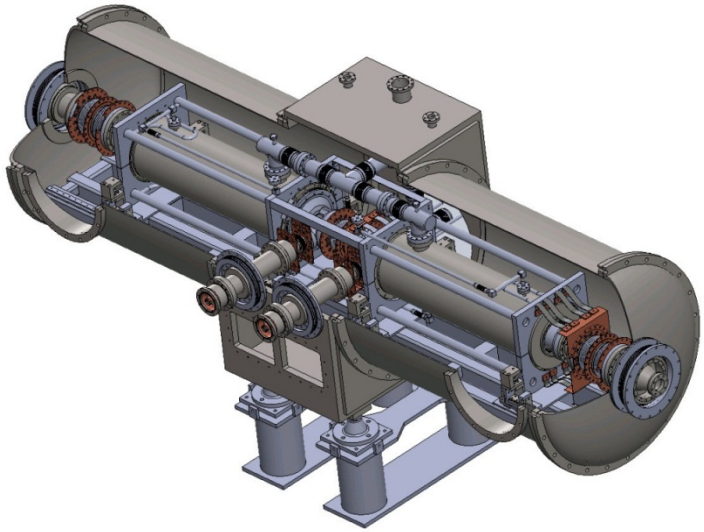
Status of Main Linac Cryomodule Development for Compact ERL Project



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IPAC12(@ New Orleans)

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Contents

- Compact ERL (cERL) project
- Main linac cryomodule
- 9-cell cavity development
- Input coupler
- HOM absorber
- Frequency tuner
- Schedule
- Summary

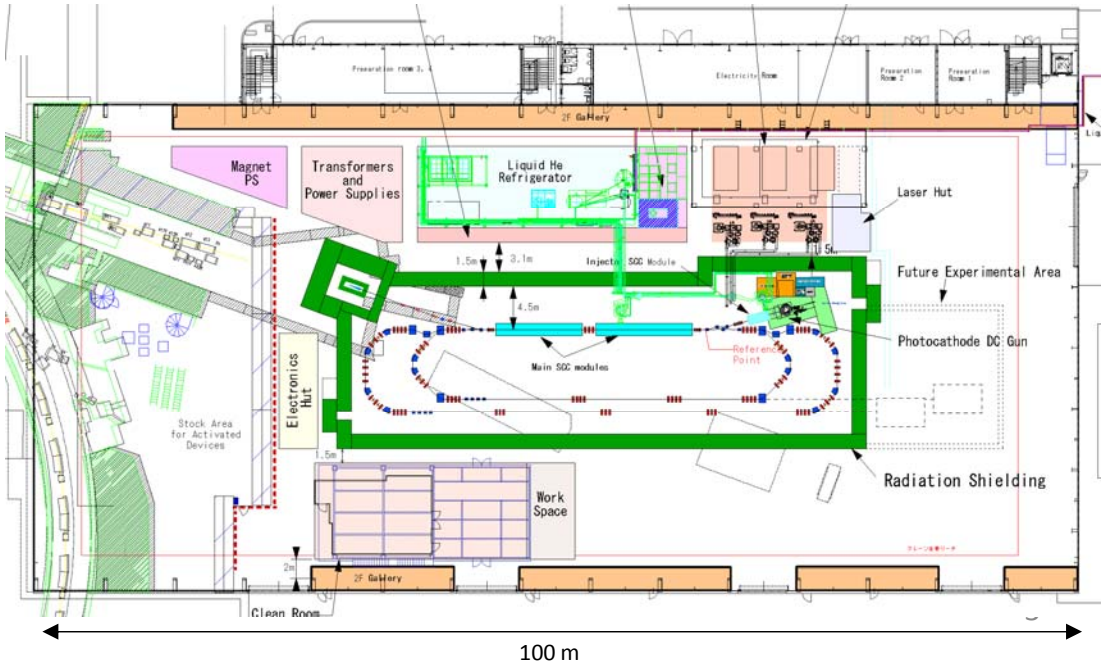
Compact ERL(cERL) project

Demonstrate the technologies needed for future multi-GeV class ERL, and show its beam performances

Parameters of the Compact ERL

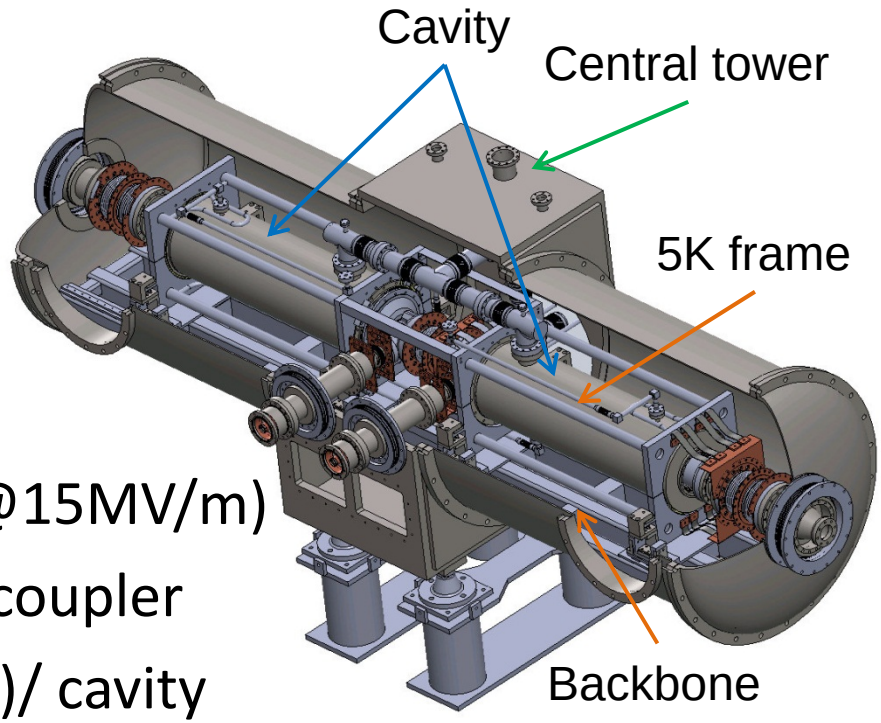
	Parameters
Beam energy	35 - 200 MeV
Injection energy	5 MeV
Average current	10 - 100 mA
Acc. gradient (main linac)	15 MV/m
Normalized emittance	0.1 - 1 mm·mrad
Bunch length (rms)	1 - 3 ps (usual) ~ 100 fs (with B.C.)
RF frequency	1.3 GHz

※ red numbers are parameters for initial stage

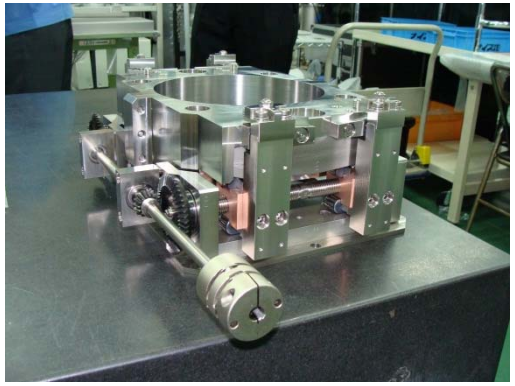


ERL main linac cryomodule

- Accelerate 30MV by two 9-cell SC cavities
- Follow High Pressure Gas Safety Act in Japan
- CW operation (1.3GHz)
- Dynamic loss
  - Cavity : 25 W (for 2K) / cavity(@15MV/m)
  - Input coupler : 1.5 W (for 5K) / coupler
  - HOM absorber : 150W (for 80K)/ cavity



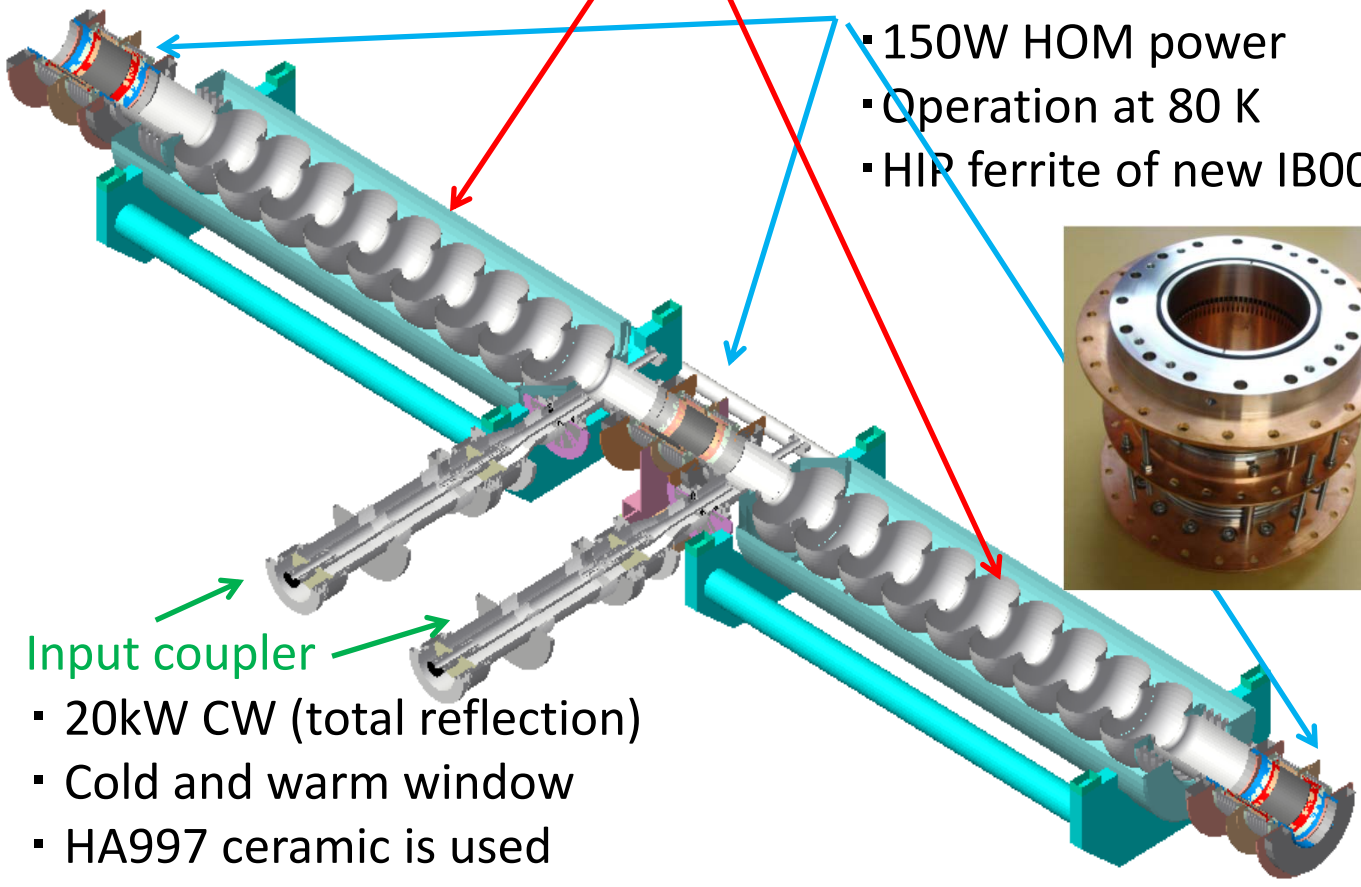
- Alignment
  - Target : 1mm across beam axis after cooling down
- Support
  - Cavity(2K) – 5K Support frame – Backbone(RT) – Central tower(RT)

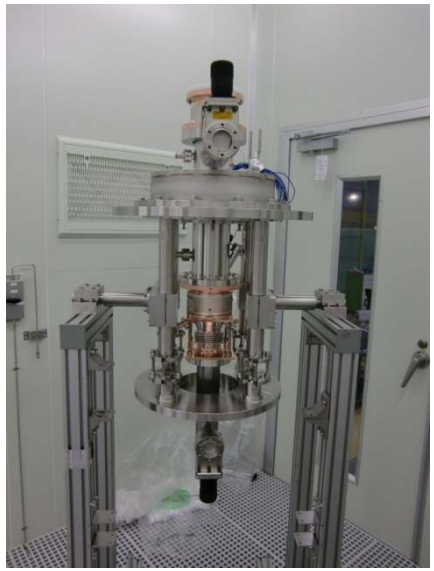


9-cell cavity
- HOM damped cavity shape
- Eacc=15-20MV/m
- 100mA CW
- Energy recovery

Frequency tuner
- Slide-Jack tuner
- Piezo tuner
- Located on 4 K

HOM absorber
- 150W HOM power
- Operation at 80 K
- HIP ferrite of new IB004

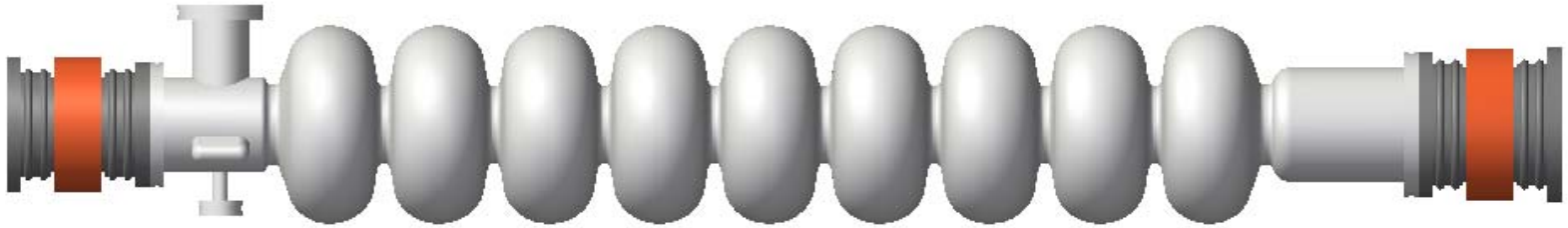




Input coupler
- 20kW CW (total reflection)
- Cold and warm window
- HA997 ceramic is used

ERL main linac 9-cell cavity

- Requirement
  - Eacc = 15 ~ 20 MV/m
  - $Q_0 > 1x10^{10}$ at 15 MV/m
  - CW operation
- KEK-ERL model-2 cavity
  - Optimized cell shape for strong HOM damping
  - Large iris diameter, 80mm
  - Epeak/Eacc =3.0
- Important to suppress field emission
  - reduce cryogenic loss
  - Less dark current



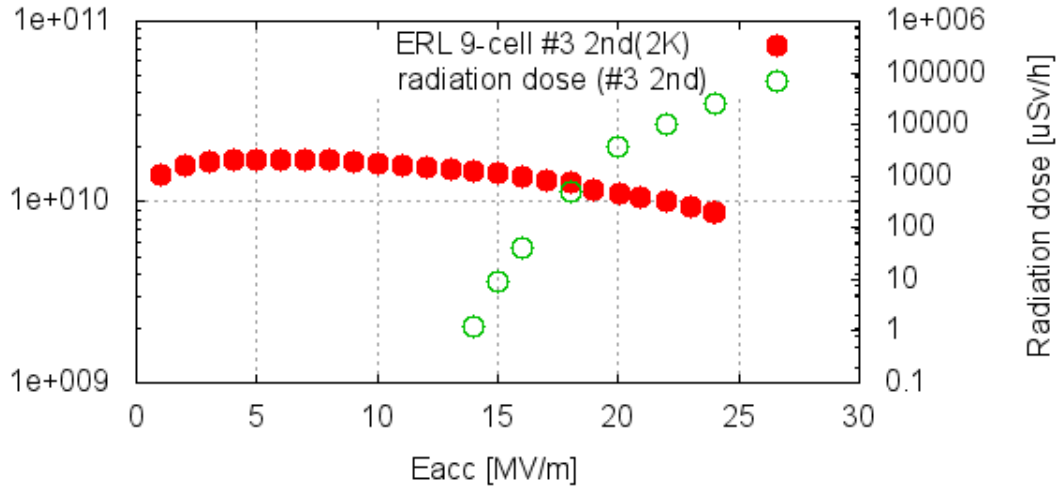
Results of vertical tests

WEPPC011
K. Umemori

Two 9-cell cavities were fabricated for cERL and vertical tests were performed two times for each cavity. (followings are results for 2nd tests)

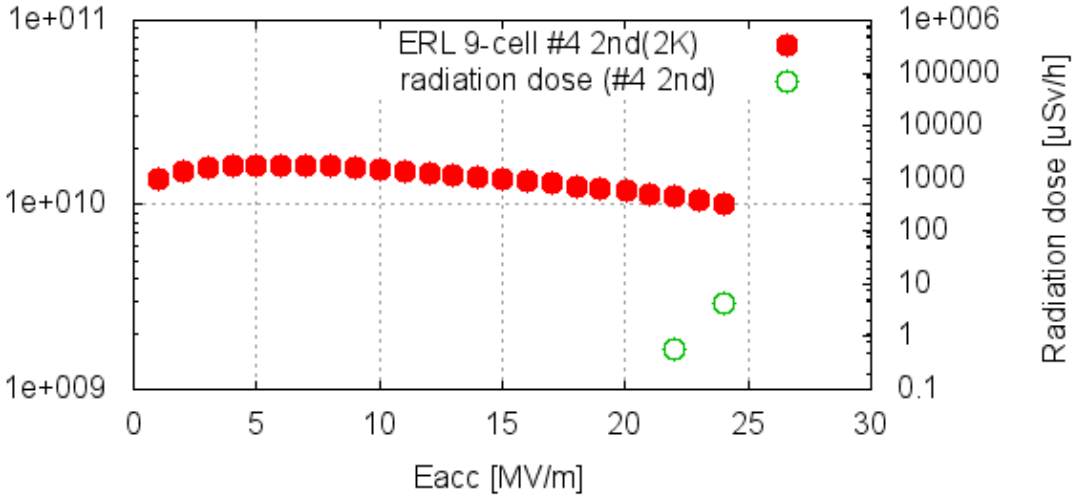
ERL 9-cell #3 cavity

- Field reached to 25 MV/m
- No limitation up to 25 MV/m
- Q > 1e10@15MV/m
- Satisfied cERL specification
- X-ray onset around 14 MV/m



ERL 9-cell #4 cavity

- Field reached to 25 MV/m
- No limitation up to 25 MV/m
- Q > 1e10@15MV/m
- Satisfied cERL specification
- X-ray onset around 22 MV/m



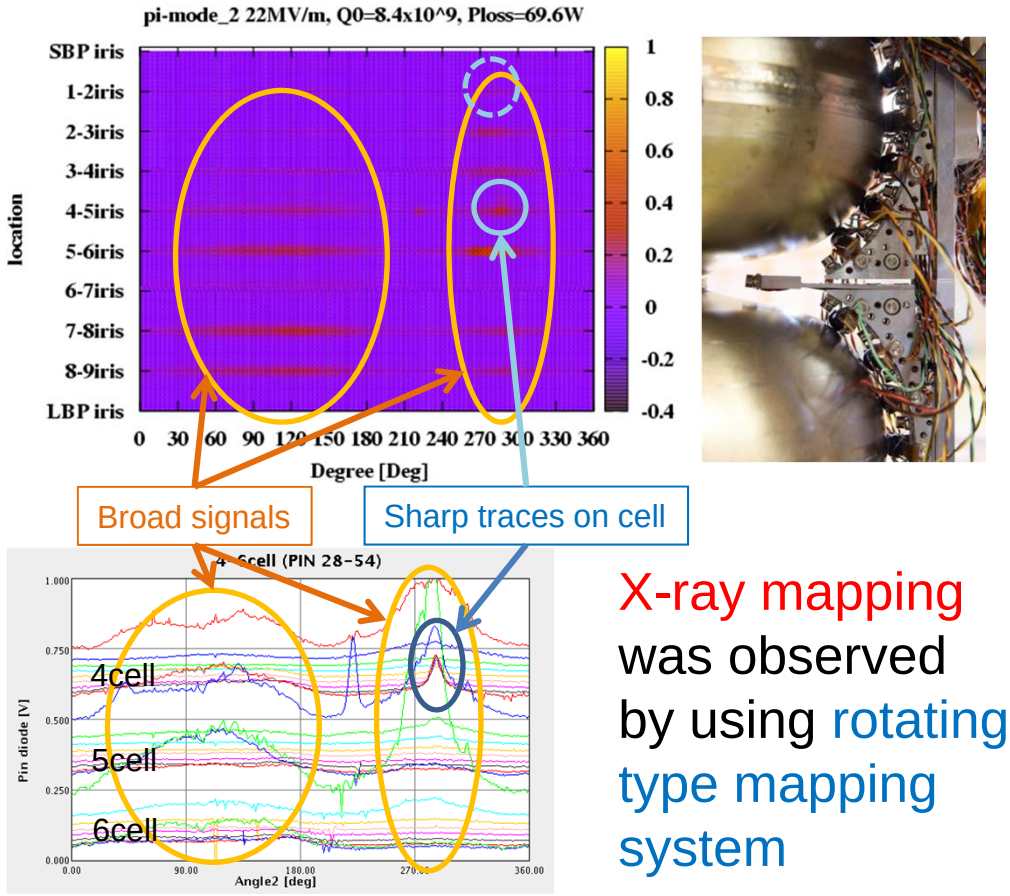
Our approach against field emission

① What we did before vertical test

- Low current density, 32mA/cm^2, EP to suppress remaining Sulfur
- Careful flange assembly using ionized gun and particle counter

② Diagnostics at vertical test

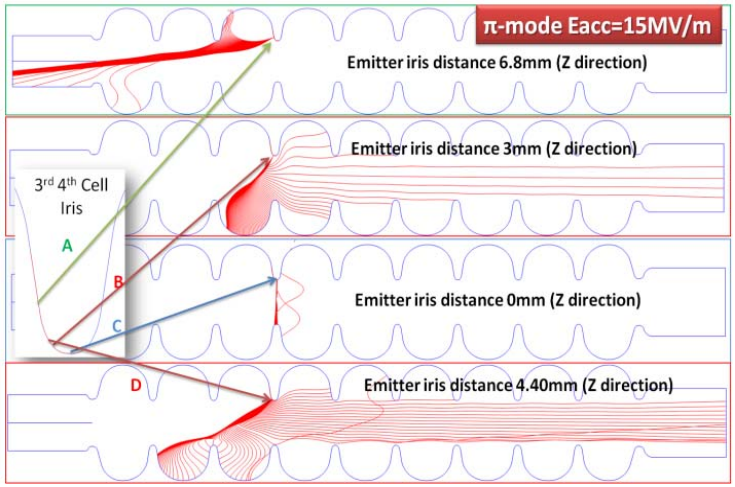
Example of X-ray mapping(#3 cav., 2nd VT, Eacc=22MV/m)



X-ray mapping was observed by using rotating type mapping system

③ Calculation

MOPPC070
E. Cenni



Trying to deeply understand phenomena of field emission by calculation, using Fishpact

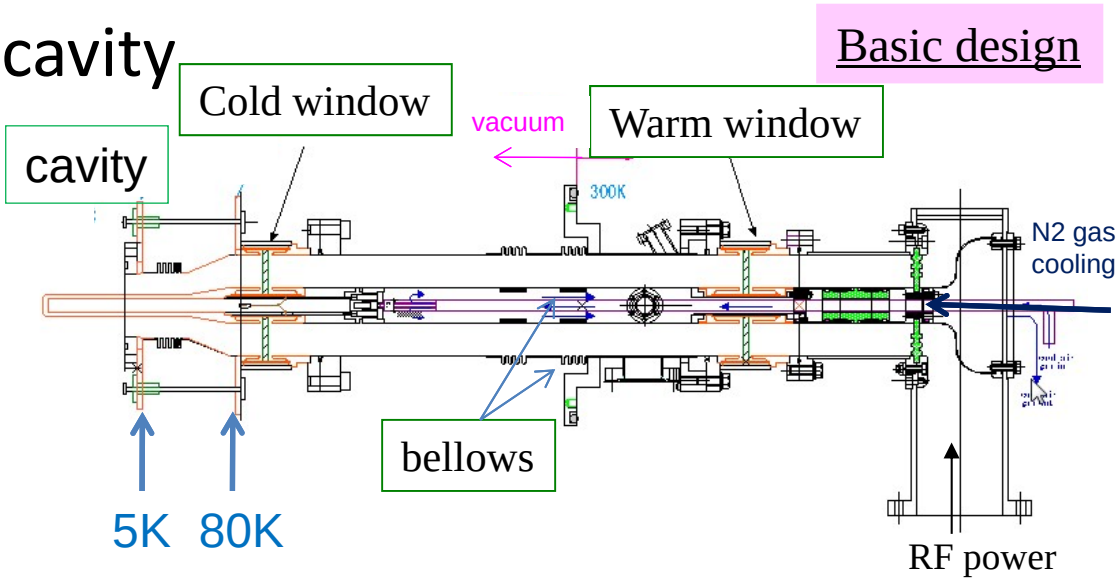
Input coupler

Requirement

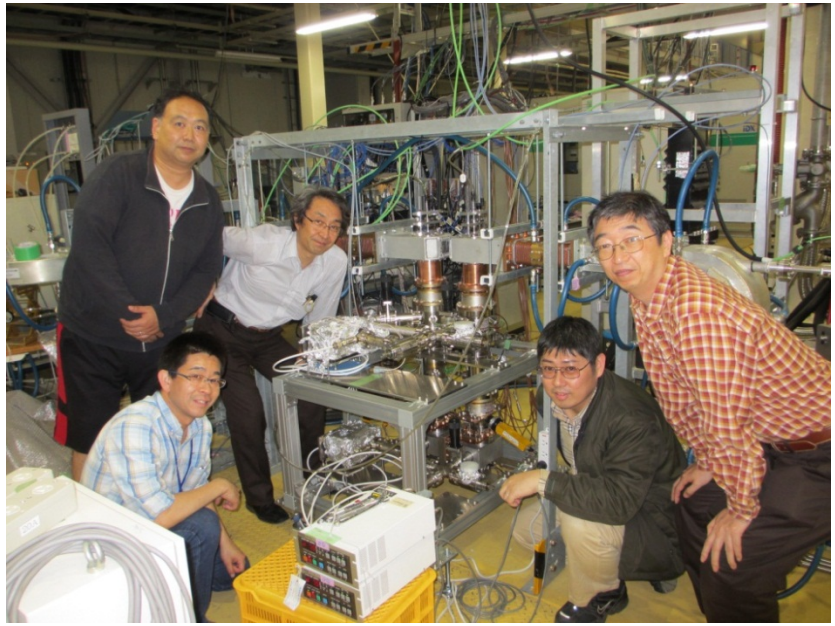
- Max 20 kW standing wave (Total reflection)
  - Compensate field fluctuation due to micrphonic detuning
  - No beam loading because of energy recovery
- Qext = 1~4x10^7 and variable coupling

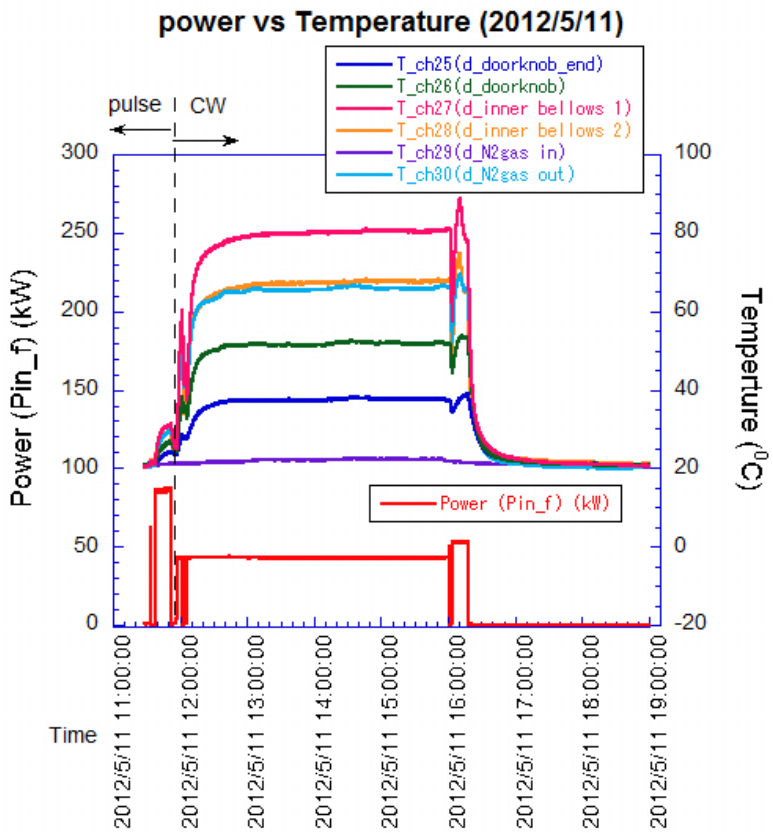
Coupler design

- Coaxial type double windows to avoid dust contamination into cavity
- HA997 ceramic
- 5K and 80K anchor
- N_2 gas cooling for inner conductor



Results of coupler conditioning for cERL

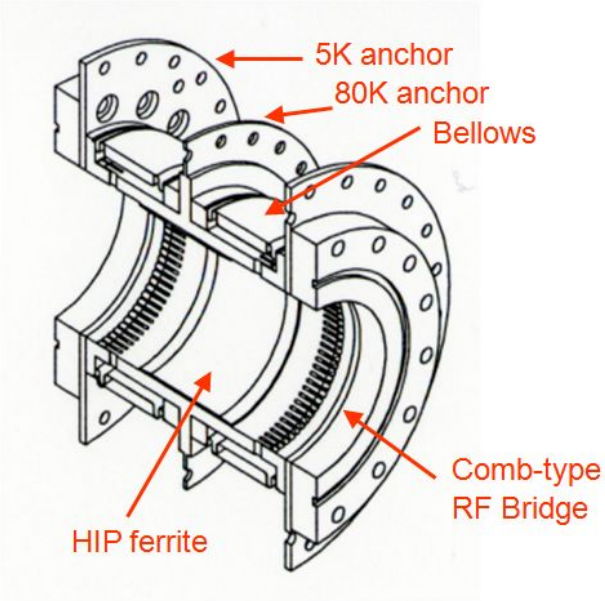


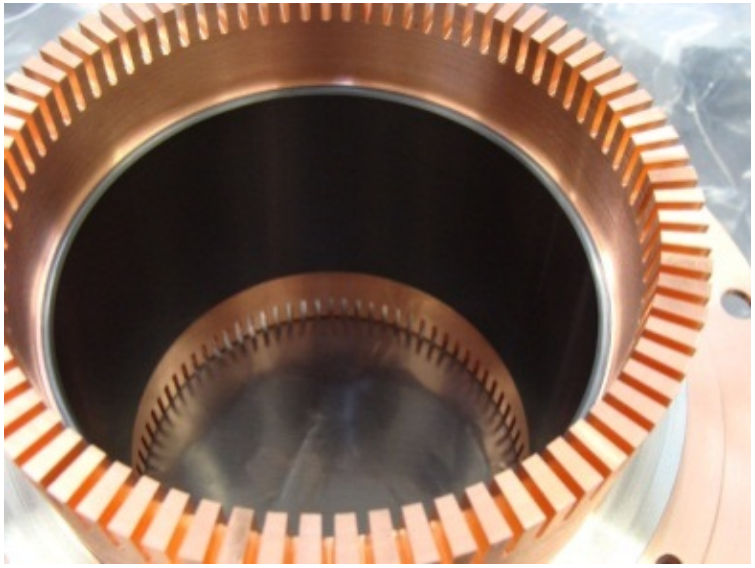


- Two input couplers for cERL were fabricated.
- Conditioning by traveling wave using 300kW klystron
- RF power up to 100kW (pulse)
  40kW(CW)
- Keep 40kW CW, 4hours
- Highest Temp: bellows of inner conductor (ΔT~60degree, OK)

HOM absorber

- HOM absorber located on 80K region
- Heat load of 150W/cavity is estimated for 100 + 100mA electron beam with 3ps bunch length
- New IB004 ferrite is HIP bonded on Cu pipe
- Outside: bellows, Inside: Comb-type RF bridge

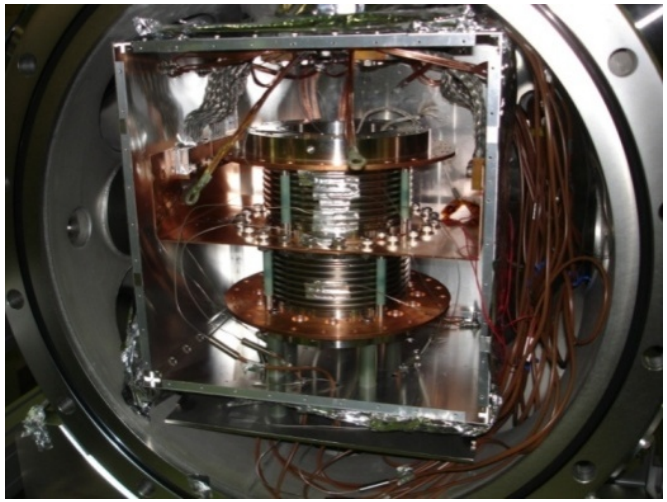




Test of HOM absorber using prototypes

Cooling test at 80K

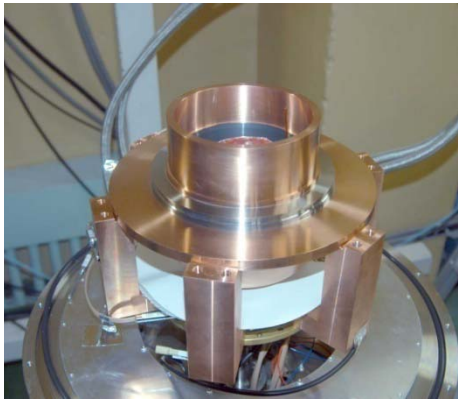
(using prototype without ferrite)



・Cooling ability against 150W HOMs was tested under 80K condition.
・Generally, it went well.
・Contact at the tip or side of Comb-structure could give large thermal conductance.
・Modification for Comb-shape

Heat cycle test (RT – 80K)

(using prototype with ferrite)



• Heat cycles, between RT to 80K, were applied to prototype HOM absorber.
• Some cracks were observed
• Modification of ferrite structure, especially taper part, which close to the boundary section.

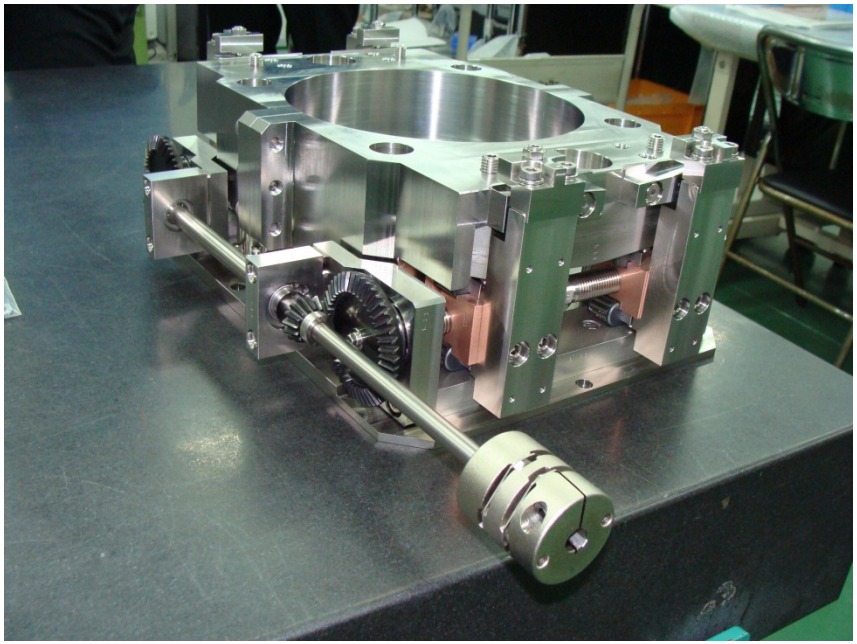
⇒ Modified version of HOM dampers for cERL are almost fabricated.

Frequency tuner

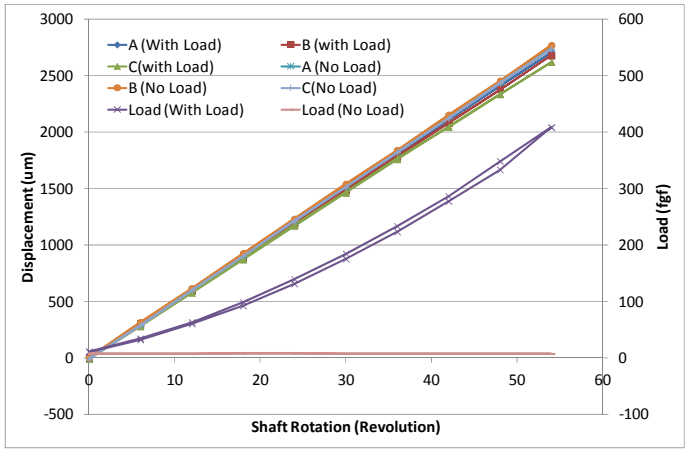
- Tuner system basically developed for STF-BL cavity
- Mechanical tuner for course tuning
  - Slide-Jack tuner
  - Stroke 3mm → 900kHz frequency change
- Piezo tuner for fine tuning
  - Stroke 80um at RT

    ⇒ ~8um at 4K

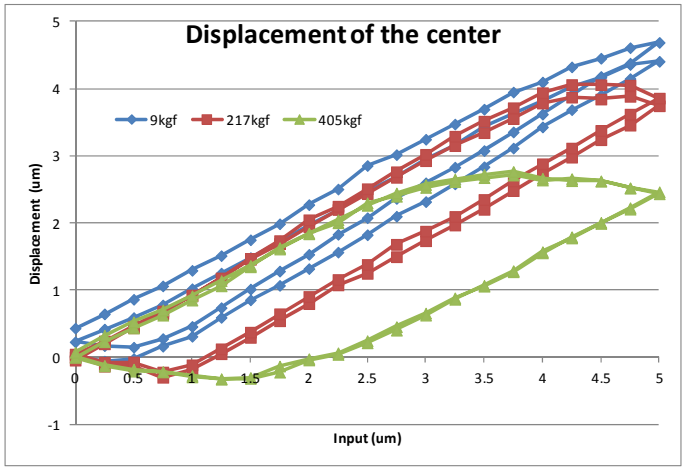
    ~4um for cavity
- Piezo tuner compensate microphonic detuning
- QL = 2×10^7 (Δf = 65 Hz)
- Two frequency tuners were fabricated for cERL



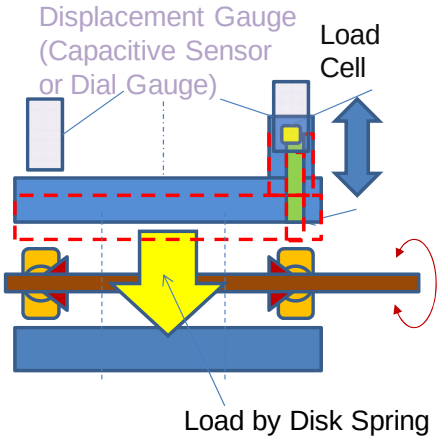
Performance test of prototype mechanical tuner at RT



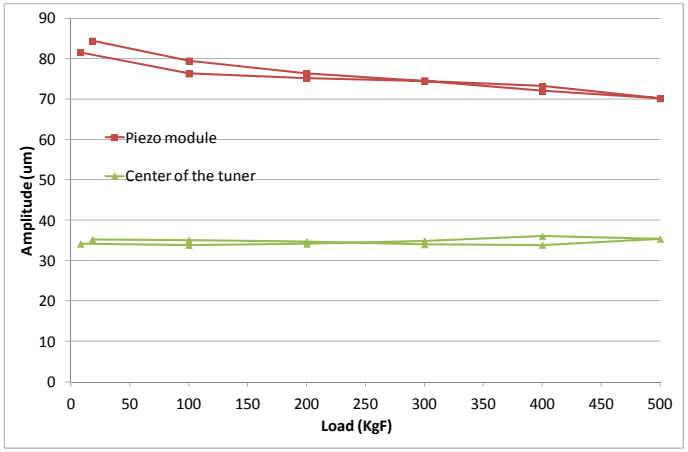
Stroke is OK (3mm)



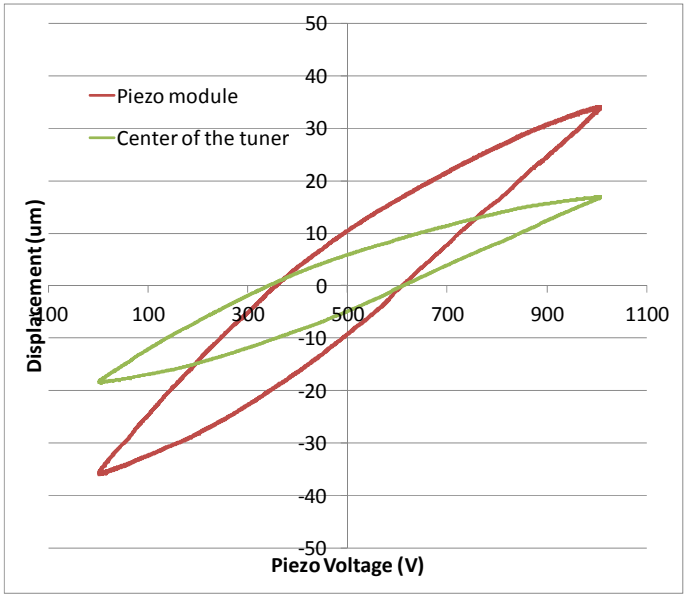
Max. backlash ~0.4um



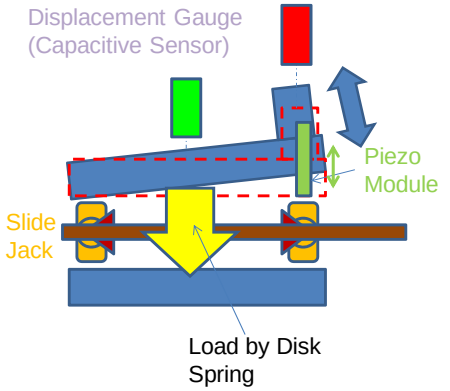
Performance test of prototype piezo tuner at RT



Stroke is OK (80um)

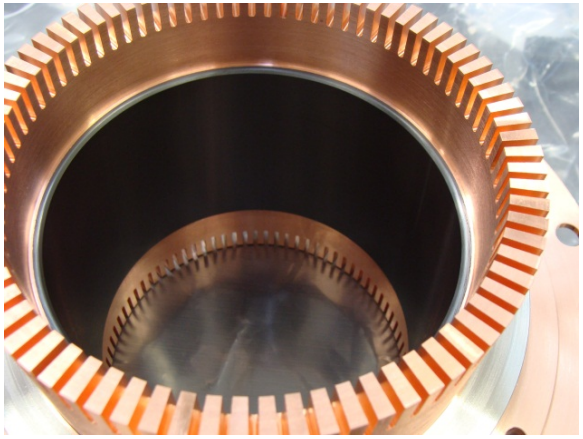


Reproducibility of hysteresis curve is fine

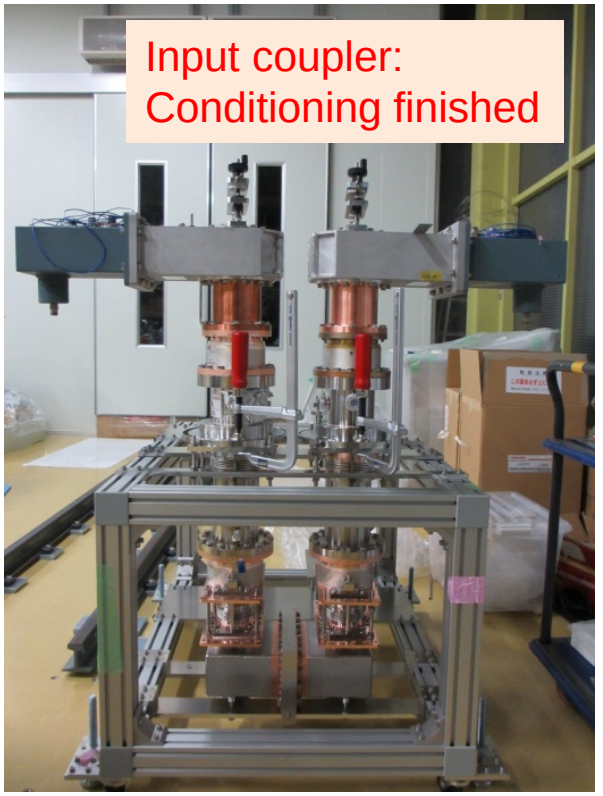


Status and future plan

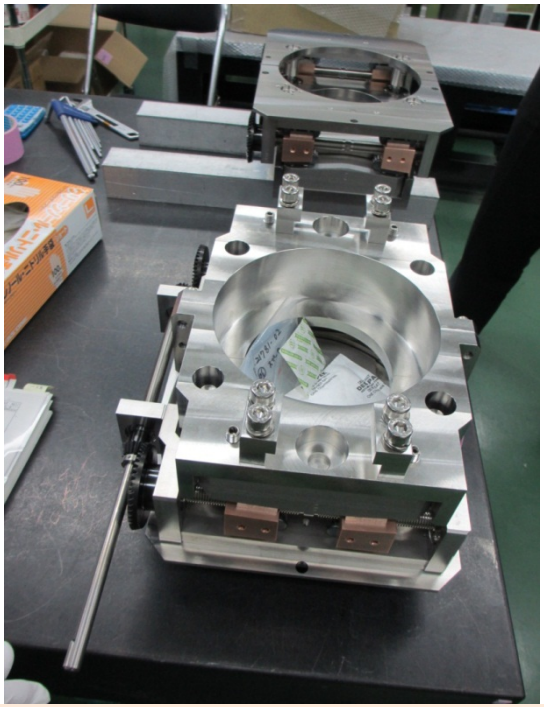
Cavity: He jacket was mounted



HOM damper: fabricated
※ picture: before bellows and flanges were attached.



Input coupler:
Conditioning finished



Frequency tuner: fabricated

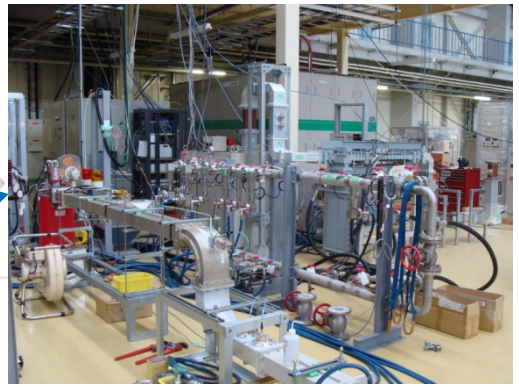
- Almost all components are ready
- Cryomodule assembly this summer
- Cooling test and first high power test within this year
- ERL beam will come to main linac next year

ERL Development Building

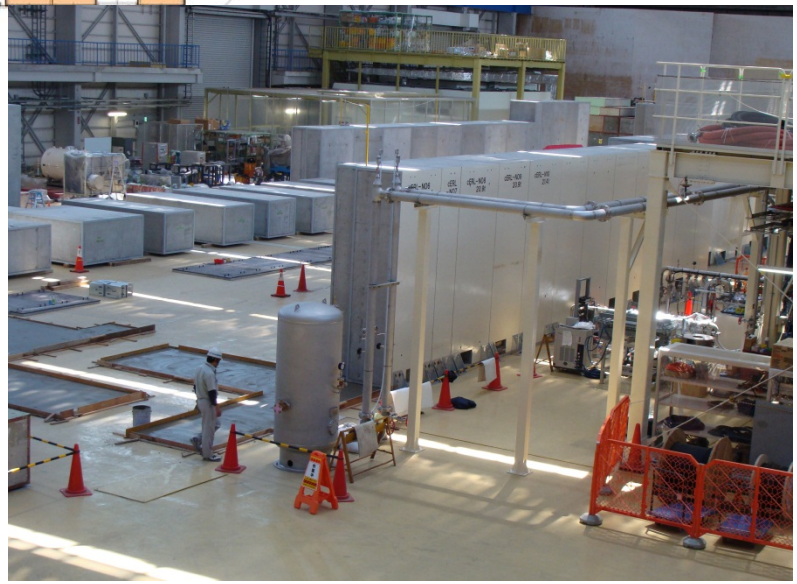
2K refrigerator system

300 kW klystron

30 kW klystron and IOT



Concrete shield



Cleanroom for
module assembly

Summary

- cERL is under construction in KEK.
- Development and fabrication of components for cERL main linac cryomodule has been finished.
  - Two 9-cell cavities were fabricated. They successfully reached to > 25 MV/m. He jackets were mounted on them.
  - Two sets of input couplers were prepared. They successfully passed > 100 kW pulse/40 kW CW traveling wave.
  - HOM absorbers are almost fabricated.
  - Two sets of frequency tuners were fabricated.
- Cryomodule will be assembled in this summer.
- Cooling test and high power test will be scheduled in this year.
- Beam operation will start next year.