Development and Operation of the JAERI ERL (Energy Recovery Linac)

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1. JAERI FEL Developmental Strategy 3 steps and NEXT

JAERI non ERL and ERL FELs

#1st STEP Super-Conducting Linac FEL Driver without ERL

1989-1995 Powerful FEL Driver

Other Possible e-Beam Applications

#2nd STEP Most Powerful FEL Lasing without ERL

1996-2000 Laser beam Applications

#3rd STEP ERL-FEL Efficient FEL Lasing Under Development

2001-2005 Large-scaled Laser Beam Applications

Nuclear Energy Industries

Next STEP ERL-LS Conceptual Design and Key Components

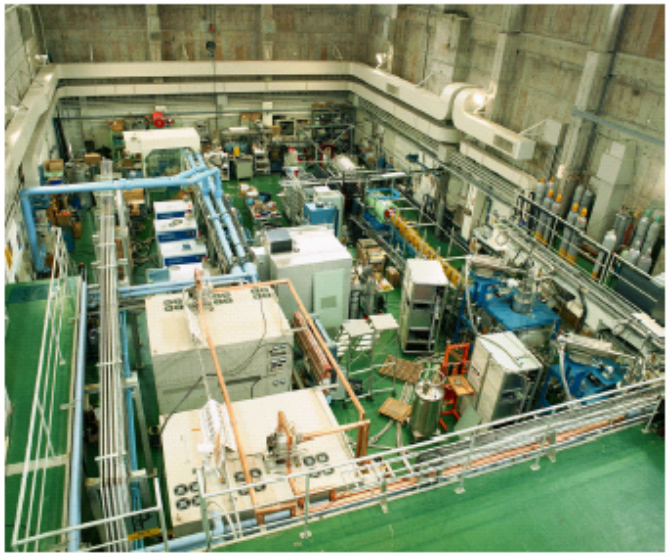
#1st STEP JAERI Non ERL Super-Conducting Linac FEL Driver

~100kW Beam Power for FEL Lasing

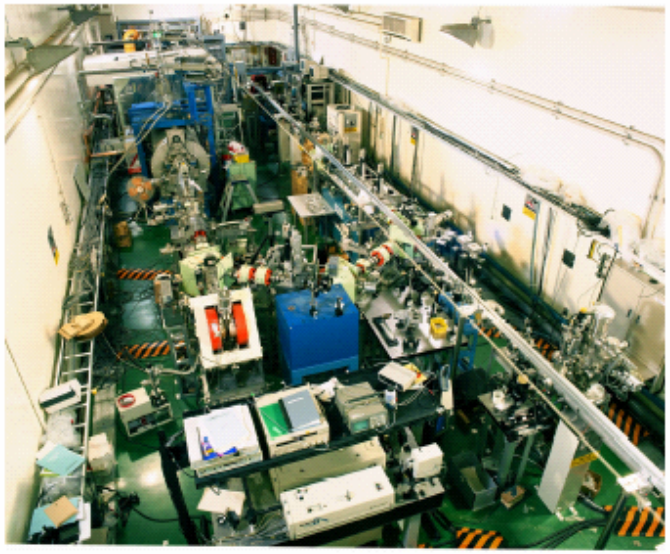
UHF SC Linac Driver and JAERI FEL at Tokai

Since 2001.April the JAERI FEL was shut-down and was under construction to assemble Energy Recovery Loop.

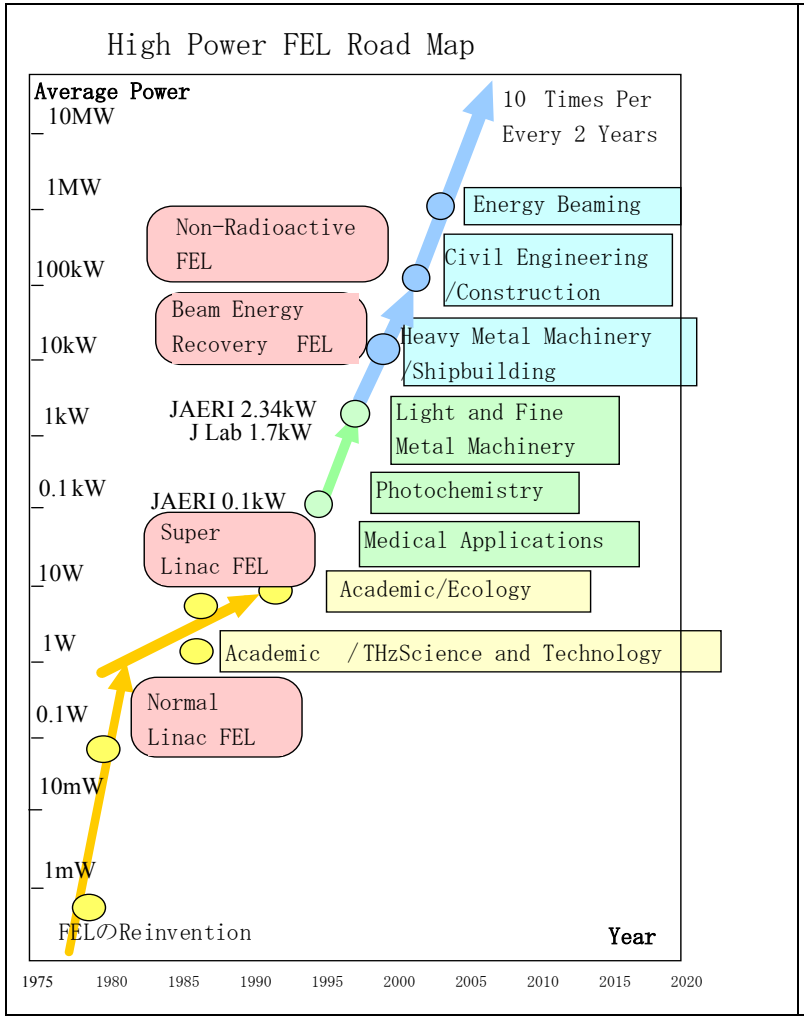
Old FEL Experimental Hall

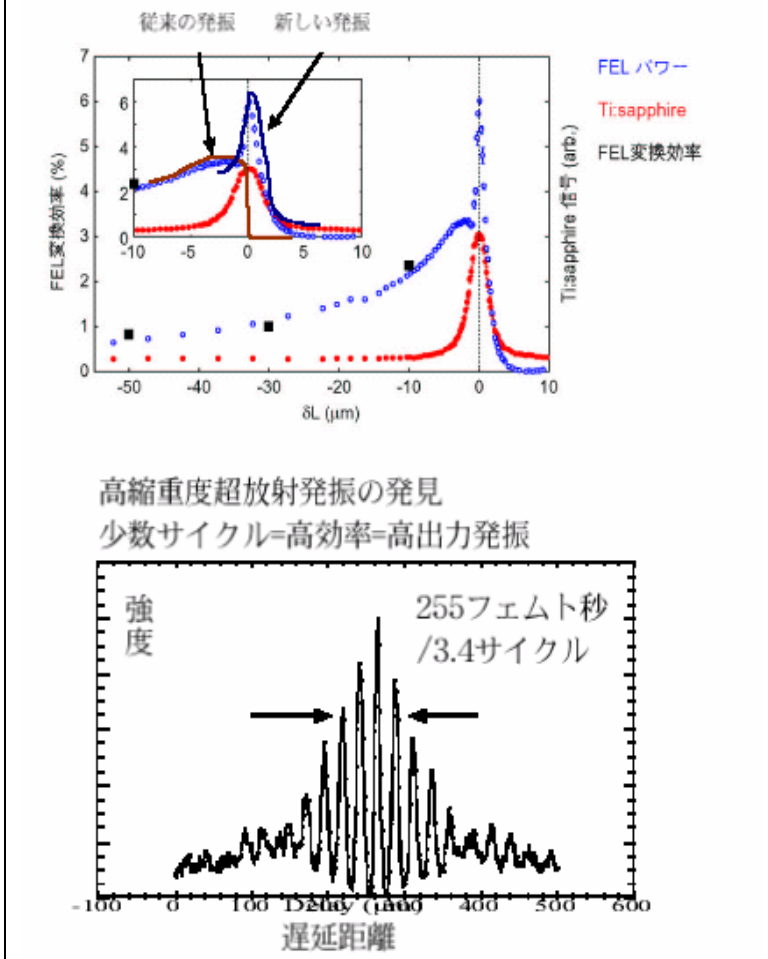


Old FEL Main Accelerator Vault



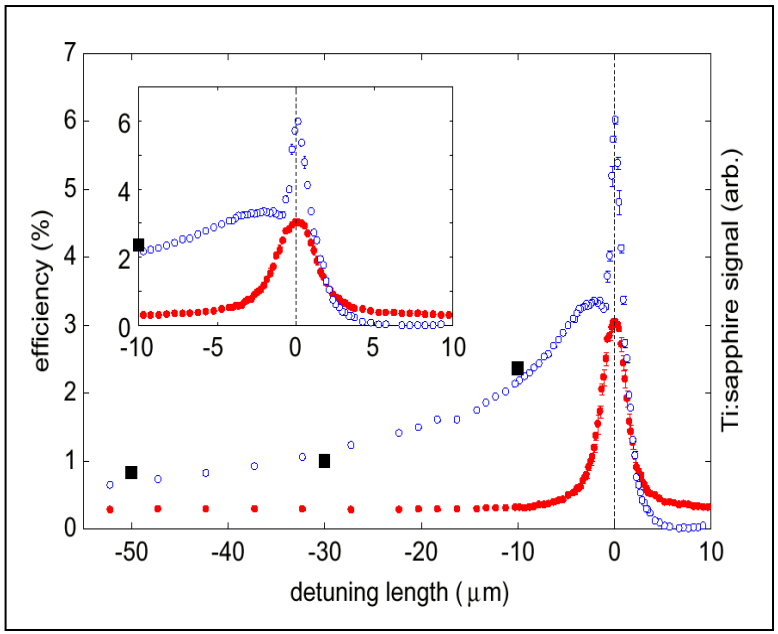
#2nd STEP Toward the Most Powerful FEL Lasing Up to Over 2kW

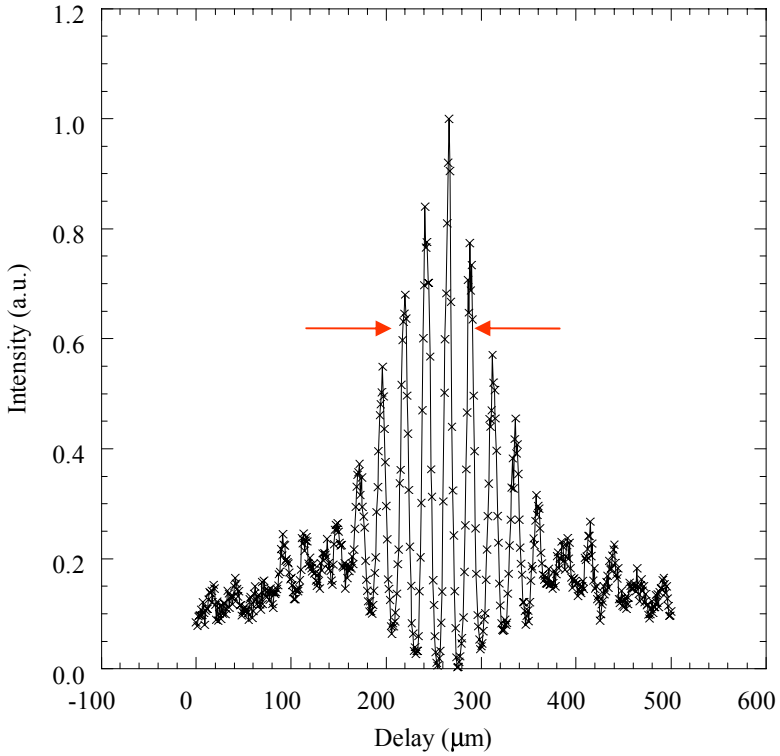




#2nd STEP Toward the Most Powerful FEL Lasing Up to Over 2kW

Energy = 16.5MeV
Bunch charge =510pC
Bunch length < 5ps
Bunch rep. = 10.4125MHz
FEL l = 16-23μm
FEL power = 2.34kW
High-efficiency η=6%



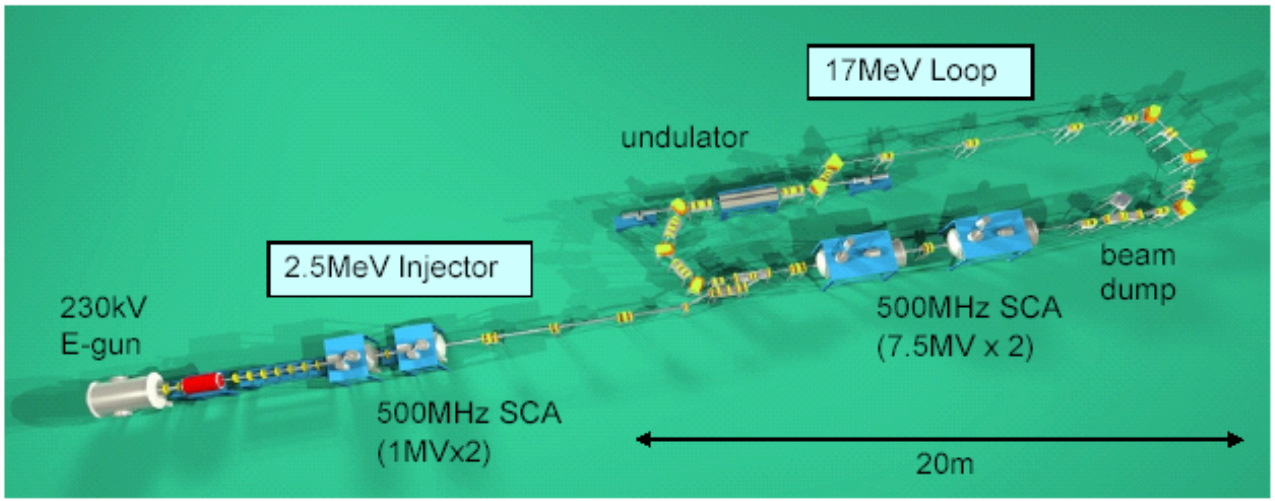


ultrashort pulse

255fs(FWHM) = 3.4 cycles

#3rd STEP ERL-FEL Most Efficient FEL Lasing Up to 10kW

JAERI Energy-Recovery Linac for 10kW FEL



- Natural extension of the original configuration.
- 8 times larger e-beam power.
- Fitting to the concrete boundary.

Energy = 17MeV

FEL : λ = ~22μm

Bunch charge =500pC

Bunch length = ~15ps (FWHM)

Bunch rep. = 10.4MHz – 83.3MHz

Average current = 5.2mA – 40mA

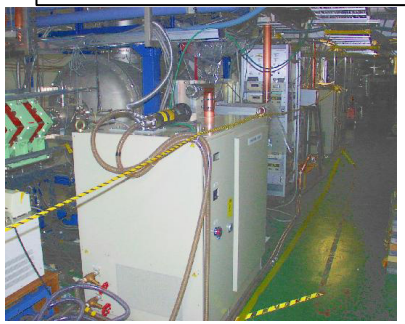
after injector-upgrade

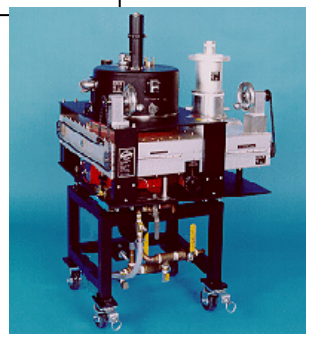
Upgrading in Injector

Original
0.5nC x 10.1425MHz = 5mA

After
0.5nC x 83.3MHz = 40mA

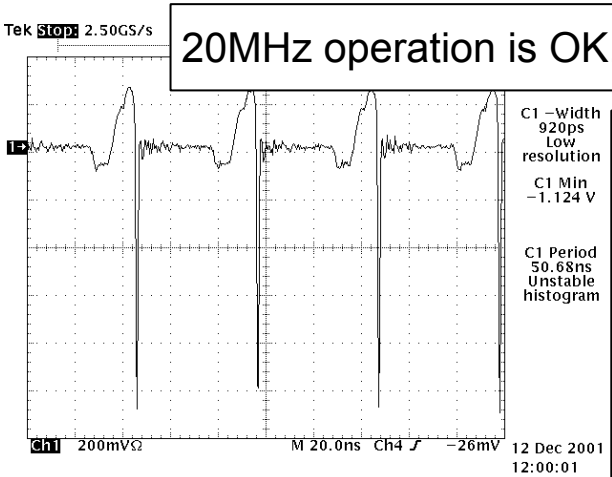
- New RF sources for the injector.
- New grid pulser for the e-gun



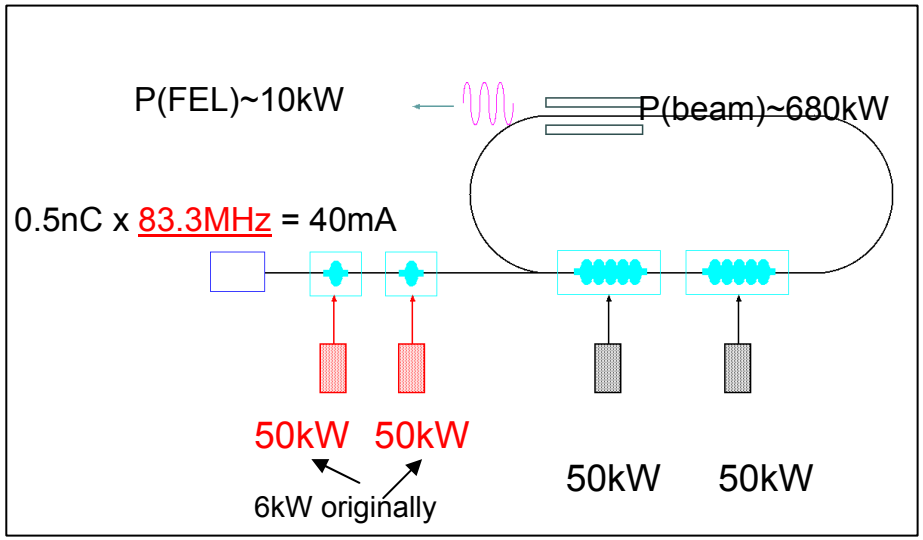


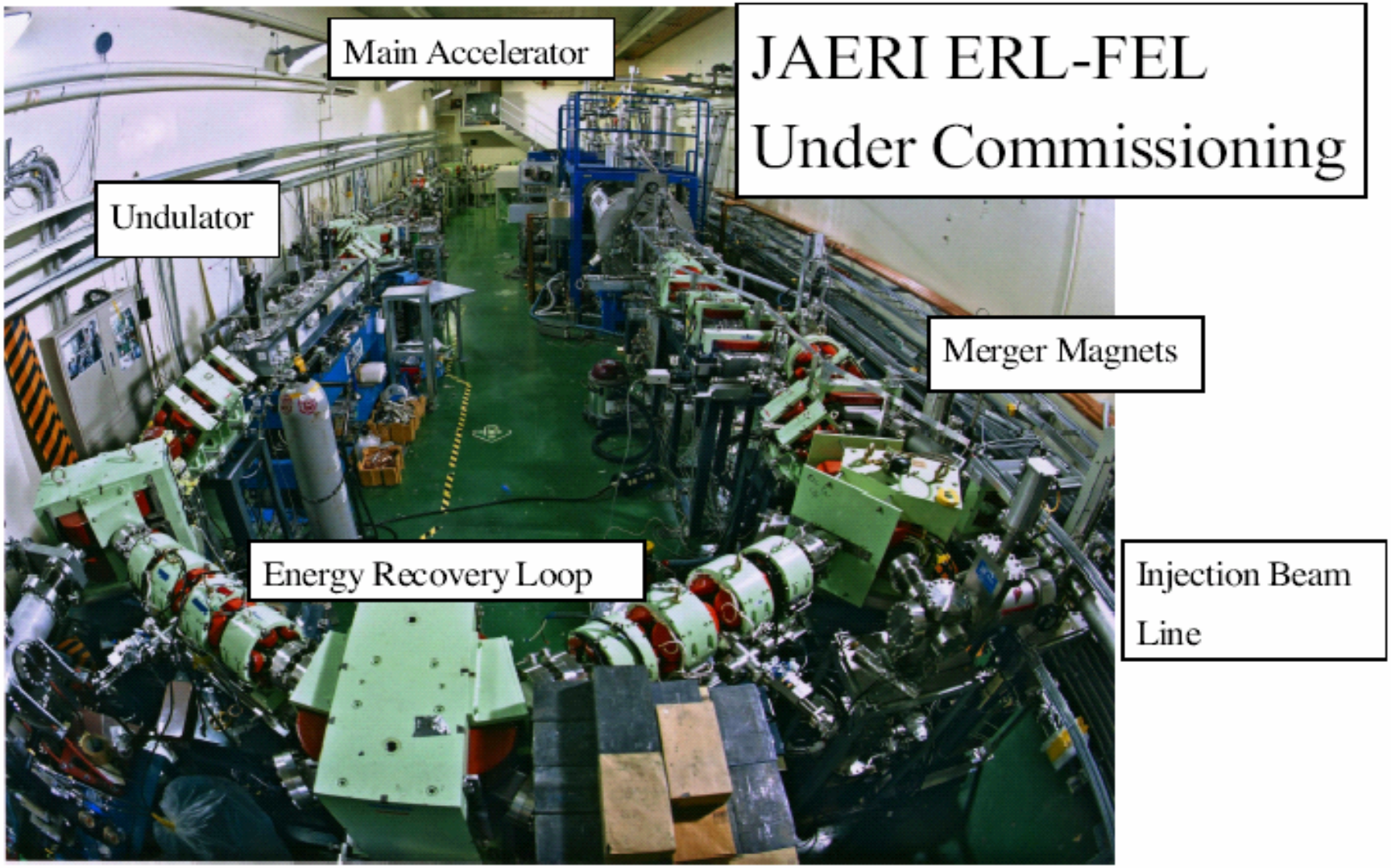
IOT-klystrode (50kW)

20MHz operation is OK.



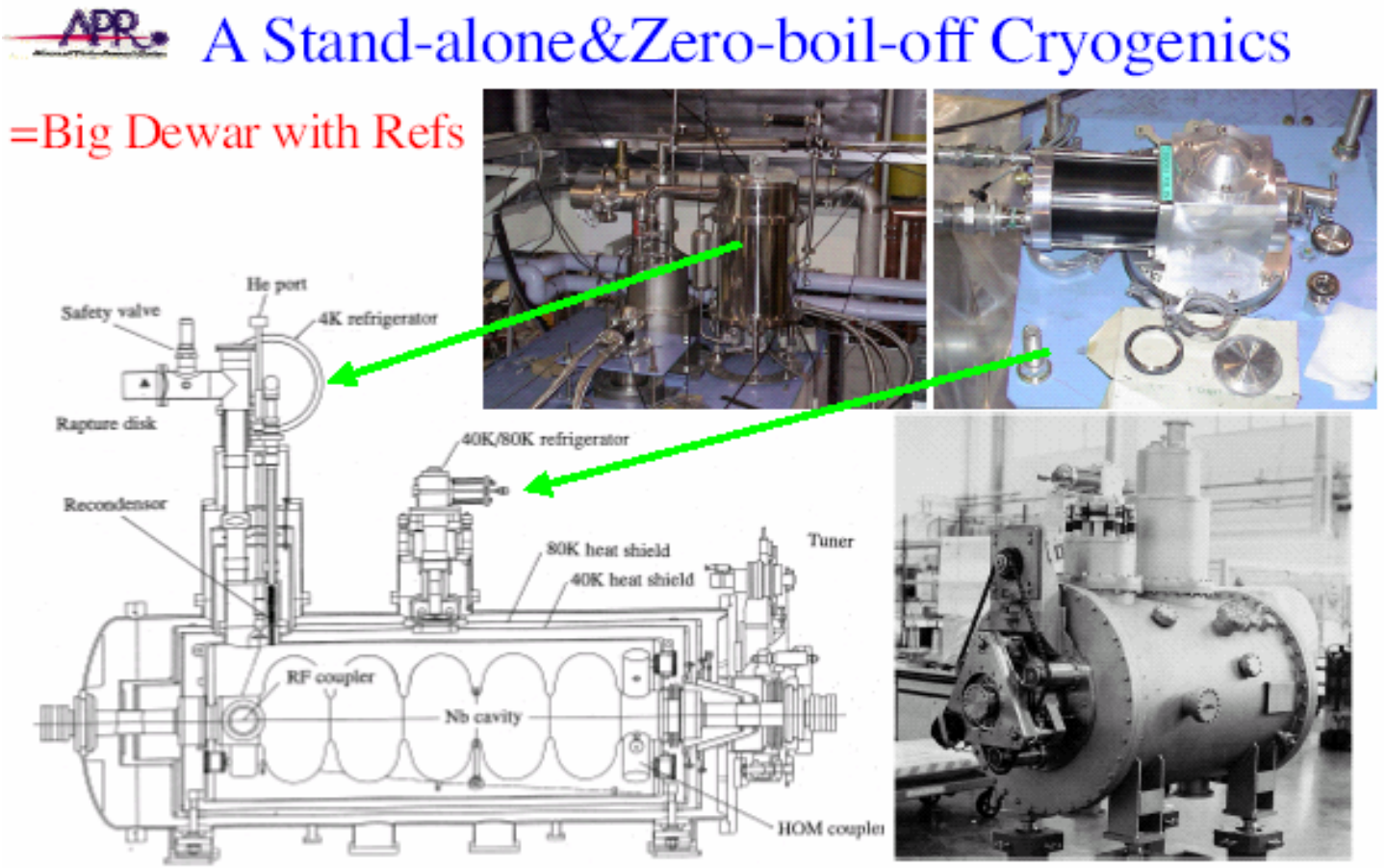
N. Nishimori et al. (THP-16029)




Main Accelerator
JAERI ERL-FEL
Under Commissioning
Undulator
Merger Magnets
Energy Recovery Loop
Injection Beam
Line

2. Refrigerator and Cyogenic Operation of JAERI SCA

JAERI Stand-alone Zero-Boil-Off Cryostat = Liq.He Container with refrigerators



Easiness in Maintenance and Operation of JAERI ERL-FEL

NonStopLowTempOperation or NoWarm-up Op

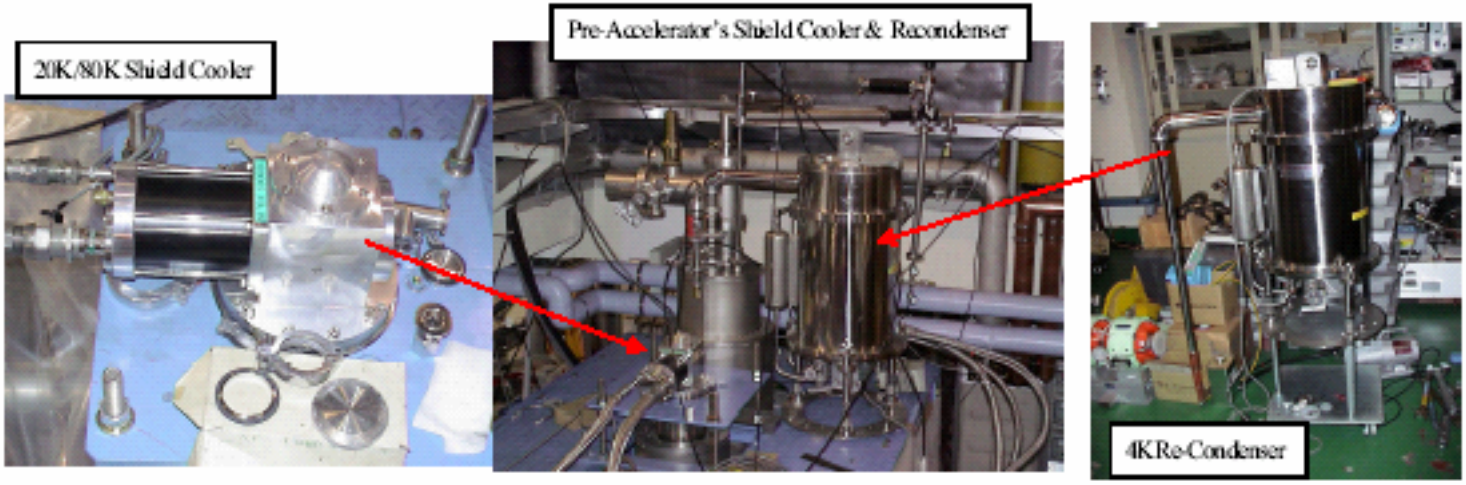
Possible Only for the JAERI Stand-Alone & Zero-Boil-Off ERL-SC linac ,

1)Cold Maintenance for Both Shield Cooler & Recondenser within a few tens minutes

2)No Liq.He Loss, 24hours Over 10-20years Continuous Operation. No need to reload

3)No Regulation of Domestic Pressure Vessel Code required for the Cold Maintenance

Bonus of the No Warm-up; (1) No Conditioning Required After the first , (2)Nearly No Deterioration of all the Cryogenic Components and Conditions, (3) Always Ready to fire,



Statistics of the continuous Zero-Boil Off Operation 1 Year Left and 3 years Right

#5 Whole Cryostat System Cold Over Twenty Years/Cold Maintenance

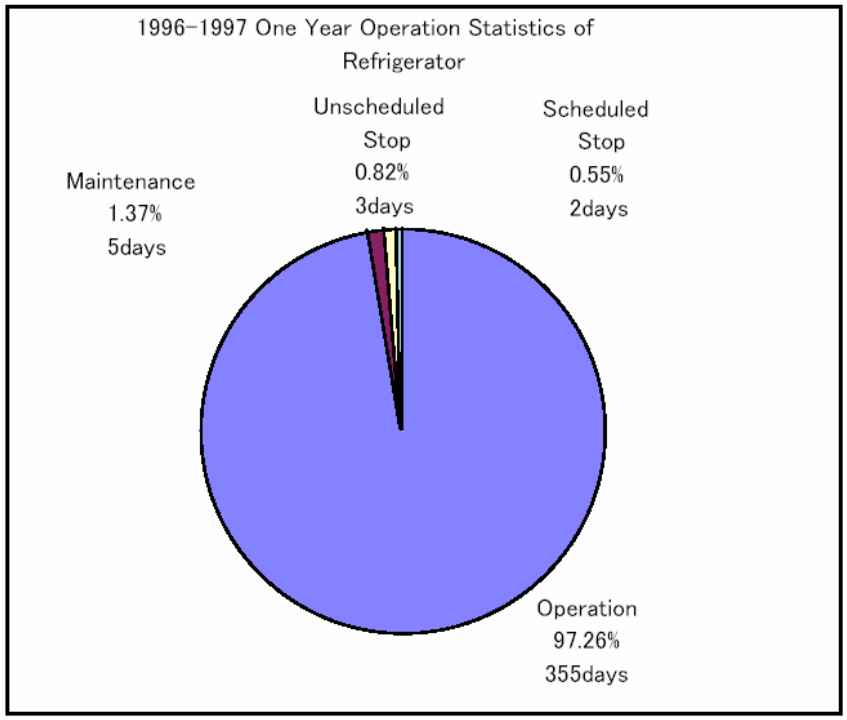


Figure 3a: Statistics of the cryogenic system operation in 1997 Japanese fiscal year

#6 Non-Stop and Continuous Operation of Cryogenic Refrigerator System Except for Unscheduled Emergency or Power Failure

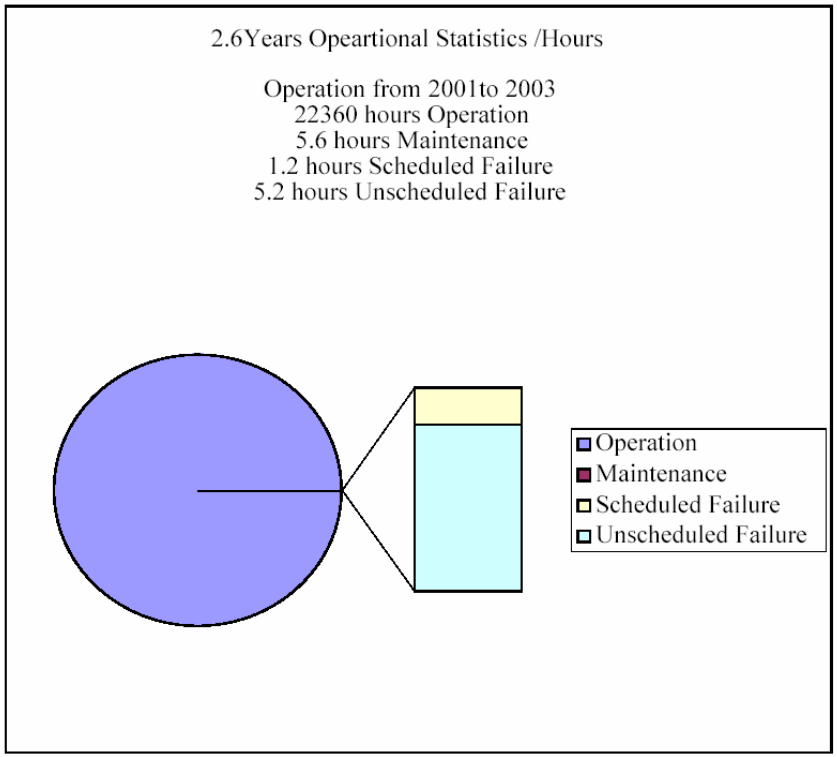
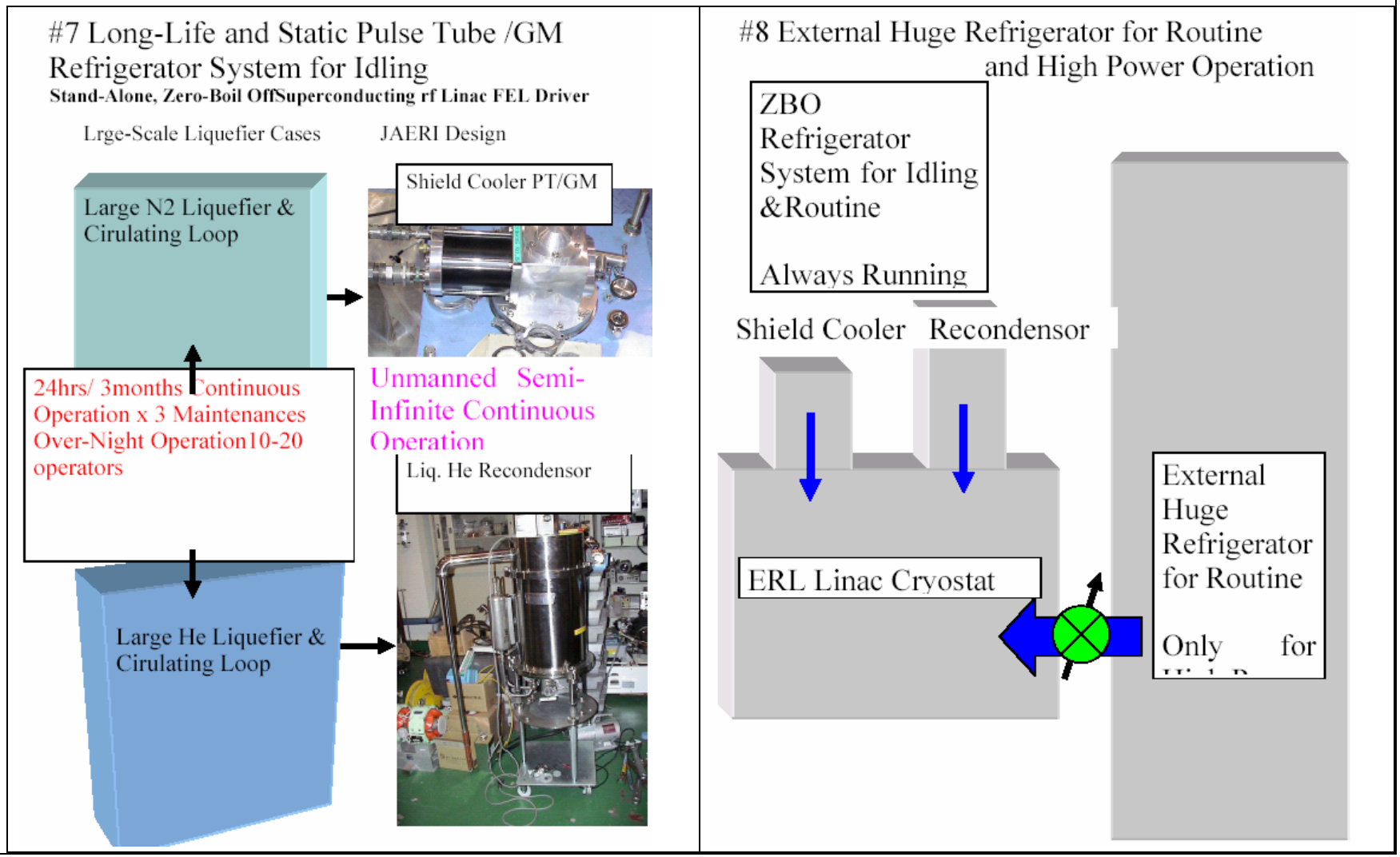


Figure 3b: Statistics of the cryogenic system operation in 2001-2003 Japanese fiscal year.

Combination between Zro-Boil Off Cryostat and Large Scale 2K and 4K External Liquefier



Current Activities :

Upgrading from Over2 kW to 10kWClass Lasing

#DC gun Capacity Improvement from 5mA to >40mA

#PreAcceleerators RF Amplifier Upgrading from 6kW to 50kW

#Main RF Amplifier Upgrading from Transister to IOT CW capability

#Amplitude and Phase Control Circuit Improvement

Reproducibility and Accuracy Up to 0.1Degree and 0.1%

#PC-based Control System Upgrading

Reliable and High Level Control Capability

#Beam Monitor Upgrading from Destructive to Non-Destructive

#Cable Network Upgrading to Low Temperature Coefficient Cable and

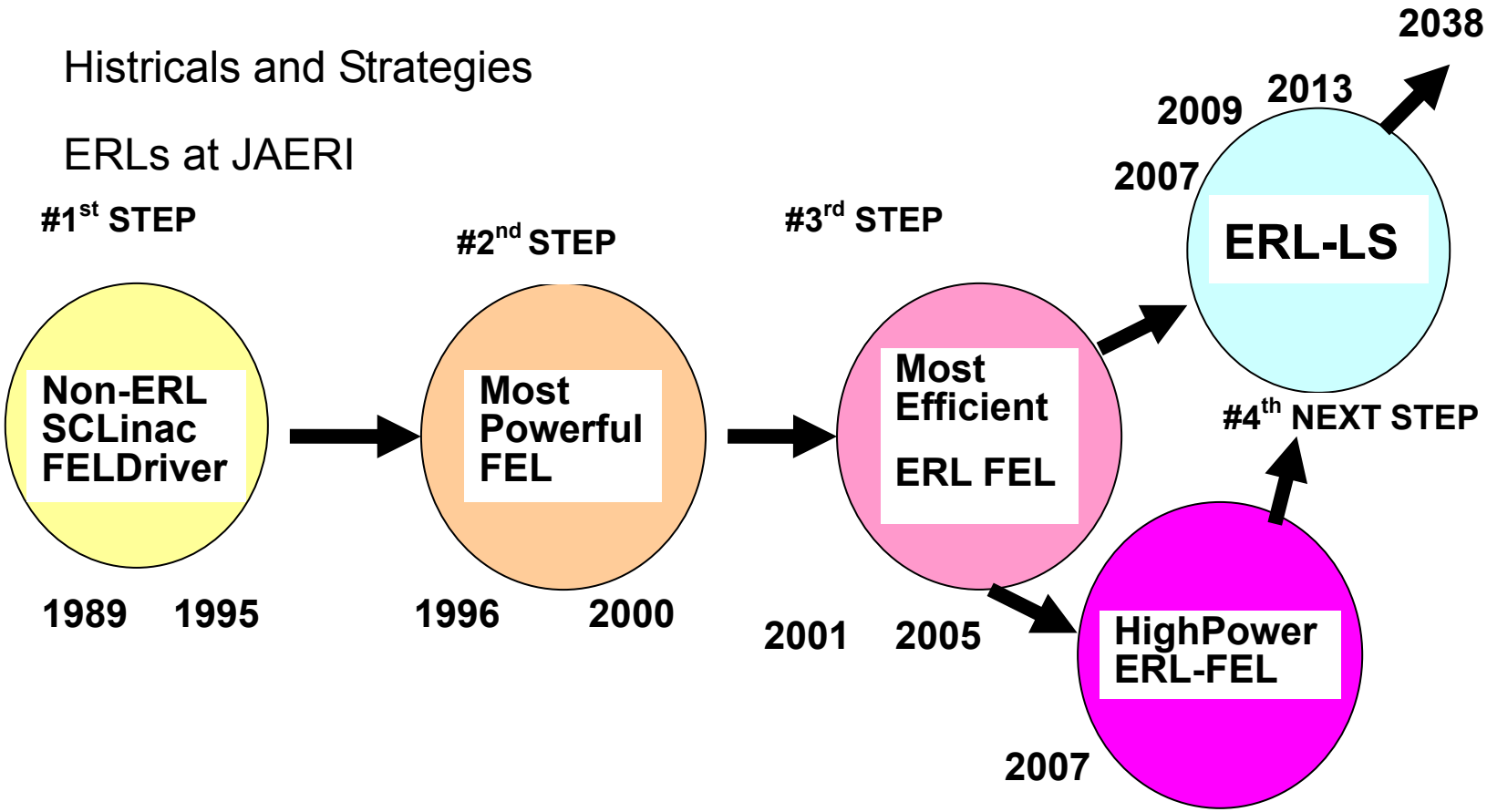
#Temperature Stabilized Network

#FEL Optical Transport System to FEL Experiment Rooms

4. JAERI ERL Future Plans and Programs

Histricals and Strategies

ERLs at JAERI

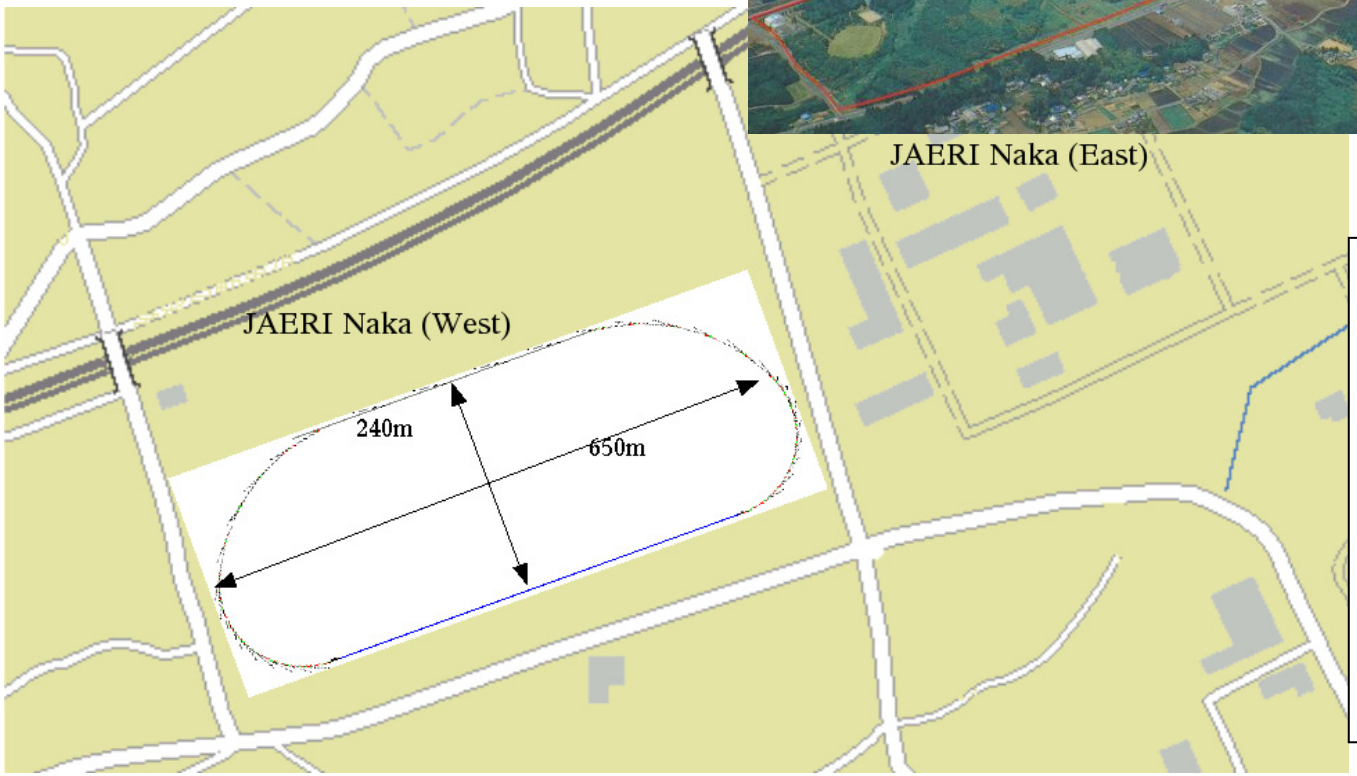


6GeV ERL light source planned in Japan

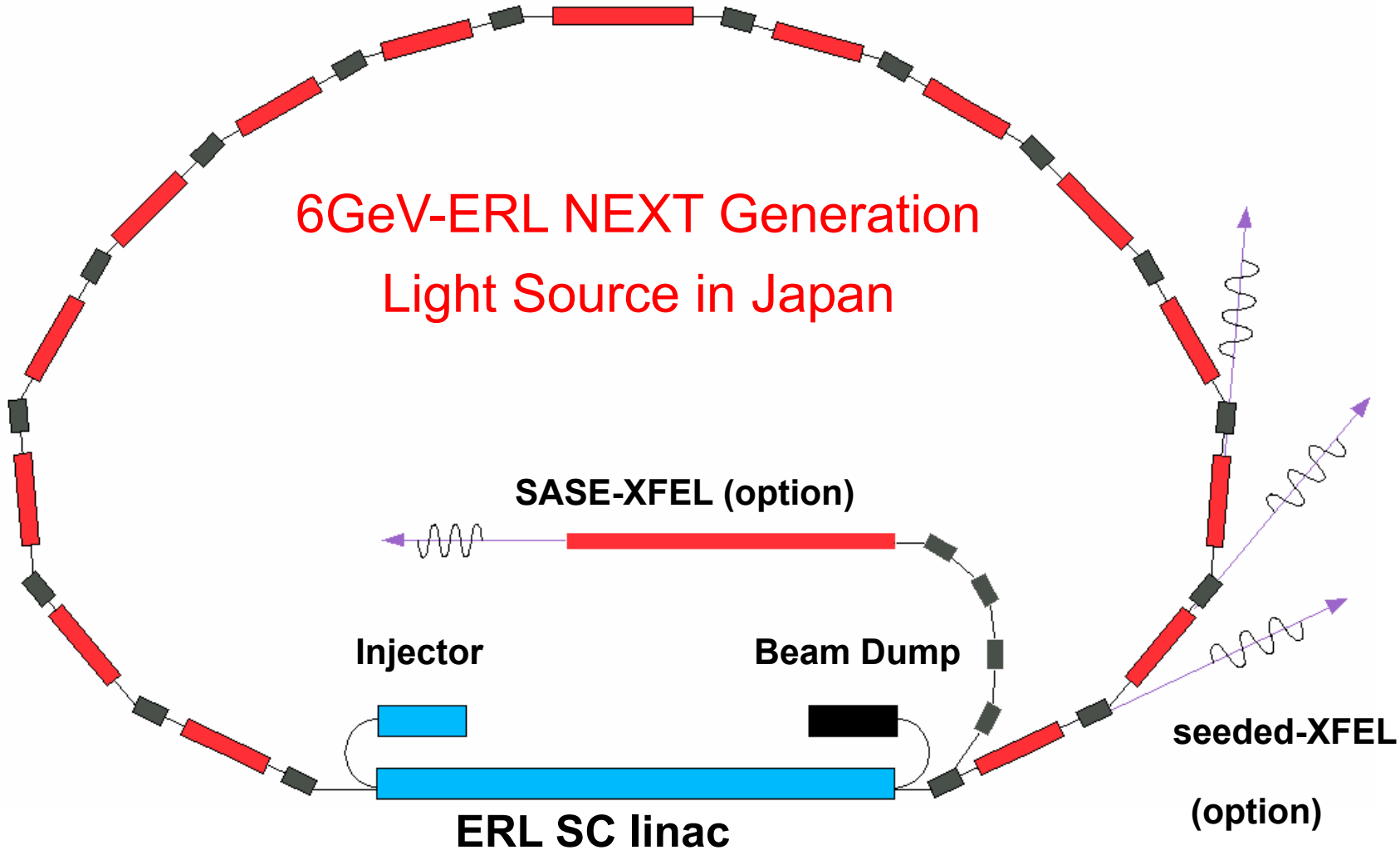
linac = 20MV/m x 457m x (300/457)

arc = 12deg. x 15 x 2

straight section = 5m x 20 + 27m x 10 + 270m



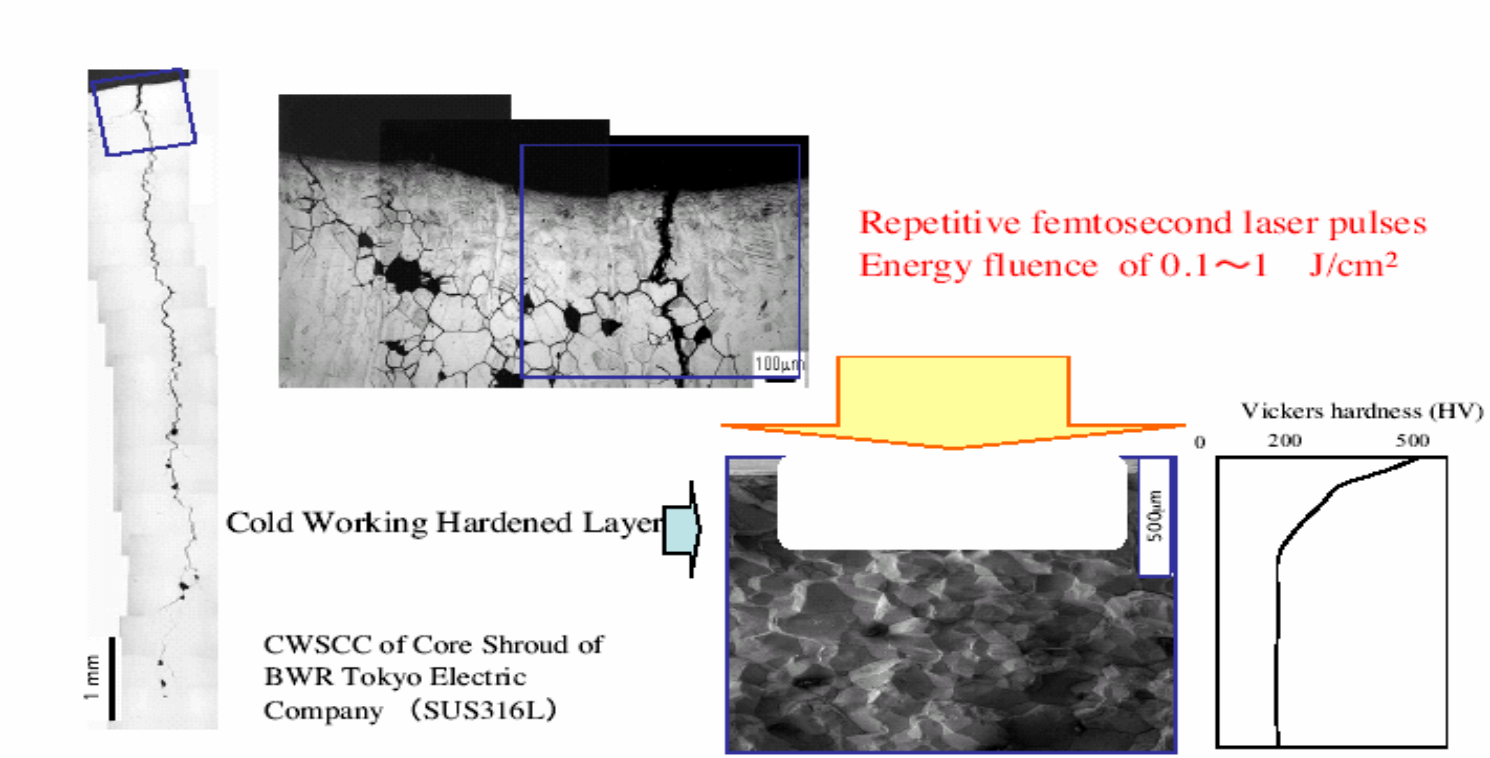
ERL light Source planned Site where is located in 140km North East from Tokyo, a several km from Tokai.


6GeV-ERL NEXT Generation
Light Source in Japan
SASE-XFEL (option)
Injector
Beam Dump
seeded-XFEL
(option)
ERL SC linac

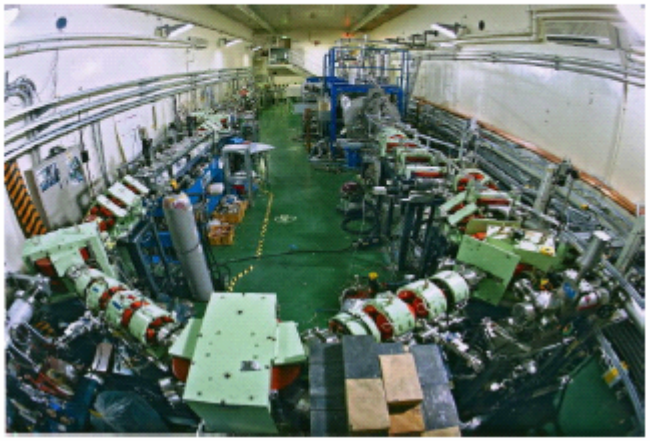
Nuclear Energy Industry Applications

Prevention of Cold-Worked SCC

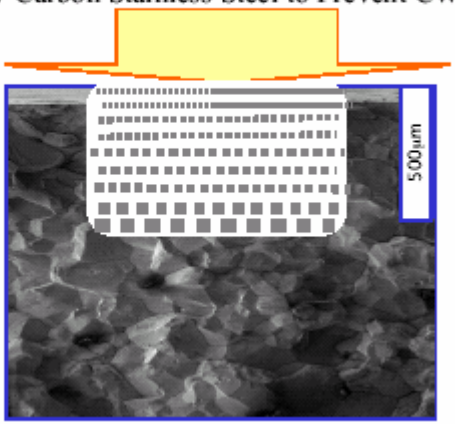
Femtosecond laser pulses can remove the cold-working hardened layer without thermal effects.

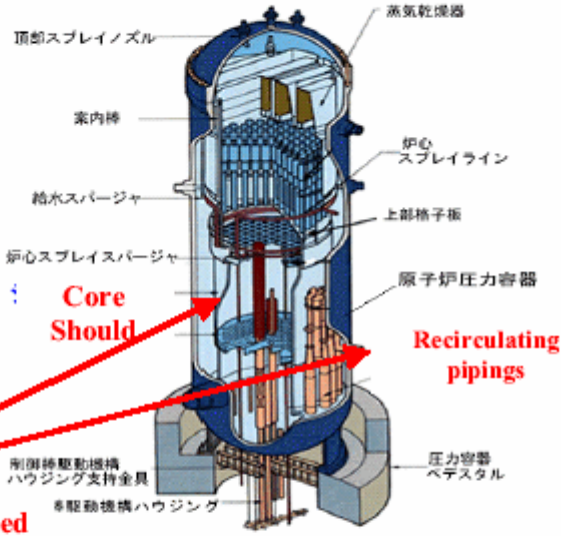


JAERI-Femtosecond High Average Power FEL Removes Residual Tensile Stress and Susceptible Materials without Heat Generation- Prevention of SCC and improve BWR lifetime and Safety



Femtsecond High RepitionJAERI-FELIrradiates
Low Carbon Stainless Steel to Prevent CWSCC

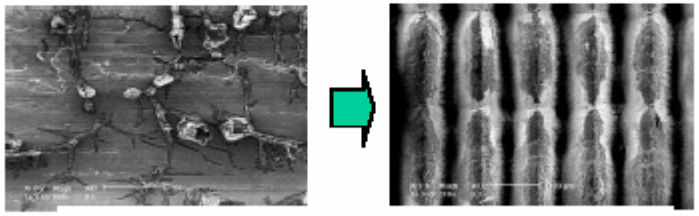




Core Should

Recirculating pipings

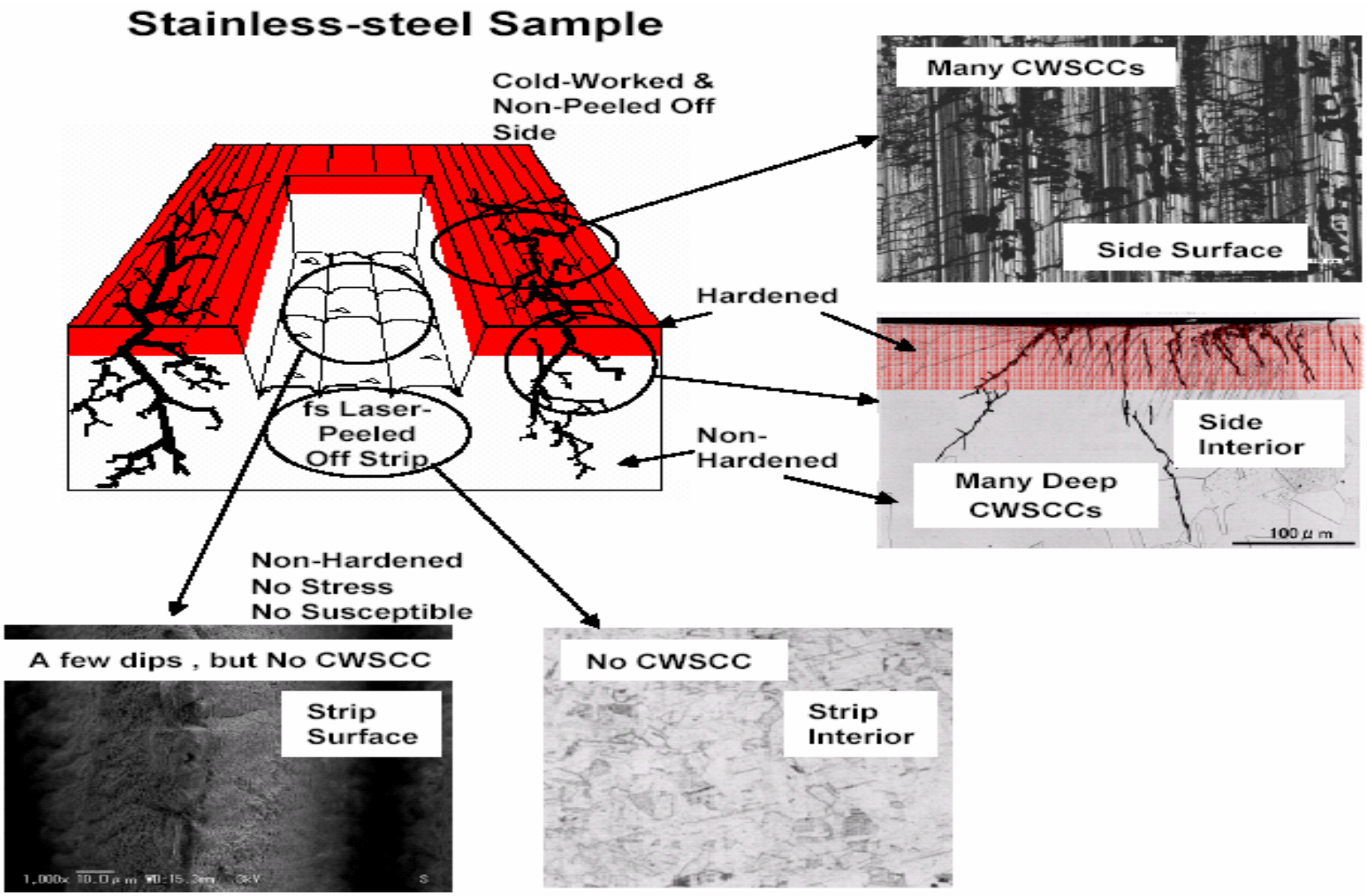
Adopt Cold Worked Compnents



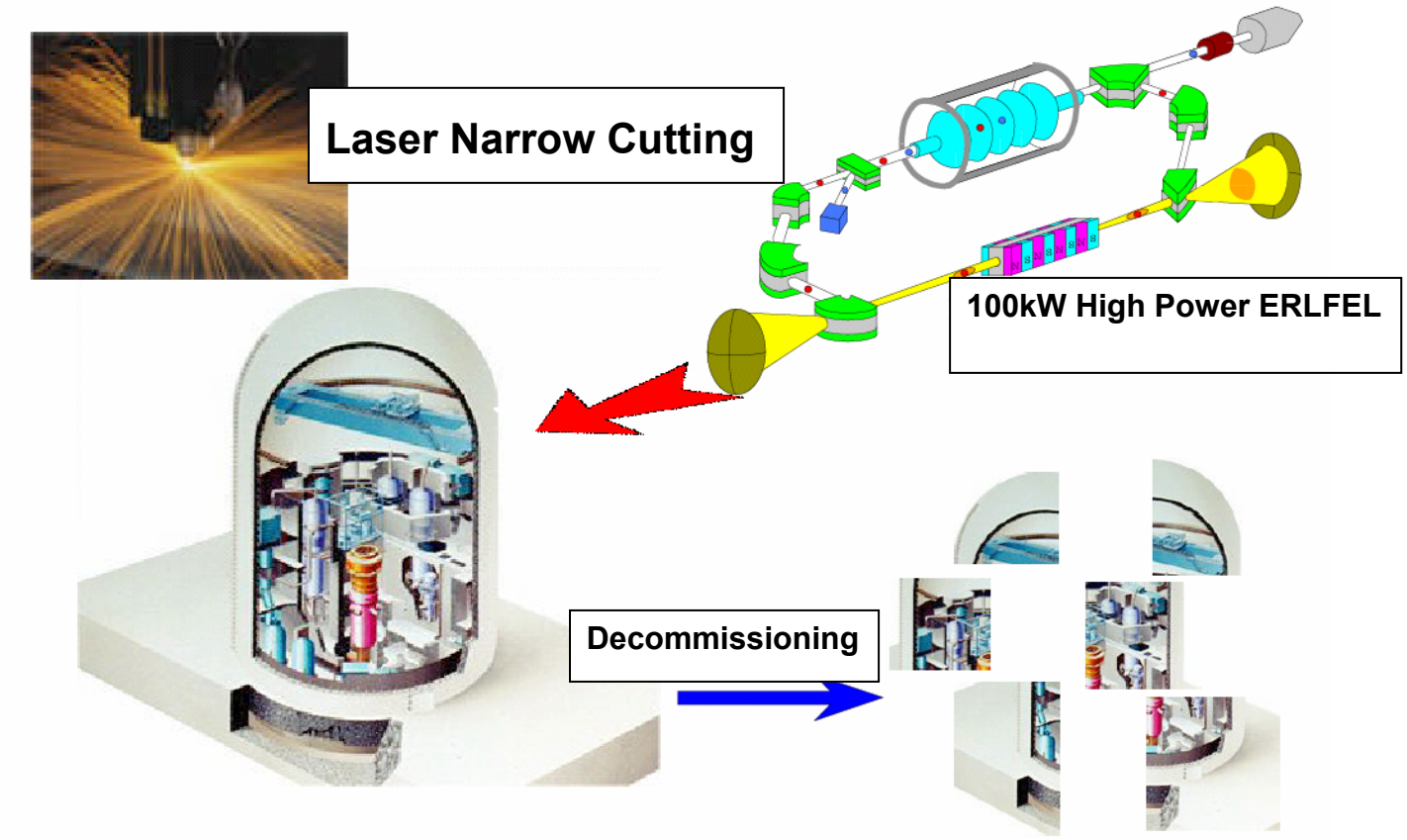
Modified Non-Susceptible Surface

(MgCl2 SCC Test Results)

Stainless-steel Sample



Narrow Cutting and Low RI Contamination Using 100kW High Power FEL



Decommissioning of the Nuclear power Plants

JAERI ERL Contributions in the Workshop Related with ERL-LS

#1 State-of-the-Art: Optics and Beam Transport R. Hajima
#2Linear matrix analysis of electron beamdynamics for the CSR effect in an ERLrecirculation loop R. Hajima
#3 Multi-parameter optimization of an ERLinjector R. Hajima, R. Nagai
#4 Velocity bunching in a main linac of ERL R. Hajima, H. Iijima
#5 Preliminary result of diamond film secondary-emission cathode T. Nishitani, E. J. Minehara, R. Hajima
#6 Beam-based Alignment with HOM couplers.M. Sawamura and R. Nagai
#7 Status of RF system for the JAERI Energy-Recovery Linac FEL M. Sawamura and R. Nagai
#8 Cryostat Design Consideration of the Energy Recovery Super-conducting Linac (ERL) Driven Light Sources and FELs E. J. Minehara
#9 Preliminary Report on Single and Multi-Crystal Diamond Electron Cathodes E. J. Minehara
#10BBU codes overview M. Sawamura
#11JAERI gun, and #12Superlattice GaAs photo cathode T.Nishitani

Summary

#1 Past and Current Activities of JAERI ERL FEL

Development and Operation, Especially About Cryogenics

#2 Activities in the 10kW Upgrading

Upgrading Beam Power from <100kW to <800kW

#3 Preliminary Results of Nuclear Energy Industry Applications

CWSCC prevention, Decommissioning in Nuclear Reactors

#4 Some Contributions will be in the ERL Workshop

Conceptual Design Activities of ERL-LS likeHOM-BBU, CSR

PC gun Activities As Key Components