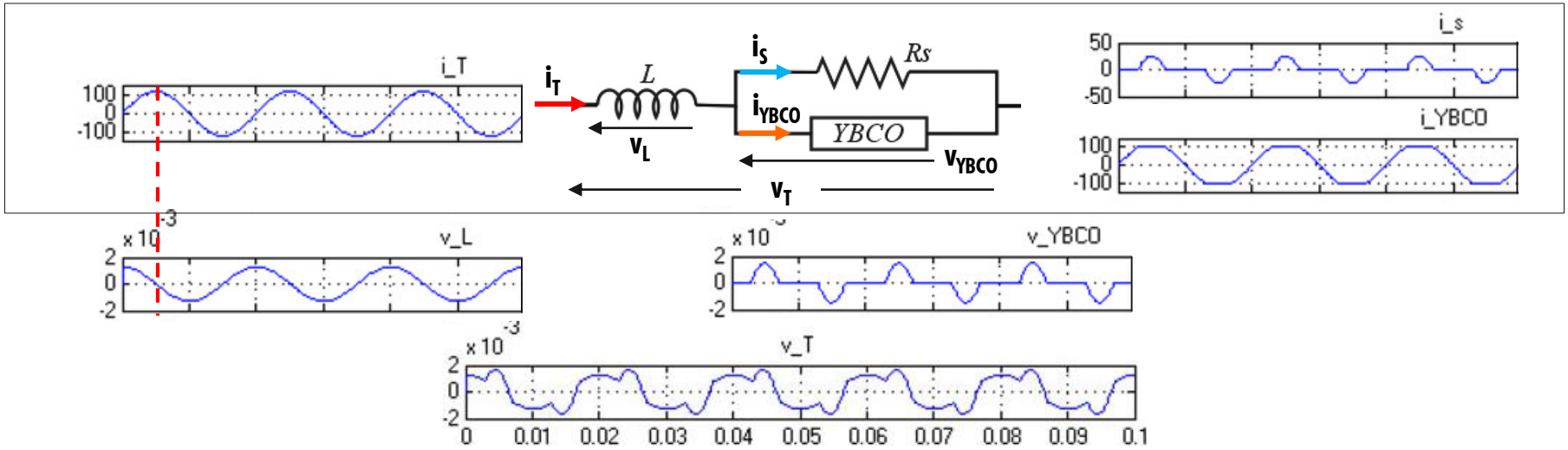
BASIC COMPUTER MODEL

Simulink





Conclusions

An engineering model of a superconducting tape can be done from simple experimental parameters

A more deep study of the stabilizer resistance is carried out.

The study of the thermal behavior for transition is needed.

The study of the external magnetic field for complex element is needed.

Thank you for your attention

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