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Power challenge for SuperKEKB

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Introduction

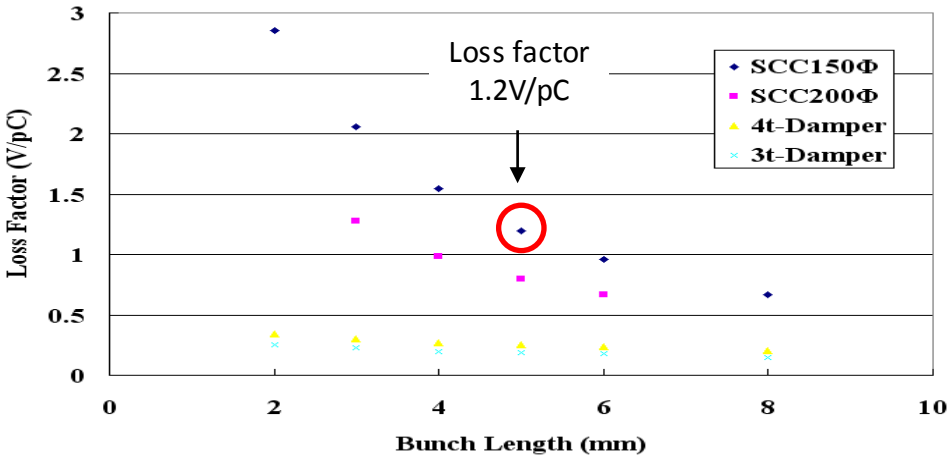
- Eight superconducting accelerating cavities for KEKB will be used for SuperKEKB.
- One of serious issues related to high beam current operation is large HOM power.
- HOM power has to be sufficiently absorbed by RF absorbers (HOM dampers).
- We need HOM dampers that can absorb RF power more than 40 kW.
- We are developing new HOM dampers for SuperKEKB.
- We present R&D status of damper development.

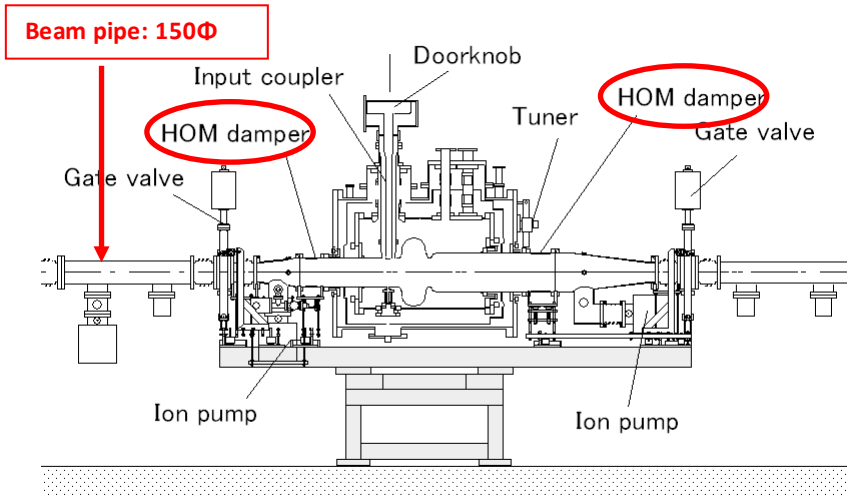
Machine parameters of SuperKEKB and expected HOM power
Issues related to present ferrite dampers
HOM power absorption achieved at KEKB
Development of new dampers
High power test results of prototype dampers
Other methods to handle large HOM power

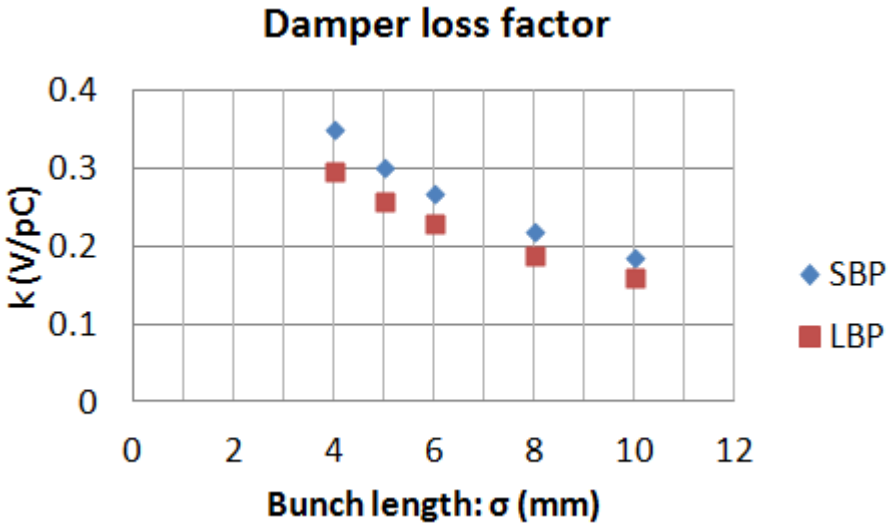
Machine parameters and HOM power

- Machine parameter of SuperKEKB/HER
  - BeamCurren : 2.6A/2500 bunches
  - Bunch length : 5mm
- Loss factor of SCC : 1.2V/pC@σ=5mm
  - Expected HOM power : 31kW
  - LBP damper load : 26kW
    - Self loss=0.26 V/pC
  - SBP damper load: 20kW
    - Self loss=0.30 V/pC
  - Total heat load per cavity : 46kW

Parameters of HER
Maximum current: 2.6A ←1.4A
Bunch length: 5 mm ←6-7mm
# of bunches: 2500 ←1600







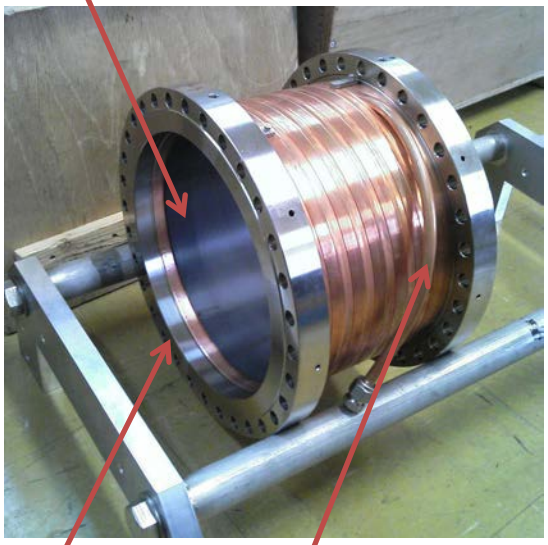
Issues related to present ferrite HOM dampers

- Present ferrite HOM dampers were developed for KEKB.
- Ferrite material is sintered on copper base pipe by hot isostatic press (HIP) method.

- Ferrite
  - Thickness: 4 mm
  - Ferrite surface temperature : 170-190℃ @2.6 A
  - Outgas from ferrite trigger high voltage breakdown
- Cooling water
  - Water temperature＜60℃
    - To prevent air bubbles
    - Deaeration system needed ?
  - Flow rate＜8L/min
    - To prevent erosion - corrosion
- Chiller unit
  - Total heat load : 46 kW
  - Cooling capacity（with a safety margin）: 60kW
  - Cooling capacity of present chiller: 27 kW

Beam current	SBP load	LBP load
(A)	(kW)	(kW)
2	12	15
2.6	20	26

Hipped ferrite（Thickness : 4mm）



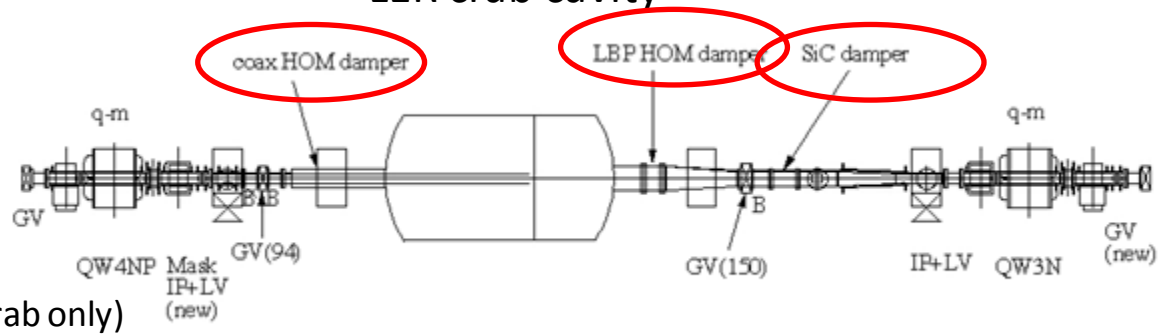
Cupper pipe (3/8”) for cooling channel

Flange: Stainless steel

HOM power absorption achieved at KEKB machine operation (Superconducting cavities)

- Superconducting accelerating cavity
  - SBP ferrite damper
  - LBP ferrite damper
- Superconducting crab cavity
  - Coaxial damper (ferrite)
  - Beam pipe damper (ferrite)
  - Beam pipe damper (SiC, LER crab only)

LER crab cavity

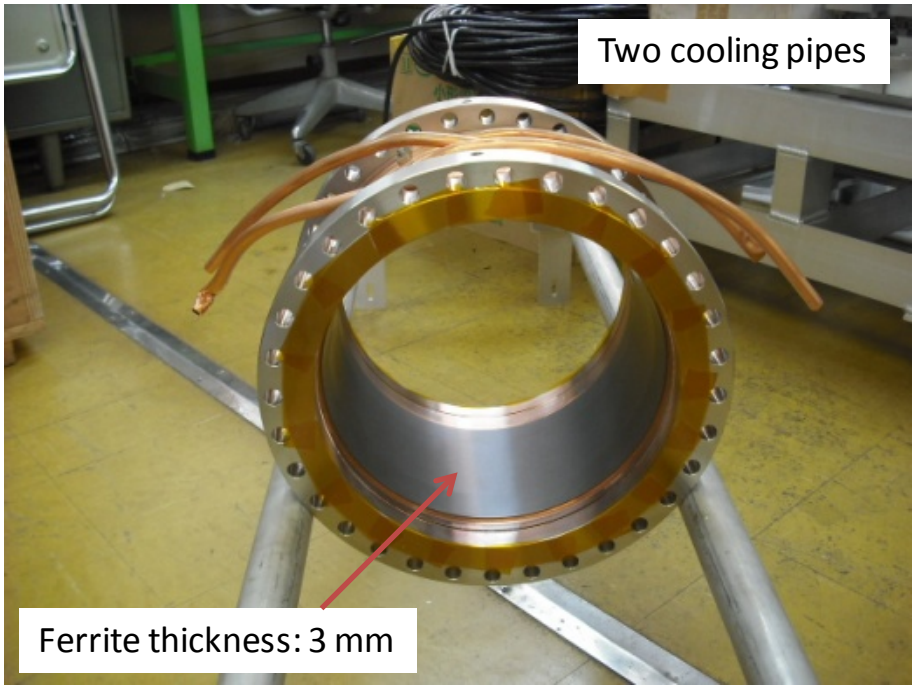


Damper type	Diameter (mm)	Thickness (mm)	Length (mm)	Max. power absorption (kW)	Beam current
SBP(SCC)	220	4	120	16	1.35 A/1389 bunches
LBP(SCC)	300	4	150		
Coax(HER Crab)	240	4	120	3	1.25 A/1585 bunches
BP(LER Crab)	240	4	120	12	1.64 A/1585 bunches
SiC(LER Crab)	150	10	240	16	1.64 A/1585 bunches

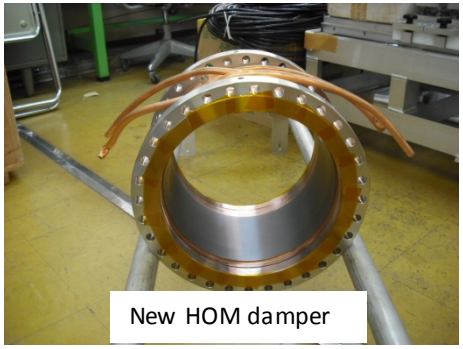
Development of new HOM dampers for SuperKEKB

- To suppress outgas from ferrite material
  - Suppress temperature rise of ferrite surface
  - Use 3 mm thick ferrite (KEKB damper: 4 mm)
    - For better thermal conduction
    - Self loss factor is expected to be reduced
- To suppress temperature rise of cooling water
  - Introduce 2nd cooling pipe
  - Cooling channels are doubled

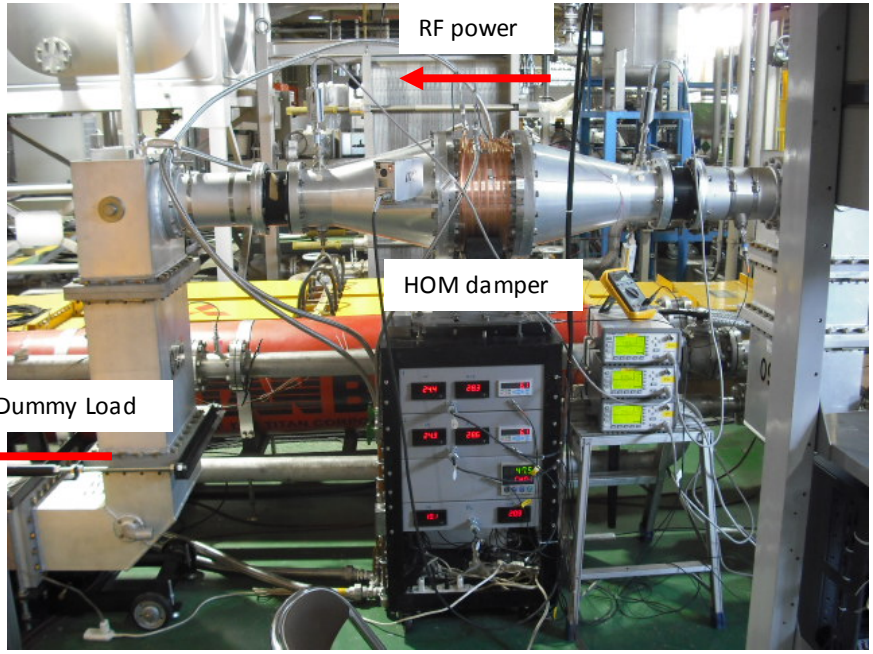
Prototype dampers were fabricated

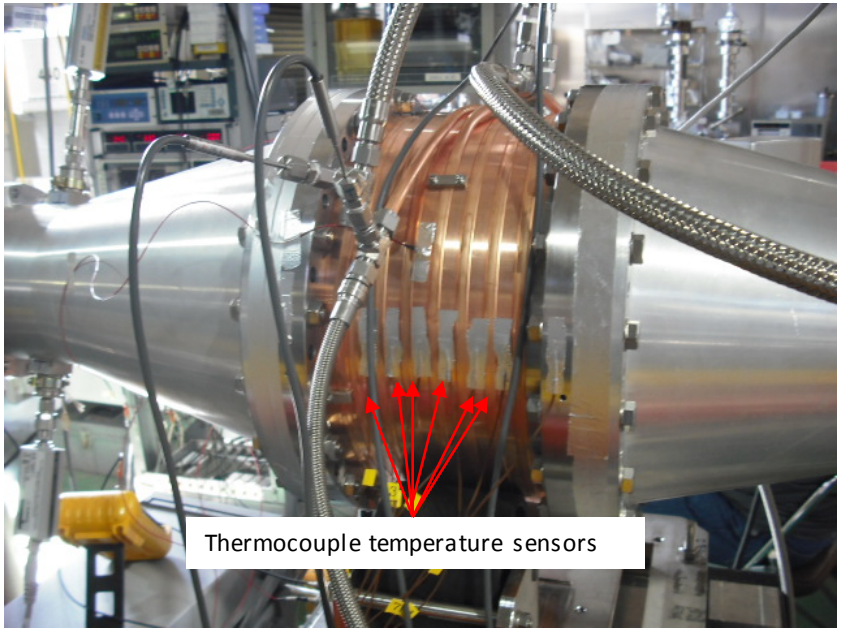


High power test of prototype dampers



Tapers and inner conductor were assembled

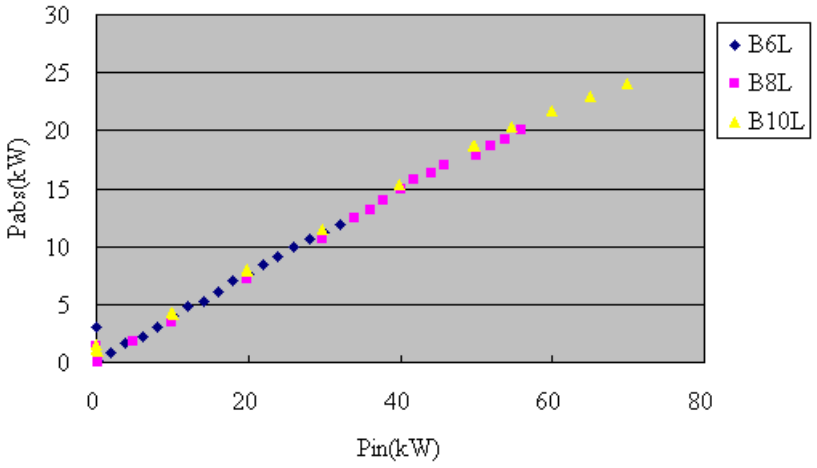




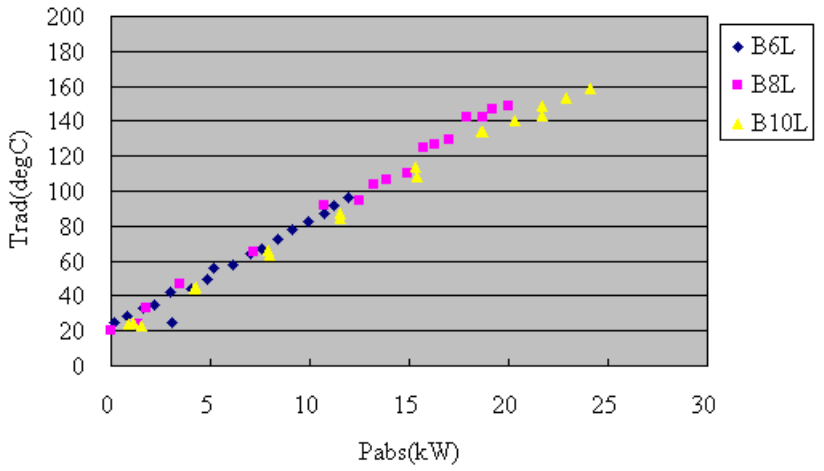
New LBP HOM damper

High power test results
(New LBP damper, prototype #1)
Flow rates of the cooling water were 6, 8, 10L/min
Copper base pipe temperatures were blow 60℃

Input RF power vs absorbed power
LBP damper absorbed RF powers up to 24 kW



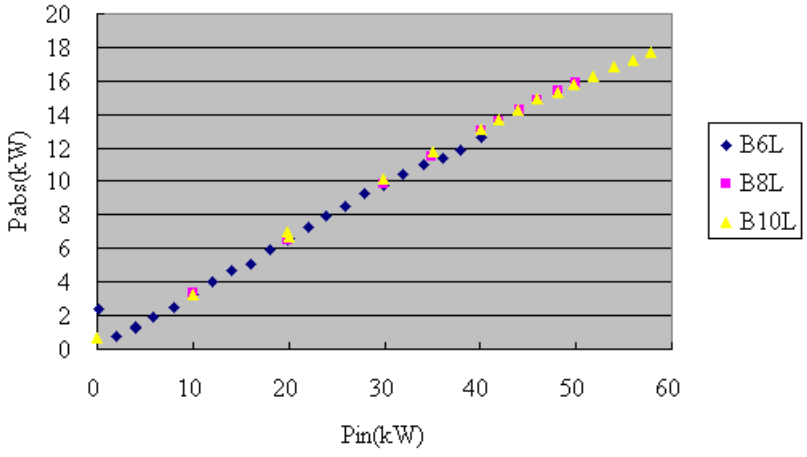
Absorbed power vs ferrite temperature
Temperature was 160℃ at 24kW



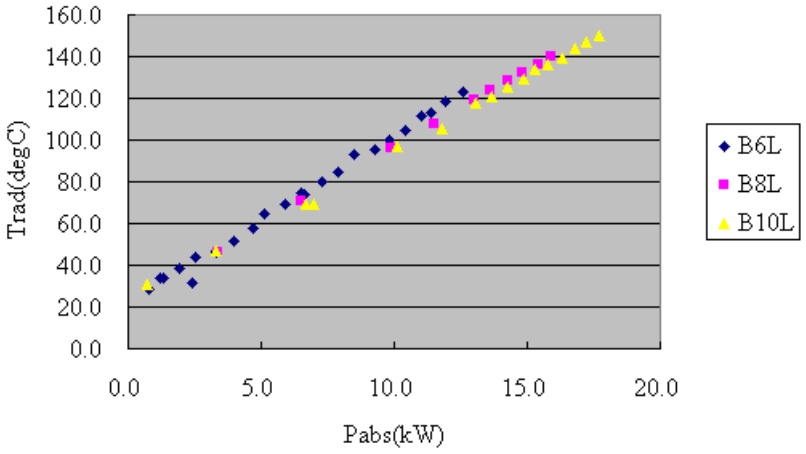
New SBP HOM damper

High power test results
(New SBP damper, prototype #1)
Flow rates of the cooling water were 6, 8, 10L/min
Copper base pipe temperatures were blow 60℃

Input RF power vs absorbed power
SBP damper absorbed RF powers up to 18 kW



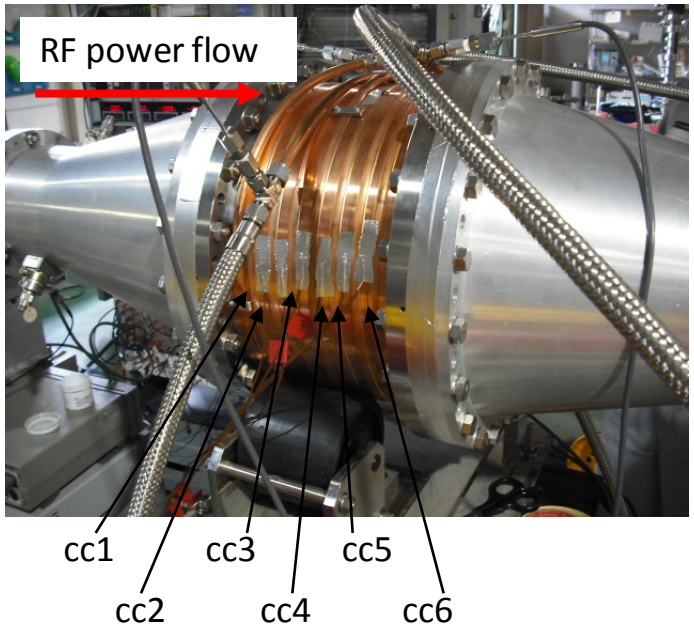
Absorbed power vs ferrite temperature
Temperature was 150℃ at 18kW



Temperature distribution of copper base pipe

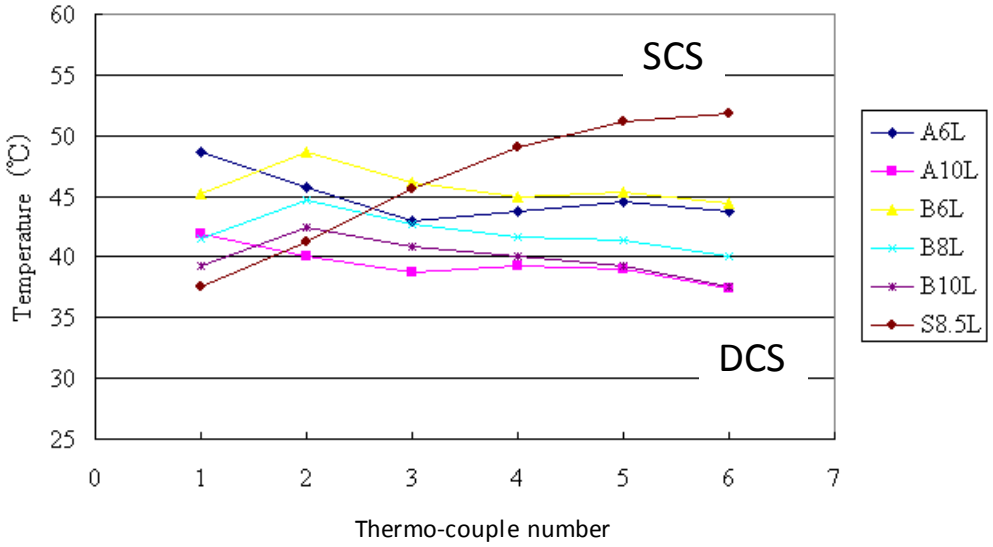
Double cooling structure can reduce temperature rise of the copper base pipe and temperature rise of the cooling water.

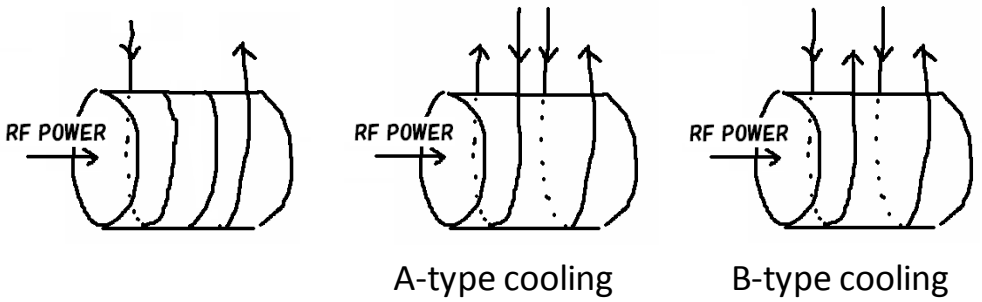
Prototype #1



Several thermo-couples were attached on the copper base pipe and temperatures were measured.

Temperature distribution at 14 kW





A-type cooling B-type cooling

Single cooling structure Double cooling structure

Summary of high power test results

KEKB type dampers were tested in 2004

Damper type		Ferrite thickness (mm)	Cooling channel	Max. absorbed power (kW)	Ferrite temperature (℃)	Crack
LBP	KEKB type	4	Single	26	170	
	Prototype #1	3	Double	24	160	
	Prototype #2	3	Double	26	170	○
SBP	KEKB type	4	Single	19	190	
	Prototype #1	3	Double	18	150	
	Prototype #2	3	Double	19	170	○

New LBP and SBP dampers absorb expected HOM power at SuperKEKB.

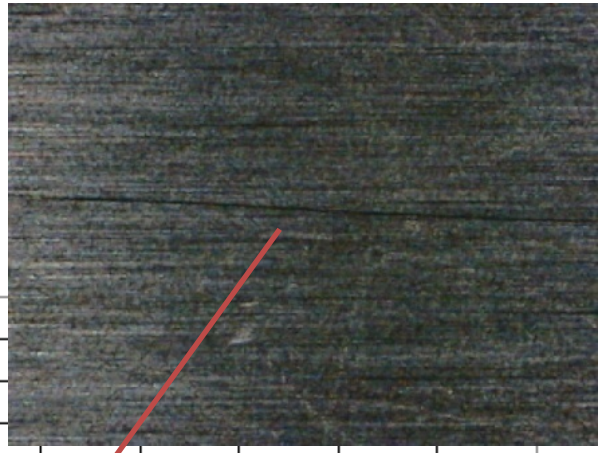
However, Surface temperature of the ferrite could not be reduced significantly. If we can not reduce the temperature rise significantly, there is no merit to replace present dampers with 3 mm thick ferrite dampers. Before we conclude definitely, we need further studies.

Furthermore, 2nd prototype damper cracked during the high power test. The tensile strength of 3 mm thick ferrite may not enough.

2nd prototype dampers cracked during high power test

- Dampers cracked at
  - LBP: 25kW absorption
  - SBP: 15 kW absorption

Microscopic picture of the crack



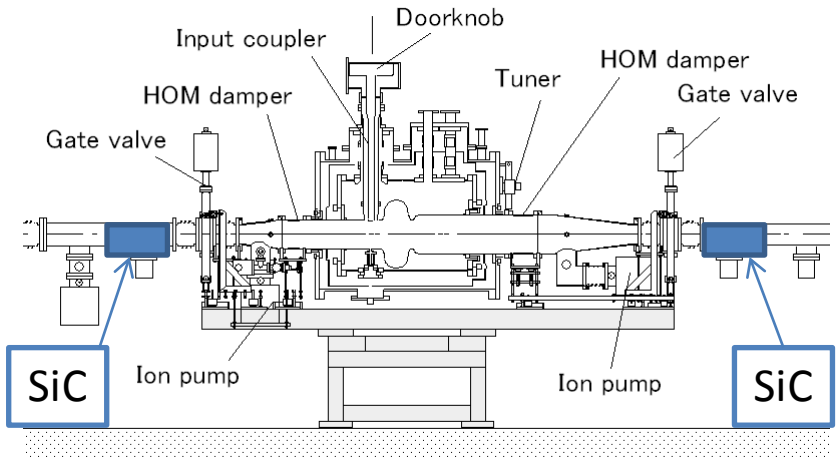
2nd SBP prototype damper

Other methods to handle large HOM power

- Increase beam pipe diameter
  - 150ϕ→200ϕ
  - Decrease loss factor
  - Decrease HOM power

Beam pipe structure	Loss factor @σ＝5mm （V/pC）	Modifications to be made
Present BP	1.2	
200ϕ BP	0.8	GV dia. Bore dia. (Q-mag.)
200ϕ BP Taper (200ϕ→150ϕ)	0.95	GV dia.
200ϕ LBP only Taper (200→150ϕ)	1.05	LBP-GV dia.

- Additional dampers
  - Add SiC dampers on the beam pipe
  - To reduce ferrite damper load
  - 150ϕ or 200ϕ
  - Need studies for power reduction



Power challenge for SuperKEKB
Summary

- In order to absorb HOM power more than 40 kW, new HOM dampers have to be developed for SuperKEKB.
- Development of new ferrite dampers is ongoing.
- Prototype dampers were fabricated and absorbed expected HOM powers at SuperKEKB.
- However ferrites of some dampers cracked during the high power test.
- Further studies are needed for damper development.
- Other methods to handle large HOM power have to be taken into account.
  - Lower loss factor structure
  - Addition of SiC dampers