Accelerating Cavities for the Damping Ring (DR)

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For KEKB-RF/ARES Cavity Group
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The 16th KEKB Accelerator Review Meeting
February 8, 2011
Old RF Model

shown in the 15th KEKB Accelerator Review Meeting, February 16 (2010)

\[ R/Q = 150 \, \Omega \]
\[ Q_0 = 29000 \, \text{(IACS90\%)} \]
\[ V_c = 0.5 \, \text{MV} \]

Loss Factor : 1.9 [V/pC]

(Normal View)  (Transparent View)

- Bullet-shaped HOM Absorbers (SiC; Hexoloy)
- Tuner
- SiC Duct (Cerasic-B)
- Input Coupler (Used one from APS)
- Pumping Port
- Taper (\(\phi_{150} \leftrightarrow \phi_{40}\)) with L=400mm
[Basic Conditions]
A) Frequency: 508.887MHz (= the freq. of the MR)
B) Based on KEKB-MR/ARES, but without S-cav and C-cav
C) Connection to φ40 beam ducts (→ taper near the cavity)
D) Max. Total $V_c$: 0.5 → 2MV
   • Against microwave instabilities from CSR effects
   • Should be higher enough than the current design value: 1.4MV

[Main Topics]
1. 3 Cavities (max) with 0.7MV/cav in the RF section (~5m-long)
2. SiC tiles for all the HOM dampers
3. Grooved Beam Pipe (GBP) made common between the neighboring cavities
4. Connection between the cavity and GBP
5. HOM Impedances for CBIs
6. RF-absorption power in each HOM damper
7. Coupled oscillations of the accelerating mode
Specification of the Vc and Wall Loss of the DR Cavity

Based on the results of the HPT of the ARES Prototype performed in the KEK/AR Tunnel (1997)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>KEKB Design</td>
<td>0.50</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Max. Continuous</td>
<td>0.70</td>
<td>133</td>
<td>74</td>
</tr>
<tr>
<td>Max. Instantaneous</td>
<td>0.82</td>
<td>193</td>
<td>94</td>
</tr>
</tbody>
</table>

(Appendix A)

(From T. Kageyama's presentation @DR mtg)

Note: The DR cavity has been designed with the same basic structure as the ARES/A-Cav on the basis of its successful experiences.

(Appendix B)
New RF Model
ver.2011-02-08

- 3 cavities with 0.7MV/cav
- GBP common between the neighboring cavities
- HOM dampers with SiC tiles
- SiC tiles on the duct work similarly to SiC ducts.
- Loss Factor : 2.5 [V/pC]

(Dimensions in mm)

Tuner
SiC tiles
Pumping Ports
Input Couplers
(from KEKB-MR)
Two Types of Components

1. Cavity
2. Grooved Beam Pipe (GBP) with SiC tiles

Connection:
- Welding for vacuum sealing
- RF shield inside

We do not use flanges because of:
- No space for bellows
- Non-circular duct (GBP)
- Thermal stress by the ACC mode
Connection between the Cavity and GBP

Lip welding for vacuum sealing, like:
- Cycle: "Welding → Cutting" possible several times

Finger-type RF shield, like:
- Safe for low beam currents, such as 70mA

Vacuum

(Based on the Y. Takeuchi’s drawing) (Conceptual)
The basic HOM damped structure is the same as that of the KEKB-MR/ARES cavity, but the HOM absorbers are all SiC tiles: t20mm x 48 mm x 48mm.

Bullet-shaped SiC absorbers used for the KEKB-MR/ARES

SiC tiles are:
- brazed on a copper plate.
- water-cooled via the copper plate.

**Power Capability:** ~1 kW/Set (@1.3GHz)
Longitudinal Impedance of the RF section: and CBI

Estimated from Finite-Difference Time-Domain parallel computations of GdfidL with the PC cluster (256 cores & 512GB memory)

CBI threshold for Total Vc: 1.4MV

\[ s_{max} = 500 \text{ m} \]

\[ s_{max} = 1000 \text{ m} \]

Growth Time \( > 20 \text{ms} \)
\( > 5 \text{ms (rad. damping time)} \)
Transverse Impedances of the RF section: and CBI

Estimated from Finite-Difference Time-Domain parallel computations of GdfidL with the PC cluster (256 cores & 512GB memory)

(Tuner Position: 30mm inside)

CBI threshold for Total Vc: 1.4MV

\[ s_{\text{max}} = 1000 \text{ m} \]

\[ \text{For Growth Time: 200 [ms]} \]

\[ \text{For Growth Time: 30 [ms]} \]

\[ \text{max}(\text{Re}[Z_{\perp}]) \text{ [kOhm/m]} \]

\[ \text{max}(\text{Re}[Z_{\perp}]) \text{ [kOhm/m]} \]

Growth Time \( > 30\text{ms} \)

\( > 10\text{ms} \) (rad. damping time)
Power of RF Absorption in Each Set of SiC Tiles

HOM Power from the Long-Range Wakefield

Estimated from the time-domain computation of GdfidL (smax=1000m) with the conditions:
- Bunch charge: 8nC
- Bunch length: 6mm
- Beam offset: 2mm (X,Y)

Scalar sum over four bunches

~15W
~15W
~14W
~19W

~58W
~58W
~58W
~58W

~16W
~16W
~15W
~18W

<< (Power Capability: 1kW/set)
Heating Value by the ACC Mode for SiC Tiles

Eigenmode Analysis
- Using CST-MWS
- With 40 MeshLines/WaveLength

Electric Field of the ACC mode

Tail of the Electric Field of the ACC mode (magnification)

(6 SiC tiles are approximated by one plate.)
Heating Value by the ACC Mode

Simulation Results

For the mechanically innermost position

\[
\frac{P_{\text{loss}}^{(\text{All-SiC})}}{P_{\text{loss}}^{(\text{Wall})}} = 0.1\% \\
P_{\text{loss}}^{(\text{Wall})} = 133\text{kW} \text{ for } 0.7\text{MV/cav} \\
P_{\text{loss}}^{(\text{All-SiC})} = 133\text{ W}
\]

“Heating value < 100W/set << Power Capability: 1kW/set
Coupled Oscillations of the ACC Mode

Electric Field

TM mode
Cutoff: 1.51 GHz

TE mode
Cutoff: 588 MHz

Close to the ACC-mode Frequency: 508.9 MHz

Coupled Oscillations of the ACC Mode might be non-negligible via the TE mode.
Step 1: Two-Cavity System

“Electric Short” or “Magnetic Short”

Conditions:
- Lossfree approximation
- Cavity interval: 956mm
- 6 SiC tiles approximated by one plate

Compute Mode Frequencies using CST-MWS and GdfidL.
Two-Cavity System

\[
\frac{f_{acc}}{Q_0} \approx \frac{509\text{MHz}}{30000} \approx 20\text{kHz}
\]
Step 2: Periodic Structure

Periodic Boundary Condition with a phase shift: 0 or 180 deg

One Unit
Periodic Structure

\[ \text{ACC-Mode Frequency (} f_{\text{acc}} \text{) } \text{ [MHz]} \]

\[ \begin{align*}
\text{MWS (0-mode)} & \quad 509 \\
\text{MWS (π-mode)} & \quad 509 \\
\text{GdfidL (0-mode)} & \quad 509 \\
\text{GdfidL (π-mode)} & \quad 509 
\end{align*} \]

\[ \approx \]

\[ \begin{align*}
\text{Coupling Strength (} \propto \text{)} & \quad \frac{f_{\text{acc}}}{Q_0} \approx \frac{509 \text{MHz}}{30000} \approx 20 \text{kHz}
\end{align*} \]
The Coupled Oscillations of the ACC Mode are negligible.
# Schedule

<table>
<thead>
<tr>
<th>JFY</th>
<th>Cavity No. to be made</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>0</td>
<td>HPT to be done by May 2012; Could be a spare.</td>
</tr>
<tr>
<td></td>
<td>(prototype)</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>Feedback from the HPT of the Cavity No.0</td>
</tr>
<tr>
<td>2013</td>
<td>2</td>
<td>Get ready for the commissioning with the two cavities.</td>
</tr>
<tr>
<td>201X</td>
<td>3</td>
<td>If needed</td>
</tr>
</tbody>
</table>
Starting the commissioning with two cavities:

Dummy GBP

Total Vc: 1.4MV

Install the 3rd Cavity if needed

Total Vc: 2MV
Summary

- The design of the accelerating structure for the DR has been modified for the total \( V_c : 2 \text{MV}(\text{max}) \).
  - Based on the KEKB-MR/ARES
  - Three cavities with 0.7\( \text{MV/cav} \)
  - GBP made common between the neighboring cavities

- SiC tiles are used for all the HOM dampers.
  - Based on the established technology used for KEKB-MR/ARES
  - \((\text{RF absorption power})/\text{set} < 180\text{W} \ll \text{PowerCapability: 1kW/set}\)

- CBIs driven by the HOM impedances
  - Longitudinal Growth Time \( > 20 \text{ ms} > 5 \text{ ms (rad. damping time)} \)
  - Transverse Growth Time \( > 30 \text{ ms} > 10 \text{ ms (rad. damping time)} \)

- Coupled Oscillations of the ACC-mode: negligible
  - OK
Appendix A

Assumptions for estimating wall temperatures of the DR cavity

- Cooling-water flow: 200 L/min
- Cooling-water temperature: 30 degC
- Cooling-water velocity: 2.0 m/s
- Hydraulic equivalent diameter of the cooling-water channel: 9.1e-3 m
- Reynolds number: 2.2e4 (turbulence)
- Heat-transfer coefficient from the channel to the water: 8.9e3 W/m^2/K
- Thermal conductivity of copper: 4.0e2 W/m/K
Appendix B

Accelerator Resonantly-coupled with Energy Storage

3-cavity system stabilized with the $\pi/2$-mode operation

consists of

- HOM-damped accelerating cavity (A-cav),
- Energy-storage cavity with $\text{TE}_{013}$ (S-cav),
- Coupling cavity (C-cav) with a parasitic-mode damper.

We use only this for the DR.

Perpendicular to the beam axis

Along the beam axis
Backup Slides
Horizontally-Polarized Dipole Mode in the Cavity Couples to the TE mode in the GBP.

Cutoff: 588MHz (TE in GBP)

TM_{110} (630MHz)
ACC-Mode Frequency with or without the **Input Coupler**

**Tuner Position: 0mm**

507.191 MHz

506.286 MHz

= 0.905 MHz

$$\Delta f_{\text{acc}} = 40 \text{ kHz} / \text{mm} \text{ (by the tuner)}$$

→ **“0.905MHz”** corresponds to 22.6 mm in the tuner position.
Shift=10mm & LoopAngle=79.5deg

**ACC-Mode Frequency [MHz]**

- 0.50873
- 0.5089
- 0.51
- 0.5105
- 0.511

**Cavity Diameter [mm]**

- 442
- 442.5
- 443
- 443.75
- 444.5
- 445
- 445.5

**β (fit)**

- 0.8
- 1
- 1.2
- 1.4
- 1.6
- 1.8
- 2

**Q₀ = 30000**

- **Shift: 0 mm**
- **Shift: 5 mm**
- **Shift: 10 mm**
- **Shift: 15 mm**
2. Upgrade of the HOM Damper

*Grooved Beam Pipe with SiC Tiles Installed*

Absorbs Horizontally-Polarized Dipole Mode (TM$_{11}$)

![Grooved Beam Pipe with SiC Tiles Installed](image)

In the case of SC cavities

- Needs large ducts, which reduce $R_{sh}$.

![Diagram of SC cavities](image)

In the case of ARES (NC)

- The Cutoff Freq. of TM$_{11}$ can be made lower without reducing $R_{sh}$.

![Diagram of ARES (NC)](image)

- Cutoff Freq. of TE$_{11}$ in a Regular $\phi$150 Duct

- SiC *Indirectly* water-cooled

(by T. Kageyama using MAFIA)
2. Upgrade of the HOM Damper

More Power Capability

Grooved Beam Pipe with SiC Tiles Installed $\rightarrow$ **Winged Chamber Loaded with SiC Bullets**

$P_{\text{HOM \, Capability (1.3GHz)}} \approx 1 \text{ kW}$

$P_{\text{HOM \, Capability (1.3GHz)}}$ to be $5 \text{ kW}$

SiC **Directly** water-cooled

SiC **Indirectly** water-cooled

Like the HOM damper at the Movable Mask Section