Integrated Vacuum Control System for RF

Operation Status of SCC

SuperKEKB MAC2016

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The integrated vacuum control system with PLC has been developed together with digital LLRF system.

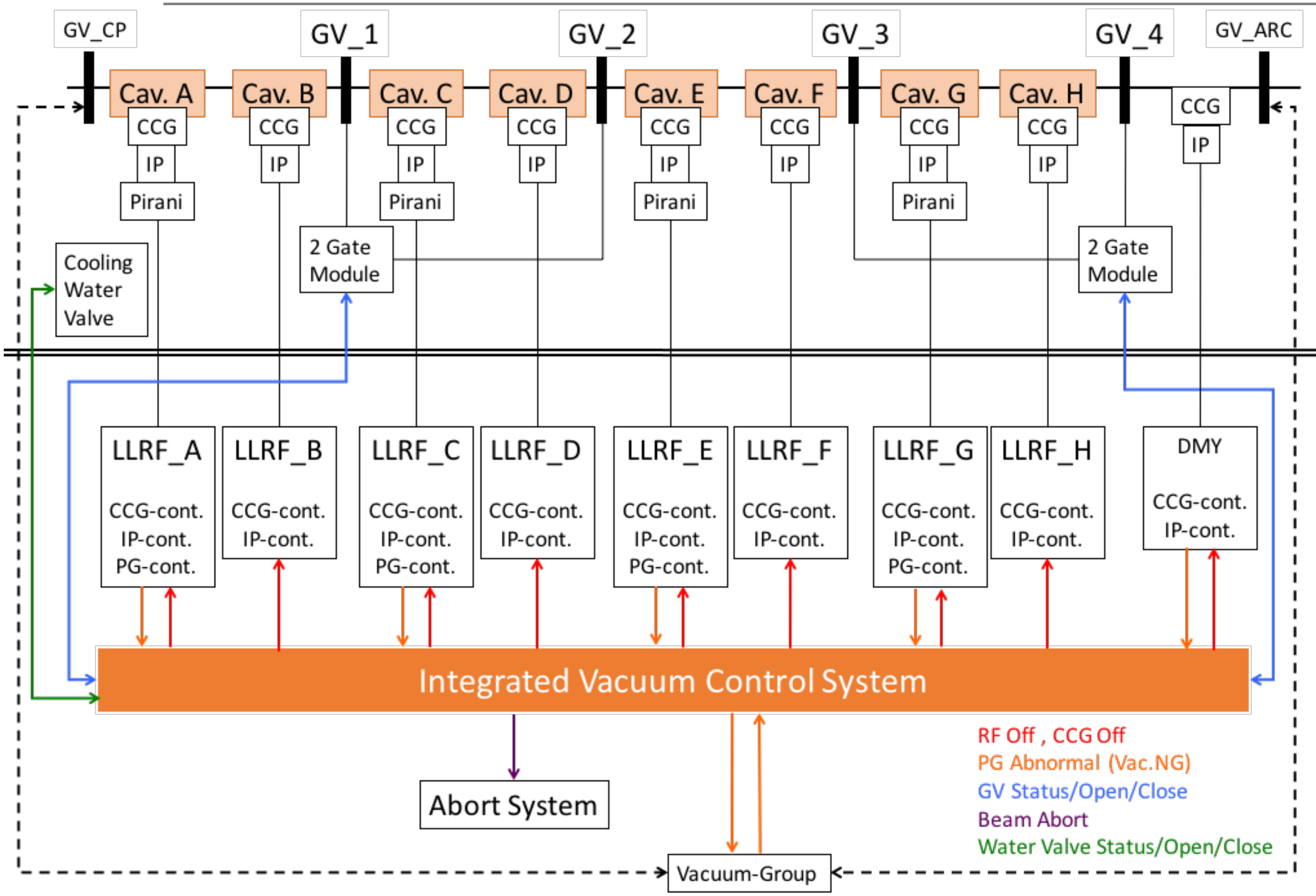
The basic purpose of the system is to protect the cavities from vacuum pressure rise as an interlock system.

The PLC is embedded with ladder-CPU and EPICS-IOC on Linux-CPU. The system with PLC can control vacuum components overall and build a simple and flexible interlock system.

Our system can absorb a variation in the number of cavities and configurations of vacuum components and GVs depending on RF section. The configurations of cavities can be set simply by dip switches at a local control panel. Therefore, LLRF system can be used without arrangement to fit the configurations of vacuum components.

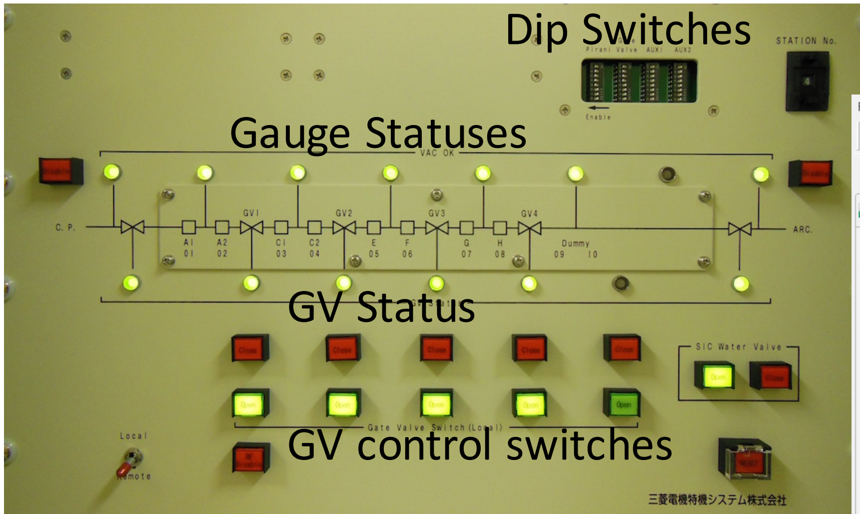
The system has been installed to two RF sections, D4 and D5 area with digital LLRF and is operating with no issues.

Schematic View

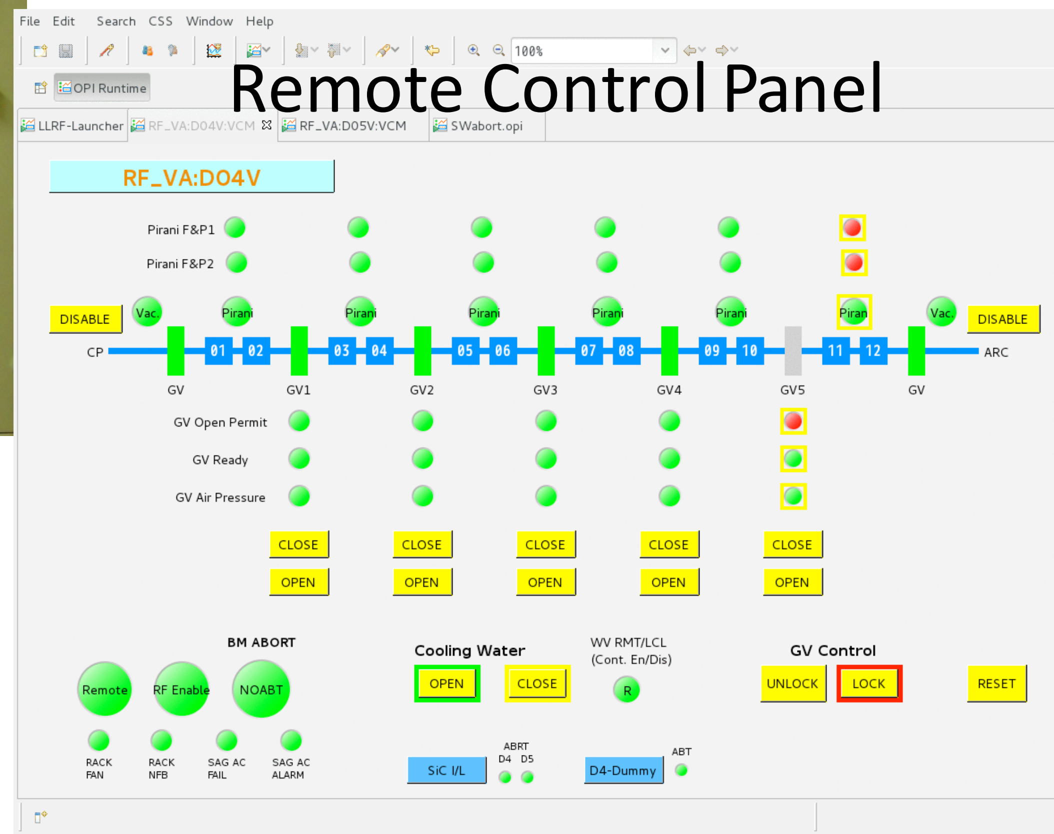


- Monitor and judge the status of
  - ✓Pirani Gauges
  - ✓GVs
- Interlock signal output to LLRF, abort system and other groups
  - ➢RF off
  - ➢GV close
  - ➢Beam Abort
  - ➢etc.

Control Panels



Local Control Panel



Summary of Integrated Vacuum Control System for RF

The integrated vacuum control system has been developed together with digital LLRF system.

The system is flexible and simple interlock system by using PLC with ladder and EPICS.

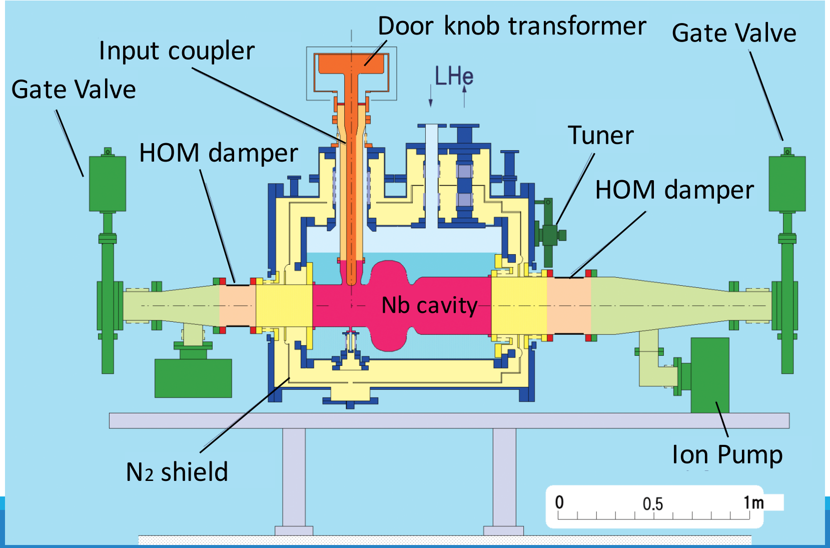
The system is functioning well in Phase-1 operation.

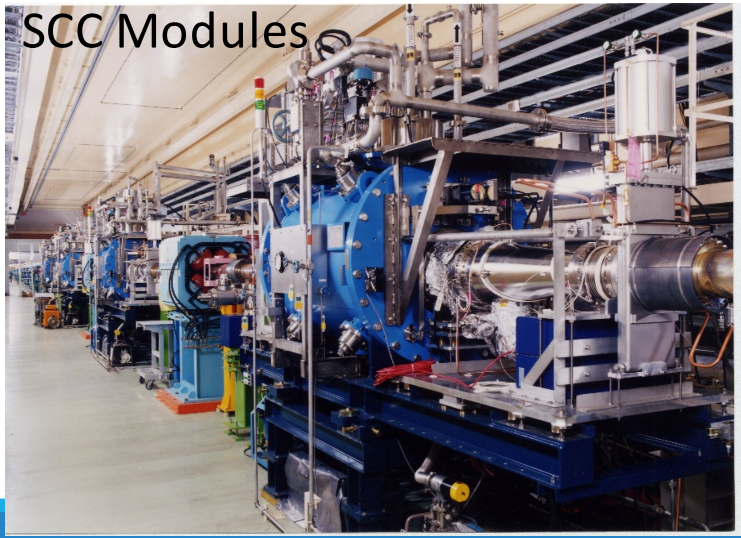
Operation Status of Superconducting Cavity (SCC)

SCC for SuperKEKB

Eight superconducting accelerating cavity (SCC) modules are operating in the electron ring (HER). In HER, RF systems are consist of 8 SCC and 8 normal conducting cavities (ARES).

A 509 MHz single cell cavity with a large iris diameter of 220 mm has ferrite HOM absorbers on both sides and a coaxial-type power coupler. All SCC modules were designed for KEKB and operated under the condition of large beam intensity in KEKB operation.





Issues for SCC

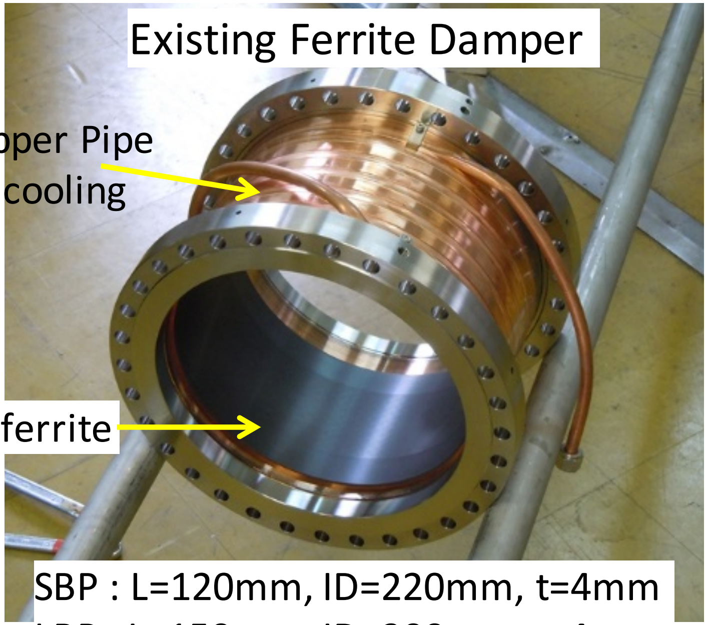
In a design of SuperKEKB, the total beam power will be 1.5 times larger than that of KEKB achieved. But the beam power in a SCC module can be kept to be the same as KEKB by sharing with ARES.

SCC-Related Parameters	KEKB (achieved)	SuperKEKB (design)
Number of Cavities	8	8
Max. Beam Current [A]	1.4	2.6
RF Voltage [MV/cav.]	1.0-1.5	1.5
External Q	5E+4	5E+4
Unloaded Q at 2MV	1E+9	1E+9
Beam Loading [kW/cav.]	350-400	400
HOM Loading [kW/cav.]	16	37

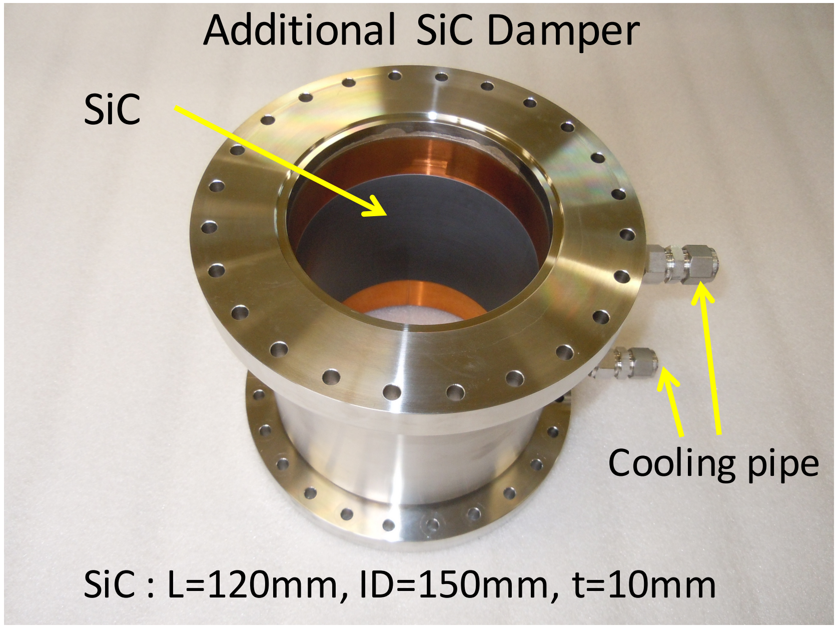
Main issues for SCC in SuperKEKB

- Large HOM Power
  - Additional SiC dampers can absorb effectively.
  - Install in Phase-2 or -3
- Degradation of Qo
  - Possible risk in the future operation
  - Horizontal HPR for 2 modules
  - Qo have been recovered.
  - One module is operating in SuperKEKB.

HOM Dampers



SBP : L=120mm, ID=220mm, t=4mm
LBP : L=150mm, ID=300mm, t=4mm



SiC : L=120mm, ID=150mm, t=10mm

Existing ferrite dampers can absorb HOM power up to 2 A operation. SiC dampers will be installed to outside of GV of LBP in Phase-2 or -3 for higher beam current operation.

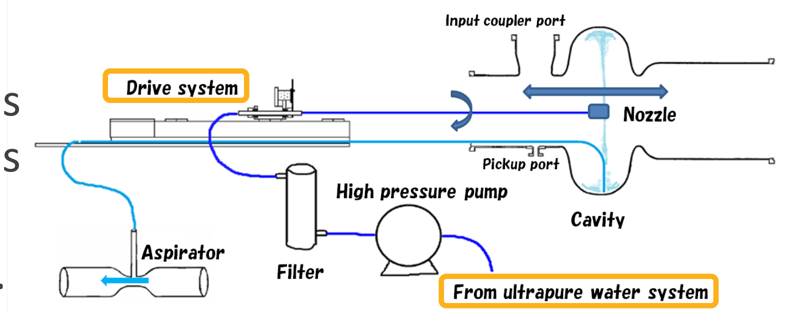
Pabs [kW]	Ferrite SBP	Ferrite LBP	SiC 240mm
Tested max.	19	26	36 (18x2)
Simulation*	9	12	24

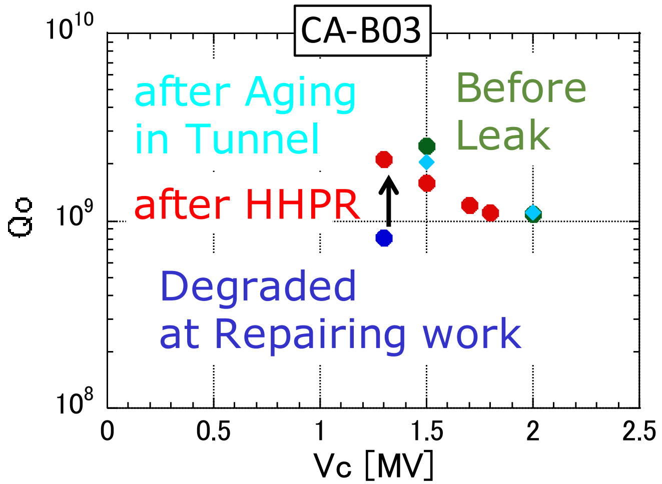
* Beam current 2.6A, Bunch length 5mm, Bunch charge 10nC

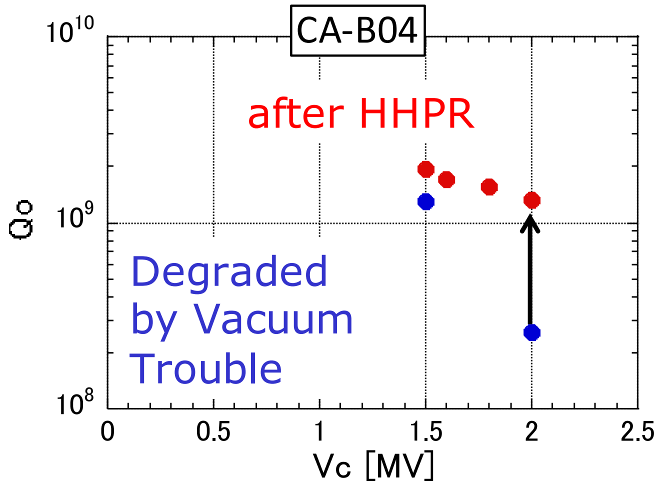
Horizontal High Pressure Rinse (HHPR)

The system can apply HPR to cavity without disassembling cryomodule. The system is equipped with automatic nozzle driving system in horizontal and rotational. Only cell and iris area are rinsed. Water in the cell is pumped up by aspiration system during rinsing.

We have already applied HHPR to two modules degraded by strong FE. Both cavity performances were successfully recovered.
One module is operating in beam commissioning.







Summary of Operation Status of SCC in Phase-1

- Cavity performance after the 5-year shutdown

Vc : almost reproduced the Vc limits within 0.15 MV before shutdown

Qo : almost reproduced Q factors before shutdown

  - One cavity slightly degraded its Q factor at 2 MV (D10A). Further conditioning may help to increase its Q factor.
  - One cavity significantly degraded its Q factor by dust contamination during start-up work (D11B). The Q factor at the operation voltage of 1.5 MV is below 1×10^9. The cavity is still acceptable since the operation voltage is still lower. We have to replace it before the full current operation.

- Cavity operation parameters during the commissioning
  - Operation Voltage : 1.1-1.38 MV/cav.
  - RF Power delivered to beam : 250 kW/cav.
  - HOM Power : 3.5-4 kW/cav. at 0.8 A operation
  - Trip rate has increased significantly after vacuum bump beam study for Beast II background study.

Summary of Operation Status of SCC in Phase-1

- Cavity performance during the commissioning

Trip : Beam aborts due to cavity problem were 7 times. (~6/12)

- 4 quenches/breakdowns (3 in D11A, 1 in D10D)
- 3 discharges in input coupler and cavity (D11A, D11B)

Other trouble : Piezo tuner problem

- Six piezo stacks (in four cavity modules) failed by electric breakdown in 3.5 months operation. In two modules, broken piezo stacks were replaced to new ones, and in others, cavities are operating by using motor tuner only.
- Piezo stacks have been renewed because the model used in KEKB was discontinued. But, the new model is found to be sensitive to rapid change of voltage in operation. We have took measures of replacement of LPFs of control system to slow ones. We will continue to investigate the problem.

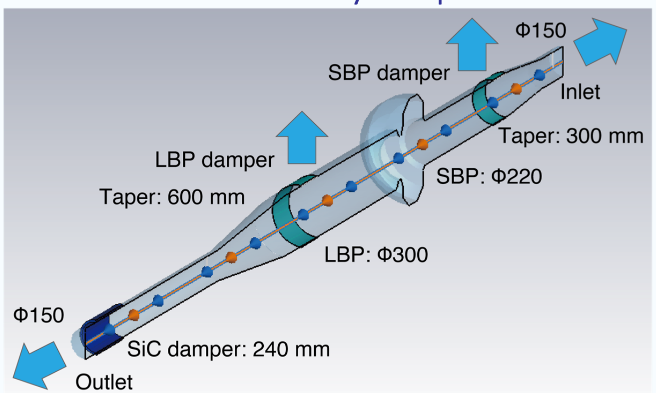
SCC operation is totally stable in Phase-1.

Thank you for your attention!

backup

Power Flow Simulation of Additional SiC Damper

Wake field simulation by CST particle Studio



- Loss Factor including HOM dampers
- Area & Time Integral of Power Flows

→ HOM loads for each part

Another option to reduce HOM power, Large Beam Pipe of 200mm in dia. model

- Same level of ferrite damper loads and outlet power as 240mm SiC model
- Need to replace Q-magnet and beam pipes of ring
- Need to open cavity to the air

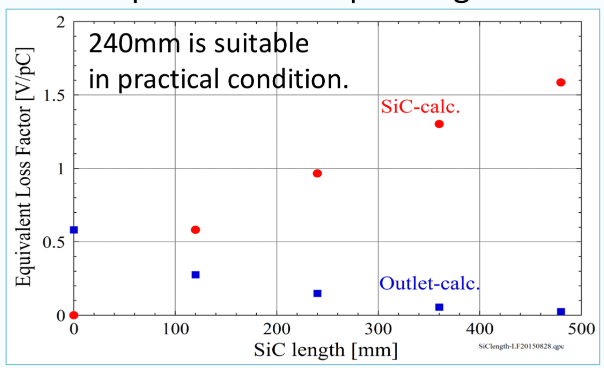
No merit in the model

- Small SBP & LBP damper loads
- Remarkable large outlet energy

→ **Additional SiC Damper at Downstream of Outlet**

	No additional damper		with 240 mm SiC	
	Eq. LF [V/pC]	HOM load [kW]	Eq. LF [V/pC]	HOM load [kW]
Inlet	0.05	1.3	0.05	1.4
Outlet	0.58	15.7	0.15	4.0
SBP damper	0.32	8.6	0.35	9.5
LBP damper	0.43	11.7	0.47	12.8
SiC damper	-	-	0.97	26.1
Total	1.38	37.4	1.99	53.8

Eq.LF vs SiC damper length



SiC damper of 240mm

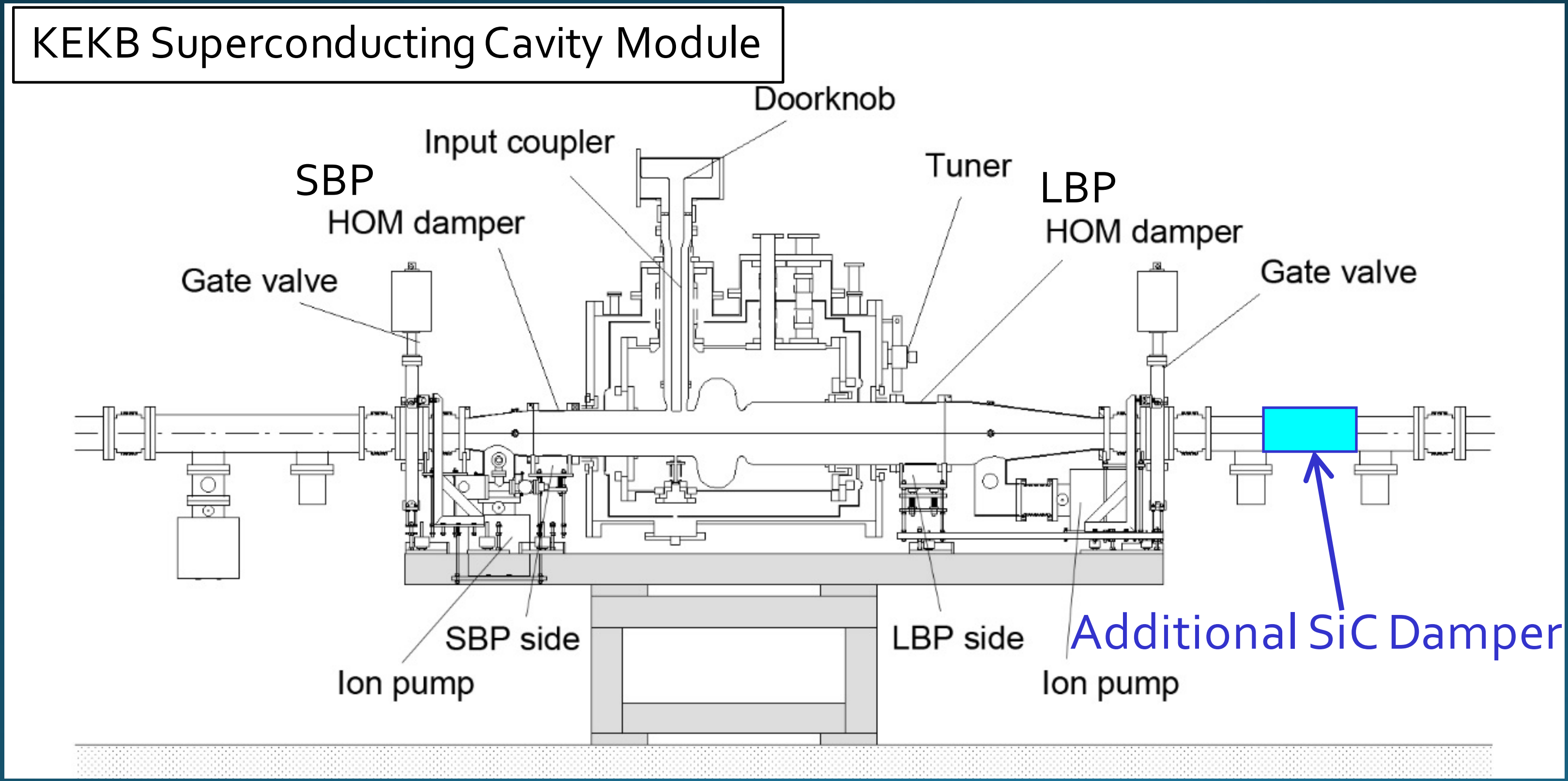
- absorbs effectively outlet power.
- does not change the loads of ferrite dampers. Ferrite temperature will be 100°C, acceptable.
- can be installed without air exposure of cavity.

Advantage of Additional SiC Damper

- Additional SiC Damper

  The damper can be installed outside of gate valve of the cavity module. The cavity surfaces do not need to be exposed to the air.

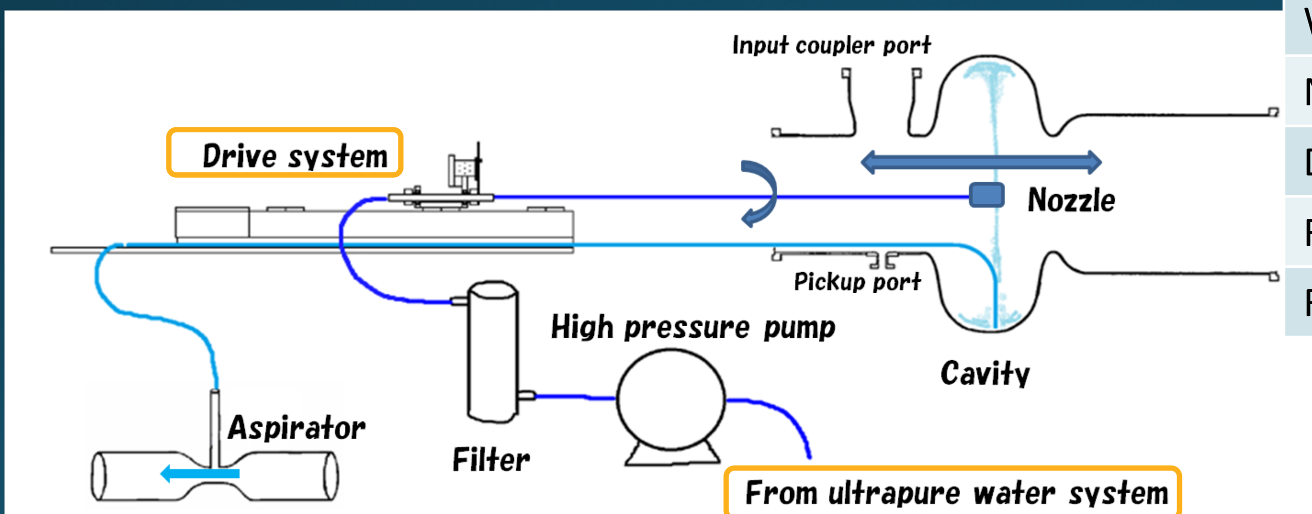
  The risk of degradation of the cavity performance can be avoided.



Horizontal HPR (HHPR) system

- New HPR ultrapure water system was developed.
- The system is equipped with automatic nozzle driving system in horizontal and rotational.
- Input coupler and both end groups, including ferrite HOM damper, taper chamber, bellows chamber, ion pump, vacuum gauges and GV, are removed before HHPR in a clean booth.
- Water in the cell is pumped up by aspiration system during rinsing.
- Only cell and iris area are rinsed.

HHPR Parameters	
Water Pressure	7 MPa
Nozzle	ϕ0.54mm x 6
Driving speed	1 mm/sec.
Rotation speed	6 deg./sec.
Rinsing time	15 min.

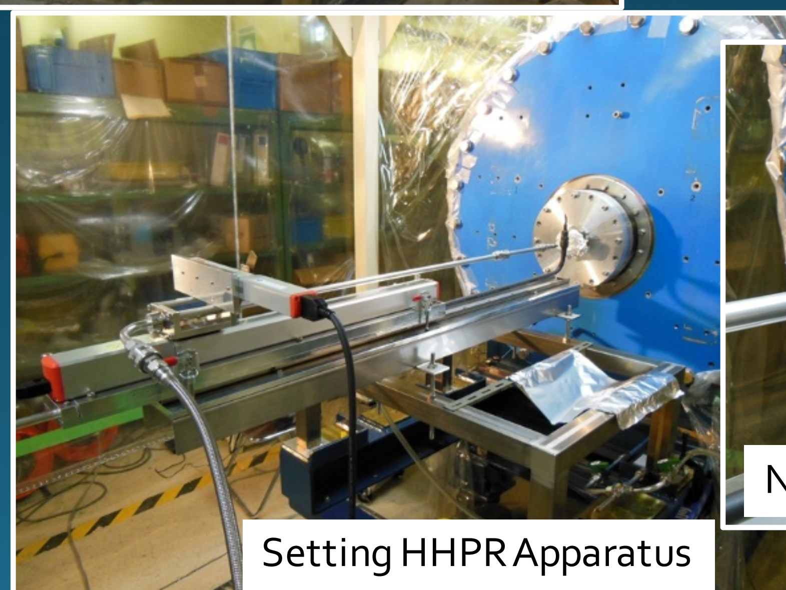


We applied HHPR to degraded cavities.

HHPR Applied to Degraded Cavity


Removing Coupler


Removing HOM dampers and vacuum system


Setting HHPR Apparatus

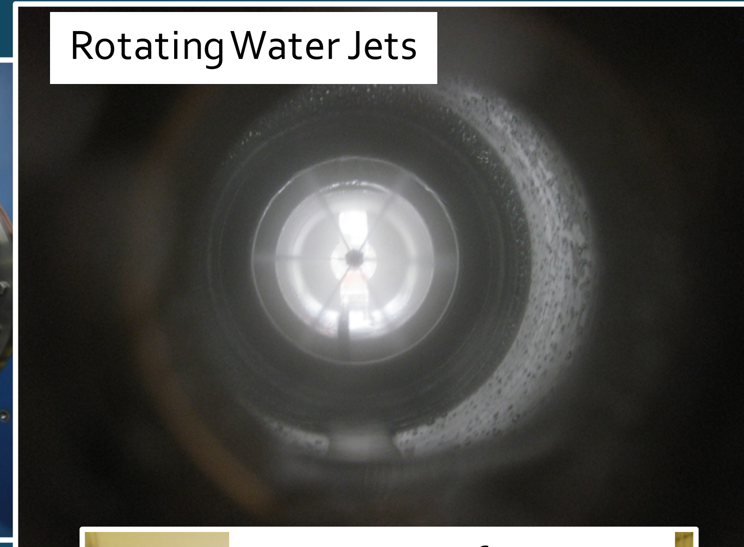

Nozzle and Aspirator Head

Before HHPR, input coupler and HOM dampers were dismounted in a clean booth.

HHPR Applied to Degraded Cavity


Opening Dummy Flange


Insert Automatic Drive Nozzle


Rotating Water Jets


High Pressure Water Pump

Aspirator Pumps


Evacuation after HHPR

Cavity was dried up by evacuation before setting the coupler and HOM dampers.