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Numerical Evaluation of Bulk HTSC Staggered Array Undulator by Loop Current Model

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- Background
- Numerical model
- Result – Comparison with experiment
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- Conclusion

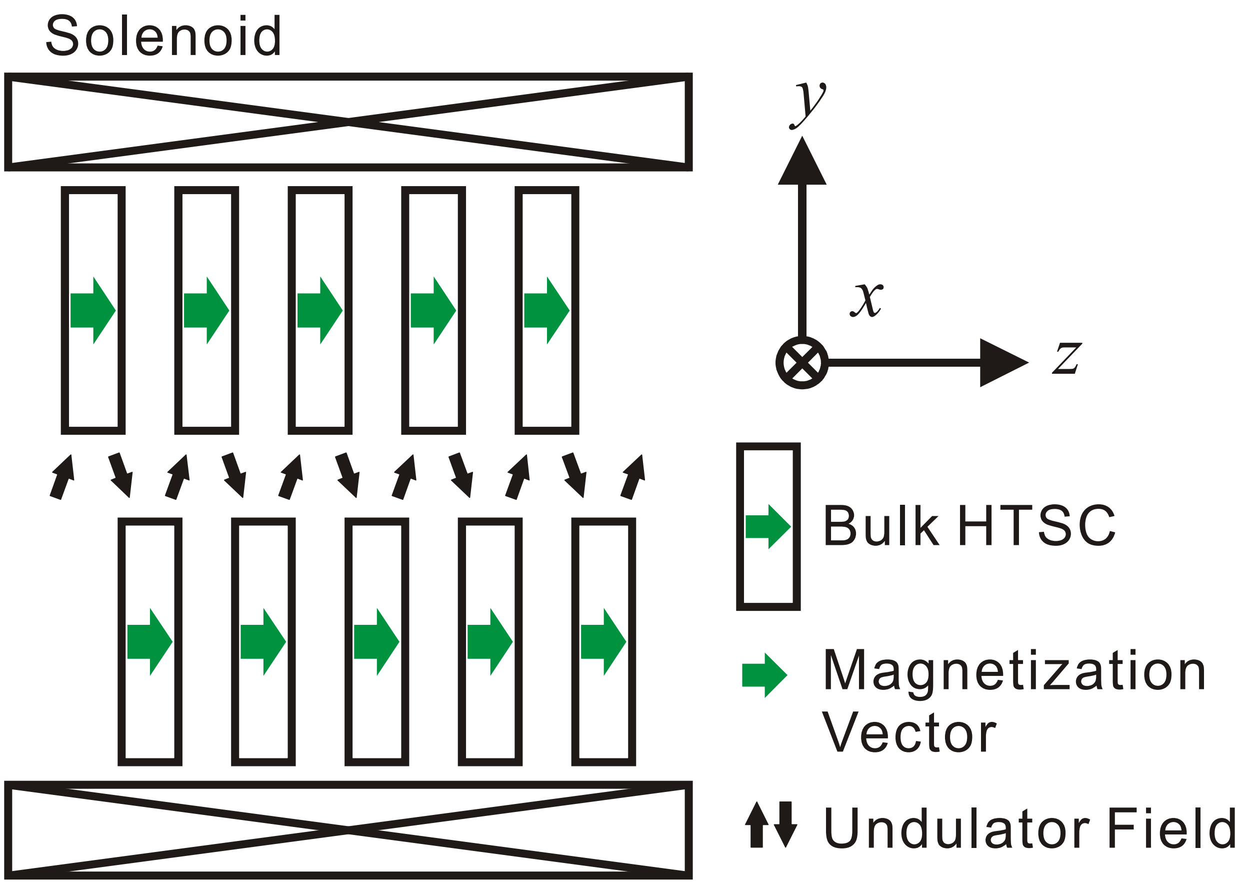
Bulk HTSC (Bulk High-T_c Superconductor)

- Bulk HTSC can be used at much higher than Lq. He temperature (4.2 K)
- It can trap very strong field at low temperature.
  - over 17 T at 29 K (bulk's radius *R* = 13 mm) [*1]

How do we magnetize Bulk HTSC and generate the sinusoidal magnetic field ?

*1 M. Tomita and M. Murakami, Nature Vol. 421, 2003

Bulk HTSC SAU
(Bulk HTSC Staggered Array Undulator)



We can control the amplitude of the undulator field by the solenoid field.

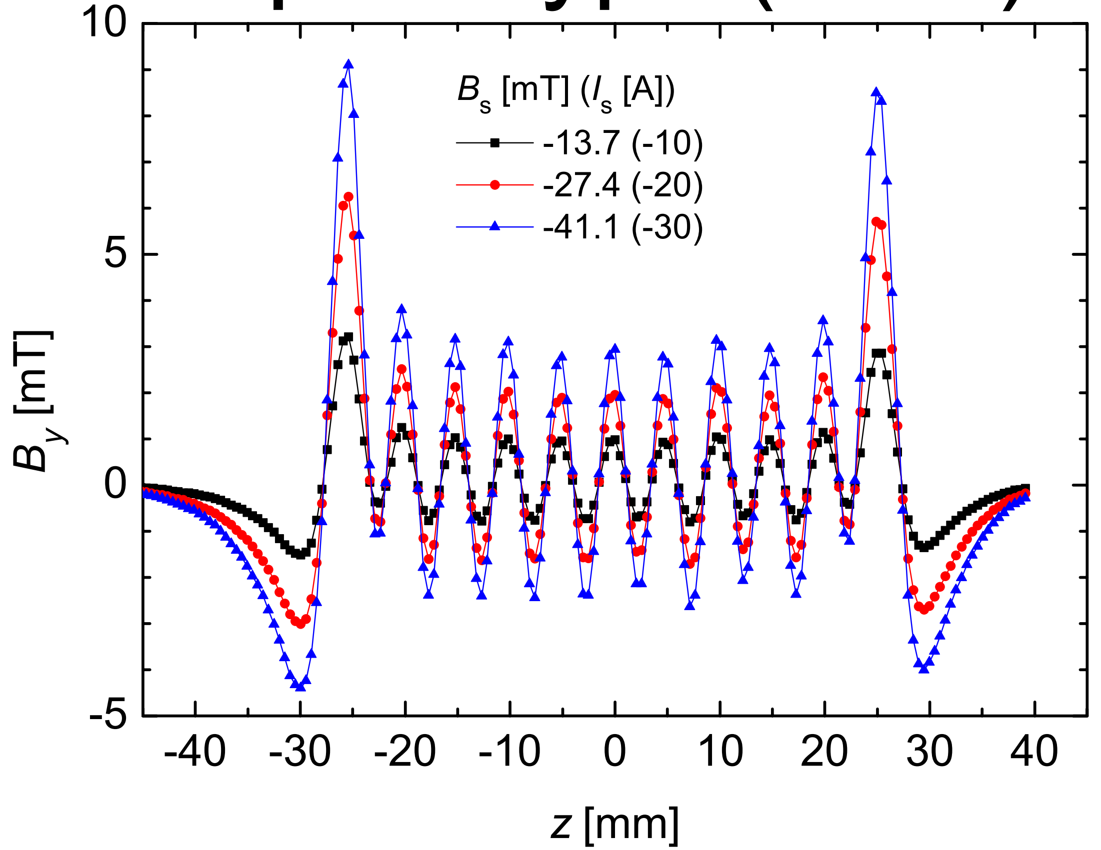
Field in 11 period prototype (77 K)

Prototype

λ_u = 5 mm

g = 4 mm

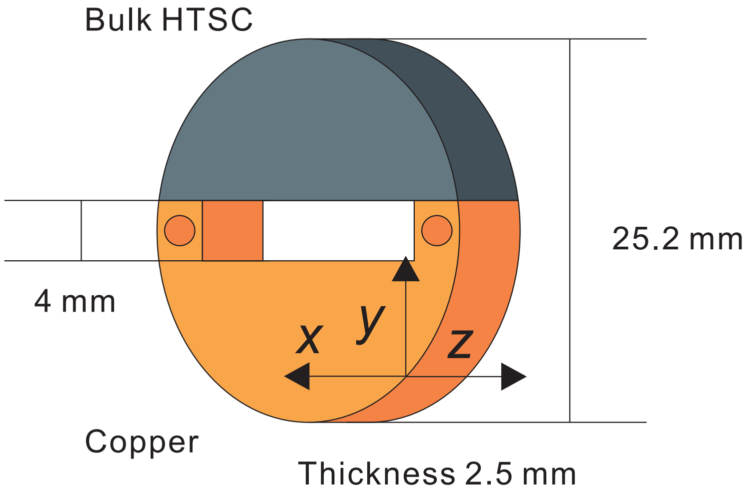
N = 11

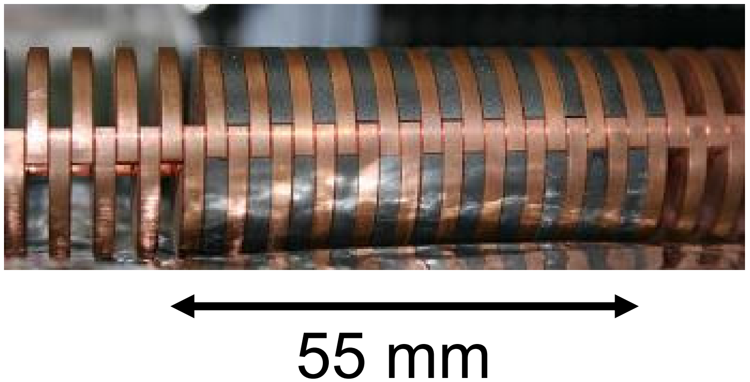


DyBaCuO

T_c ~ 91 K

J_c ~ 100 A/mm^2 @ 77 K





Objective

The undulator field is small (~ several mT) because the critical current density J_c is low at 77 K.

- To estimate the performances at lower temperatures where the critical current density is high.
  - We developed the loop current model based on Bean model.

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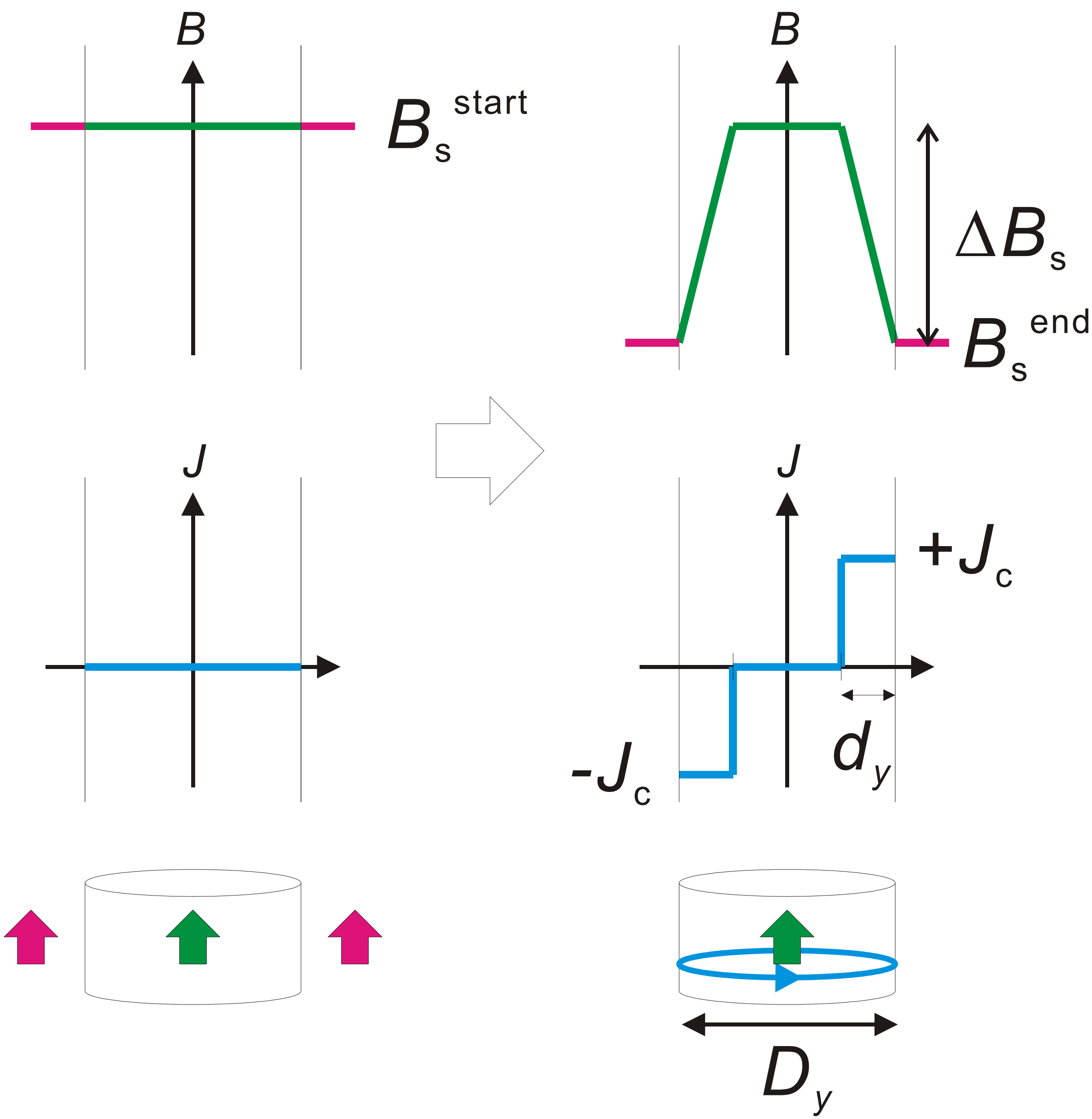
How does loop current flow in bulk?



From Bean model

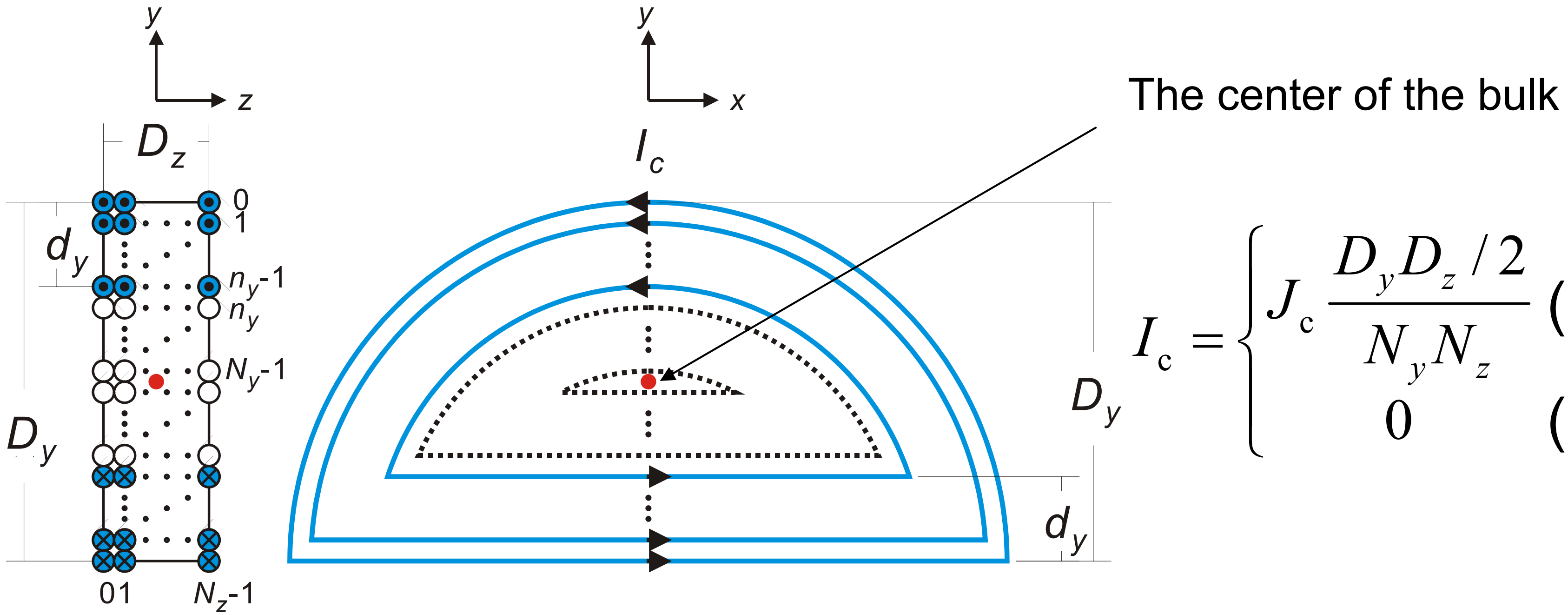
$$J = J_c \text{ or } J = 0,$$

$$\mu_0 J_c d_y = -\Delta B_s .$$

Penetration ratio Λ_d

$$\Lambda_d = \frac{d_y}{D_y / 2}$$

Loop current representation of bulk

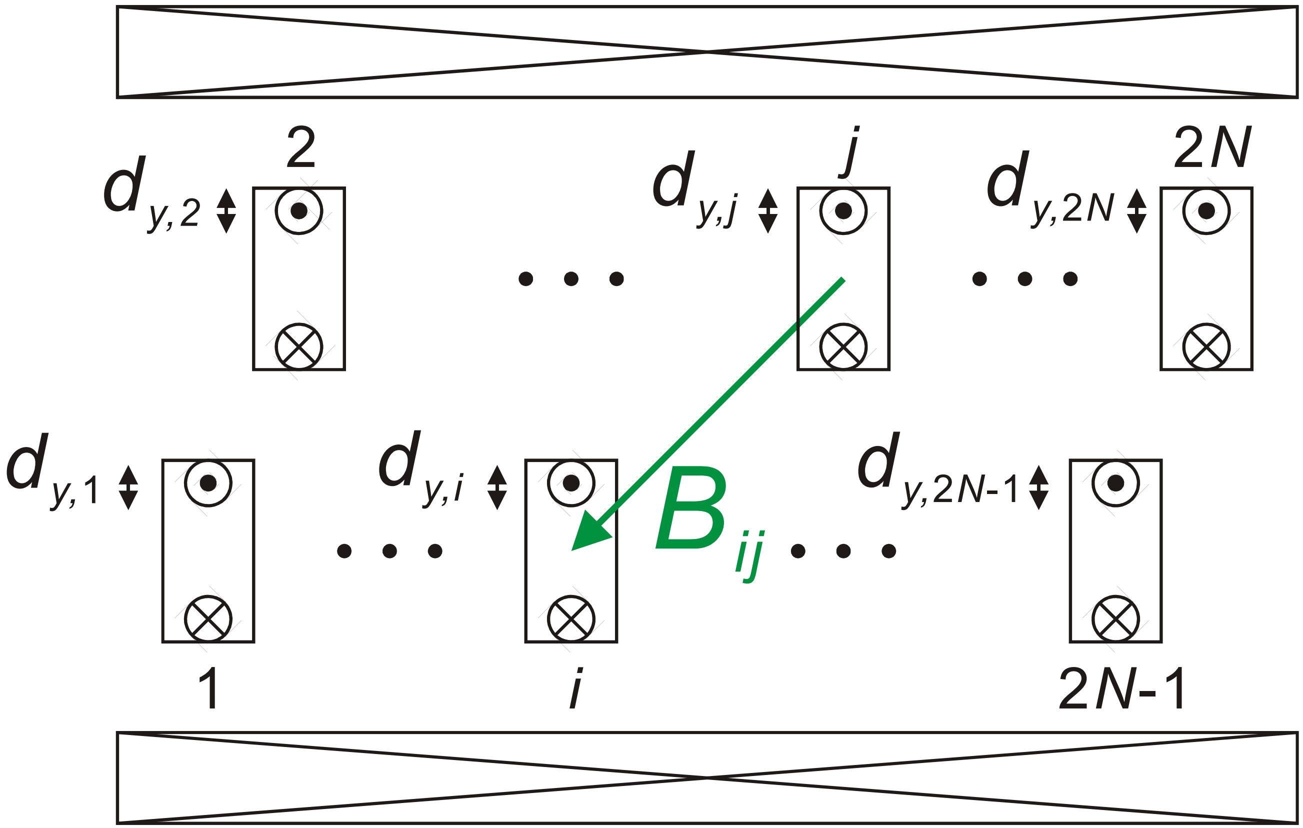


$$I_c = \begin{cases} J_c \dfrac{D_y D_z / 2}{N_y N_z} & (\text{solid line}) \\ 0 & (\text{dotted line}) \end{cases}$$

Assumption from Bean model

1. Each bulk's Λ_d $(= 2d_y / D_y)$ is determined by the changes of the magnetic field at the centre of each bulks.

How to determine d_y of bulk i ($d_{y,i}$)



$$\alpha \mu_0 J_c d_{y,i} = -\Delta B_s - \sum_{j \neq i}^{2N} B_{ij}\left(d_{y,j}\right)$$

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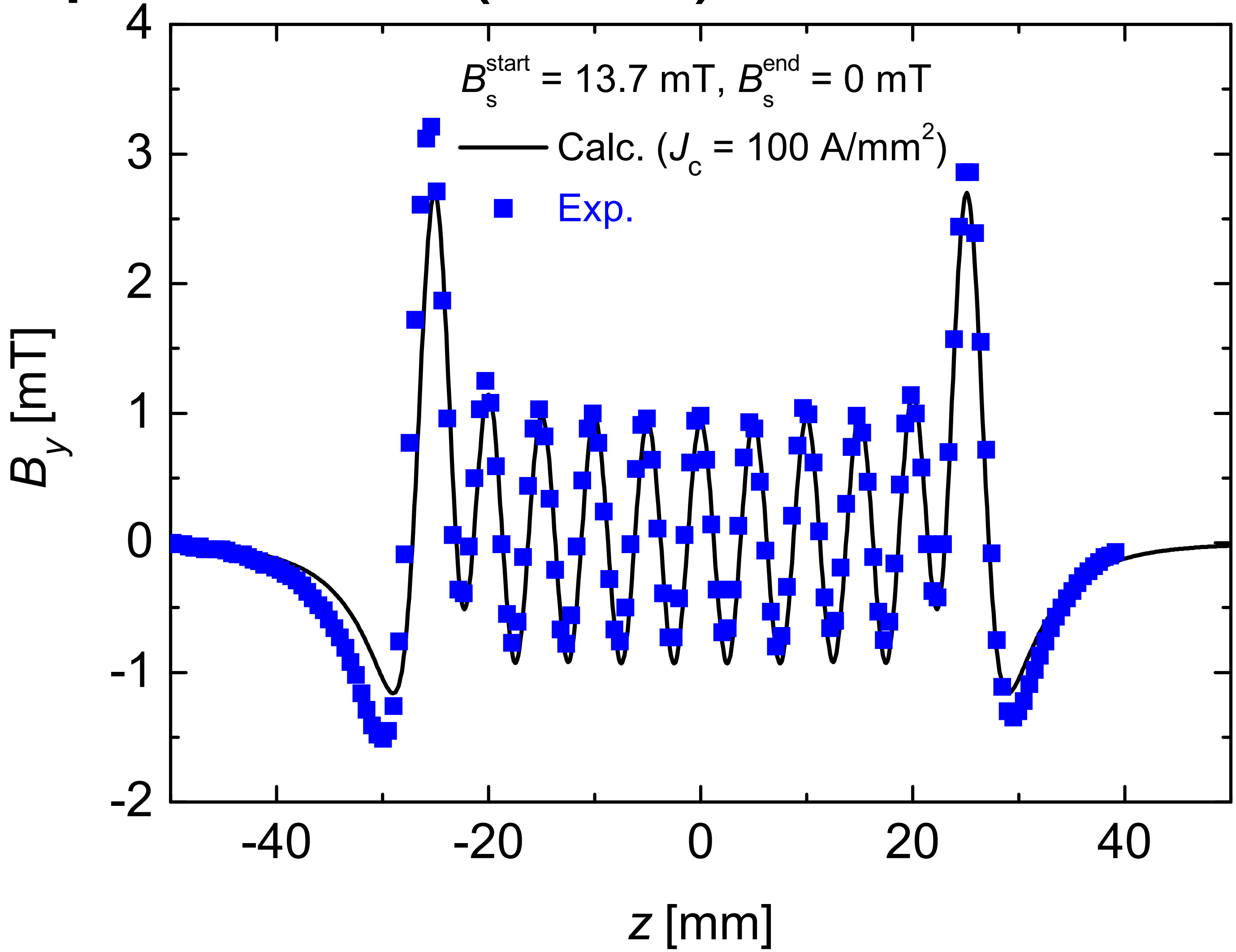
Comparison between experiment (77 K) and calculation



The calculation reproduced the result (Λ_d < 20%)

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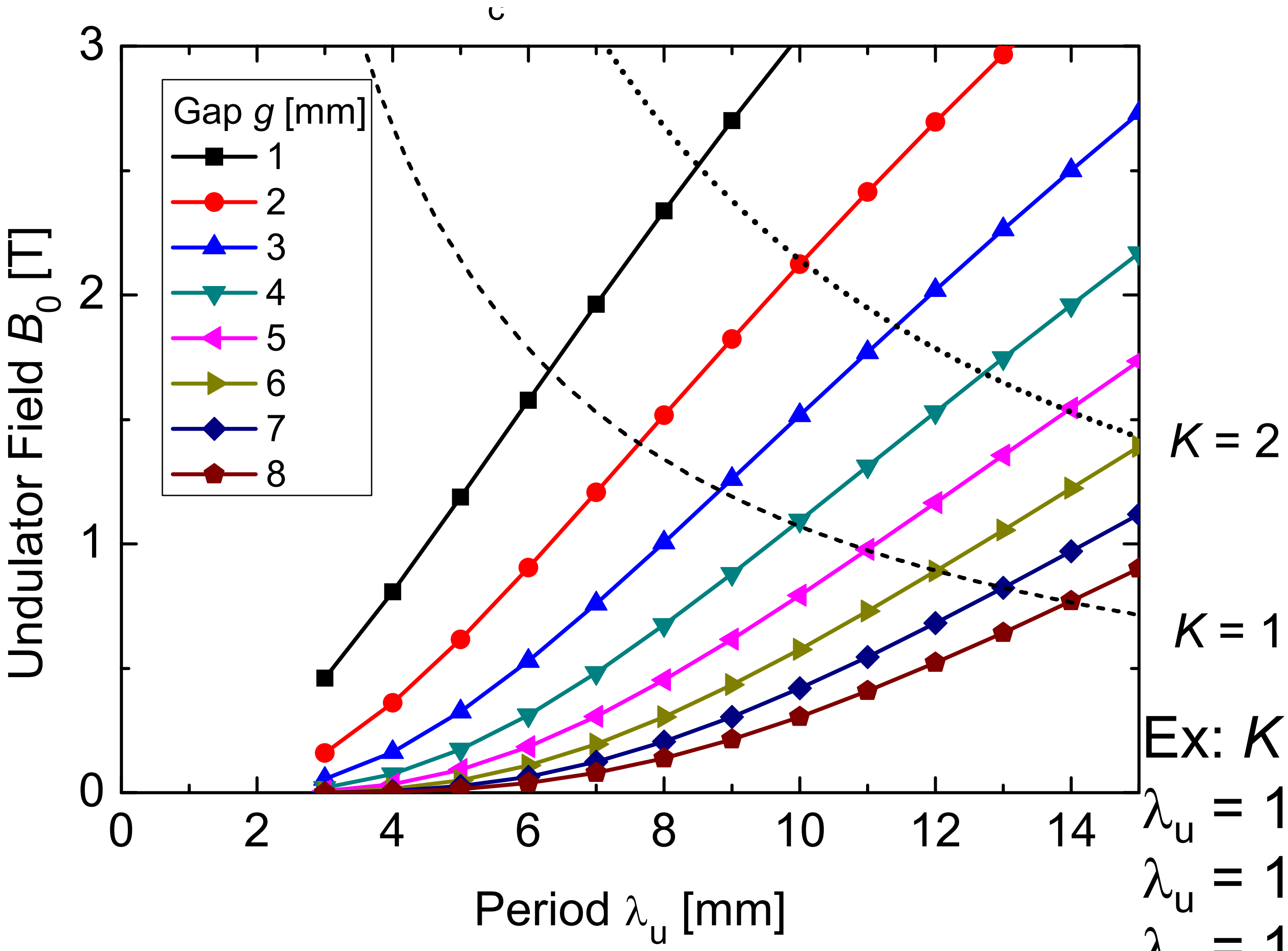
Performance estimation

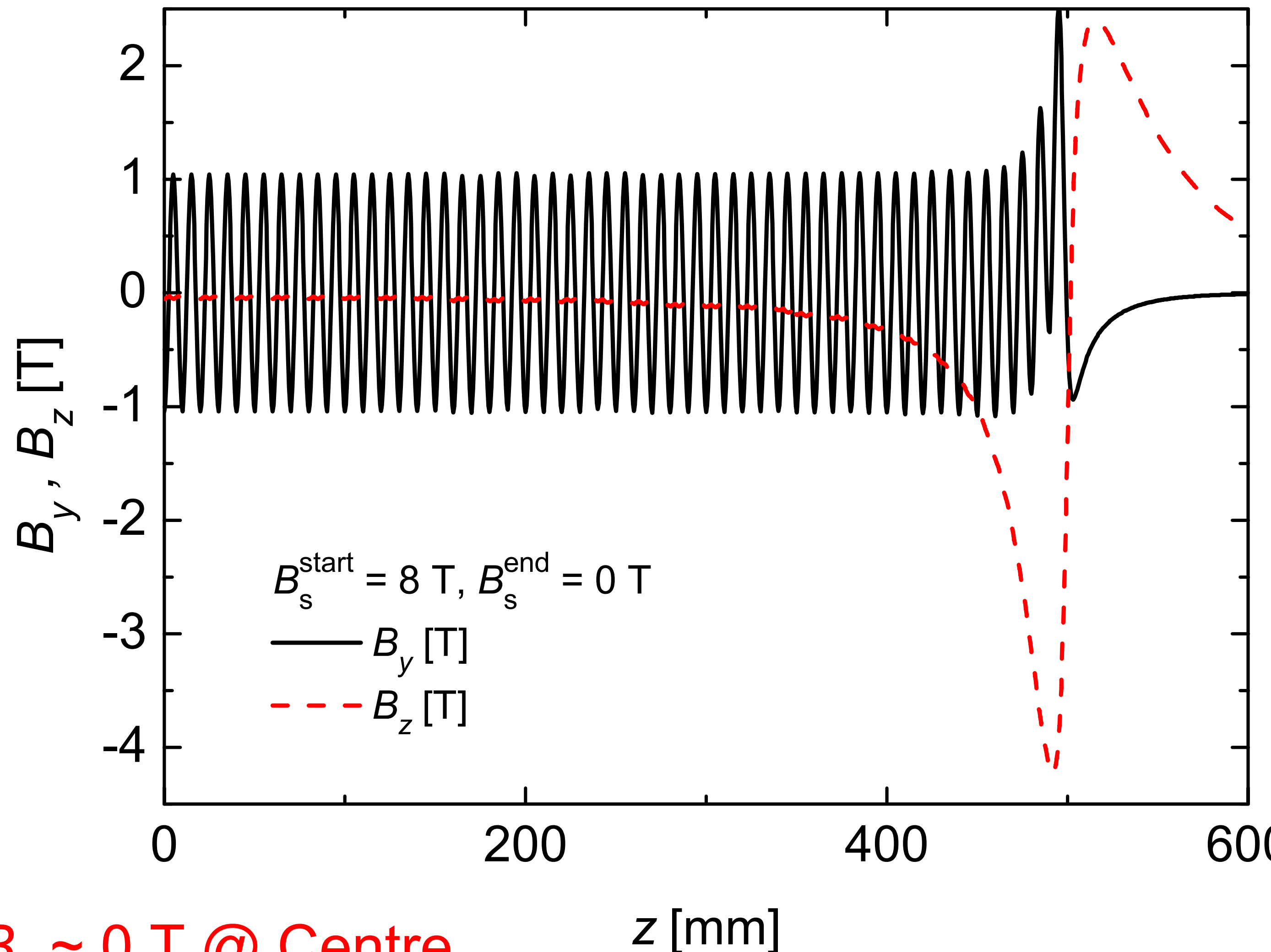
	Experiment	Performance Estimation
Period λ_u	5 mm	3-15 mm
Gap *g*	4 mm	1-8 mm
Periodic number *N*	11	100
Bulk radius *R*	12.6 mm	65 mm
Penetration ratio Λ_d	< 20 %	~ 10 % (@ centre)
Critical current density J_c	~ 100 A/mm^2 (77 K)	3.5 kA/mm^2 10 kA/mm^2

Performance @ J_c = 3.5 kA/mm^2



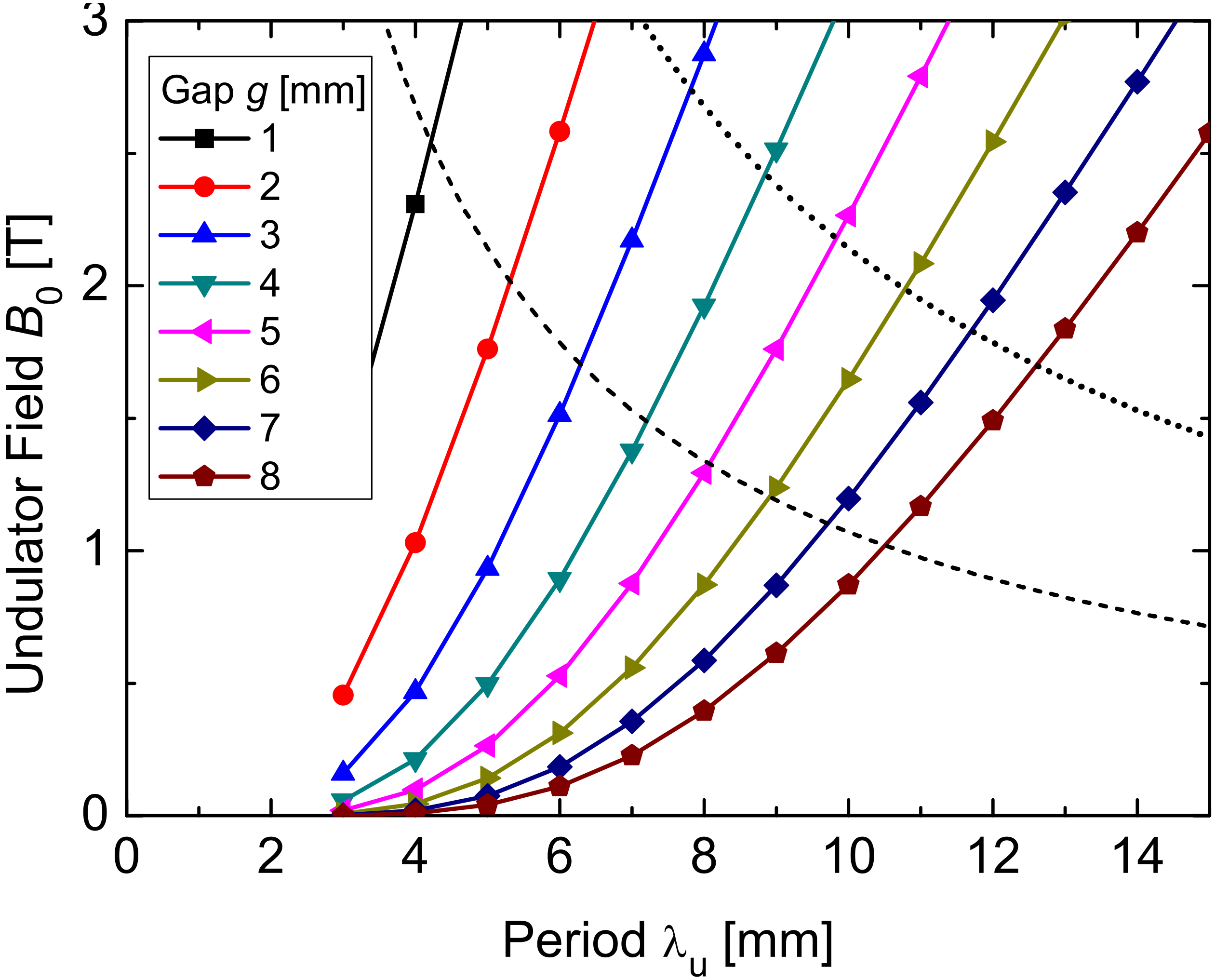
Ex: K = 1 @
λ_u = 10 mm, g = 4 mm
λ_u = 11 mm, g = 5 mm
λ_u = 12 mm, g = 6 mm

B_y, B_z @ J_c = 3.5 kA/mm^2, λ_u = 10 mm, g = 4 mm



B_y ~ 1 T (K ~ 1), B_z ~ 0 T @ Centre

Performance @ J_c = 10 kA/mm^2



Ex: K = 1 @

λ_u = 8 mm, g = 5 mm

λ_u = 9 mm, g = 6 mm

Conclusion

- We have developed the loop current model based on Bean model.
- The model reproduced the experimental field distribution at 77 K.

- We have made performance estimations at lower temperature where the critical current density is high.
- The estimated performance showed that Bulk HTSC SAU is promising for the short period undulator.