Present status of ERL project at KEK

Mini-Workshop for ERL under the collaboration meeting between CLASSE and KEK
12/March/2007

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Outline

1) **What is the requirement for the future light source?**
2) **Scientific cases at the ERL**
3) **ERL project team**
4) **Present status of the R&D for the ERL project**

What is the requirement for the future light source?

1) Specimen becomes smaller and smaller (nano-structure)

Focused beam size: μm ⟶ nm

2)Detailed information about electronic states

Higher Energy resolution

3) Structural analysis of non-crystalline materials

Coherent X-ray is essential!

4) Studies for non-equilibrium states

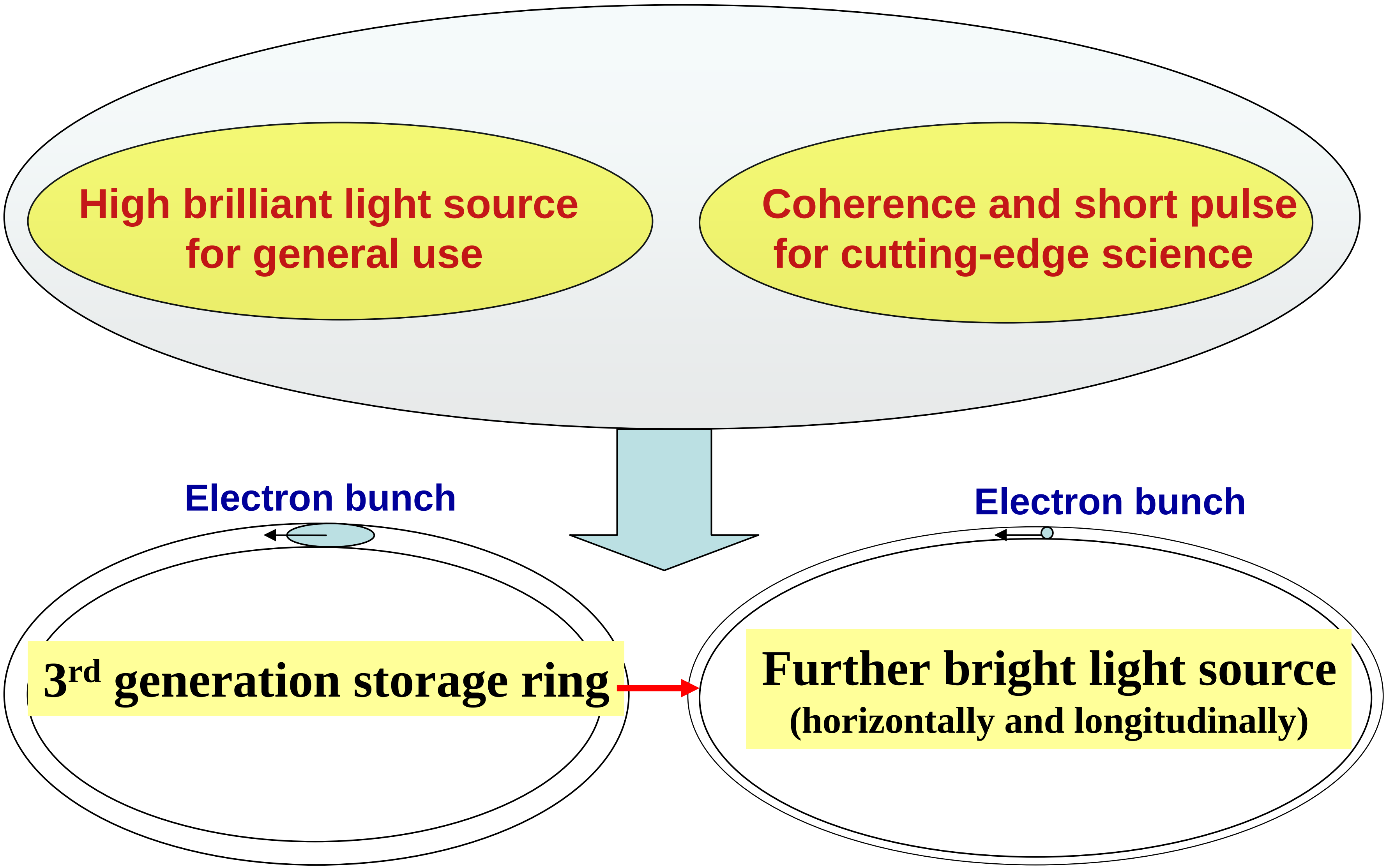
Short pulse (sub-pico second) is essential!

High brilliant light source for general use

Coherence and short pulse for cutting-edge science

It is important to realize both of them!

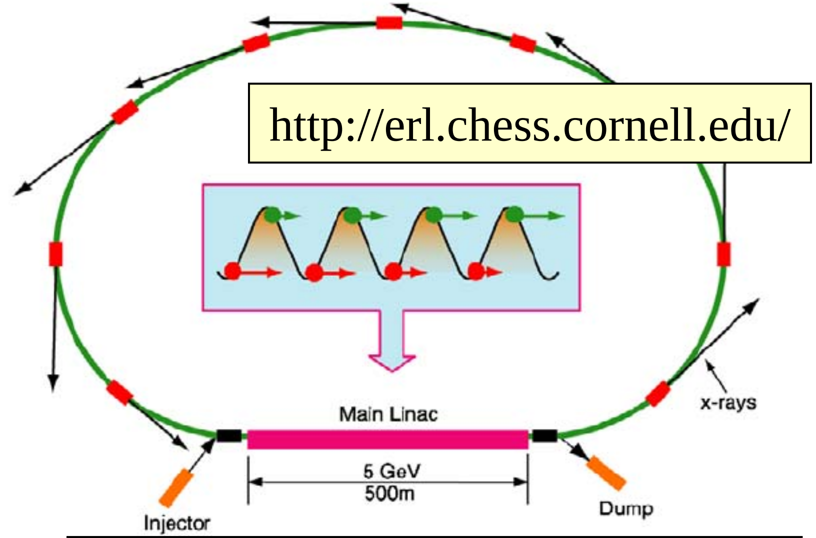
What kinds of accelerator are needed?



Specification of the synchrotron radiation from the future light source

Energy region :VUV-X (30eV-30keV)
Brilliance: 10^{21}-10^{23} photons/sec/mrad^2/mm^2/0.1%B.W. @1~10 keV
Coherent fraction: 10~20%@ 10keV

Emittance: 10pmrad~ $\lambda/4\pi$ @ 10keV
Short pulse: ~100 fs
Number of ID beamlines: ~30 lines

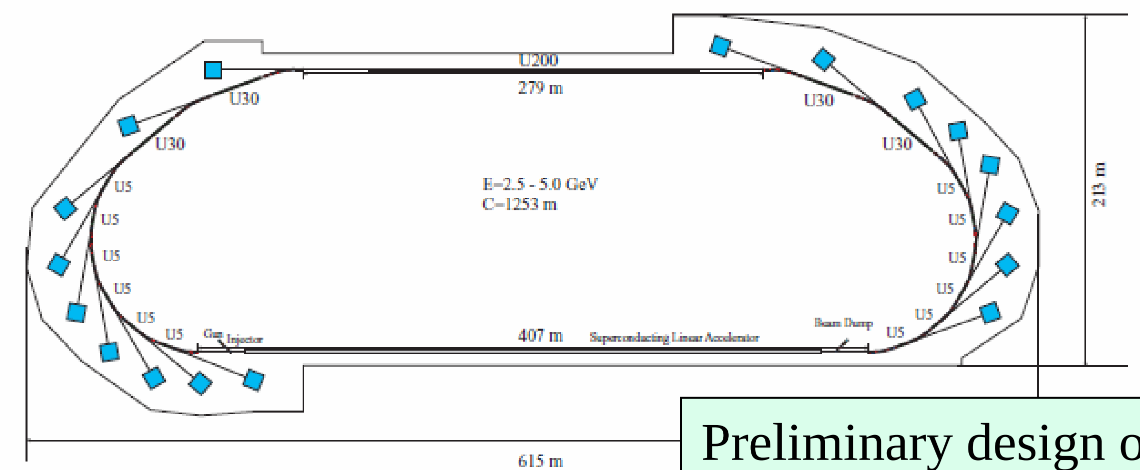


Energy Recovery Linac (ERL)

ERL is one of the most promising candidates

#) Linac based light source:
1) Emittance can be improved by a factor of $1/\gamma$ from a natural emmitance .
2) Short purse of the order of 0.1~1 pico-second can be available.
#) A great numbers of ID-beamlines can be available.
#) ERL will not provide extremely high peak brilliance, but high averaged brilliance. This feature will be suitable to keep a character for the proving light source as an usual synchrotron radiation experiments.

PF - ERL

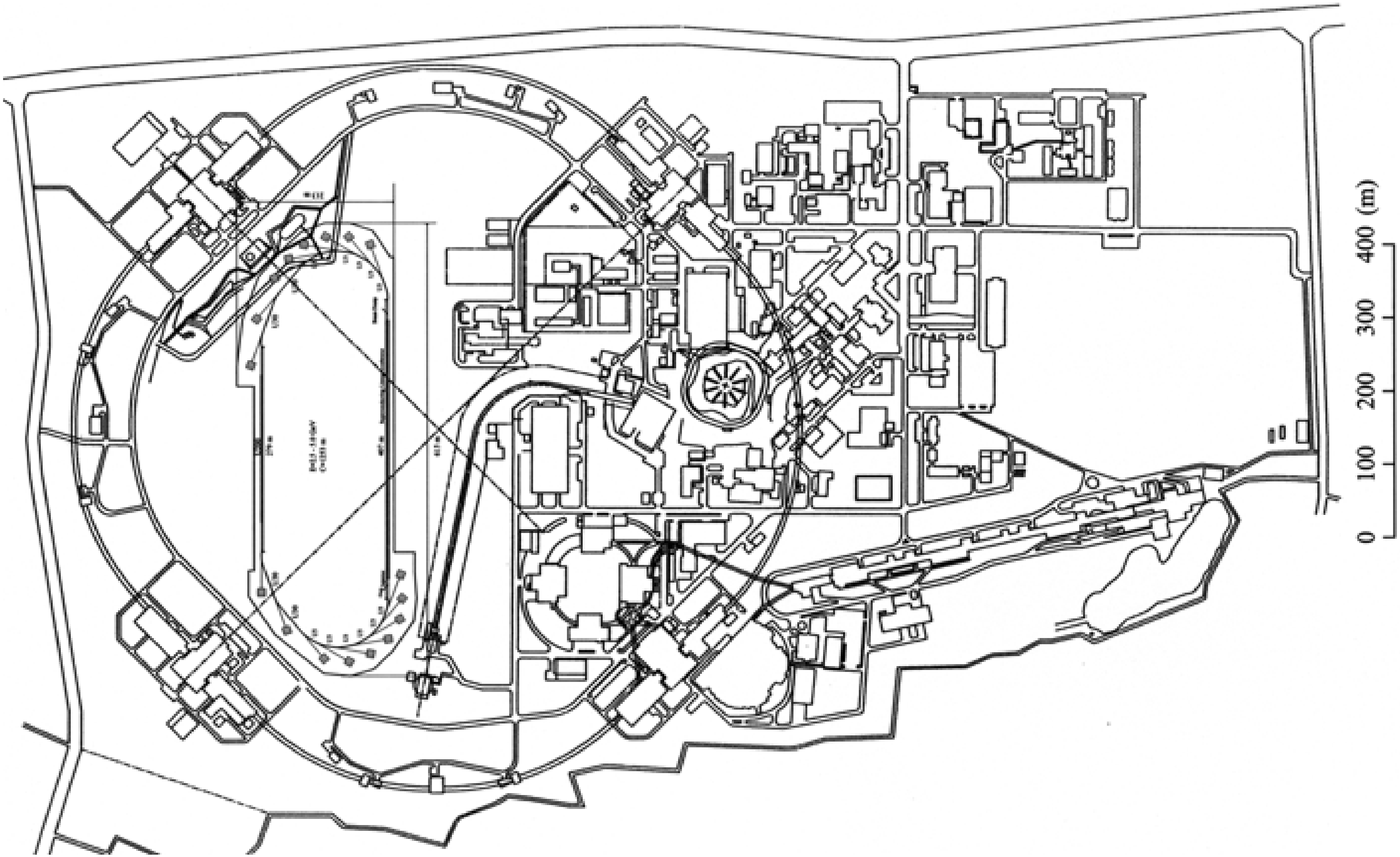


Preliminary design of PF-ERL at 2002

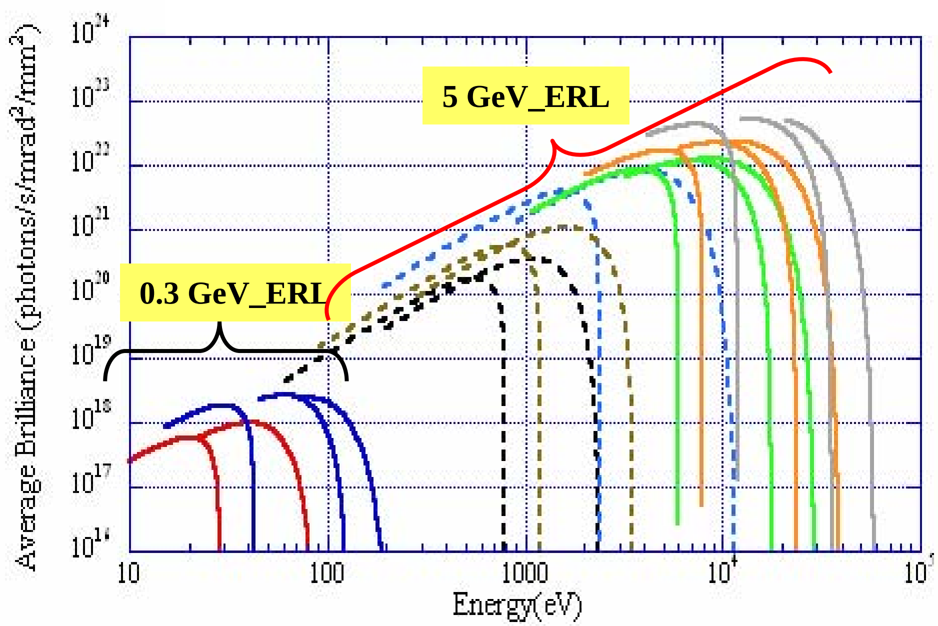
		PF-ERL undulator @ 5 GeV		SPring-8 undulator @ 8 GeV	
Beam current		100 mA	100 mA	100 mA	100 mA
Undulator length		30 m	5 m	25 m	5 m
Source size (μm)	horizontal	37.8	18.2	892	892
	vertical	37.8	18.2	22.8	10.6
Source div. (μrad)	horizontal	4.1	9.8	37.4	38.4
	vertical	4.1	9.8	4.3	10
Beam size @ 50 m (μm)	horizontal	244	510	2761	2813
	vertical	244	510	236	509
Average brilliance(ph/s/0.1%/mm^2/mr^2)		6.0×10^{23}	7.6×10^{22}	2.2×10^{21}	5.0×10^{20}
% beam coherence		19	15	0.14	0.13

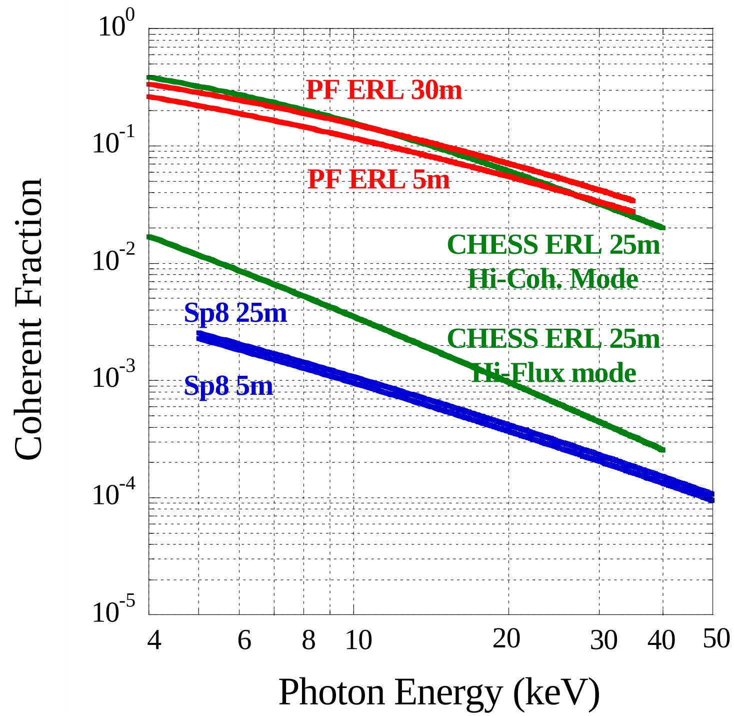
At the case of 8 keV photon energy

Size of 5-GeV class ERL



Brilliance and coherent fraction spectra from ERL(5GeV, 0.3GeV)





It is possible to cover the energy range from VUV to X-ray by using 5GeV ERL and 0.3GeV ERL.

Coherent fraction expected from ERL. It is possible to achieve the values of 10-20% at the energy range of 10keV.

Scientific cases at PF-ERL

- **Scientific subject opened by coherent X-rays**
  #Structural analysis of non-crystalline materials
  #Phase contrast imaging
  #Investigation at the fluctuation of several domains by means of X-ray photon correlation spectroscopy

- **Scientific subjects opened by short pulses (sub-pico second)**
  #Investigation of non-equilibrium dynamics.
  #Study of spin dynamics in material.
  #Chemical reaction.
  #Photo-induced phase transition and related materials
  #Reaction process at protein (life science)

- **Scientific cases opened by nano beam**
  #Combination with the other general experimental method.

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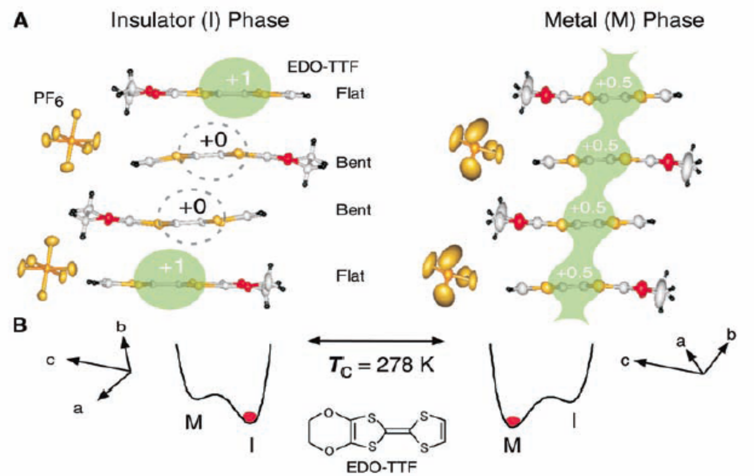
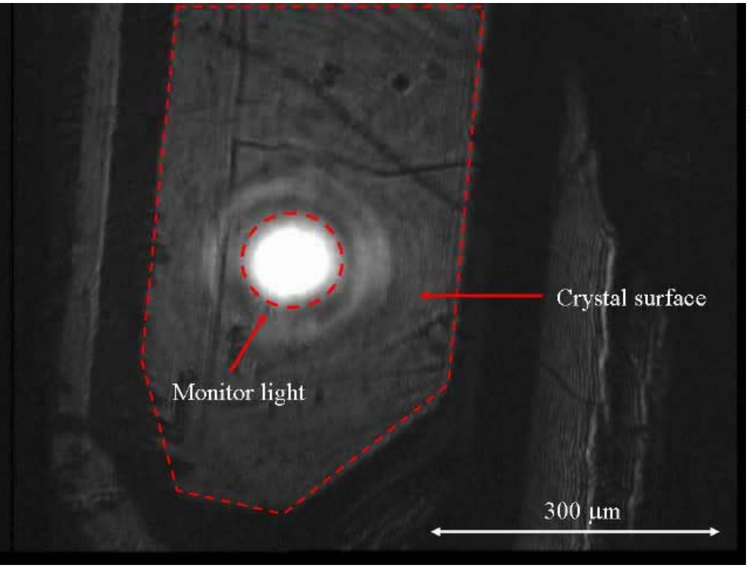
Local structural analysis, Local electronic state, Microscopic studies, Structural analysis of small crystals (~100 nm), etc.

Photo-induced phase transition
(Strongly-Correlated Electron Systems)

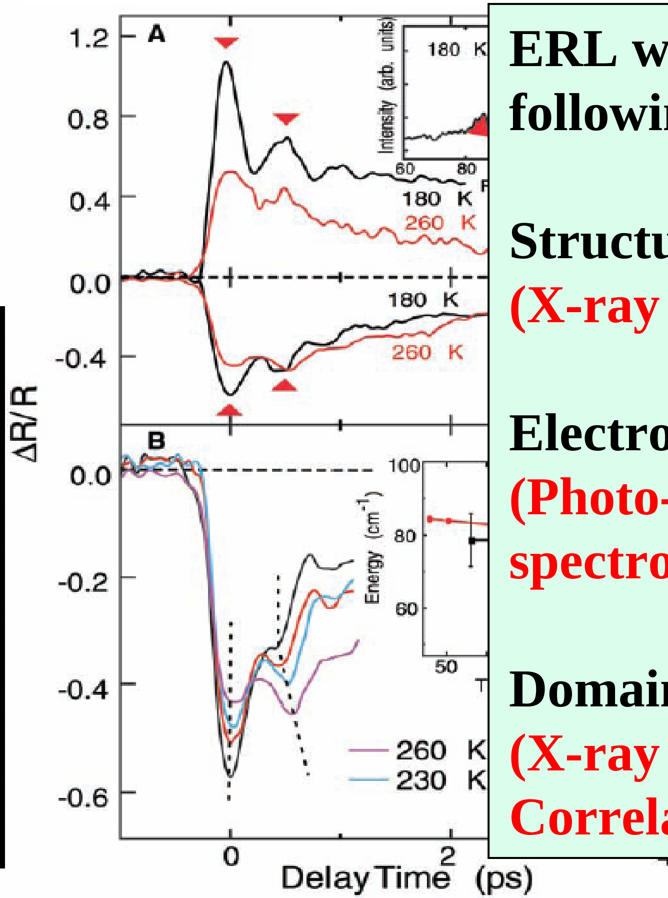


Collet et al. (2005) Science 307, 86



Koshihara et.al. (Tokyo Institute of Tech.)

Sub-pico second Photo-induced metal-insulator phase transition
- Application for a THz-switching device -



ERL will provide us following information!!

Structure?
(X-ray diffraction)

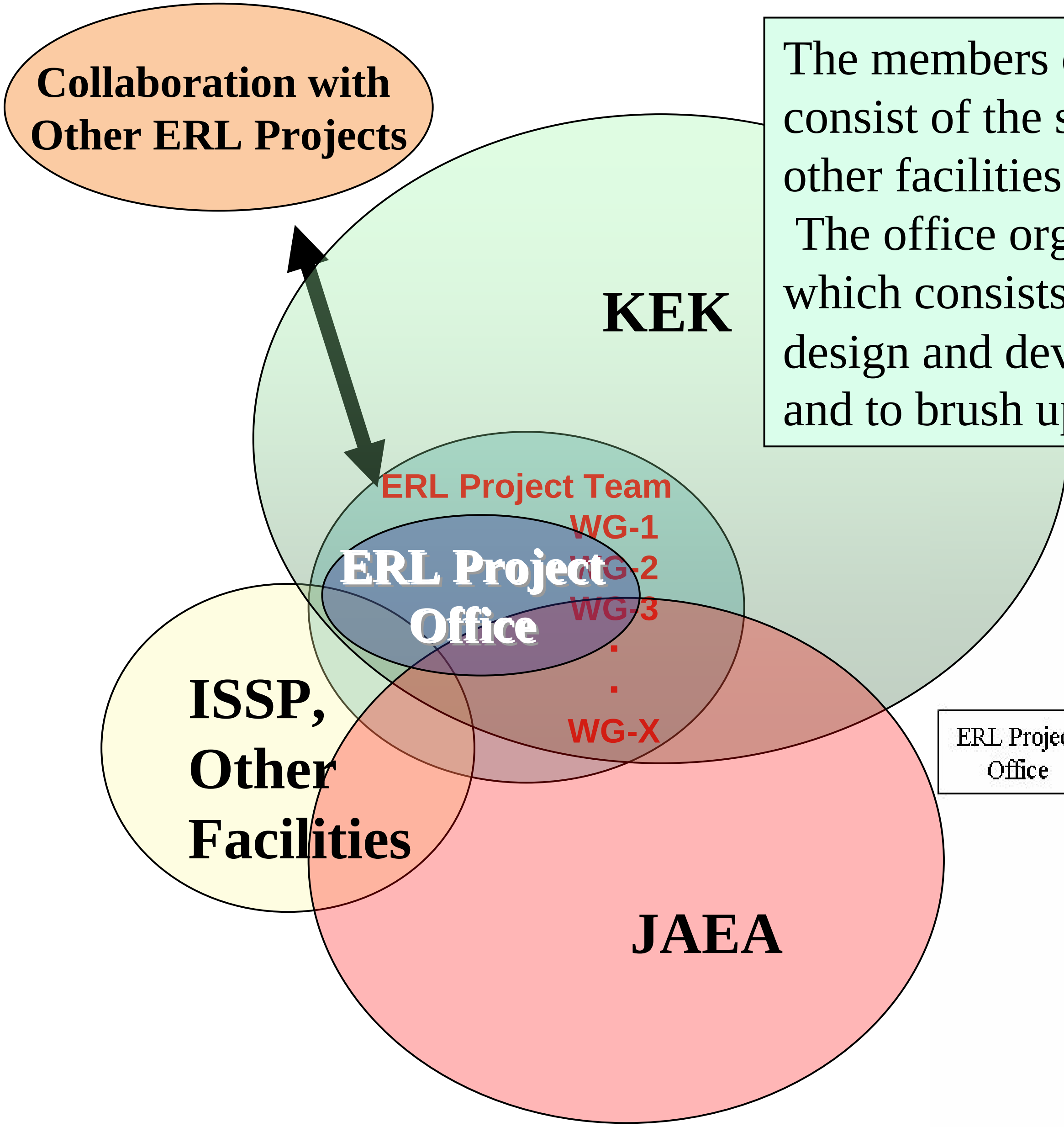
Electronic state?
(Photo-emission spectroscopy)

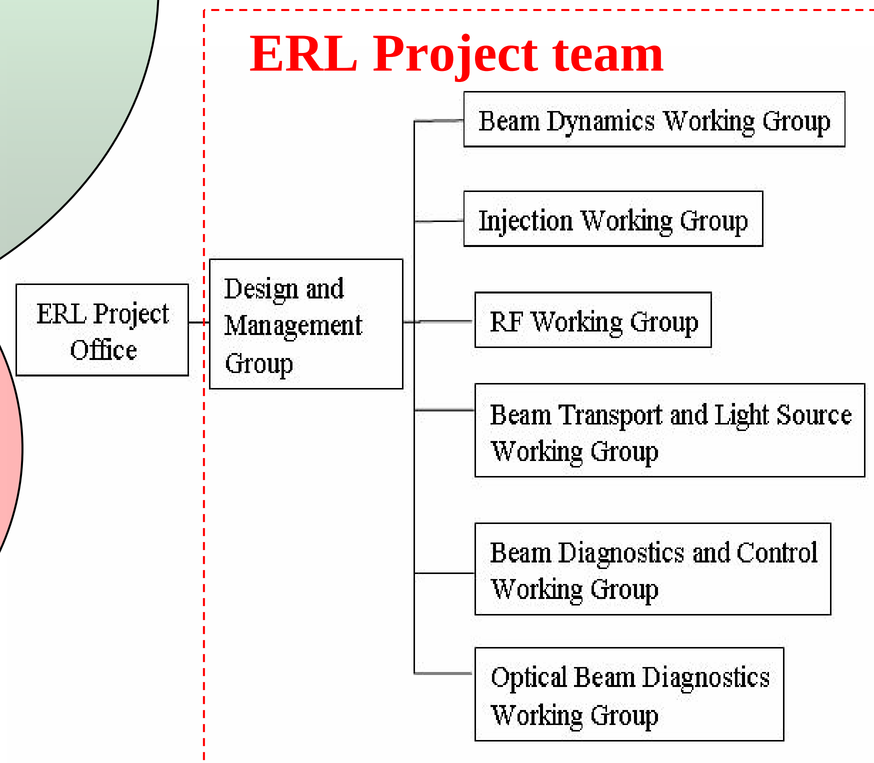
Domain formation?
(X-ray Photon Correlation Spectroscopy)

Structure of the ERL Project Office

The members of the ERL project office consist of the staff at KEK, JAEA, ISSP and other facilities.

The office organizes the ERL project team, which consists of several working groups to design and develop the components of ERL and to brush up the scientific case of ERL .





R&D Plan towards the ERL Light Source

Development of key components

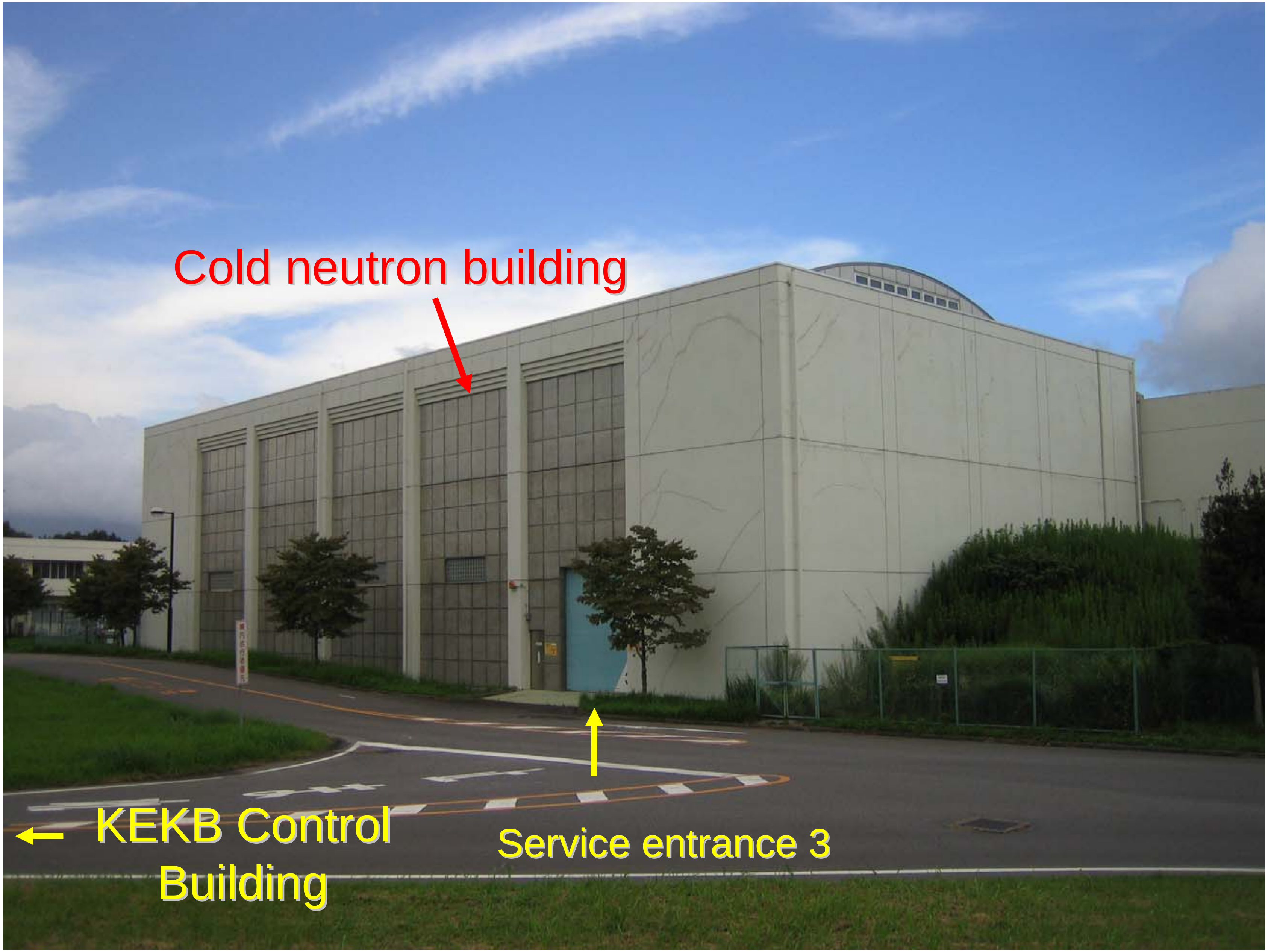
- DC photocathode gun (R. Hajima)
- 1.3GHz CW laser (R.Hajima (M. Kuriki))
- Superconducting cavities and cryomodules
  (H.Sakai (S. Noguchi), M. Sawamura (T. Furuya))
- Beam dynamics (S. Sakanaka)（

ERL test facility

- Testing critical components under beam operations
- Generation and acceleration of ultra-low emittance beams
- Investigation of accelerator physics issues (CSR, beam losses etc.)

Testing SC cavities for main linac,
Studying the instabilities. → **Return loop is necessary**

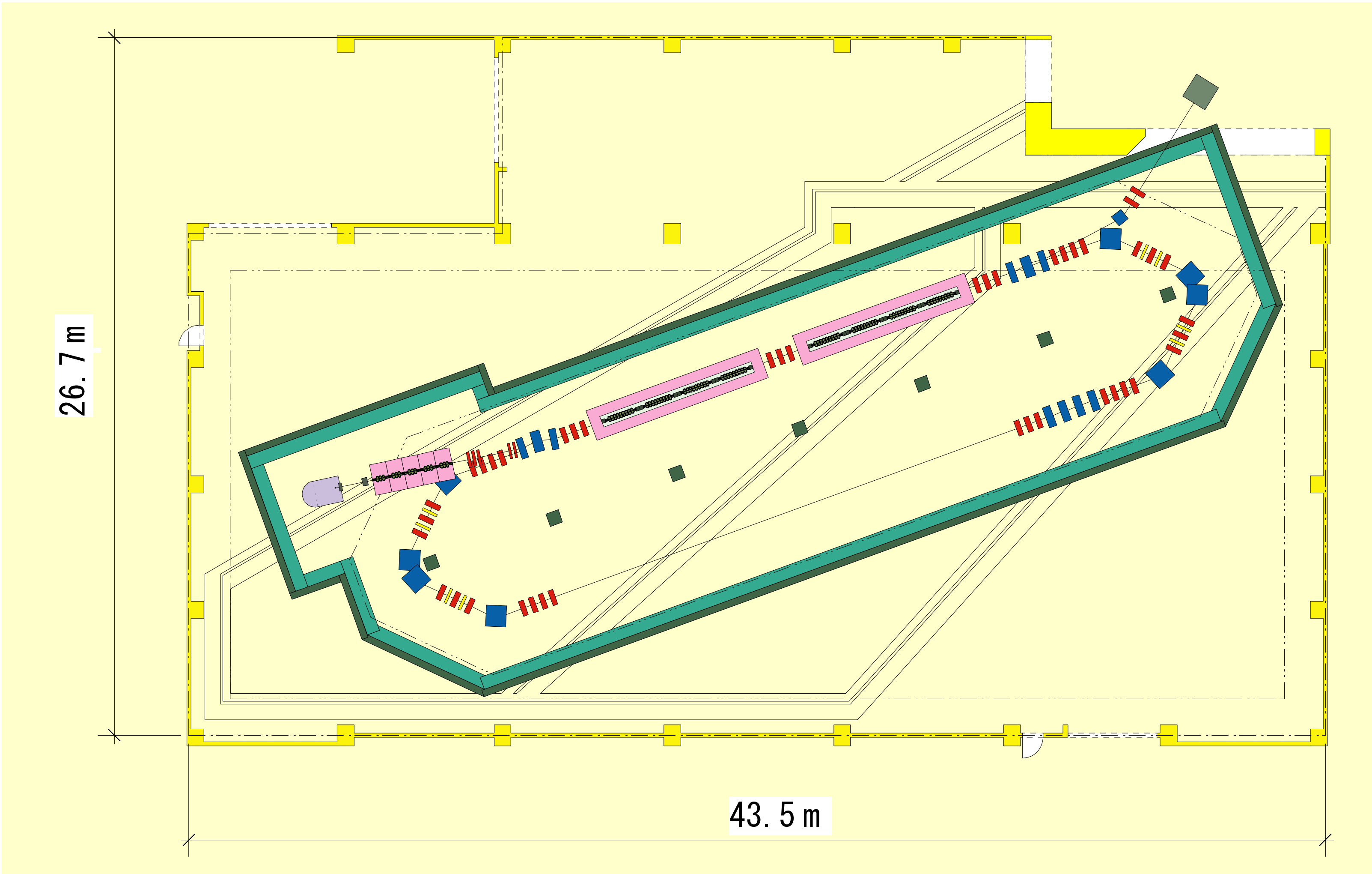
Site for the ERL Test Facility



Plan for ERL Test Facility

Maximum current: 100 mA
Beam energy: 60 – (200) MeV

Normalized emittance: 1 – 0.1 mmmrad
Injection energy: 5 MeV (10 MeV)

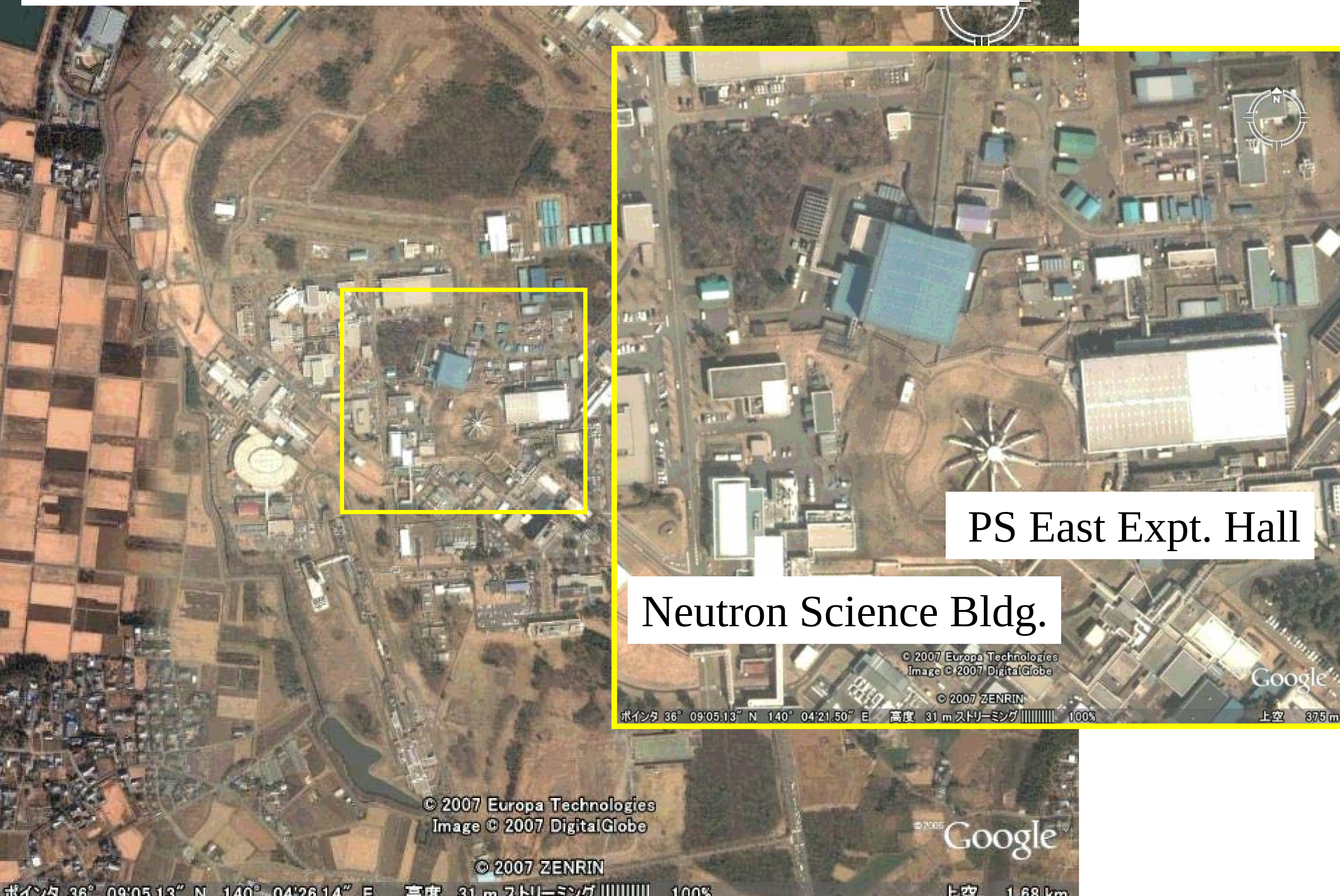


Tentative parameters

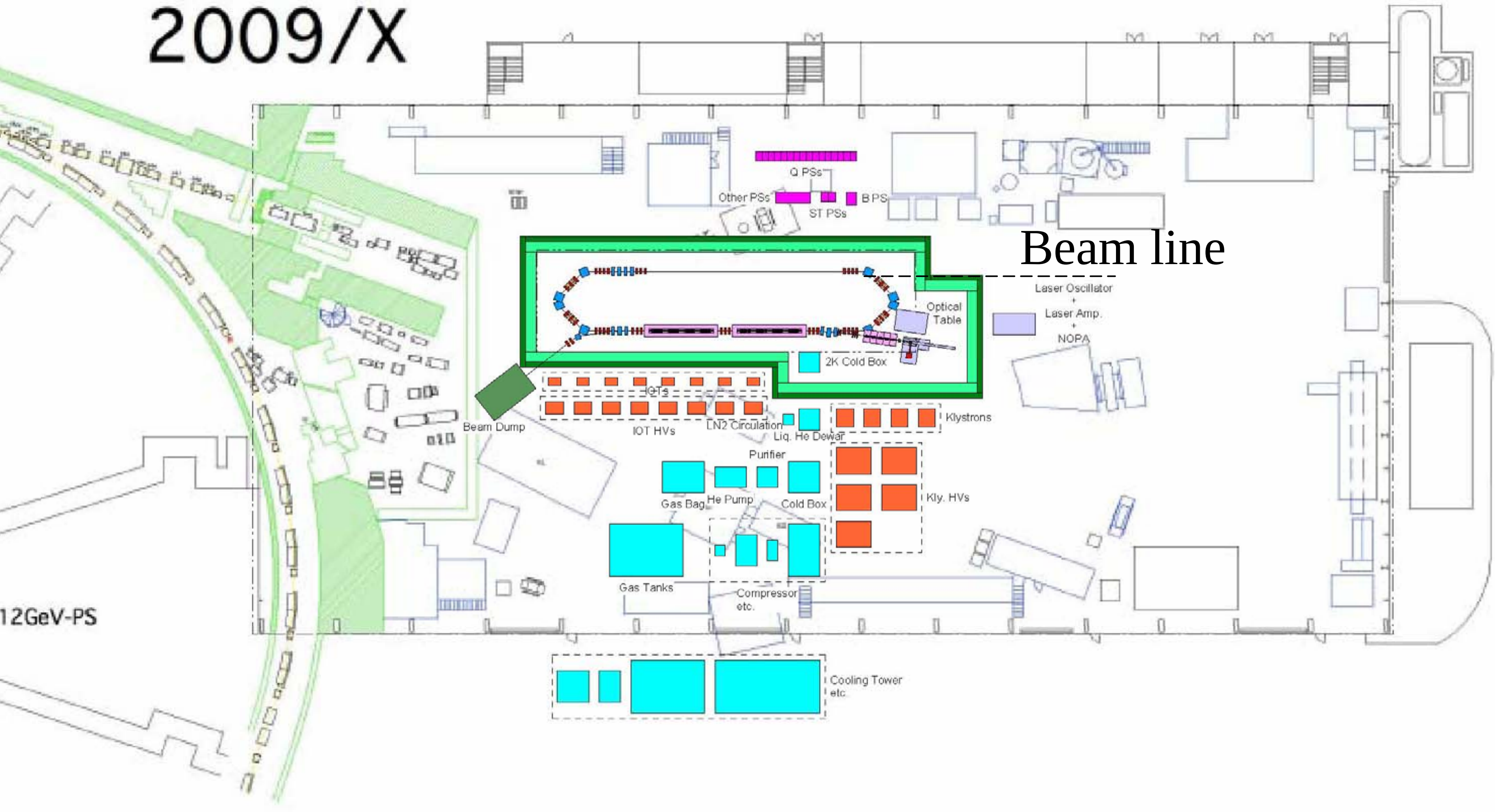
Injection energy	5 MeV (10-15 MeV)
Injector beam power	500 kW (1 MW)
Beam energy in arcs	~60 MeV (160-200 MeV)
SC cavities for main linac	9cells × 4: single module (two modules)
Normalized emittance	1 mm·mrad (0.1 mm·mrad)
Beam current	10 mA ? (100 mA)
Rms bunch length	Usual mode : σ_τ = 1-2 ps Short bunch mode: σ_τ ~ 100 fs?
Test undulator	No undulators (with an undulator)

Initial goals. Final goals are in ( ).

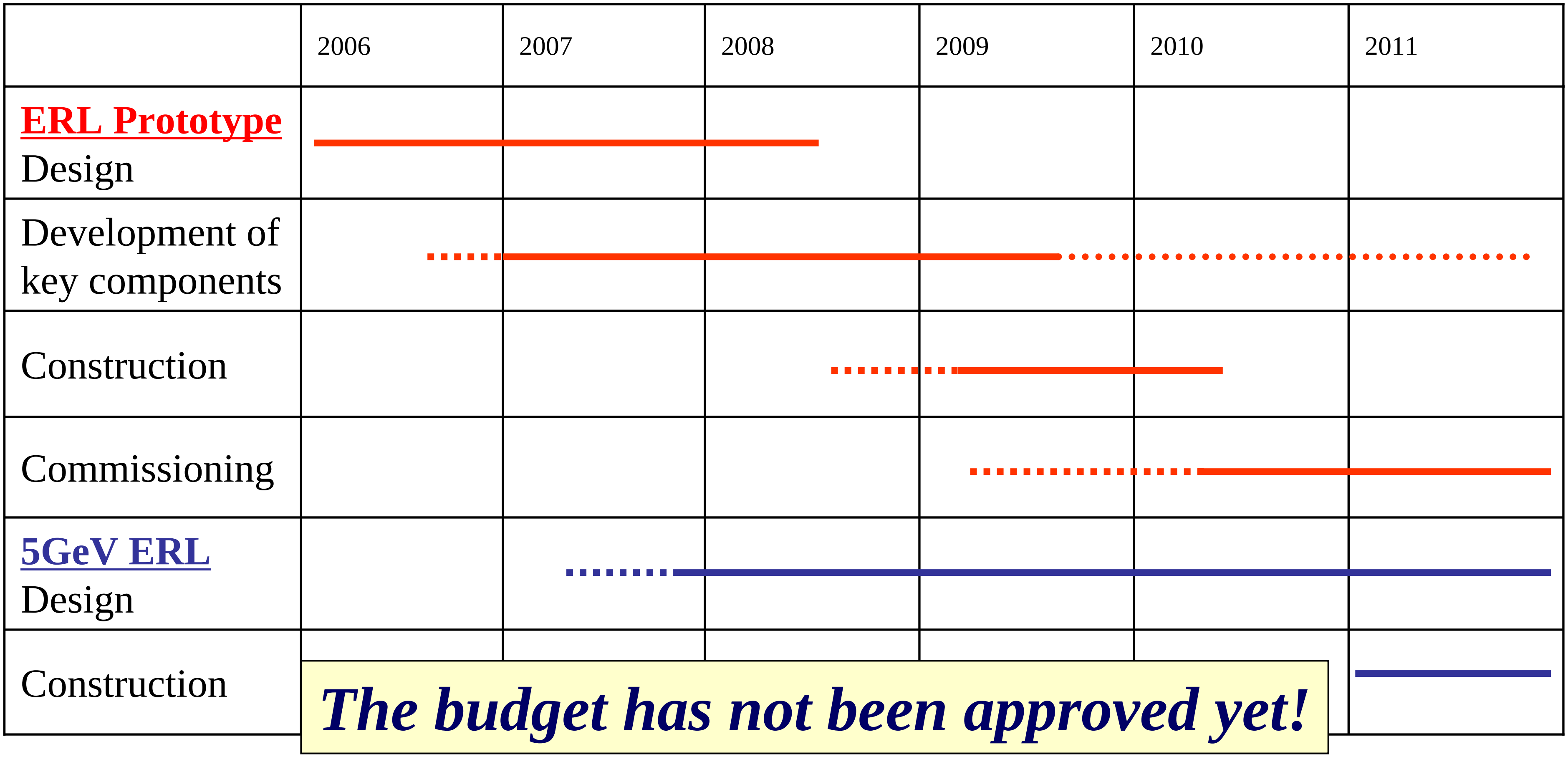
New Site for the ERL Test Facility?



Plan for ERL Test Facility in PS East Expt. Hall



Time Schedule of the ERL Project



1) Construction of a 60~200MeV class ERL (prototype).
2) Demonstration of the principle of the ERL until 2010.
3) We shall start construction of 5 GeV class ERL from ~2011.
4) We hope to start the user operation of ERL from ~2015.

Summary

- ERL is one of the most promising candidate for future light source.
- ERL project has been progressed under the collaboration with KEK, JAEA, ISSP and other facilities.
- To resolve technical & physical challenges, an ERL test facility is under consideration at KEK.
  - To test critical components under beams
  - To generate and accelerate ultra-low emittance beams
  - To investigate accelerator physics issues
- The ERL test facility will consist of a 5-10MeV injector, 1-2 cryomodules, a return loop and a beam dump. The energy will be 60 – 200 MeV.
- Design of the test ERL is underway.
- R&D for the DC photocathode gun (at JAEA) and for the SC cavities (at KEK) were started.