High Field Gradient Cavity for JAERI-KEK Joint Project

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KEK and JAERI

Cavity Parameters

	3 GeV RCS	50 GeV MR
Frequency 1st 2nd	Dual Harmonic 1.23-1.67 MHz 2.46-3.34 MHz	Single 1.67-1.72 MHz 3.34-3.44 MHz
Harmonics	2	9
RF Voltage(Max.)	450 kV	280 kV
Number of Cavity	11+(1)	6+(1)
Cavity Length	2.0 m	1.776 m
Optimum Q	2-3	10-20
Core	MA, cut core, gap 1mm	MA, cut core, gap 10 mm
Power Dissipation Peak Average	 13.8 kW/core 5 kW/core	 15.1 kW/core 9 kW/core

Why High Field Acceleration

3 GeV RCS

Fast cycling:25 Hz

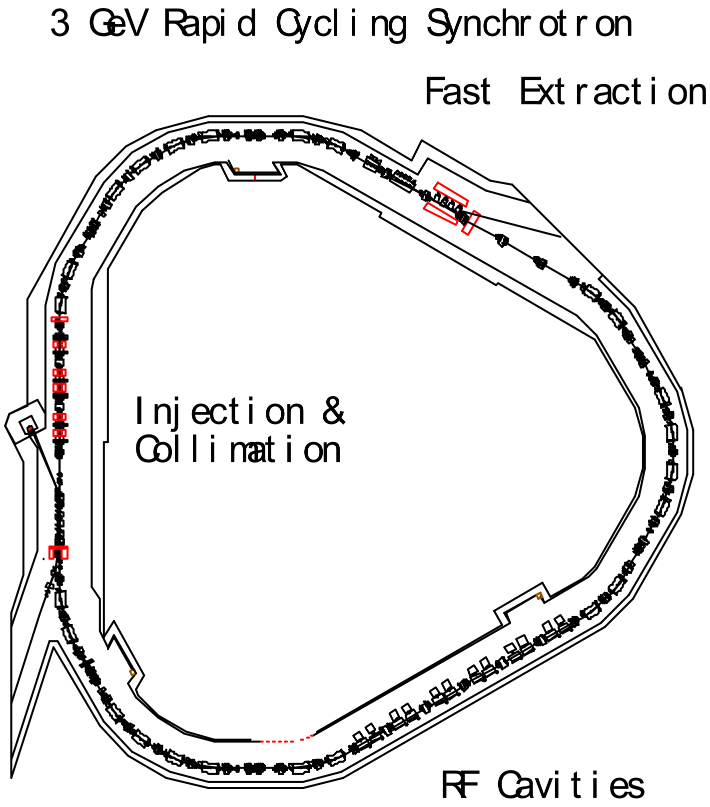
Needs high voltage:450 kV

Number of Bunches: 2 by N-users

Low Frequency:1.2-1.7MHz

Circumference is limited.

Needs spaces for extraction of 3 GeV beam with large beam size, injection and collimation.



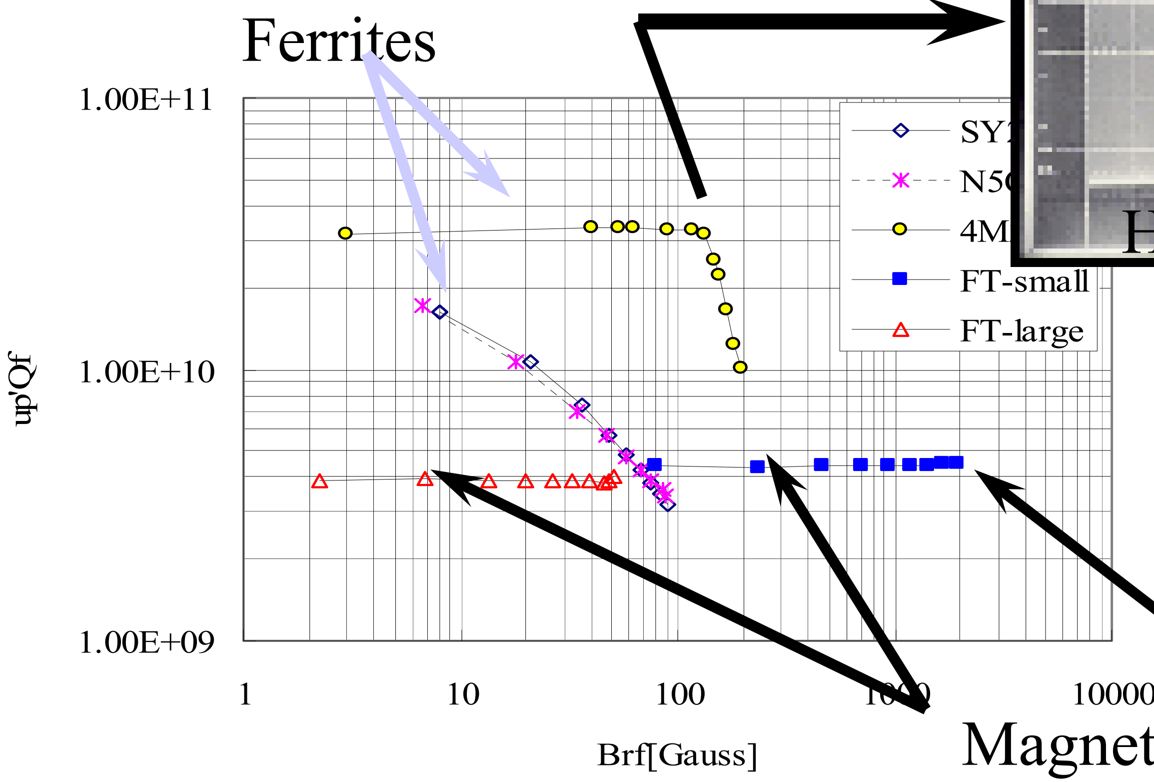
50 GeV MR

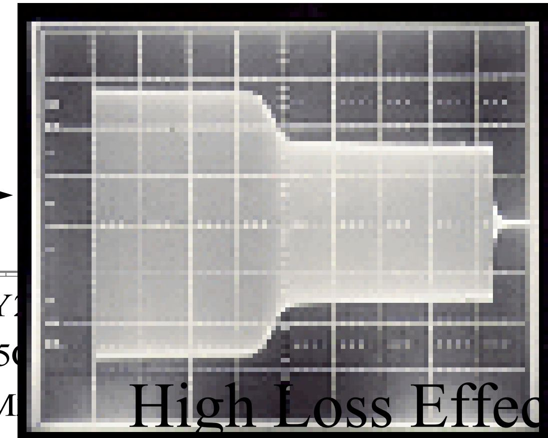
Needs high voltage: 280-600 kV

Needs space for 2^{nd} Harmonic system

Like 3 GeV RCS

Characteristics of Magnetic Cores



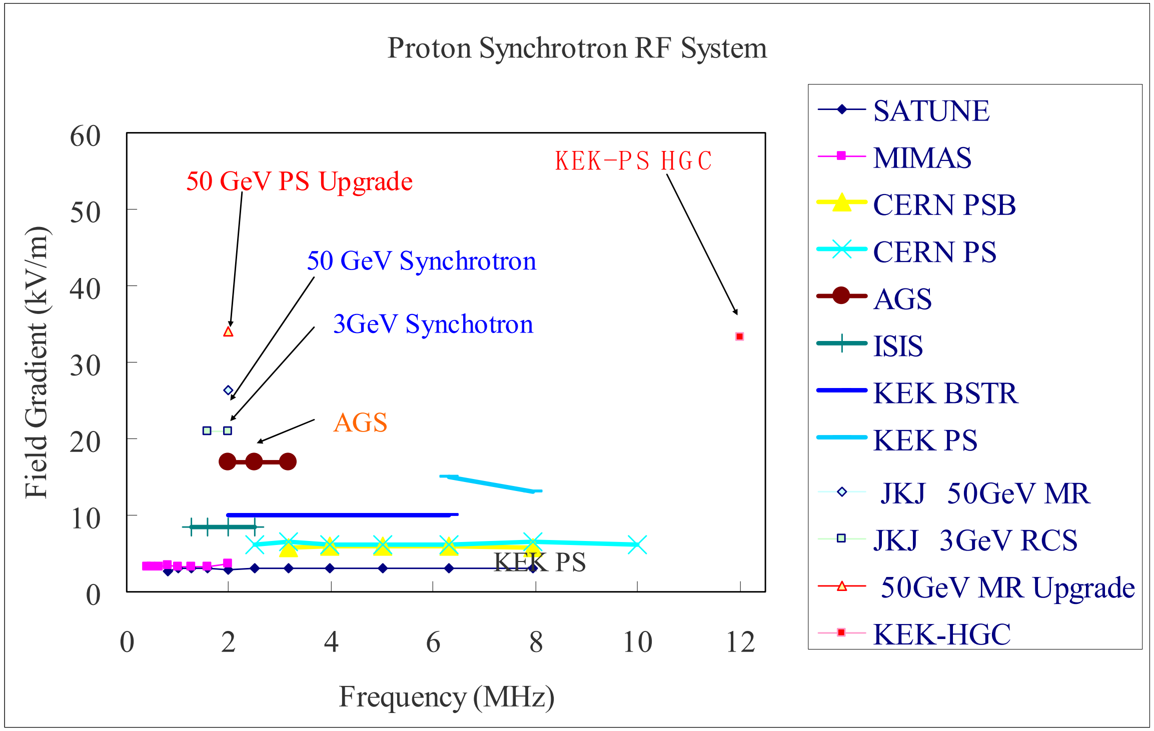


200V/div, 5ms/div

Characteristics of MA core

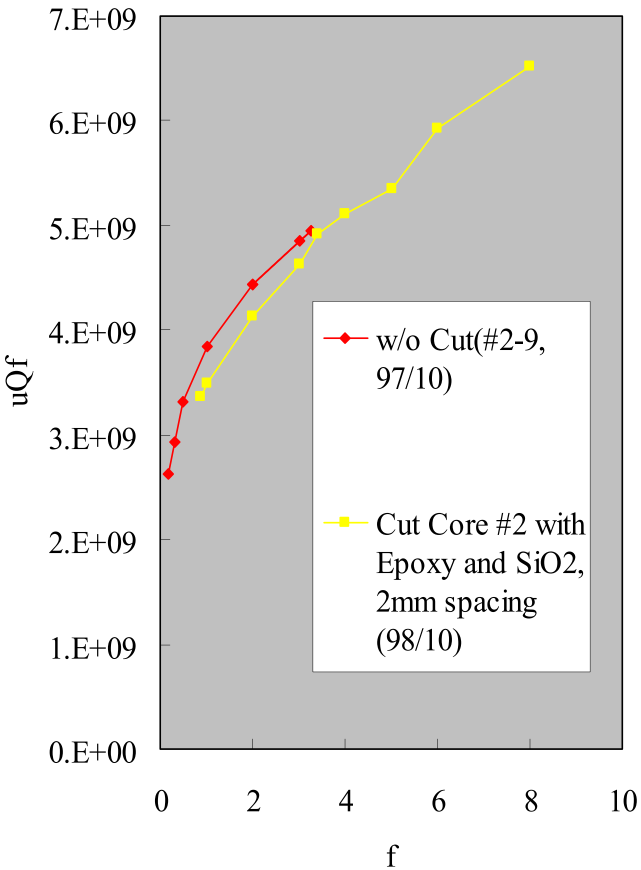
- Very large permeability- μQf-product is large.
- **μQf-product remains constant** at very large magnetic flux density. Saturation flux density is 15 kG.
  - **High Field Gradient becomes available!**
- It is stable at high temperature (170 deg.C)
  - Curie temperature (570deg.C)
- Intrinsic Q-value is 0.6 (FINEMET).
  - **Frequency sweep** without tuning system is possible
- **Q-value is variable.**

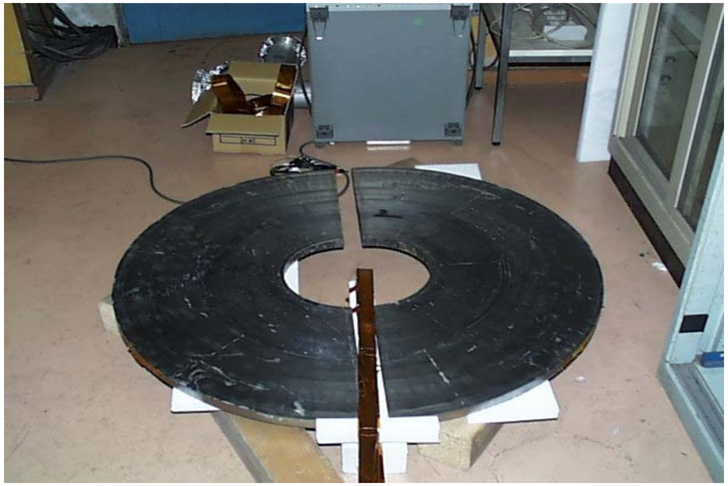
Field Gradient of Cavities for Proton Synchrotrons



Cut Core Configuration

Impedance before and after Cut





Cut Core,O.D. 95cm

By the cut, Q-value of the cavity can be increased.

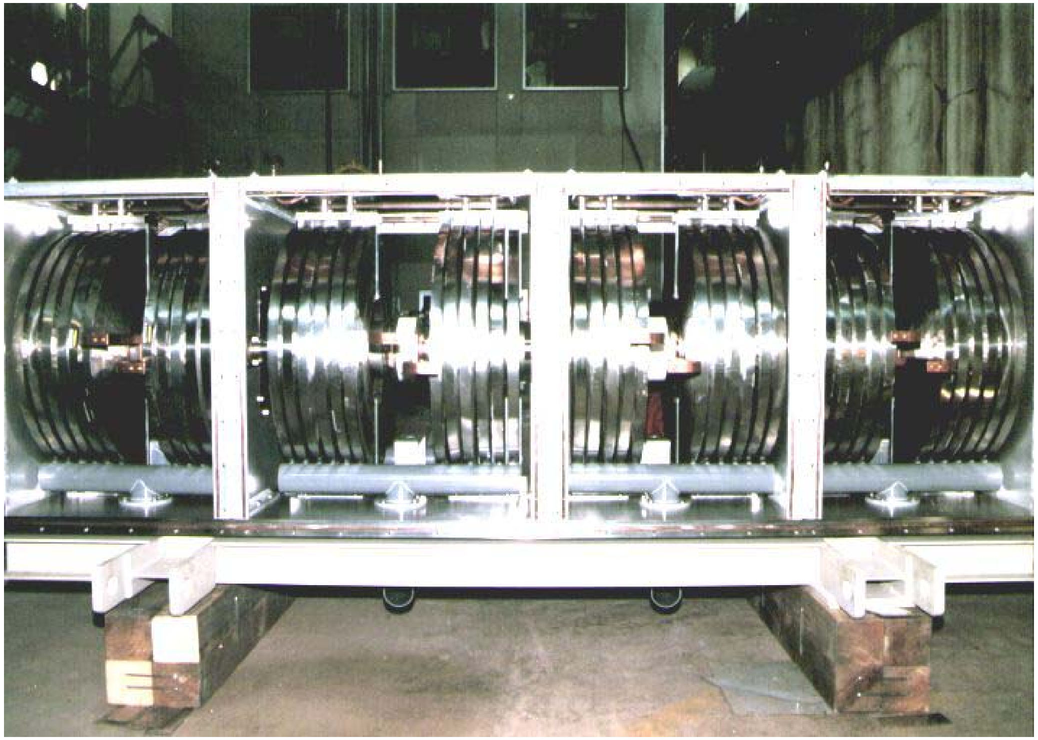
Shunt impedance was not changed.

Cavity Cooling

- For MA cavities
  - Forced Air (AGS Barrier Cavity)
  - Direct Water Cooling :
    - High Field Gradient Cavity @HIMAC
    - VitroPerm Cavity@COSY
    - Second Harmonic Cavity @KEK-12 GeV PS
  - Indirect Water Cooling:
    - FNAL MA Cavity
    - JKJ: Under development

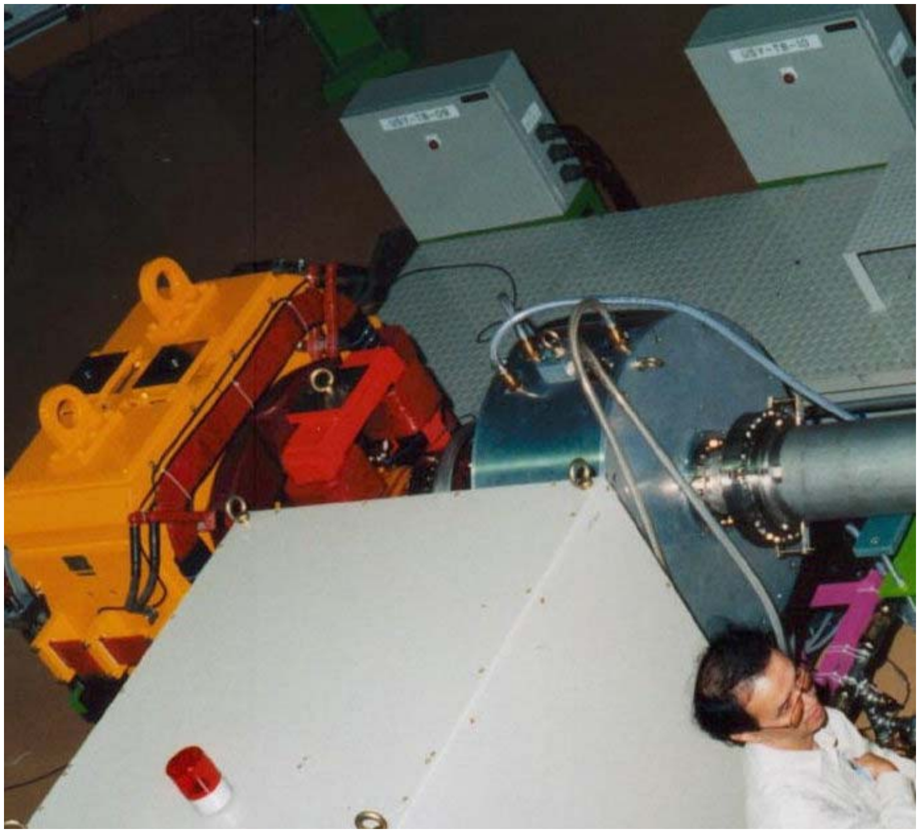
Forced Air Cooling

- First MA Cavity at KEK
- AGS-Barrier Cavity (Installed May,'98)
  - Wideband
  - 40kV/cavity
  - 2.6m
  - Peak Power: 200 kW
  - Duty: 6%
  - Average Power: 12 kW

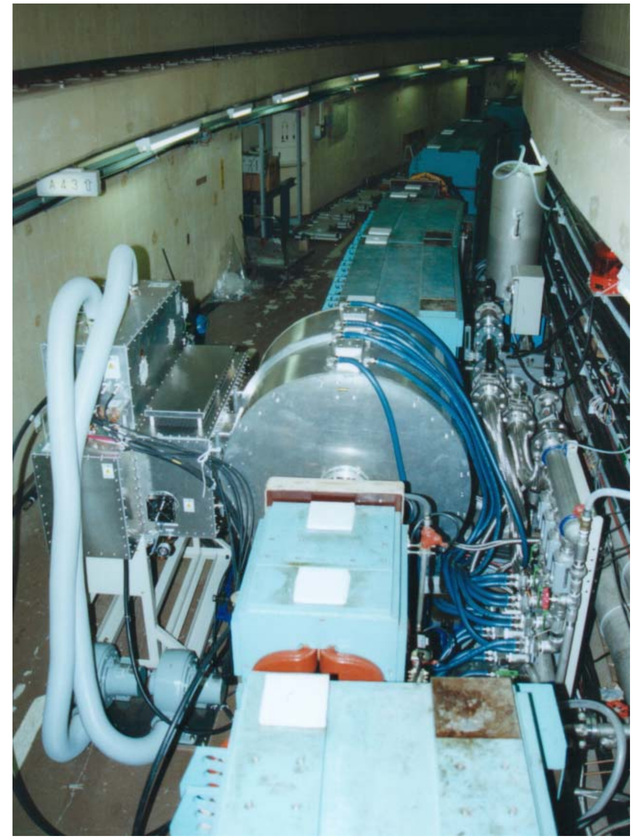


Barrier Cavity

Direct Cooling



HIMAC MA cavity: direct water cooling (Aug. ’98)



KEK-PS MA cavity: (Aug. ’00)

Fully fluorinated perfluorocarbon liquid

Direct Cooling

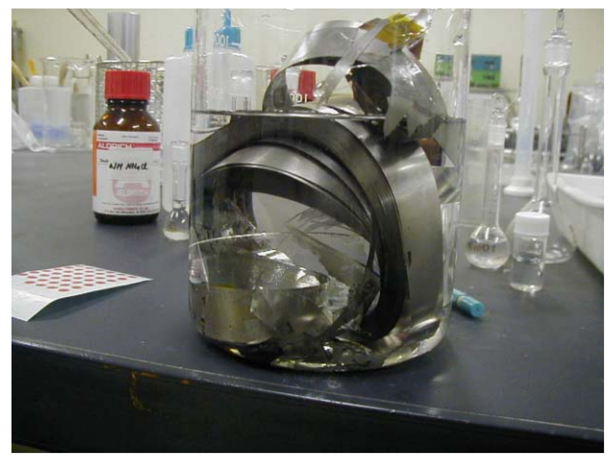
- Most powerful cooling method:
  - 12 kW/core:Water, 95 cm OD
  - About 7 kW/core: other coolant, 95 cm O.D
- Impedance reduction caused by large dielectric constant of water
  - Almost no reduction in case of other coolant
  - Only 20 % reduction by putting insulators (up to few MHz)
  - Not completely explained.
- Corrosion by the water.
  - R&D is undergoing

Corrosion test

Standard test for SUS (Hard test)
Ferric Chloride 6%, 40deg.C, 24 hours
Without epoxy : broken
With thin epoxy+coating:
0.1%wt loss

No damage on core!

Epoxy + coating after test

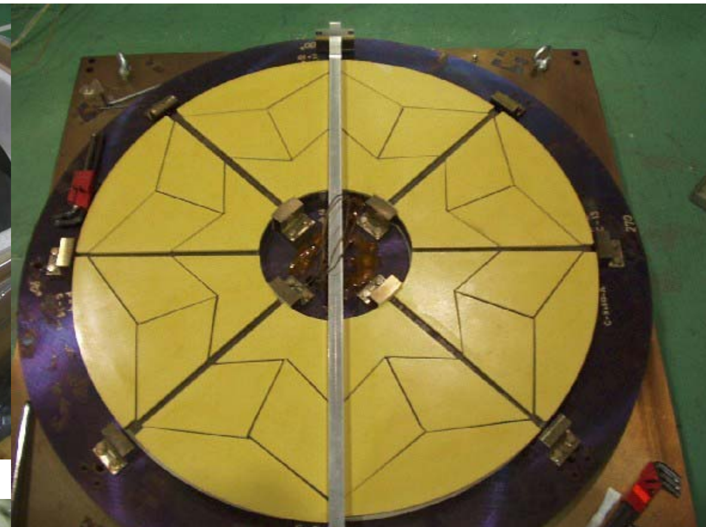


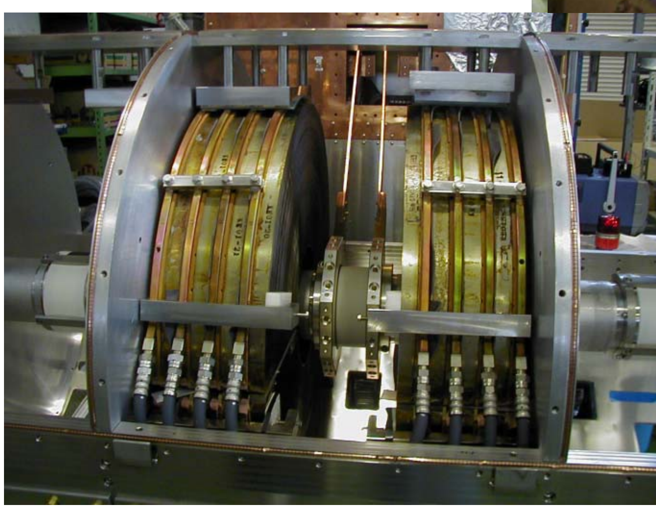
Without Epoxy after test

Indirect Cooling

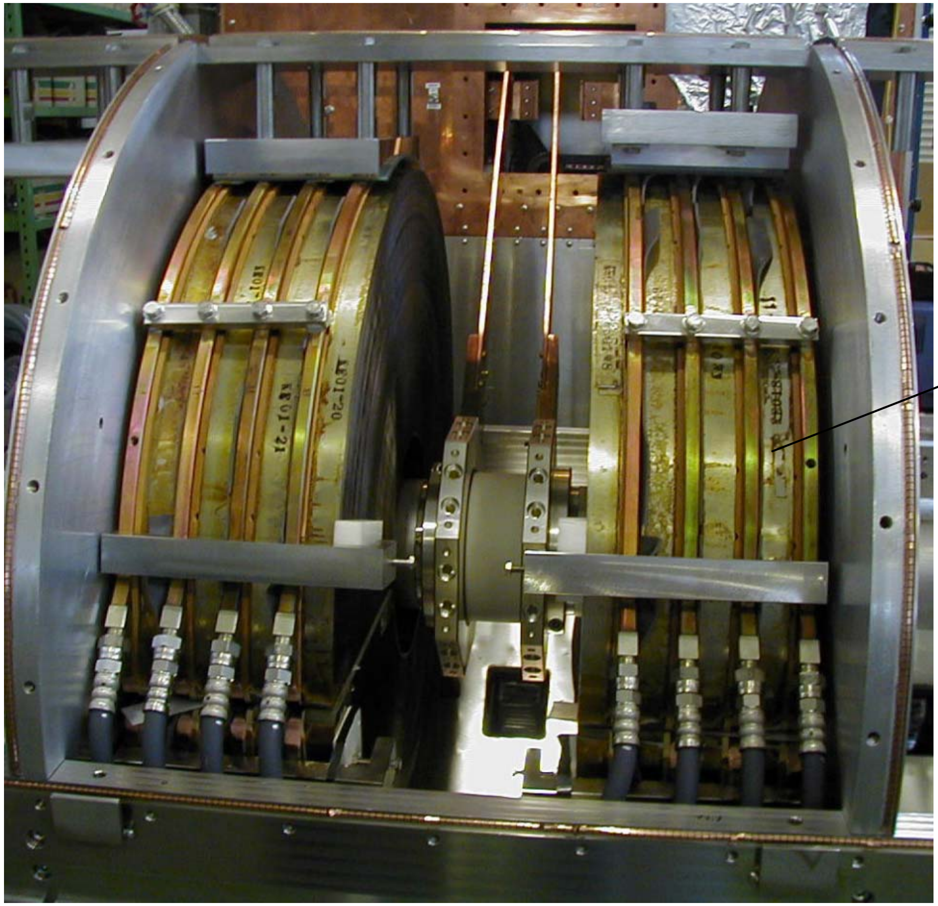
- Idea: Stack cores with cooling plates like ferrite cavity.
- Problems:
  - Conflict between impedance reduction and cooling efficiency
  - Core can not be cut without thick epoxy molding which reduces cooling.
- Solution:
  - Use insulators with high thermal conductivity (2-4W/mK).
  - Use insulators to stack the core with cooling plate for cut

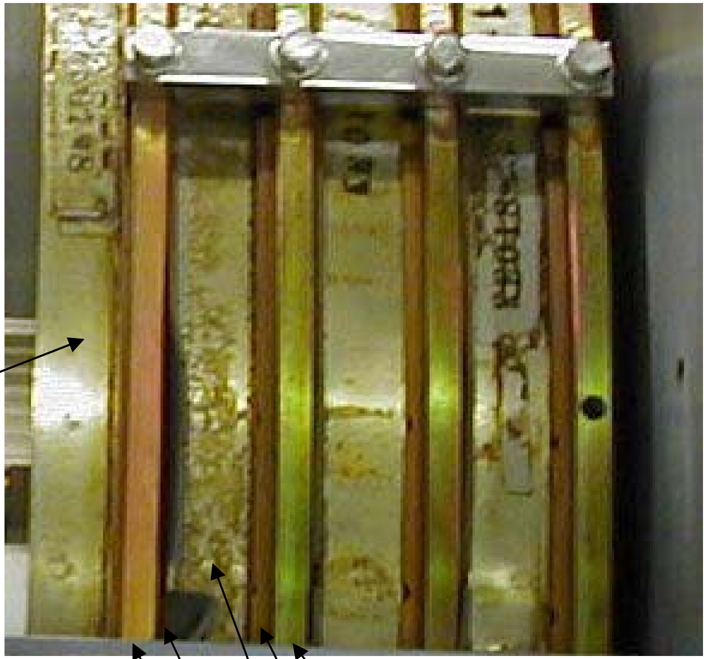
Production of Indirect Cooled Cavity

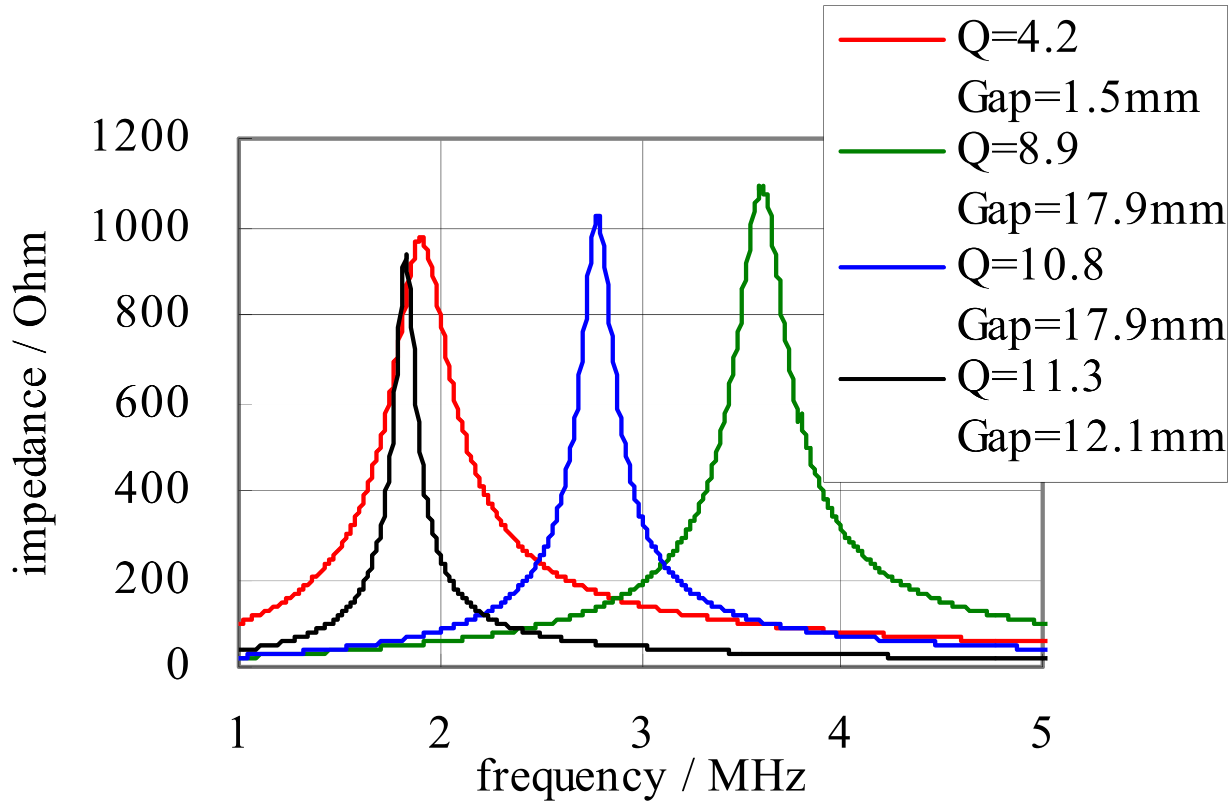



Indirect cooled cavity



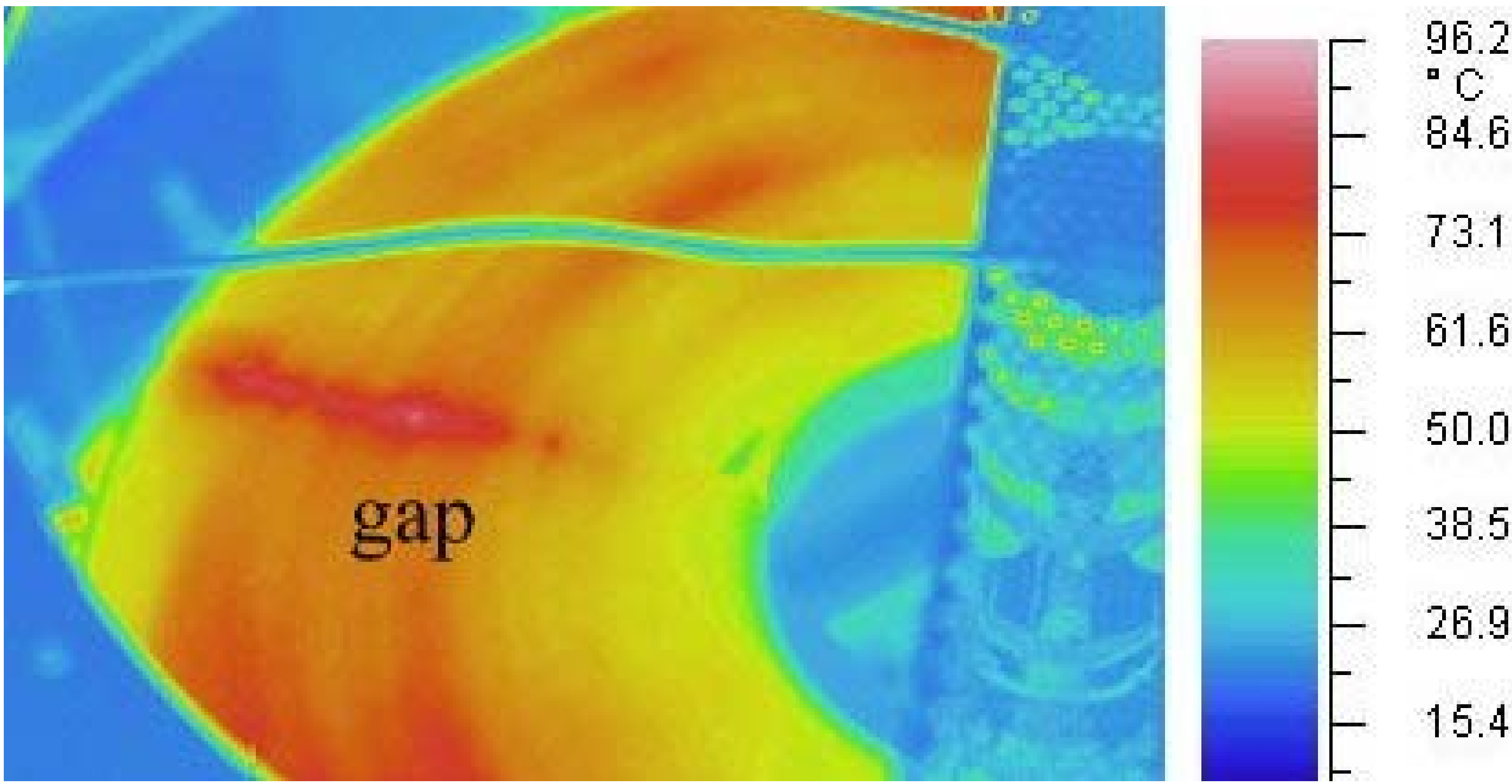


Cavity Impedance

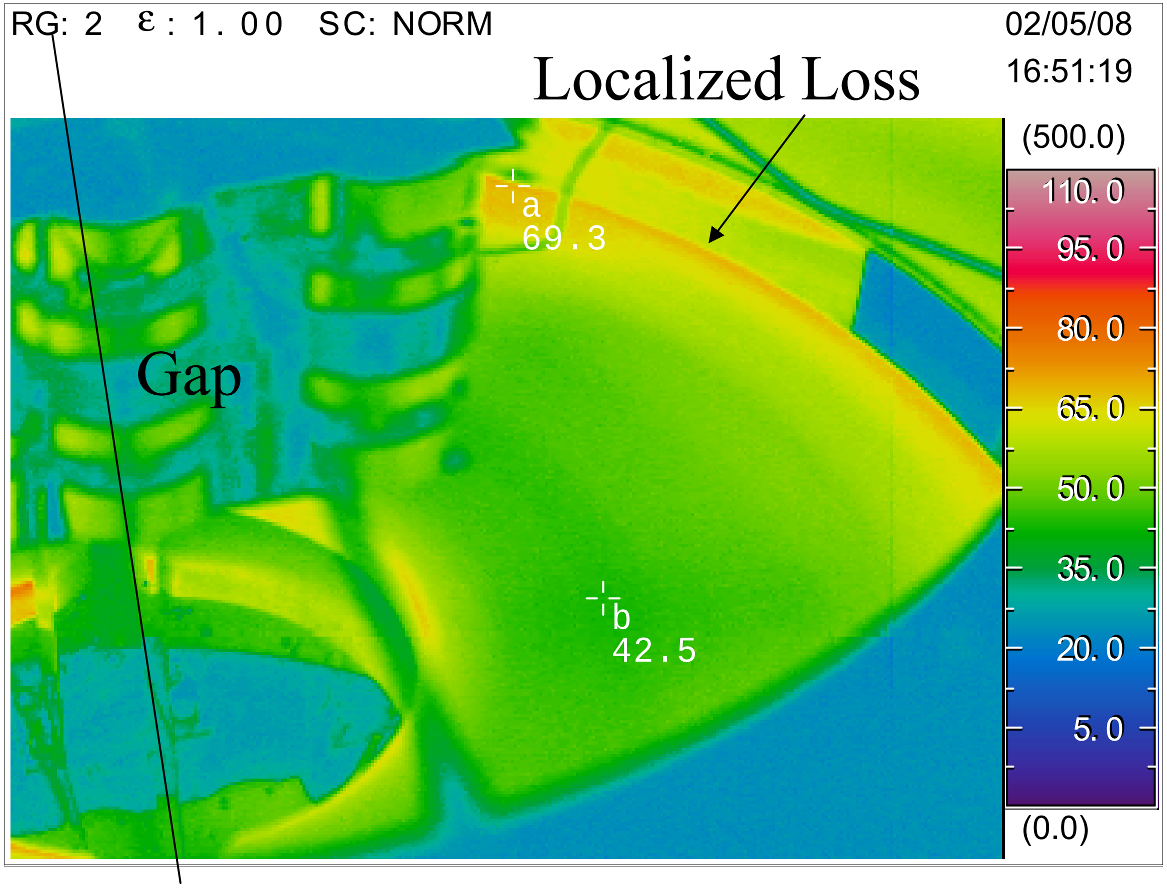


Impedance of cavity: Our target (1kΩ) was achieved.
(about 20 % impedance loss)

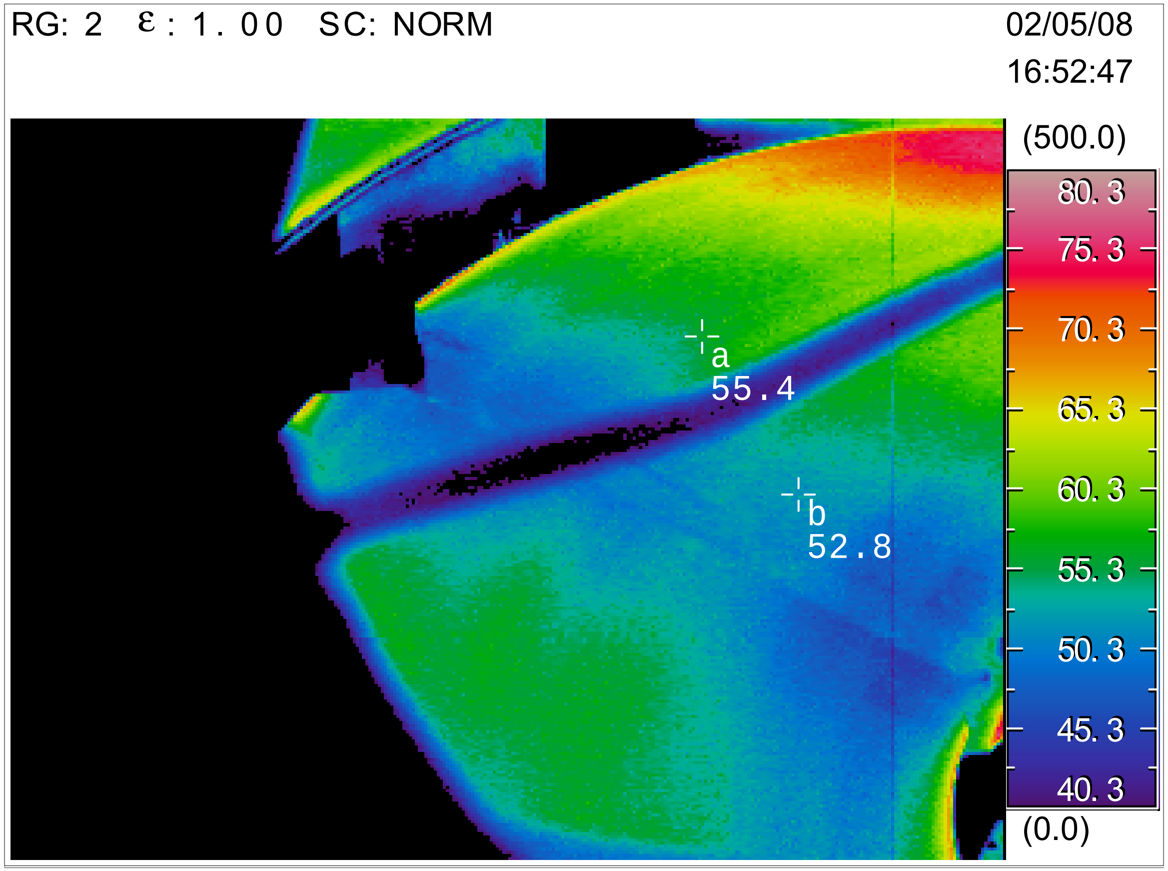
Cooling test (5kW/core) @small gap



Power test @large gap (20 mm) for high Q cavity



Power test @large gap (20 mm) for high Q cavity

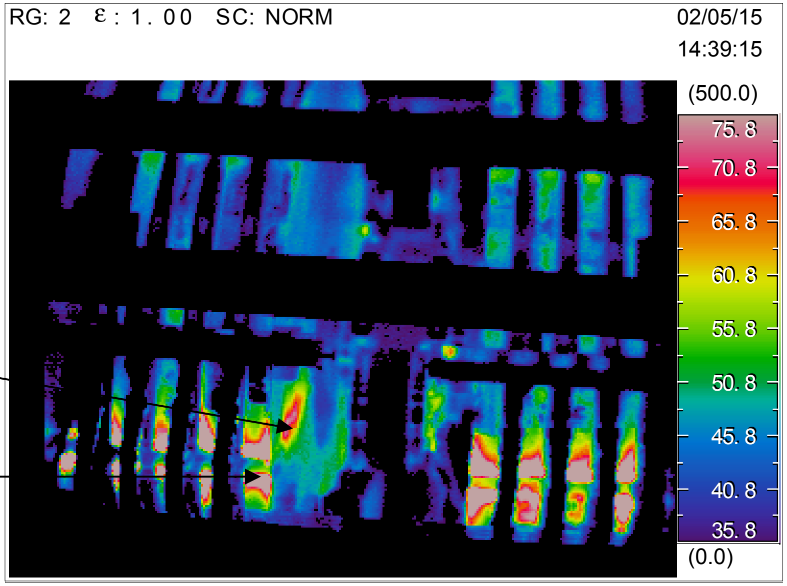


High Power Test of Cavity

- 40 kW CW was put in cavity.
- Temperature rise of water was consistent with input power.
- No smell
- Stable operation

Gap

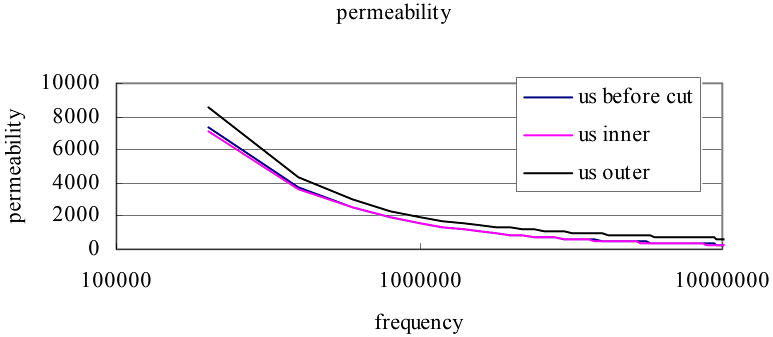
Reflection by SUS

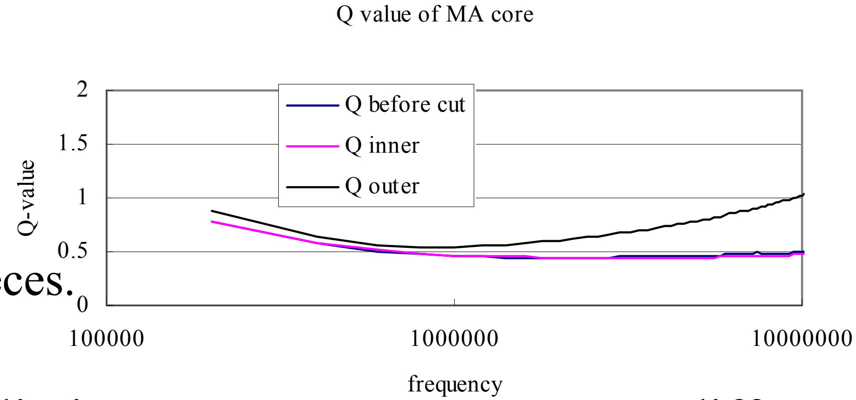


Localized Heat Loss in case of High Q Operation

- Small edge cut (10mm): Max:Min power density = 6:1
- Large edge cut (30 mm): Max:Min power density = 2-3:1
- Depends on size of edge cut and Q-value.
- Probably also related to inhomogeneous characteristics in MA core. Outer side of core had low stress during crystallization process. May have higher performance than inner. This causes the flux concentration.

Localized Heat Loss





"Onion Cut" cuts a core into two pieces.
Before cut:80cmOD.24.5cmID
Inner:60cmOD,24.5cmID
Outer:80cmOD,62cmID

Preliminary measurements suggest difference of characteristics for inner and outer parts. This may be another cause of localized loss.

Future R&D

- Indirect Cooled Cavity
  - Apply large edge cut(30mm) to reduce the localized heat loss.
  - Put another cooling plate near the gap to cool only outer side.
  - Put more power to achieve 9kW/core.
- Localized Heat Loss
  - Power test of a core stack with “Onion Cut”
  - Preliminary results show the reduction of heat loss by few ten percent.
- Water-proof MA core

Conclusions

- Two different type of MA cavity are developed.
- Test of Indirect Cooled Cavity is started and 5kW/core for low Q Cavity was achieved.
- Localized heat loss was observed and it is explained by edge effect and inhomogeneity in MA core. Need more R&D to achieve 9kV/core for high Q Cavity.