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Bulk Superconductor and its Application for Insertion Device

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Contents

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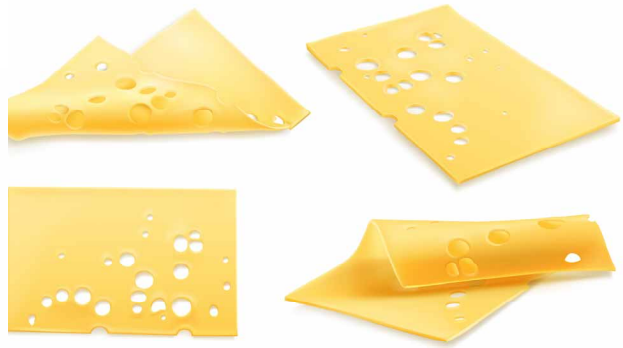
What is a bulk superconductor?

Wire/tape/film

spaghetti

tagliatelle



sliced cheese

Single Cristal

ice cube

Bulk ?

?

Bulk is something like…

"Tiny ice crystals pressed together"

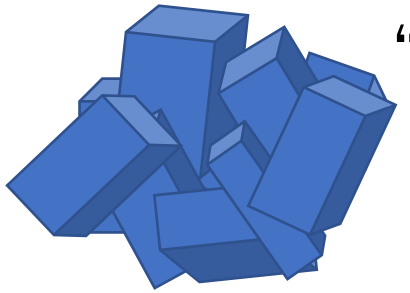
intragranular J_c
intergranular J_c of bulk superconductor

Higher intragranular J_c is better! (J_c : critical current density)

And,

should be well connected between micro-crystals.

Because …



"Superconductor weak link problem" exists.

If crystals are not well aligned, **inter J_c is limited.**

This problem typically depends on the structure of SC crystal.

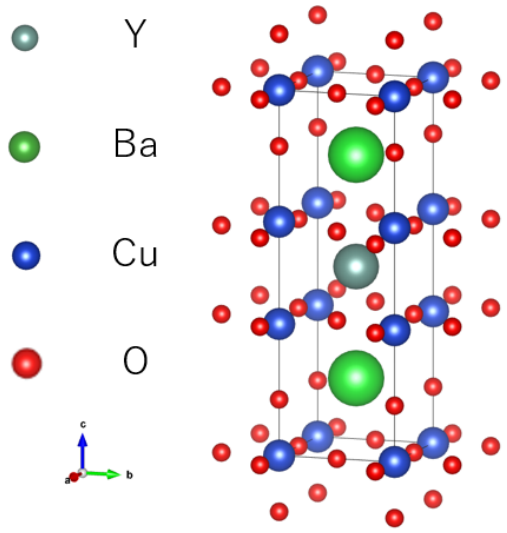
Not only material,

But also texture!

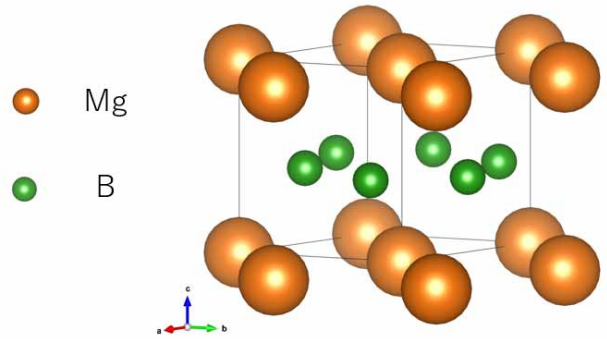
Superconductor weak link problem of different bulk superconductor

REBCO

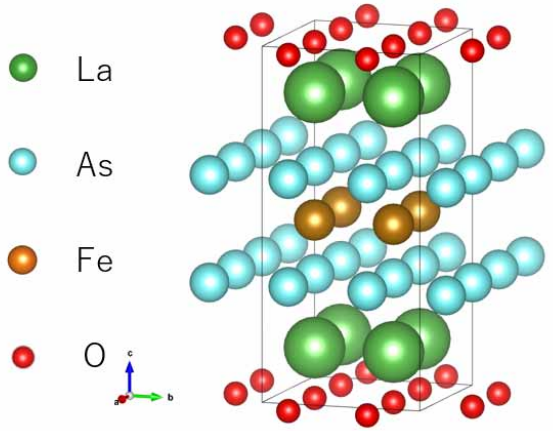
Rear earth barium cupper oxide



MgB_2



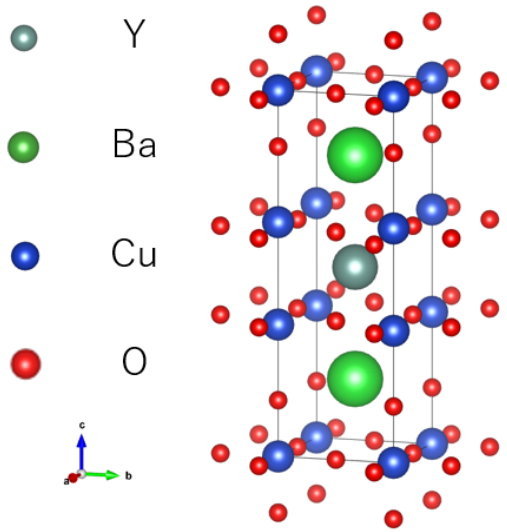
Iron Pnictide

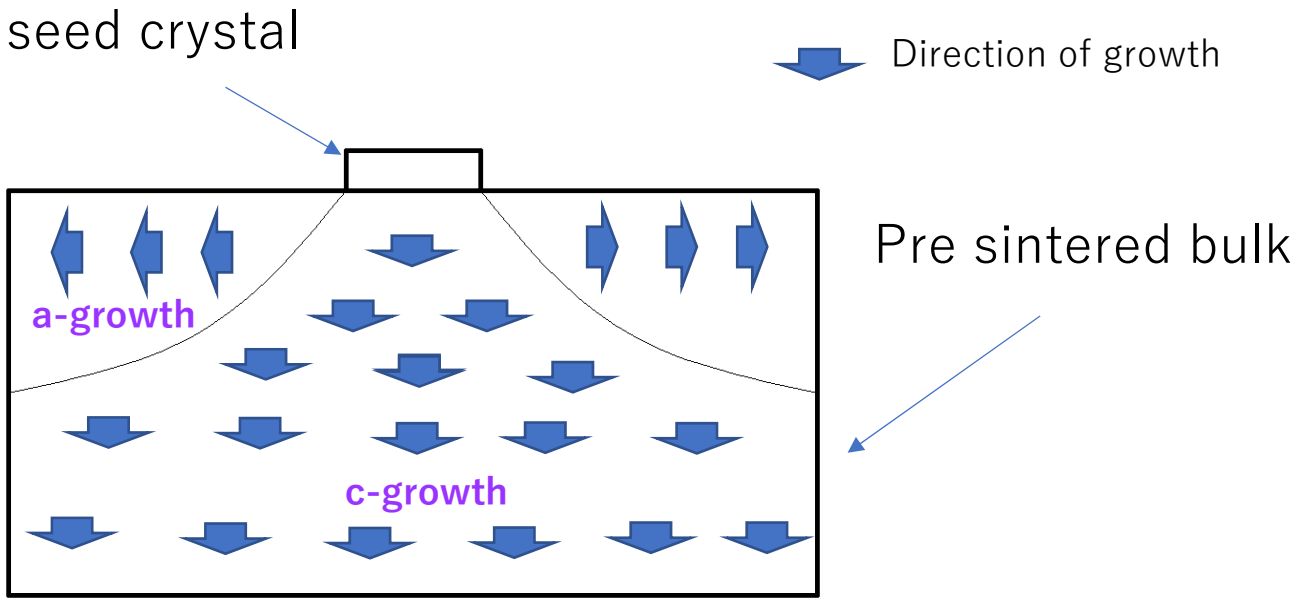


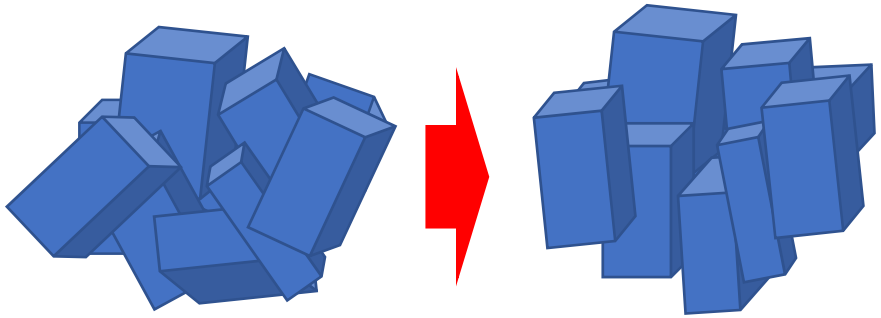
“High aspect ratio” correlates **“Weak link problem”**

Re-crystallization with seed crystal

REBCO







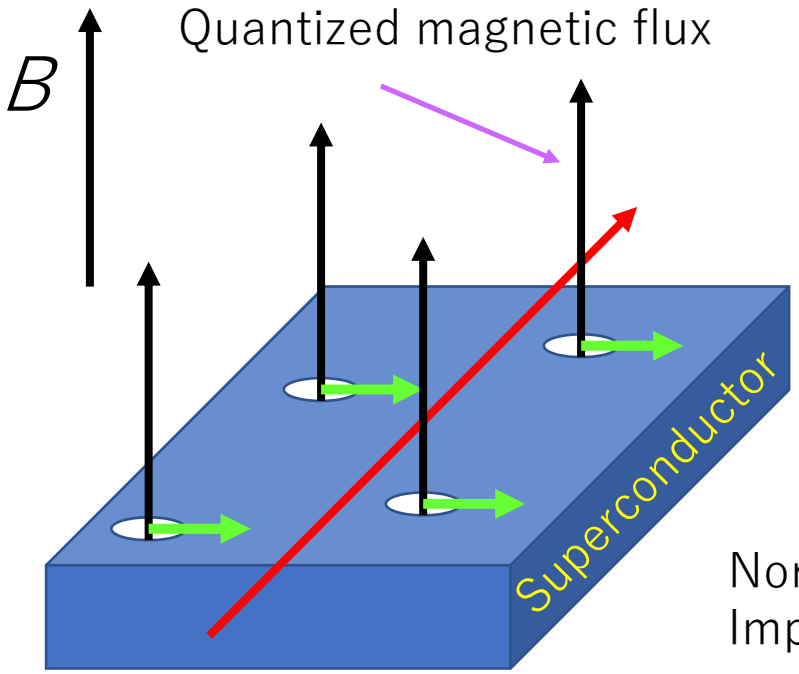
Re-arrangement of micro crystal is required!

However…
clean superconductor **is not useful.**

? ? ? ? ?

Pinning of magnetic flux in bulk superconductor

Magnetic flux flows, when current is applied!

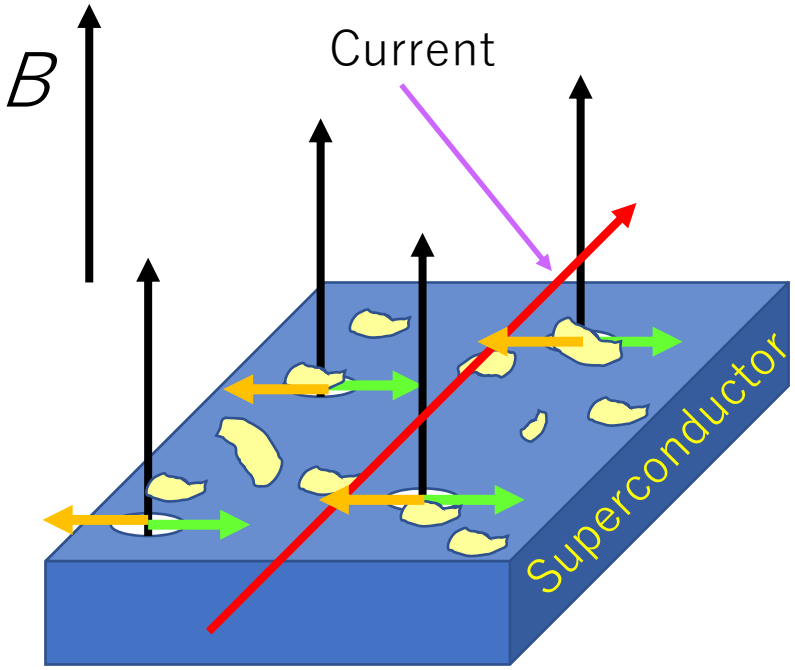


Flux flows

Lorentz force

Pinning force

Normal conducting Impurities



Flux is pinned

By adding impurity, flux is trapped in the impurity.

Impurity: “pinning center” Similar to chocolate chips in gelato!

Bulk SC for IDs

Higher inter J_c: Higher T_c is better.

Weak link problem: Re-crystallization using seed crystal
Improve intra J_c

Avoid flux flow: Introduce pinning center

Excellent reproducibility in mass production: Unsolved

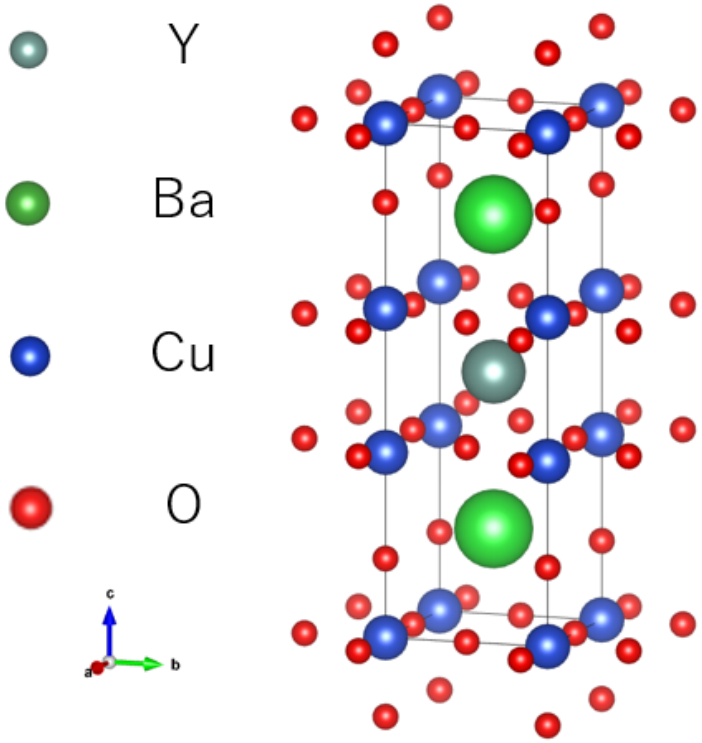
Best candidate material for IDs

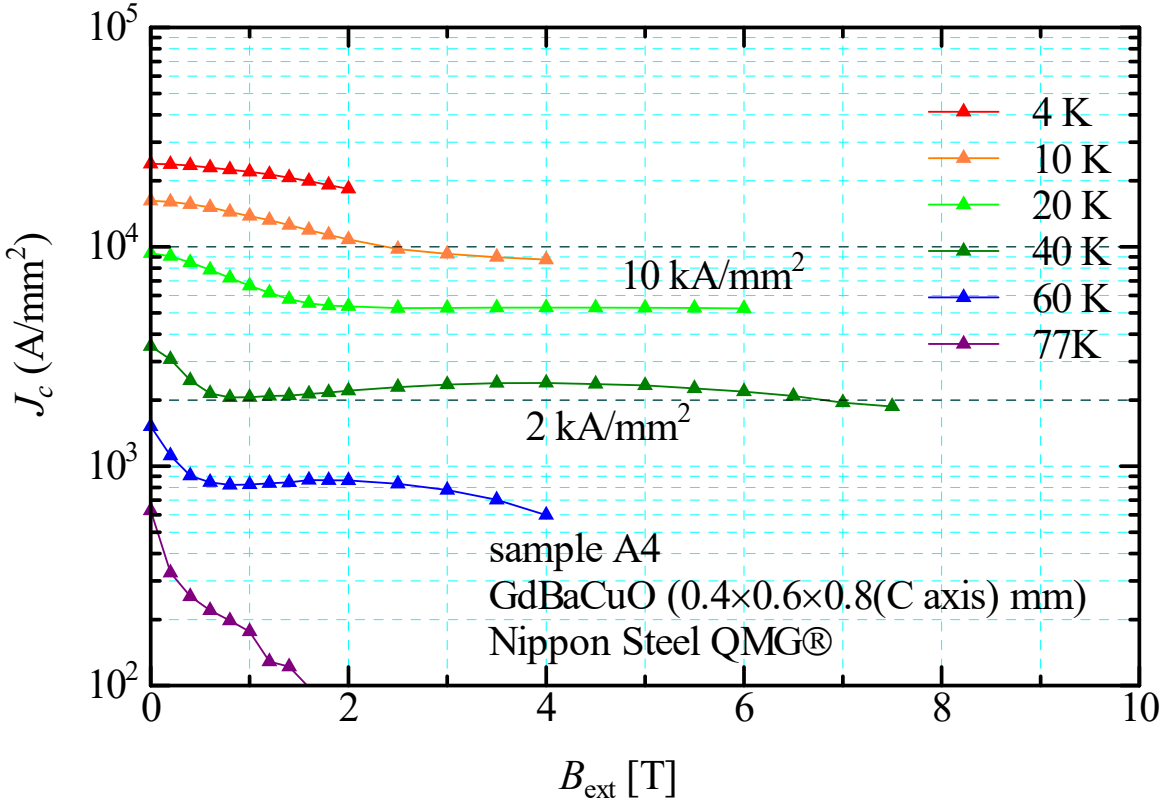
REBCO

Rear earth barium cupper oxide

$T_c \sim 90$ K

J_c : High at high B





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Lattice structure of YBCO

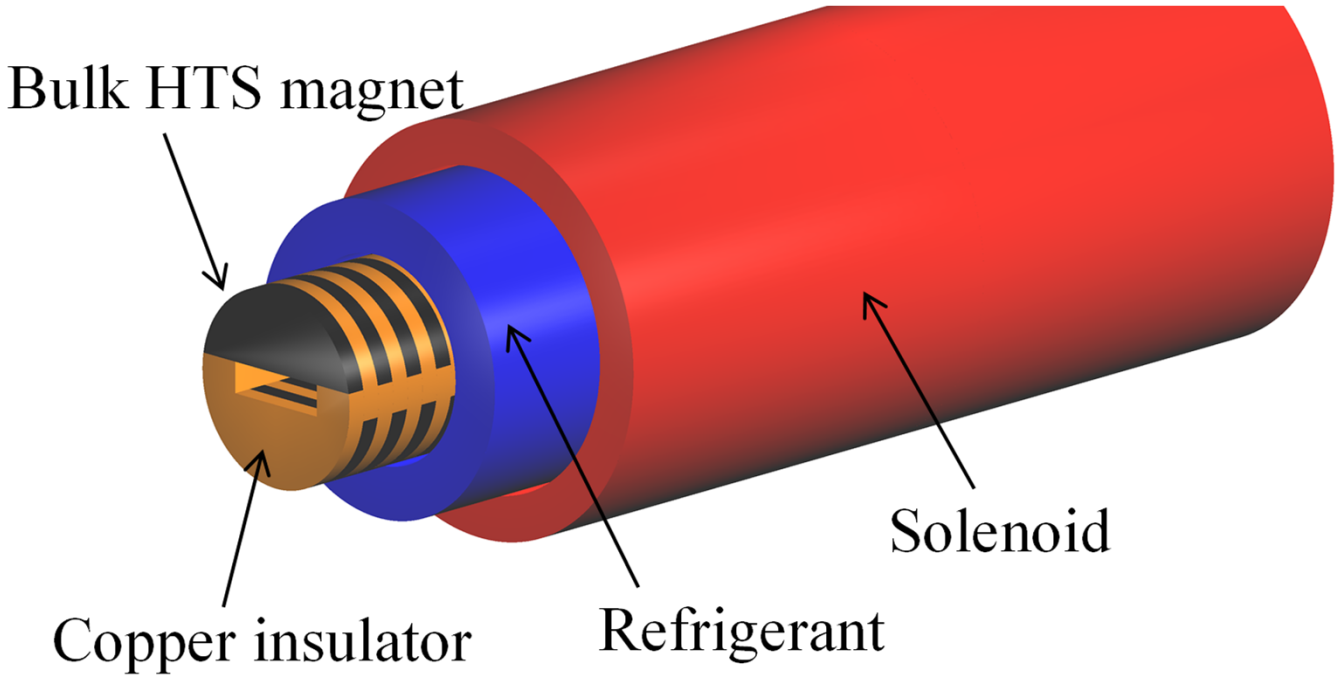
$J_c(B)$ properties of GdBaCuO

Contents

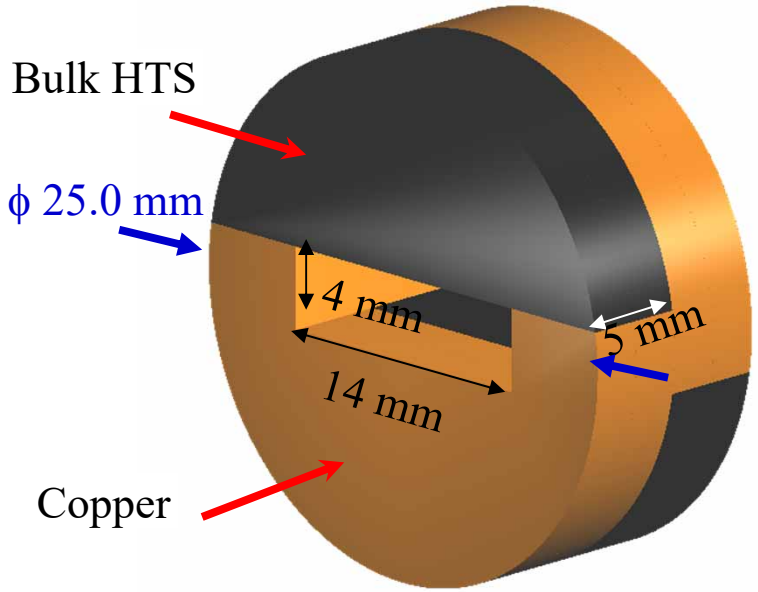
Bulk HTS SAU

We proposed new structure using bulk HTS

Bulk HTS SAU = Stacked HTS array + Solenoid



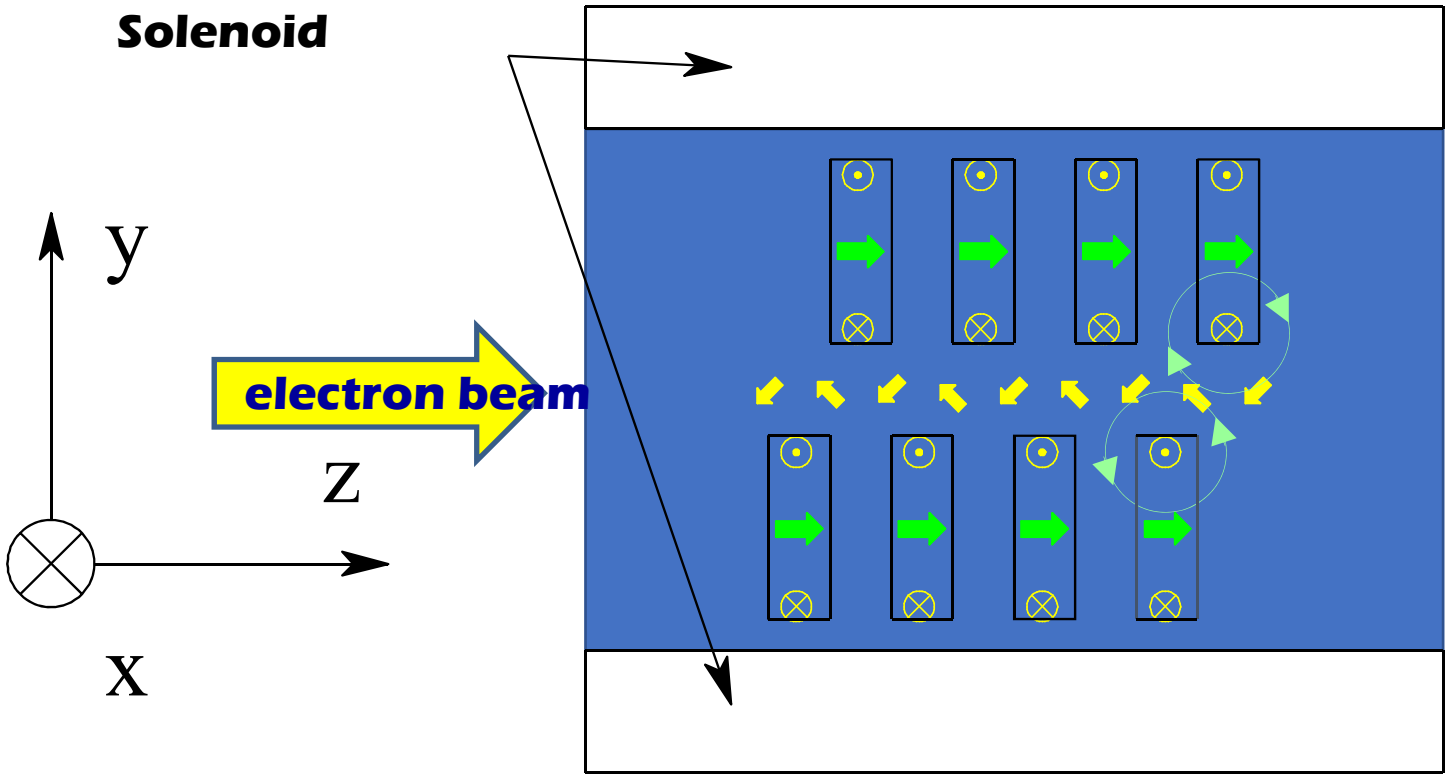
Structure of one period

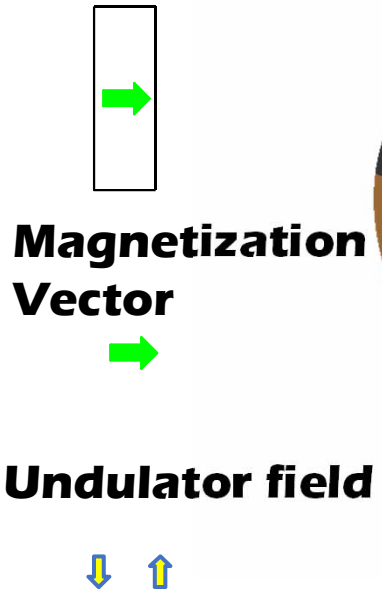


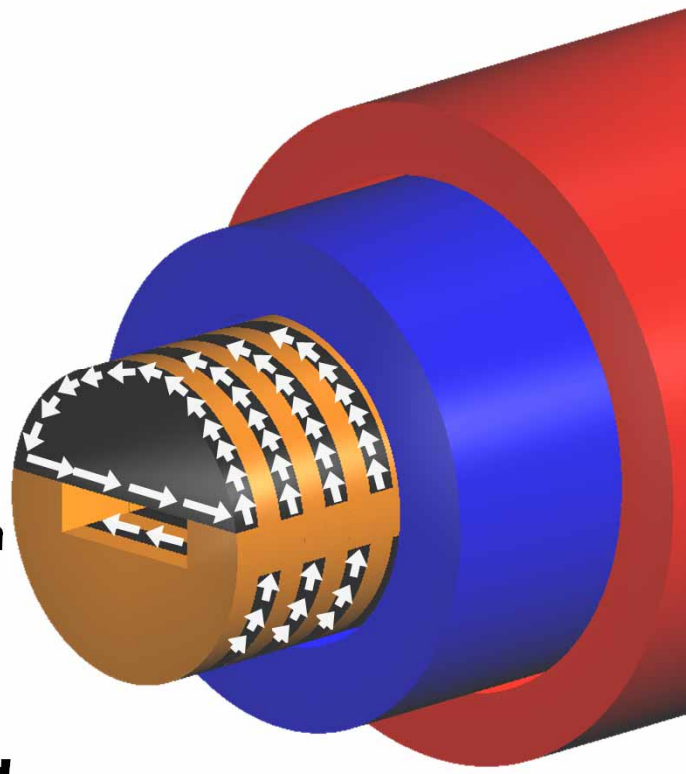
T. Kii, et al.: Proc. FEL2006 (2006) p. 653.

Principle of Periodic Field Generation

Side view of "Bulk HTS SAU"





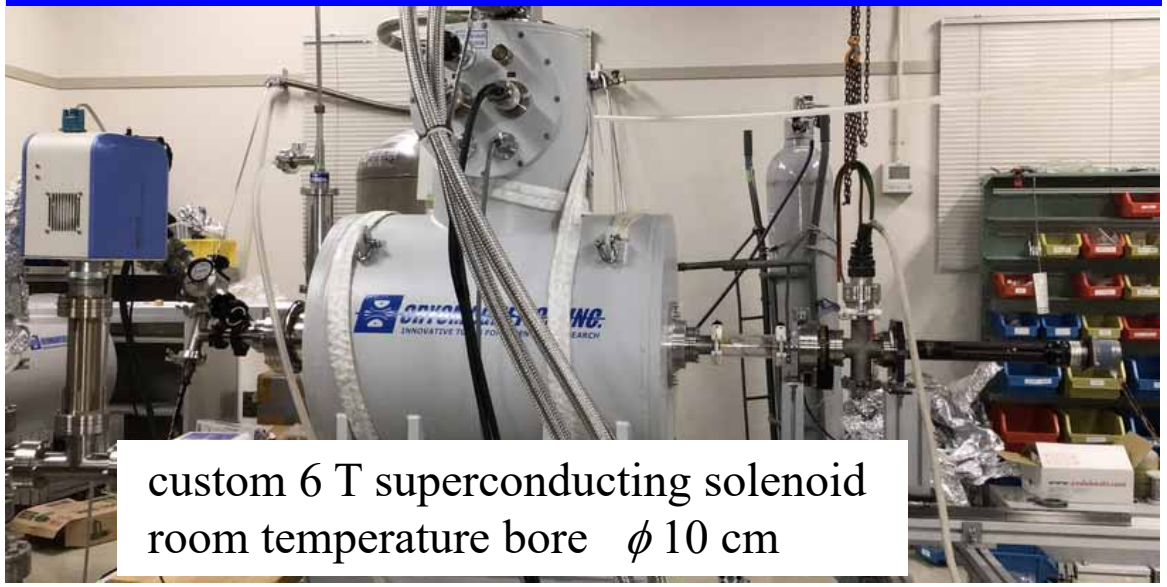


Magnetic field is changed. : B_{start} → B_{end}

Undulator field is generated by superposition of magnetic field

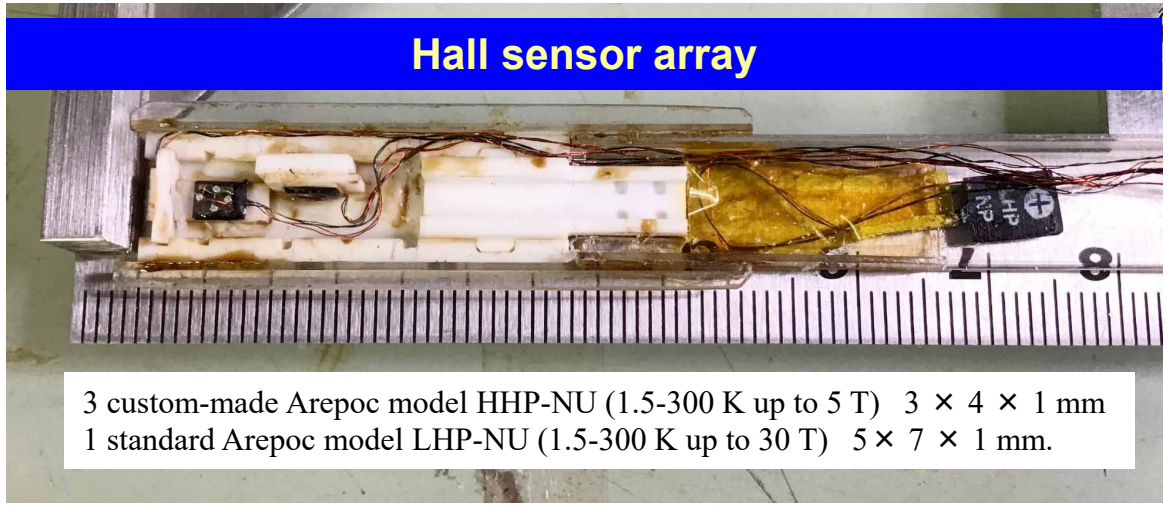
Experimental

Prototype Undulator



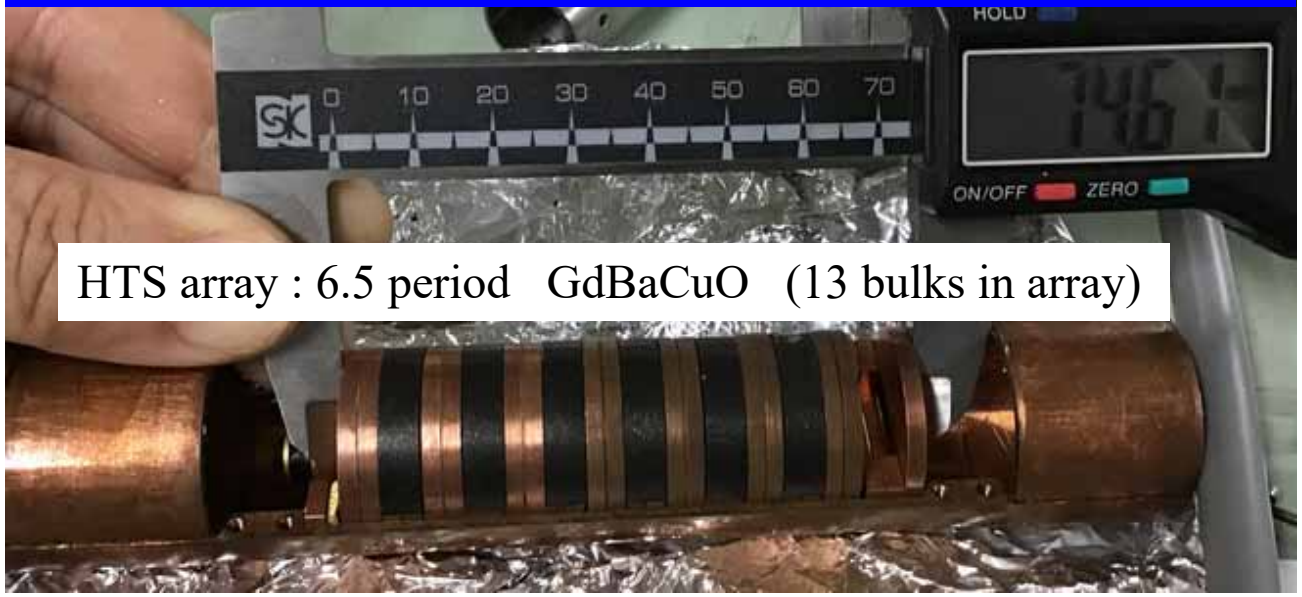
custom 6 T superconducting solenoid
room temperature bore ϕ 10 cm

Hall sensor array



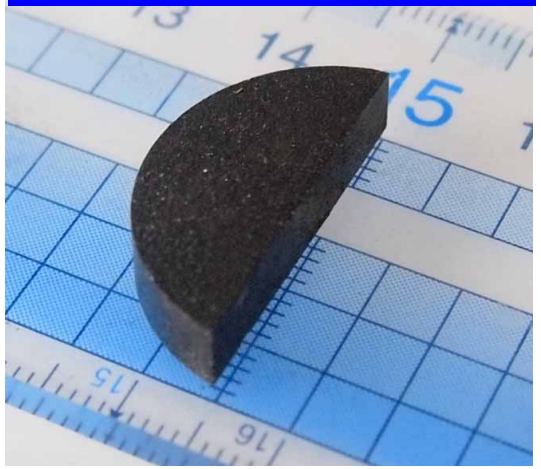
3 custom-made Arepoc model HHP-NU (1.5-300 K up to 5 T) 3 × 4 × 1 mm
1 standard Arepoc model LHP-NU (1.5-300 K up to 30 T) 5 × 7 × 1 mm.

HTS array



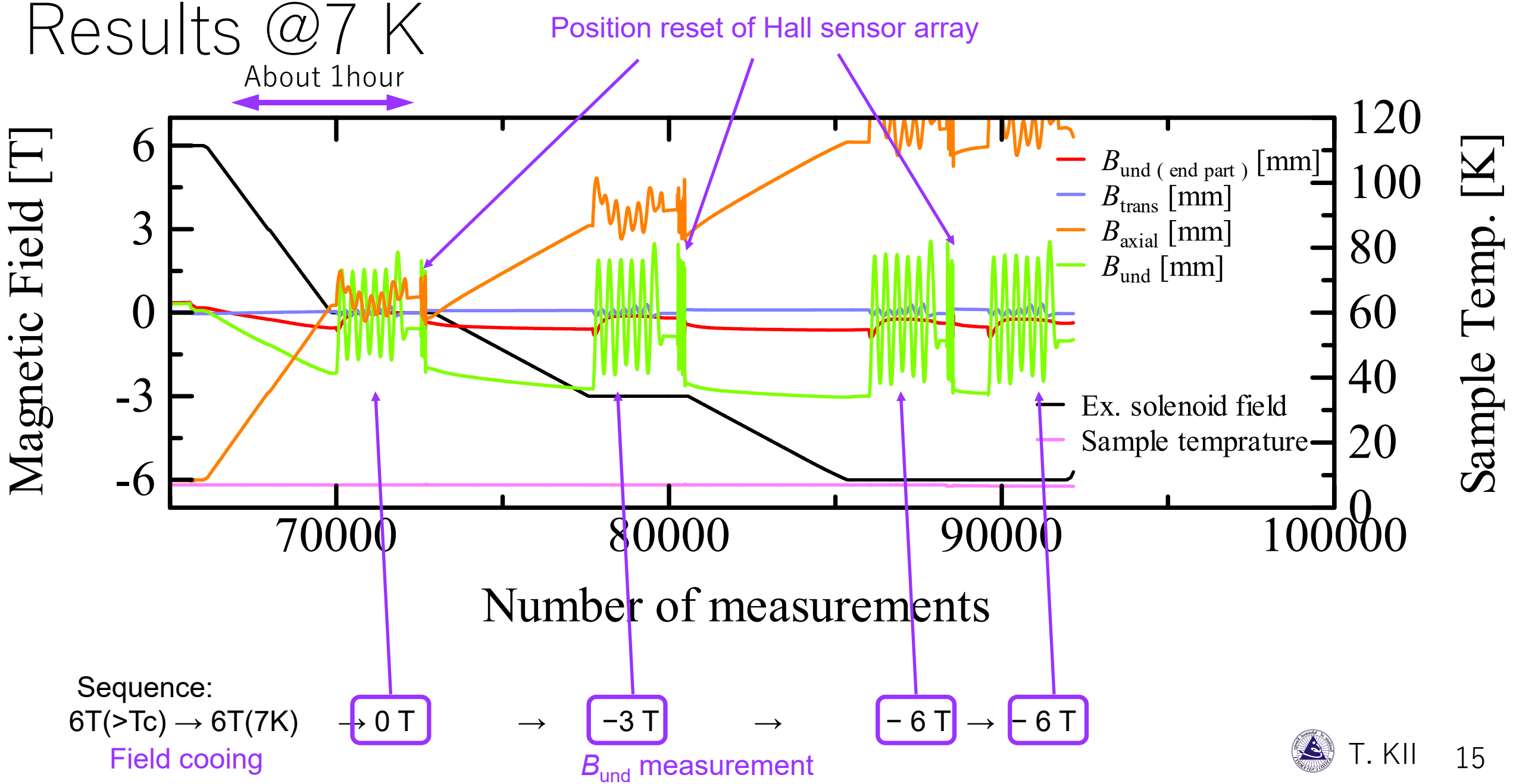
HTS array : 6.5 period GdBaCuO (13 bulks in array)

GdBaCuO bulk



Single Domain HTS
QMG™ by Nippon Steel
GdBaCuO
T_c ~ 90 K
J_c > 10 kA/mm^2 @10 K, 2T

Results @7 K


Position reset of Hall sensor array
About 1hour
Magnetic Field [T]
Sample Temp. [K]
Number of measurements
$B_{und\ (\ end\ part\ )}$ [mm]
B_{trans} [mm]
B_{axial} [mm]
B_{und} [mm]
Ex. solenoid field
Sample temprature
6
3
0
-3
-6
120
100
80
60
40
20
0
70000
80000
90000
100000
Sequence:
6T(>Tc) → 6T(7K) → 0 T → −3 T → − 6 T → − 6 T
Field cooing
B_{und} measurement

Results

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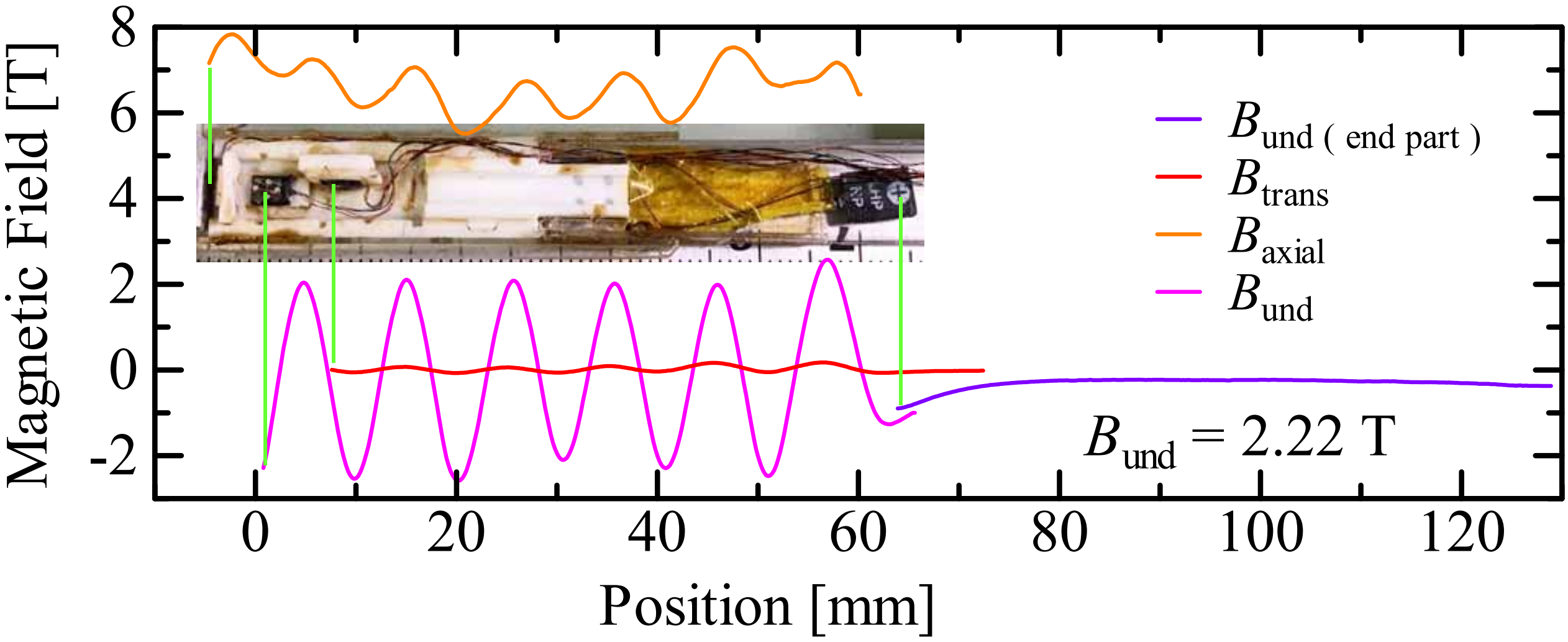
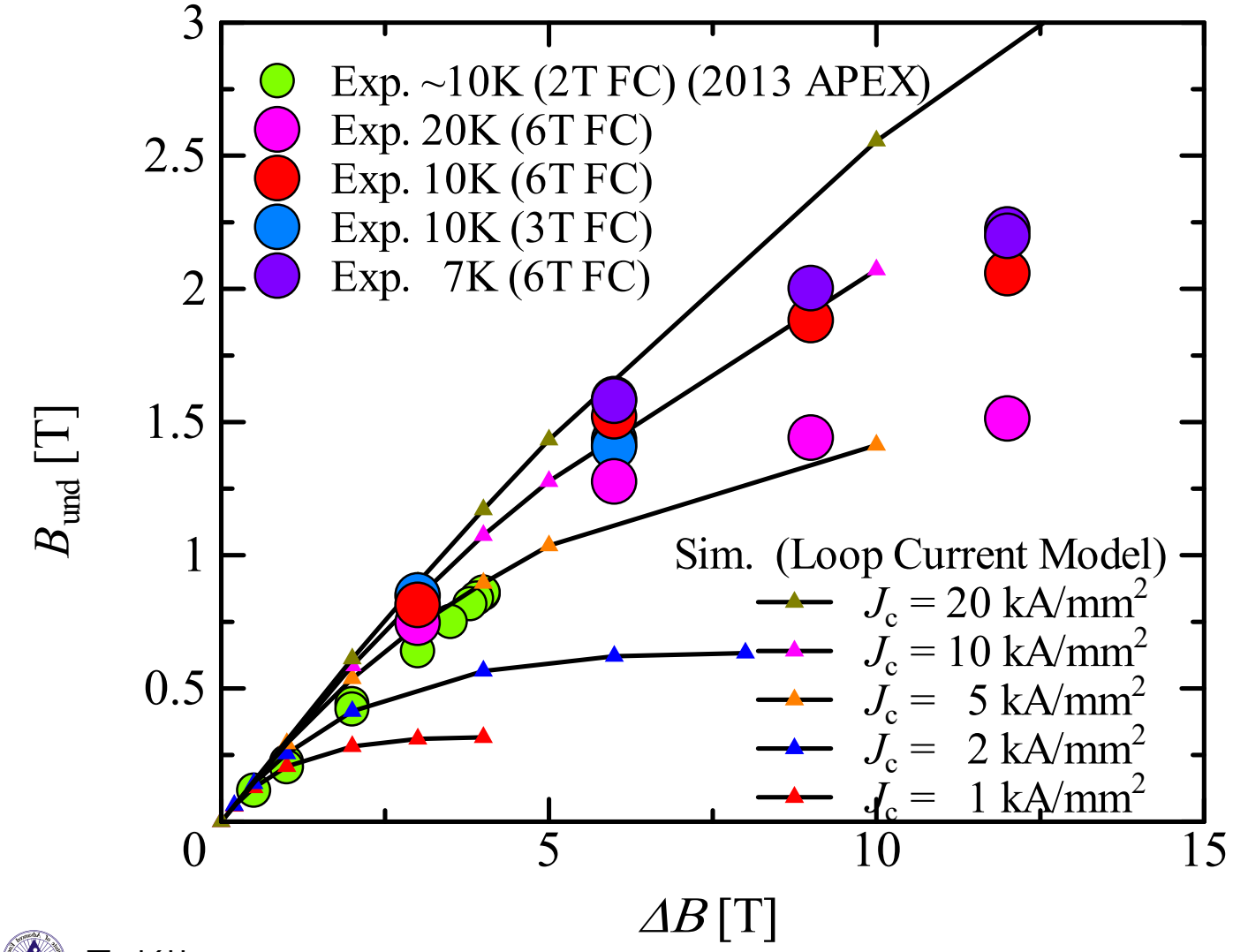
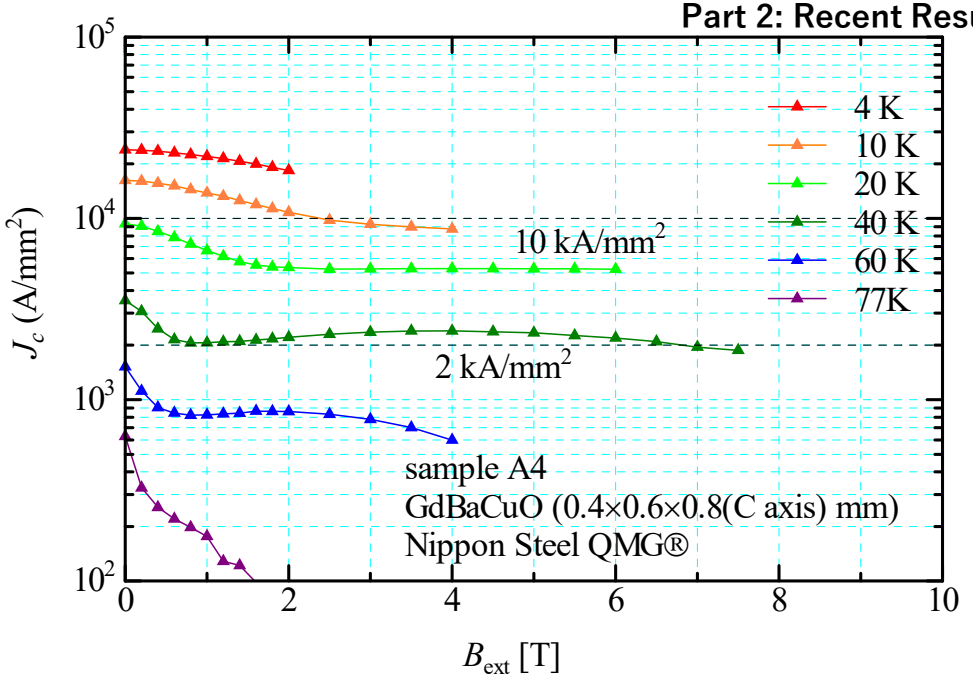


B_{und}: average of 10 peaks

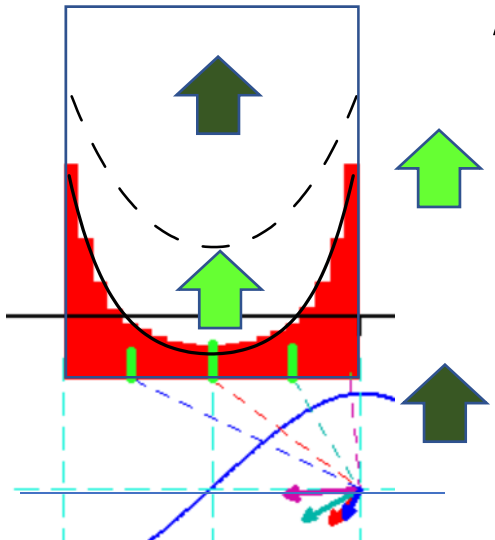
B_{und} = 2.22 T, B_{und} p-p fluctuation: ~ 10%

Results





Reason for field saturation



As increasing ΔB current front moves to center and finally saturates

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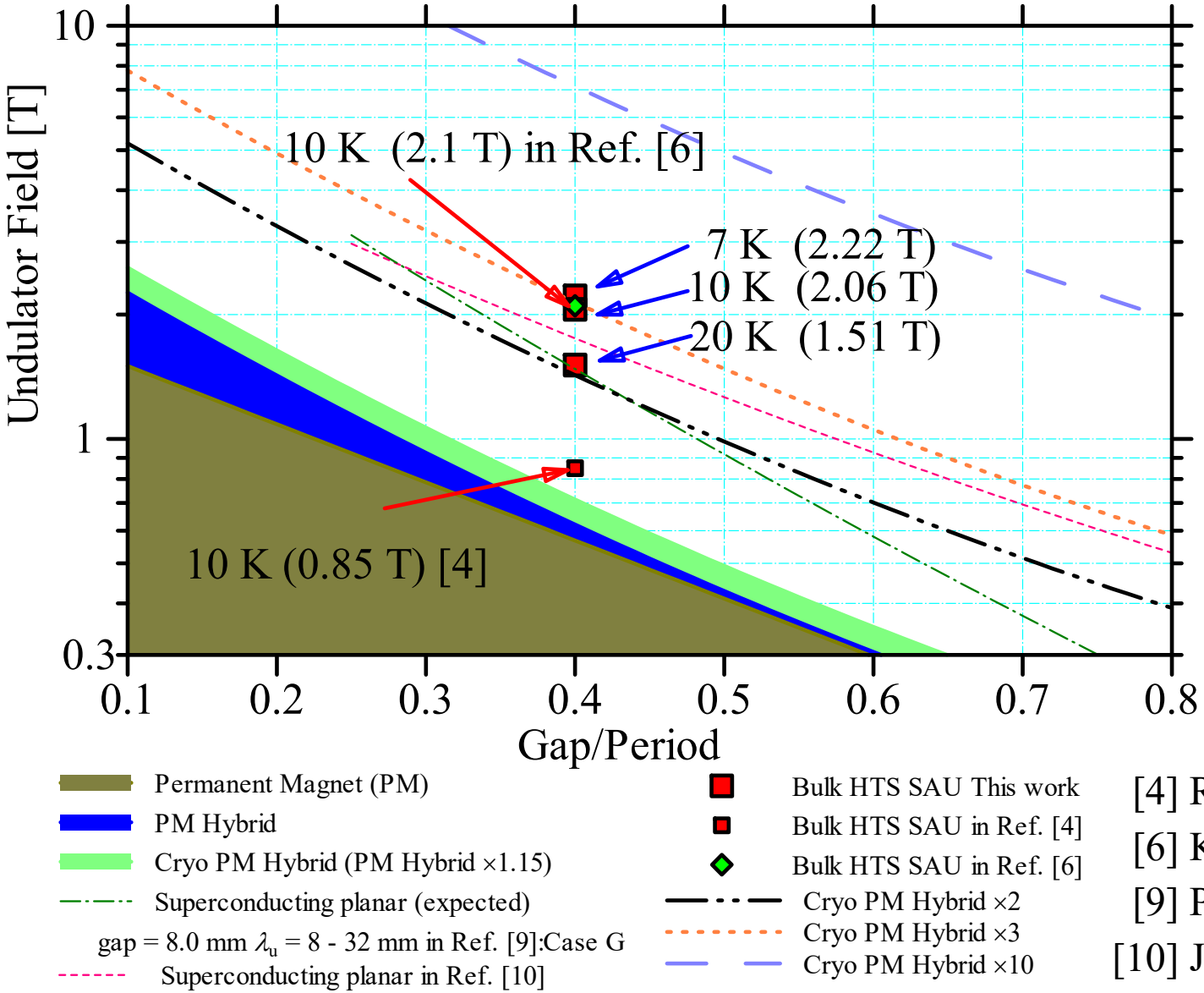
Summary



λ_{und} = 10.0 mm
gap = 4.0 mm
B_{und} = 2.22 T (@ 7K)
$K > 2$ ($T_{operation}$ <10 K)

[4] R. Kinjo *et al.*, *APEX* 6, p 042701, 2013 (Kyoto-U)
[6] K. Zhang *et al.*, *SUST* 36, p. 05LT01, 2023 (PSI)
[9] P. Elleaume *et al.*, *NIM* 455, pp. 503, 2000
[10] J.A. Clarke *et al.*, *in Proc. IPAC'11*, pp. 3320, 2011

Summary

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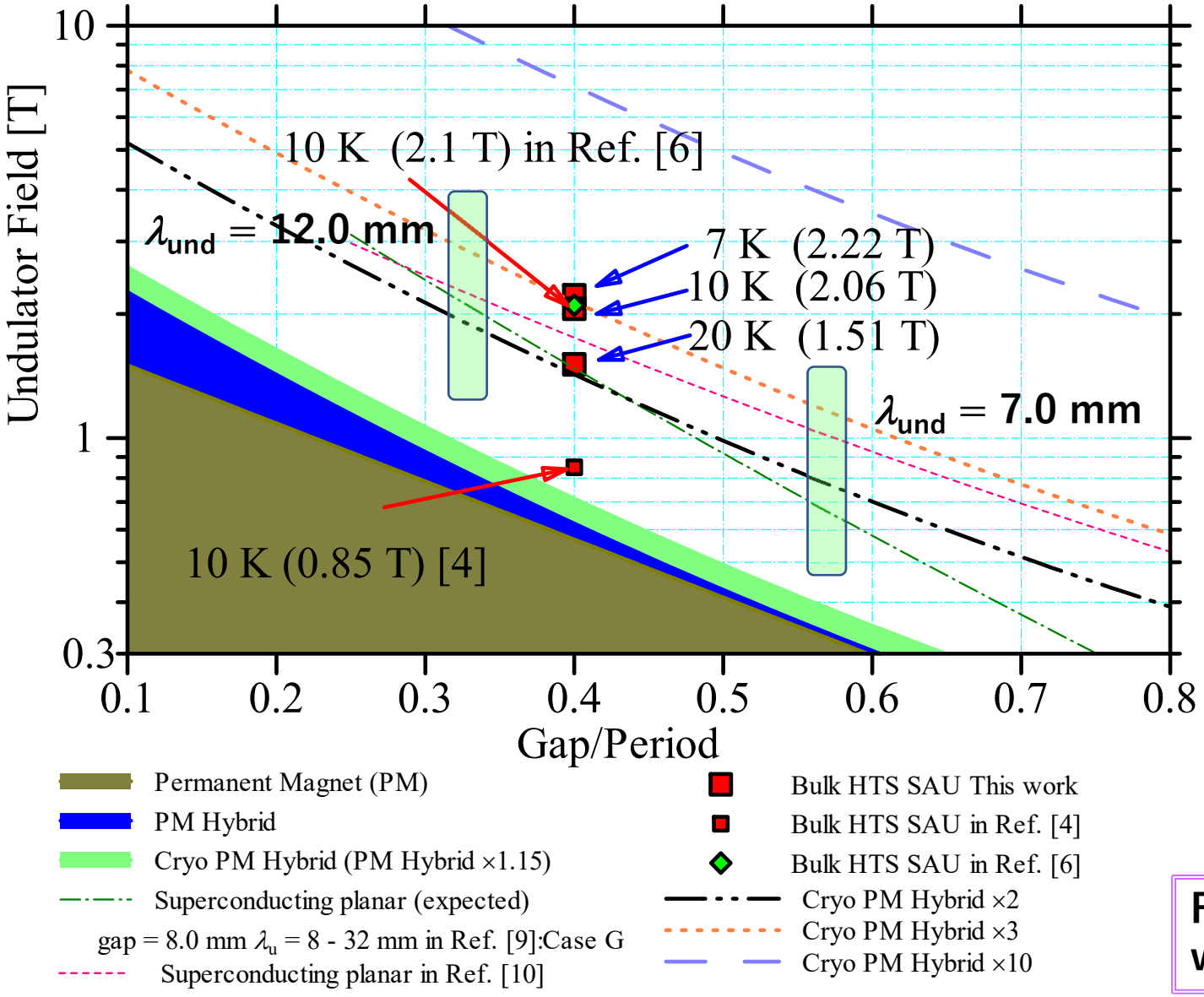
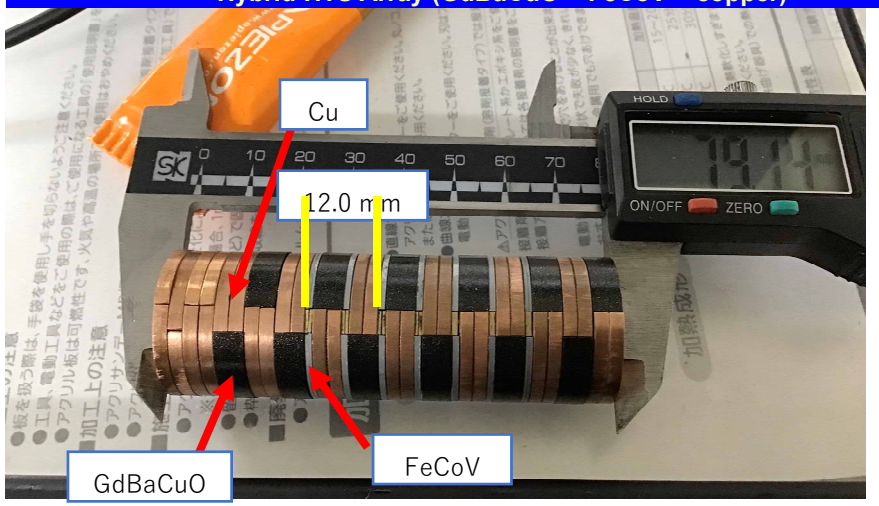
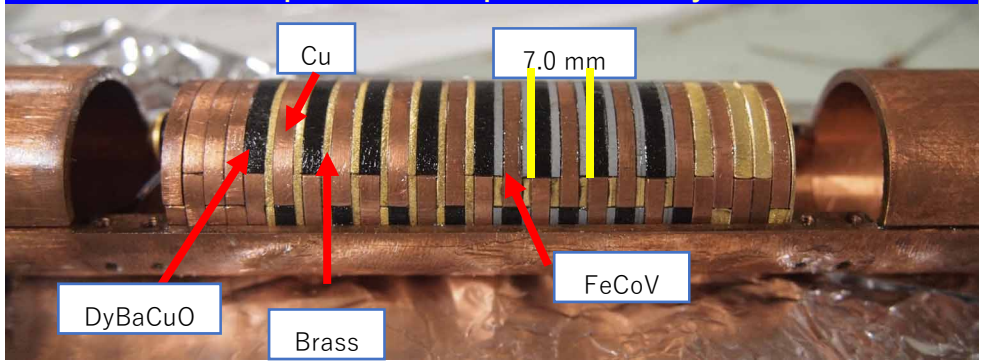


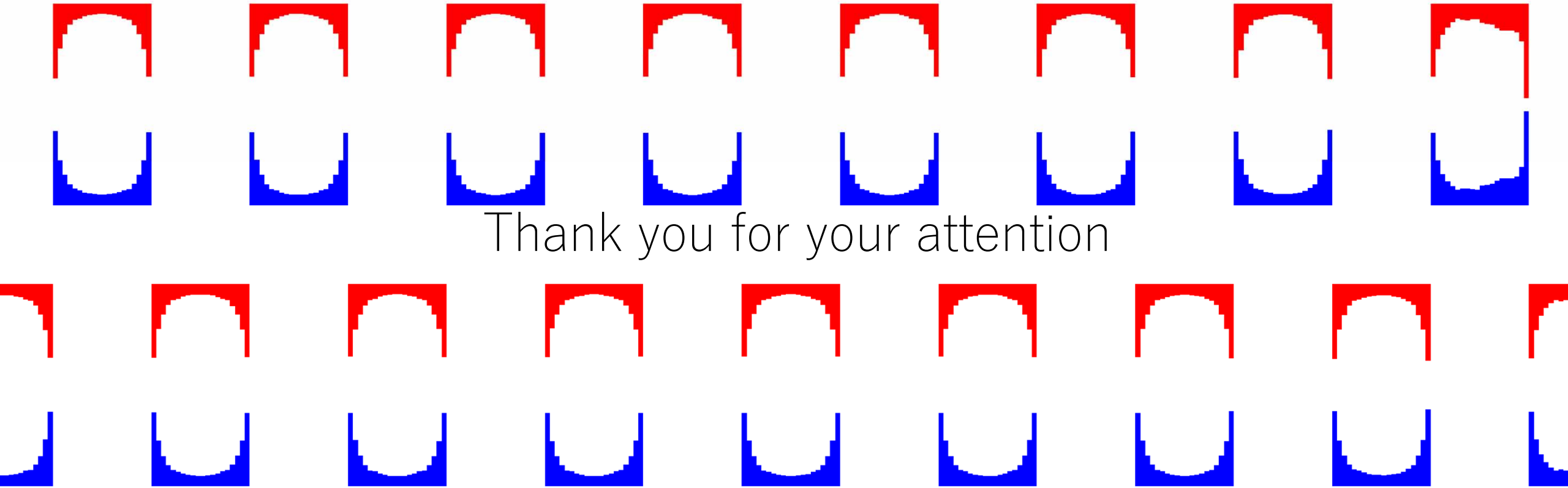
Hybrid HTS Array (GdBaCuO + FeCoV + copper)



Brass spacer & FeCoV spacer with bulk DyBaCuO



Results for λ_{und} = 7.0, 12.0 mm with hybrid structure will be unveiled soon.


Thank you for your attention