

Determination of the n-Value of 2G HTS Tapes using a thermally stabilized fast pulsed system

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Abstract

The n -value in the Power Law expression defines the transition's slope from the superconducting regimes (Flux Creep and Flux Flow) to normal state. In other words, it indicates the sharpness of the resistive transition. Overall, the n -value is a crucial parameter for numeric simulations of superconducting tapes such as Superconducting Fault Current Limiters (SFCL), coils and other practical applications involving the Power Law expression. This study proposes a conduction-cooling technique to extend data acquisition in $V - I$ curves to reach Flux Flow information in 2G HTS tape samples without their destruction or degradation.

Objectives

- Built a thermally anchored sample holder to refrigerate 2G tape samples with conduction-cooling;
- Obtain the $V - I$ curves for values of electric field way beyond E_c and reach Flux Flow regime;
- Analyze the logarithmic $V - I$ data to determine the n -value behavior in flux creep to flux flow transition;

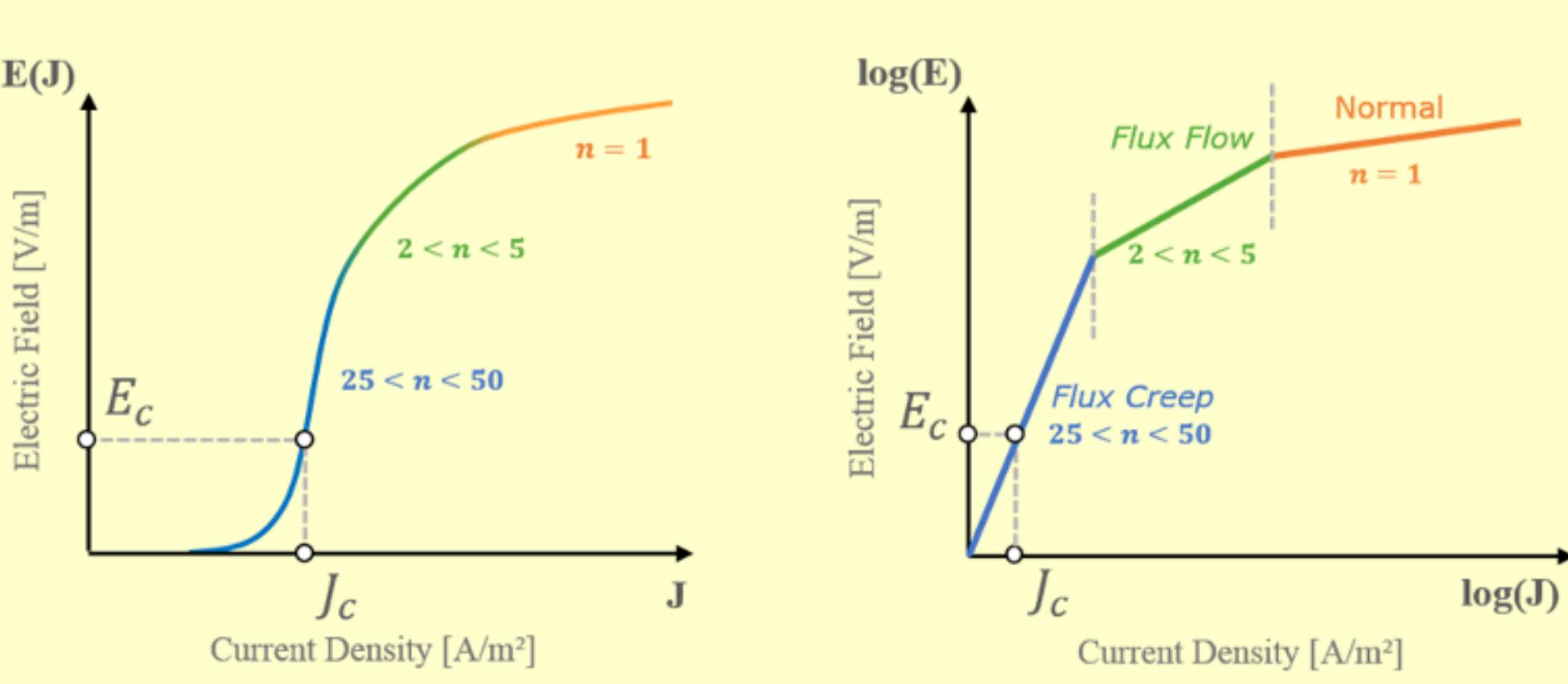
Motivation

Information of n -value reaching Normal and Flux Flow regime are much more common for HTS bulks. However, most n -value characterization studies for 2G HTS tapes are restricted to the Flux Creep regime due to Joule heating damaging effects in high current density/electrical field exposure under liquid nitrogen (LN_2) bath refrigeration. Normally, $E - J$ reliable data are given by the $V - I$ curves taken from different experimental methods. Most attempts to expose 2G tapes samples to high E values without damages have been focusing in narrowing the current pulse width to reduce heat dissipation, degradation and possible destruction.

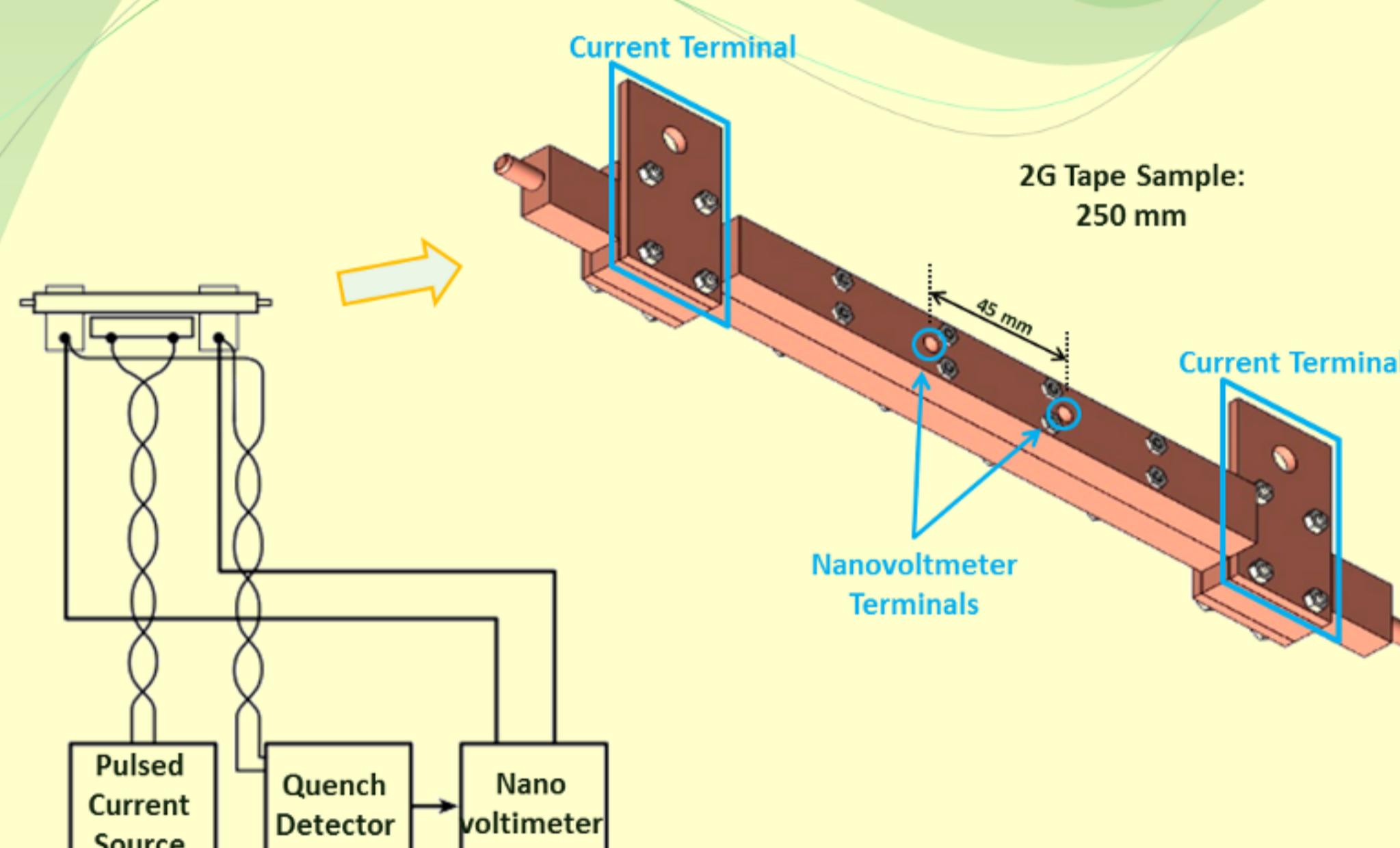
In such context, this paper proposes a simpler technique to extend data acquisition in $V - I$ curves. Instead of reducing the Joule heating through extreme narrow current pulses we improve the sample-holder in a way to allow heating to be extracted via conduction cooling, reducing the need of ultra-fast current pulses. This allows better resolution on data acquisition and more reliable results. With this approach it is possible to stabilize the temperature of different coated conductors and reach values of E hundreds of thousands of times E_c in $V - I$ characterization curves. Then the n exponent can then be calculated by a simple linear interpolation of the power law in its logarithmic form:

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

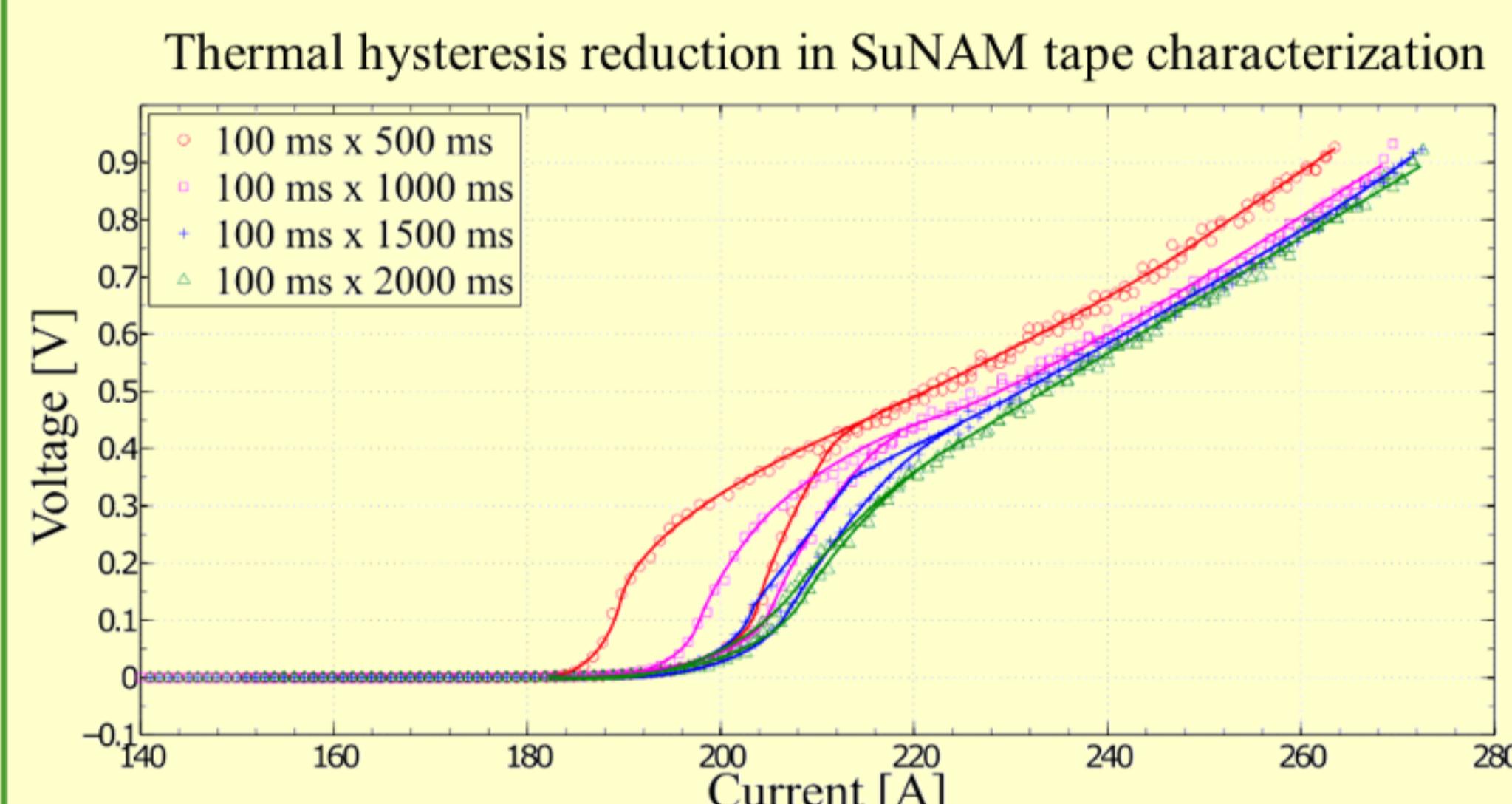
$$\log\left(\frac{V}{V_c}\right) = n \log\left(\frac{I}{I_c}\right) \therefore y = n x$$



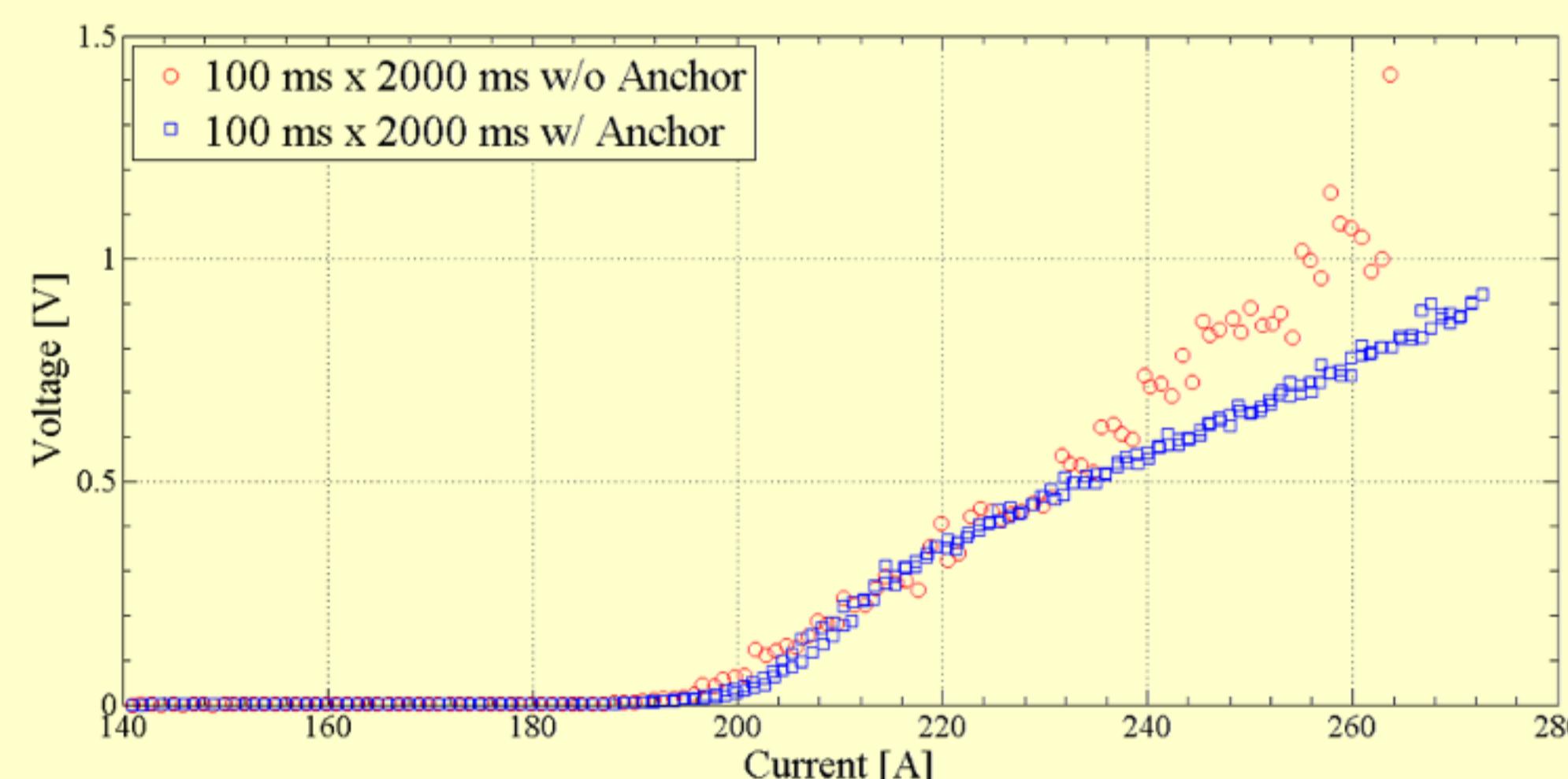
Sample Holder and Pulsed Current Measurement System



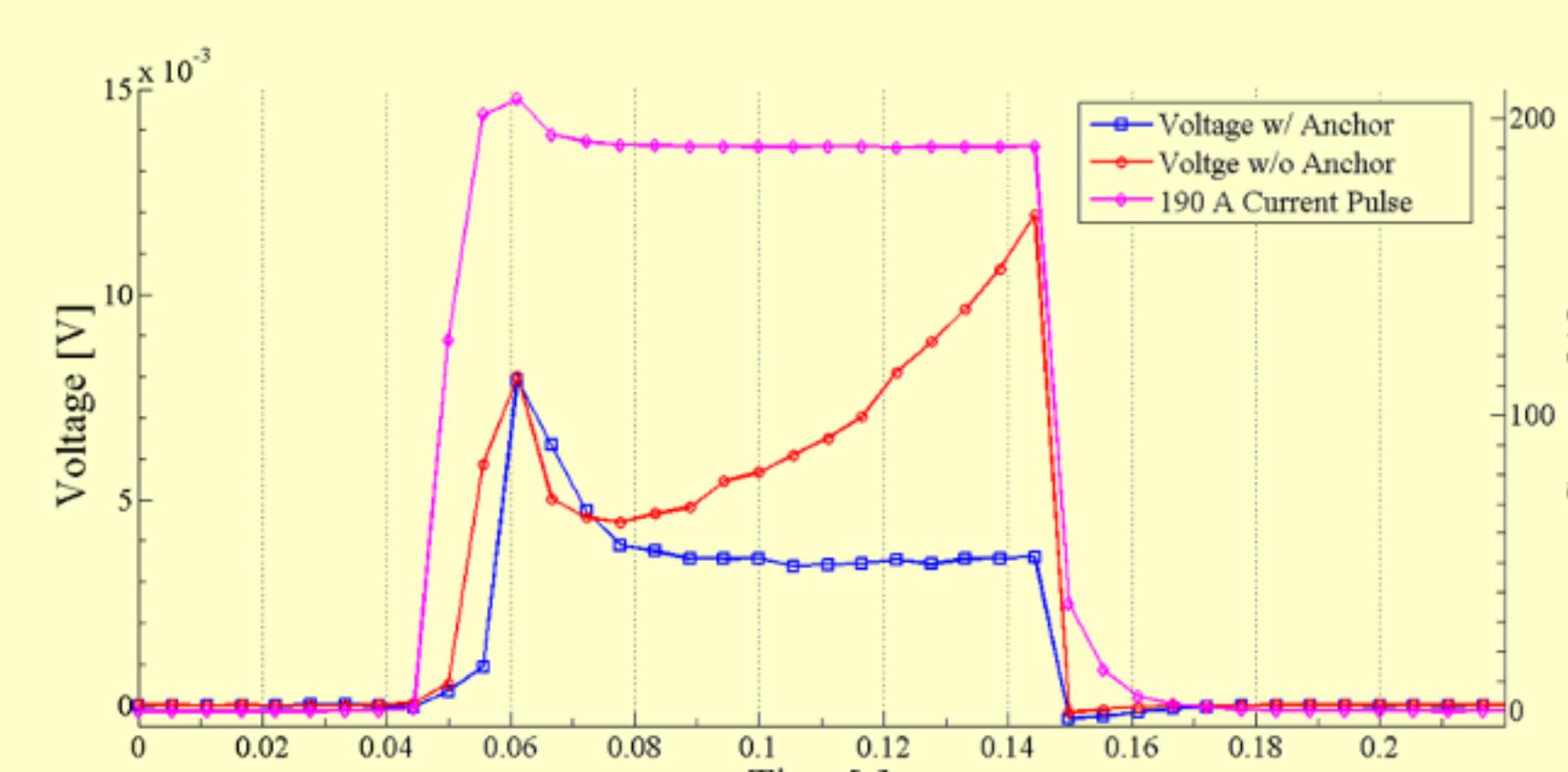
Characterization



Comparison between SuNAM V-I curves taken with the thermal anchor sample holder and direct liquid nitrogen bath.



Comparison between SuNAM V-T curve during a 190 A, 100 ms current pulse with Thermal anchor and LN_2 bath.

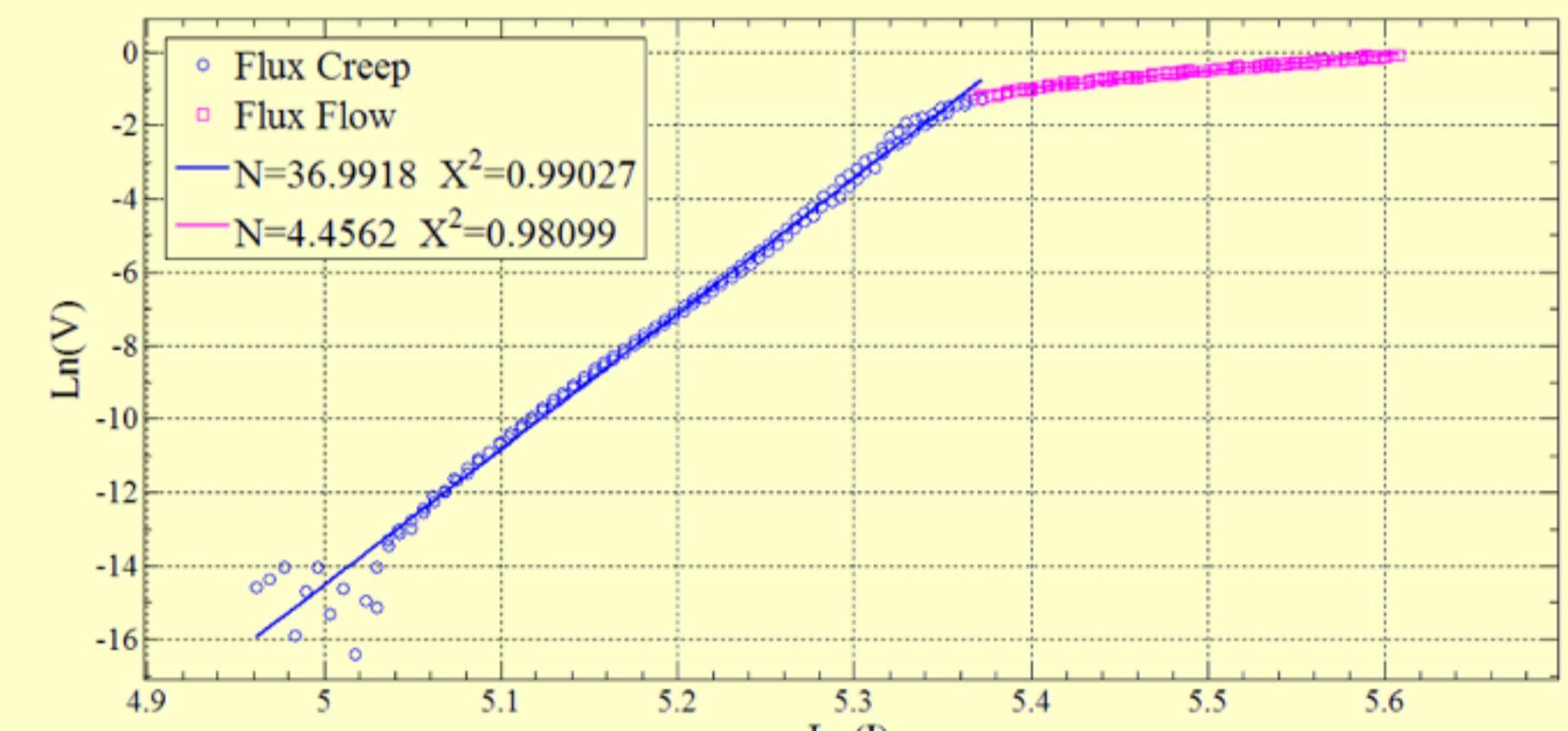


Results

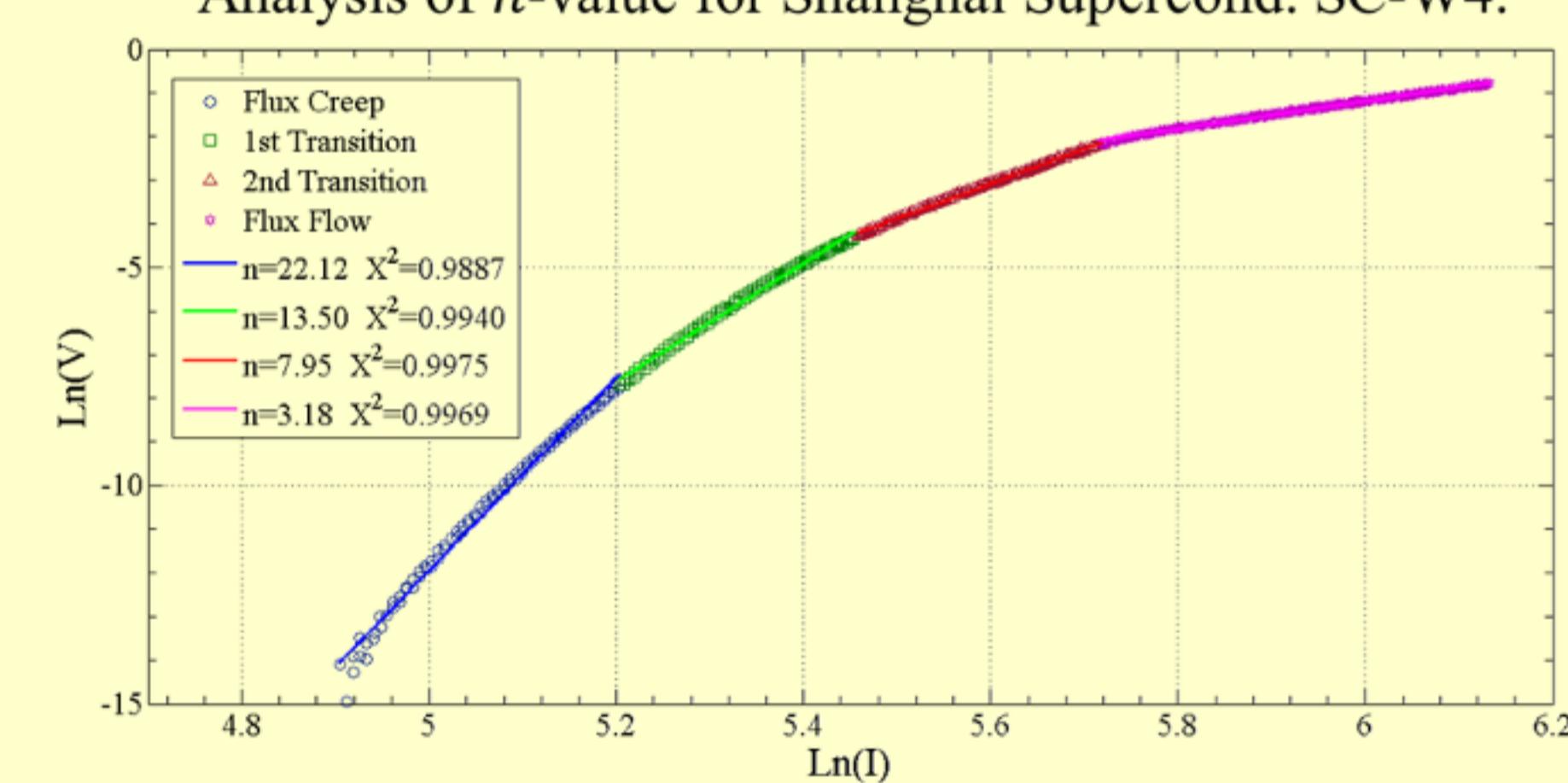
Table with the 2G tape's construction details.

Specs	SuNam	Shangui	Super Power
Model	HCK04150	SC-W4	SCS4050-API
Substrate	60 μm C276	60 μm C276	50 μm C276
(Re)BCO	1.5 μm GdBCO	2 μm YBCO	1 μm GdBCO
Stabilizer	1.5 μm Ag	1.5 μm Ag	2.0 μm Ag
Shunt	$\approx 20 \mu m$ Cu	30 μm SS	1.5 μm Cu
Insulation	Polyimide	None	Polyimide
I_c	150 A	150 A	120 A

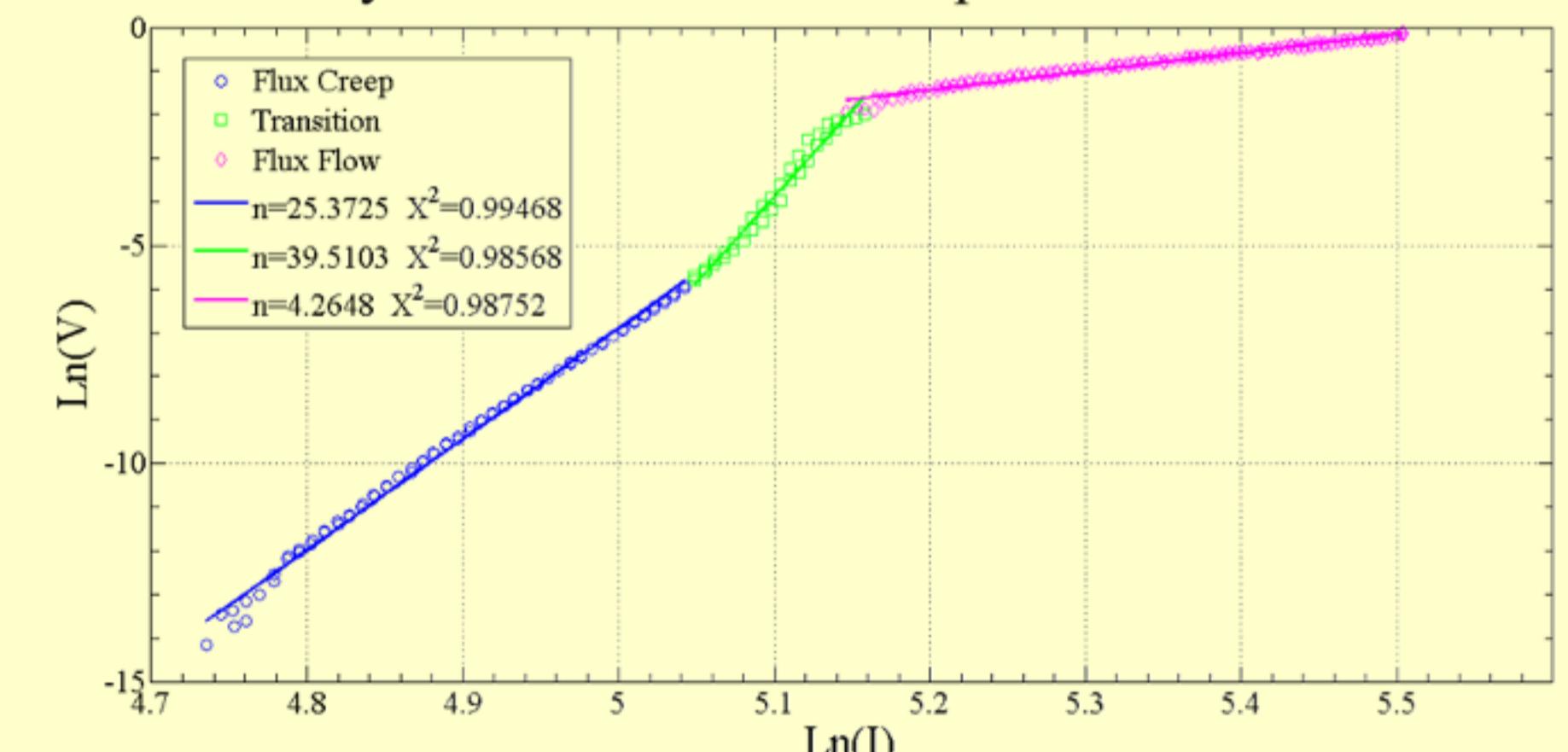
Analysis of n -value in the SuNam HCNK04150



Analysis of n -value for Shanghai Supercond. SC-W4.



Analysis of n -value in the Super Power SCS4050.



Conclusion

This study introduced a combination of thermal anchor technique with pulsed current measurement to obtain the V-I curves of 2G HTS tapes. The flux flow region ($E \gg E_c$) was reached without damaging the samples. In addition, this methodology enabled the use of relative large current pulses (100 ms) in comparison to previous works.

Moreover these results suggest the feasibility of a cryogen free conduction cooled SFCL.

Acknowledgments

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