Overview for Quantum Beam project at KEK

Junji Urakawa (KEK, Japan) at Tomsk Polytechnic University, 2012.8.14

Under development of Quantum Beam Technology Program(QBTP) supported by MEXT
from 2008.9 to 2013.3 (5 years project)

Contents :

1. Introduction
2. STF Status
3. Status of basic technologies
4. New Laser Storage Scheme using ~10ps (FWHM) mode-locking 1μm laser with super-cavity and other
5. New plans and schedule

Evolution of photon source : X-ray source based on accelerator and laser

2011, ~mJ 0.1nm 10fs X-ray pulse is realized

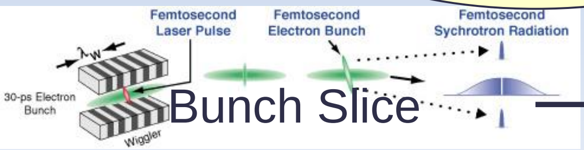
DESY-XFEL (~2015)

SPring8-XFEL — 2011

SLAC-XFEL — 2010

Next Generation Photon Source

Coherent Ultra-short Pulse, Compact X-ray source



Bunch Slice

Ato-sec. Science

2000

ERL proposal

Third Generation Photon Factory

Ultra-high field Science

Plasma X-ray

XFEL proposal

1990 — **Higher harmonic wave : Coherent soft-X-ray**

Femto-sec Science

Chirped Pulse Amplification(1985

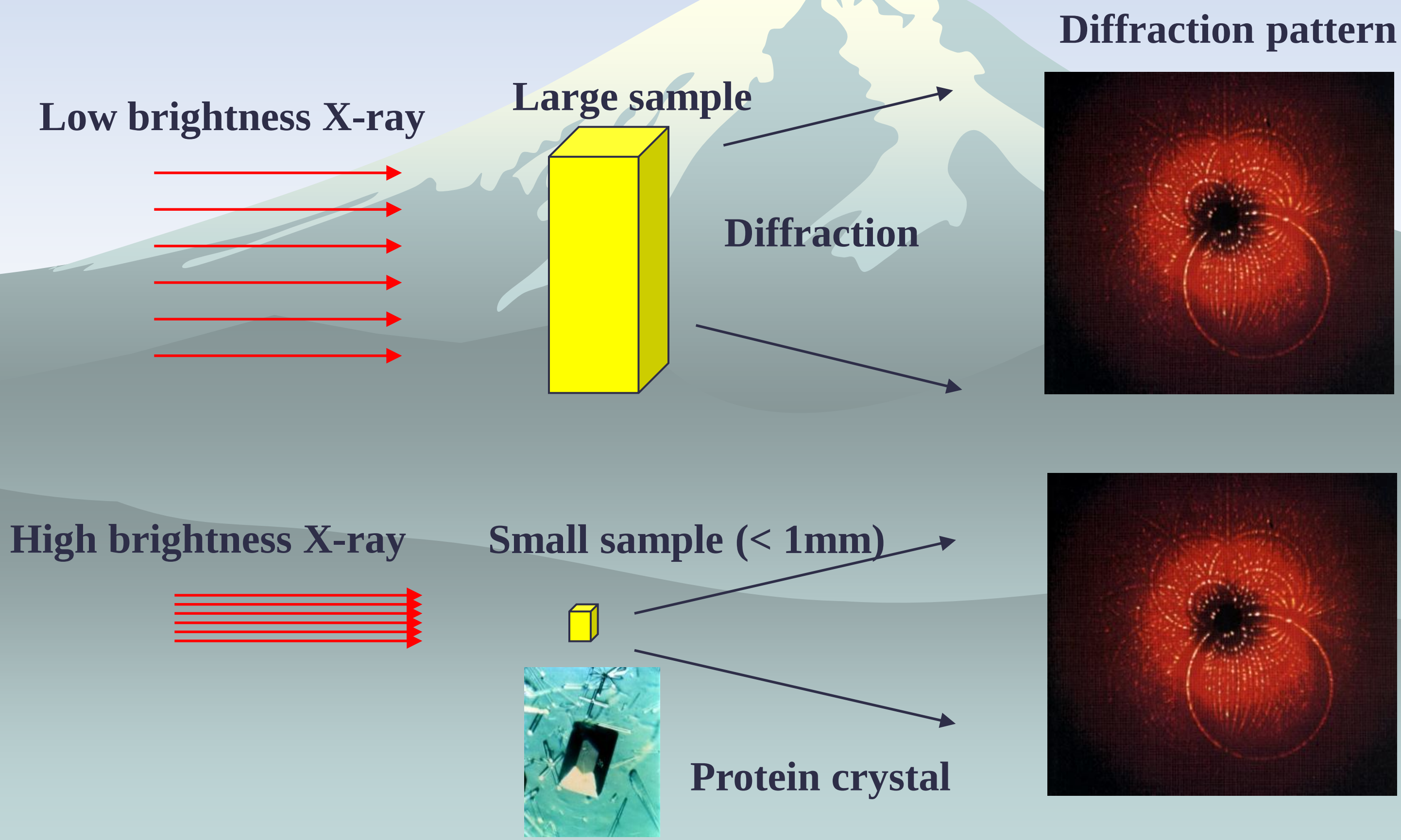
Second Generation Photon Factory

1980

To stronger and brighter photon beam

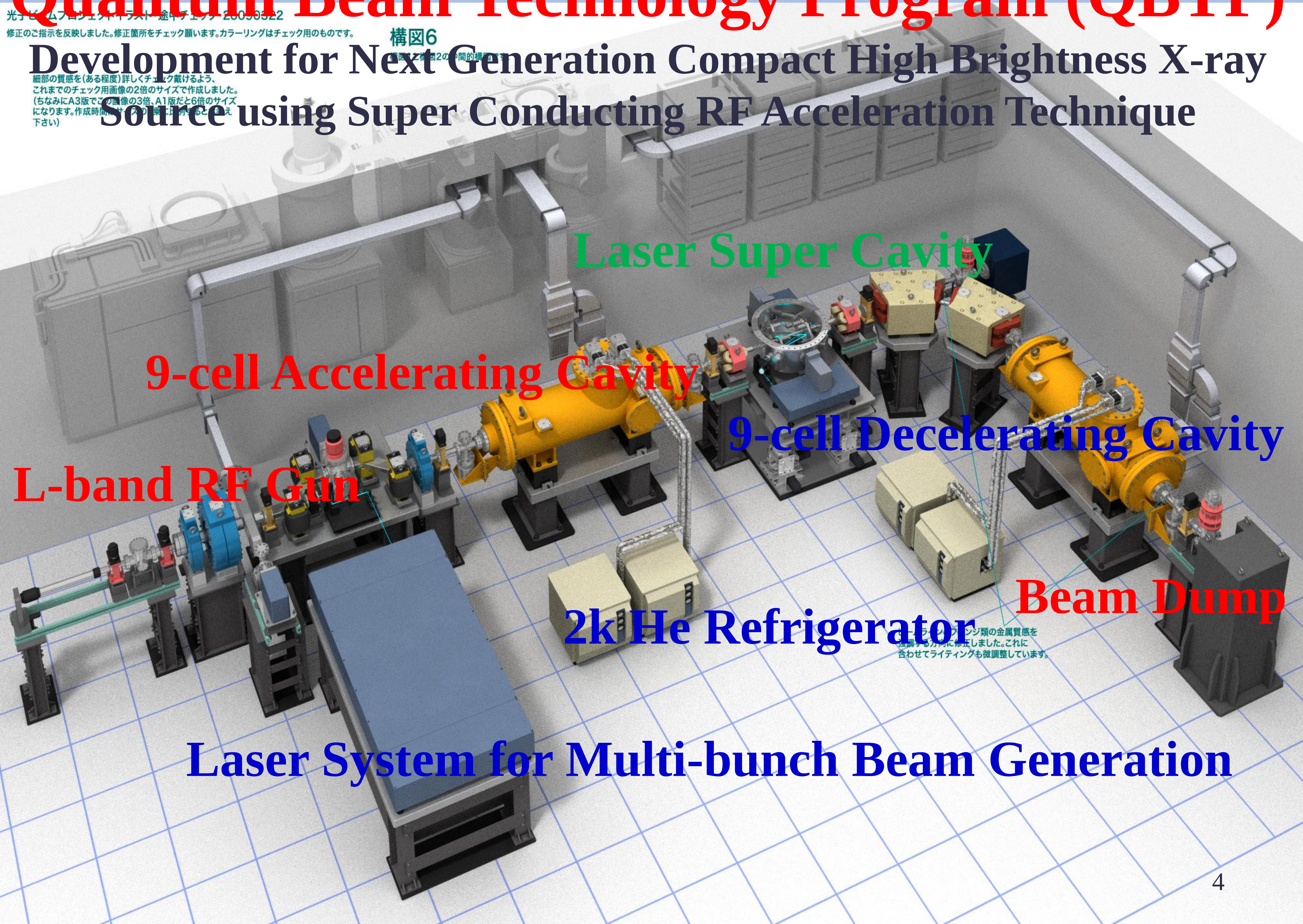
$$Brightness = \frac{photons/\sec}{(\mathrm{mrad})^2(\mathrm{mm}^2(source-area))(0.1\%\ \ spectrum-width)}$$

10μm photon source is considered, which means 0.2 mmmrad normalized emittance.
1mrad angular spread collimation means small energy spread.



Quantum Beam Technology Program (QBTP)

Development for Next Generation Compact High Brightness X-ray Source using Super Conducting RF Acceleration Technique

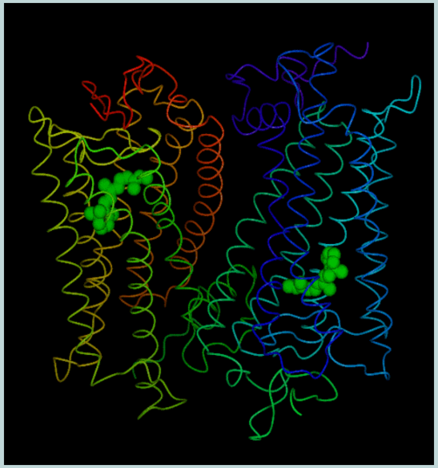


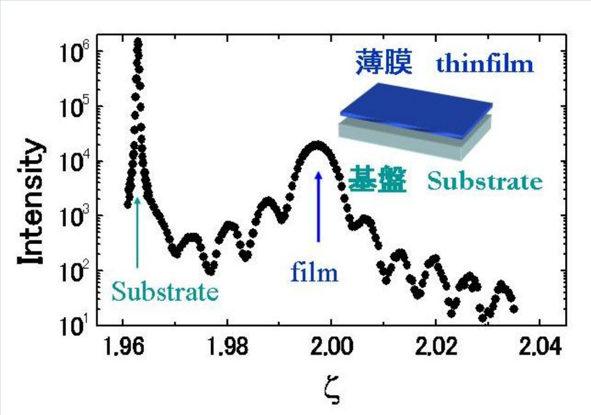
Characteristics of this device

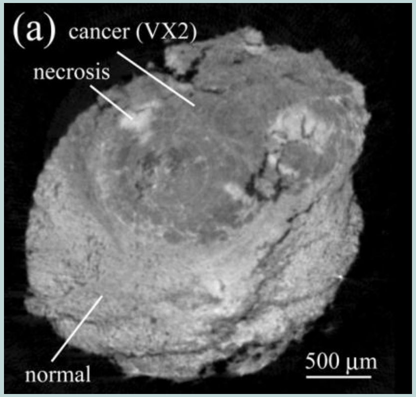
Compact (less than 10m total length) **Monochromatic** (less than 1% energy spread)
High flux (100 times compact normal conducting X-ray: 10^{11} photons/sec 1% b.w.)
High brightness (2.5 generation photon factory: 10^{17} photons/sec mrad^2 mm^2 0.1% b.w.)
Ultra-short pulse (40 fs ~)

Superconducting accelerating technology

Genome structural analysis, Evaluation of Nano-material, Precise fine X-ray Imaging



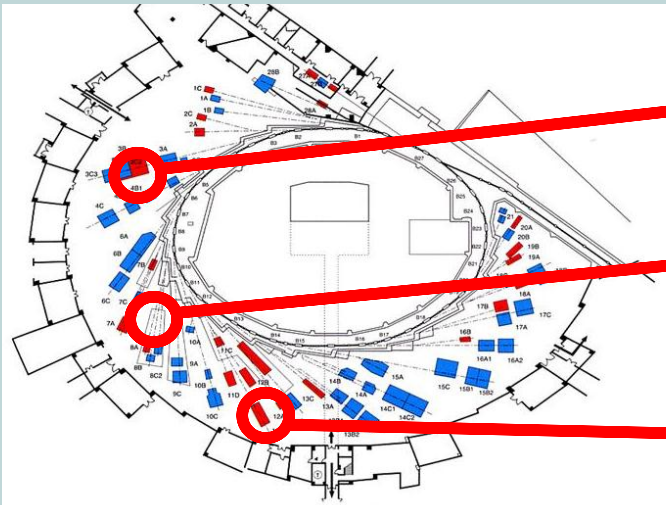




http://mml.k.u-tokyo.ac.jp/

Impact of compact high brightness X-ray

1) Performance of second generation photon factory is obtainable at experimental room.

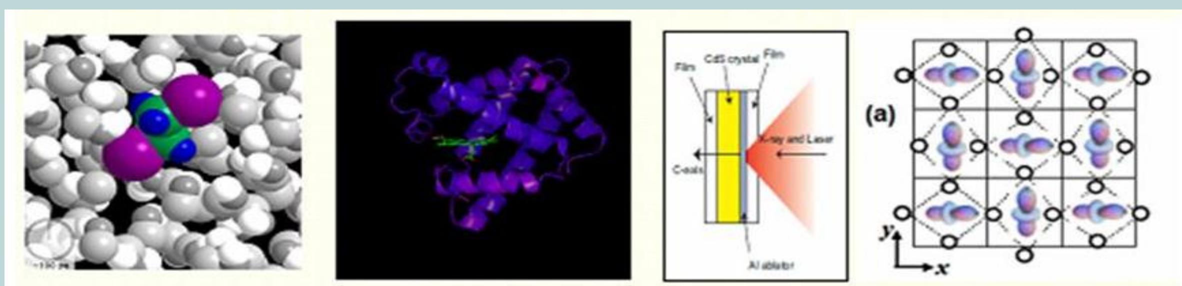


Genome structural analysis
@A University

Evaluation of Nano-material
@Laboratory of B Co.

Precise fine X-ray Imaging
@C Hospital

2) ***sub-psec X-ray is obtainable at experimental room.→research for fast dynamic phenomena***

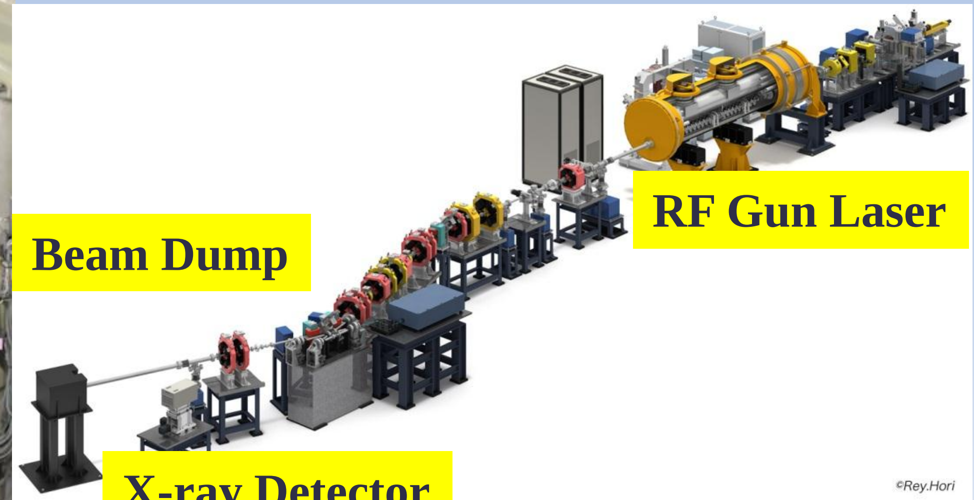


Chemical reaction in solvent, function of protein, destruction by impulse, phase transition induced by photon

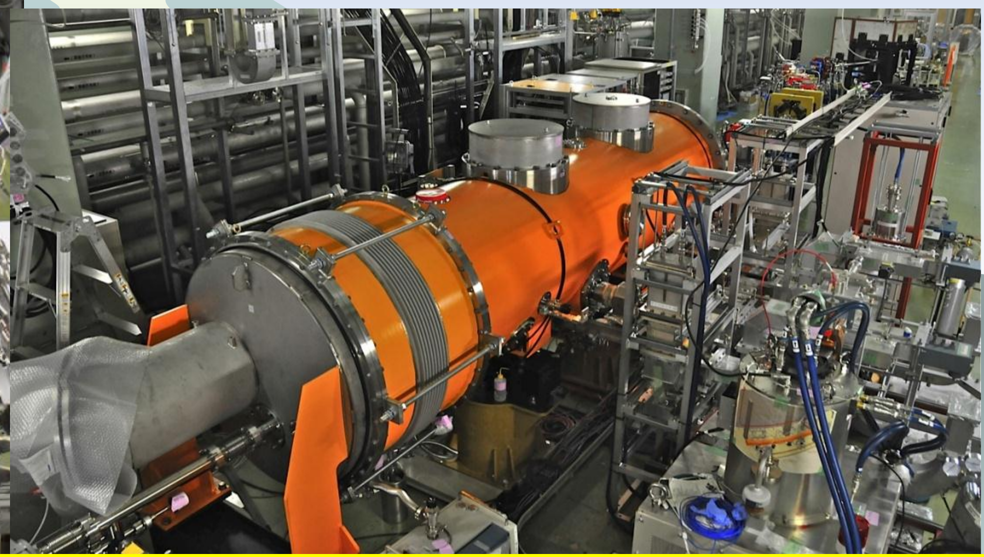
3) ***isotope detection of radioactive nuclear wastes (solution of energy and environmental problems)***

300MeV ERL or small storage ring is necessary.

View of QBTP from Beam Dump



To contribute the development for life science innovation and green innovation

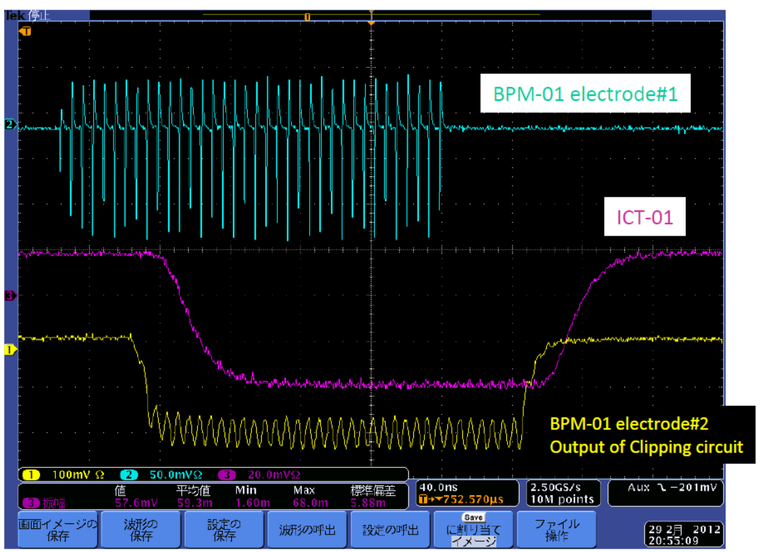


Quantum Beam Technology Program: Beam commissioning started from mid. of February.

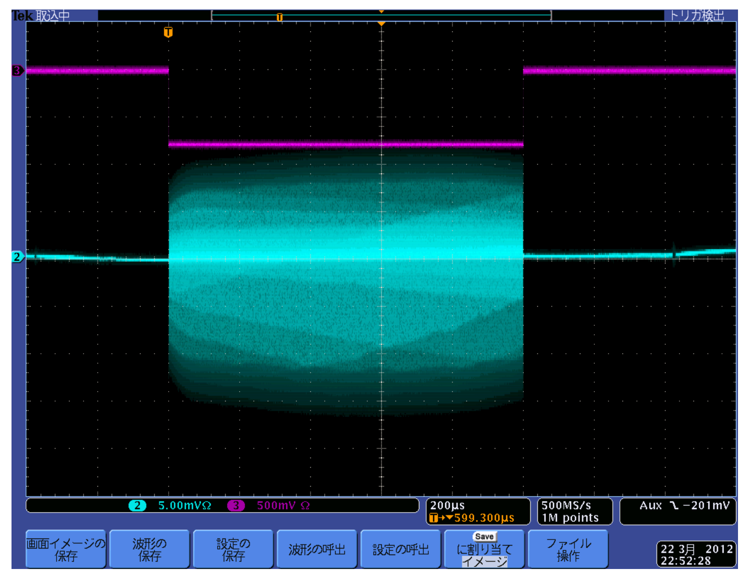
Operation at STF control room

Electron beam parameter

	QBTP	STF Phase 2
Pulse length	1 ms	0.9 ms
Repetition Rate	5 Hz	5 Hz
Bunch Spacing	6.15 ns (162.5 MHz)	369.27 ns (2.708 MHz)
Number of Bunch	162500	2437
Bunch Charge	62 pC	3.2 nC
Total Charge	10,000 nC	7,798 nC
Beam Current	10 mA	8.7 mA
Bunch length	12 ps (Laser, FWHM)	10 ps (Laser, FWHM)
Max beam energy	50 MeV	21.5 MeV
Beam power	Max 2.5 kW (50 MeV) Usually 2.0 kW (40 MeV)	0.8 kW (21.5 MeV)

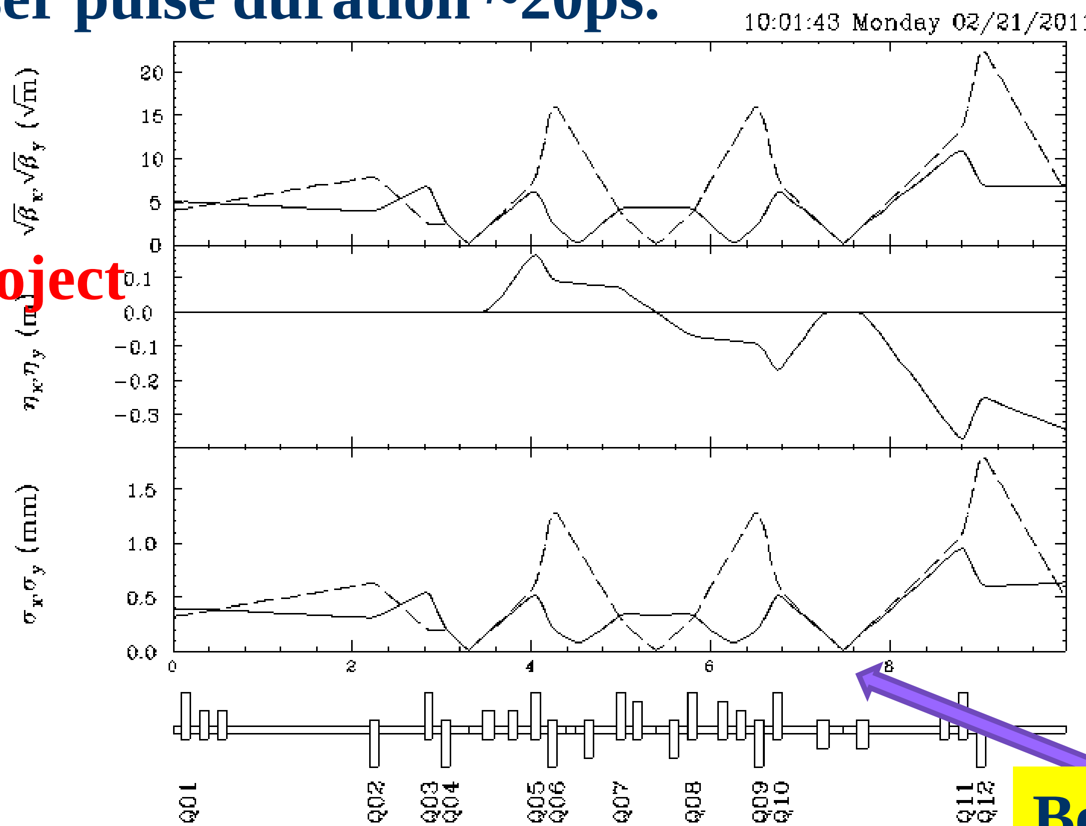


BPM and current monitor signals

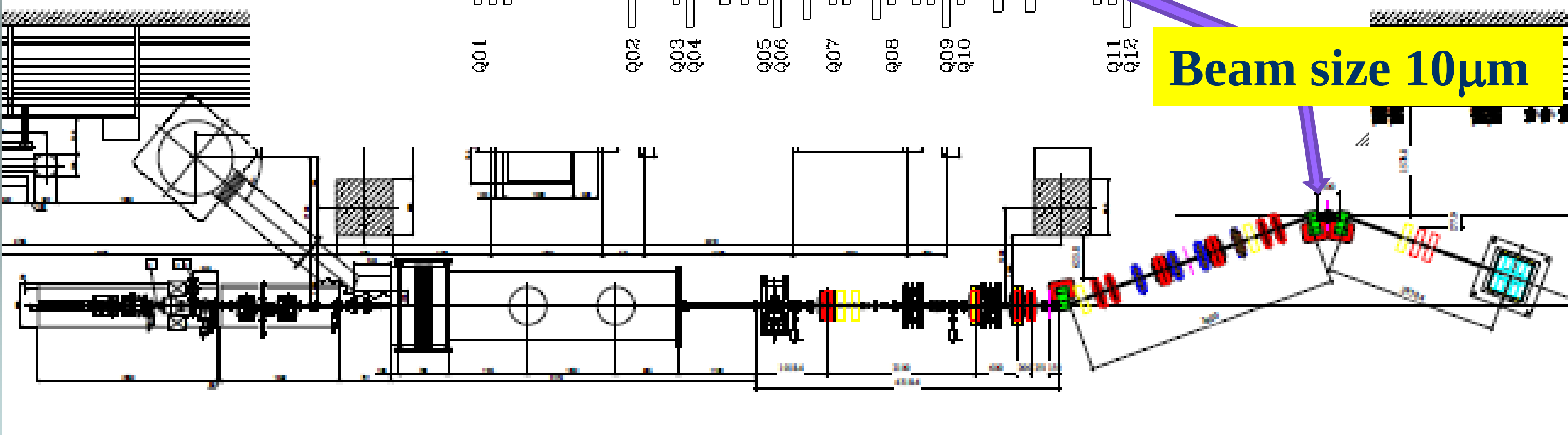


1ms Flat Beam（30~40pC/bunch）

Change to head collision scheme to get another enhancement of 5 and to increase laser pulse duration ~20ps.



Quantum project at STF



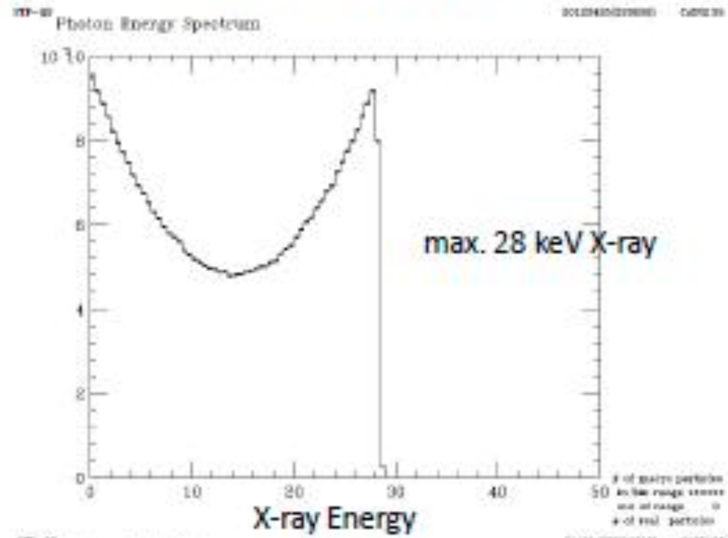
Beam size 10µm

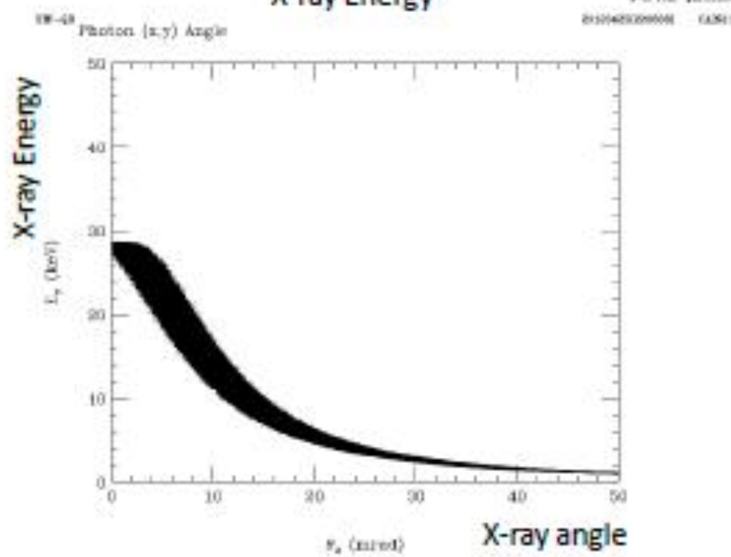
Plan of X-ray generation by Inverse-compton scattering

4-mirror laser accumulation, head-on with e-beam

	Electron	Laser
Energy	40MeV	1.17eV (λ=1064nm)
Energy spread	0.1% (rms)	
Beam size(rms)	10μm	10μm
Pulse width(FWHM)	12ps	12ps
Intensity	61.5 pC/bunch	50mJ/pulse
Number of bunches	162500	----
Emittance	0.5π mm mrad	
Collision angle	0deg (Head on)	
Rep. Rate	5Hz	

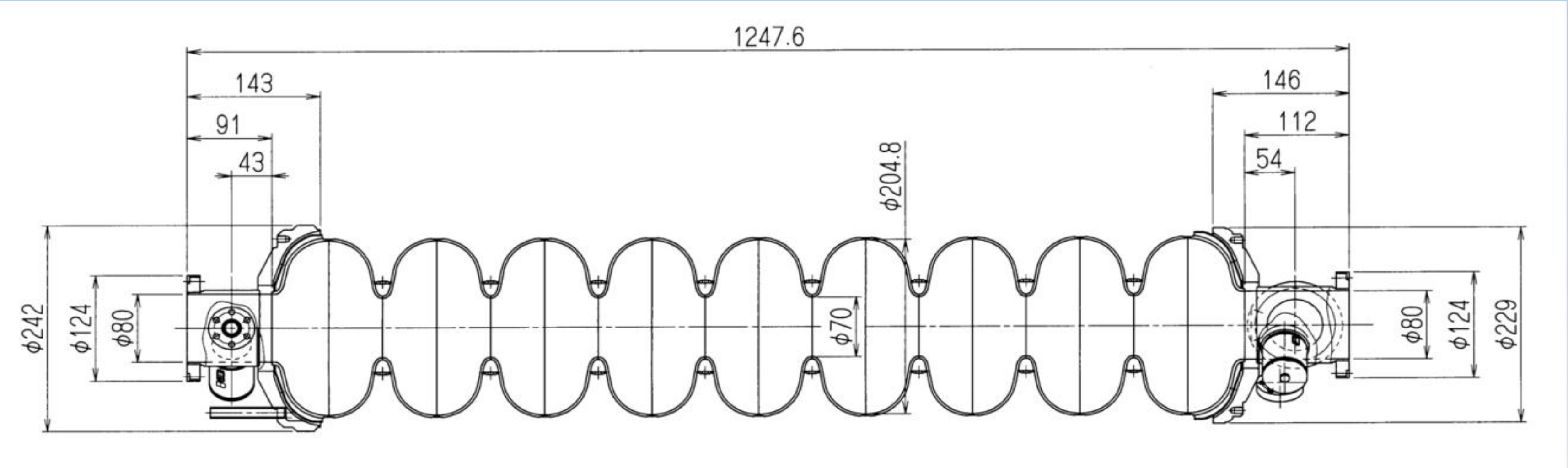
40MeV, head-on collision

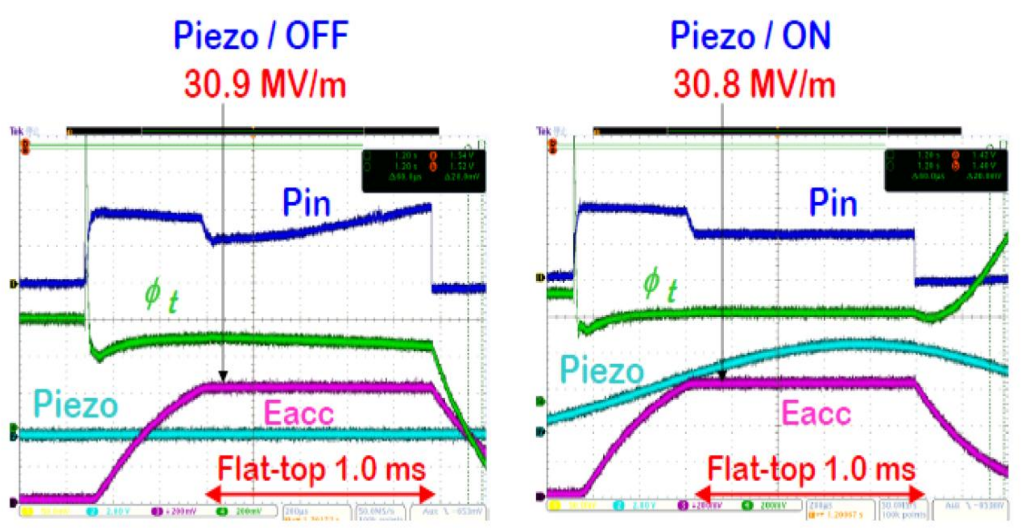


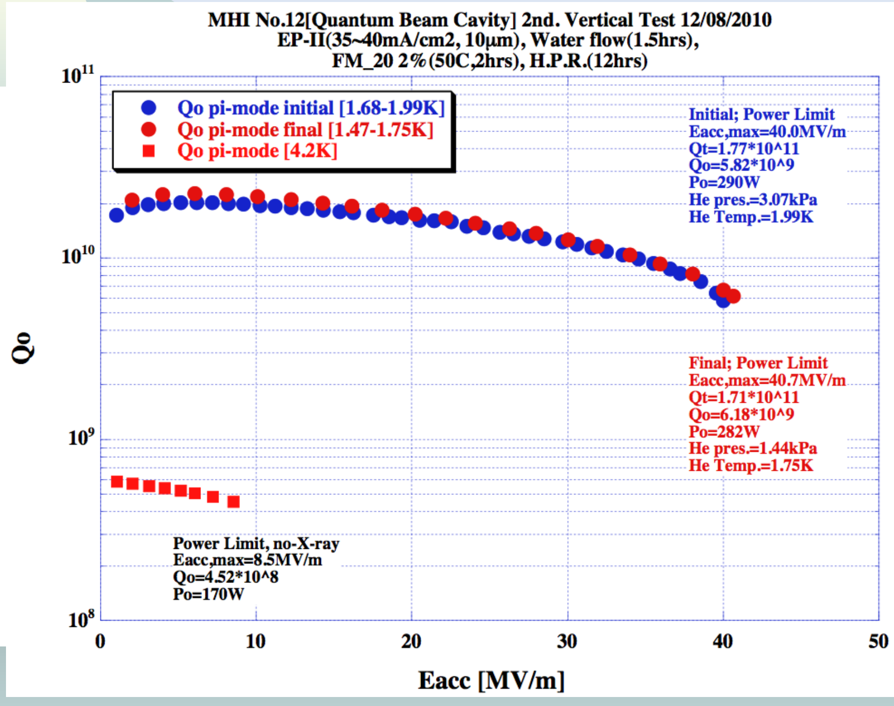


target: 1.3×10^{10} photons/sec/1%bw

Manufactured and Tested four 9-cell super conducting cavities



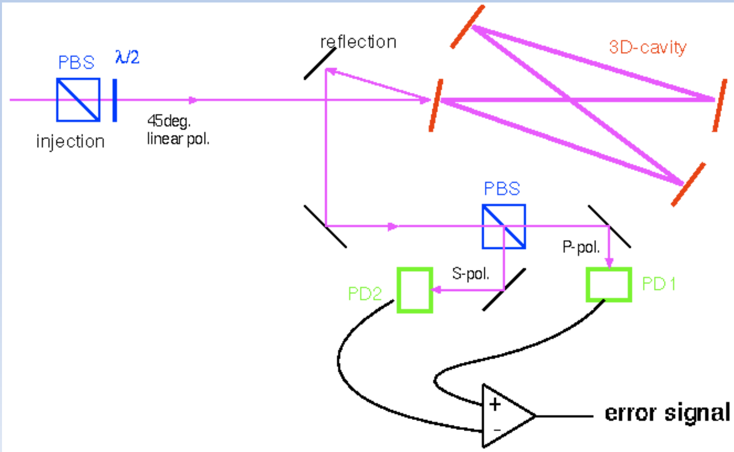




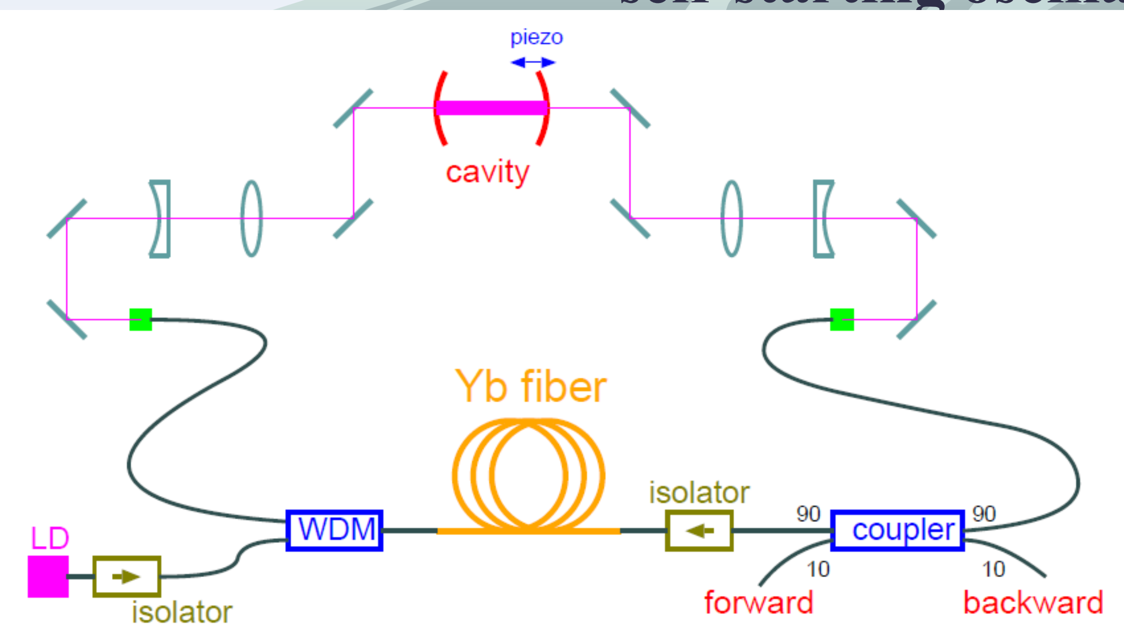
Recently, we operated the 9-cell cavity with **38MV/m**.

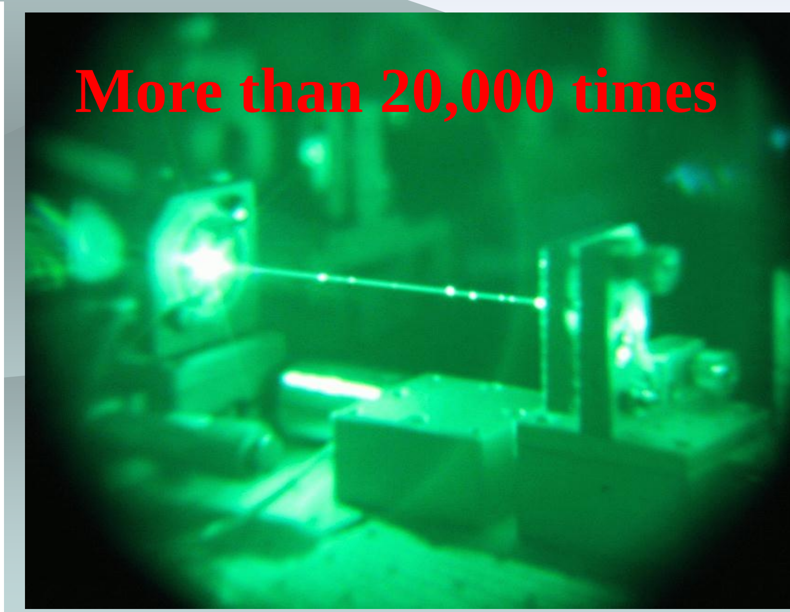
New fast switching for circular polarization X-ray

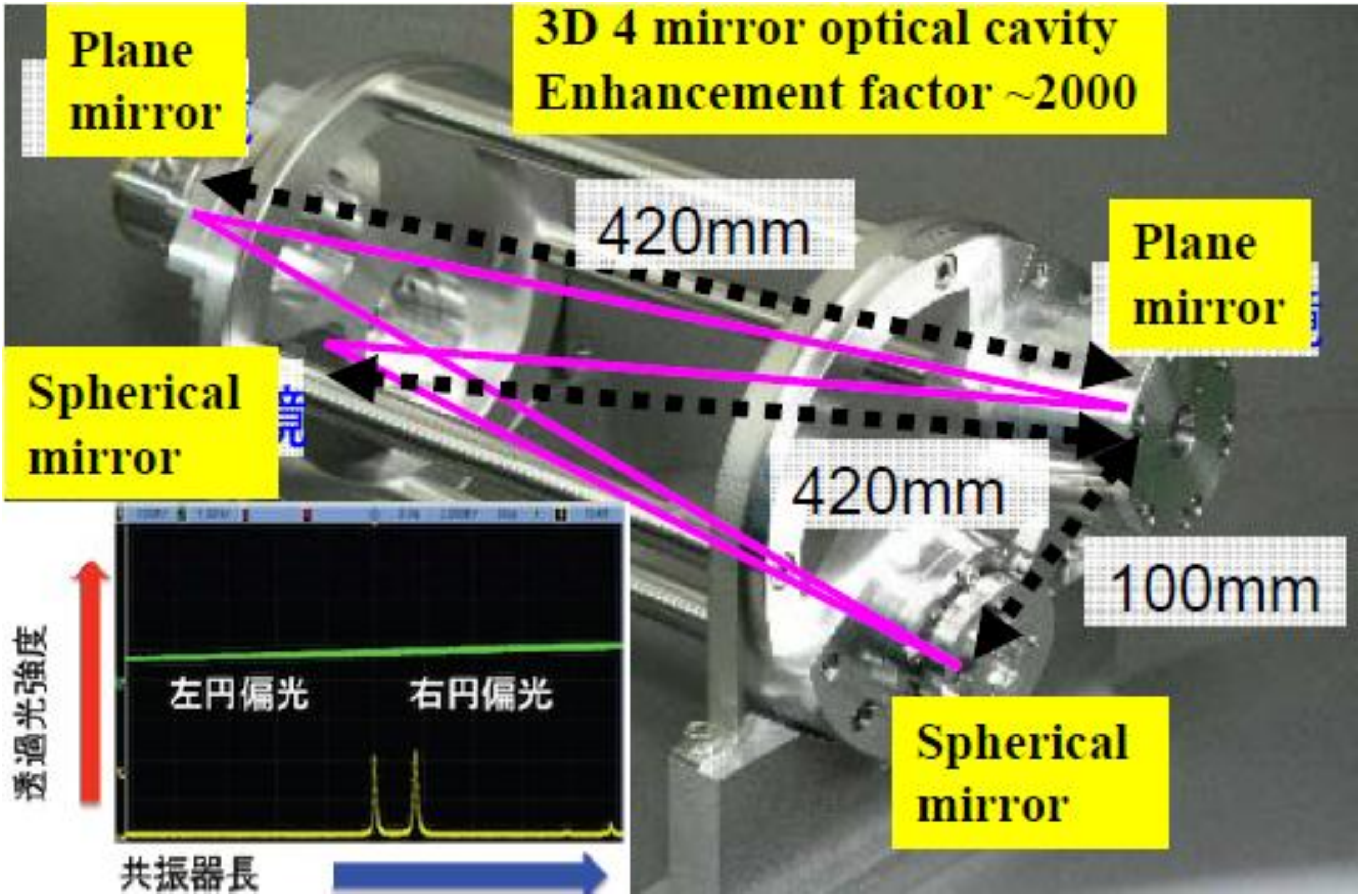
Development for laser accumulation



New laser storage scheme, so called ‘self-starting oscillator scheme‘

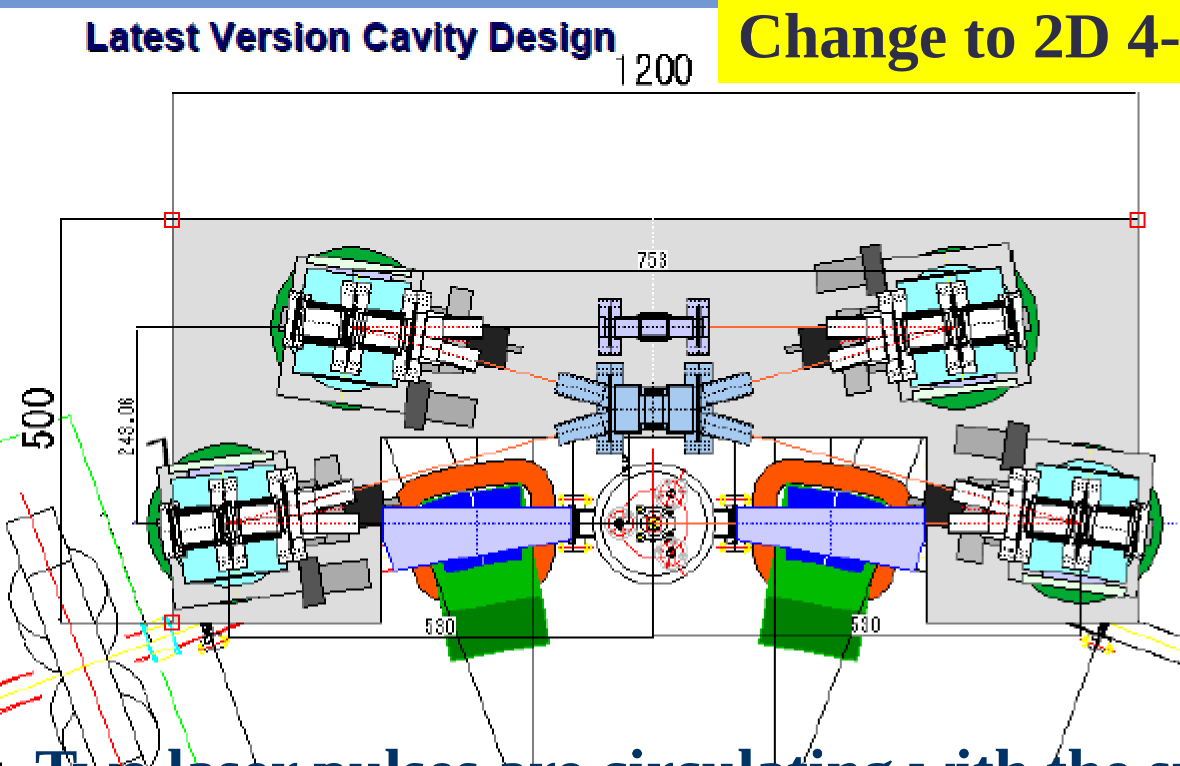


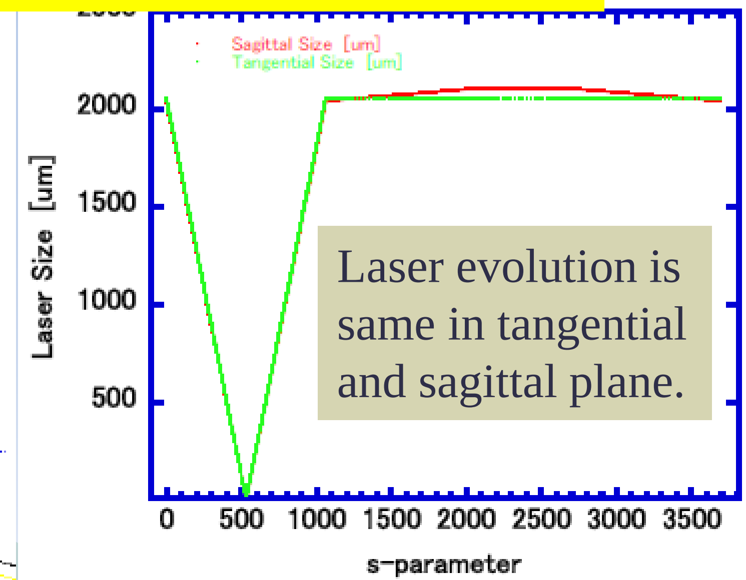




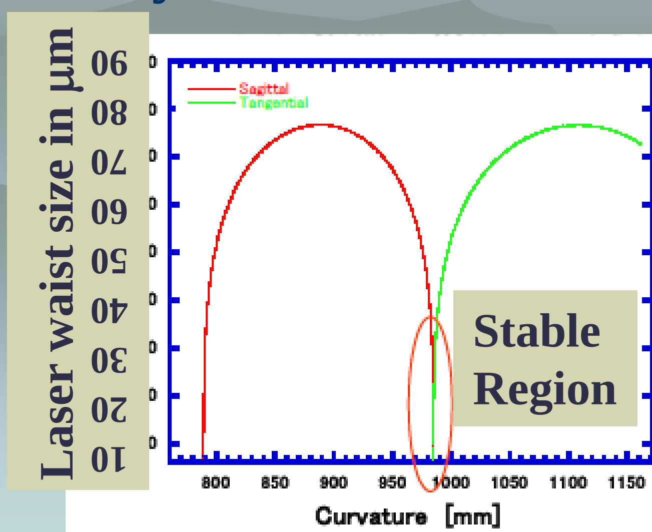
Finesse 5800, gain ~2000 was confirmed by generation of gamma-ray last year. Also, laser waist size was less than 15μm.

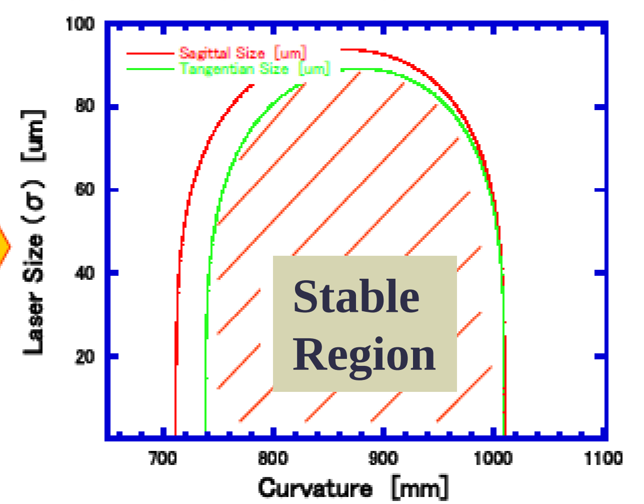
Change to 2D 4-mirror optical cavity



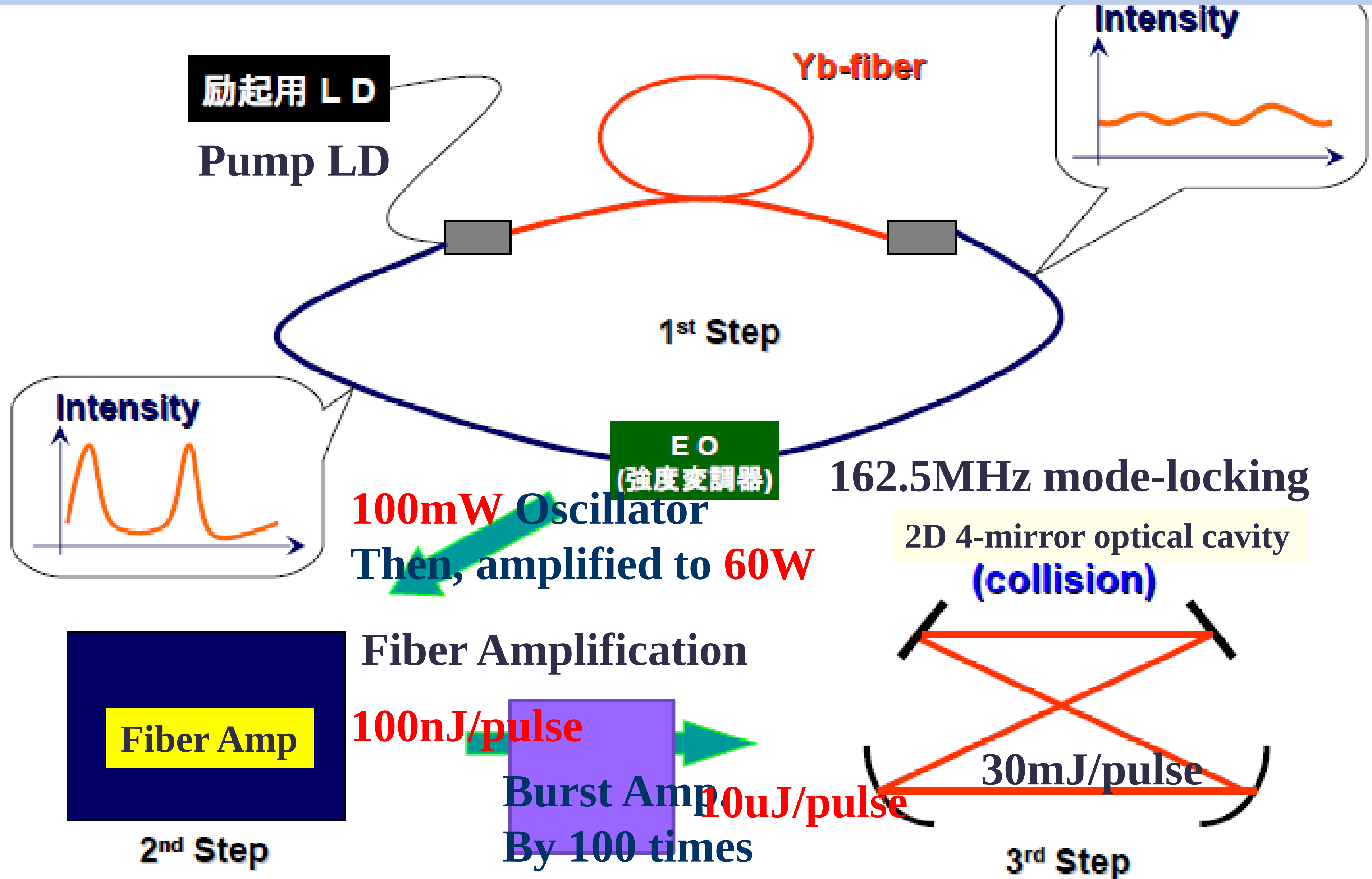


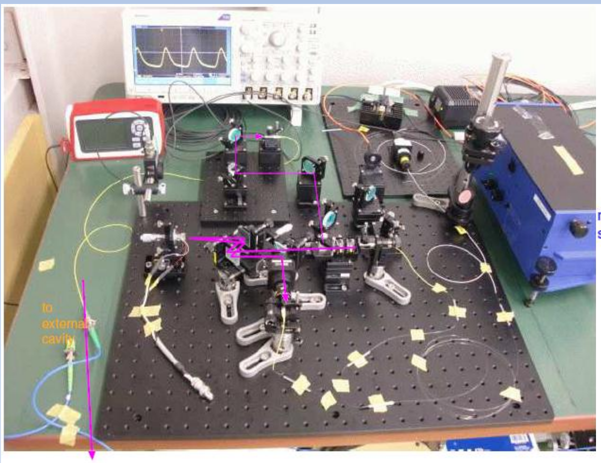
Two laser pulses are circulating with the spacing of 6.15ns in a ring optical cavity.

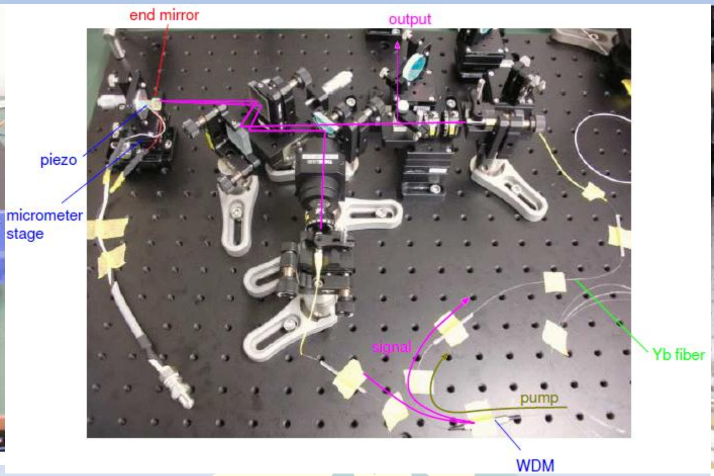


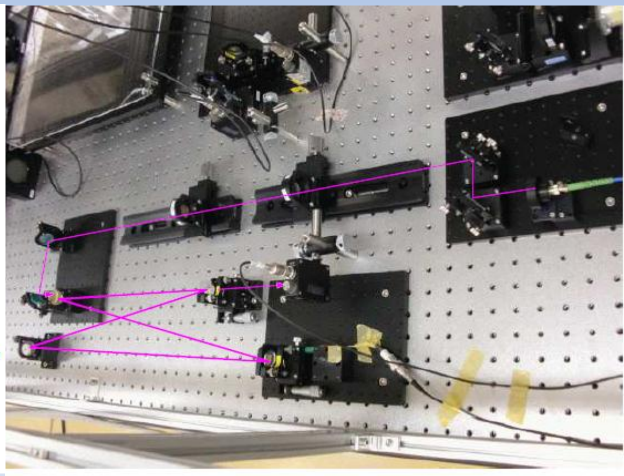


Laser System Development for Optical Cavity

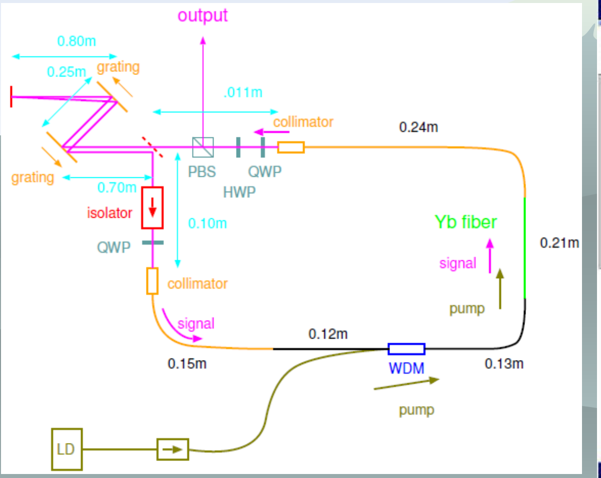


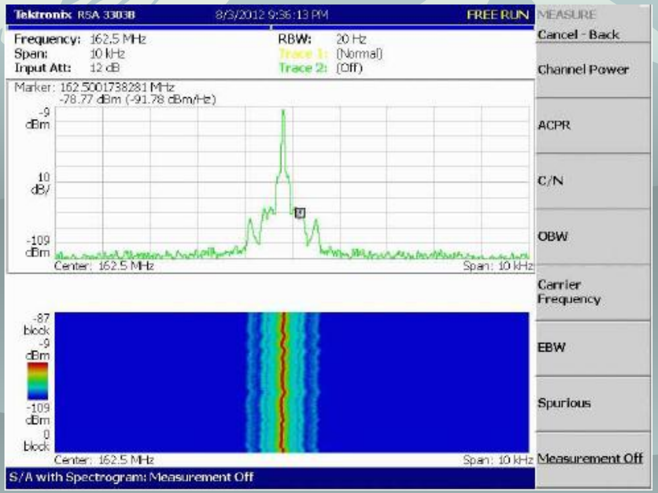


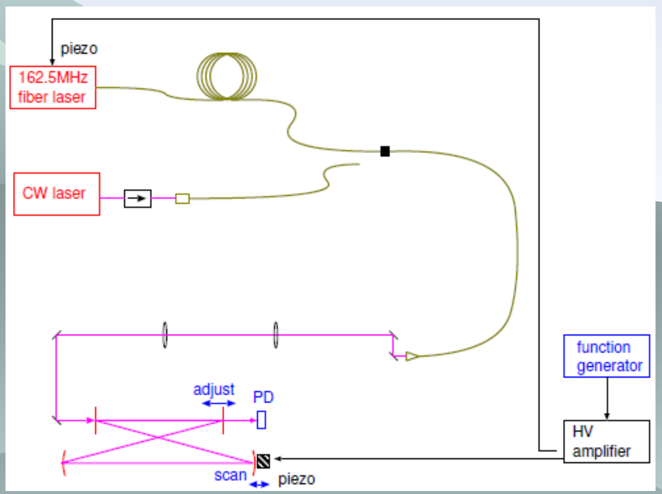




NLPR passive mode lock oscillator (162.5MHz)



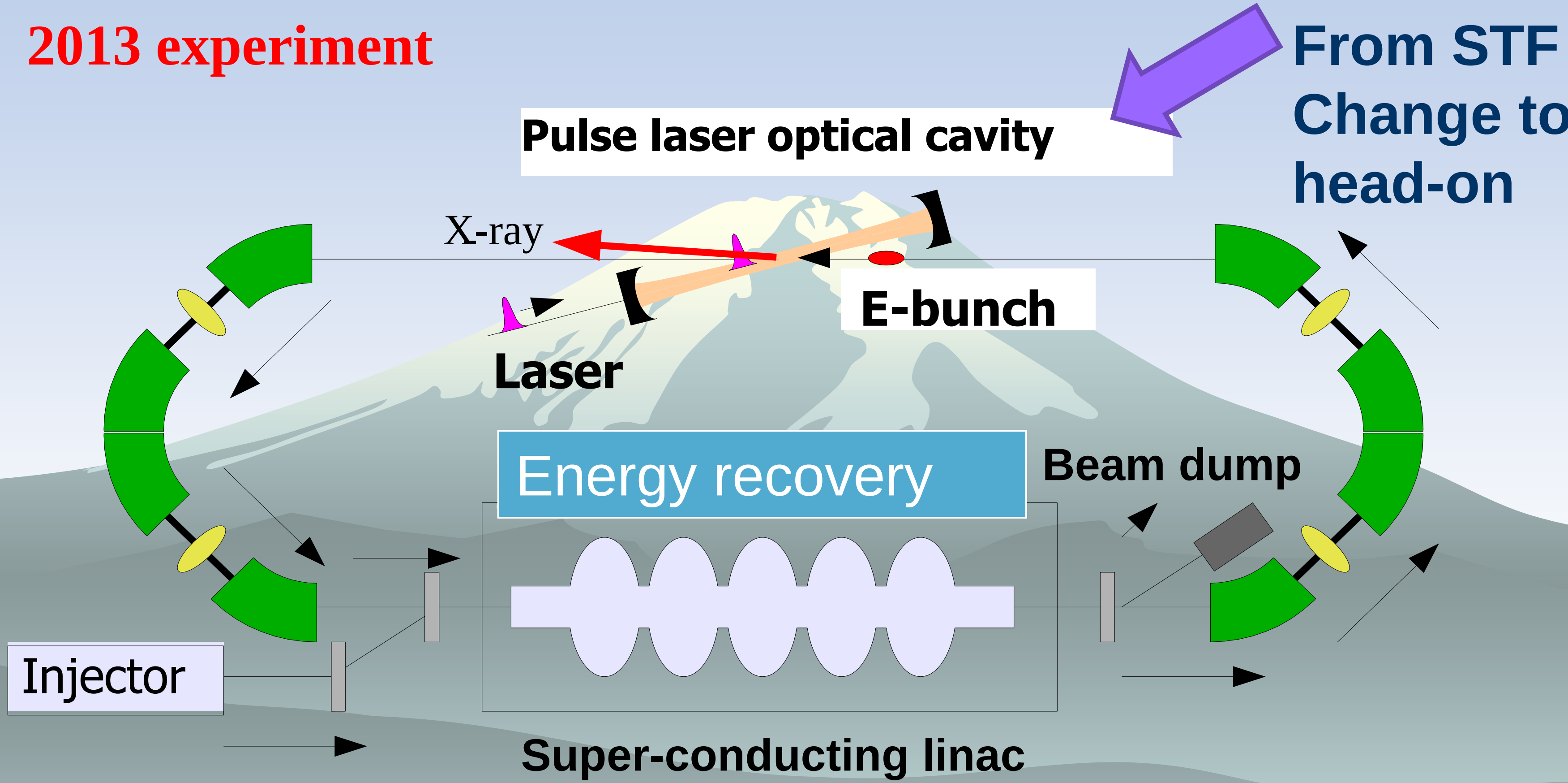




162.5MHz, 350fsec pulse duration, 43mW

High brightness X-ray generation by ERL
Demonstration by beam experiment if possible

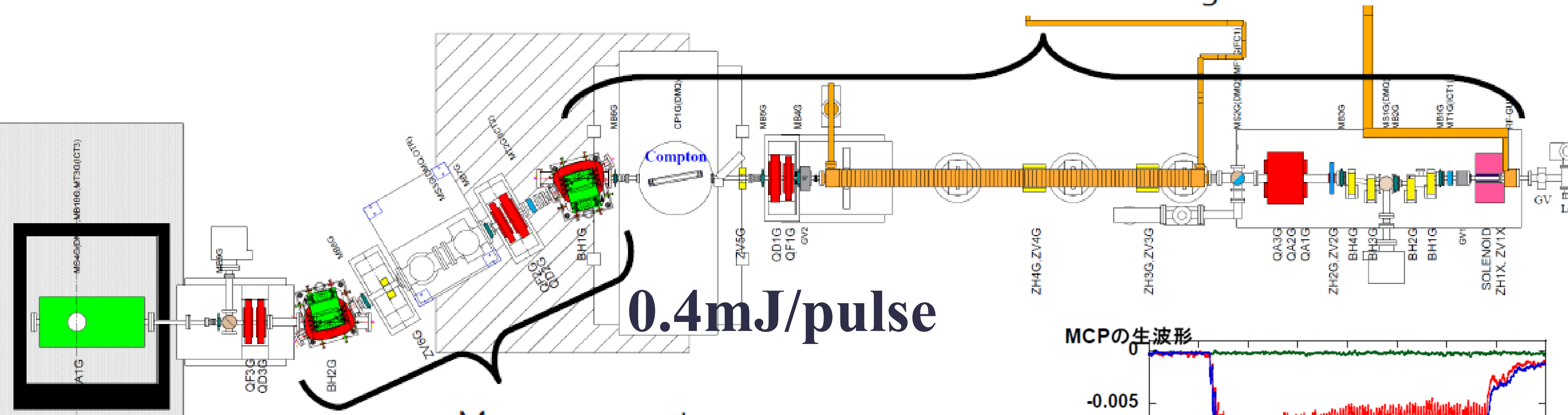
2013 experiment



10^{13} photons/(sec・1%b.w.)

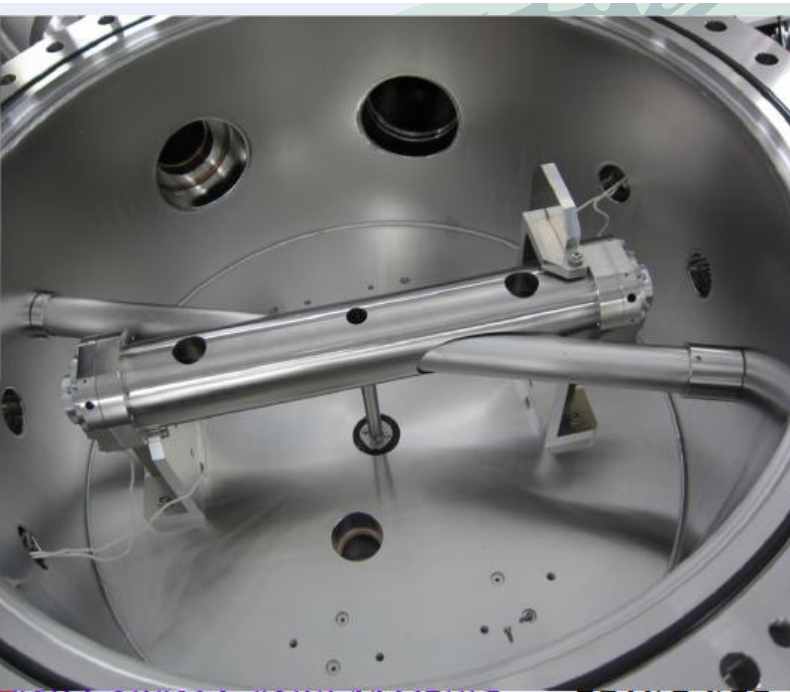
35MeV electron beam x 1μm laser = 23keV X-ray

Measurement & tuning



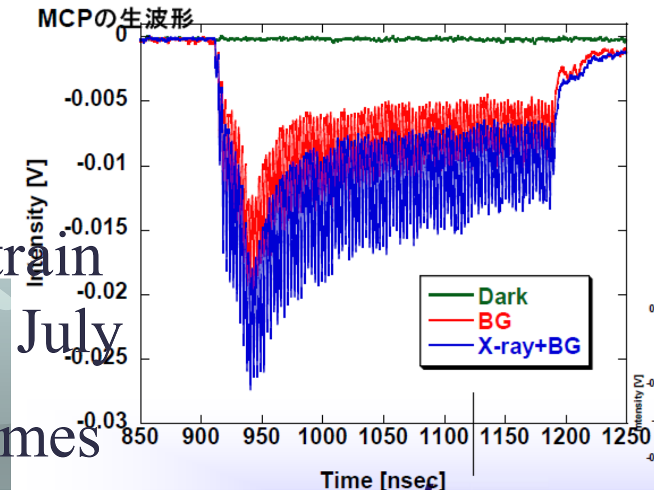
0.4mJ/pulse

Measurement
&
tuning if possible

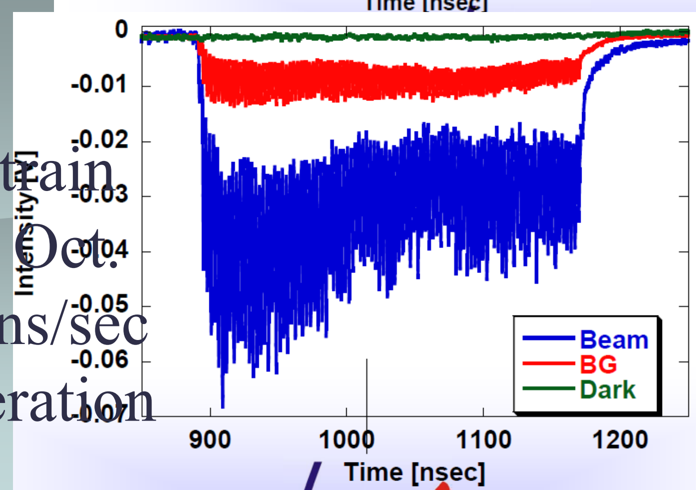


X-ray yield
334 photons/train
at detector on July

2〜3 times

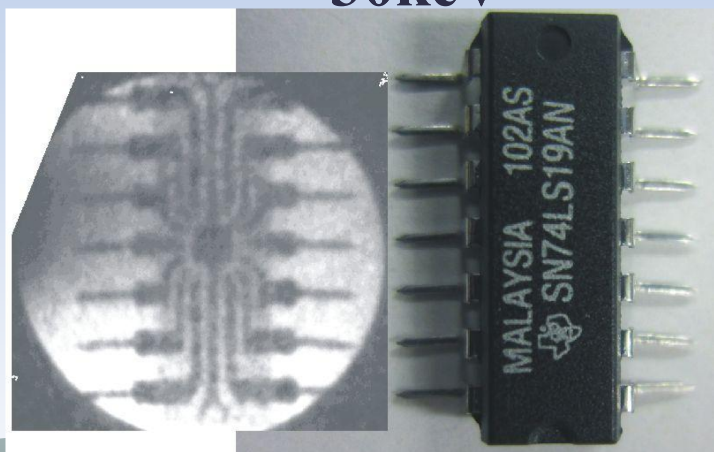


X-ray yield
1447photons/train
at detector on Oct.
2.1×10^5 photons/sec
at 12.5Hz operation

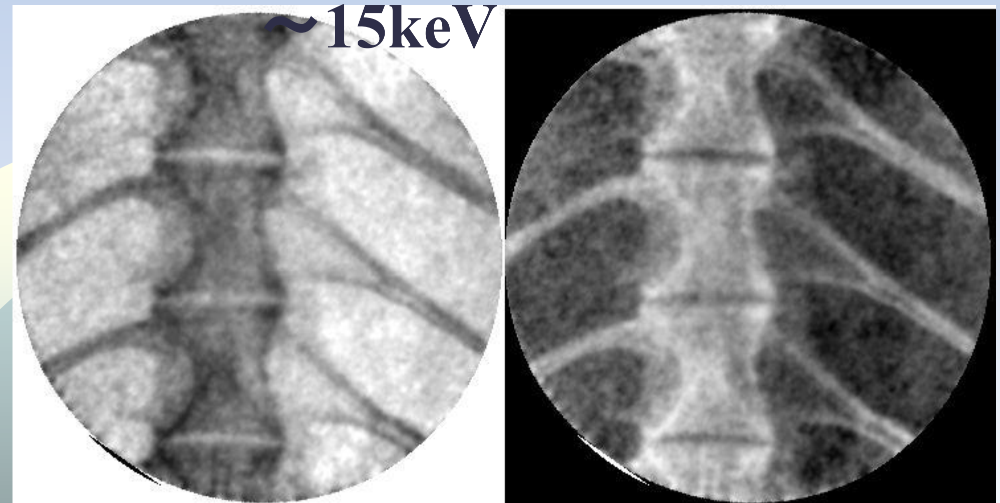


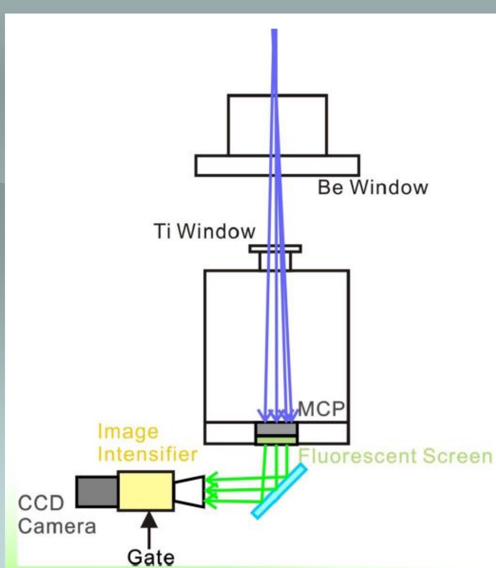
X-ray Imaging by I-MCP+I.I. and SOI
Phase contrast X-ray imaging is next step at LUCX.

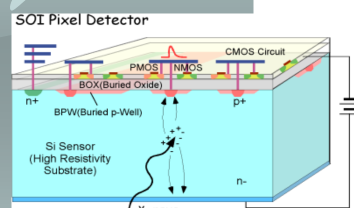
～30keV

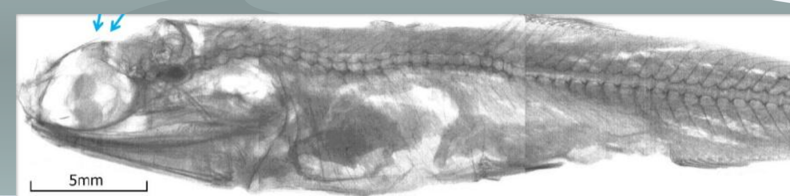


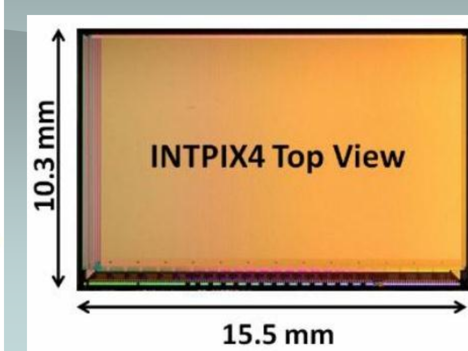
～15keV

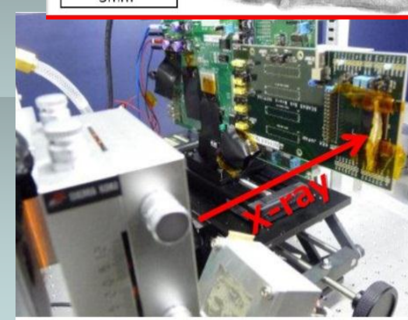








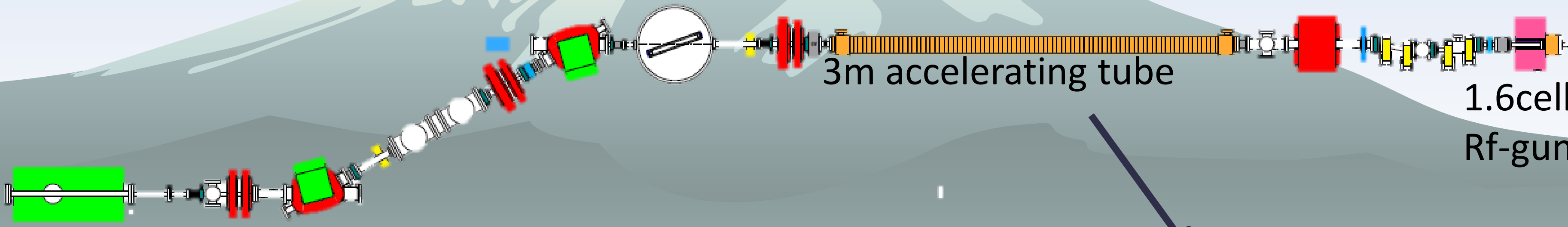


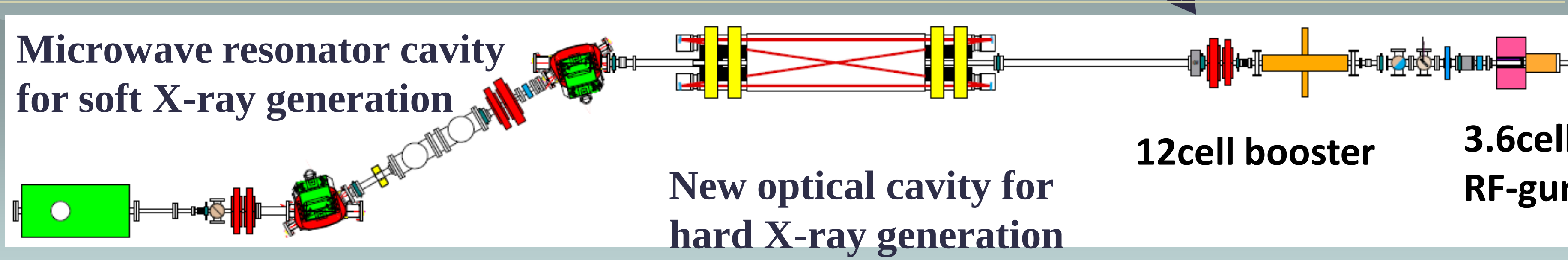


X-ray Imaging by SOI Pixel Detector

Future plan for LUCX accelerator

- To downsize the accelerator, we have planed to install a 3.6cell rf-gun and a 12cell booster.
  - 3.6cell rf-gun
    - Beam test has been started from Jan 2012.
  - 12cell booster
    - This booster is installed now.

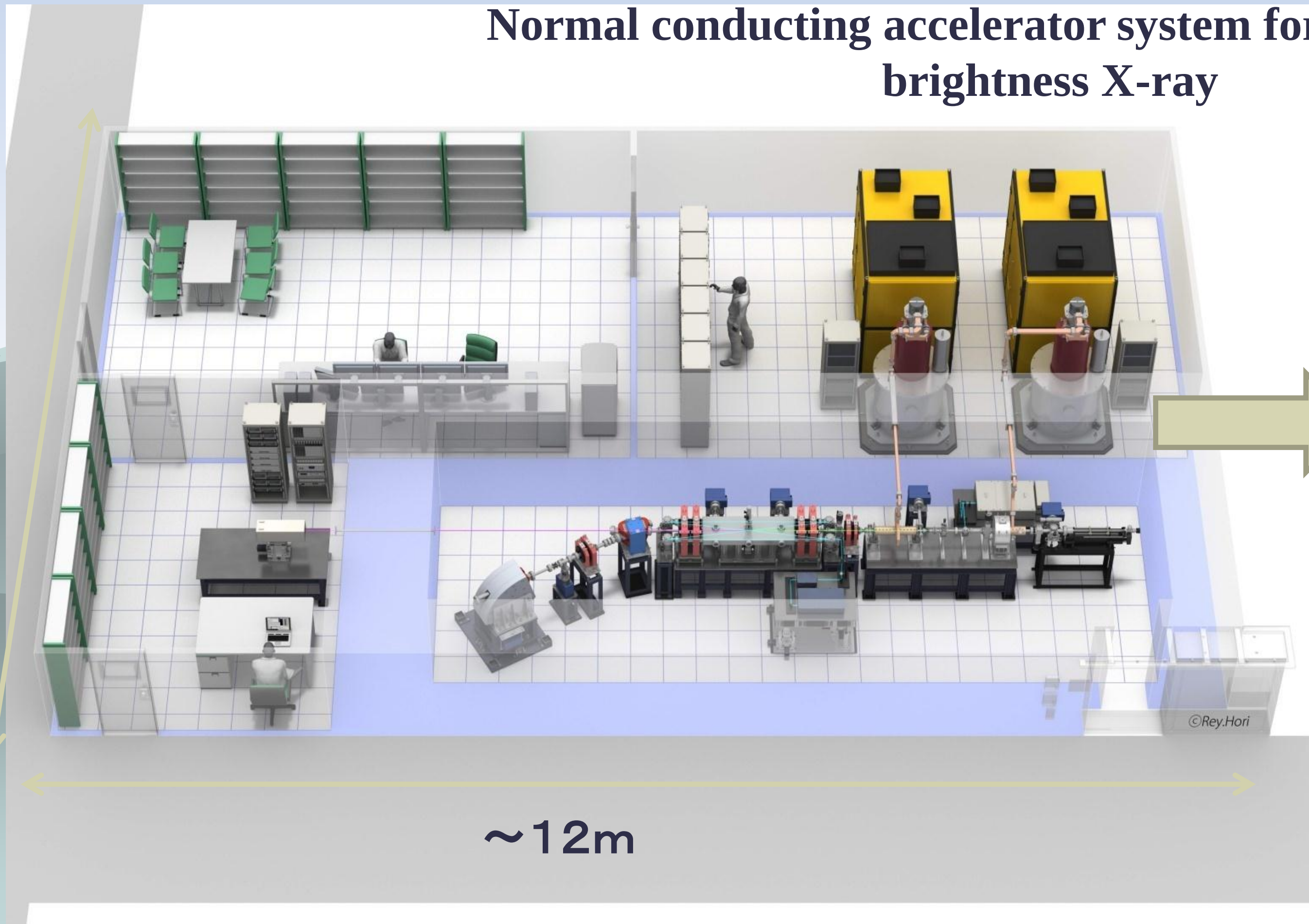




New Quantum Beam Technology Program(QBTP) supported by MEXT from 2013.4 to 2018.3 (5 years project)

Approved project should include two Japanese Companies at least and the development for CW super conducting acceleration technologies. Normal conducting accelerator system and super conducting accelerator system for compact high brightness X-ray source should be realized by joint research with companies.

Normal conducting accelerator system for compact high brightness X-ray



~8m

~12m

Downsizing to 6m x 8m

Demonstration experiment for ERL

Compact ERL is to use laser Compton γ-ray generation and it's application

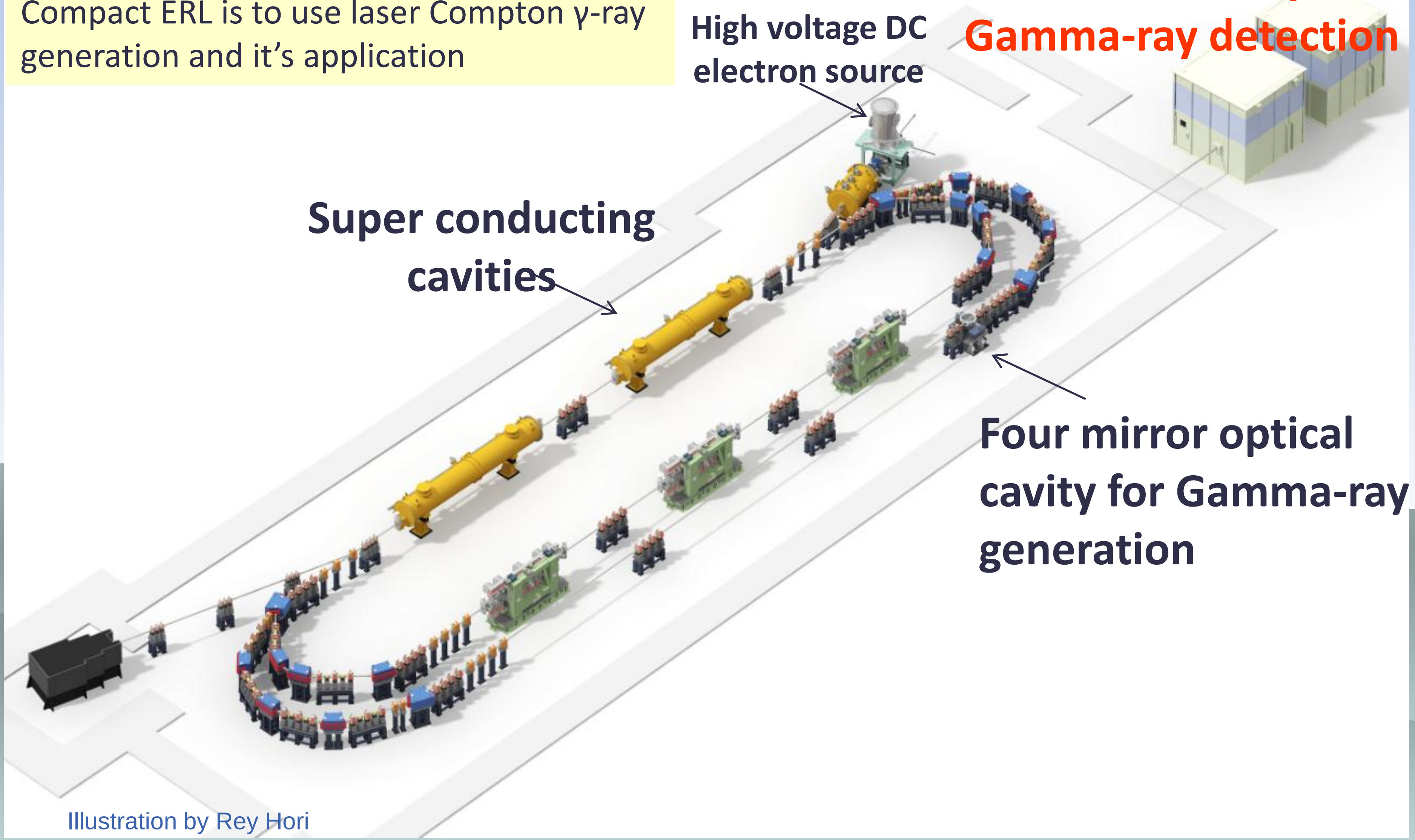


Illustration by Rey Hori