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IPAC2018 WEXGBD1 @ Vancouver

Development of Very-Short-Period Undulators

1. Target & Circumstances
2. Formation of a "very short period" field
3. Field measurement & characterization
4. Magnet elongation
5. Observation of the first light

Photon Factory, KEK

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山本　樹

Development of very-short-period undulators

Target: Produce the higher energy photons by the shorter period of an undulator (λ_u) with the lower (1^{st}) harmonic and the lower energy LS

if λ_u =4mm possible, 12keV-photons by 1^{st} harmonic @ 2.5GeV LS

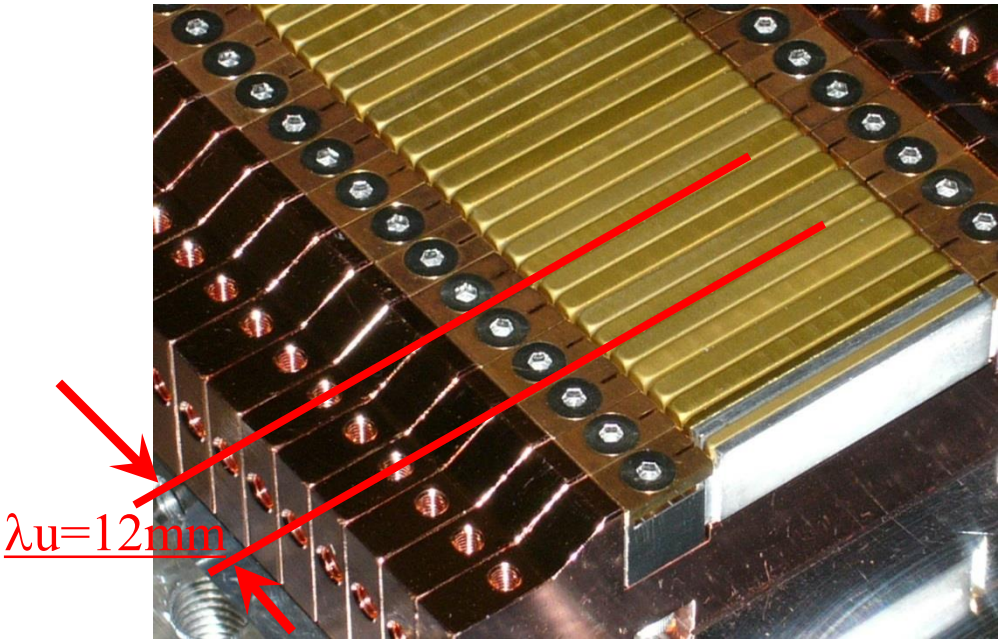
Back ground: In KEK we invented and constructed the In-Vac Undulators to reduce λ_u

In other institutes: 3G LS (SPring-8, ESRF, APS):
In-vac Us (λu~several cm)
Compact 3G LS:
In-vac Us (λu~2 cm)

1. Target & Circumstances

In KEK we constructed the In-Vac Us to reduce the period length:

In-vac Us (λu=4cm)
@ ~~6.5GeV PF-AR (since 1989)~~



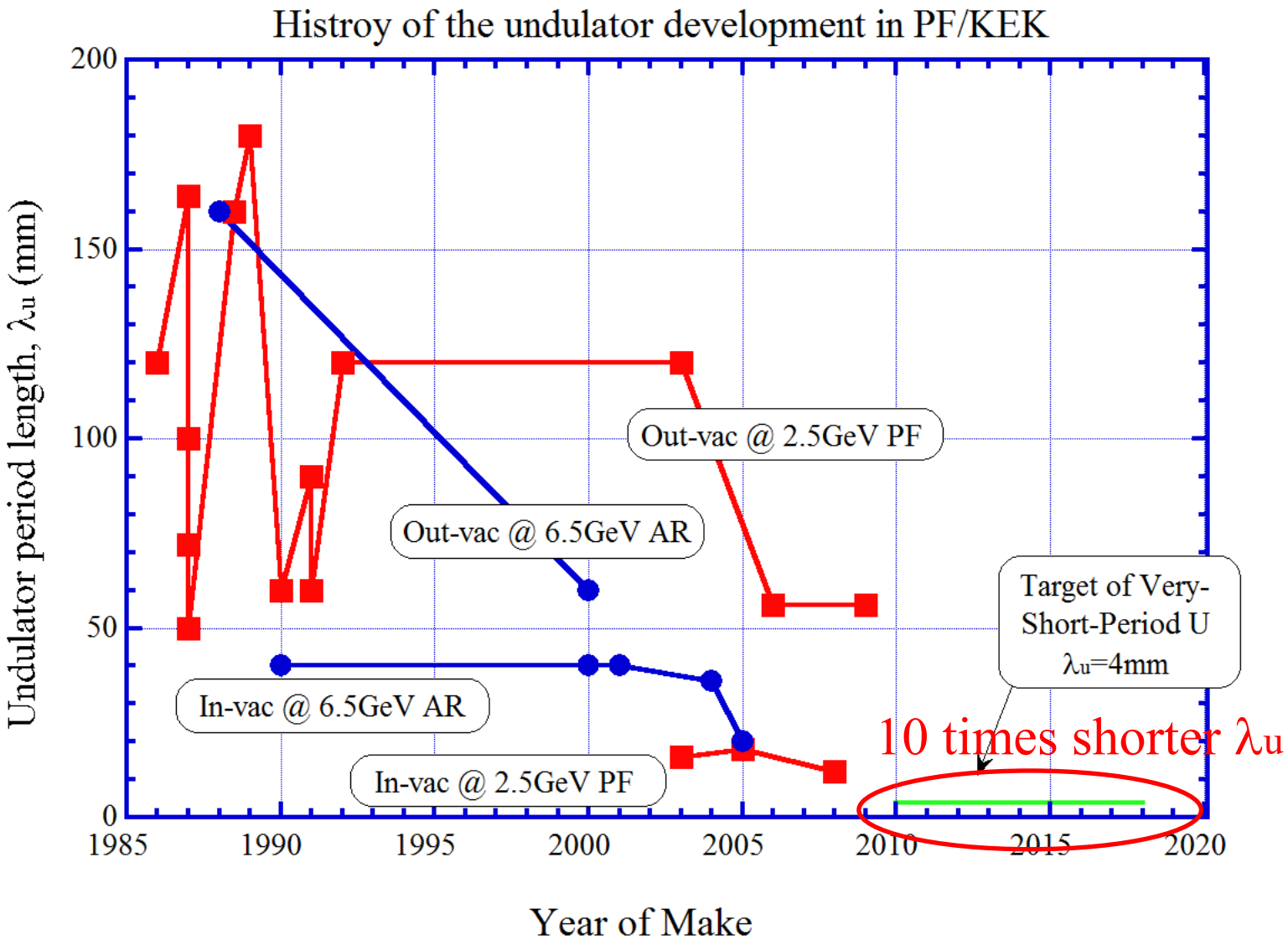
In-vac Short Gap Us (λu~2cm)
@ 2.5GeV PF (2003-08)

What is the next target of λ_u?

Very short λ_u = several mm (4mm)

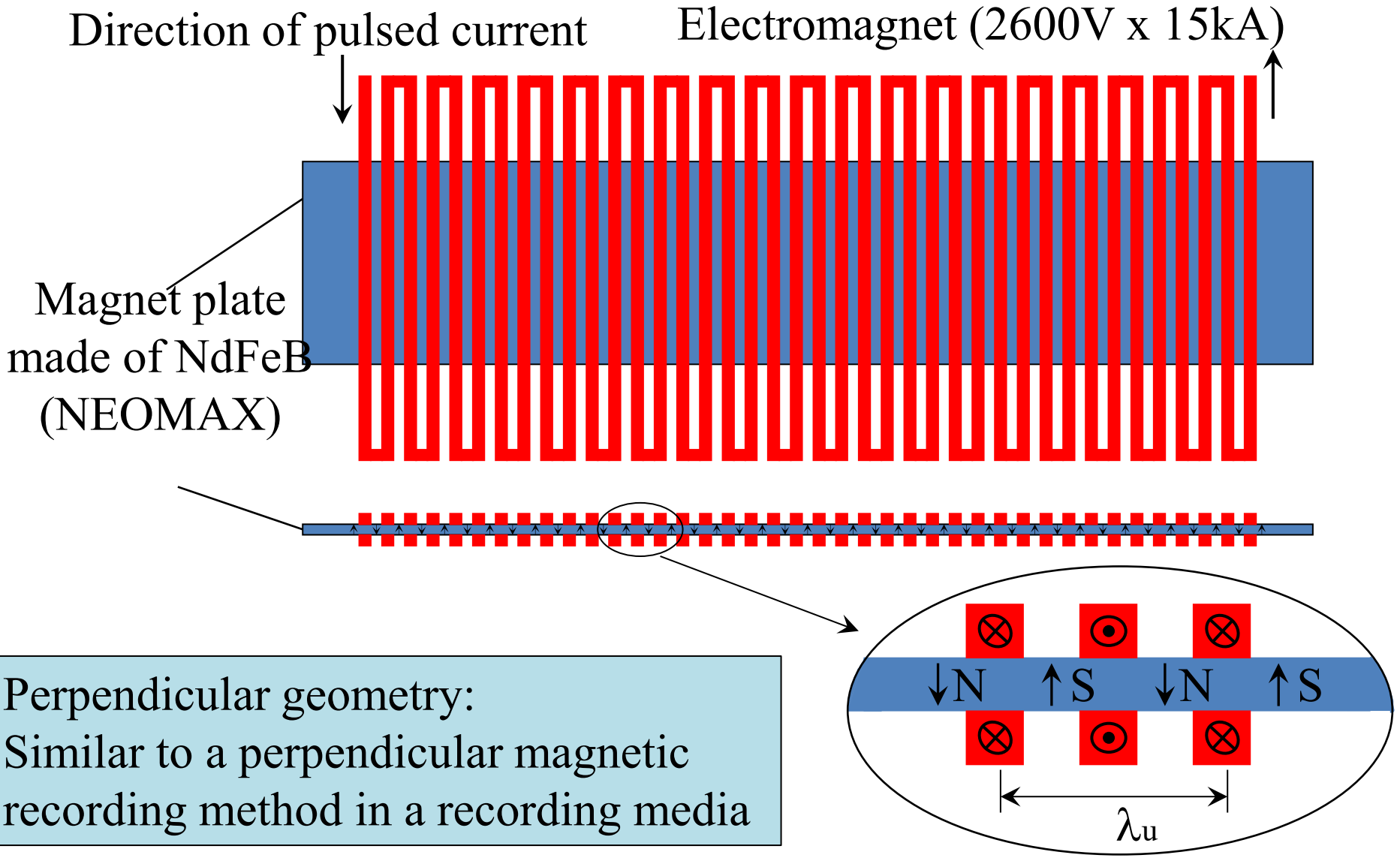
= several cm (ordinary type) x 1/10

Reduction of λu at PF/KEK



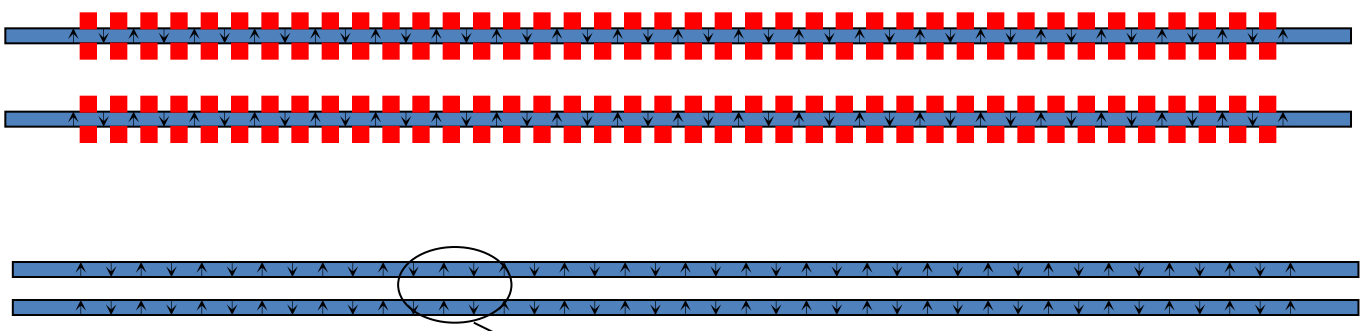
2. Formation of a "very short period" field: multi-pole magnetization

How to fabricate very short period undulator magnets



Perpendicular geometry:
Similar to a perpendicular magnetic recording method in a recording media

2. Formation of a "very short period" field: multi-pole magnetization

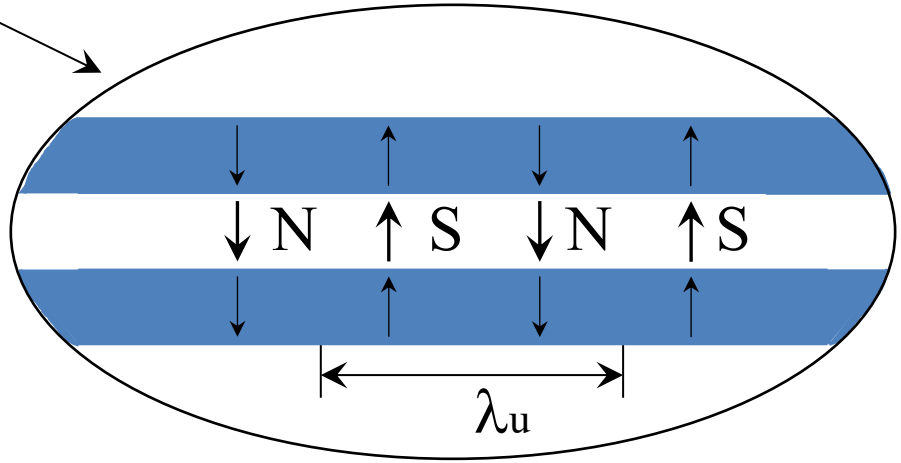


Magnetization #1

Magnetization #2

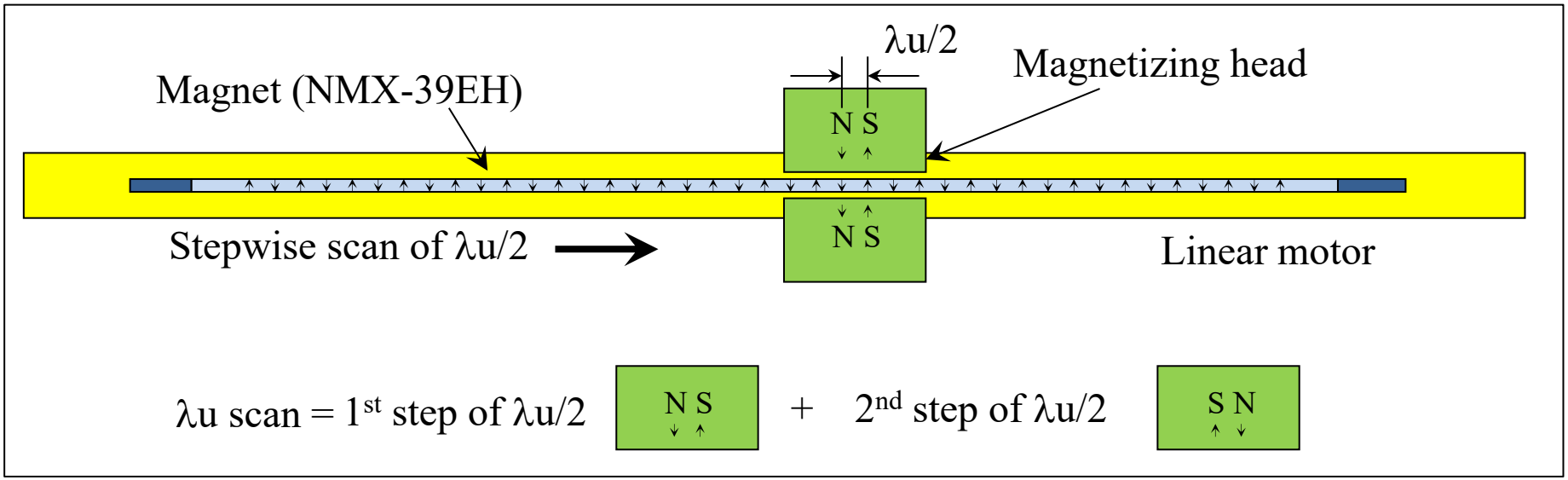
In a gap between

a pair of the magnets



2. Formation of a "very short period" field: multi-pole magnetization

To achieve a simple development, a step-wise multipole magnetization was adopted in the perpendicular geometry.

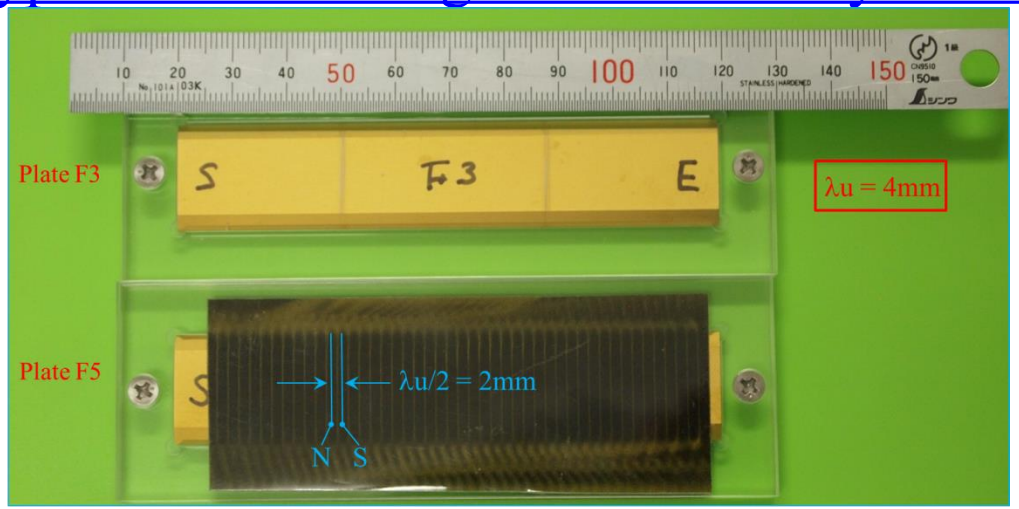


The plate magnet is driven stepwise by a linear motor and the plate is magnetized at each step by the fixed head, which is excited by the pulsed current.

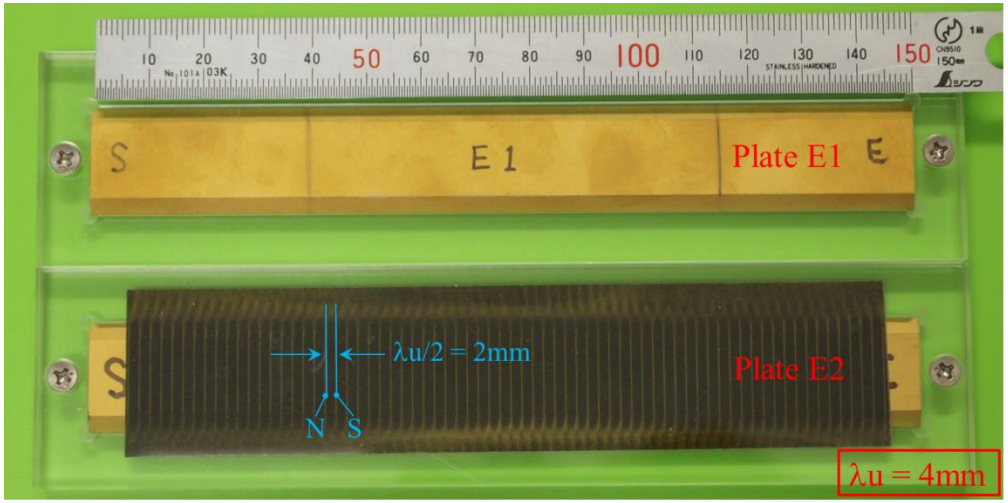
The step width of the linear motion is set to a half of the period length (2mm). At each step of the plate movement, the current direction is reversed to form the 4mm period length.

2. Formation of a "very short period" field: multi-pole magnetization

Plate type undulator magnets with a very-short-period undulator field



(a) 100mm long, 20mm wide, 2mm thick; 25 periods



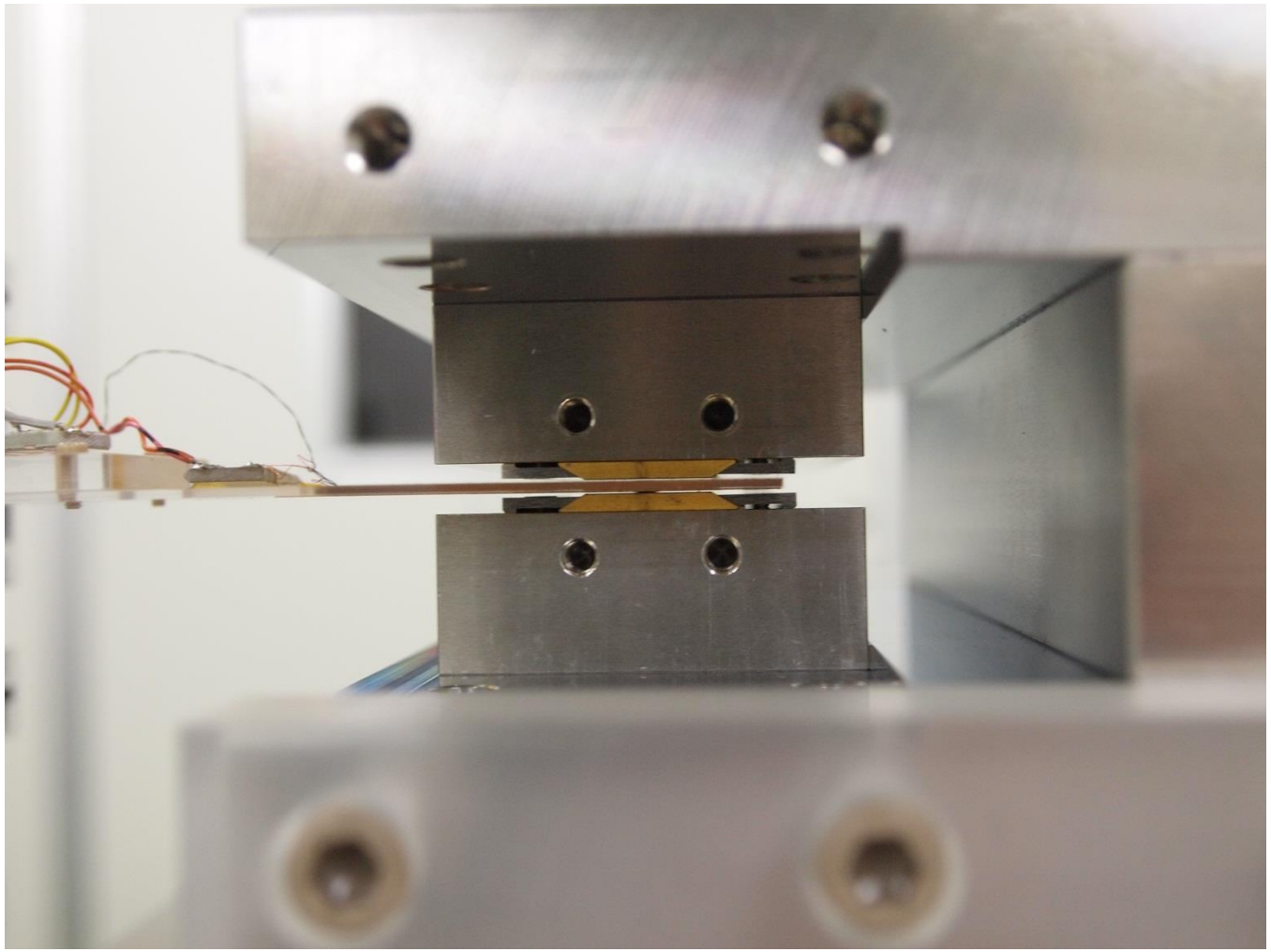
(b) 152mm long, 20mm wide, 2mm thick; 38 periods

Field pattern seen through a magnetic viewer sheet

NMX-39EH TiN coated
(Br =12kG, iHc=25kOe)
20mm wide, 2mm thick

Reduction of magnet volume enables the downsizing & weight reduction of the total undulator system

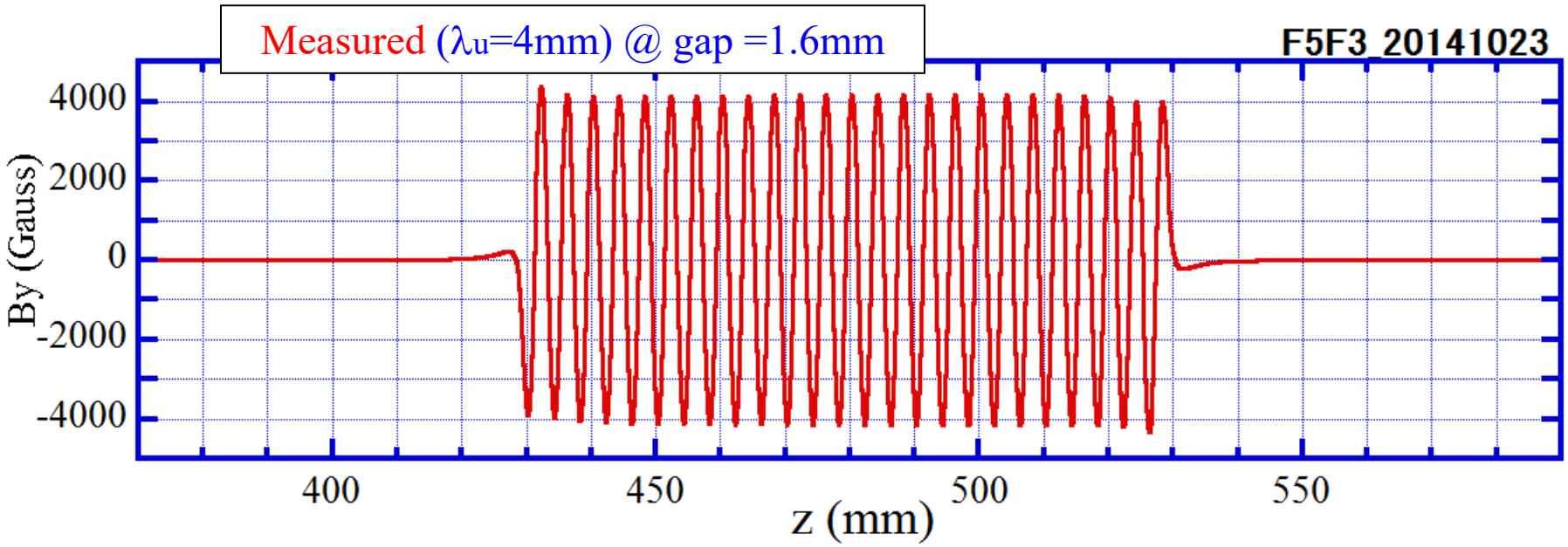
Measurement @ fixed gap=1.6mm

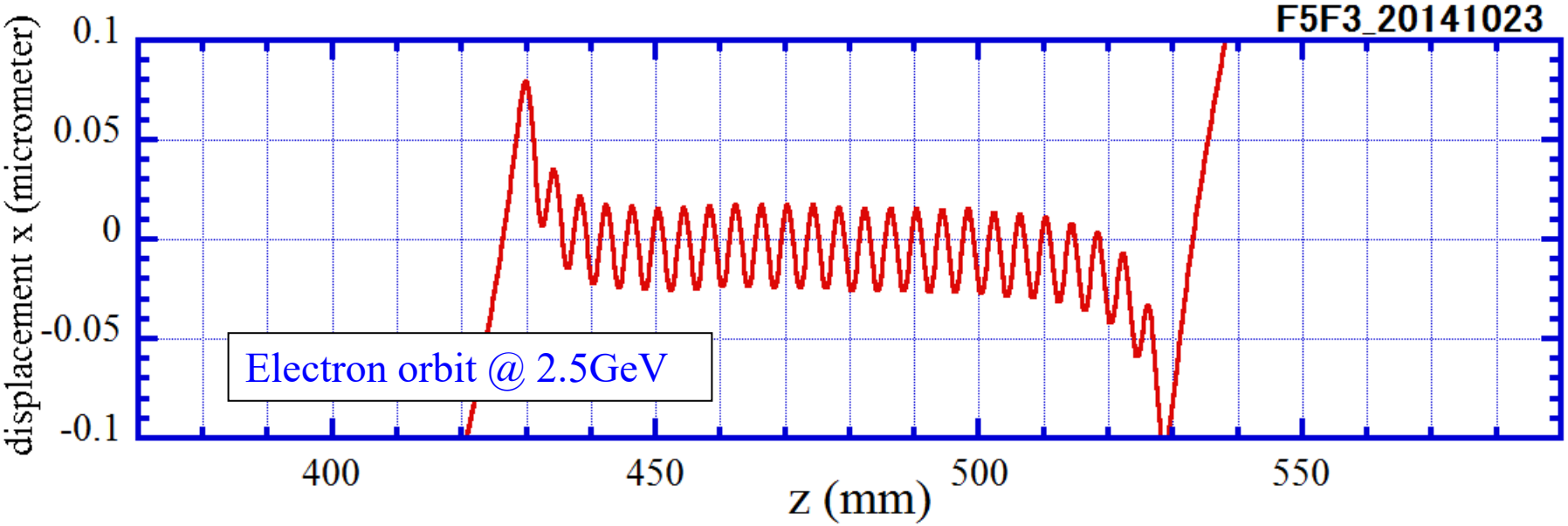


Hall probe ~1.3mm thick with 0.05 x 0.05 mm^2 resolution

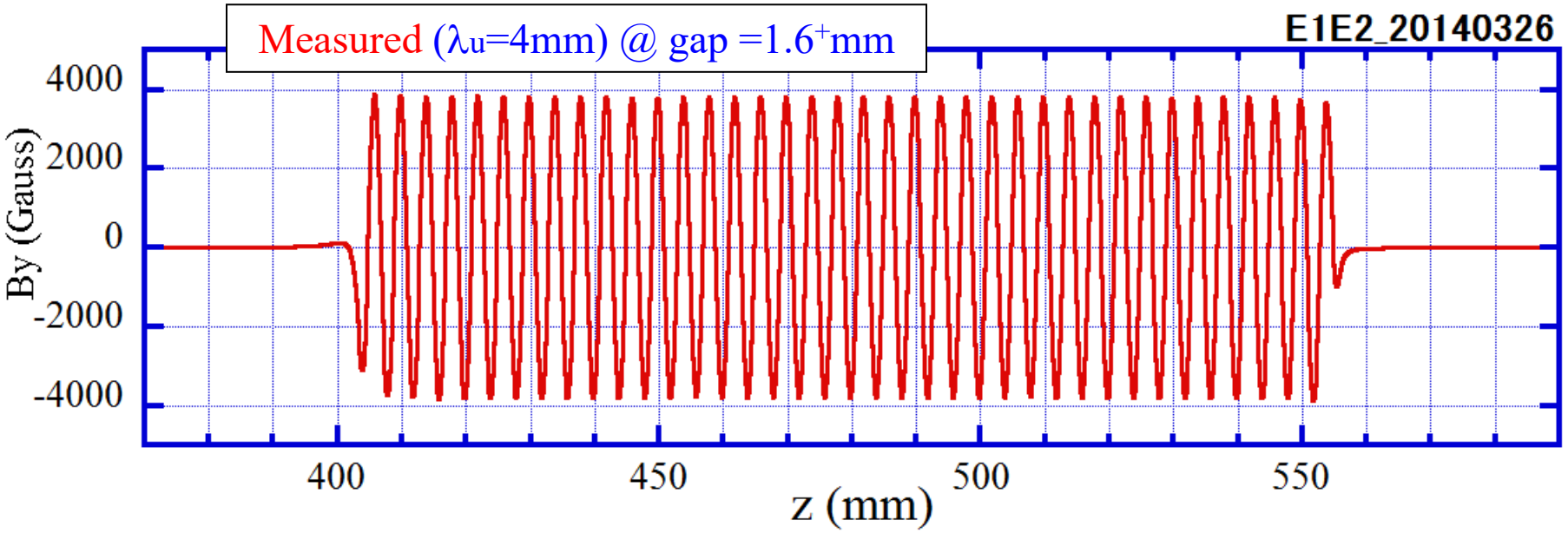
Gap > 1.6mm

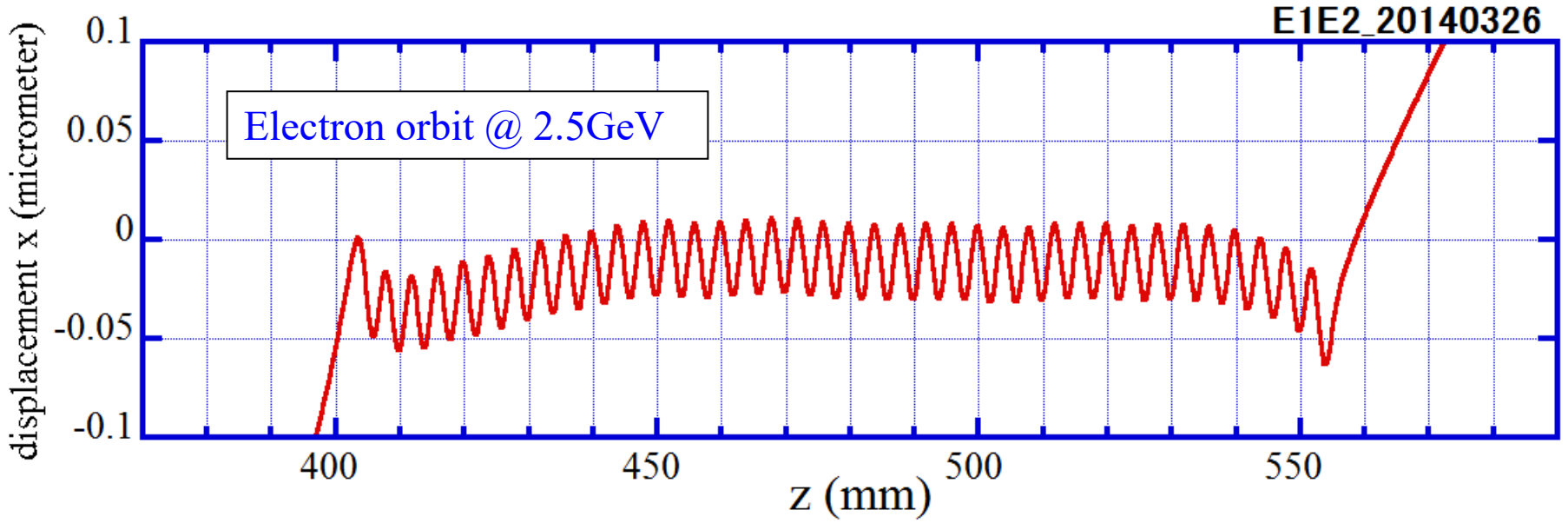
3. Field measurement & characterization





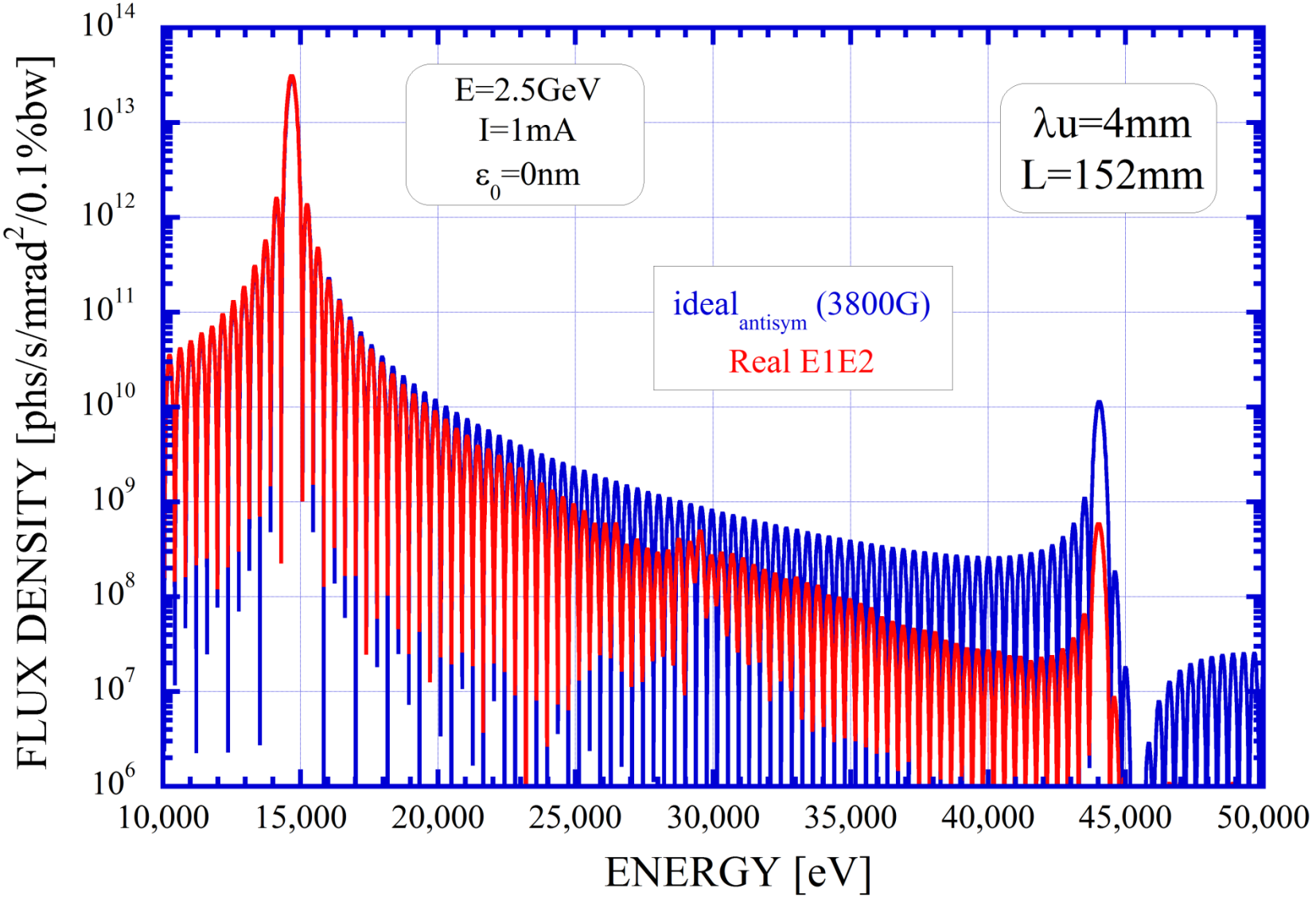
3. Field measurement & characterization





3. Field measurement & characterization

Measured field is compared to ideal field with the same strength

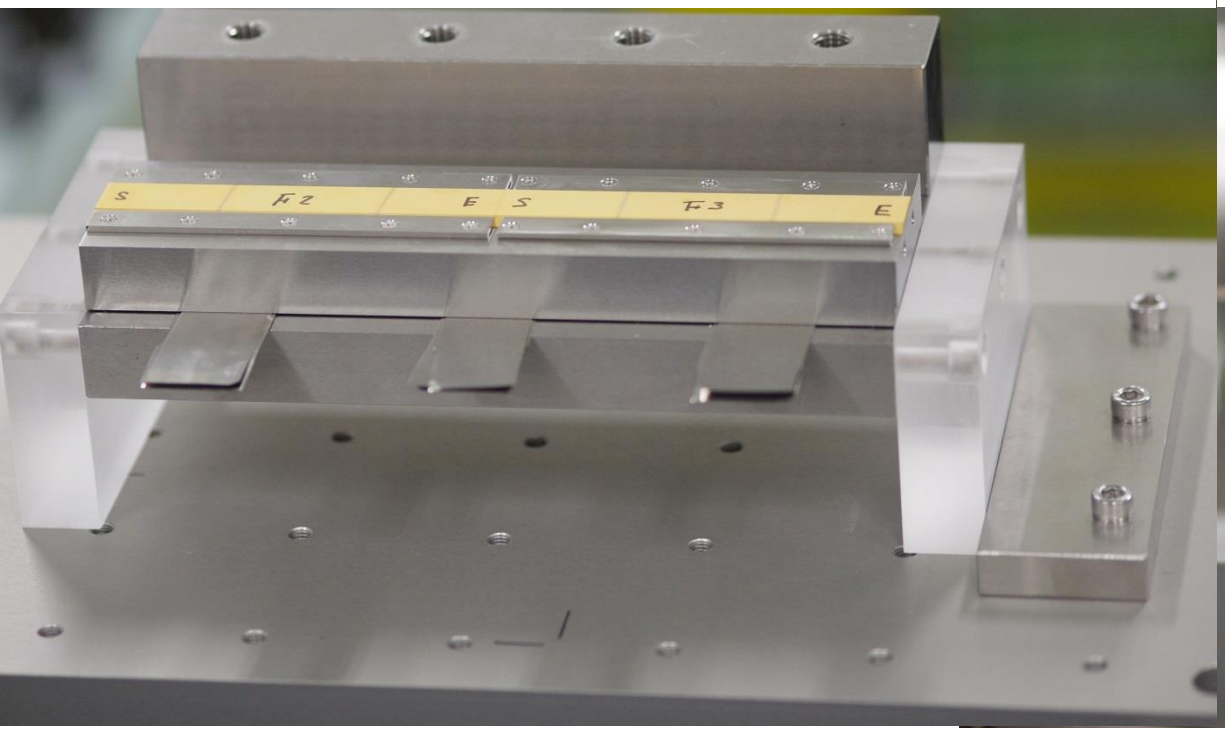


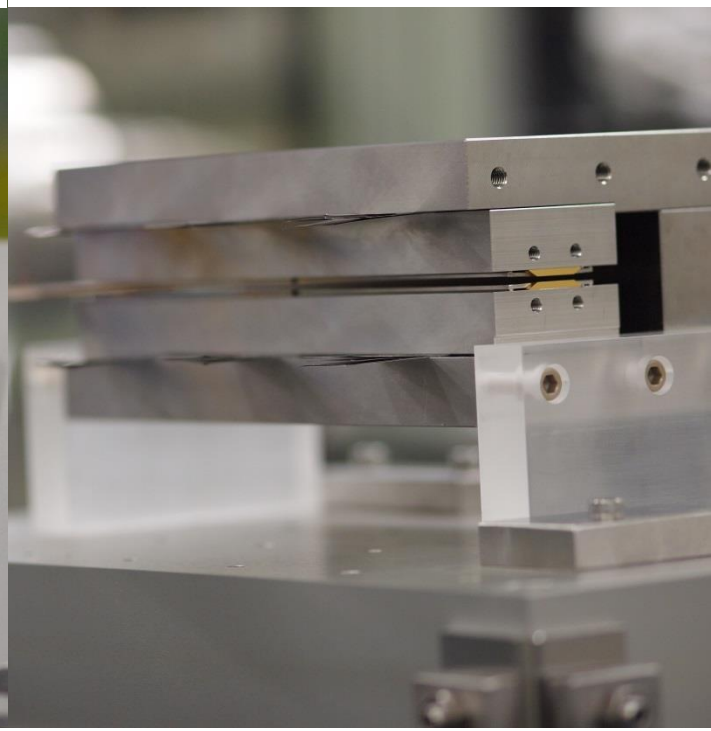
Undulator field (λ_u = 4mm) of 3800G @ gap=1.6mm

4. Magnet elongation

We need a new method to elongate the undulator length by connecting magnets, since the magnets longer than 200mm may not easy to fabricate.

Two plates are magnetized independently and then connected longitudinally.

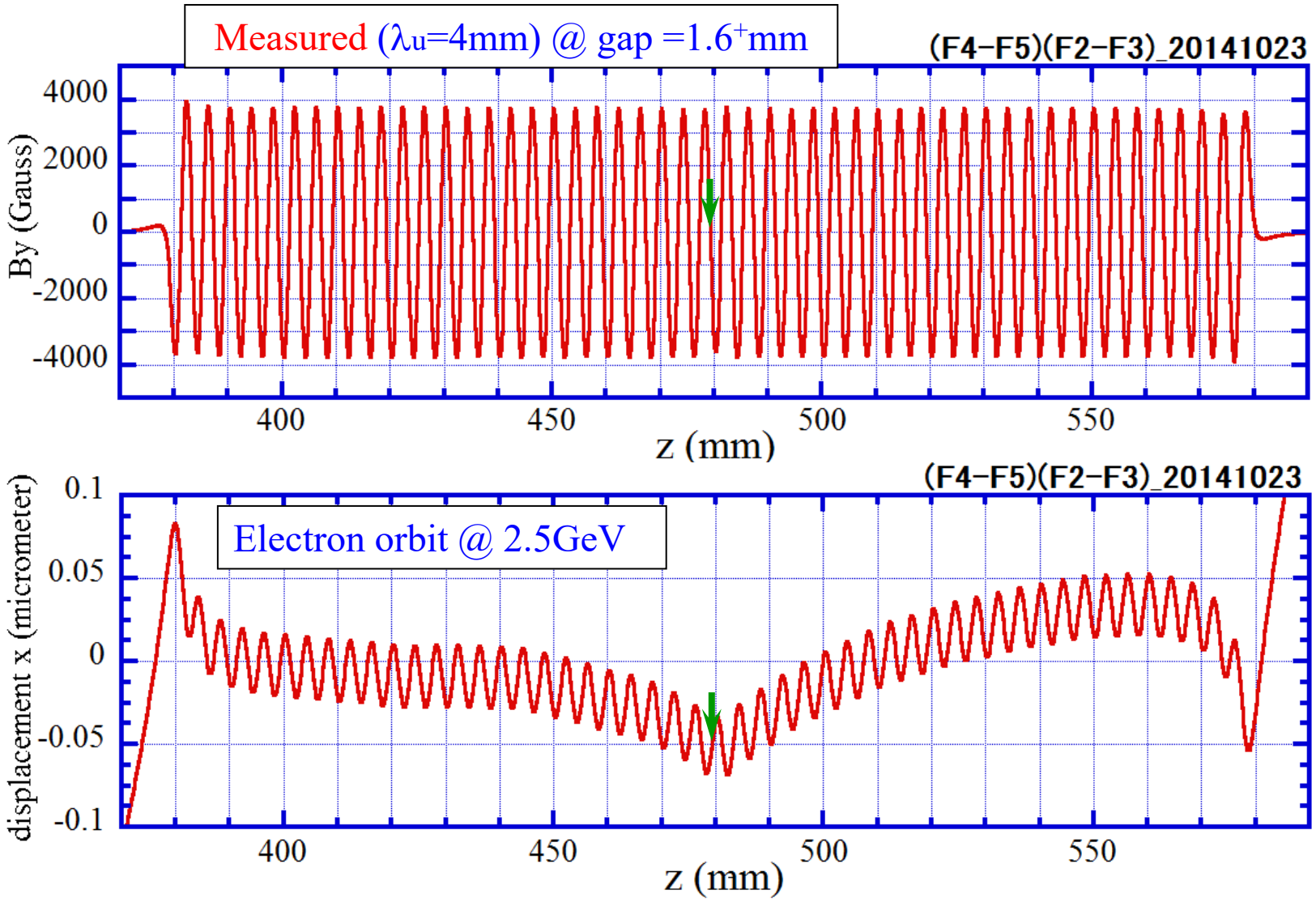




NMX-39EH TiN coated (Br =12kG, iHc=25kOe)
100 long, 20mm wide, 2mm thick

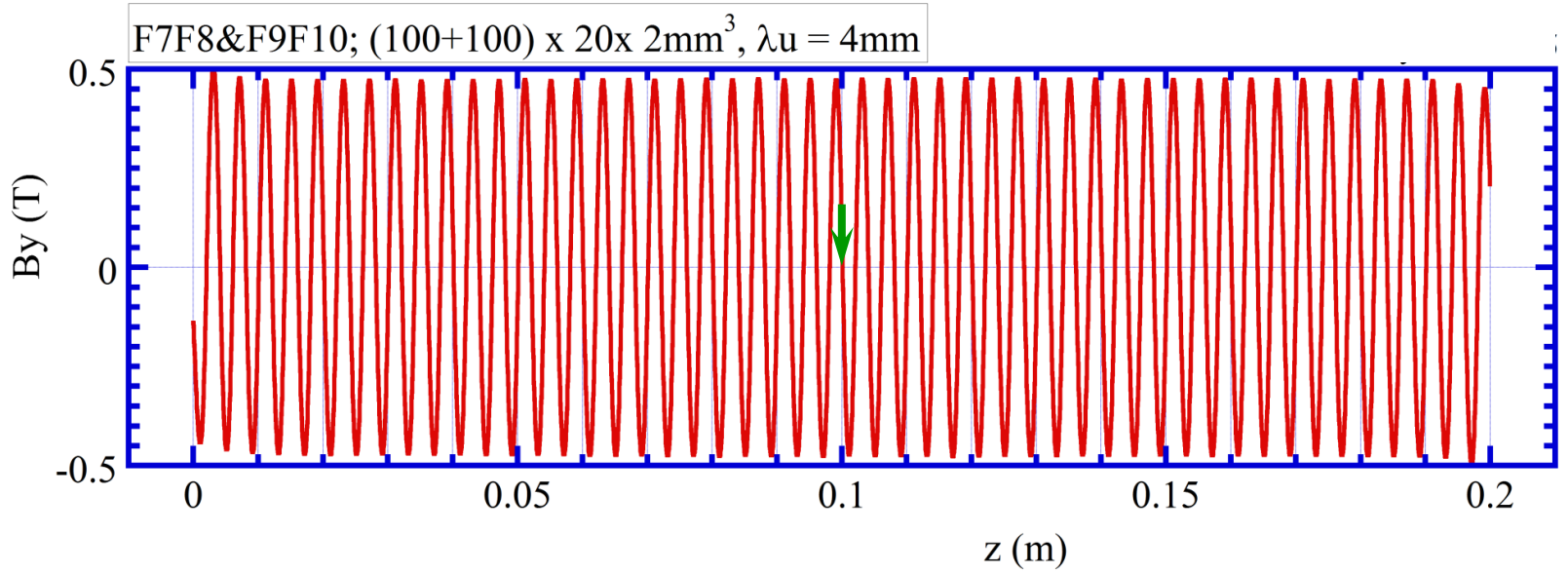
4. Magnet elongation 1

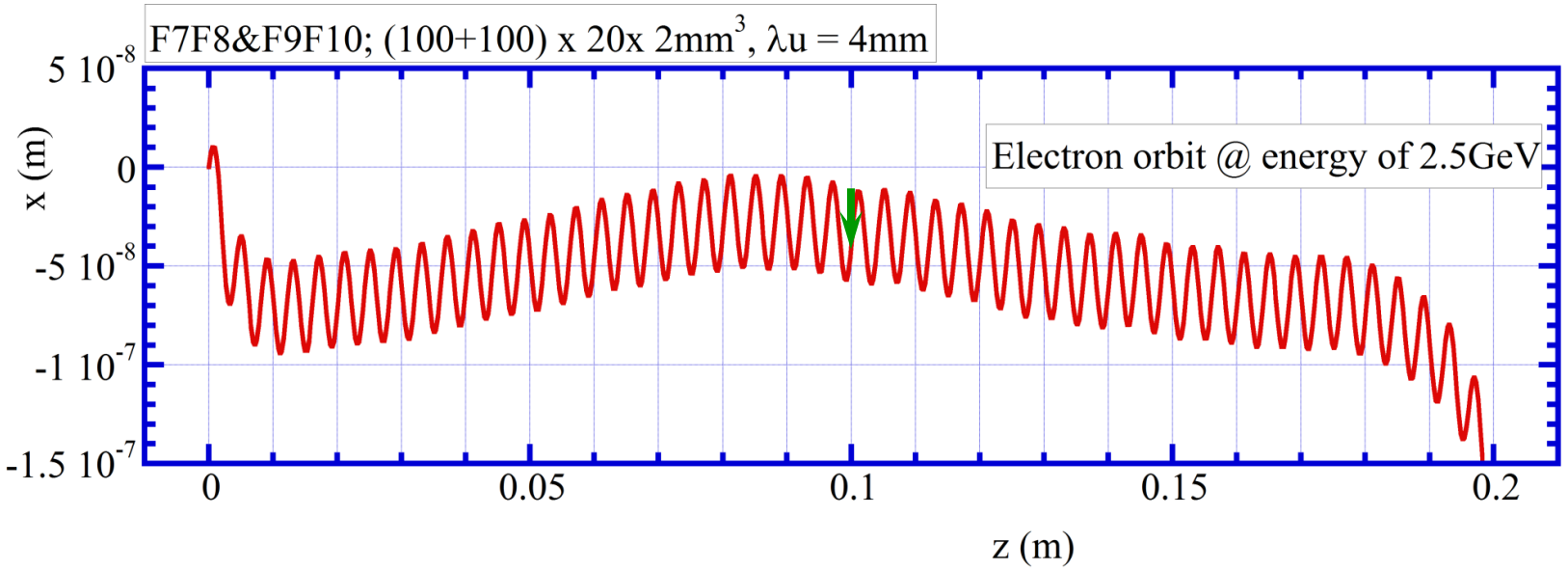
Connection of magnet plates magnetized independently



4. Magnet elongation 2

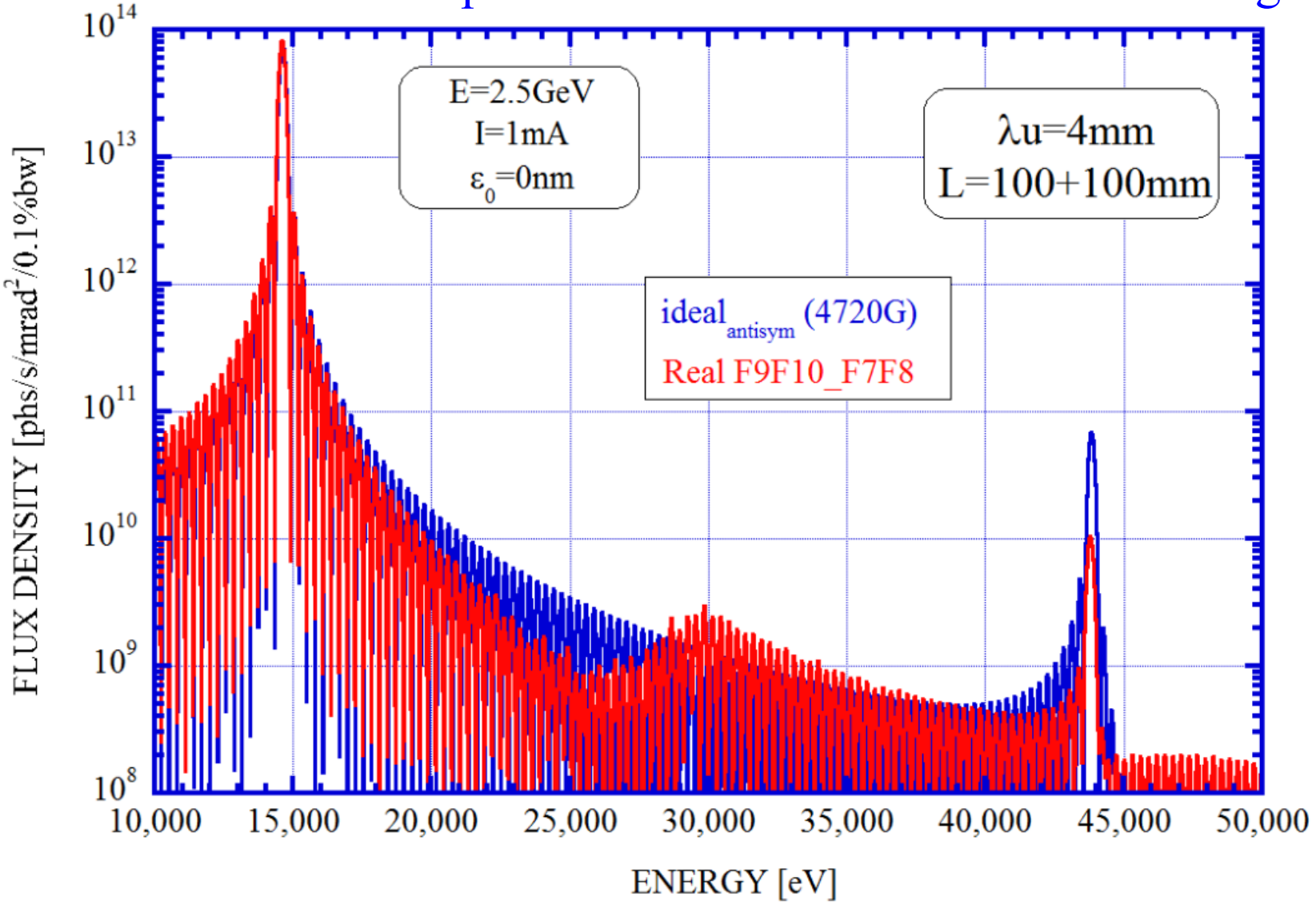
Magnet plates magnetized as one plate





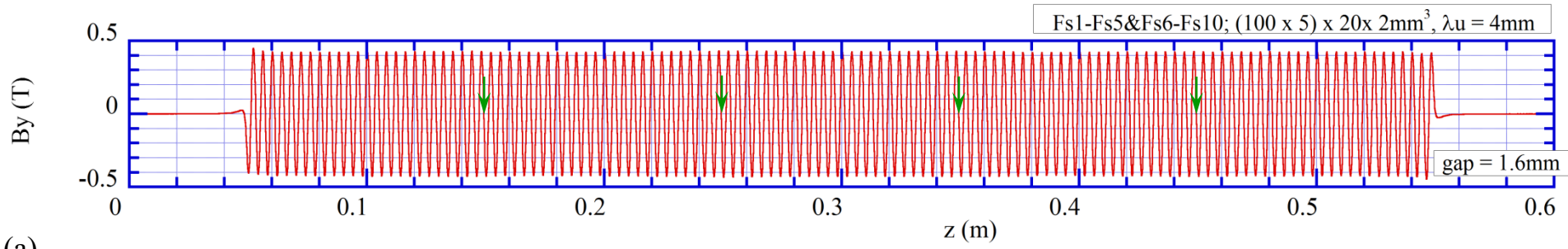
4. Magnet elongation 2

Measured field is compared to ideal field with the same strength

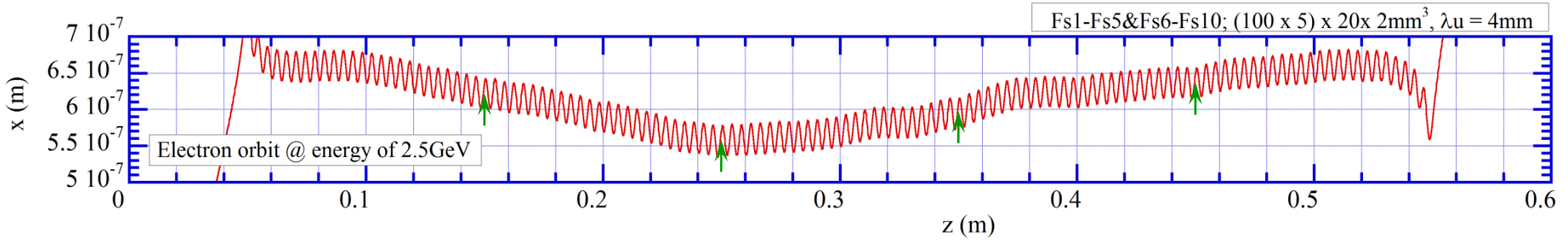


Undulator field (λ_u = 4mm) of 4720G @ gap=1.2mm

4. Magnet elongation 2



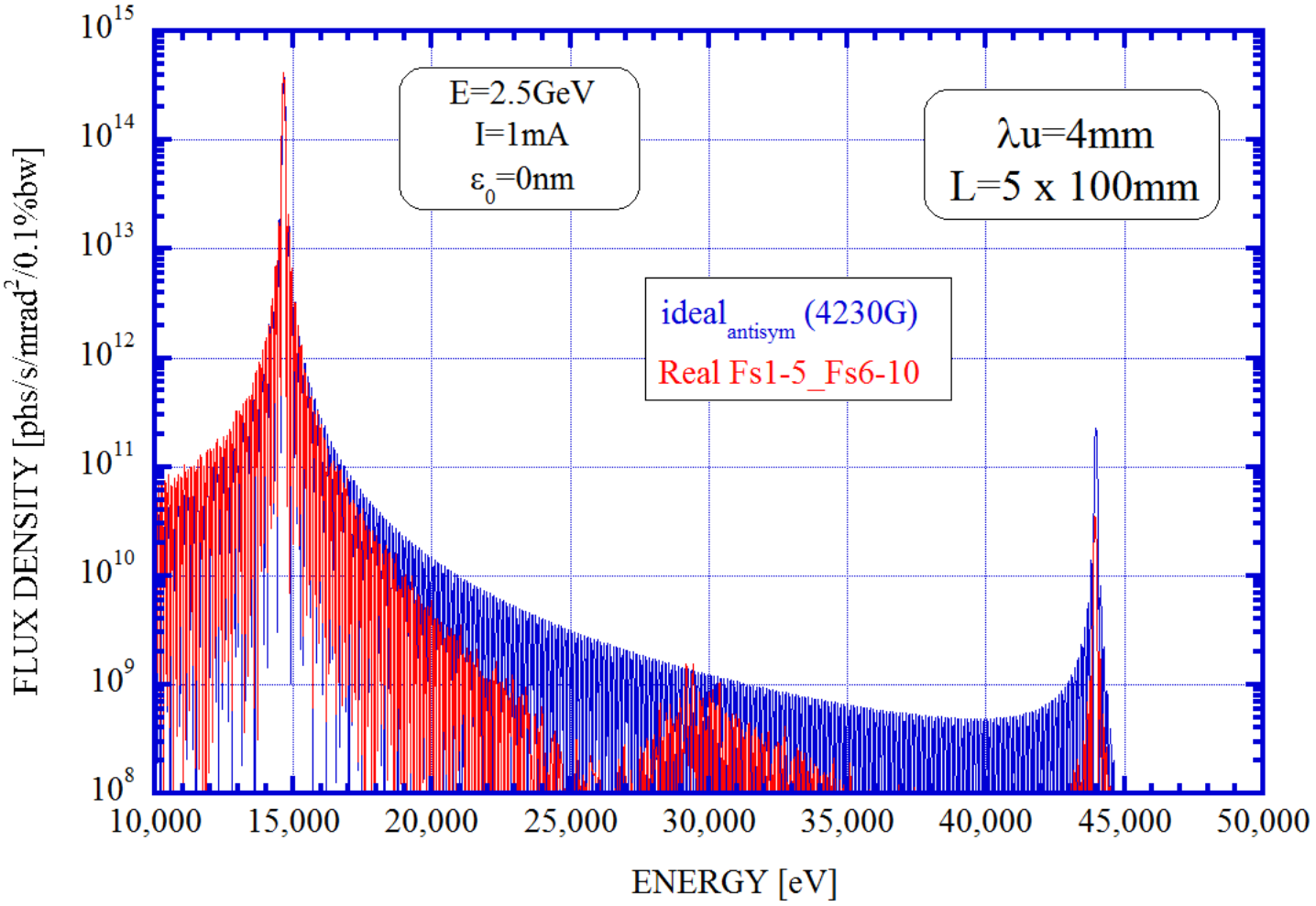
(a)



(b)

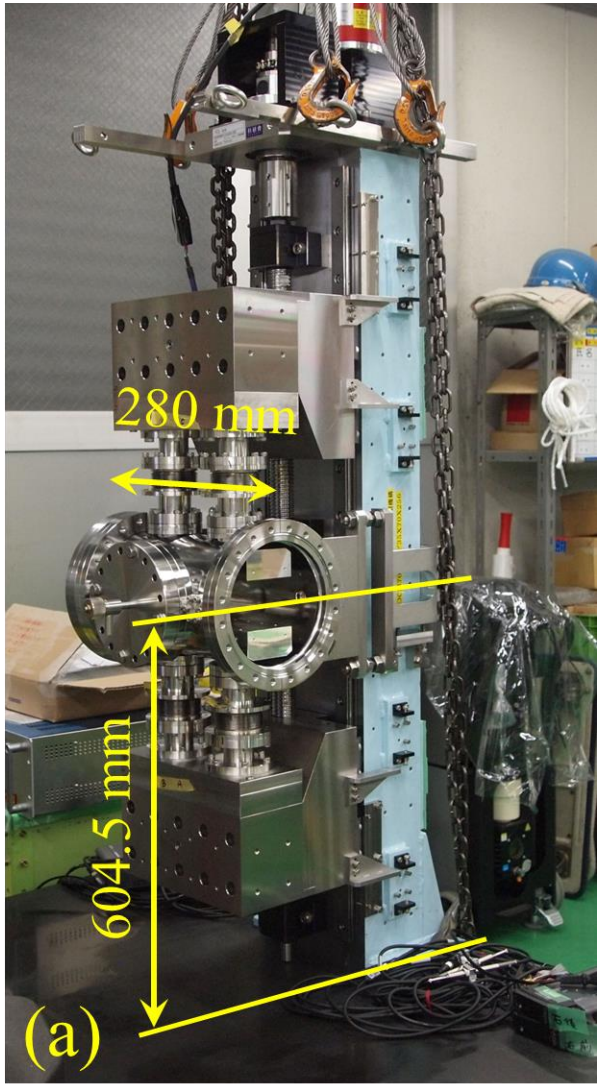
4. Magnet elongation 2

Measured field is compared to ideal field with the same strength

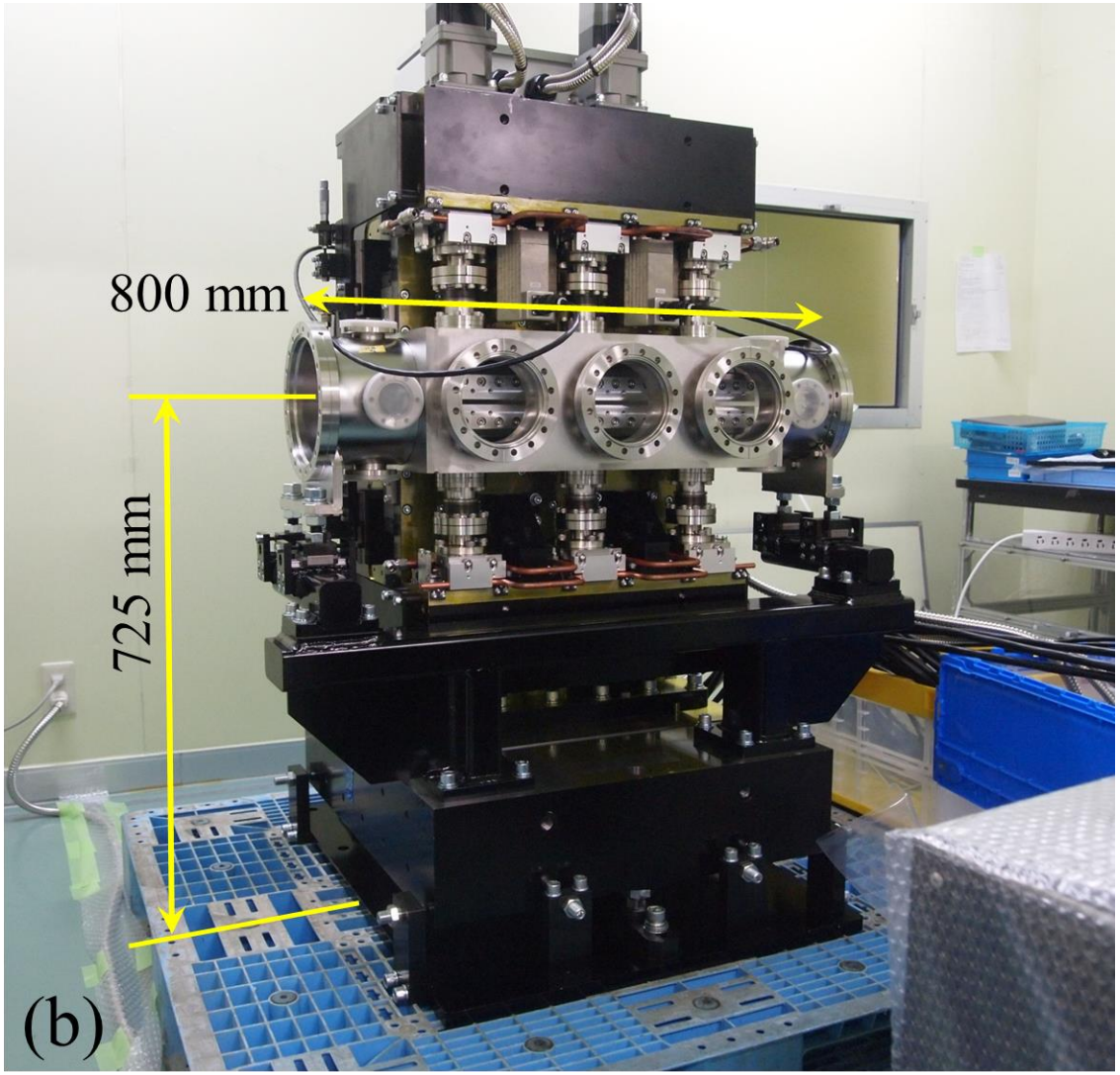


Undulator field (λ_u = 4mm) of 4230G @ gap=1.6mm

4. Magnet elongation 2: construction of mechanical frames

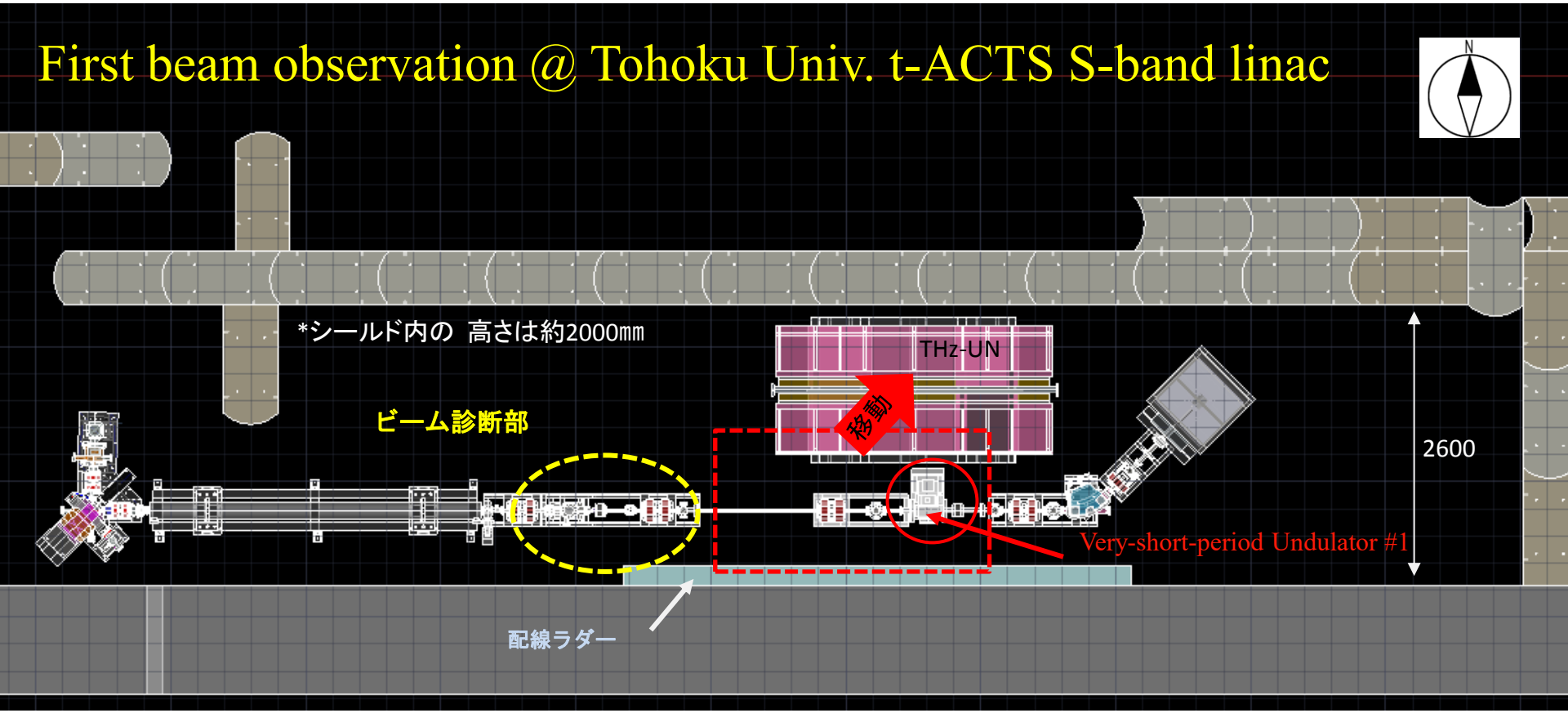


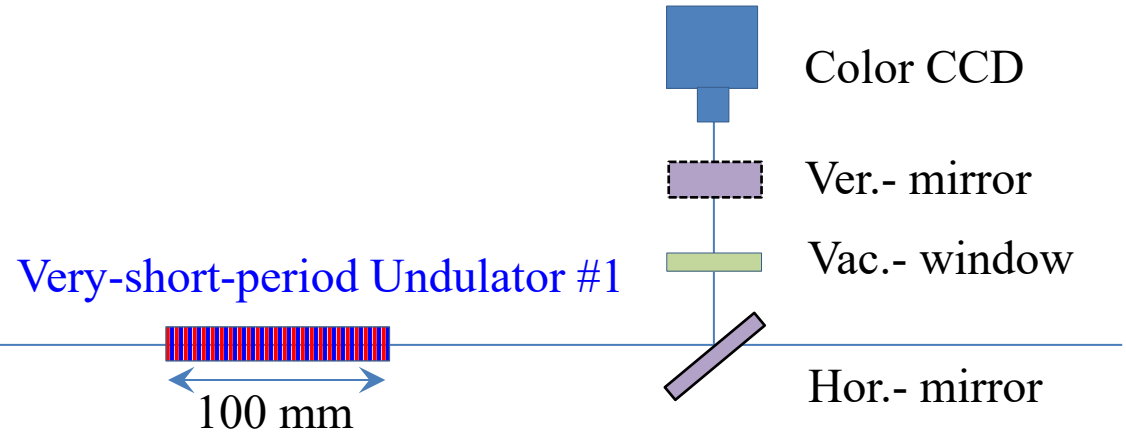
Very-short-period Undulator#1
for use @ Tohoku Univ.
S-band Linac



Very-short-period Undulator#3
for the use in Laser-wake filed acceleration
facility @ SP-8

5. Observation of the first light



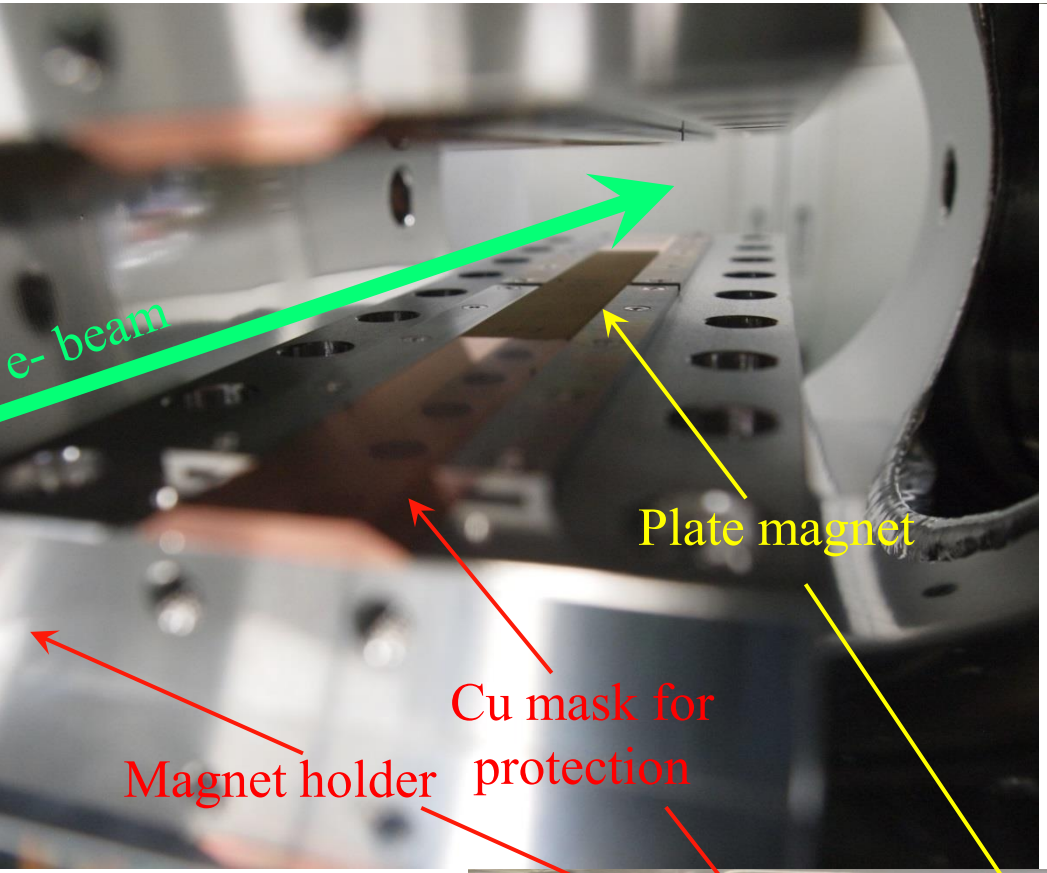


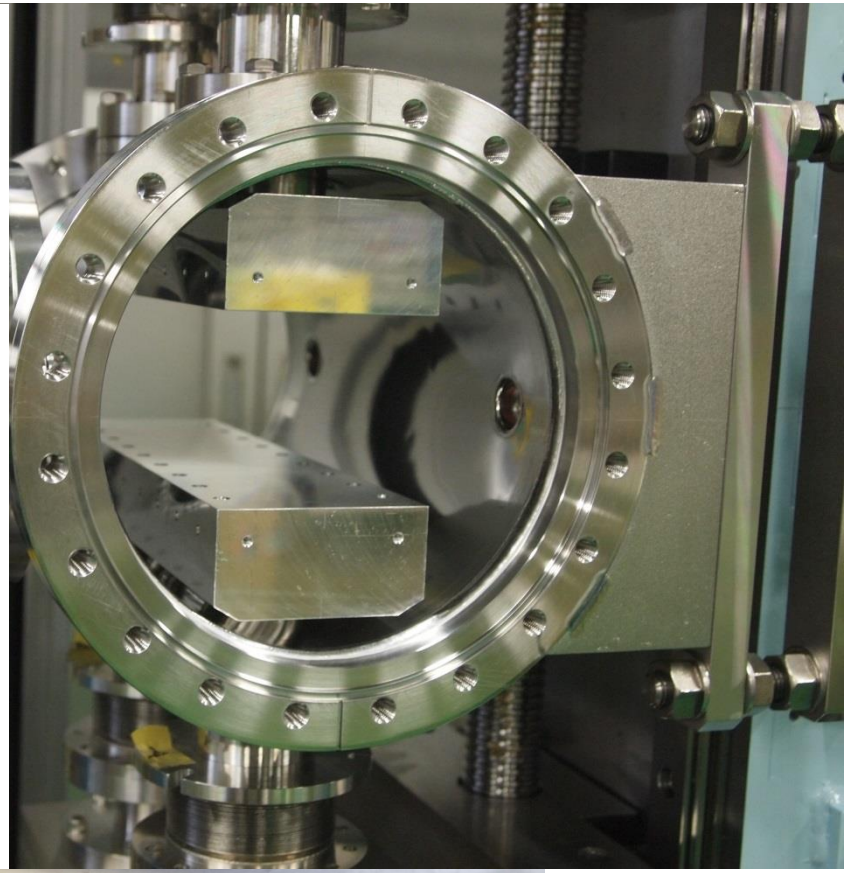
Linac: 2Hz operation
E = 34MeV
1 macro-pulse =3.5pC x 5700 μ bunch
ε_n = 1mm mrad (H), 3mm mrad (V)
σ_y = 250μm

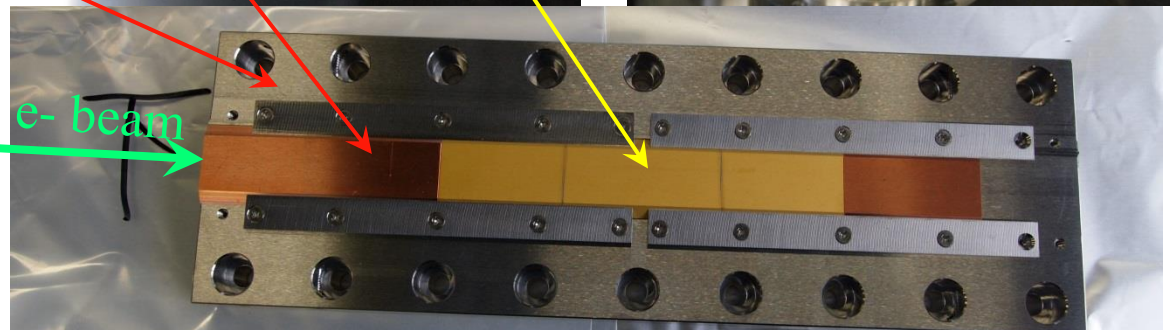
Beam trans. > 90% @ gap = 1.7mm

5. Observation of the first light

Installation of 100-mm long magnets
into the frame of the Very-short-period Undulator #1







6. Summary

We have been resolving major subjects and taking the right direction to develop the very short period undulaotrs.

We have very clear perspective to make a very-short-period but long undulator magnet.

Also, we believe that the present successful result of the first light observation will be followed by the experiments combined with a laser-accelerated electron beam in the near future.

I am happy if this technology is useful to compactify light source system including FEL & ring type SR sources.

R&D for the very short period undulators

極短周期アンジュレータ研究開発

supported by:

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