# High Field-Gradient Cavity for J-PARC 3 GeV RCS

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KEK and JAERI

# J-PARC(Japan Proton Accelerator Research Complex)

RCS

- JAERI and KEK Joint Project
- 400 MeV Linac (181MeV in Phase I)
- 3 GeV RCS
  1 MW
  for neutron and μ users
- 50 GeV MR
  0.75 MW
  for ν, nuclear and particle physics

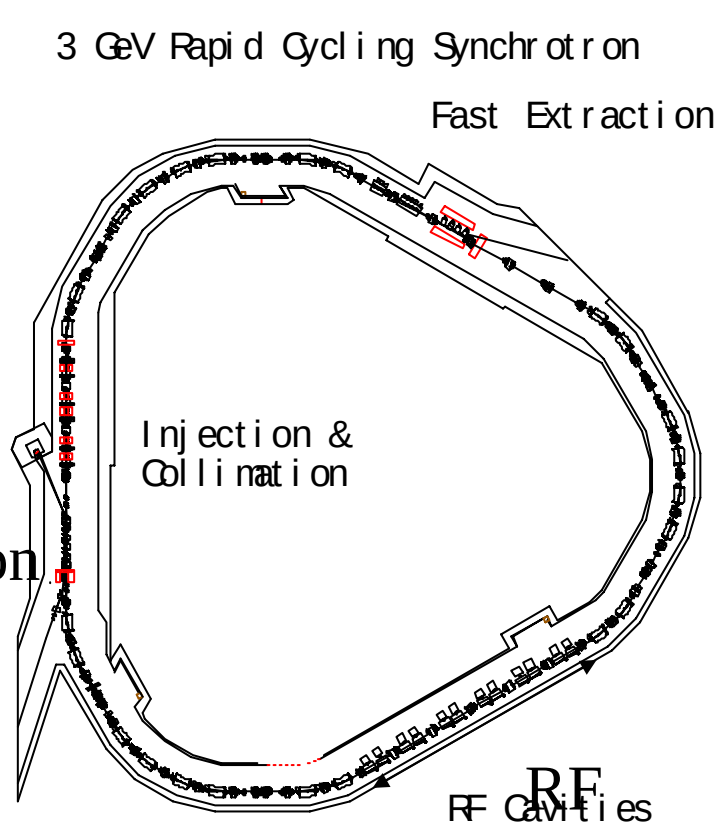
# Cavity Parameters (Phase I)

| | 3 GeV RCS | 50 GeV MR |
|---|---|---|
| Frequency<br>1st<br>2nd | Dual Harmonic<br>0.94-1.67 MHz<br>1.88-3.34 MHz | Single<br>1.67-1.72 MHz<br>(or 3.34-3.44 MHz) |
| Harmonics | 2 | 9 (or 18) |
| RF Voltage(Max.) | 450 kV | 280 kV |
| Number of Cavity | 11+(1) | 6+(1) |
| Cavity Length | About 1.8-2.0 m | 1.776 m |
| Optimum Q | 2- | 10 (20) |
| Core | MA, cut core, gap 0.5mm | MA, cut core, gap 10 mm |
| Power Dissipation<br>Average | <br>6.6 kW/core | <br>13.2 kW/core |

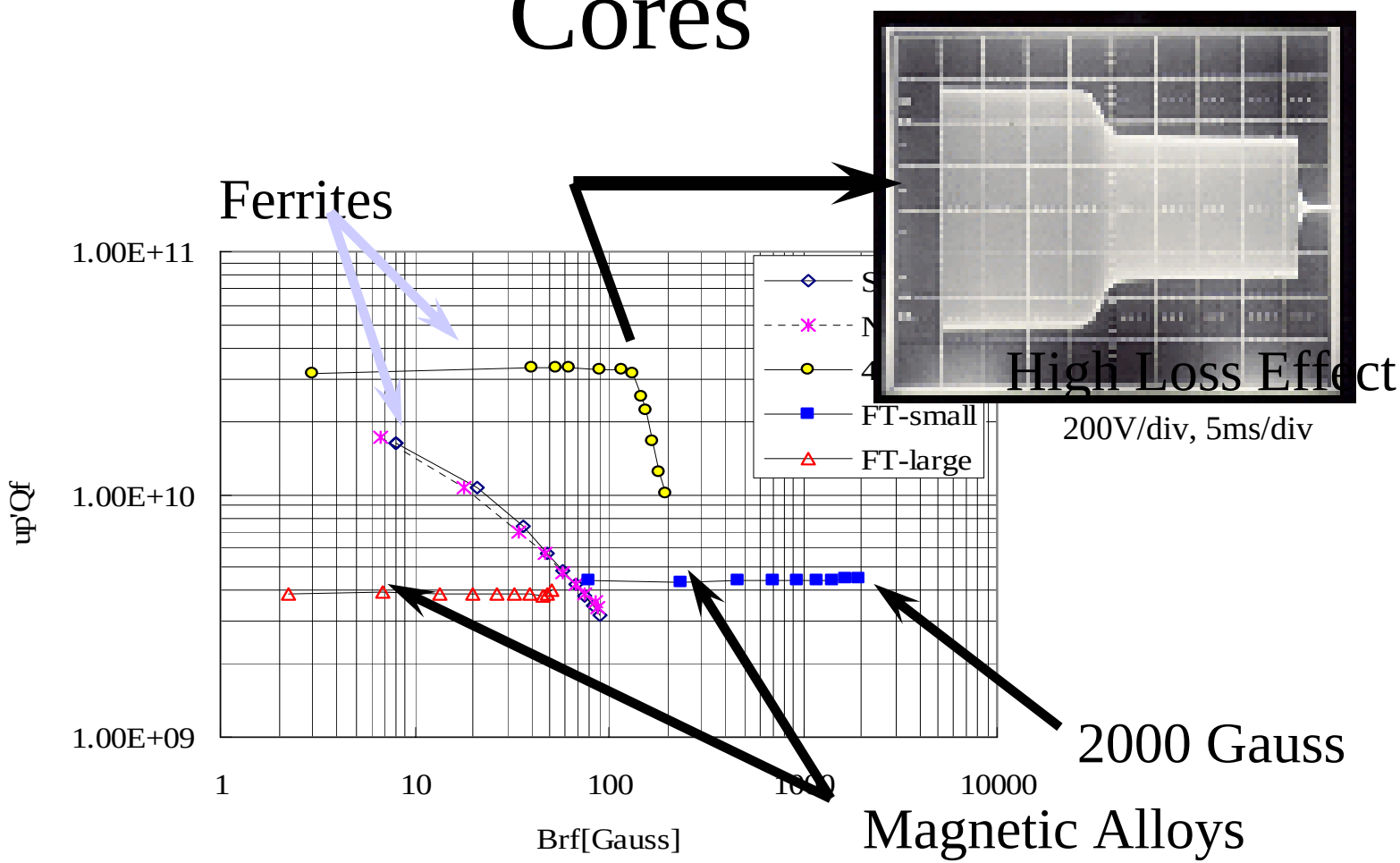
# Why High Field Acceleration

3 GeV RCS
Fast cycling:25 Hz
    Needs high voltage:450 kV
# of bunches: 2 (by neutron-users)
Rise time of Extraction Kicker
    Low Frequency:0.94-1.7MHz
Circumference is limited.
Needs spaces for extraction, injection and collimation.

High Field Gradient using MA core



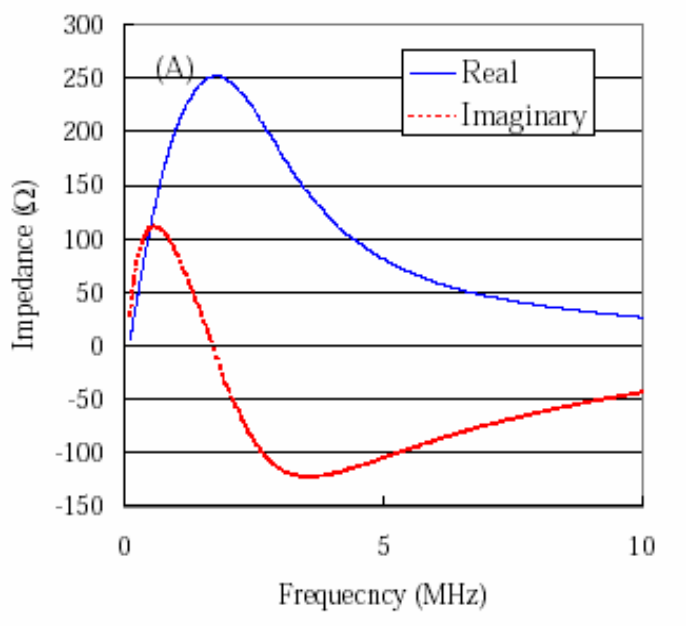
# Characteristics of Magnetic Cores

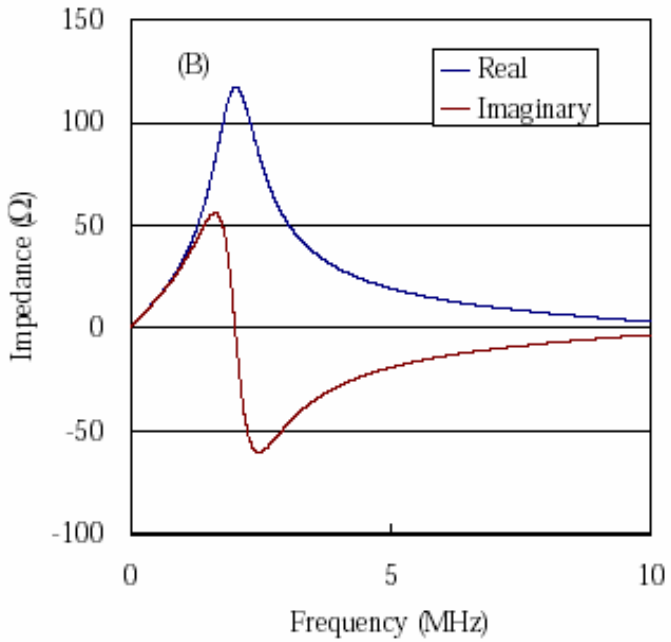


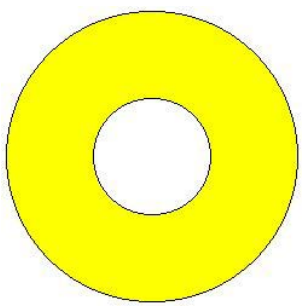
# Characteristics of MA core

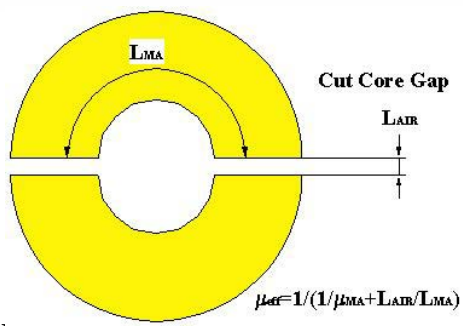
- Core is made of thin Magnetic Alloy ribon tape.
- Very large permeability- $\mu Qf$-product is large.
- **$\mu Qf$-product remains constant** at very large magnetic flux density. Saturation flux density is 15 kG.
  - **High Field Gradient becomes available!**
- Intrinsic Q-value is 0.6 (FINEMET).
  - **Frequency sweep** without tuning system is possible
  - Dual (Multi-) Harmonics system
- **Q-value is variable by Cut Core Configuration.**

# Cut Core Configuration



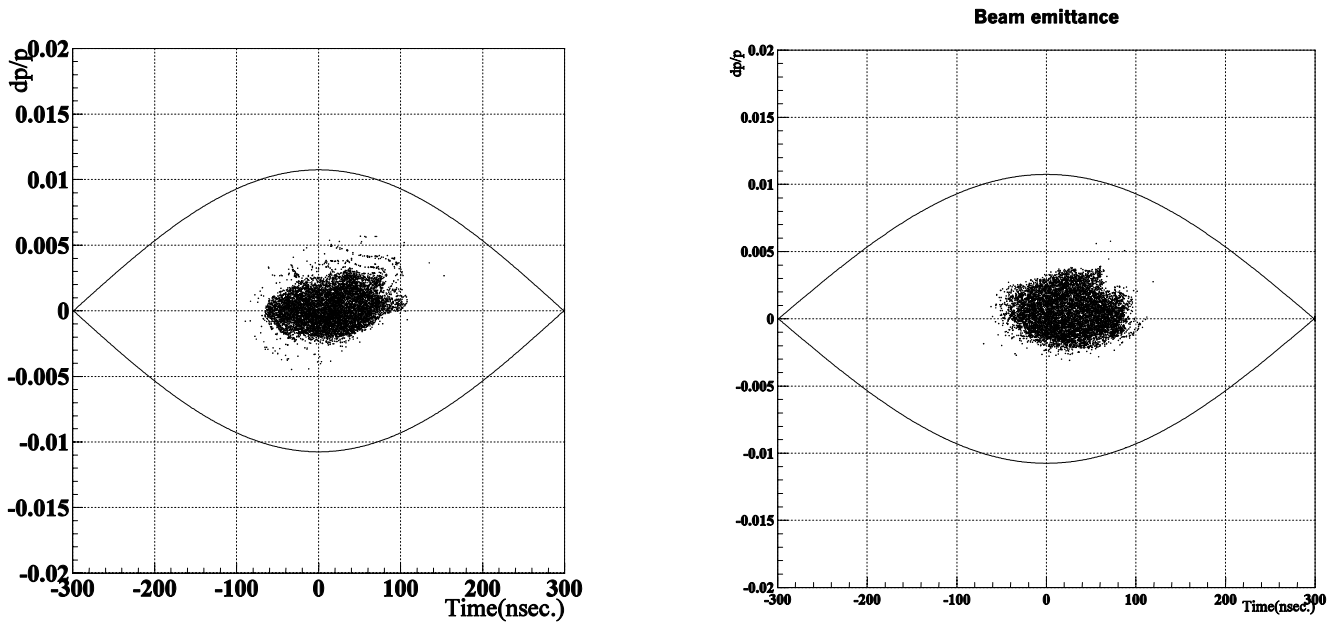


# Optimum Q-value (Beam Loading)

Optimum Q-value is 2.

Bandwidth for dual harmonic acceleration

Less beam loading effects with H=2,4,6 compensation

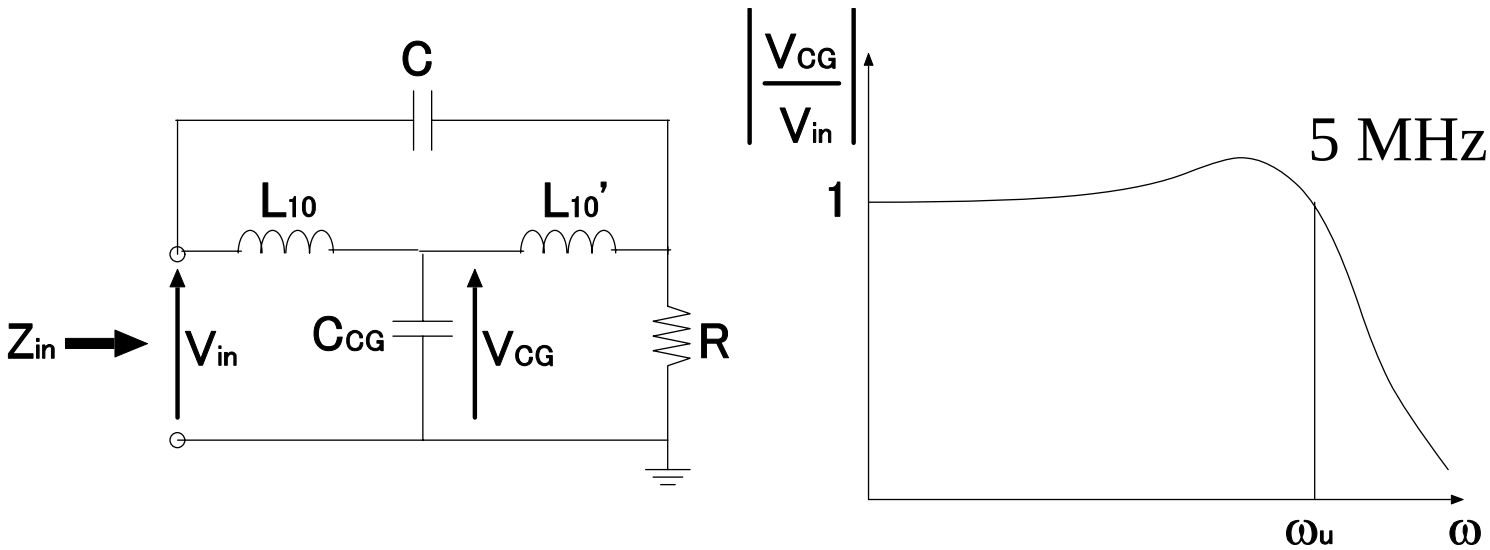



Although multi-H compensation (H=1,..,6) is applied, beam loss is expected, in case of Q=0.6(left). No beam loss in case of Q=2(right) TUPLT072 M. Yamamoto

# Optimum Q-value

## Bandwidth of RCS RF System

- 2 X 600 kW tetrode tubes have 1 nF grid capacitance.
  - Bandwidth of input circuit is 5 MHz




All pass network

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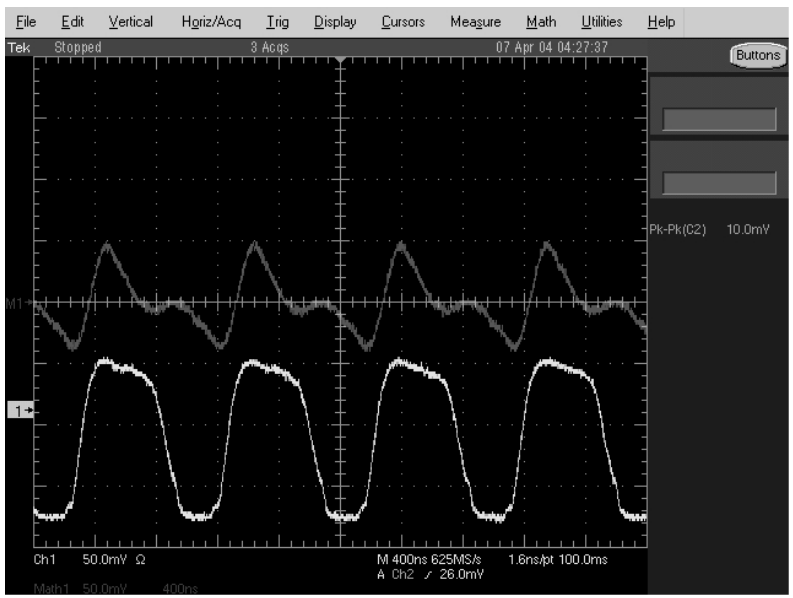
# Optimum Q-value (Dual Harmonic Operation)

- Q=2 can cover the 2nd harmonic frequency around the injection.
- Dual Harmonic RF will help to reduce S.C. effects.

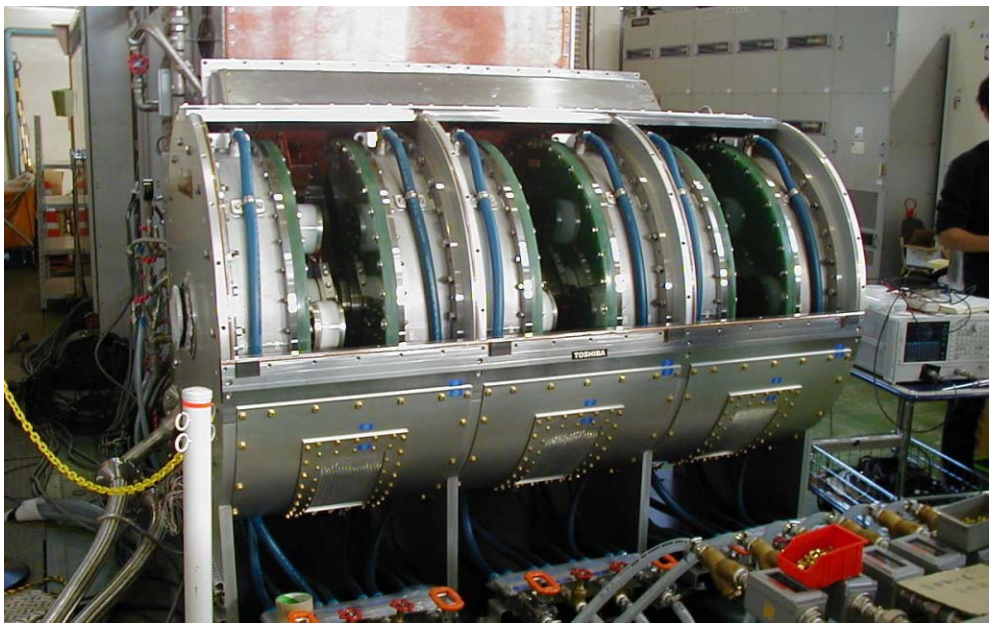


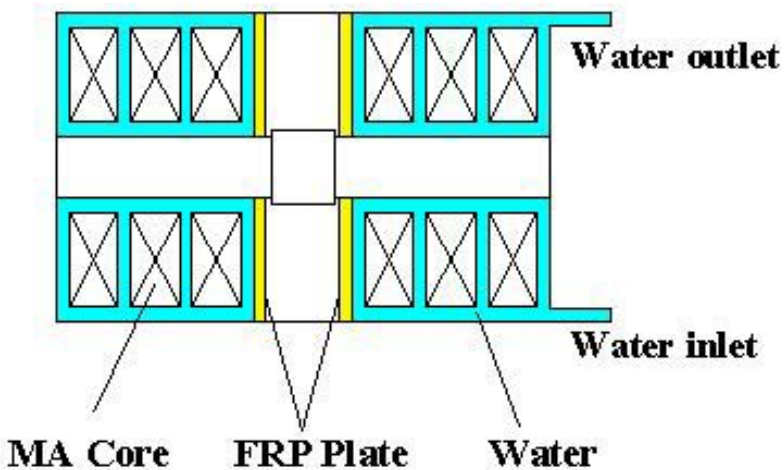

An Example of dual harmonic rf using a MA cavity in HIMAC(May '04).

Adding the 2nd Harmonics, acceleration efficiency was improved by 30 %. Another 10 % was improved by the 3rd Harmonics.

C. Ohmori, A. Takagi(KEK), M. Kanazawa, K. Noda, A. Sugiura(NIRS)

# Cooling Scheme

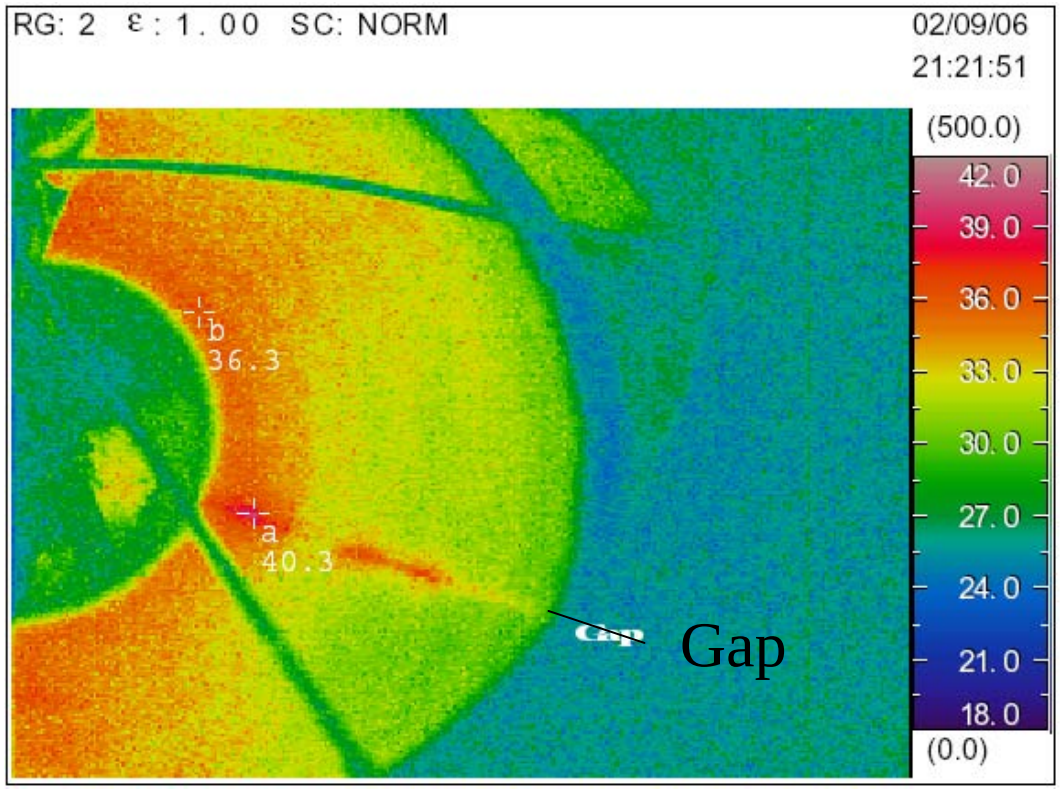





Direct

Both direct and indirect water cooling schemes were tested.
Direct cooling is used for J-PARC for high cooling efficiency.
High Power test has been performed

# Power Loss in Cut Core

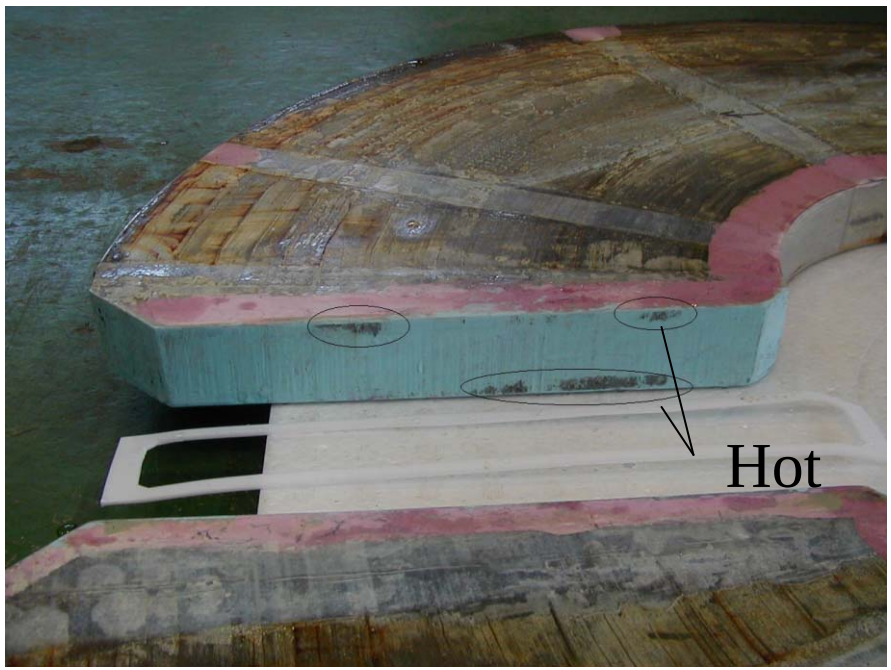



The temperature was measured using a "Infra-red Camera"

In case of a large cut core, only a limited choice of cutting method (water jet).

Localized temperature rise has been observed.

# Temperature Rise at Cut Surface




Core surface after 8-hours high power test with 0.4 W/cc (1.2 X J-PARC spec) . No significant damage was observed on the core.

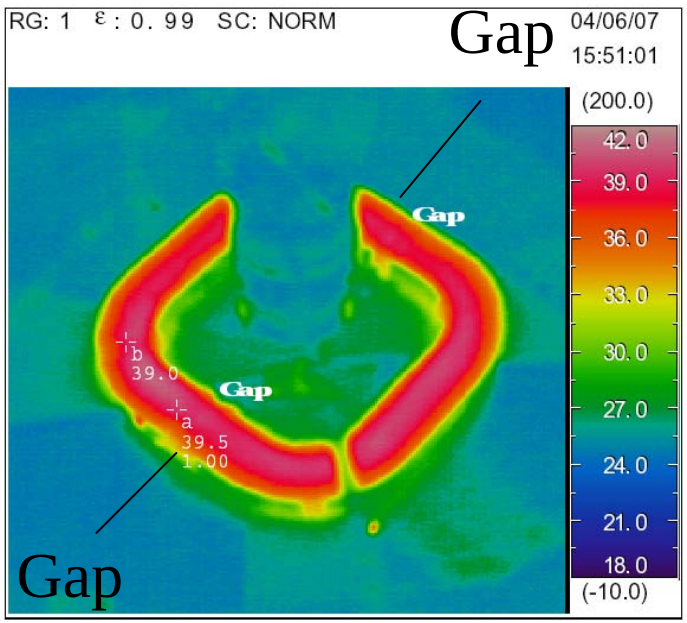
By improving the water flow going through the cut core gap, cooling efficiency was improved.

Thermo-paint was used to measure the temperature during the test .

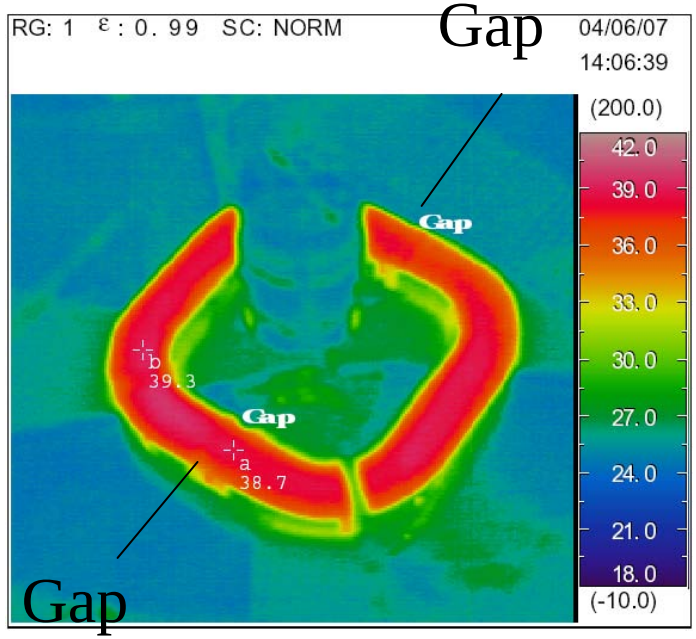
Only limited spots which were covered by gap spacer are still hot.

# Power Loss in Cut Core

Temperature distribution on other cut core.




Q=2

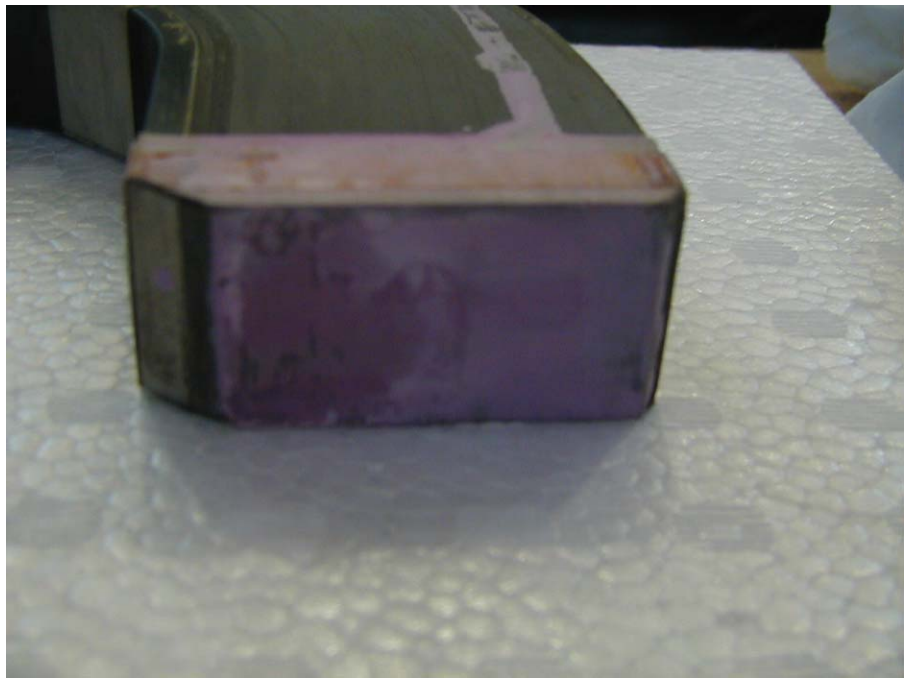



Q=4

In case of cut core with a good cut surface, no localized temperature rise has not been observed.

# Temperature Rise at Cut Surface

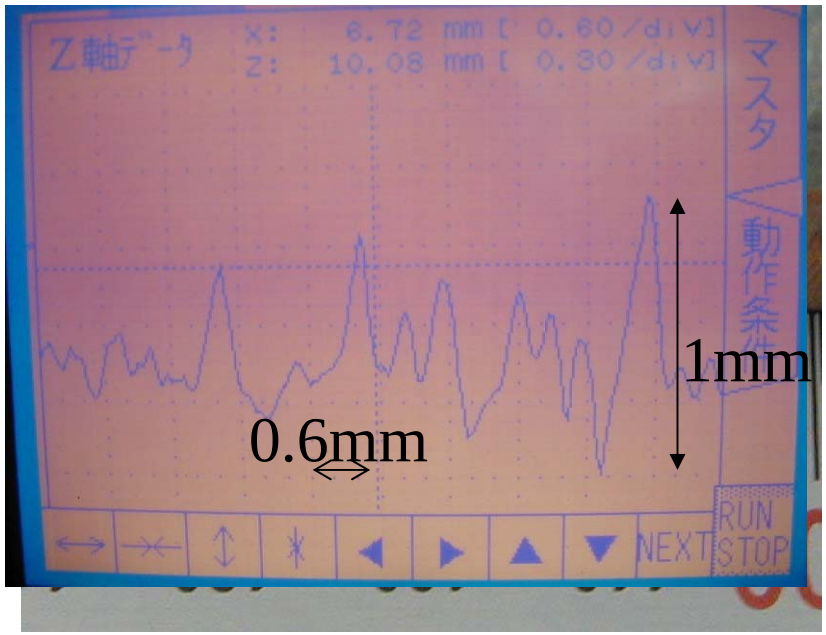
Core surface after 8-hours high power test with 0.4 W/cc (1.2 X J-PARC spec)



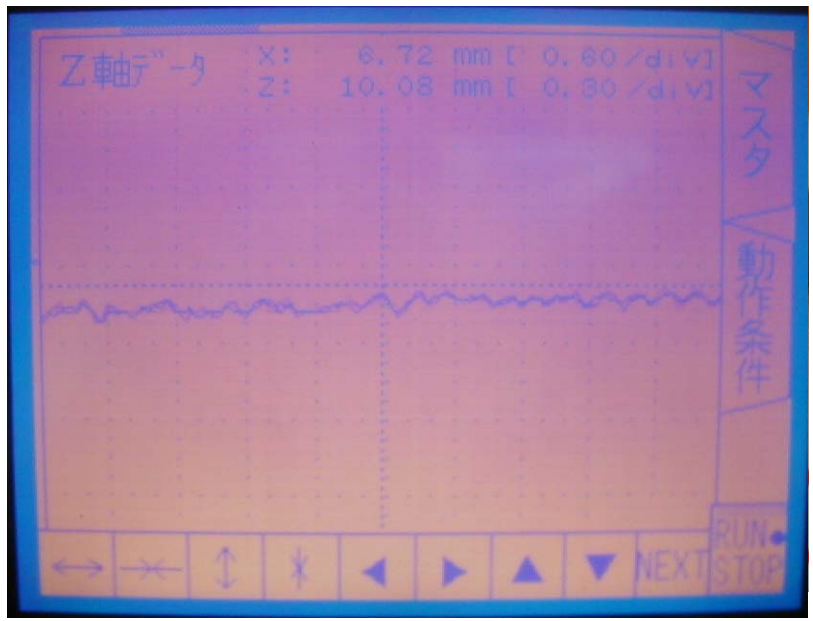
Core surface after 0.5-hours high power test with 0.8 W/cc (2 X J-PARC spec)

# Cut Core Surfaces

Water Jet Cut



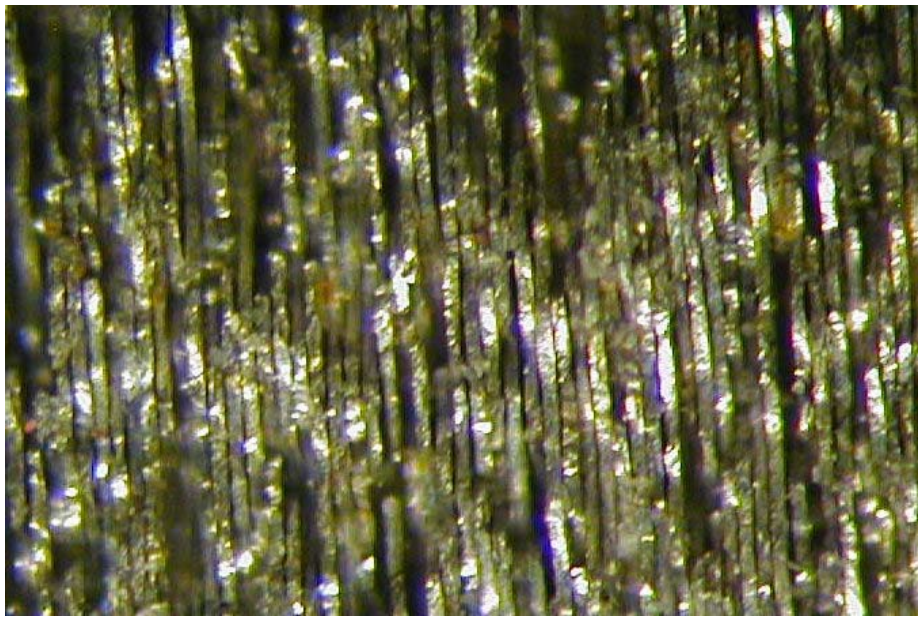

Grindstone + Etching



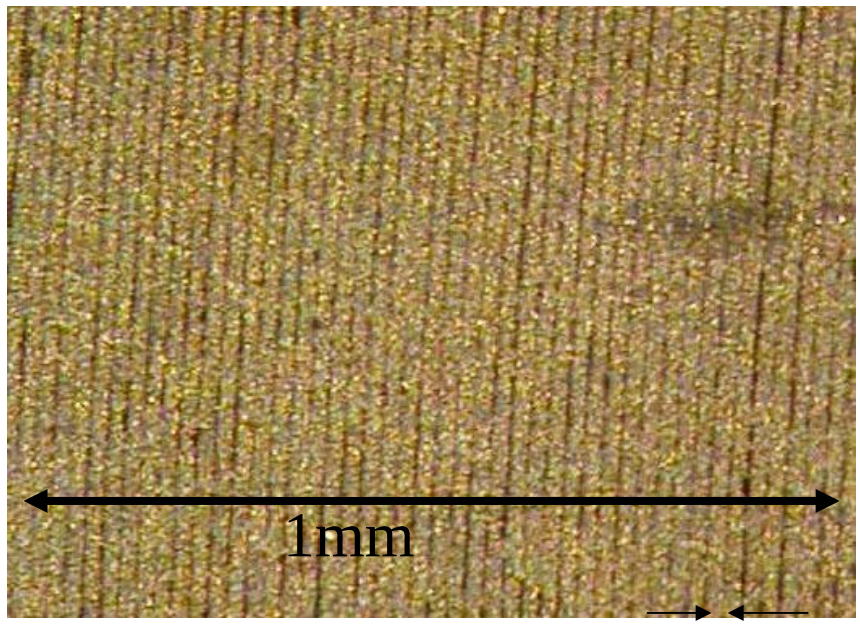

Measurements using Laser depth-meter

# Cut Core Surfaces

Water Jet Cut



Grindstone + Etching



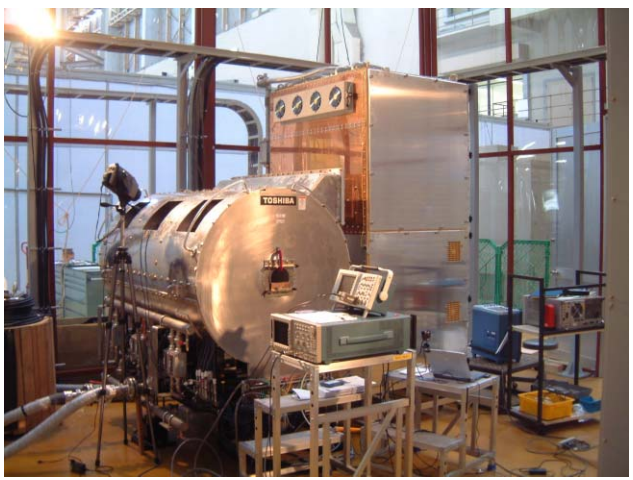

Finmet layer with 18 μm thickness is shown in both pictures. The surface by water jet cut is not flat.

Localized temperature rise is related to the condition of cut core surface.-> A smooth cutting scheme is under development.

# Status of 3 GeV RCS RF

- Core : Production (40 cores for 2 cavity)
- Cavity: Designing
- APS : Production & Testing
- AMP : Production & Testing
- D-AMP : Designing*
- Low Level : Designing

* Based on CERN-KEK collaboration.




# Summary

- A wideband RF system using MA cavities is used for J-PARC RCS.
- The optimum Q-value for acceleration and for whole RF system is 2 to cover the 2$^{nd}$ harmonics.
- Cut core configuration is used to increase the Q-value. However, localized loss was observed if the surface is rough. A smooth cutting scheme is under development.
- By improving the water flow in the water tank, temperature rise is acceptable for acceleration and no damage was observed.
- MA cores, Anode PS, Amplifiers are in production. Cavities and others will start manufacturing.