ARES Status 2004(JFY)

Tetsuo Abe
for KEKB-RF/ARES-cavity group
High Energy Accelerator Research Organization (KEK)

<Outline>
1. Fundamentals of the ARES-cavity system
2. Operation status
3. D04C/ARES multipactoring problem
4. Summary

KEKB Review
@KEK
2005.02.21
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 TE\(_{013} \) (S-cav)
- Coupling cavity with a parasitic-mode damper (C-cav)

Perpendicular to the beam axis

Along the beam axis
Operation with the Accelerating $\pi/2$ Mode

- The field of the $\pi/2$ mode is the most stable against:
  - Beam loading,
  - Detuning of A-cav ($\Delta f_a$)

- The stored-energy ratio: $U_s/U_a$
  - $\Delta f_{\pi/2} = \Delta f_a / (1 + U_s/U_a)$

- The parasitic 0 and $\pi$ modes
  - Can be damped selectively out of C-cav (C-damper)

Advantages:

- $U_s/U_a = k_s^2 / k_a^2$

![Diagram showing modes and their interactions]
Energy-storage Cavity (S-cav)

- $Q_0(S\text{-cav}) \approx 1.7 \times 10^5$
- Stores large electromagnetic energies in $TE_{013}$
- To suppress the longitudinal CBIs

Optimum detuning

$$\Delta f = \omega_R - \omega_0$$

$$= -\frac{I \sin \phi_s R_a}{2V_c Q_0} f_a$$

$$= -\frac{P_b \tan \phi_s}{4\pi U}$$

$$\Delta f_{\pi/2} = \frac{U_a}{U_a + U_s} \Delta f_a = \frac{\Delta f_a}{1 + (U_s/U_a)}$$

$U_a : $ energy in A-cav

$U_s : $ energy in S-cav

$\Delta f_a : $ optimum detuning of A-cav

$\Delta f_a = -200$ kHz in KEKB/LER (2.6A, 20 sets)

$\Delta f_a = 710$ kHz in SuperKEKB/LER (9.4A, 28 sets)

Cf. $f_{rev} = 99$ kHZ

S-cav’s

Movable tuner on A-cav

$E \quad \rightarrow \quad H$

$S$-cav’s
# ARES in the KEKB Tunnel

## Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_c$</td>
<td>0.5MV</td>
</tr>
<tr>
<td>$R_a/Q_0$</td>
<td>15 $\Omega$</td>
</tr>
<tr>
<td>$Q_0$</td>
<td>11x10$^5$</td>
</tr>
<tr>
<td>$P_{in}$</td>
<td>400kW</td>
</tr>
<tr>
<td>$P_c$</td>
<td>150kW</td>
</tr>
<tr>
<td>$U_s/U_a$</td>
<td>9</td>
</tr>
</tbody>
</table>

(Waveguide from klystron)
Operation Status @

(Jan.–Feb., 2005)

- **LER: 20 cavities**
  - Total Vc: 8.0MV (0.4MV/cav)
  - Beam current: ~1.6A
  - Input RF power /cav: ~300kW
  - HOM power: >~ 5kW
  - Trip rate: <1 /cav /3months

- **HER: 12 cavities (+ 8 SCCs)**
  - Total Vc = 15MV (~13MV)
    = 4.09MV(ARES) + 10.91MV(SCC)
    (0.34MV/cav)
  - Beam current: ~1.20~1.27A
  - Trip rate (ARES): < 1 /cav /3months

**Stable Operation!!!**
D04C/ARES Multipactoring Problem
--- worse vacuum and discharge ---

- The vacuum in the ARES cavities (No.1 and No.2) of the D04C station became worse significantly (~3 times).
- Even with lower P_kly-out and/or V_c
- No conditioning effect
- Input-power dependence
- Discharge in the input couples observed with the TV cameras

The vacuum in the ARES cavities (No.1 and No.2) of the D04C station became worse significantly (~3 times).

Example of the discharge snapshots
The input couplers were wiped with dilute sulfuric acid in Nov. 2003 (winter shutdown).

Before Soot?  

After Clean!
Still bad! (on cav1)

HER beam current
Vac(D04C-cav1)
Vac(D04C-cav2)
Vac(D05C-cav1)
In the summer shutdown 2004

- Two input-couplers replaced by new ones
- Input-coupler ports scraped
- Ion pumps replaced by new ones
- High power test (with no beam) \(\Rightarrow\) OK
  - The vacuum condition was good.
  - No discharge observed
  - We reached a target power soon!
Again bad on Cav1 in the KEKB operation
Options

I. To leave the cavities as they are
   - No effort, no cost and no time to be spent
   - Might cause terrible accidents.

II. To replace the whole ARES cav. by new ones
   - Effort, high cost and long time to be spent
   - No guarantee (?)

III. To do studies, not to replace the cavities
   - Effort and time to be spent, free of cost
   - More scientific
Choice

III. To do studies, not to replace the cavities
   ➔ Effort and time to be spent, free of cost
   ➔ More scientific
Simulation Study on the Multipacting in the coaxial line of the Input Couplers

- Solving eq. of motion with the Runge-Kutta method
- Assuming the SEY of conditioned copper
- Count number of collisions.

Example of the Orbits
Multipacting Zone from the Simulation

![Graph showing multipactoring zone from simulation with input RF power vs. reflection coefficient (Γ) axes. The graph indicates over-coupling and under-coupling regions.](image-url)
OLD route before summer 2004

Vc(D04C)=0.54MV

Recovery (no beam)

Over-coupling

Under-coupling
A good operating region must be inside!

Over-coupling

Under-coupling
Machine Studies

Search for an operating region with

- good vacuum,
- no discharge,
- low trip rate

based on the simulation results.

(in the D04 local control room)

(at the D04C klystron)
NEW route in 2005

With a higher $V_c(D04C)=0.68$MV

Recovery (no beam)

Beam Increase

Over-coupling

Under-coupling

$D04C$-cav1 data
in 2005.01.30_16:37:45-17:50:00
Comparison with the Data

Good Agreement!

Measurements

Simulation

D04C-cav1

After aging

Measurements

Simulation

Good Agreement!
Prediction comes true!

Measurements
D04C-cav1

Base pressure
in the other cavities

Simulation

D04C-cav1 data
But the region is not so wide.
Considering the fact that "Cavities out of condition are in a minority",

We can keep an input RF power in a region with a good vacuum condition by changing the cavity phase (or beam loading) automatically.
Scan of the vacuum pressure and a target power region

D04C (2005.01.24_2:10-2:45)

Target region

Reflection Coefficient (T)

Input RF Power /kW

Vac(CCG)/Current [V/A]

Vac(CCG) [V]

Cav1

Cav2

P_{cav-in} [kW]

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Quick passage through the multipactoring zone!
No beam-current dependence!
D04C-cav1 data in CIM
\( (V_c(\text{D04C}) = 0.68 \text{MV}) \)

Before

After

AutoPhaseChanger ON
Feb. 3

Feb. 4

Feb. 5

Feb. 6

AutoPhaseChanger ON

HER beam current

Vac(D04C-cav1)

Vac(D04C-cav2)
Summary and Future

- 20+12 ARES cavities are working well.
  - Low trip rate
  - Stable operation

- D04C/ARES multipacting problem
  - Good operating region found by the simulation and machine studies
  - Solution: *keeping an input RF power in a region with a good condition by changing the cavity phase automatically.*
  - The feedback program has been working well since Feb.4.

- R&D activities for SuperKEKB
  - To be continued on the tomorrow’s talk…