Status of the RF Accelerating Cavity for the Damping Ring (DR)

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RF Accelerating Structure for the DR

Based on the ARES cavity with the long successful operation at KEKB

1. Accelerating-Mode Frequency: 508.887[MHz] (same as in the Main Ring (MR)
2. Cavity Voltage (spec.): 0.7[MV/cav] (→ Wall-loss power: 133kW/cav)
3. Cavity Voltage (challenge): 0.8[MV/cav] (→ Wall-loss power: 180kW/cav)
4. Max. stored beam current: 70.8[mA]
5. Grooved Beam Pipe (GBP) Common between cavities
6. Cavity-GBP Joint with a weld-ring gasket (not using a flange)
7. Multi Single Cell Structure
8. Reuse of input couplers and tuners proven at KEKB-MR/ARES
9. Good vacuum in cav. (< 10^-6[Pa]) needed for high-power input couplers

1MW Klystron to be used

Very low compared to (Super)KEKB-MR

Pumping port on each cavity

Dimensions in mm
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>
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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)

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)
Four Types of Components

1. Cavity (main body)
2. HOM(Higher-Order-Mode)-WG(WaveGuide) load
3. GBP (btwn)
4. GBP (end)

Joint:
- Welding for vacuum sealing
- RF shield inside
1. Cavity (main body)

- Material: Highly-Pure Copper (C1011-C1) except for the ports, GBPs, and HOM-WGs
- Mirror symmetry except for the E-bends, tuner, and monitor ports.
- Two input-coupler ports, one of which is to be used as a pumping port.

Cross-section: 240mm x 28mm

(Along the beam axis)

(Flange)

(Dimensions in mm)
2. HOM-WG Load

- Material of the WG: SUS
- HOM Absorber: SiC (Silicon Carbide) ceramics
  - Brazed on a copper plate
  - Water-cooled via the copper plate
  - Same as used in the KEKB-MR/ARES
- Power Capability: ~1kW/1set(@1.3GHz)
- Max. HOM Power: ~30W/WG
A First Set of SiC Tiles for the DR Cavity/HOM-WG or GBP To be Delivered Soon
OLD  (Shown last year)

NEW
HOM-WG Load Optimized for the Broadband Performance

(Simulation Results using CST-MWS/FD-Solver)

Cutoff Freq. of TM$_{01}$ in a $\phi$40mm circular duct (5.7GHz)

OLD

NEW (Single set of SiC tiles)
CBI threshold for Total Vc: 1.4MV

OLD

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

NEW HOMWG Load

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

CBI threshold for Total Vc: 1.4MV

For Growth Time: 20 [ms]
For Growth Time: 30 [ms]

Growth Time > 30ms
> 5ms (rad. damping time)

Simulation by GdfidL for

- At 0.76 GHz
- At 2.8 GHz
- At 8.0 GHz
3. GBP (btwn)

- Material: SUS
- 4 sets of SiC tiles (same one as used for HOM-WGs)
- Max. HOM + Accl.-mode: ~300W/duct

(Dimensions in mm)

(Cross-section perpendicular to the beam axis)
4. GBP (end)

- Material: SUS
- 4 sets of SiC tiles
- Max. HOM + Accl.-mode: ~300W/duct
GBP(dummy)

✓ Material: SUS
✓ No HOM absorbers
✓ To be used for the two-cavity configuration

4-R10 (Dimensions in mm)

4-R3

(Dimensions in mm)

(Cross-section perpendicular to the beam axis)

Along the beam axis

556

340

30

$\phi$ 150

(Along the beam axis)
Cavity-GBP Joint

Weld Ring Gasket with Lip Sealing, like:

“Welding → Disassembly → ReWelding” Possible Several Times

Finger-type RF shield
- Successful experience at KEK/PF:
  - Be-Cu, @KEK/PF

Single-Bunch-Mode Operation
- Beam current: 70 mA (max.)
- Bunch length: 24 mm

(SUS)

(Fixed with 16 M12 bolts)
Reasons why we adopted the structure mentioned in the previous slide for the Cavity-GBP joint

• **Successful experience** at KEKB-MR/ARES (C-cav and S-cav) on leakproof vacuum sealing during high power operation with heat deformation of the cavity

• We do not need to disassemble the structure so often. (twice at max. from our experience at KEKB-MR/ARES)
  – “Welding → Disassembly → **ReWelding**” possible 3 times in the spec.

• Finger-type RF shield
  – Measure **against heat deformation** of the cavity during high power operation
  – Should be **safe** for low beam currents, such as the DR.
  – **Successful experience** at KEK/PF.
  – **Negligible** wakefield and HOM heating (see the following slides)
Solid Model of the Cavity-GBP Joint with RF Fingers

(Created by using CST STUDIO SUITE)

Blue Region: Vacuum
The Geometry Converted to GdfidL

Wakefield Simulation By GdfidL with 0.1mm Mesh Size

Finite-Difference Time-Domain parallel computation using 64 cores in the PC cluster
Results of the Calculation (1/2)

Longitudinal Wakepotentials

\[ W_\parallel [\text{V/pC}] \]

- *Without the Fingers*
- *With the Fingers*

Suppressed and Damped!

Longitudinal Impedances

\[ Z_\parallel [\text{Ohm}] \]

- *Without the Fingers*
- *With the Fingers*

\[ s_{\text{max}} = 45 \text{ m} \]

No Resonance!
Results of the Calculation (2/2)

<table>
<thead>
<tr>
<th></th>
<th>Loss Factor [V/pC]</th>
<th>Loss Power from the Loss Factor [W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without the Fingers</td>
<td>0.017</td>
<td>9.7</td>
</tr>
<tr>
<td>With the Fingers</td>
<td>0.00048</td>
<td>0.27</td>
</tr>
</tbody>
</table>

For the DR Parameters:
- Bunch Charge: 8nC
- Bunch Length: 6.5mm
- # of Bunches: 4/ring
- Circumference: 135.5m

This loss power is negligible!!
Current Status of Cavity No.0 (prototype)  
~ Low-Level RF Measurement Done ~

- Movable Tuner (mockup)
- HOM-WG
- GBP (mockup)
- Monitor (antenna)
- WG-Coax. Transformer
- Coupling Loop of the Input Coupler
- Network Analyzer
- Input Coupler
- HOM-WG
Examples of the Measurement Results

$Q_{0}@\text{operation} = \sim 26000 \text{ (80\%IACS)}$
Simulation by CST-MWS

An Example

Curved Tetrahedrons

05 Steps per Wavelength

Port1

60 Steps per Wavelength

Fit with

\[
\arg(S_{11}) = -2 \tan^{-1} \left( \frac{Q_{ext}}{f_a - f} \right) + \theta_0
\]

(Red: floating parameters in fitting)
<table>
<thead>
<tr>
<th>JFY</th>
<th>Items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>CavityNo.0 (prototype) x 1 HOM-WG load x 1</td>
<td>→ to be high-power tested at the D1A test stand</td>
</tr>
<tr>
<td></td>
<td>GBP(btwn) x 1</td>
<td>→ to be high-power tested at the D1C test stand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>→ to be high-power tested at the D1C test stand</td>
</tr>
<tr>
<td>2012</td>
<td>CavityNo.1 x 1 HOM-WG load x 4 GBP(btwn) x 1</td>
<td>← Feedback from the High Power Test of CavityNo.0</td>
</tr>
<tr>
<td></td>
<td>GBP(end) x 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GBP(dummy) x 1</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>CavityNo.2 x 1 HOM-WG load x 4 GBP(btwn) x 1</td>
<td>→ Start of DR commissioning with Cavity No.1 and No.2</td>
</tr>
<tr>
<td></td>
<td>GBP(end) x 1</td>
<td></td>
</tr>
<tr>
<td>201X</td>
<td>CavityNo.3 HOM-WG load x 4</td>
<td>If needed</td>
</tr>
</tbody>
</table>
Summary

■ The accelerating structure for the DR
  ➢ Based on the KEKB-MR/ARES cavity with the long successful operation at KEKB

■ HOM-WG Load Optimized
  ➢ 2 sets → 1 set of SiC tiles /WG
  ➢ Better Performance

■ Cavity-GBP Joint by
  ➢ Weld-Ring Gasket with Lip Sealing
    ✓ Successful experience at KEKB/ARES (C-cav and S-cav) on leakproof vacuum sealing during high power operation with heat deformation of the cavity
    ✓ “Welding→Disassembly→ReWelding” possible 3 times (enough from our experience)
  ➢ Finger-type RF Shield
    ✓ Flexible for heat deformation of the cavity during high power operation
    ✓ Should be safe for low beam currents
    ✓ Successful experience at KEK/PF
    ✓ Negligible HOM heating (<< 1W)

■ The prototype cavity almost in the final stage
Fin.
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

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.
Starting the commissioning with two cavities:

Dummy GBP

Total Vc: 1.4MV

Total Vc: 2MV

Install the 3rd Cavity if needed
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

Growth Time > 30ms
> 10ms (rad. damping time)