Development of new FFAG RF Cavity at KURRI

Fukui University

Tomoya Minamikawa

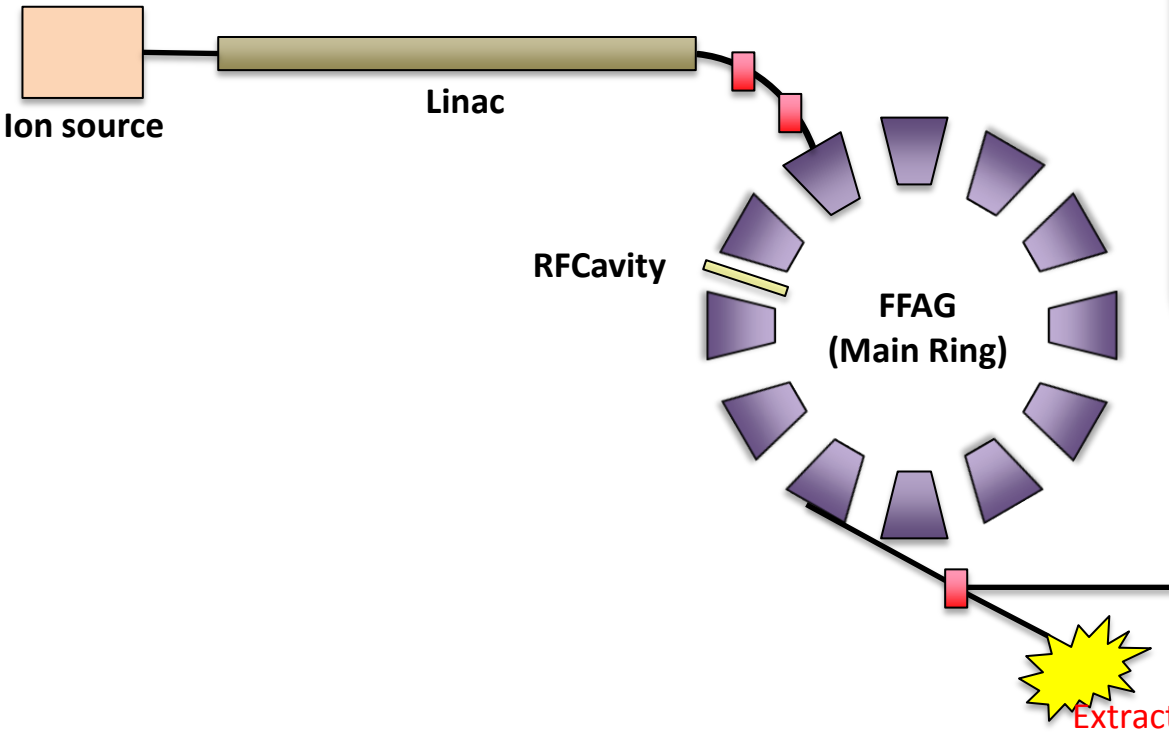
Contents

- Background
- Introduction
- Flow of my work
- considering shape
- the processing new magnetic core
- Experiment
- Summary

Background

- Analyze properties of materials using neutron beam
- Accelerator Driven Subcritical Reactor
- (Cancer therapy with neutron beam)

FFAG at KURRI



ADSR

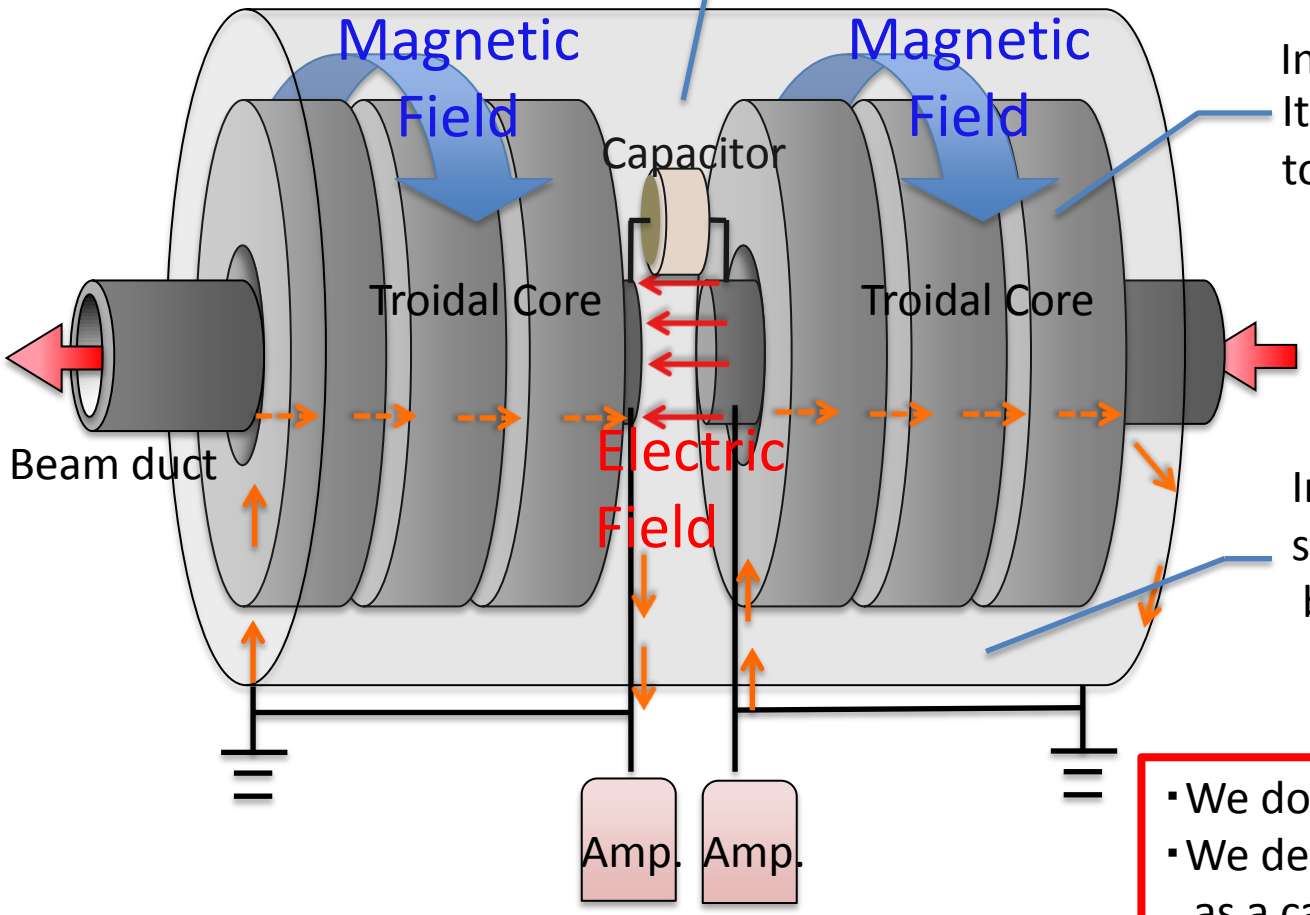
Proton Beam strikes the neutron target
→Neutron breaks out

- Stop reactor safely
- Recycle spent nuclear fuel by radiation of neutron beams.
- Disposal of long life radio nuclide.

ADSR

For cancer therapy

Typical of the RF Cavity



Installing Troidal Core,
It can apply acceleration Gap to Voltage efficiency.

- Impedance depends mostly on Magnetic Alloy

Installing Troidal Core,
standing wave length become shorter.

- We don't use any capacitor.
- We deal with the gap and the plate as a capacitor.

Introduction

We want to get more acceleration voltage to get High power beam.

If the acceleration voltage is more higher, we can increase repetition rate.
It means,

- we can increase Average output beam current
- The beam can avoid the foil quickly. Beam doesn't lost particles.

We should Install another cavity.

Present spec

Energy (MeV)	100
Accelerating Voltage (KV/turn)	4
Repetition rate (Hz)	20
Cavity Impedance (Ω)	500
Number of cores	2

We try to get High power Beam reusing J-PARC RCS Core .

BUT

Horizontal aperture is not enough.

Flow of my work

Consider the shape

Examination of the shape.

Process the Core

Making ”Ribbon Core”.

Investigate the property of the Core

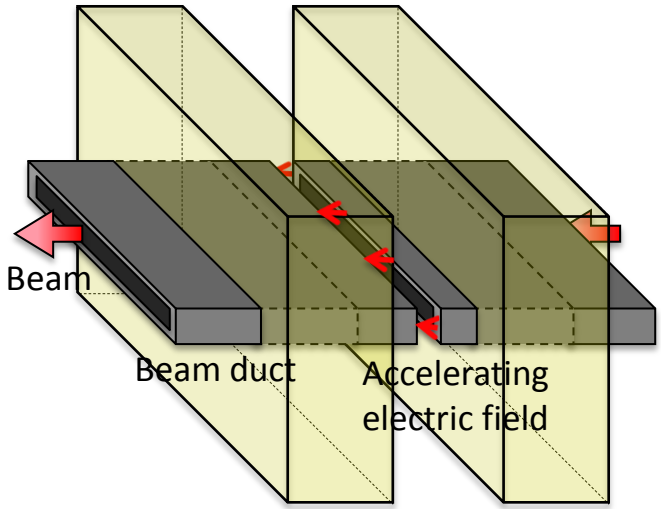
To determine the Impedance.
verify the effect of the cutting Core.

Construct New Cavity

Determine the Impedance to confirm the boundary
(put it in the New cavity)
Input high power and do the thermal test

Install New Cavity

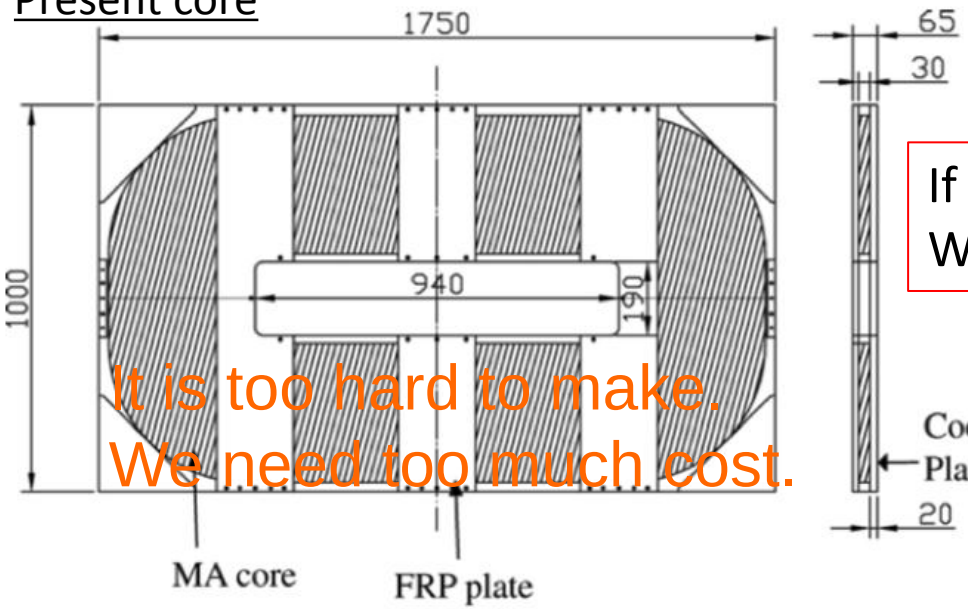
Consider the shape(1)



RF Cavity has rectangular beam duct.

▷We should make
the large aperture core.

Present core



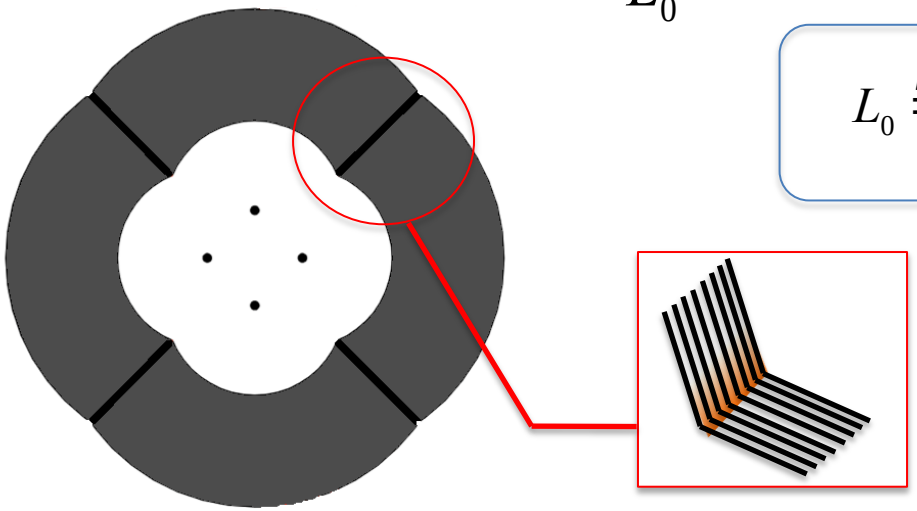
It is too hard to make.
We need too much cost.

If the new core can be made from RCS core,
We don't have to use a large oven.

It is useful technique
to make the core from piece.

Consider the shape(2)

Flower core

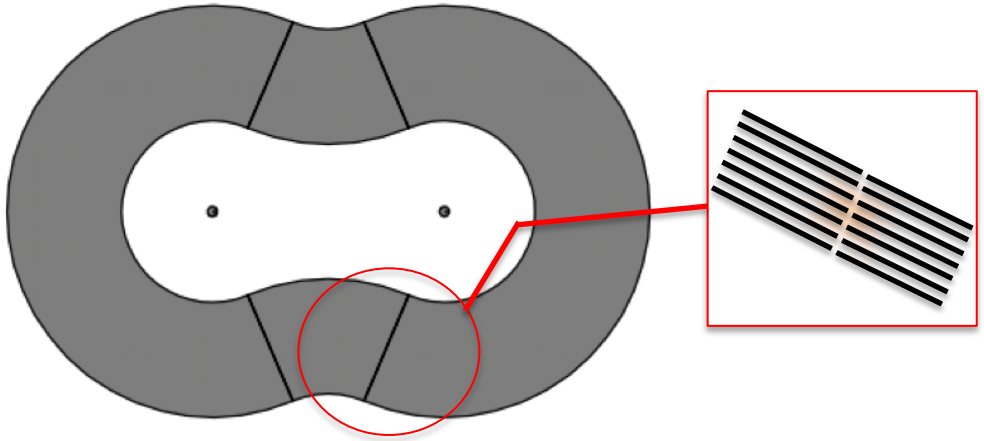


L_0:The factor depends on the shape of MA core

$$L_0 = \frac{N^2 \mu_0 t}{2\rho} \ln\frac{b}{a} \times \text{density}$$

Outer circumference(mm) : 3238.68
Inner circumference(mm) : 1758.13
ln(OC/IC) :0.265
Compare with RCS L_0 :0.74

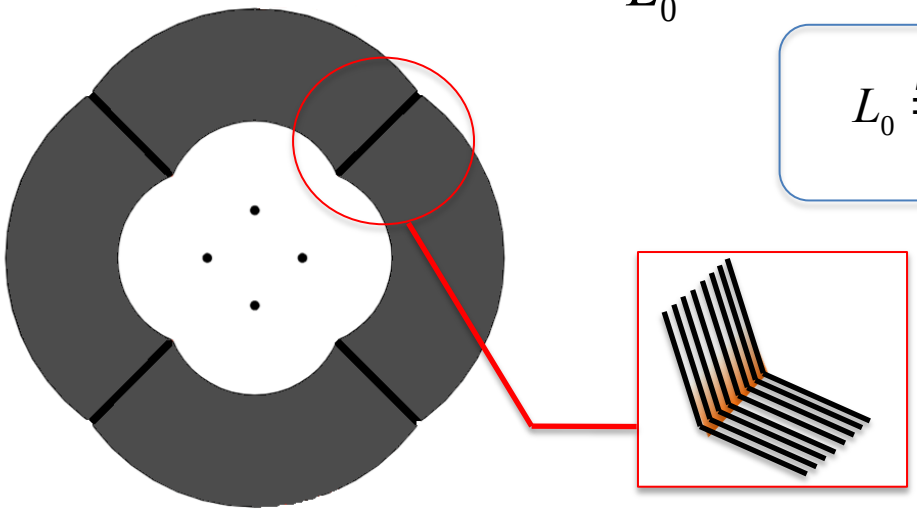
Ribbon core



Outer circumference(mm) : 3656.79
Inner circumference(mm) : 2164.53
ln(OC/IC) :0.227
Compare with RCS L_0 : 0.57

Consider the shape(2)

Flower core

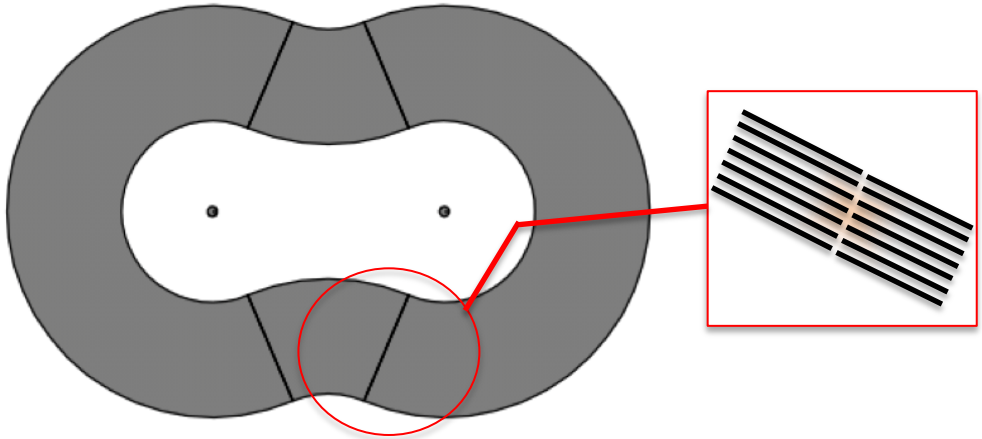


L_0:The factor depends on the shape of MA core

$$L_0 = \frac{N^2 \mu_0 t}{2\rho} \ln\frac{b}{a} \times \text{density}$$

Outer circumference(mm) : 3238.68
Inner circumference(mm) : 1758.13
ln(OC/IC) :0.265
Compare with RCS L_0 :0.74

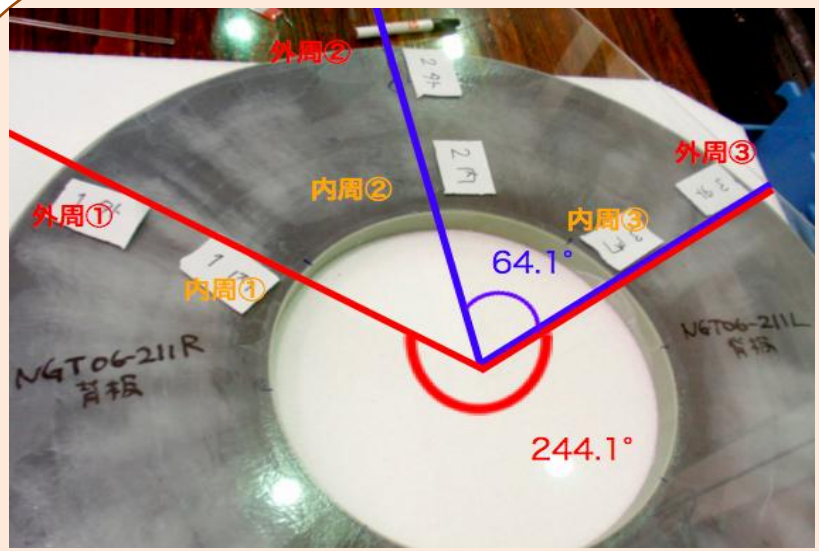
Ribbon core



Outer circumference(mm) : 3656.79
Inner circumference(mm) : 2164.53
ln(OC/IC) :0.227
Compare with RCS L_0 : **0.57**

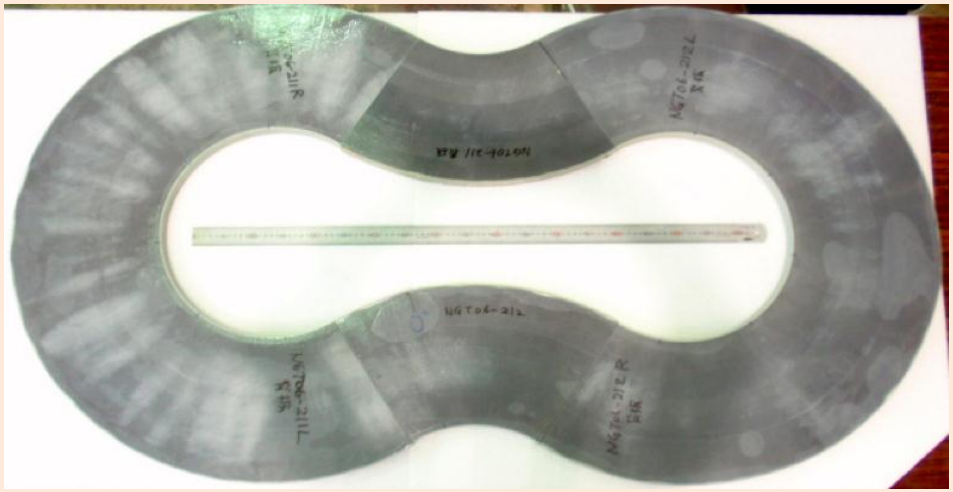
Cutting core

How to make Ribbon Core

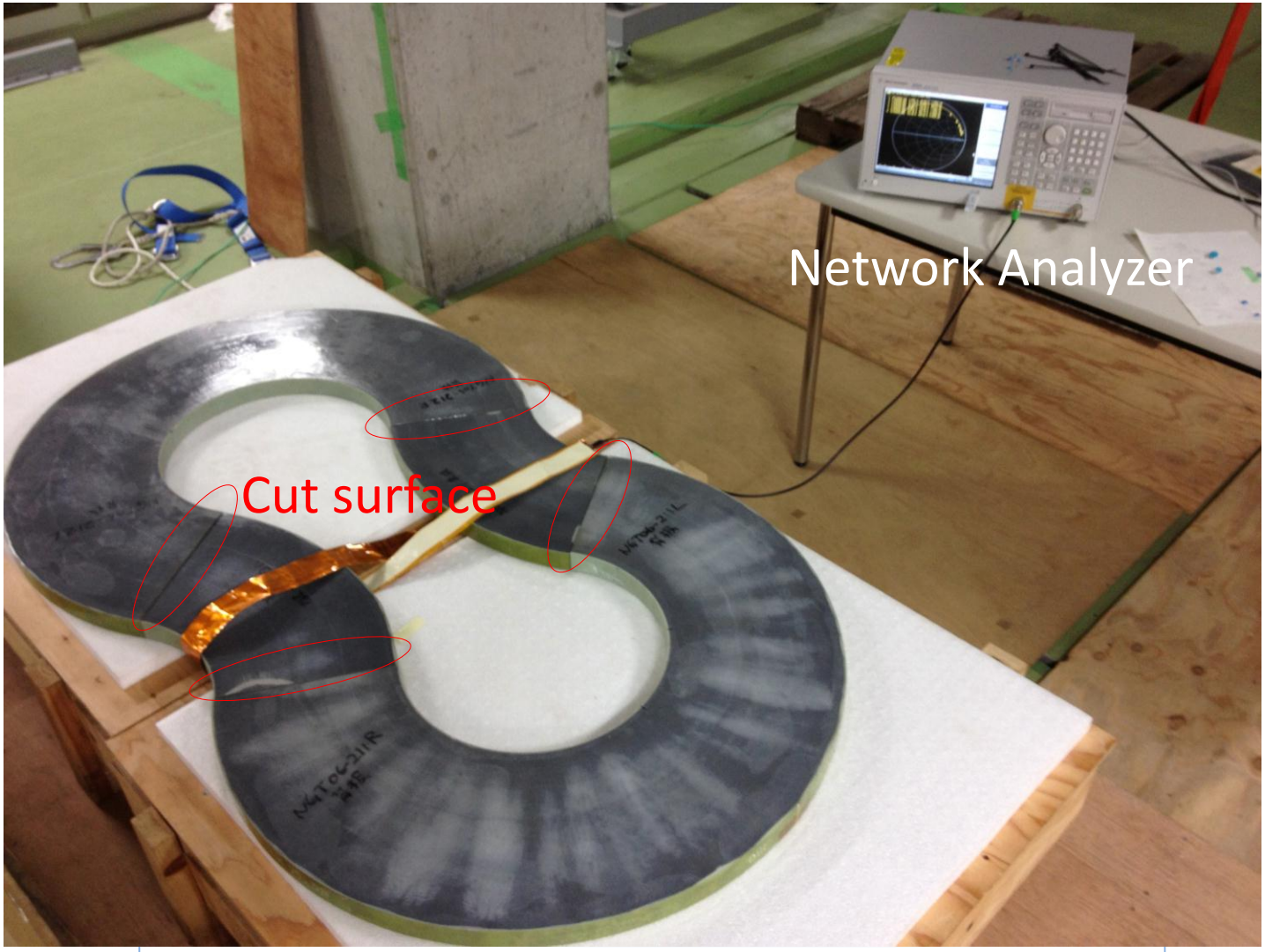


Cut troidal core

Polish the cut surface
and shape the flower cavity

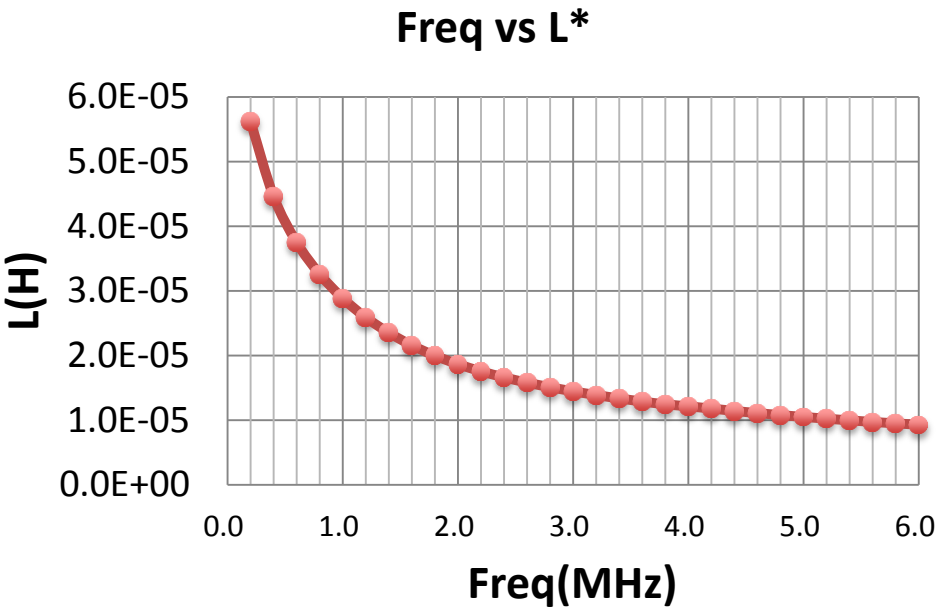


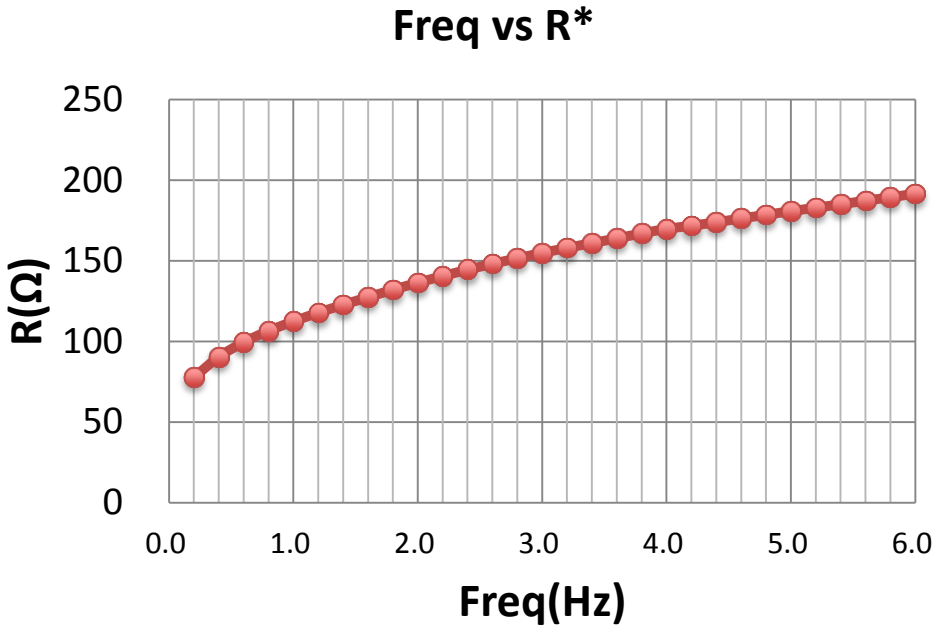
Exp1-Impedance



Change the gap of the cut surface : 0mm , 1mm

Result - Exp1, : Impedance-





J-parcRCS
Flower Core 0mm
Flower Core 1mm

$$Q = \frac{\mu'}{\mu''} = \frac{R}{\omega L}$$

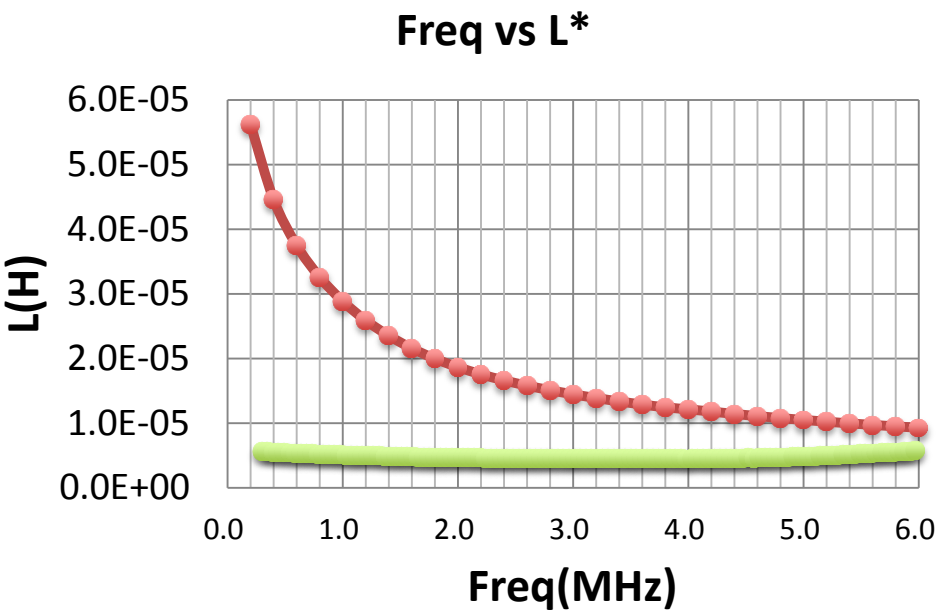
- The form of the Impedance doesn't change almost.
- RCS Inductance is larger than Flower core's.
- "Flower Core 0mm L" is larger than "Flower Core 1mm L".

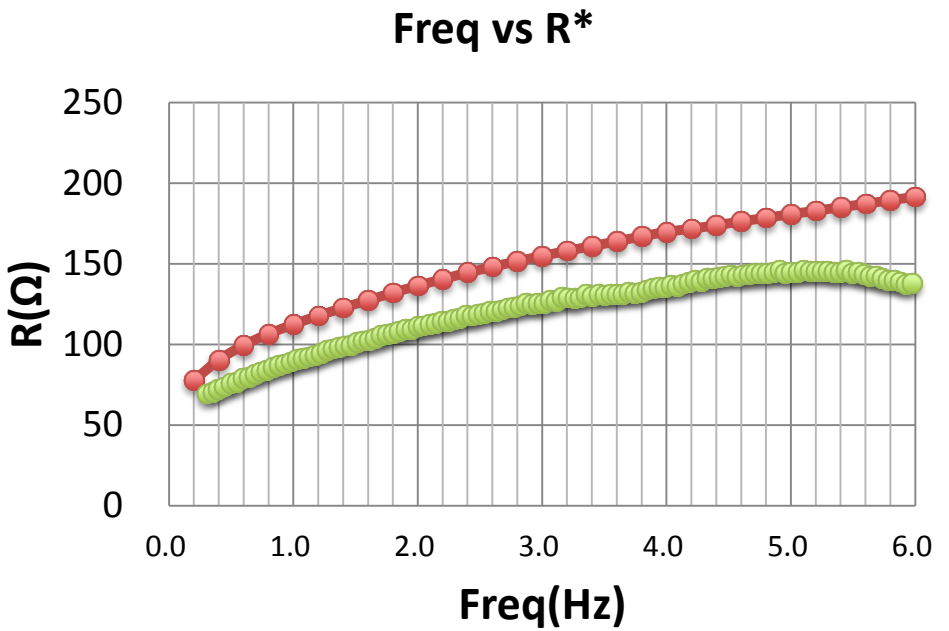
▷Inductance depends on the gap of the cut surface.

Decreasing Inductance means
Impedance may not be so broad(Q is higher) → should check if it can be used on the whole frequency range

*L,R of the J-parcRCS are normalized by L,R of Flower Core

Result - Exp1, : Impedance-





J-parcRCS
Flower Core 0mm
Flower Core 1mm

$$Q = \frac{\mu'}{\mu''} = \frac{R}{\omega L}$$

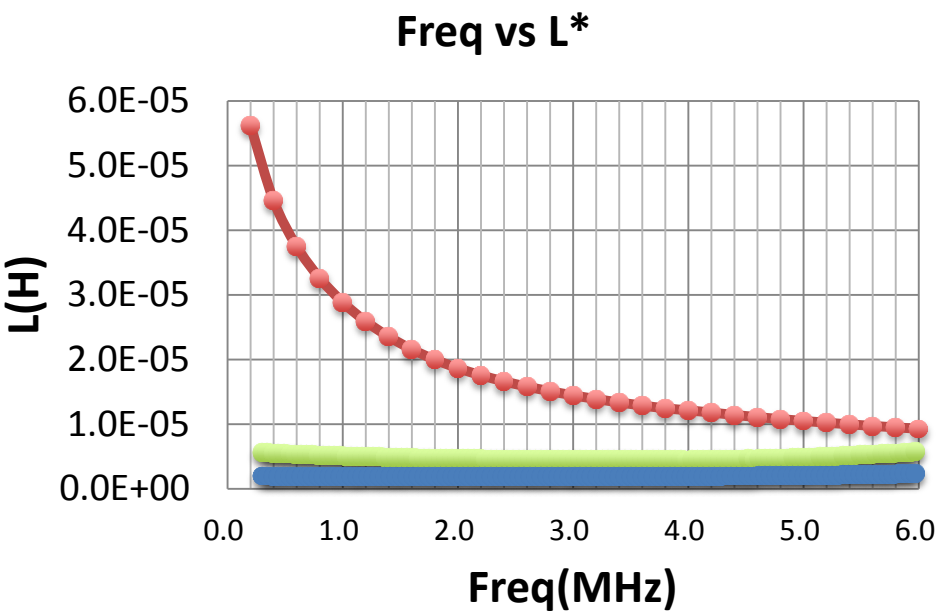
- The form of the Impedance doesn't change almost.
- RCS Inductance is larger than Flower core's.
- "Flower Core 0mm L" is larger than "Flower Core 1mm L".

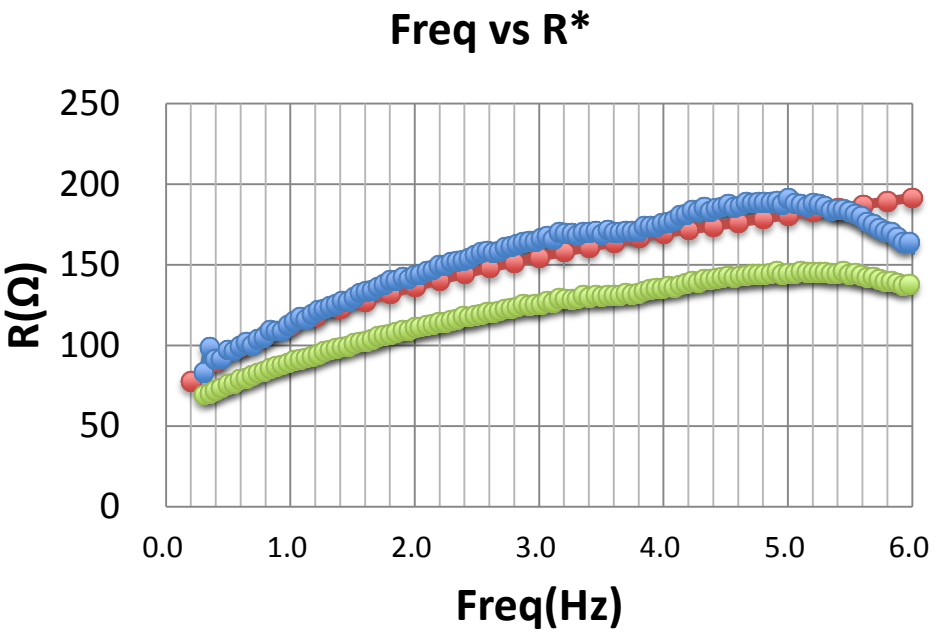
▷Inductance depends on the gap of the cut surface.

Decreasing Inductance means
Impedance may not be so broad(Q is higher) → should check if it can be used on the whole frequency range

*L,R of the J-parcRCS are normalized by L,R of Flower Core

Result - Exp1, : Impedance-





J-parcRCS
Flower Core 0mm
Flower Core 1mm

$$Q = \frac{\mu'}{\mu''} = \frac{R}{\omega L}$$

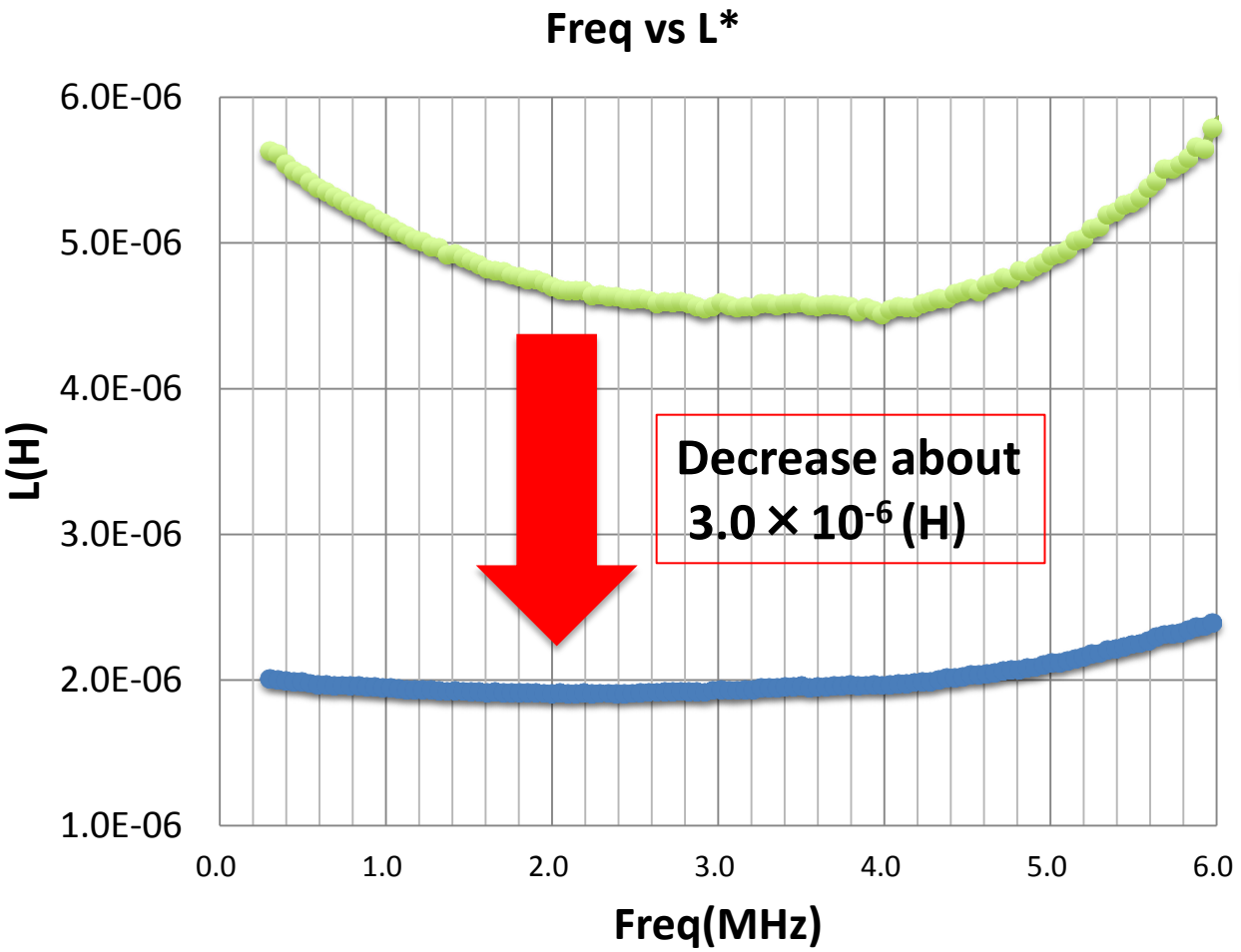
- The form of the Impedance doesn't change almost.
- RCS Inductance is larger than Flower core's.
- "Flower Core 0mm L" is larger than "Flower Core 1mm L".

▷Inductance depends on the gap of the cut surface.

Decreasing Inductance means
Impedance may not be so broad(Q is higher) → should check if it can be used on the whole frequency range

*L,R of the J-parcRCS are normalized by L,R of Flower Core

Result - Exp1, : Impedance-



$$Q = \frac{\mu'}{\mu''} = \frac{R}{\omega L}$$

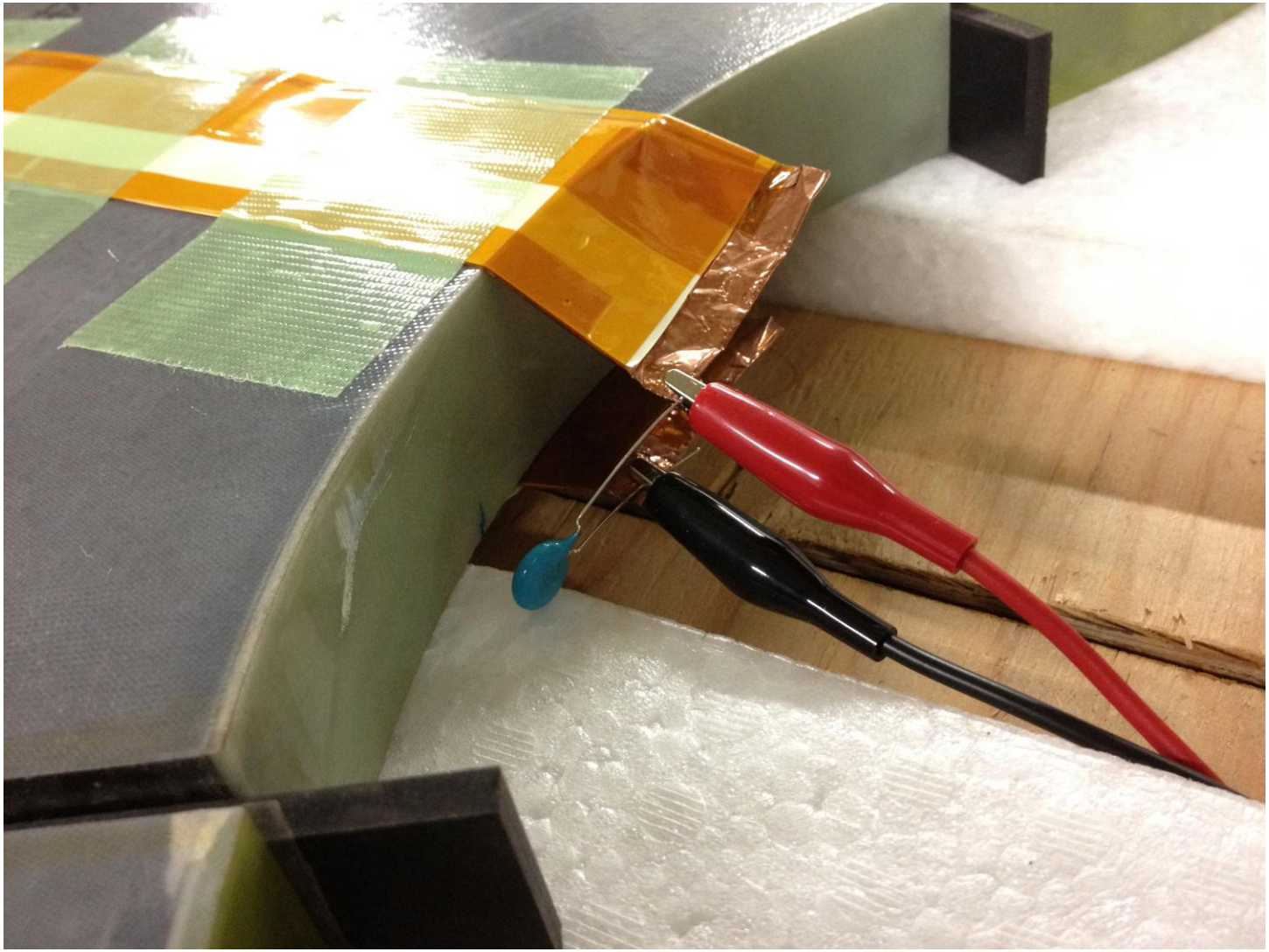
If we make the gap 1mm,

- ▷Inductance decrease about 3.0×10^{-6}(H)
- ▷Q_{blue} is 1.6 times Q_{green} .

If the core has more large gap, Q value is increased quickly.

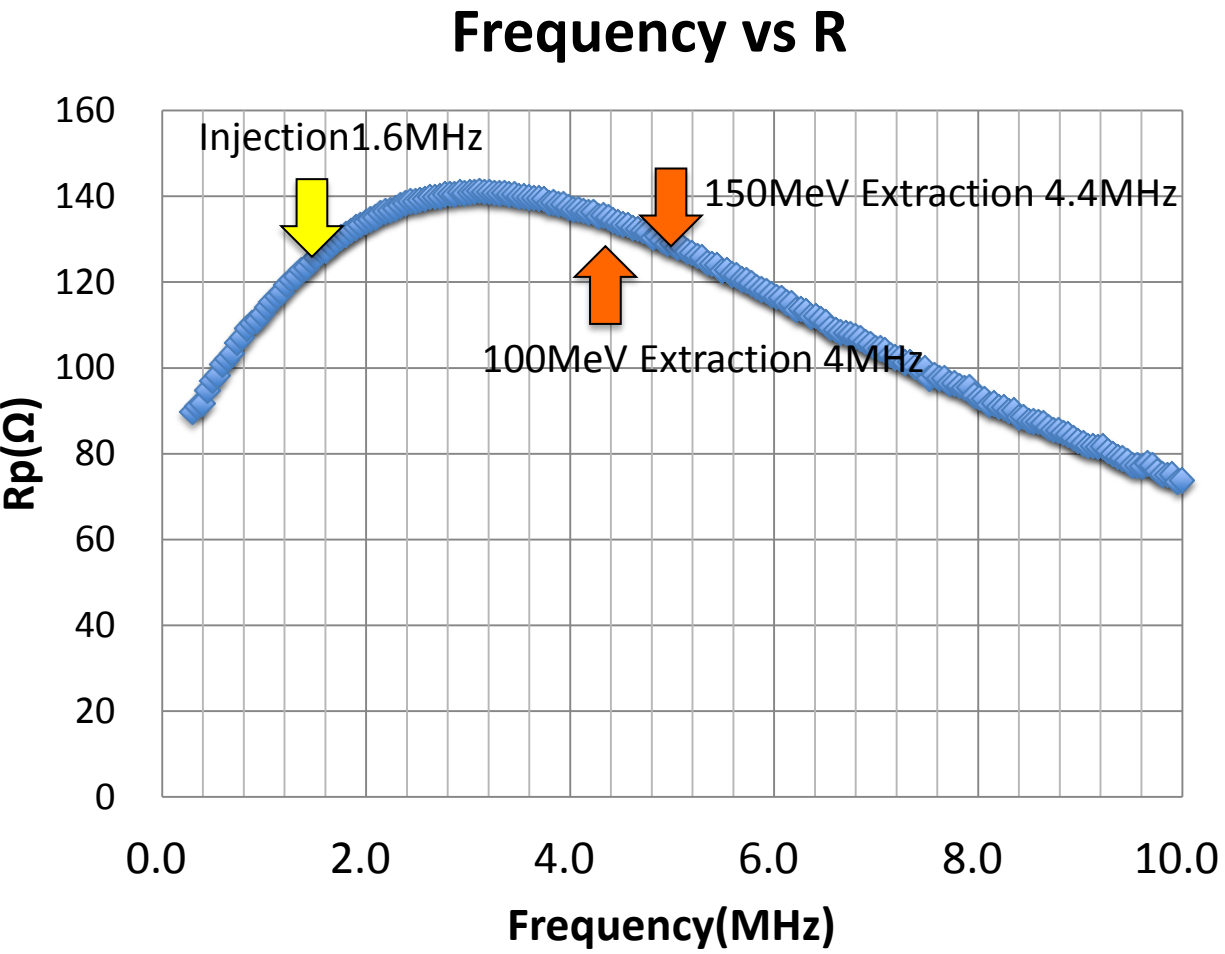
I must not to make the gap as possible.

Exp2-Impedance with Capacitor



Set the resonance point at 2MHz using capacitor (1,200pF)

Result - Exp2, : Impedance with Capacitor-



Set the resonance point at 2MHz using capacitor

Accelerating Freq :
1.5MHz ~ 4.4MHz

Impedance is broad. We can get High Accelerating voltage constantly.

Result - Exp2, : Impedance with Capacitor-

We can get the Impedance **130~140 Ω** at whole frequency range.

If we install **4 cores** on the new RF cavity and input ***14~15 kW**, we can get **4kV** per turn.

We will be able to make The New Cavity **Reusing RCS Cores**.

Impedance par a core(Ω)	How many cores can we install	Aim of the Acc Vol "V_{RF}"(kV)	Input Power we need (kW)
130～140	4	4kV	14~15

Summary

【Summary】We will Install New RF Cavity to get high power beam

- Cut J-PARC RCS core and make new core “Ribbon core”
- Measure the Impedance R and Inductance L”
  which concern performance of the cavity.
- Effect of the L_0
  Flower Core is **0.57** times the RCS Core
- Effect of the cut surface
  Impedance almost doesn’t change, Inductance decreased
  →Impedance may not be so broad(Q is higher)
- Impedance with Capacitor

  Broadband Impedance
  On the cavity, we install 4 cores and input 15kW.
  ▷Get 4kV of the Accelerating Voltage.

【Future plan】

- Put the core in the new cavity and measure the Impedance.
- Input high power
- Thermal test


Thank you for your attention

Impedance

Effect of the Flower cavity

*Input Power is

$$P = \frac{V^2}{2R}$$

①Shape(Form factor : L_0)

Impedance : $Z = jw\mu L_0$

L_0:The factor depends on the shape of MA core

$$L_0 = \frac{N^2 \mu_0 t}{2\pi} \ln\frac{b}{a} \times \text{density}$$

$$R = \omega\mu'' L_0$$

$$L = \mu' L_0$$

Ribbon Core is **0.57** times the RCS Core

②Effect of the cut surface

Decrease Magnetic field at cut surface → Decrease L

▷We may not get the Impedance which is broadband.

$$Q = \frac{\mu'}{\mu''} = \frac{R}{\omega L}$$