HarmonLIP 2022, 11-12 October 2022, MAX IV

Status and development of harmonic-cavity projects at KEK

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15 minutes + 5 minutes for questions

Insight through Accelerators.
KEK

Present and future Photon Factory

Present and future Photon Factory

PF-AR (6.5 GeV) (1987~)

Beam energy	6.5 GeV
Beam current (with single bunch)	50 mA
Circumference	377 m
Beam emittance ε_{x0}	293 nm·rad
Synchrotron radiation loss per tuen U_0	6.66 MeV
Total accelerating voltage V_c	16 MV

PF 2.5 GeV ring (1983~)

Beam energy	2.5 GeV
Beam current	450 mA
Circumference	187 m
Beam emittance ε_{x0}	34 nm·rad
Syncorotron radiation (per electron, per turn) U_0	399 keV
Total accelerating voltage V_c	1.7 MV

At now,
There is no HC in the both rings.

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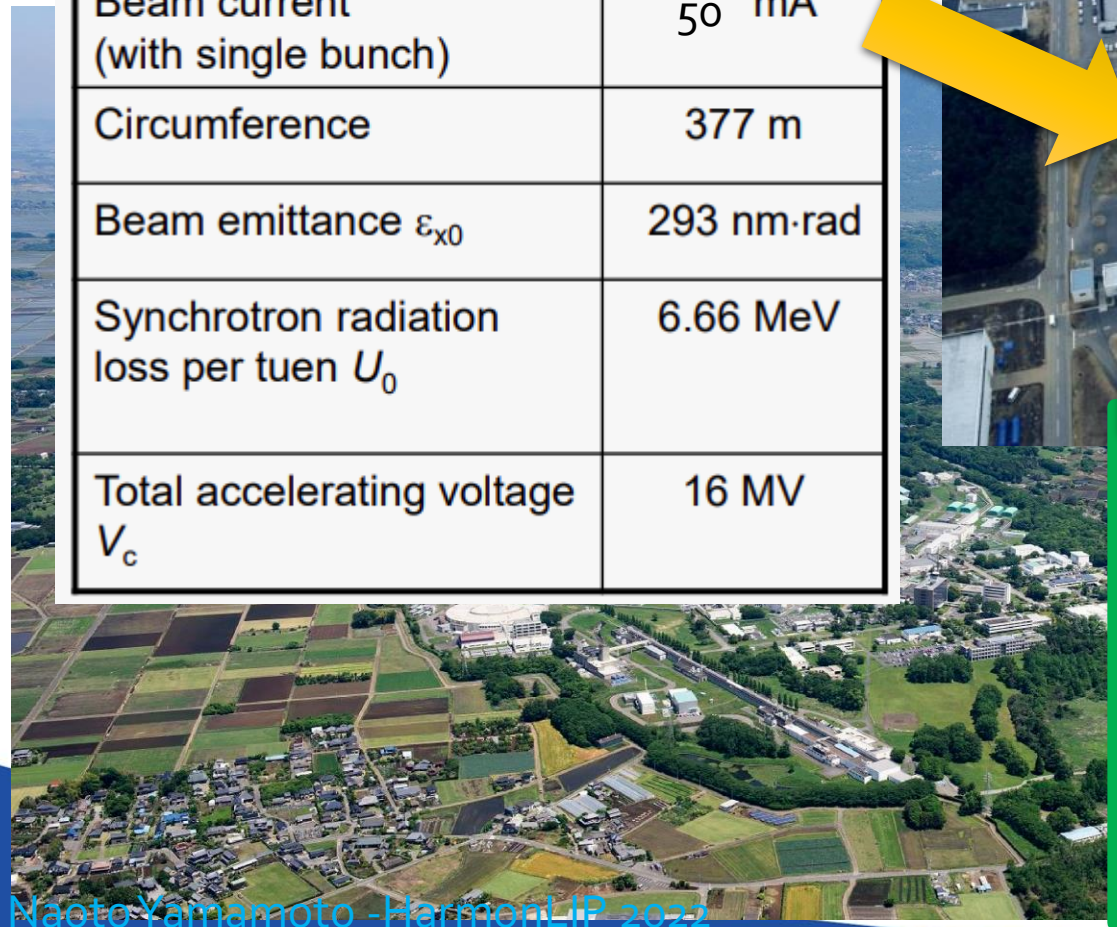
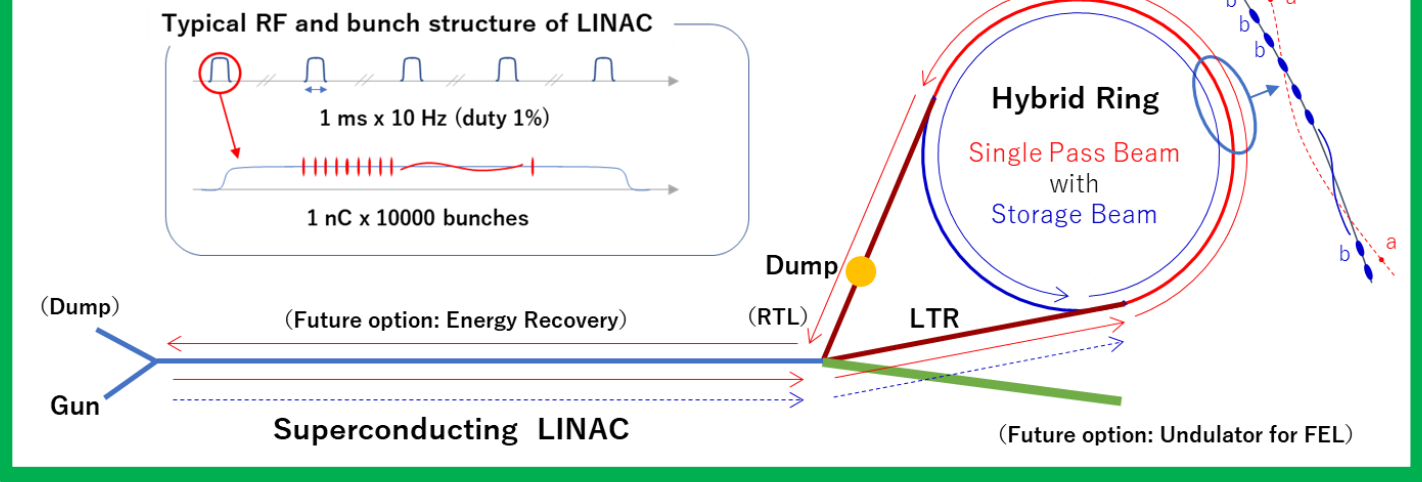


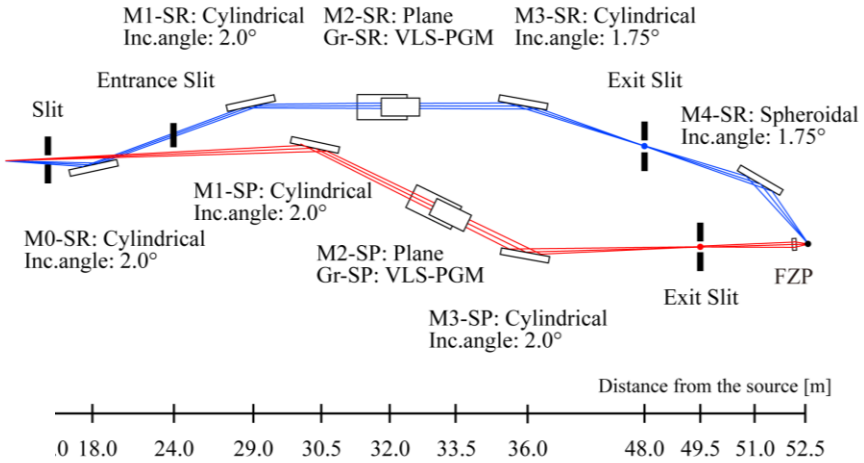
Future Photon Factory (203X~)

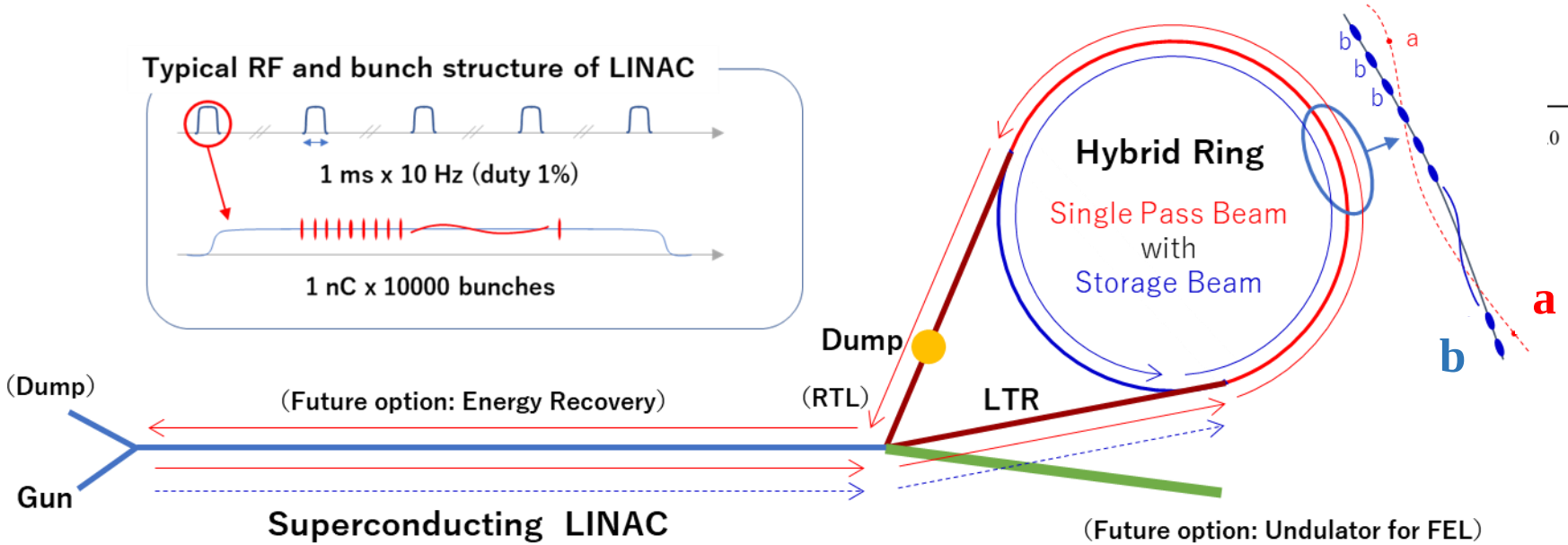


Future Light Source at KEK and HC projects

- Hybrid ring, a storage ring light source combined with a long pulsed superconducting linac, is proposed as a future(after 2030) light source at KEK.
- It is designed to be operated with the coexistence of the storage (SR) bunches b) characterized by the performance of the storage ring, and the single-pass (SP) bunches a) characterized by that of the SC linac.
- HCs will be introduced into the storage ring.

* K. Harada, N. Funamori, N. Yamamoto *et al.*, "Conceptual design of the Hybrid Ring with superconductng linac," *J. Synch. Radiat.*, vol. 29, no. 1, pp. 118–124, 2022.





a: SP beam **(3GeV case)**

Emittance = 0.1 nmrad

Bunch duration = 50 fs

Average current = 0.1 mA

b: SR beam (multi bunch)

Emittance < 1 nmrad

Average current = 500mA

HC R&Ds

HC project for PF-2.5GeV ring

- HC for Hybrid filling operation mode

  For the purpose to increase single bunch current from 30mA to 50mA, a introduction of NC-HCs is under consideration.

  Bunch lengthening factor of 1.6 is expected with two NC-HCs.

PF 2.5 GeV ring

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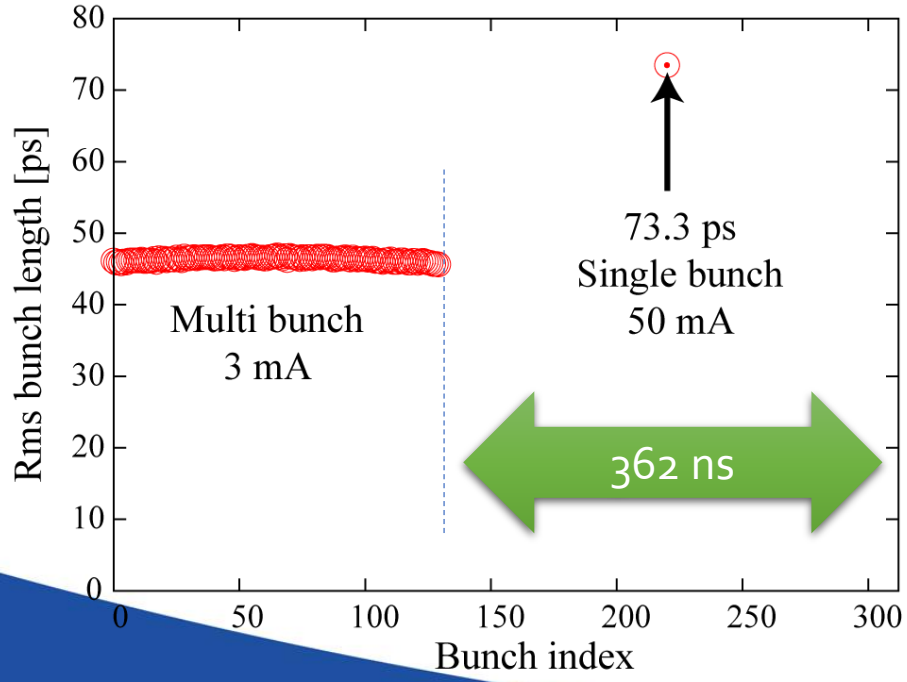
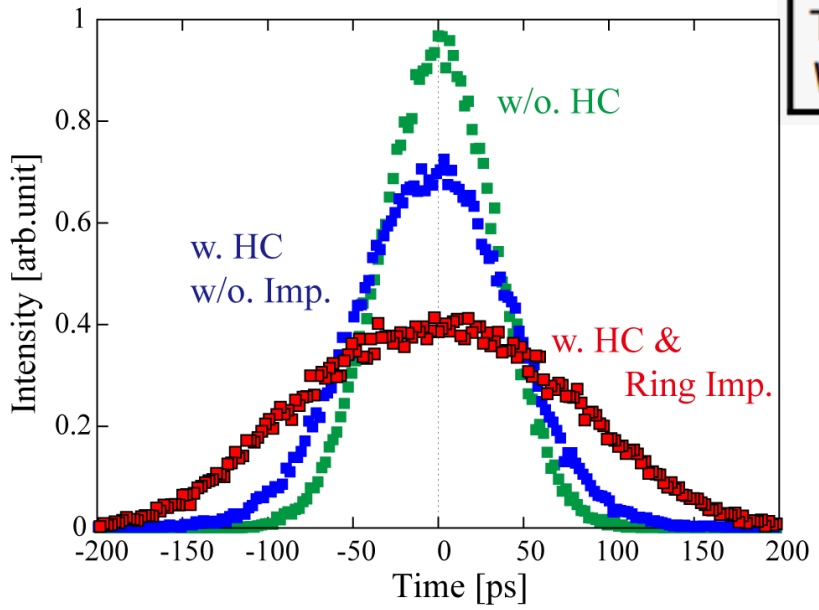




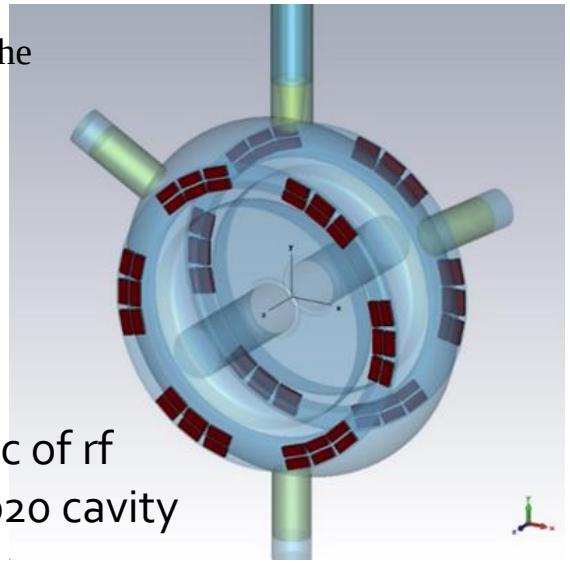
← Fig. Simulation (mbtrack) result for PF Hybrid operation mode.

Insight through Accelerators.
KEK

HC project : Development of Harmonic cavity

* T. Yamaguchi et al., “Low-power test of the 1.5 GHz TM020-type harmonic cavity for the future synchrotron light sources,” in Proc. PASJ2021, paper WEOA03, 2021.
* T. Yamaguchi et. al., “High-power model design of the 1.5 GHz TM020-type harmonic cavity for the future synchrotron light sources”, in Proc. PASJ2022, 2022

- 1.5GHz-TM020 cavity
  - ✓ Freq = 1.500 GHz
  - ✓ R/Q = 34 Ohm, $R=V_c^2/(2P_c)$
  - ✓ Q_0 = 31,500
  - ✓ Pc, max = 10 kW
  - ✓ Three tuners for not affecting Q_0 of TM020 mode
  - ✓ Loop coupler : β ~ 0.5
  - ✓ Compact LOM & HOM dampers



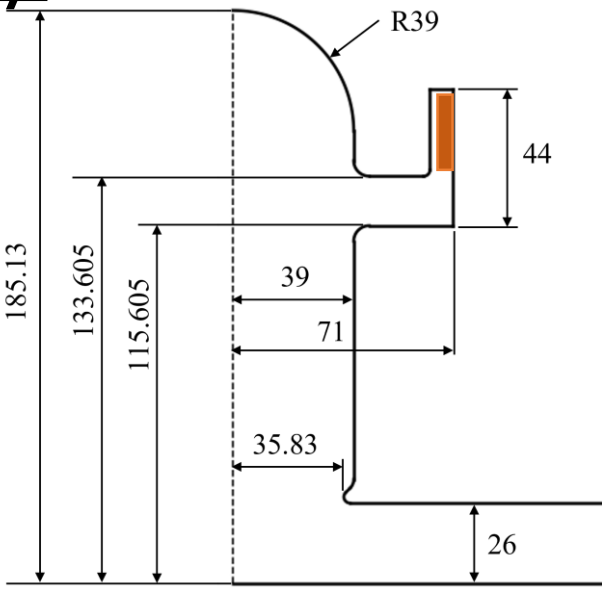
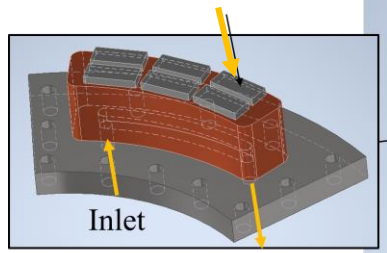


Fig. Schematic of rf model of TM020 cavity

Q factors of the principal parasitic modes

Mode	Measurement (low power model)	Simulation	Target
TM010	34.0	38.2	< 58.4
TM110	23.8	30.0	< 28.8
TM120	40.1	67.1	< 38.7
TE121	3,040	4,270	< 795

RF absorber (Ferrite)



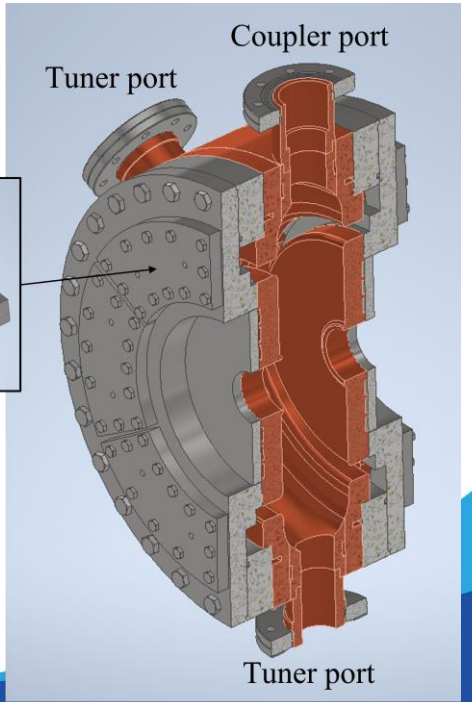
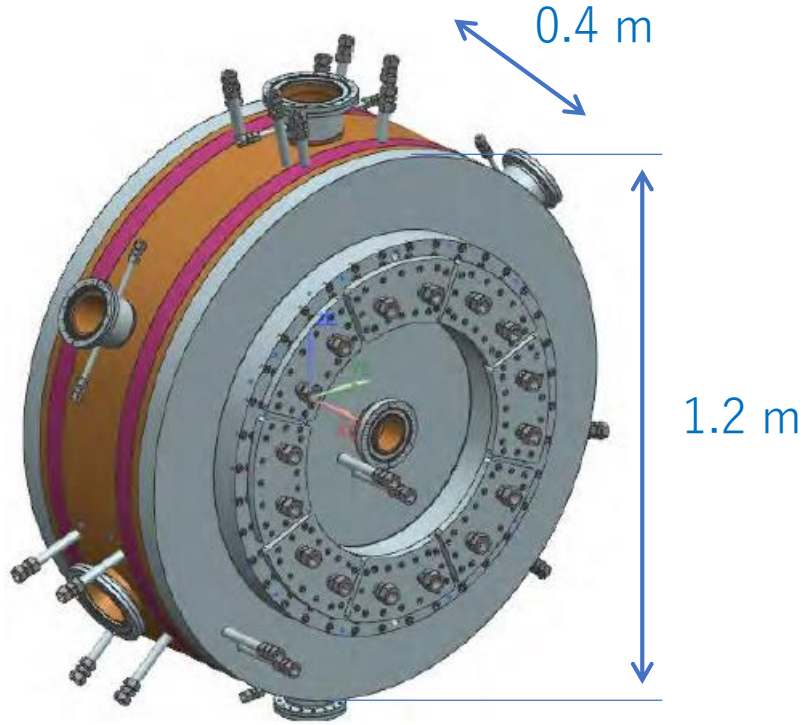
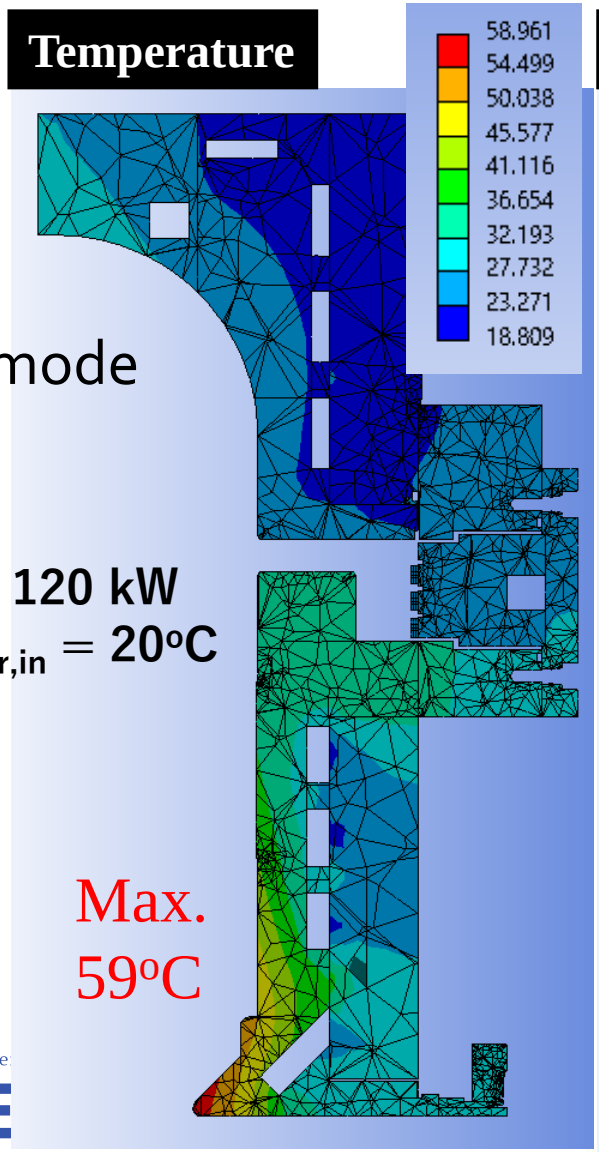


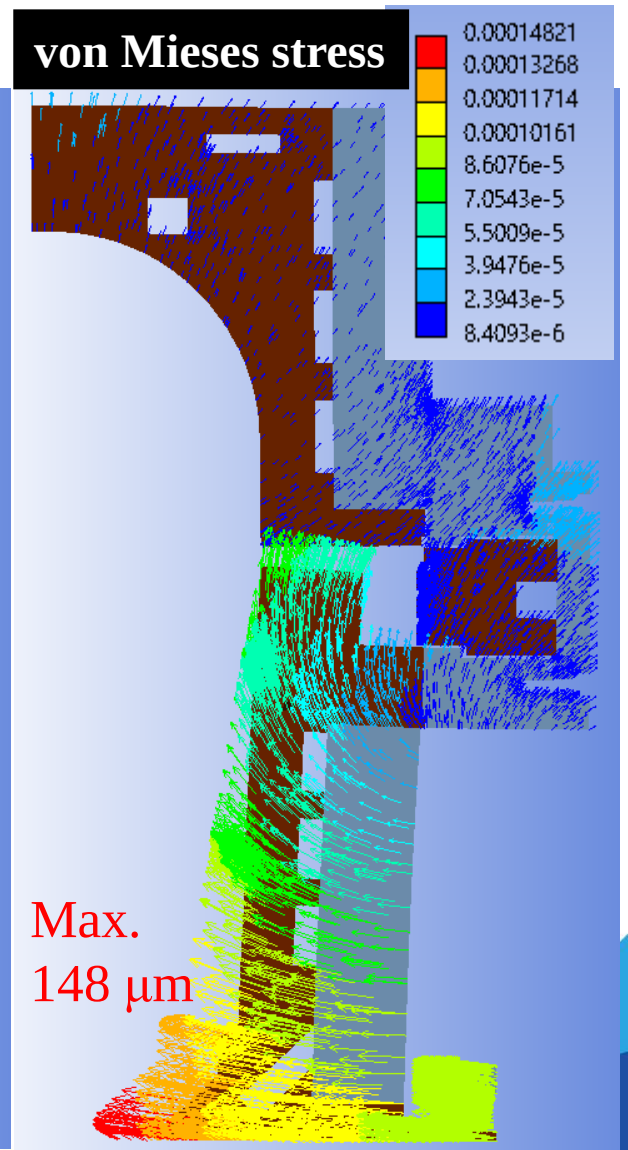
Fig. Schematic of high-power model of TM020 cavity

HC project : Development of TM020 Main cavity

- TM020-500MHz cavity for future light source
  - ✓Freq = 500.0 MHz, Q0 = 55,400
  - ✓R/Q = 58.5 Ohm, $R=V_c^2/(2P_c)$
  - ✓$P_{c,max}$ = 120 kW
  - ✓Compact LOM & HOM dampers
  - ✓Three tuners for not affecting Q_0 of TM020 mode



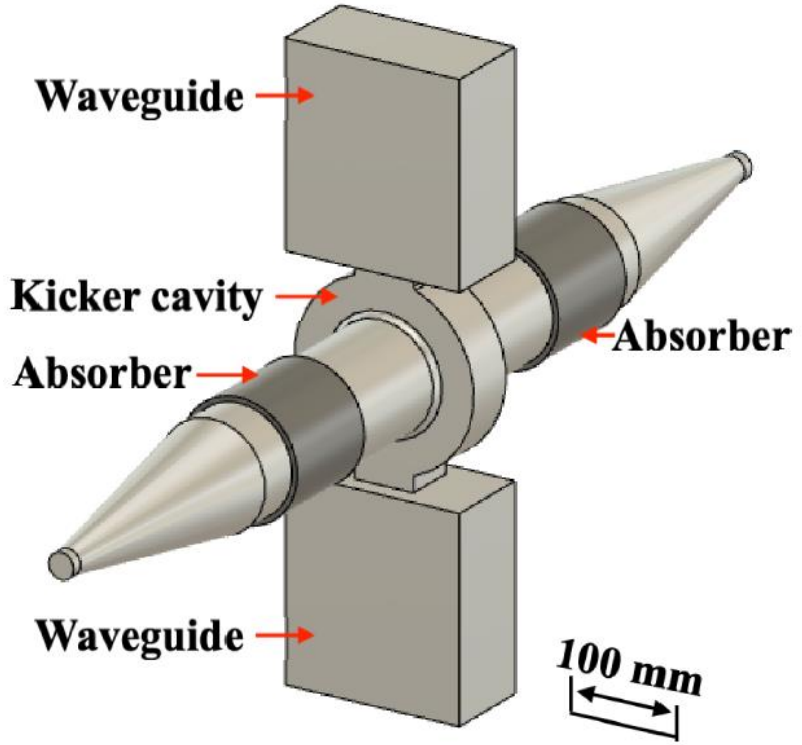


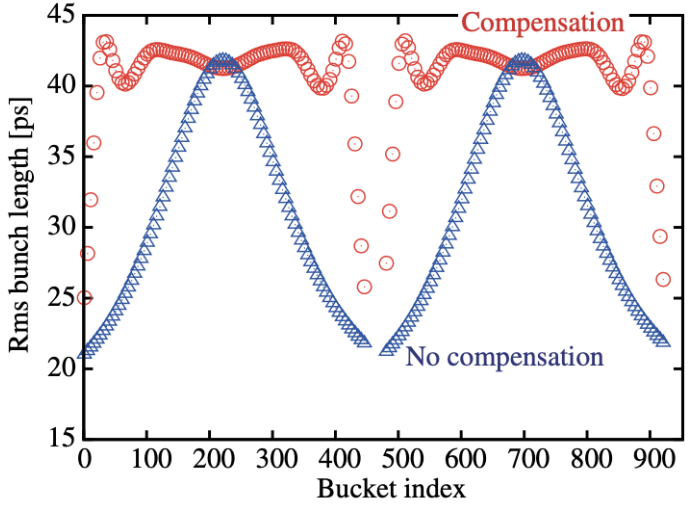


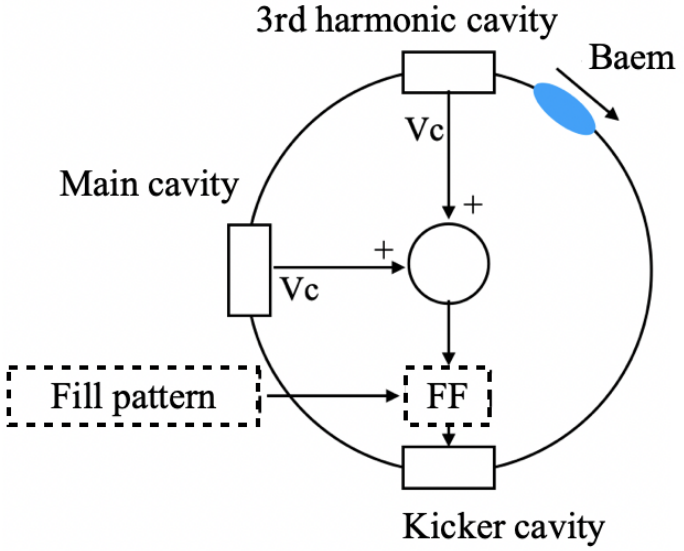
HC project : Development of Broadband kicker cavity

* N. Yamamoto et al., “Reduction and compensation of the transient beam loading effect in a double rf system of synchrotron light sources,” Phys. Rev. Accel. Beams, vol. 21, 012001, 1 2018..
* D. Naito et. al., “Design Consideration of a longitudinal Kicker Cavity for Compensating Transient Beam Loading Effect in Synchrotron Light Sources”, in Proc. IPAC21, MOPAB331,2012

- A broadband kicker cavity for Transient beam loading compensation
  - ✓ Freq = 1.50 GHz
  - ✓ Double aperture coupler for large β (~56)
  - ✓ Design Kick voltage, |Vg| = 53 kV

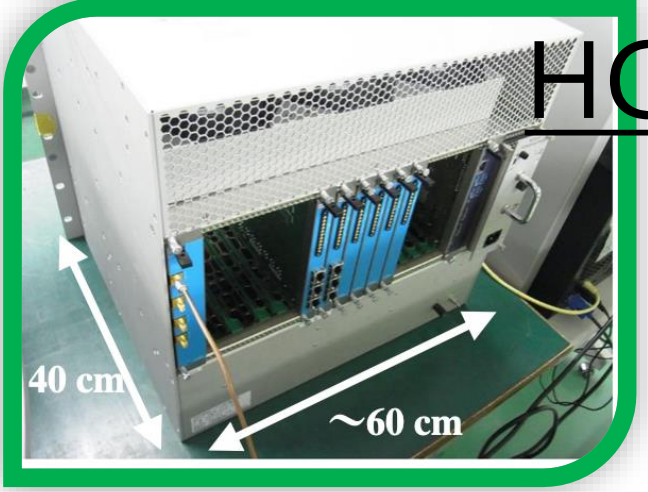






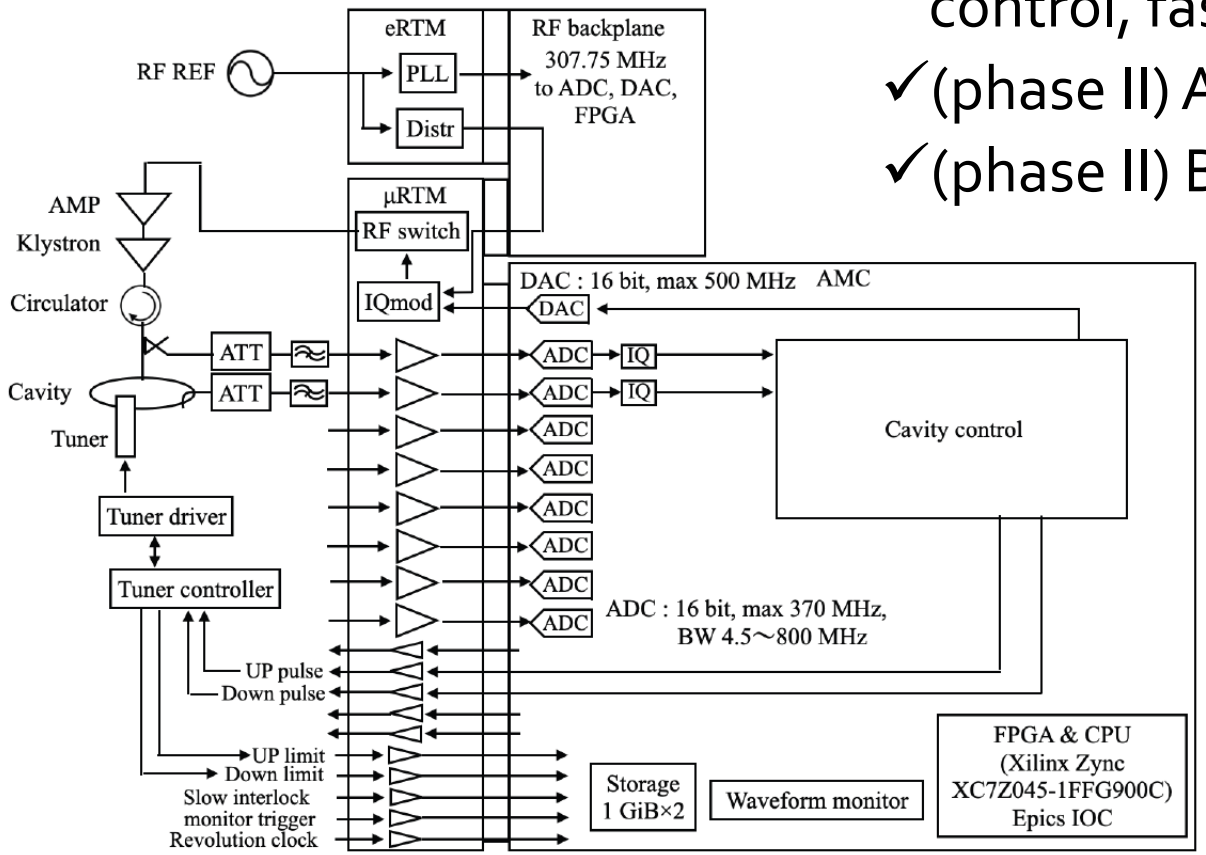
Parameter	Eigenmode	Frequency domain
Frequency	1.50001 GHz	1.50003 GHz
R/Q , $R=V_c^2/(P_c)$	59.23 Ω	59.54 Ω
Q	16853	16814
Q_L	296	291
P_c	2.52 kW	2.53 kW
Max power density	26.6 W/cm^2	25.1 W/cm^2

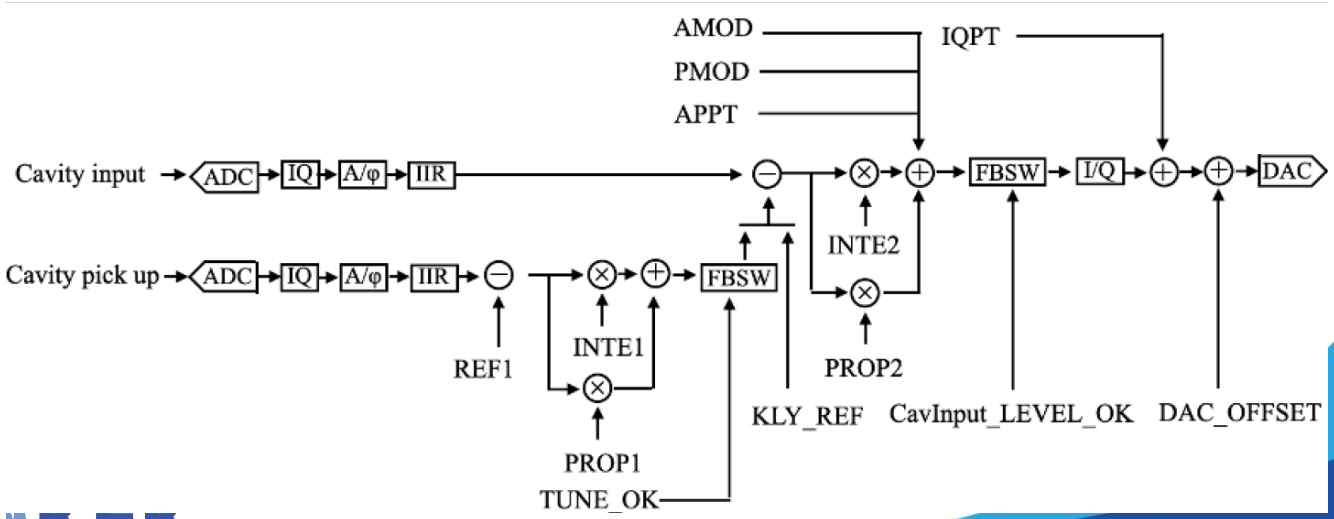
HC project : Development of Digital LLRF



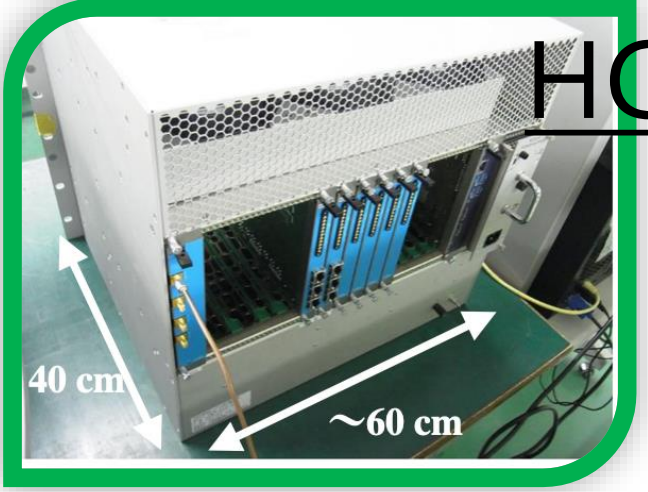
* D. Naito et al., "Investigation of bunch-phase detection method compensating TBL voltages in next generation light sources," in Proc. PASJ2021, THOA01, 2021
* D. Naito et. al., "Study of LLRF upgrade at KEK-PF", in Proc. PASJ2021, THPO048 2021

- Development of PF-2.5GeV ring new Digital LLRF
  - ✓(~2023) digital boards based on the µTCA.4 with Ig PI control, fast interlock and 2 x fs RF modulation
  - ✓(phase II) Adaptive feedfoward RF modulation
  - ✓(phase II) Bunch phase detection for TBL compensation





HC project : Development of Digital LLRF



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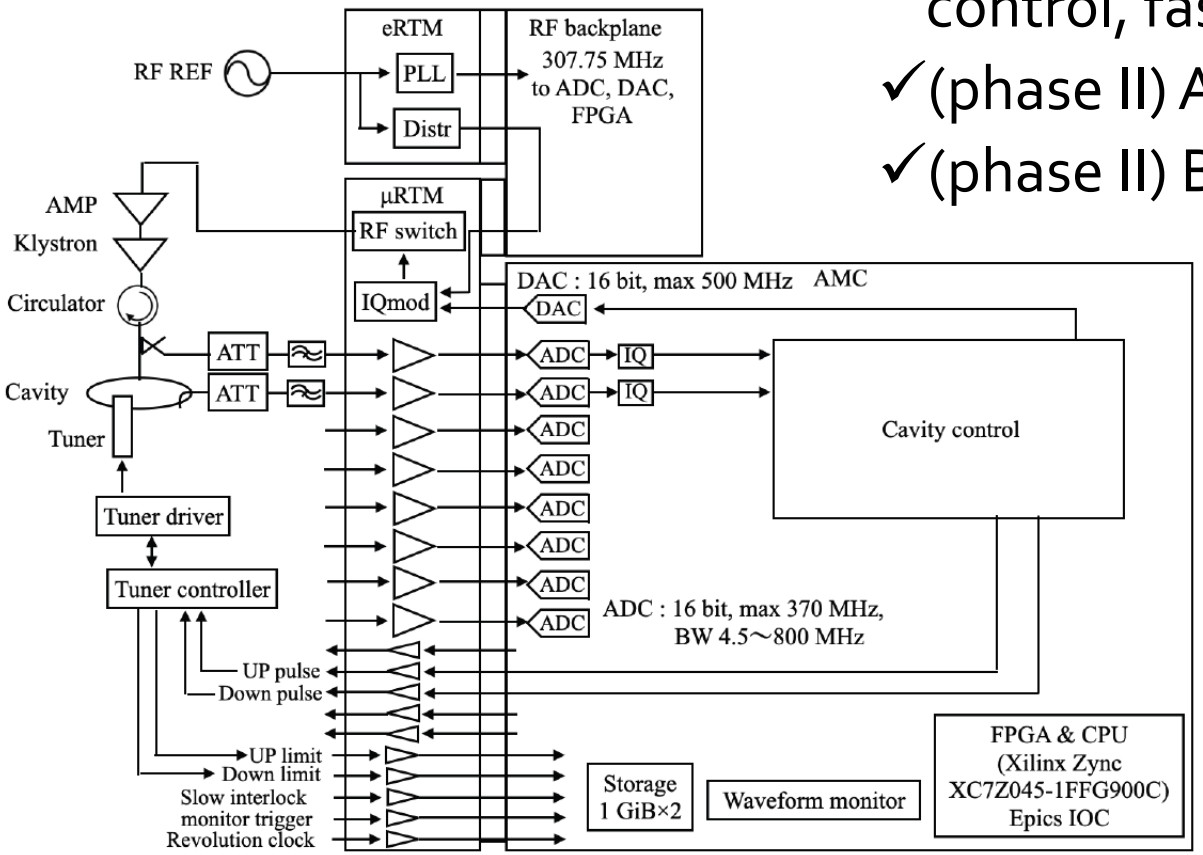
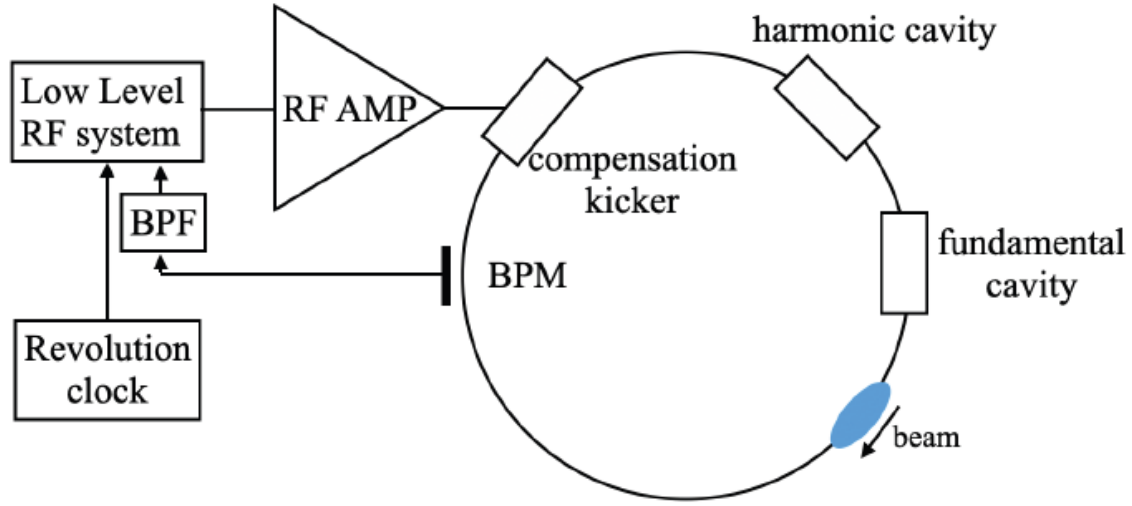
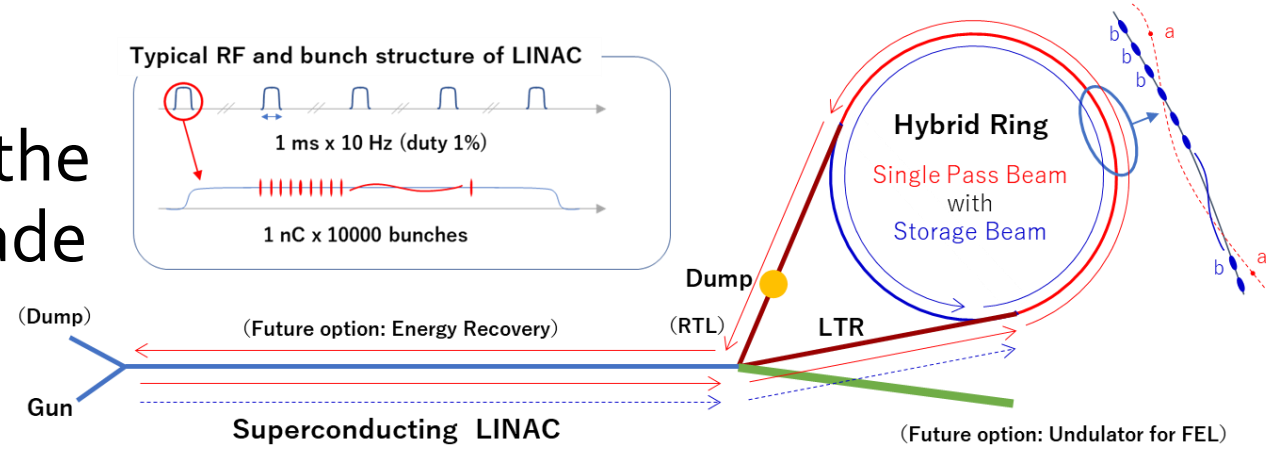




Summary

- Hybrid ring is proposed as a future (2030~) light source at KEK.
- Until the approve and operation of the new ring (2030) , R&D and PF-upgrade are planned.



- As part of PF-upgrade,
  - ✓Replacing of current analog LLRF system to digital is underway (~2023).
  - ✓Introduction of both HC (s) and new MCs to PF-2.5GeV ring are considered, the R&Ds are underway.
- For the future light source, R&D's for kicker cavity and it's control system are in progress.
  - ✓Design and low-level-model study of the 1.5GHz Kicker cavity.
  - ✓Conceptual design of Adaptive feedforward system and Bunch phase monitor