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CHUBU
Electric Power

Mechanical strength evaluation of Yoroi-coil structured non-circular REBCO pancake coil in high magnetic field

Tomonori Watanabe, Shigeo Nagaya : Chubu Electric Power Co., Inc.
Atsushi Ishiyama : Waseda University
So Noguchi : Hokkaido University
Hiroshi Ueda : Okayama University
Gen Nishijima : National Institute for Materials Science

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Contents

Introduction

High intensity and Compact multifunctional cyclotron

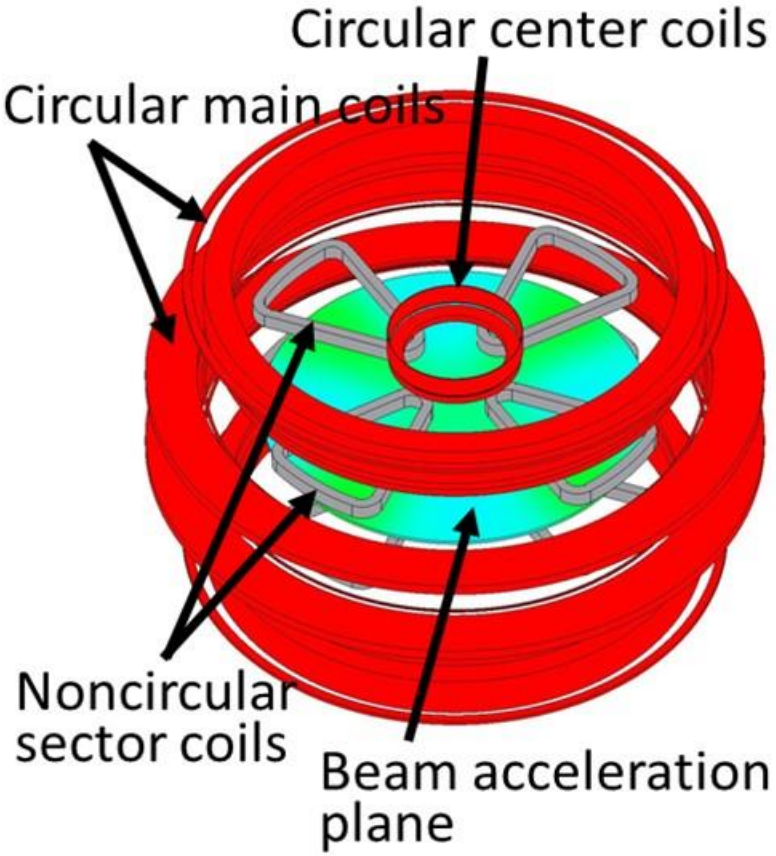
Main coils, Center coils : circle

Sector coils : non-circle

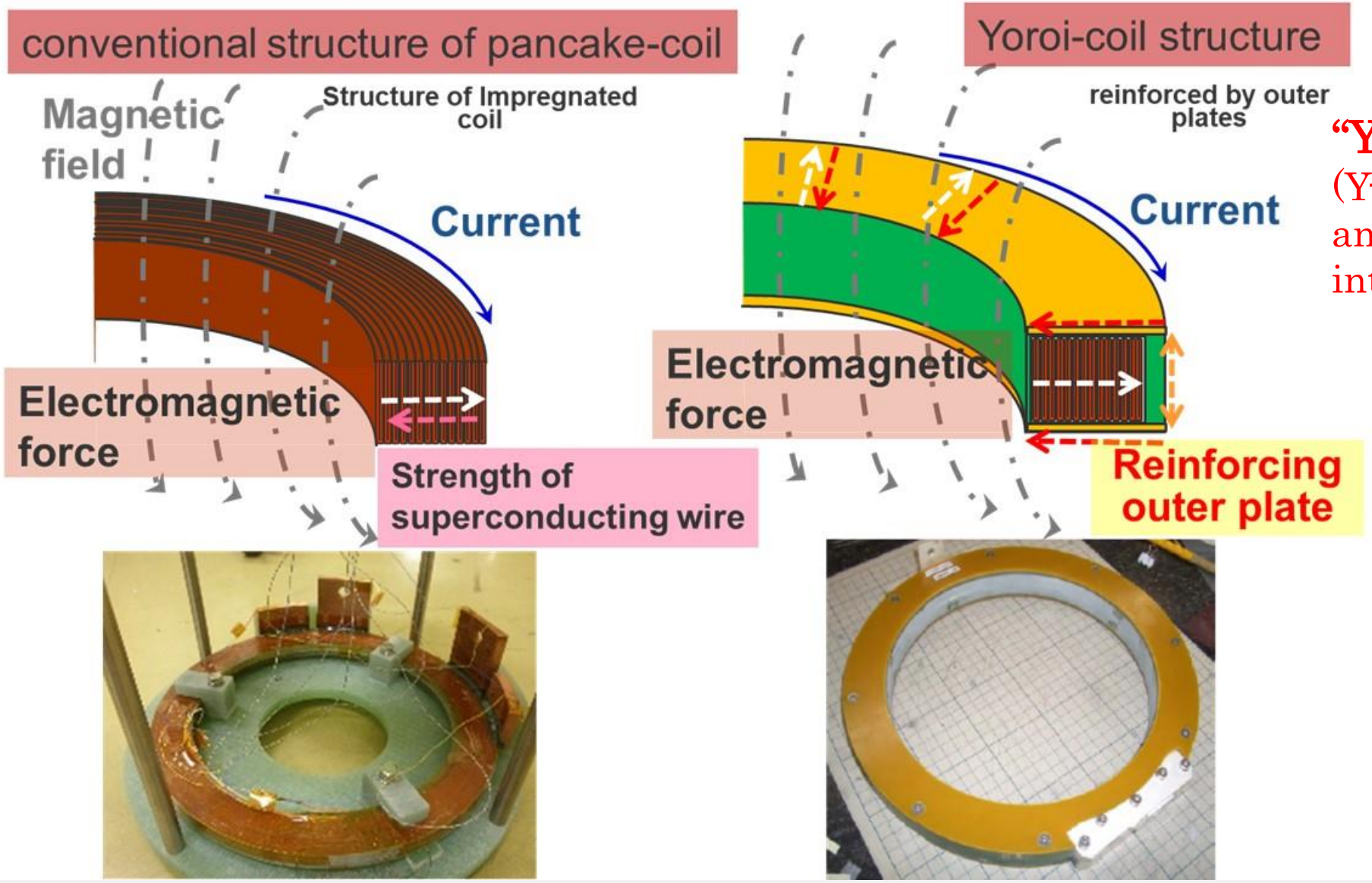
Sector coils

exposed ～several T

current density ～several hundred A/mm^2



Introduction



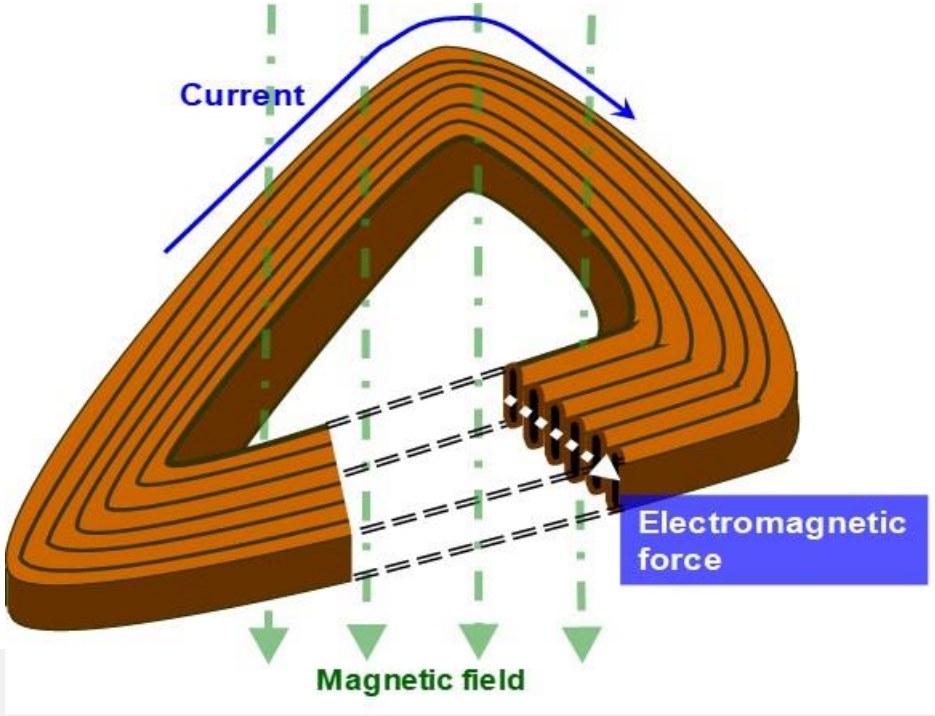
“Yoroi-coil”
(Y-based oxide superconductor and reinforcing outer integrated coil)

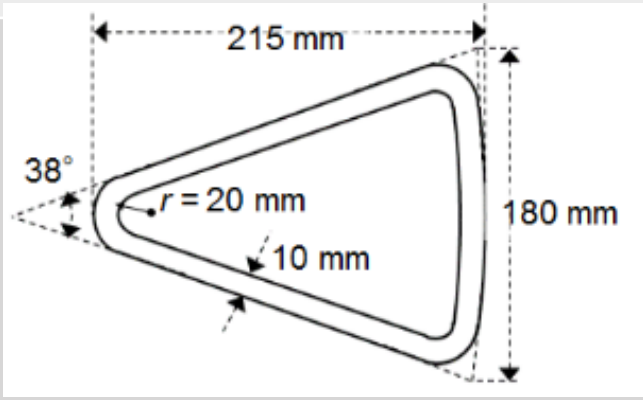
REBCO coated conductor and the reinforcing outer plates of the coil cooperate and withstand electromagnetic force.

Experiment – Preparation of Test coils

Test coil windings
Isosceles triangle shaped double-pancake coil

REBCO tape
Hastelloy Substrate : 50 μm thick
REBCO layer : about 1 μm
Winding : Metal Insulated NI winding
Co-winding: stainless steel



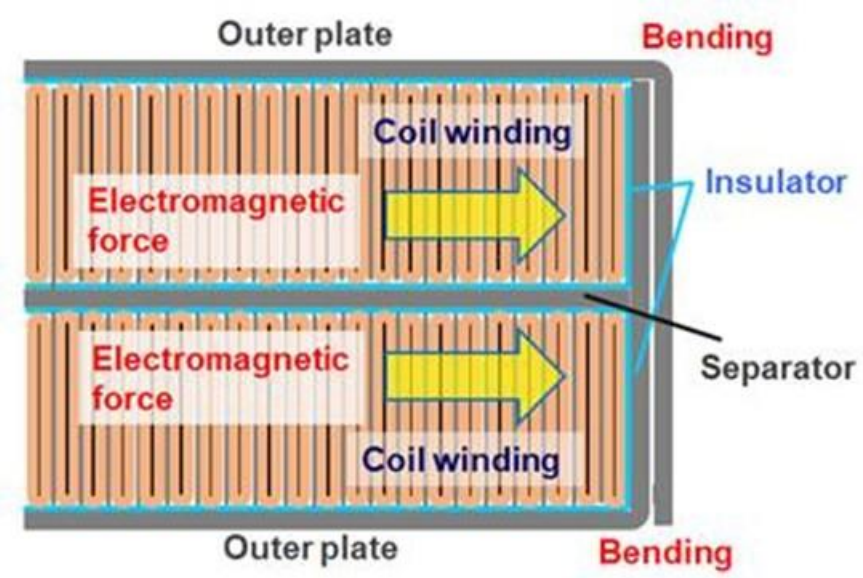
Coated conductor, length	20μm Copper plated REBCO tape, 75 m (Shanghai superconductor)
Width / Thickness of tape	6.1 mm / 100 μm
Critical current	> 180 A（1 μV / cm, 77 K）
Shape of coil winding	Hight of DP coil windings : 13.5 mm 
Co-winding	50 μm thick stainless steel tape
Number of turns per pancake	132 （66 per Pancake）

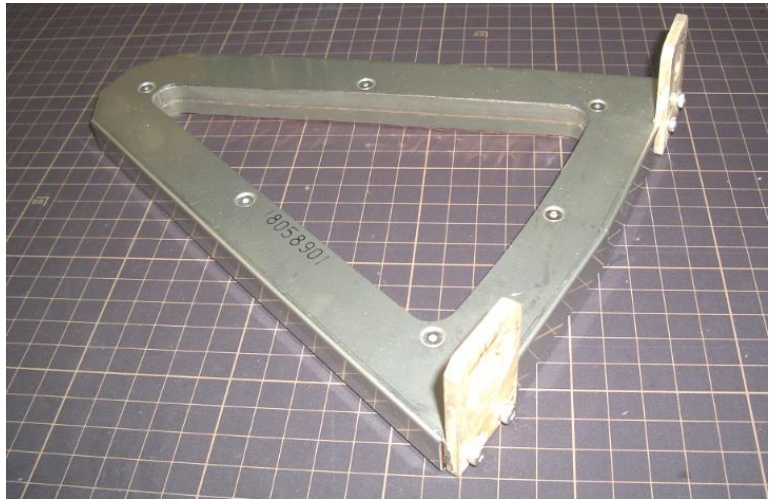
Experiment – Preparation of Test coils

Coil without reinforcement of Yoroi-coil structure

The frames of the coil were formed by bending the edges of outer plates

Thickness of plates : 0.5 mm



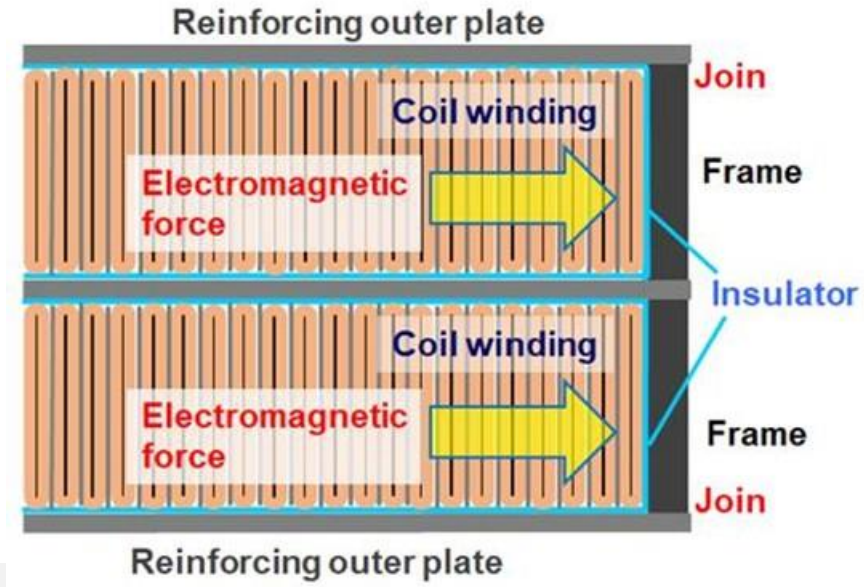


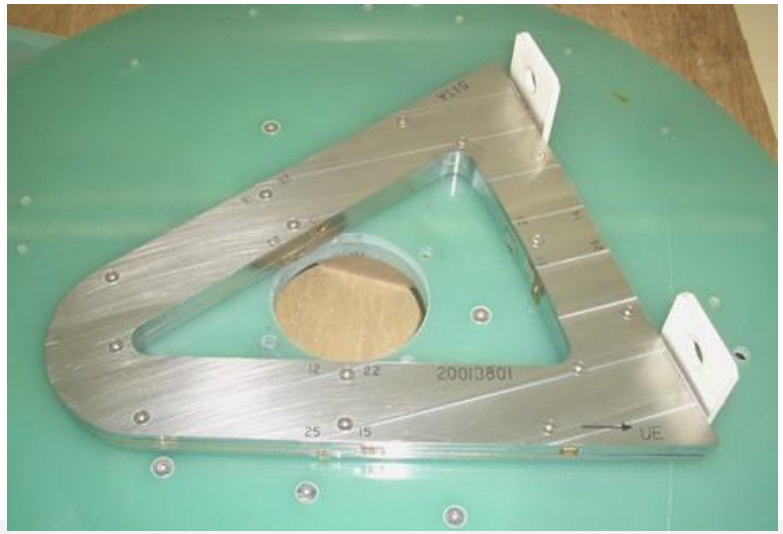
Reinforced coil with Yoroi-coil structure

The reinforcing outer plates are placed on the top surface and the base surface. The frame are connected to them by screws.

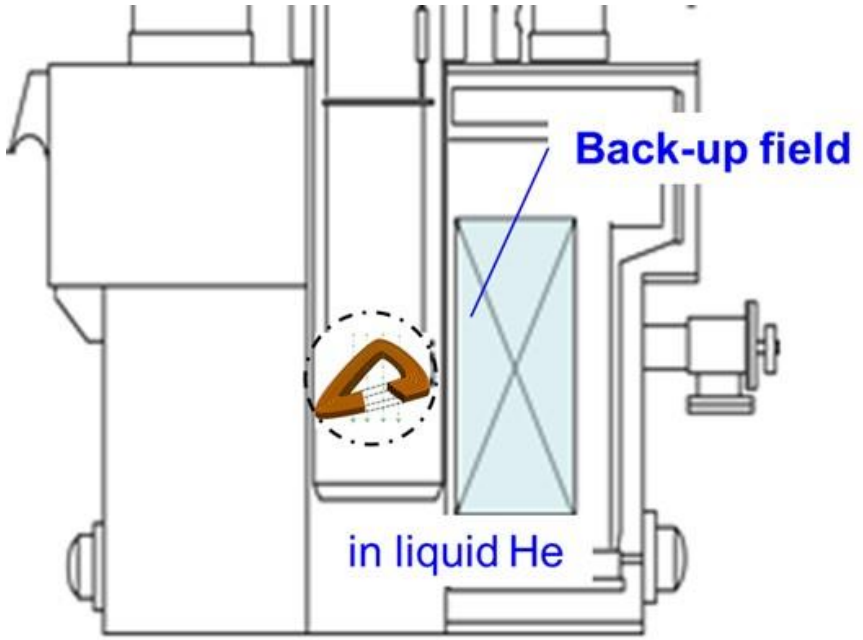
Thickness of plates : 1.5 mm (t)

Frame : 12 mm (t)



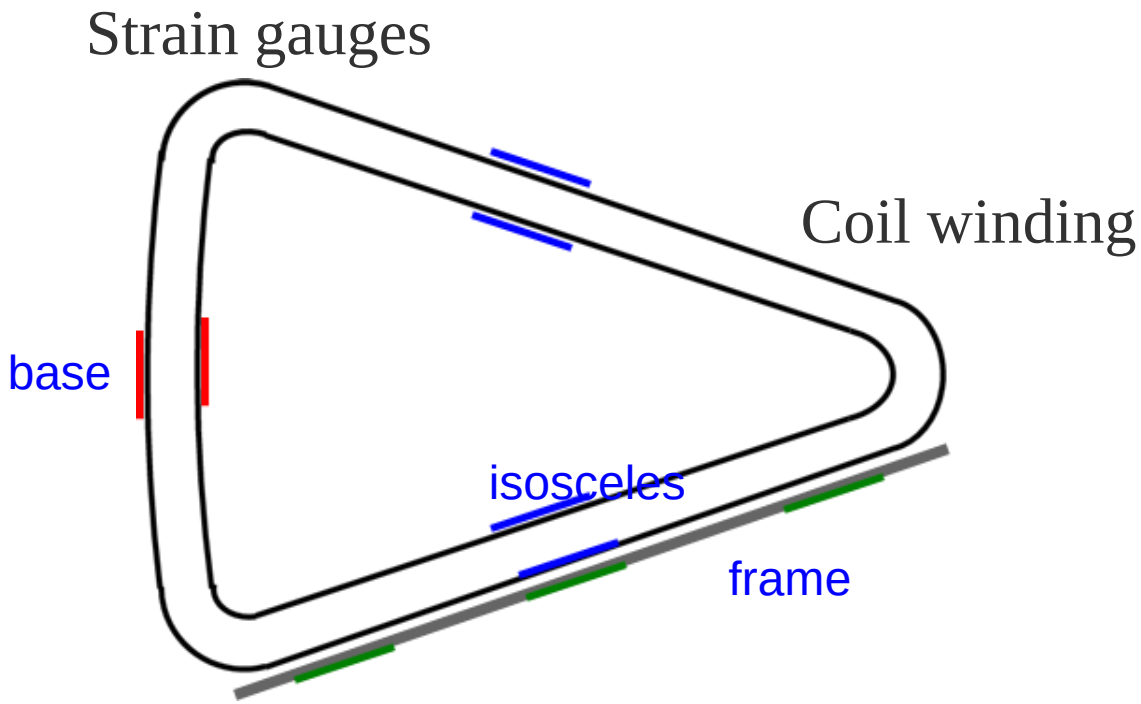


Experiment – Measurements



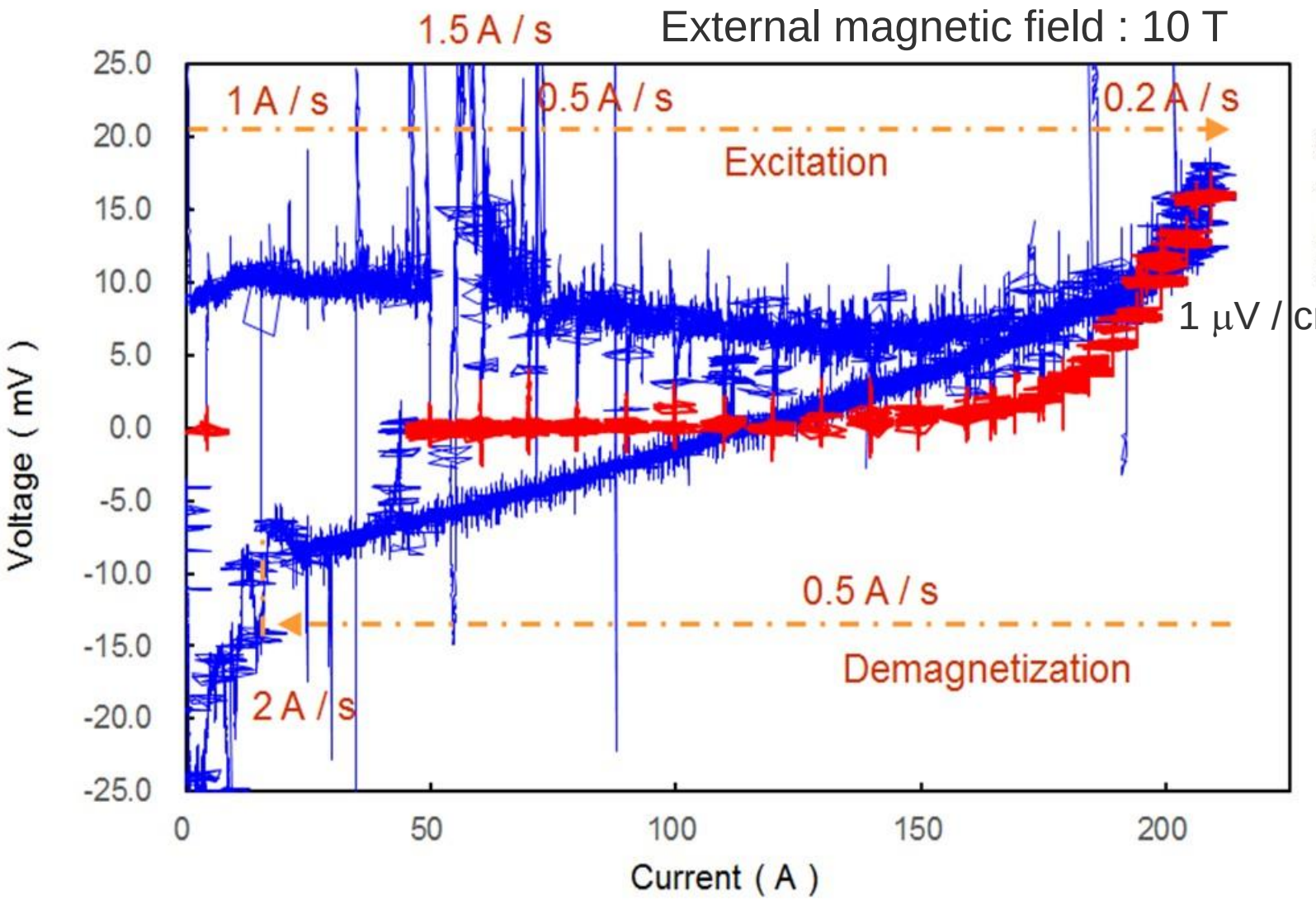
14 T large bore superconducting magnet at National Institute for Materials Science

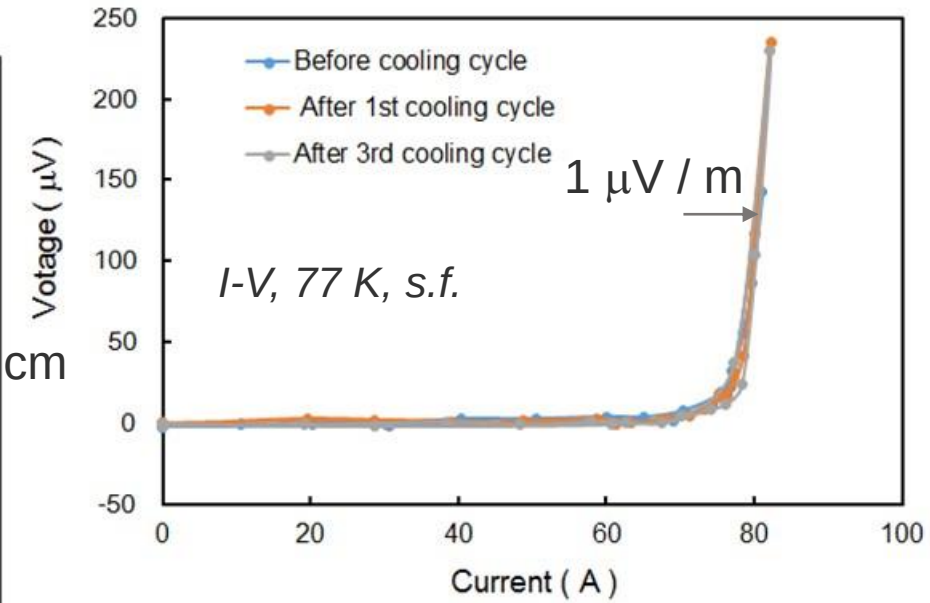
The DP coil was cooled down to 4.2 K with liquid helium immersion and external magnetic field was applied. Then coil current was flowed and ***I-V*** **characteristics** were measured by excitation.



Strains of coated conductor in the coil winding and frames were measured by strain gauges stuck on them.

Results（without Reinforcement）

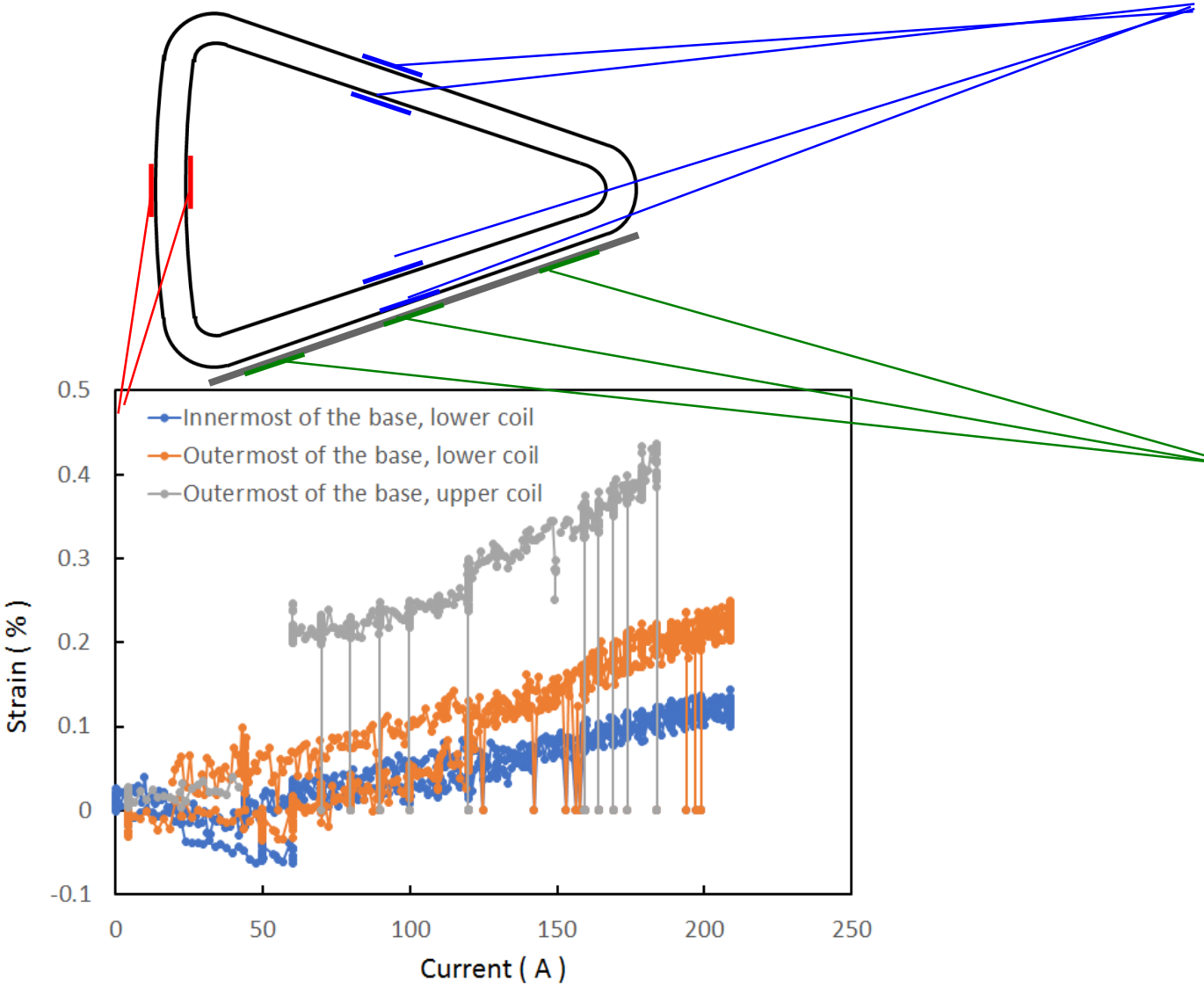


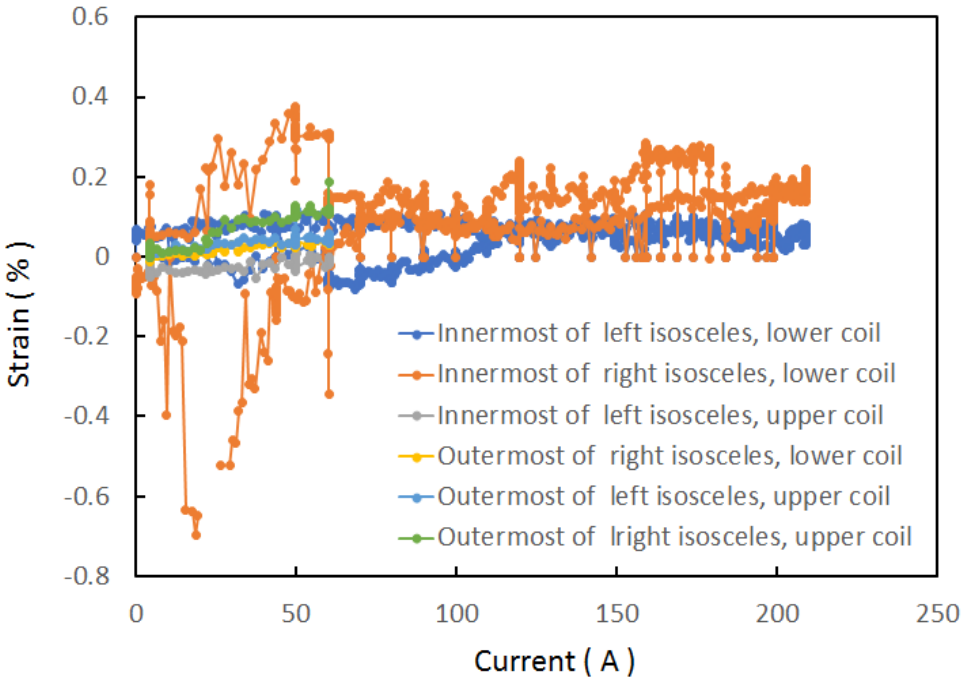


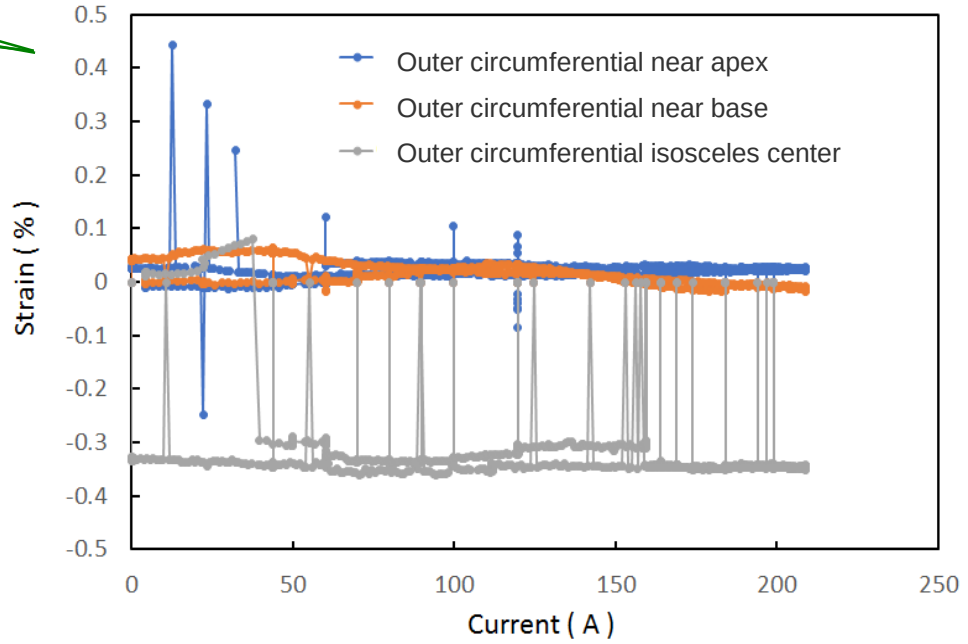
During demagnetizing (reducing the current), the voltage dropped linearly → Loss of superconductivity

NI coil winding
Sudden Voltage rise or thermal runaway was avoided.

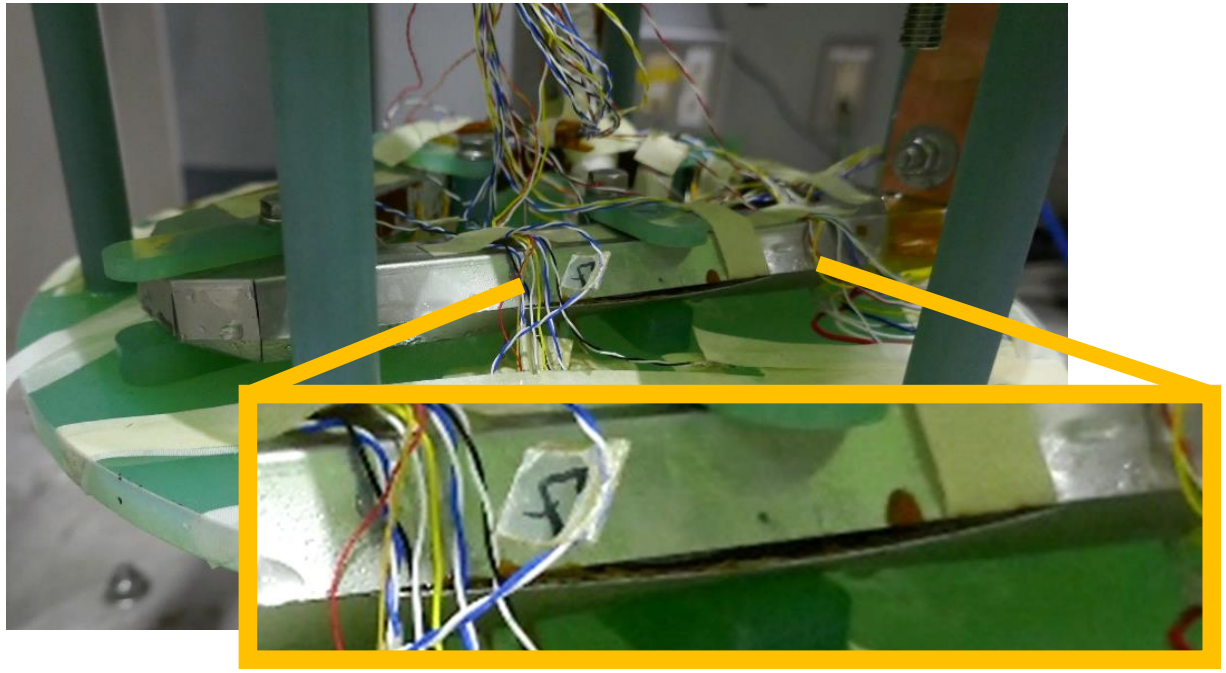
Results（without Reinforcement）







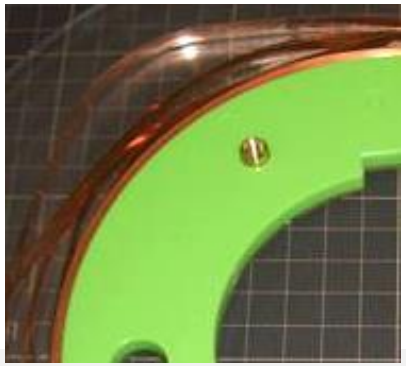
Results （without Reinforcement）



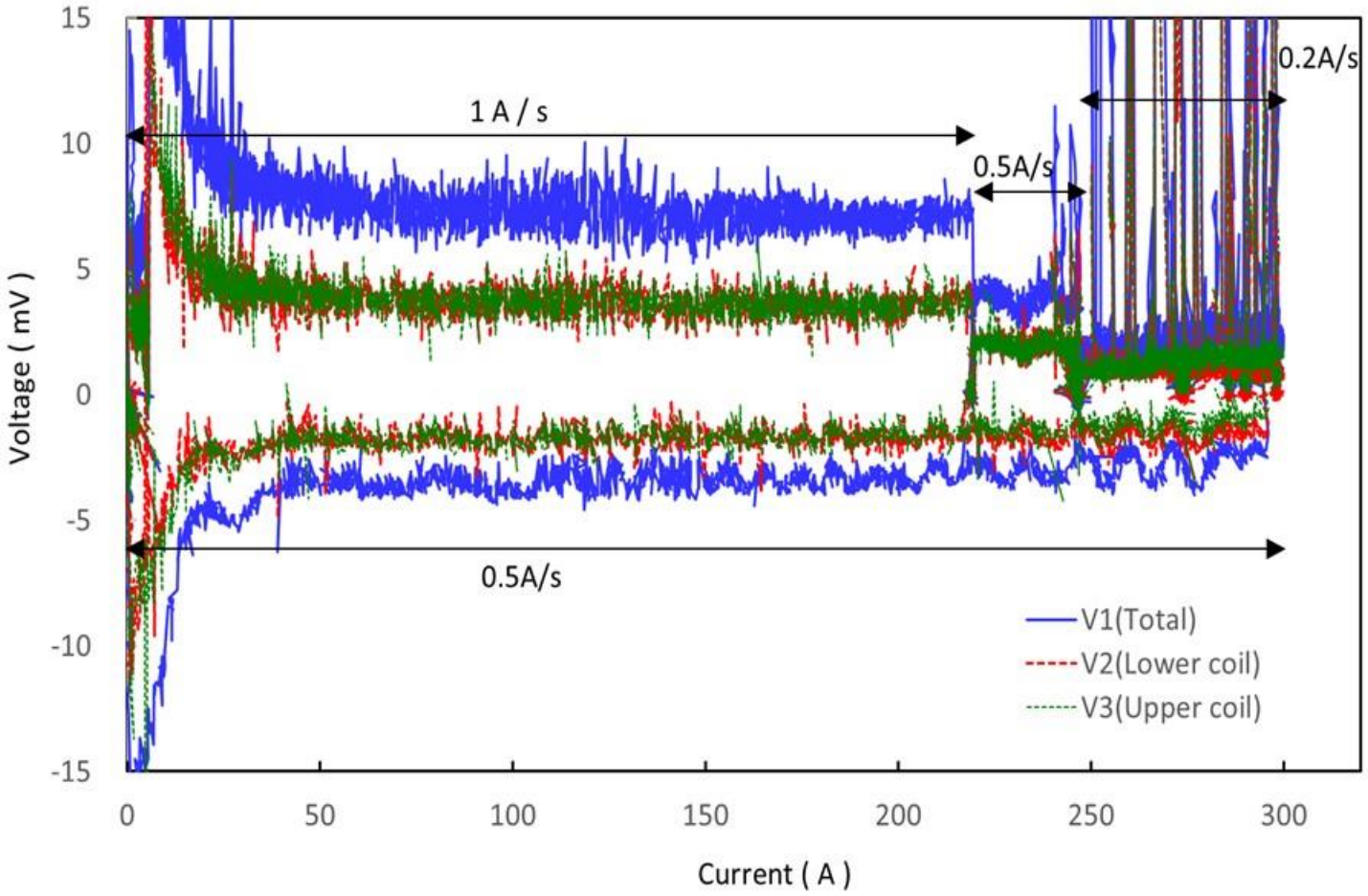
The edges of outer plates were opened outwards.

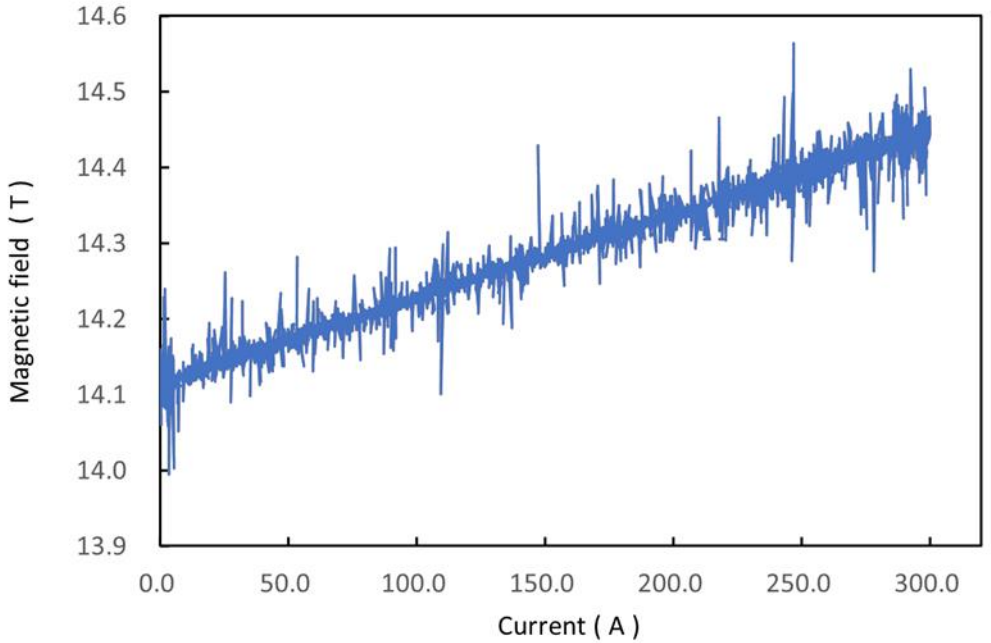
The coil winding was extended and deformed.

Lorenz force : 211.2 kN / m (160 A, 10 T)
Since the length of the isosceles side was 23 cm, a force of 48.6 kN (about 5 tons weight) per side acted.



Results（With Reinforcement by Yoroi-coil structure）

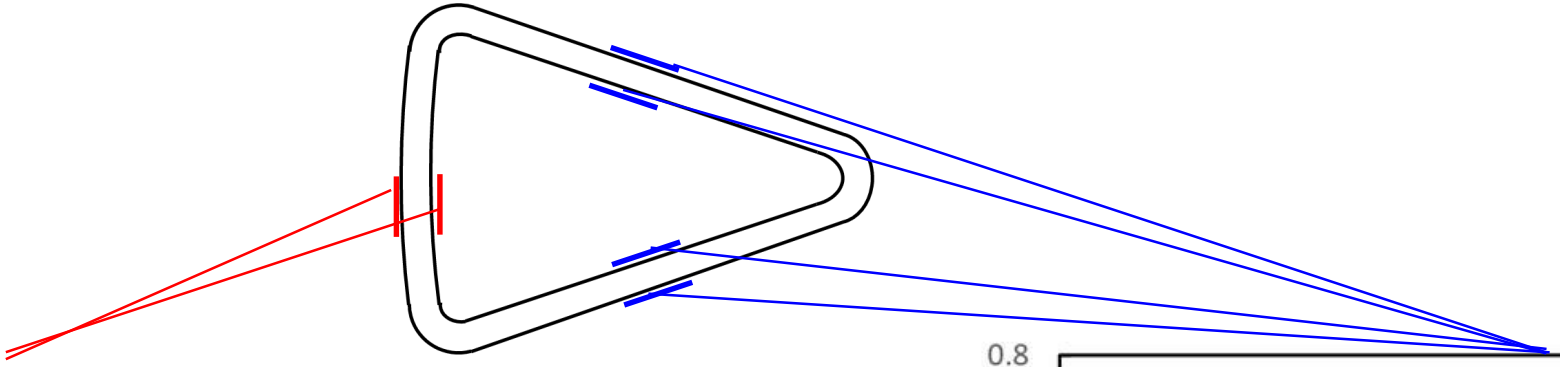


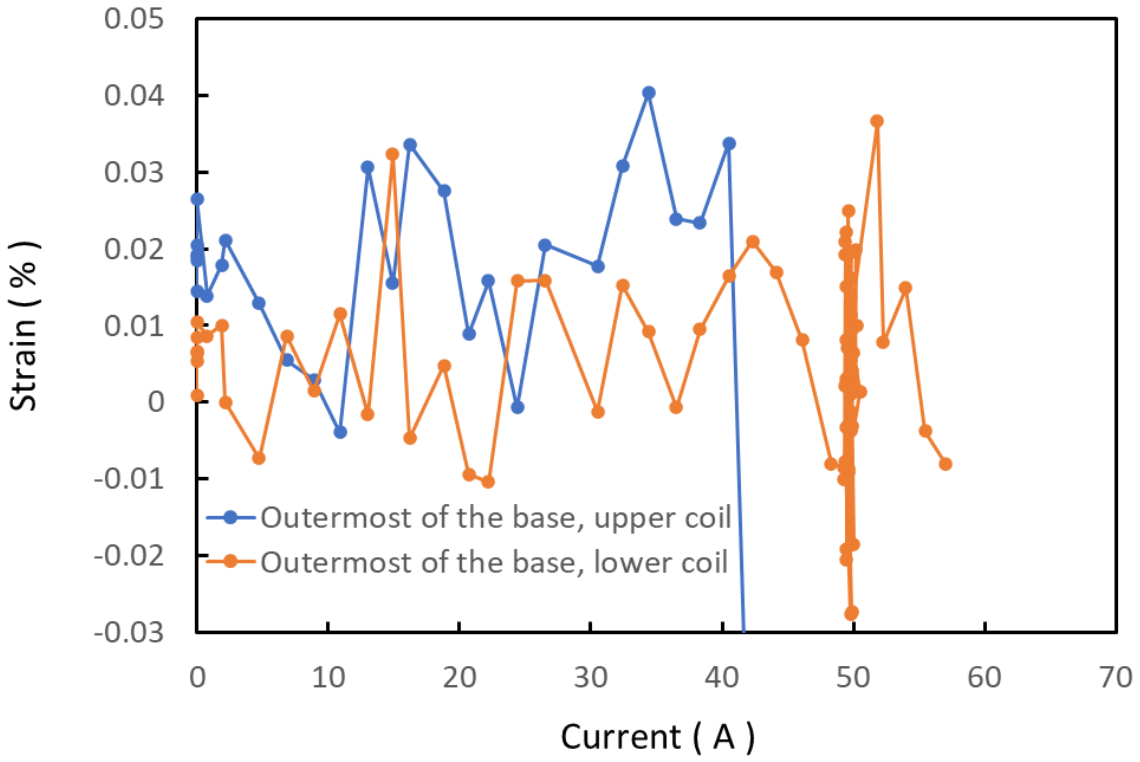


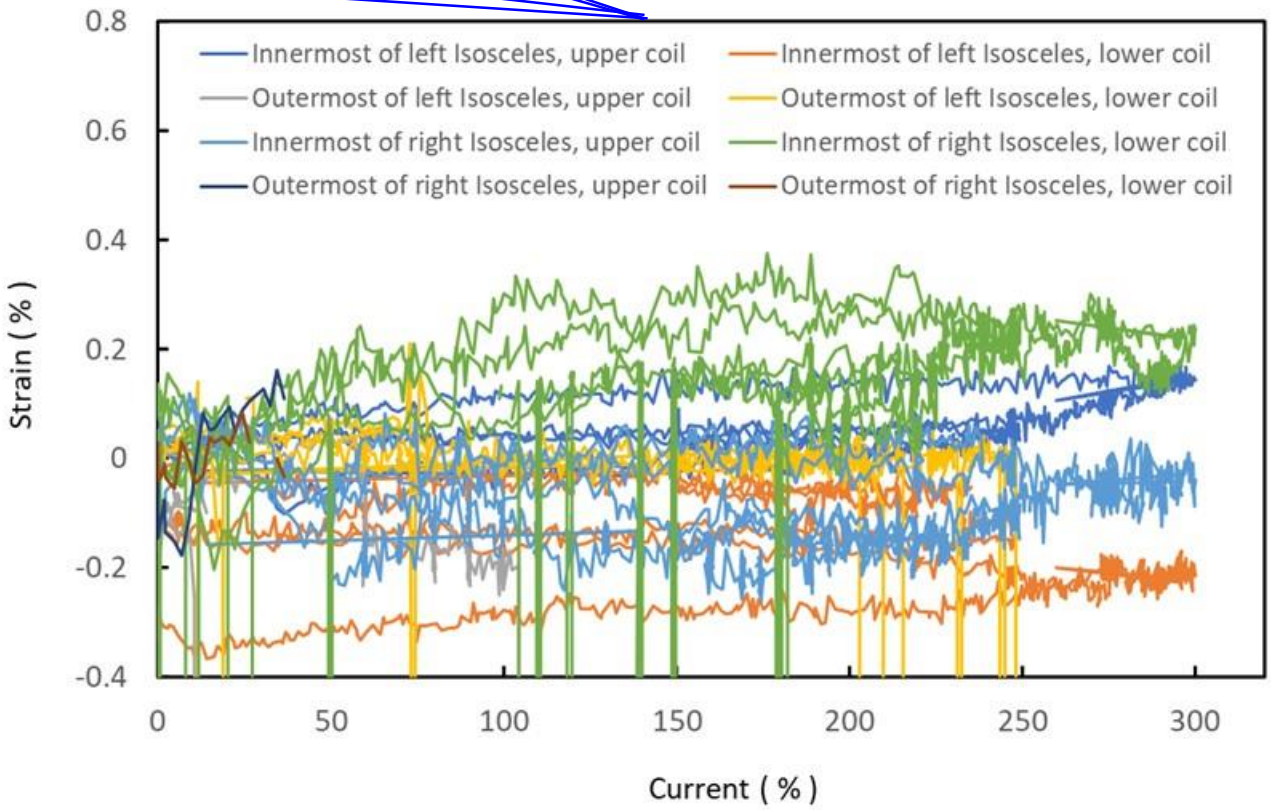
Current dependence of the magnetic field at the center of the isosceles triangular coil

External magnetic field：14 T

Results（With Reinforcement by Yoroi-coil structure）

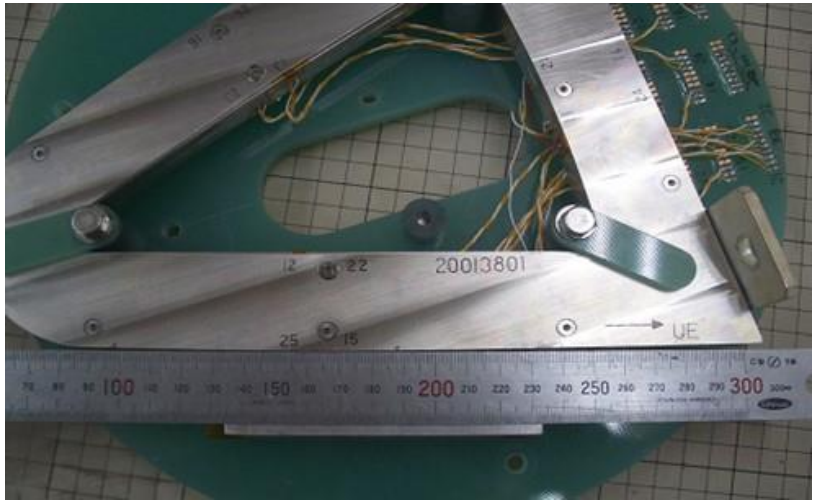


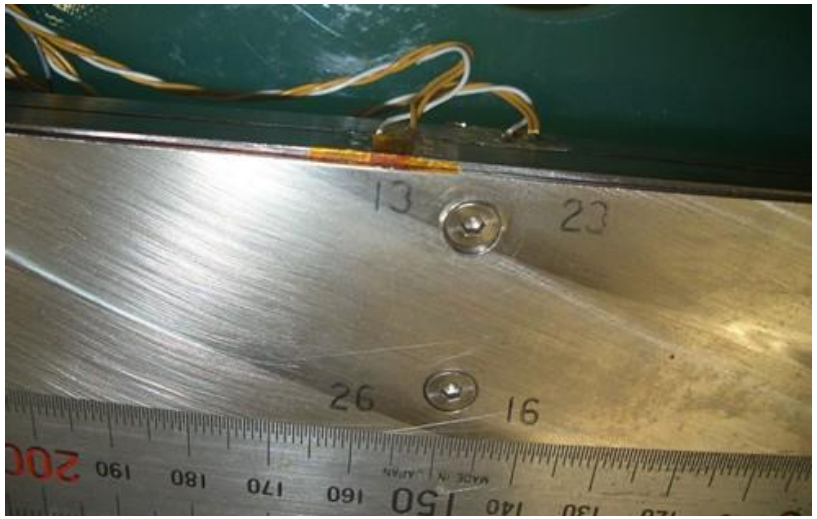




Results（With Reinforcement by Yoroi-coil structure）

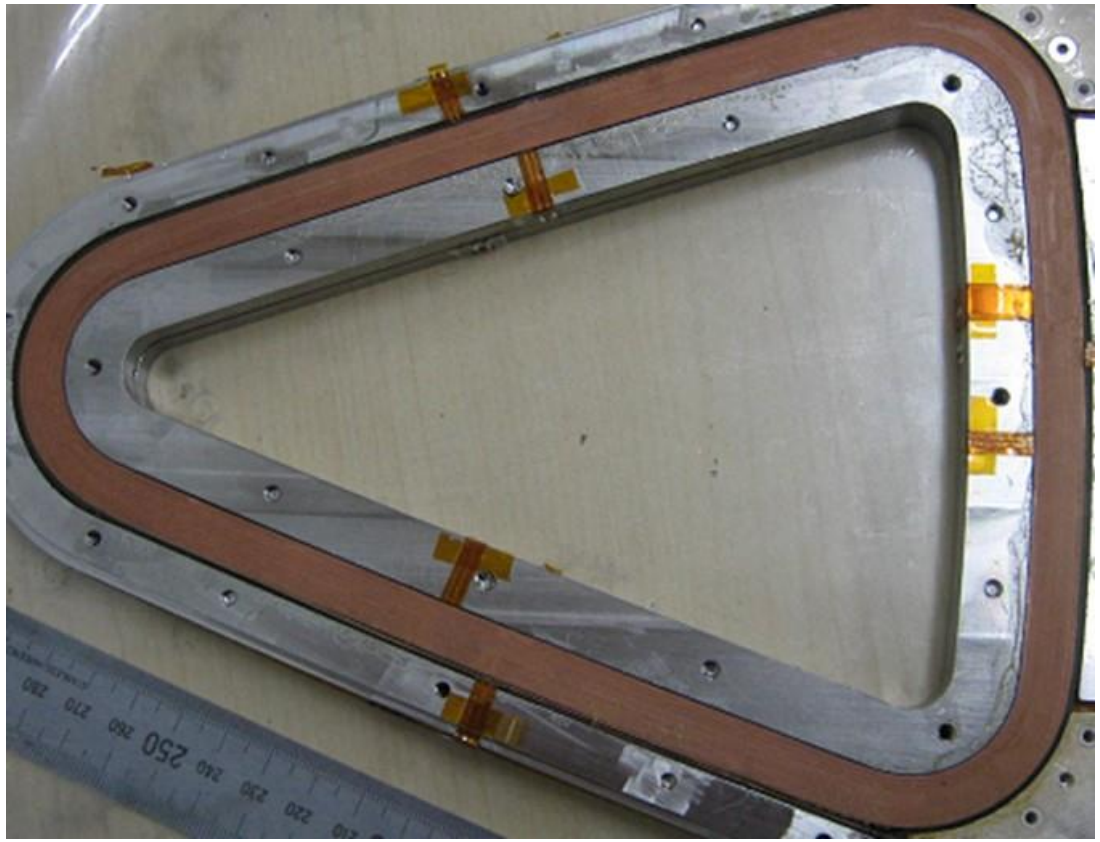
The damages of the coil look less from the appearance after electromagnetic force test.

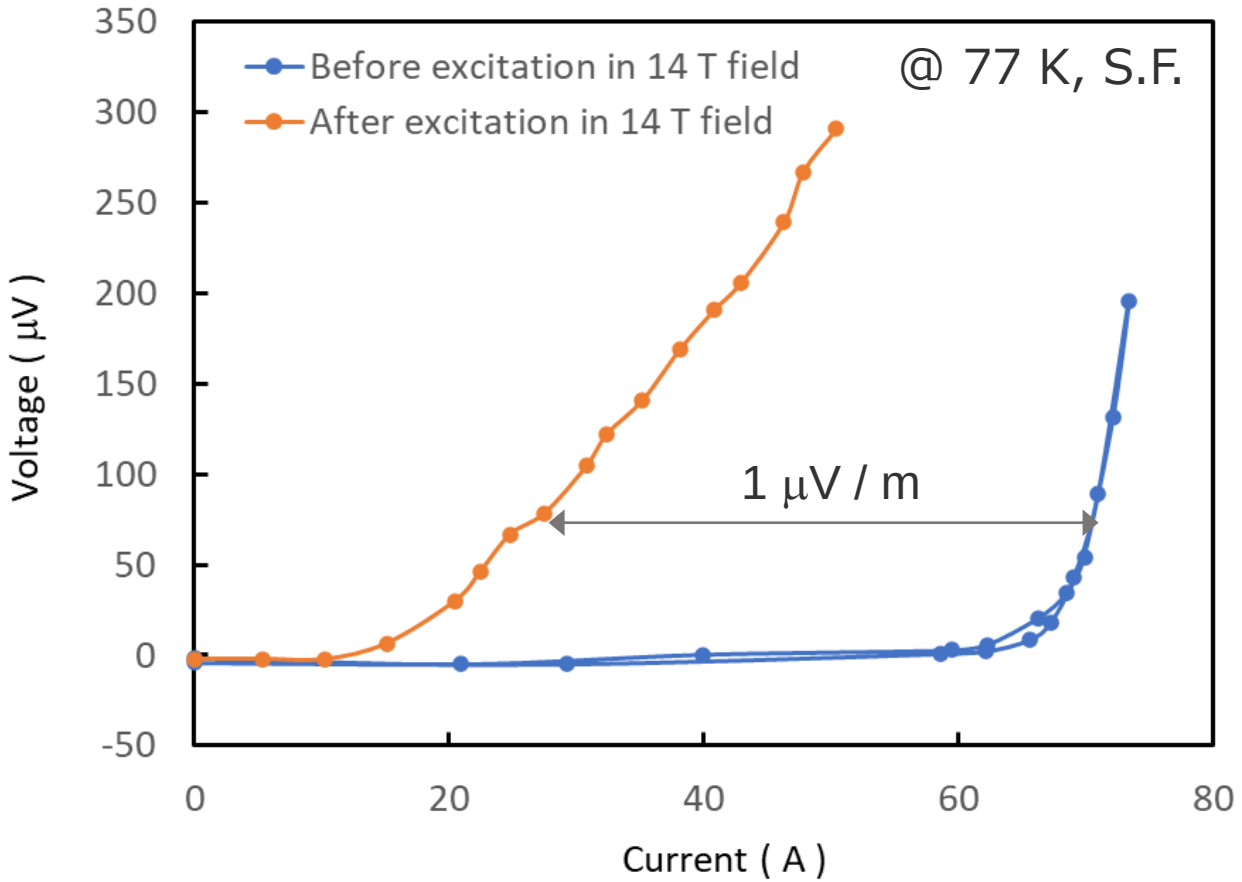




The frame was slightly deformed to the outside.

Results（With Reinforcement by Yoroi-coil structure）





Lorenz force : 554.5 kN / m (300 A, 14 T)
Since the length of the isosceles side was 23 cm, a force of 127.5 kN (about 13 tons weight) per side acted.

After the test, deterioration of *I-V* characteristics was observed in liquid nitrogen. To elucidate the deterioration mechanism bring us the improvement of coil structure.

Conclusion

The behaviors of the non-circular coils in a high magnetic field were investigated. The strength against an electromagnetic force was compared for two types of the coils with or without reinforcement by Yoroi-coil structure.

1 Without reinforcement by Yoroi-coil structure

When the coil current exceeded 160 A in 10 T external magnetic field, the flow resistance was observed and the superconducting state did not recover even after the coil current was reduced from 200 A. The isosceles triangular coil winding was plastically deformed. Sudden voltage rise was avoided due to No-insulation coil winding.

2 With reinforcement by Yoroi-coil structure

The voltage of about 0.6 mV was observed when 300 A was applied in a magnetic field of 14 T. The deformation of the coil winding was limited very much.

It is considered that the triangular sector coil with Yoroi-coil reinforcement has sufficient mechanical strength under the conditions of our air-core cyclotron.