KEKB RF System and Upgrade Plan toward SuperKEKB

KAGEYAMA Tatsuya

KEK Accelerator Laboratory
KEKB RF Group

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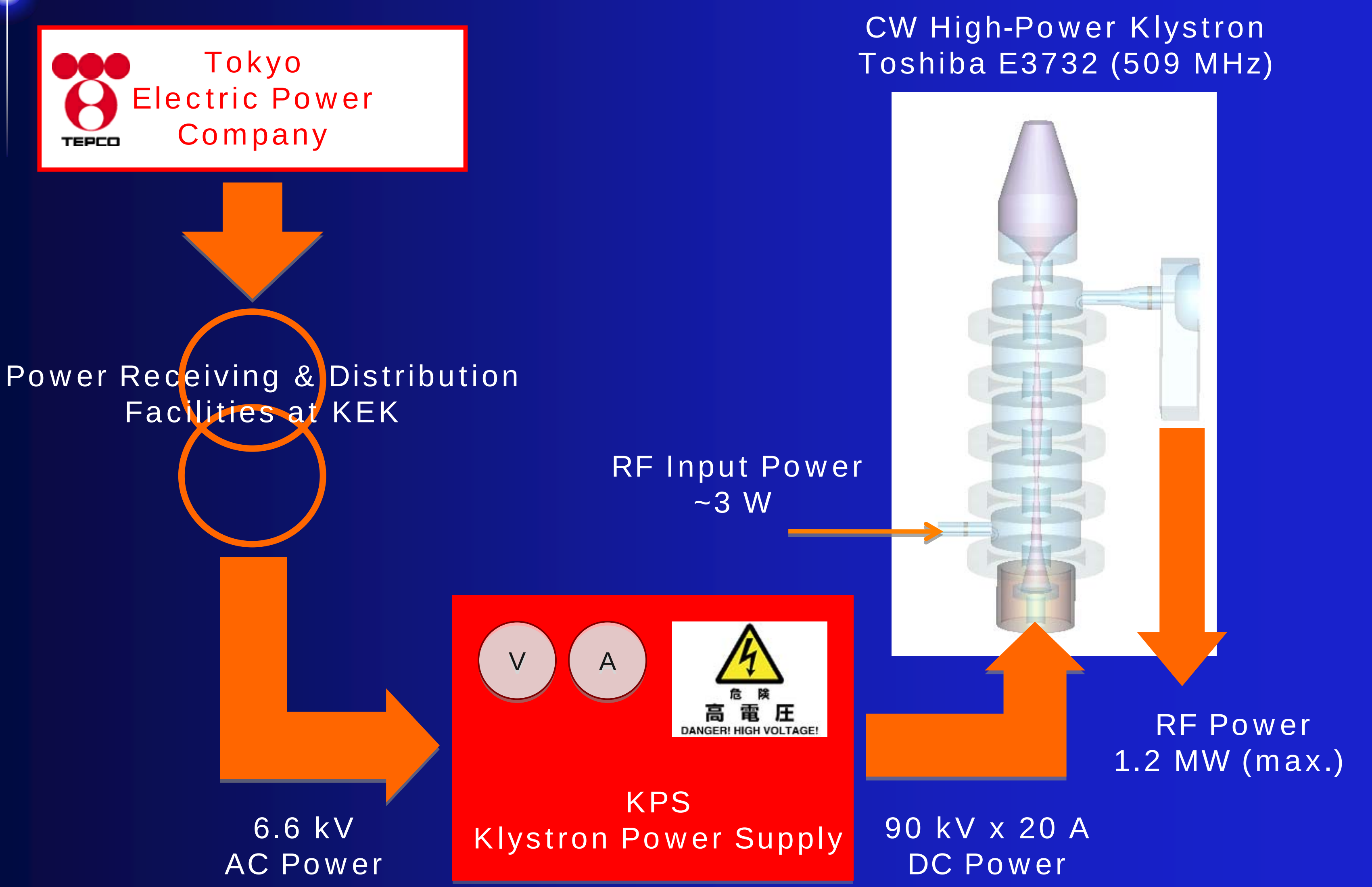
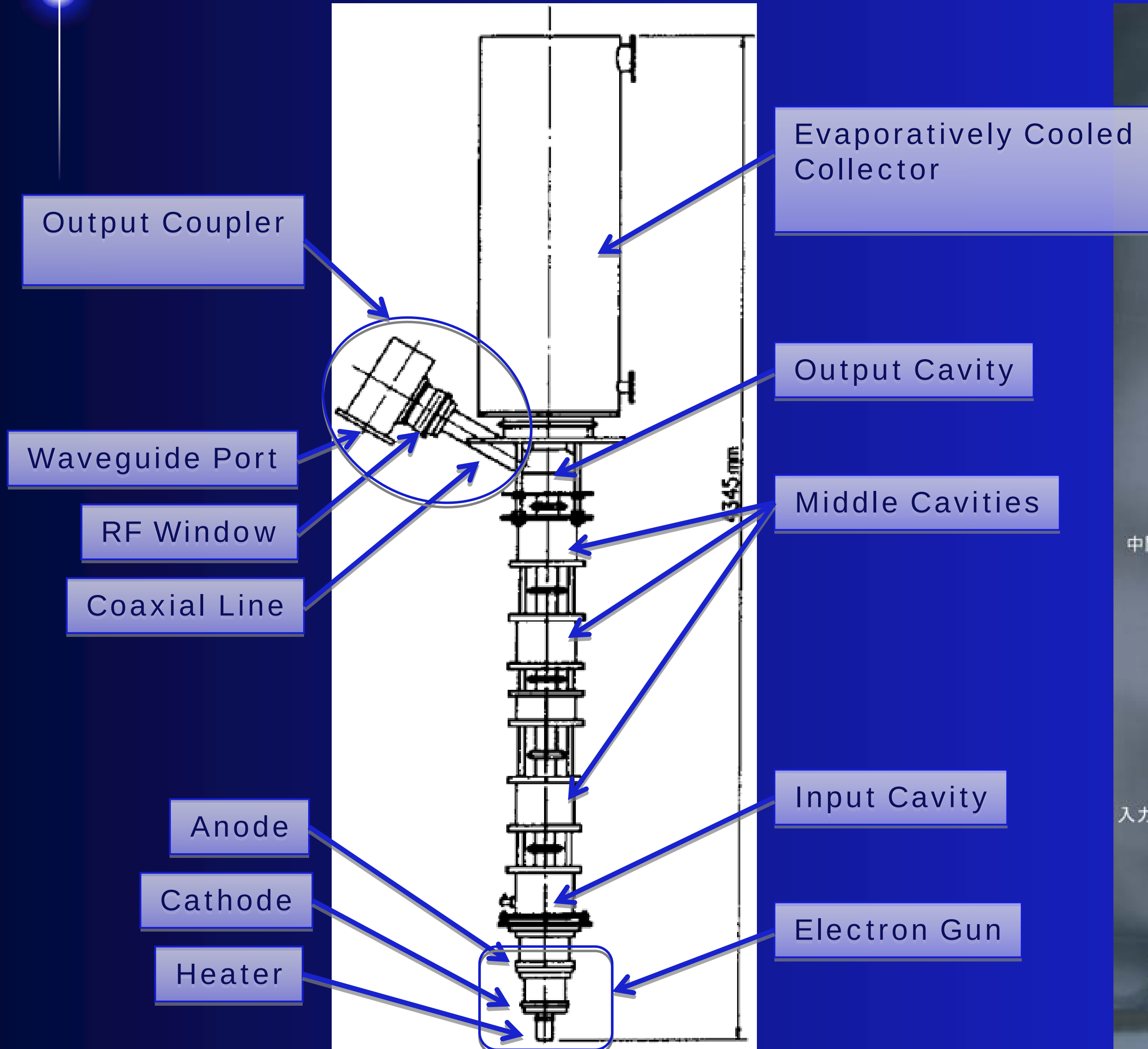
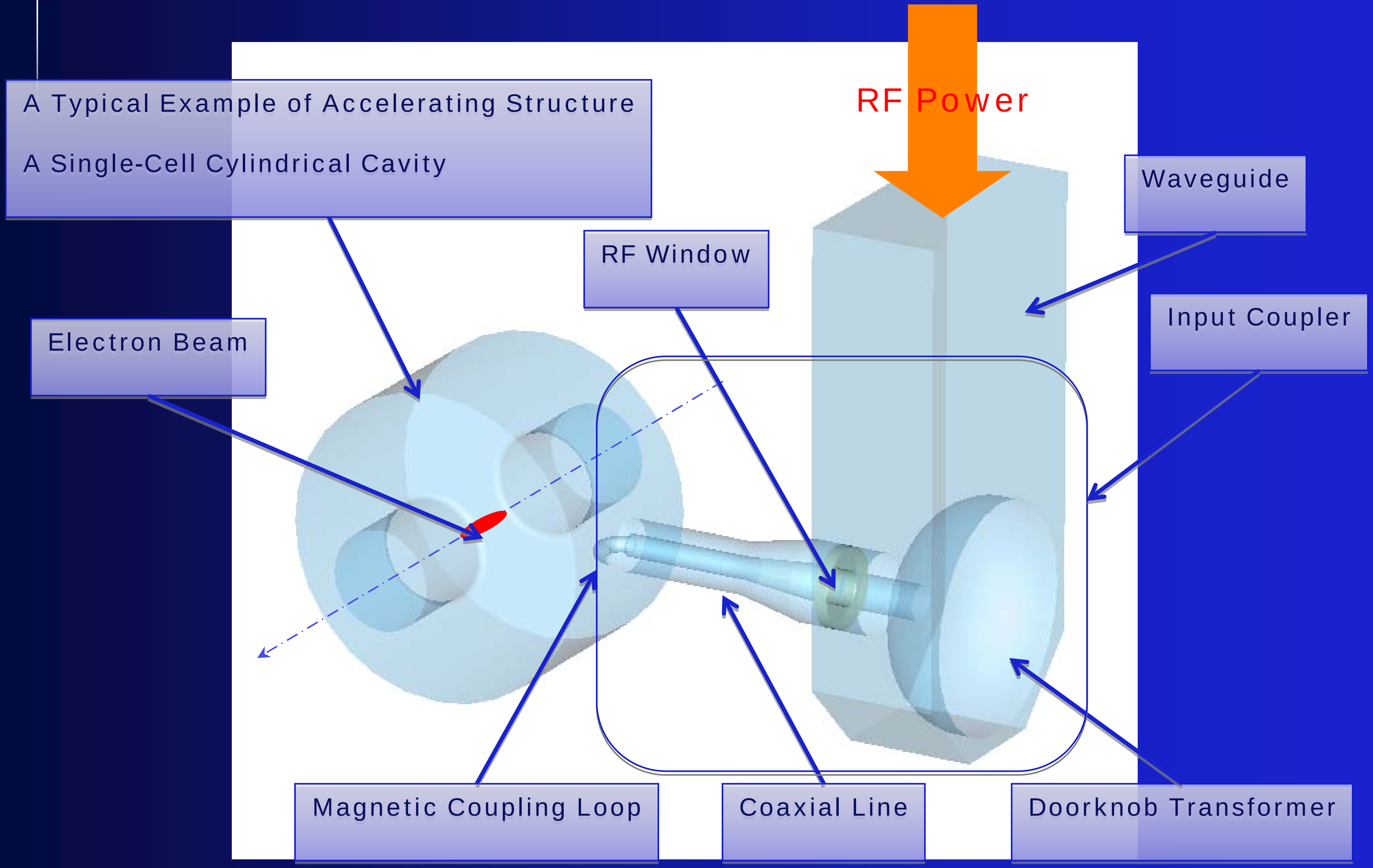


Toshiba CW Klystron E3732 (1.2 MW, 509 MHz)



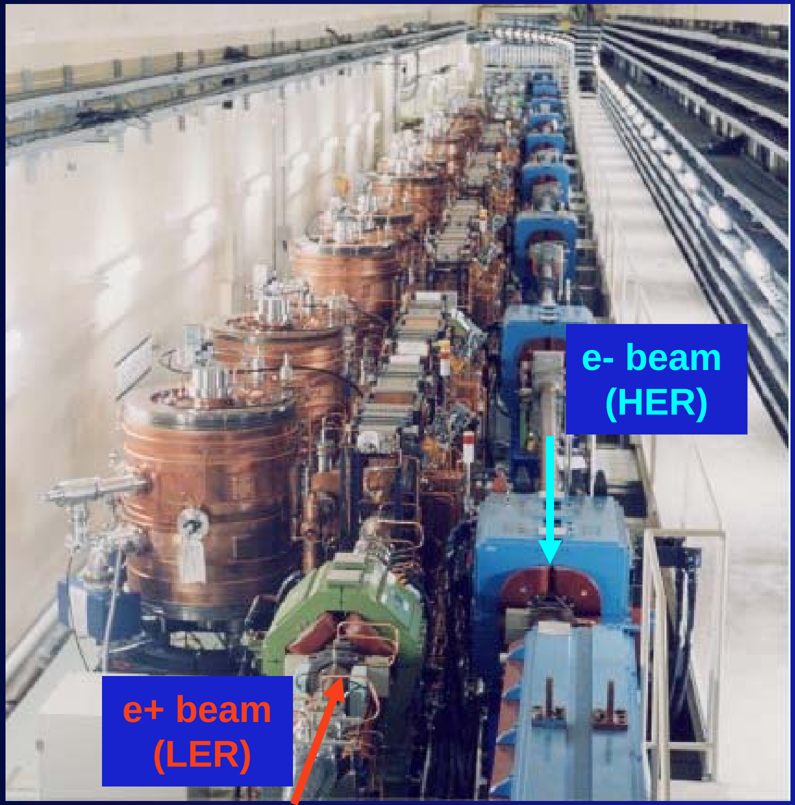
Energy Flow in RF Acceleration from RF Power to Beam Power



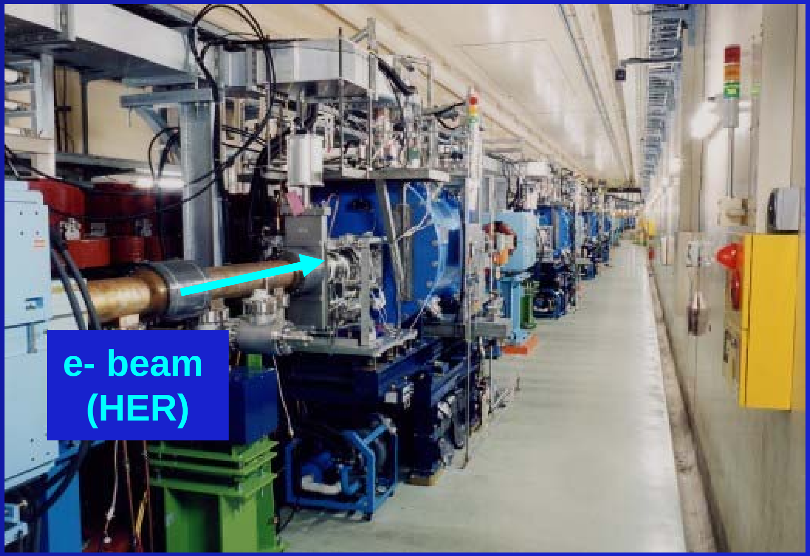
Two Types of Accelerating Cavities for KEKB

32 Normal Conducting (NC) ARES Cavities:
20 for LER and 12 for HER

8 Superconducting (SC) Cavities for HER

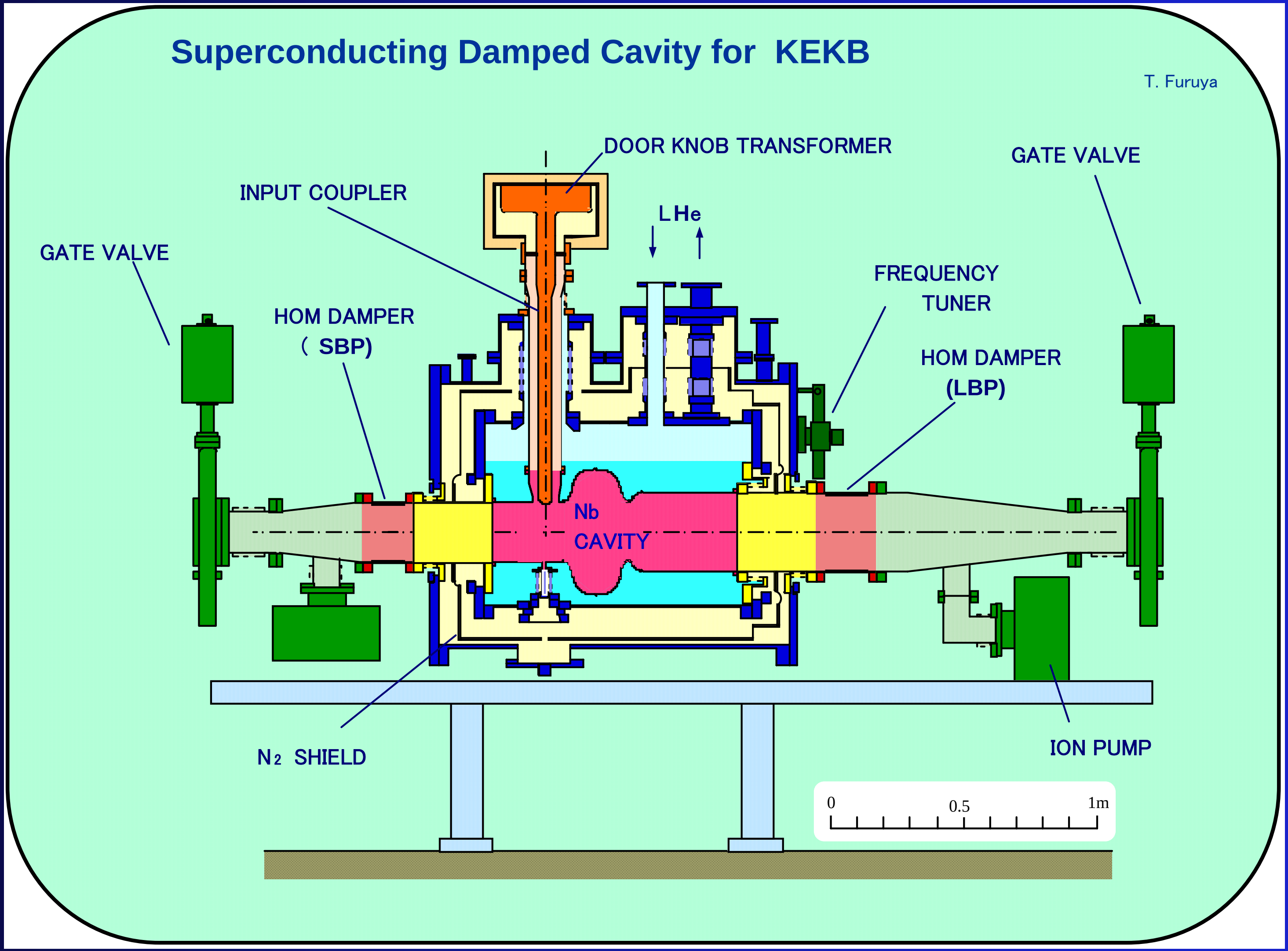


Fuji RF Section

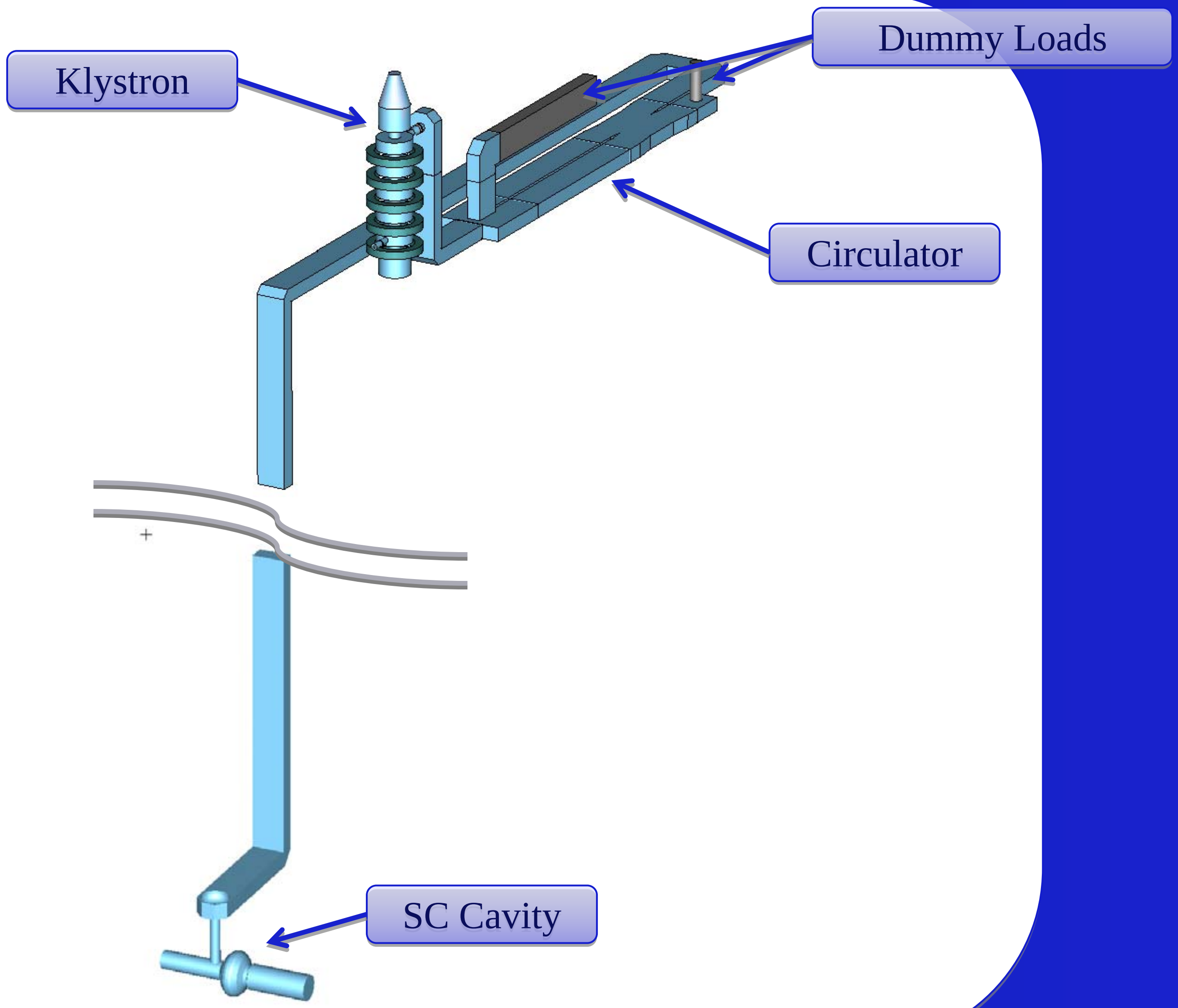


Nikko RF section

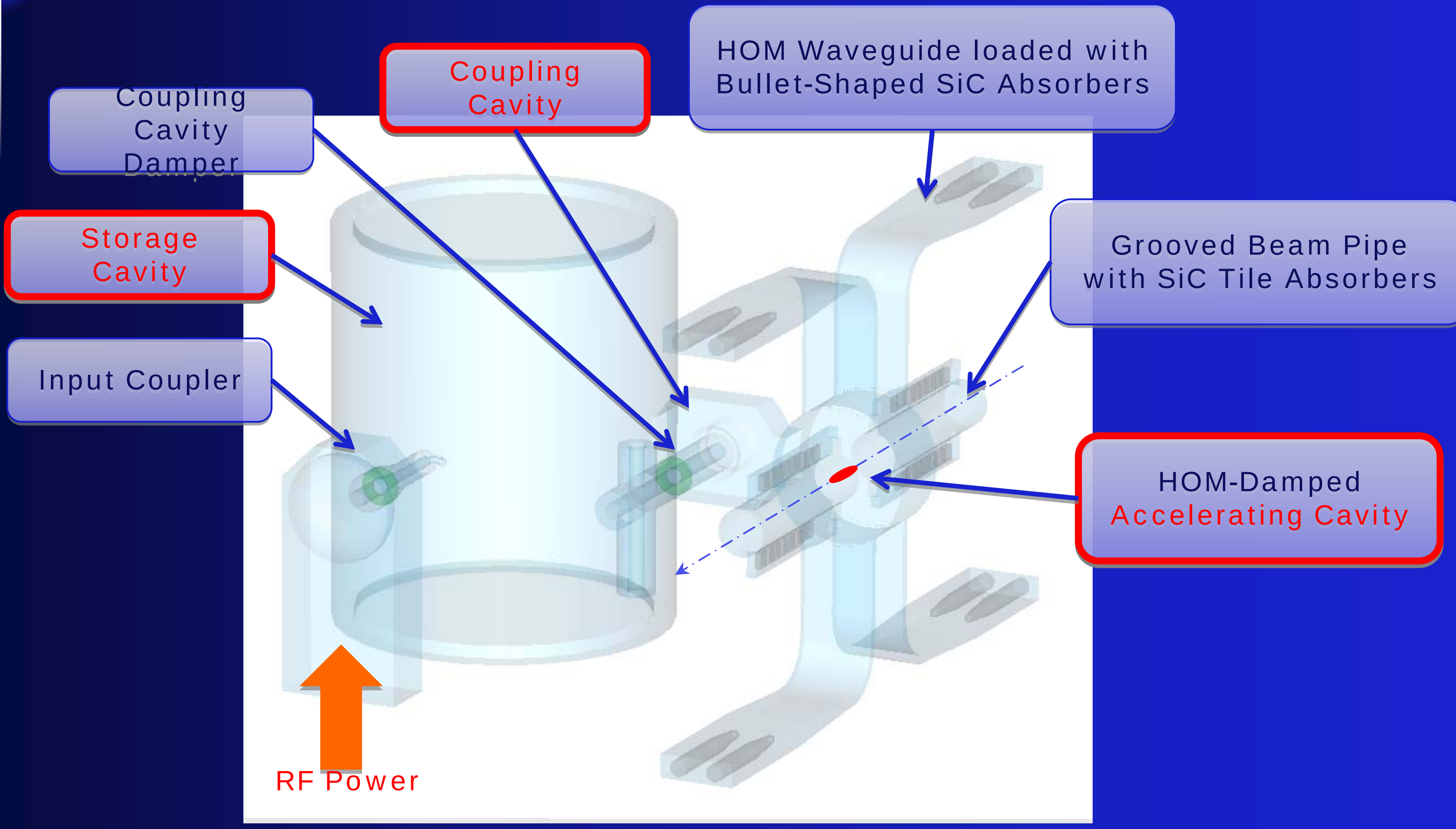
KEKB SC Accelerating Cavity
V_c = 1.5 MV (2.5 MV max.)



Configuration of KEKB SC RF Station



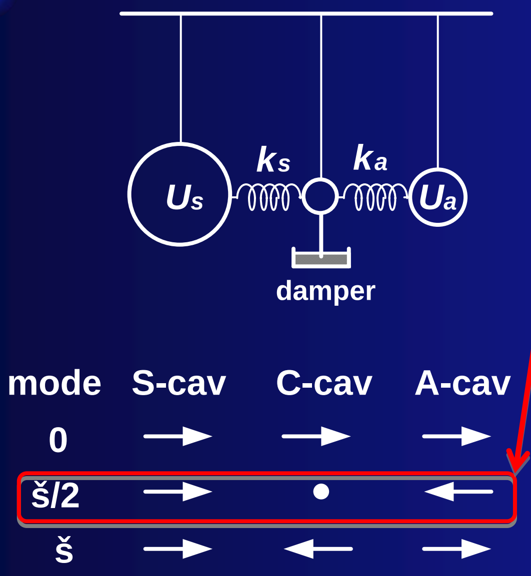
KEKB NC ARES Cavity System
V_c = 0.5 MV (0.6 MV max.)



Accelerator **R**esonantly coupled with **E**nergy **S**torage

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

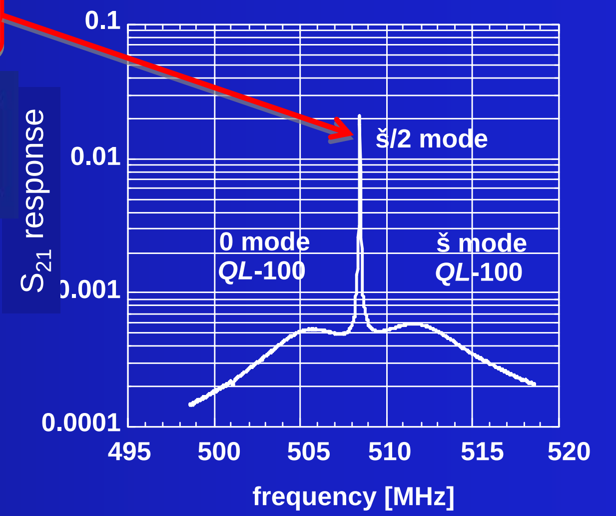
Fundamentals of the ARES Cavity System



An Equivalent Kinematic Model
of Coupled Pendulums

Accelerating Mode

$$\frac{U_s}{U_a} = \frac{k_a^2}{k_s^2}$$ for π/2 mode



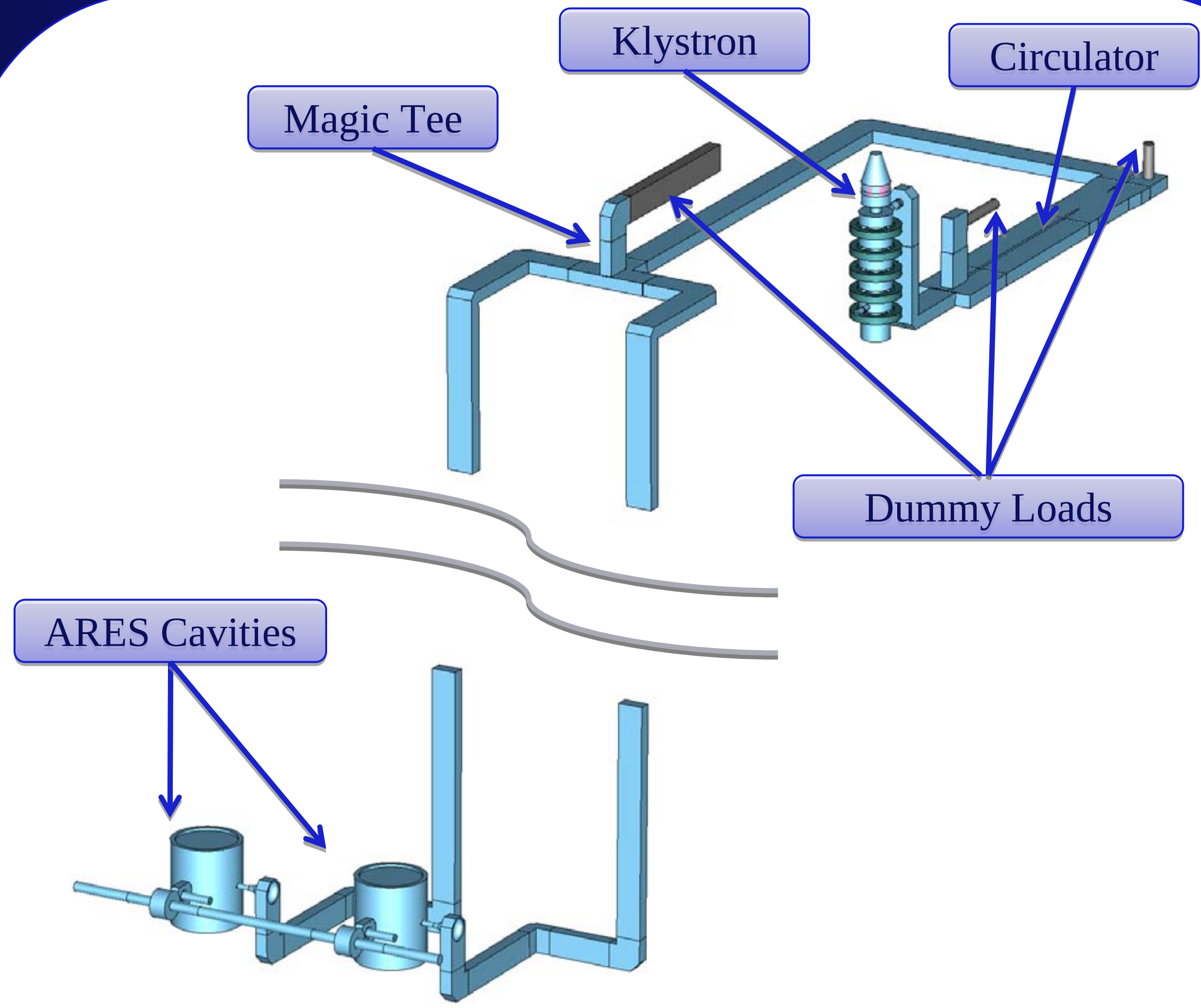
The parasitic 0 and π modes are damped
with Coupling Cavity Damper
while the π/2 mode not affected.

S cavity functions as an EM flywheel
to stabilize the accelerating mode
against heavy beam loading.

$U_s/U_a = 9$ (KEKB ARES Cavity)

U_s : EM stored energy in S cavity
U_a: EM stored energy in A cavity

Configuration of KEKB NC RF Station



The Current Configuration of KEKB RF System

TOTAL
#KLY = 25
#SCC = 8
#ARES = 32

Nikko (D10&D11)
8 SC RF Stations for HER
8 x (KLY + SCC)

Fuji (D7&D8)
10 NC RF Stations for LER
10 x (KLY + 2xARES)

Oho (D4&D5)
7 NC RF Stations for HER
5 x (KLY + 2xARES)
+ 2 x (KLY + ARES)

KEKB RF Power Statistics on Nov. 15, 2006
when the highest peak luminosity 1.71 x 10^{34} cm^{-2} s^{-1} was achieved.

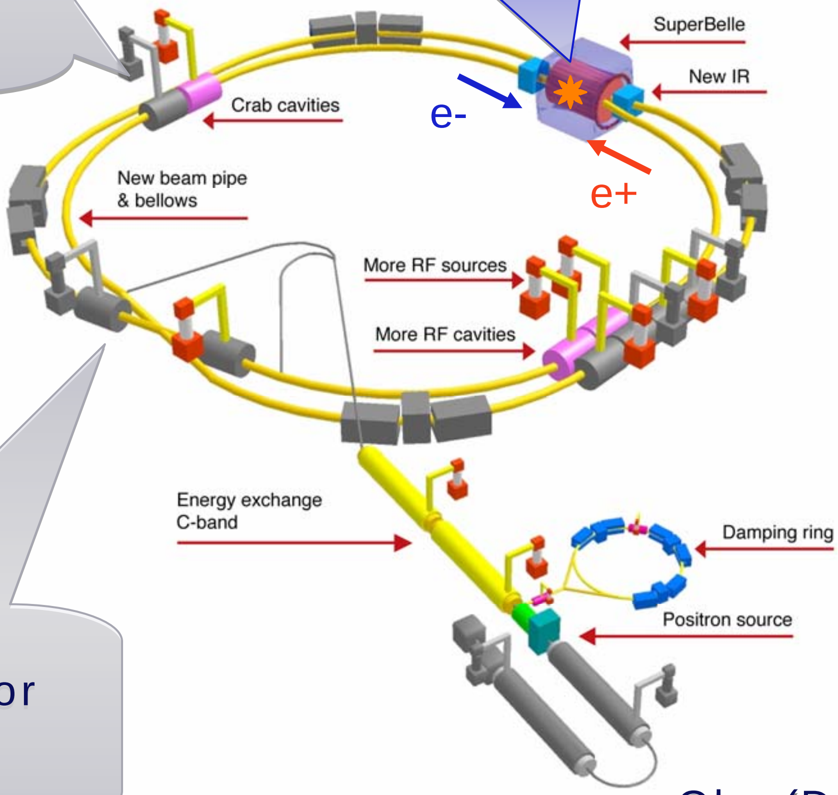
Ring	LER	HER	unit
Beam Energy	3.5	8.0	GeV
Beam Current	1.66	1.34	A
Total RF Voltage	8.0	15.0	MV
Radiation Loss	2.55	4.63	MW
Parasitic Loss	0.55	0.37	MW
Total Beam Power	3.1	5.0	MW
Total RF Power	5.4	6.2	MW
Total AC Plug Power	19		MW

Overview of Upgrade Plan for SuperKEKB

Nikko (D10&D11)
8 SC RF Stations for HER
8 x (KLY + SCC)

e^- 4.1 A x e^+ 9.4 A

TOTAL
#KLY = 48
#SCC = 8
#ARES = 40



Fuji (D7&D8)
16 NC RF Stations for LER
16 x (KLY + ARES)

Oho (D4&D5)
24 NC RF Stations for HER and LER
16~18 x (KLY + ARES) for HER
8~6 x (KLY + ARES) for LER

RF parameters for SuperKEKB

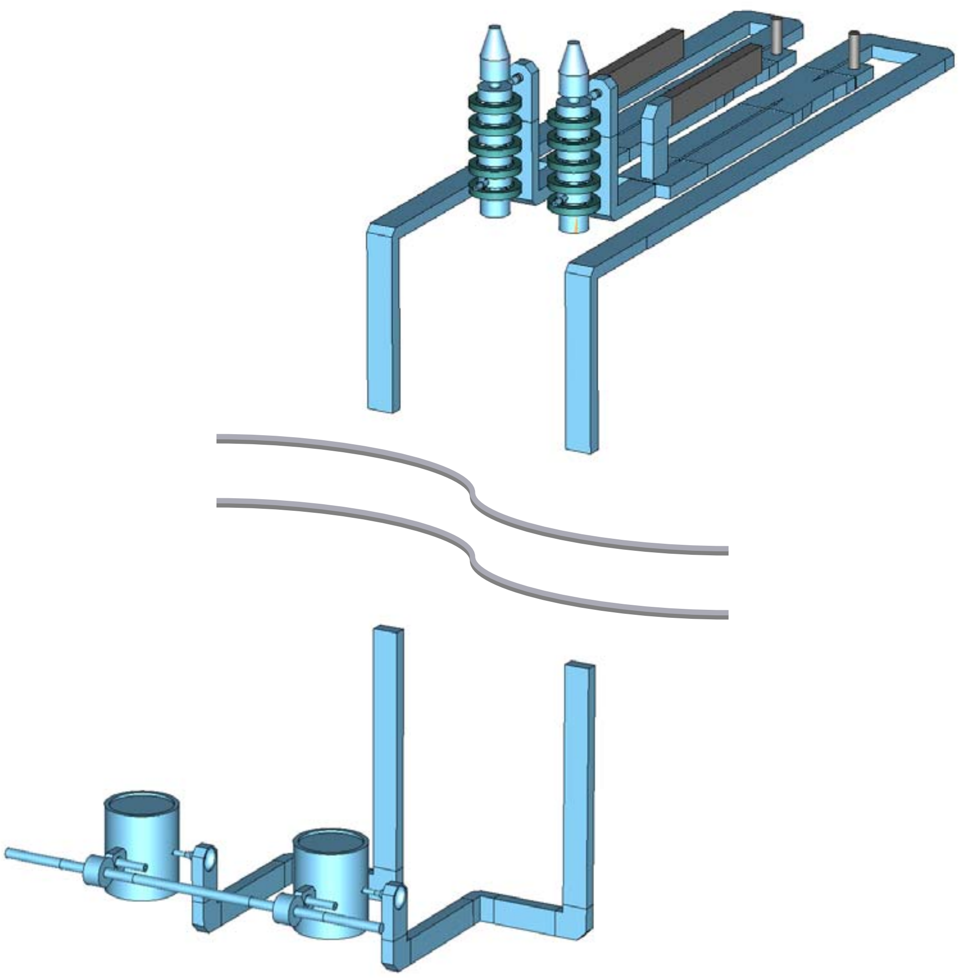
Ring	LER	HER		unit
Beam energy	3.5	8.0		GeV
Beam current	9.4	4.1		A
Energy loss /turn	0.84	3.42		MV
Radiation loss	7.91	14.02		MW
Total loss factor, assumed	40 ± 5	45 ± 10		V/pC
Parasitic loss	7.09 ± 0.89	1.52 ± 0.34		MW
Total beam power	15.0 ± 0.9	15.5 ± 0.3		MW
Cavity type	ARES (modified)	ARES	SCC	
Number of cavities (= klystrons)	22～24	18～16	8	
Voltage /cavity	0.5	0.5	1.3	MV
Beam power /cavity	650	720	460	kW
Wall loss /cavity	233	150	-	kW
Detuning frequency	44	31	75	kHz
Klystron power	940	930	490	kW
Total RF voltage	～11	～18		MV
Total AC plug power	35	33		MW

K. Akai, KEKB Upgrade Meeting, 2007.12.21

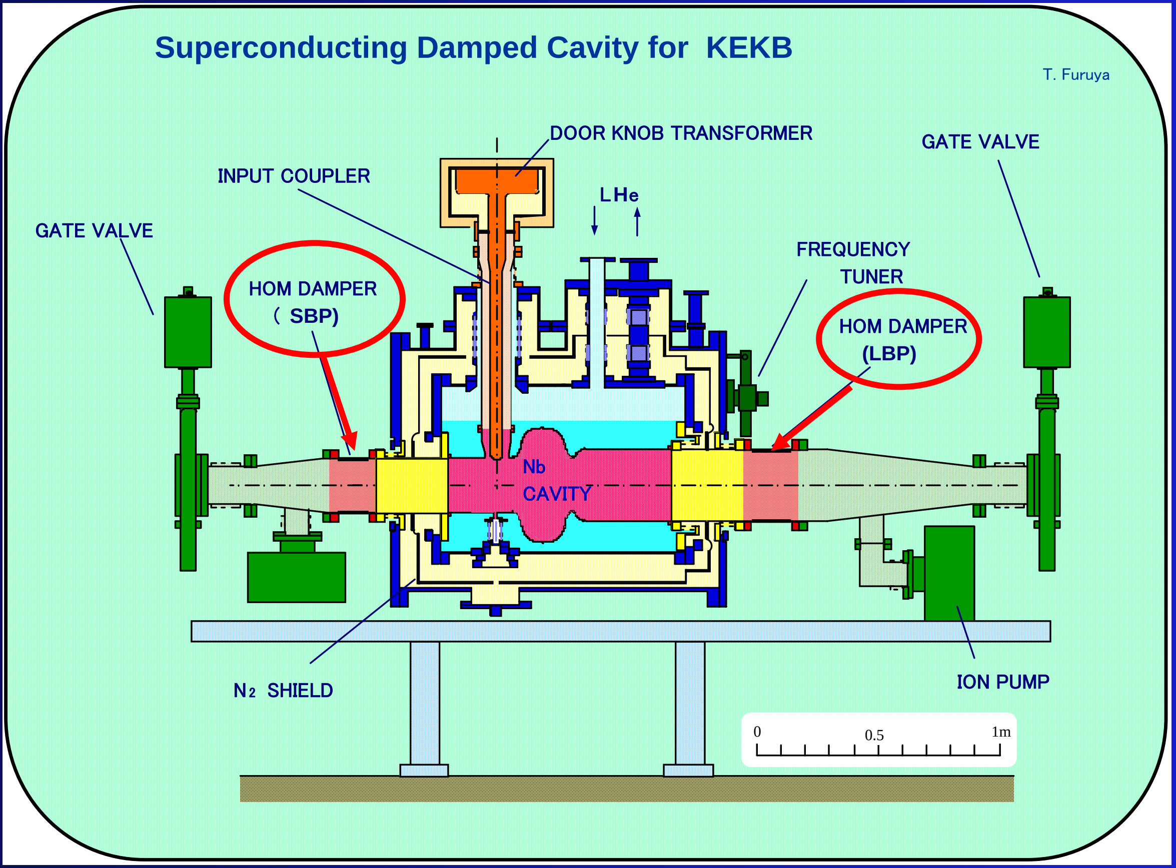
SuperKEKB requires 4 times RF Power !

	KEKB	SuperKEKB
Number of Klystrons	25	48
RF Power per SC Cavity	250 kW	460 kW
RF Power per NC Cavity	400 kW	880 kW

Configuration of SuperKEKB NC RF Station

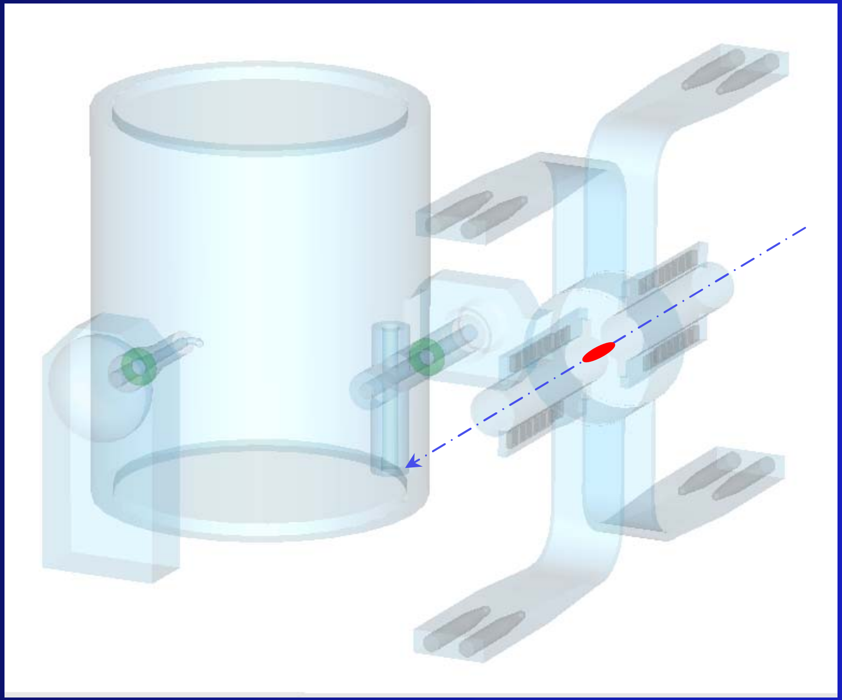


Upgrading Superconducting Cavity



- SC cavity structure not changed.
- The HOM absorbers need to be upgraded:
  The HOM power per cavity is estimated about 57 kW for the design beam current 4.1 A of HER.

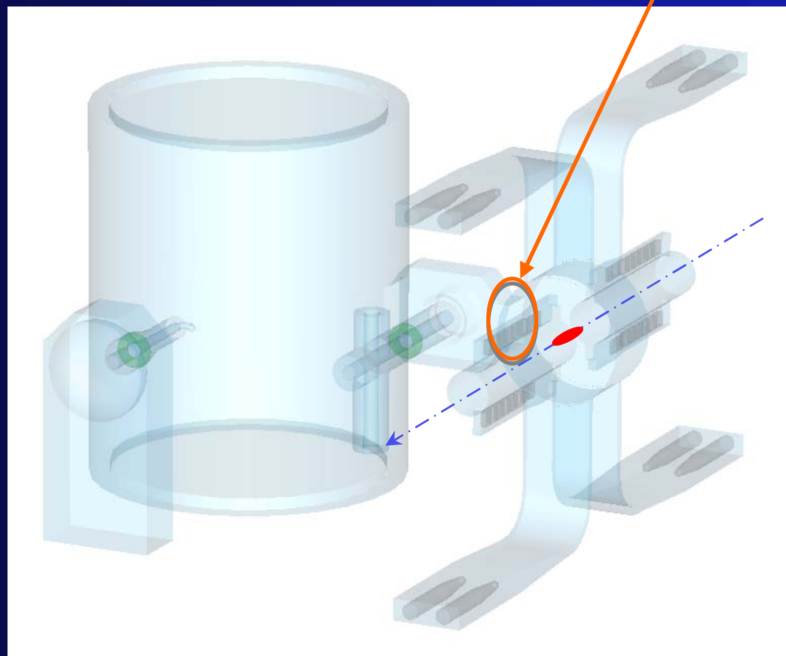
4.1 A (SuperKEKB HER) / 2.6 A (KEKB LER) = 1.6 within the Reach of KEKB ARES Cavity

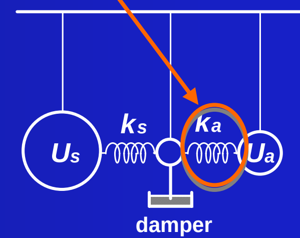


- The current KEKB ARES cavity can be used up to the beam current of ~4 A (σ_z = 3 mm, 5000 bunches).
- Without upgrades, 16~18 out of 32 KEKB ARES cavities will be reused in SuperKEKB HER.

Upgrading ARES Cavity for SuperKEKB LER

The coupling factor k_a can be increased by enlarging the coupling aperture between A-cav and C-cav.





mode	S-cav	C-cav	A-cav
0	→	→	→
š/2	→	•	←
š	→	←	→

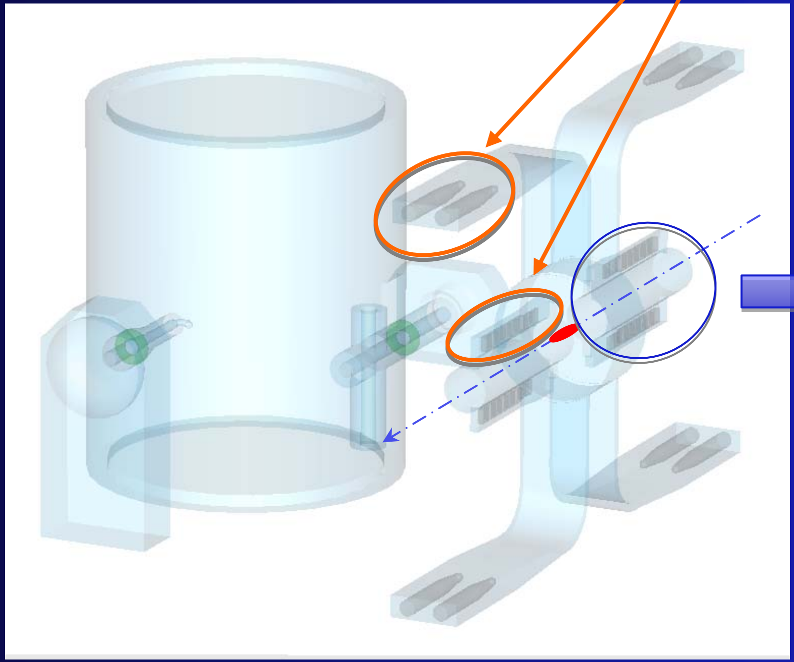
$$\frac{U_s}{U_a} = \frac{k_a^2}{k_s^2}$$ *for π/2 mode*

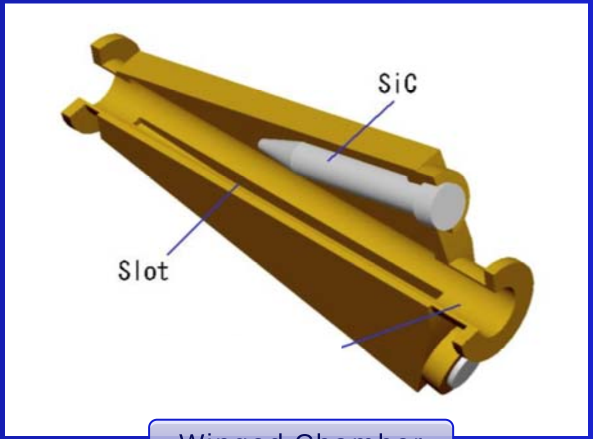
- More massive EM flywheel is needed:
  The energy ratio U_s/U_a will be increased from 9 to 15 against 9.4 A.

- ARES scheme is flexible to upgrade:
  The energy ratio U_s/U_a can be changed by modifying the coupling factor k_a only. Therefore, no change in RF design of the storage cavity.

Upgrading ARES Cavity for SuperKEKB LER

	KEKB		SuperKEKB
HOM Waveguide :	1 kW	→	20 kW per WG
Grooved Beampipe:	0.3 kW	→	5 kW per groove





Winged Chamber

The HOM absorbers need to be upgraded:

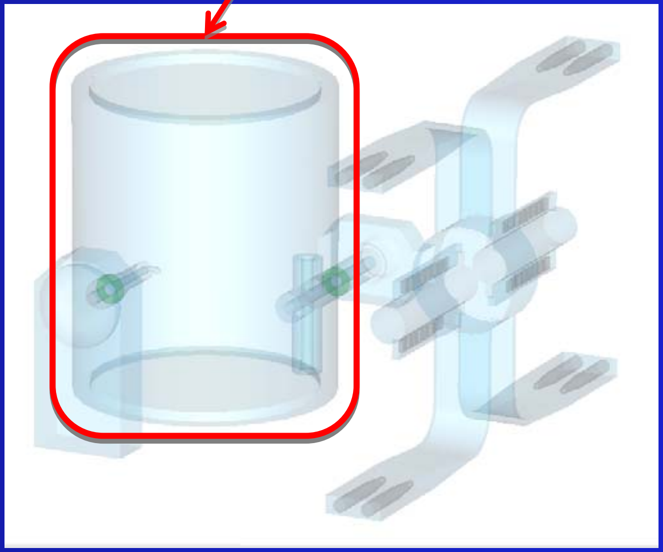
The HOM power per cavity is estimated about 100 kW for the beam current of 9.4 A (σ_z = 3 mm, 5000 bunches).

The grooved beam pipe will be replaced with a winged chamber loaded with directly water-cooled SiC absorbers.

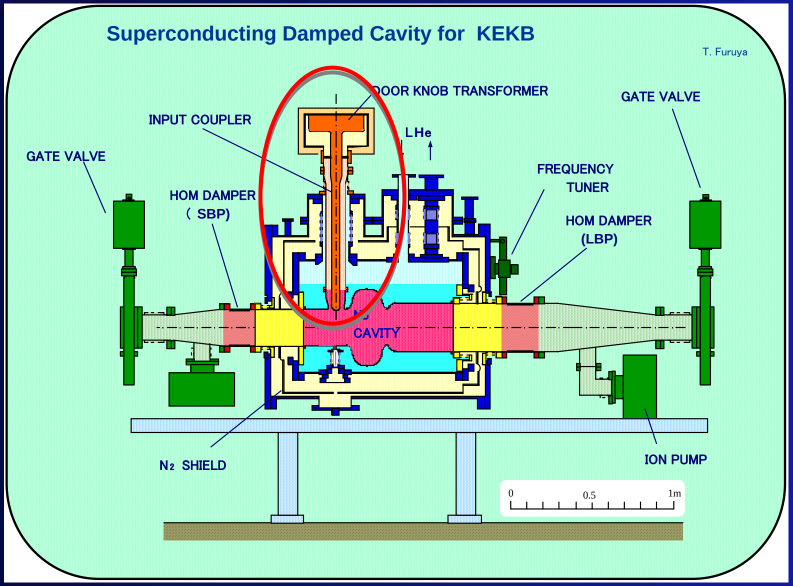
Upgrading ARES Cavity for SuperKEKB LER

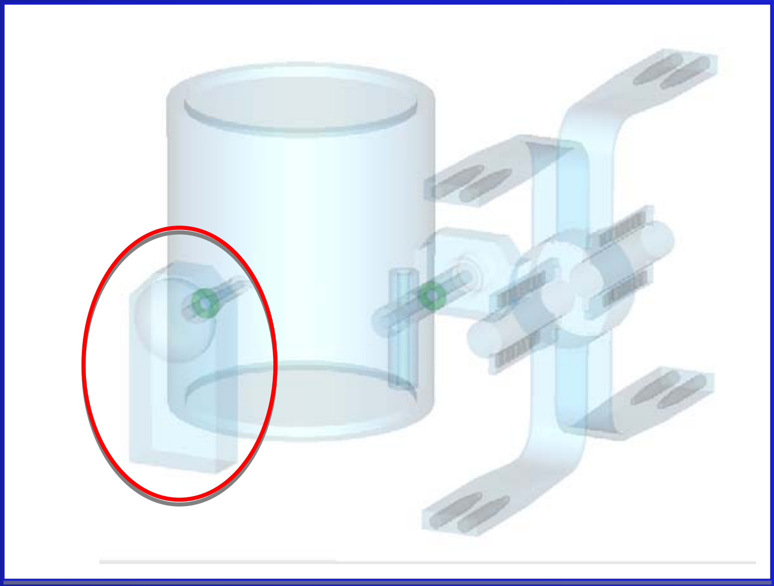
R&D on application of high-purity copper electroplating is ongoing.

We need to build 11 or more additional storage cavities, hopefully with new technologies.



Upgrading Input Couplers for SuperKEKB





Input Coupler for SC Cavity

KEKB design 250 kW with beam
(400 kW max. with beam)

460 kW with beam
(500 kW max. @ test stand)

Input Coupler for ARES Cavity

KEKB design 400 kW with beam

880 kW with beam
(820 kW max. @ test stand)

Summary

- **BASELINE:**
  - **Use the existing RF system as much as possible.**

- **RF POWER ISSUES: SuperKEKB requires 4 times RF power of KEKB.**
  - **Double the number of RF sources.**
  - **Double the RF power per cavity.**
    → **Need to double the power handling capability of the input coupler.**
  - **Need to construct additional water-cooling systems.**
  - **Need to construct additional evaporative cooling systems for klystrons.**
  - **Need to construct new buildings to store power supplies and LLRF systems.**

- **HIGH CURRENT BEAM ISSUES:**
  - **Increase the EM stored energy of the ARES cavity for SuperKEKB LER.**
  - **Upgrade the HOM loads for SC and NC cavities.**
  - **Need to construct water-cooling systems dedicated to HOM loads.**

Followed by Backup Slides