Waseda University

KEK

Refraction Contrast Imaging via Laser-Compton X-ray Using Optical Storage Cavity

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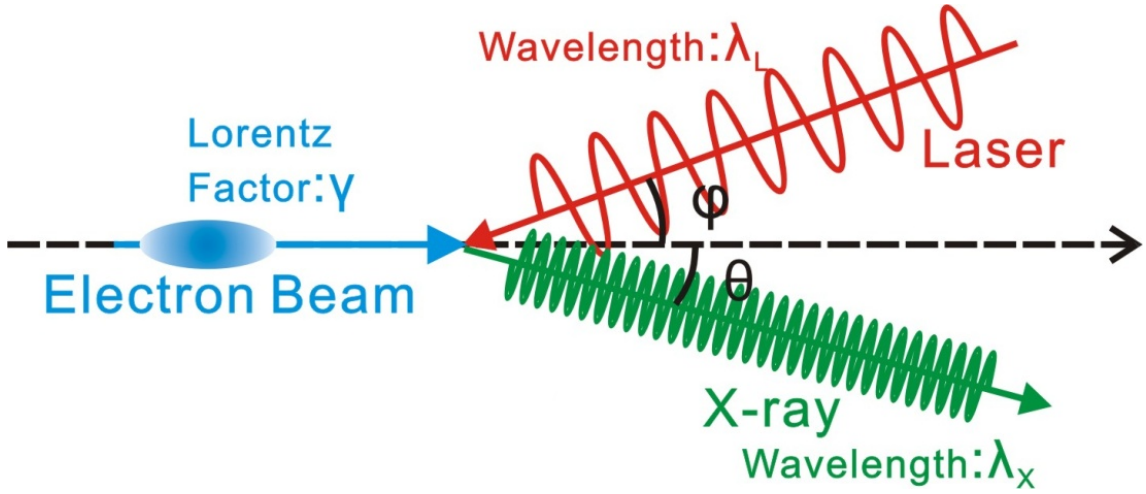
Laser-Compton Scattering

Laser-Compton Scattering



$$E_X = \frac{2\gamma^2 \cdot hc}{\lambda_L /(\cos\phi + 1/\beta)}$$

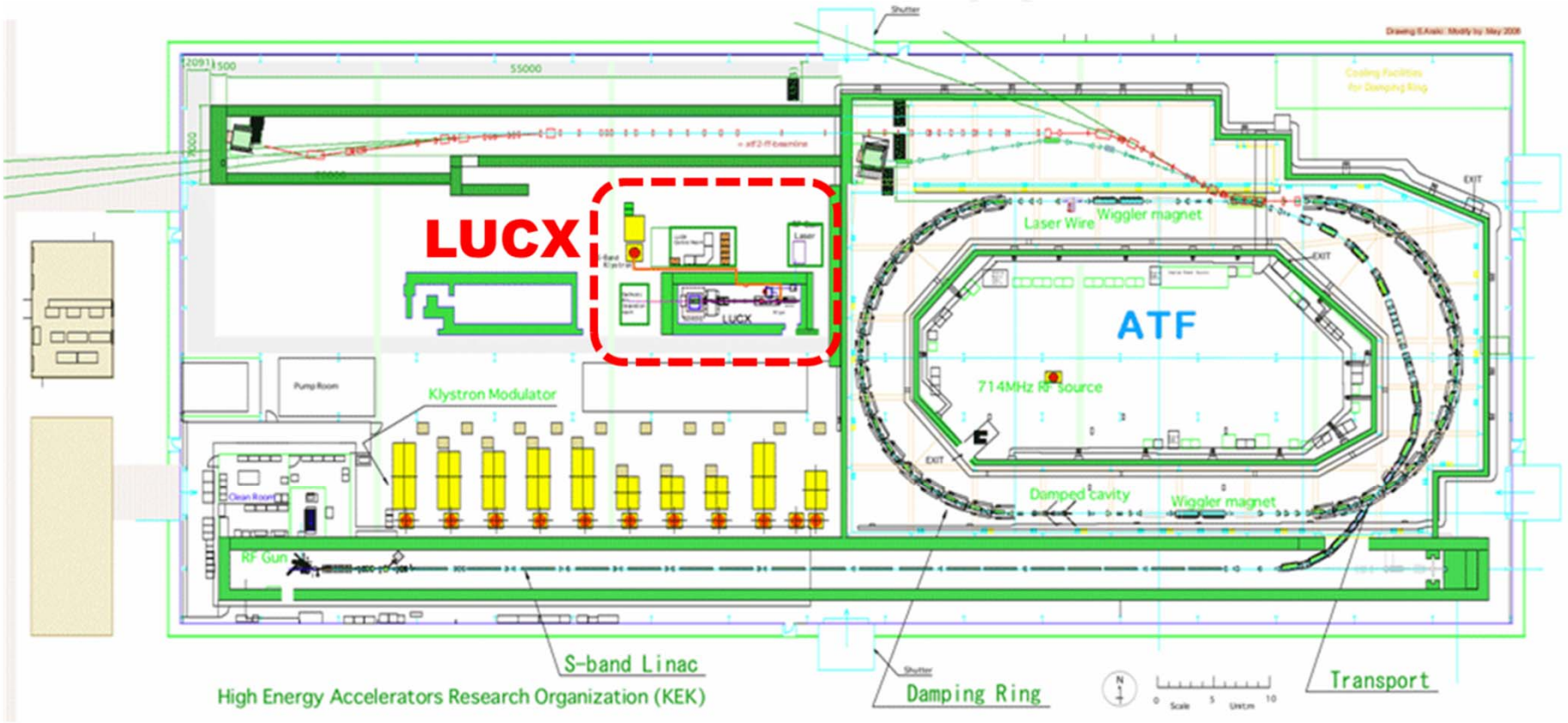
Undulation period is ~1μm

High energy photon is produced with small accelerator system

LUCX Location

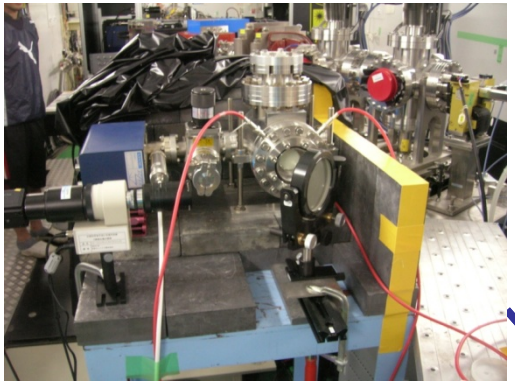
LUCX accelerator location

In the KEK-ATF building



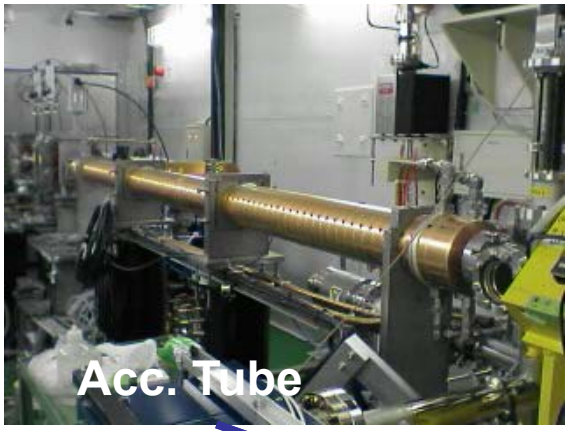
LUCX Experimental Setup

LUCX Accelerator

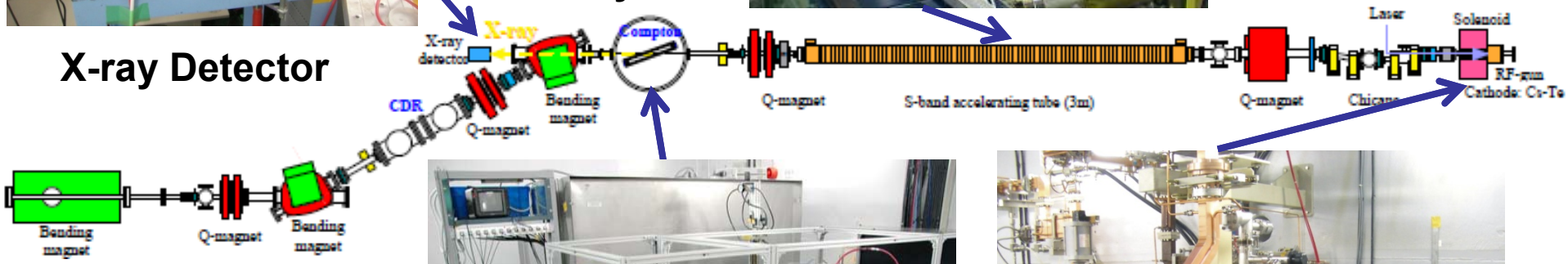


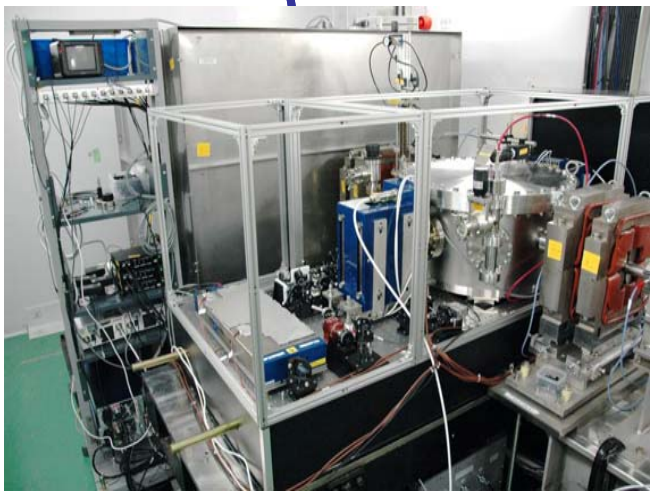
X-ray Detector

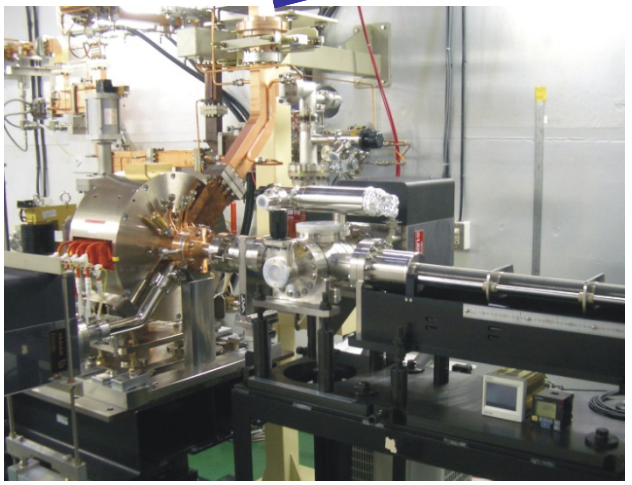
Laser Storage Cavity



Photocathode rf-gun



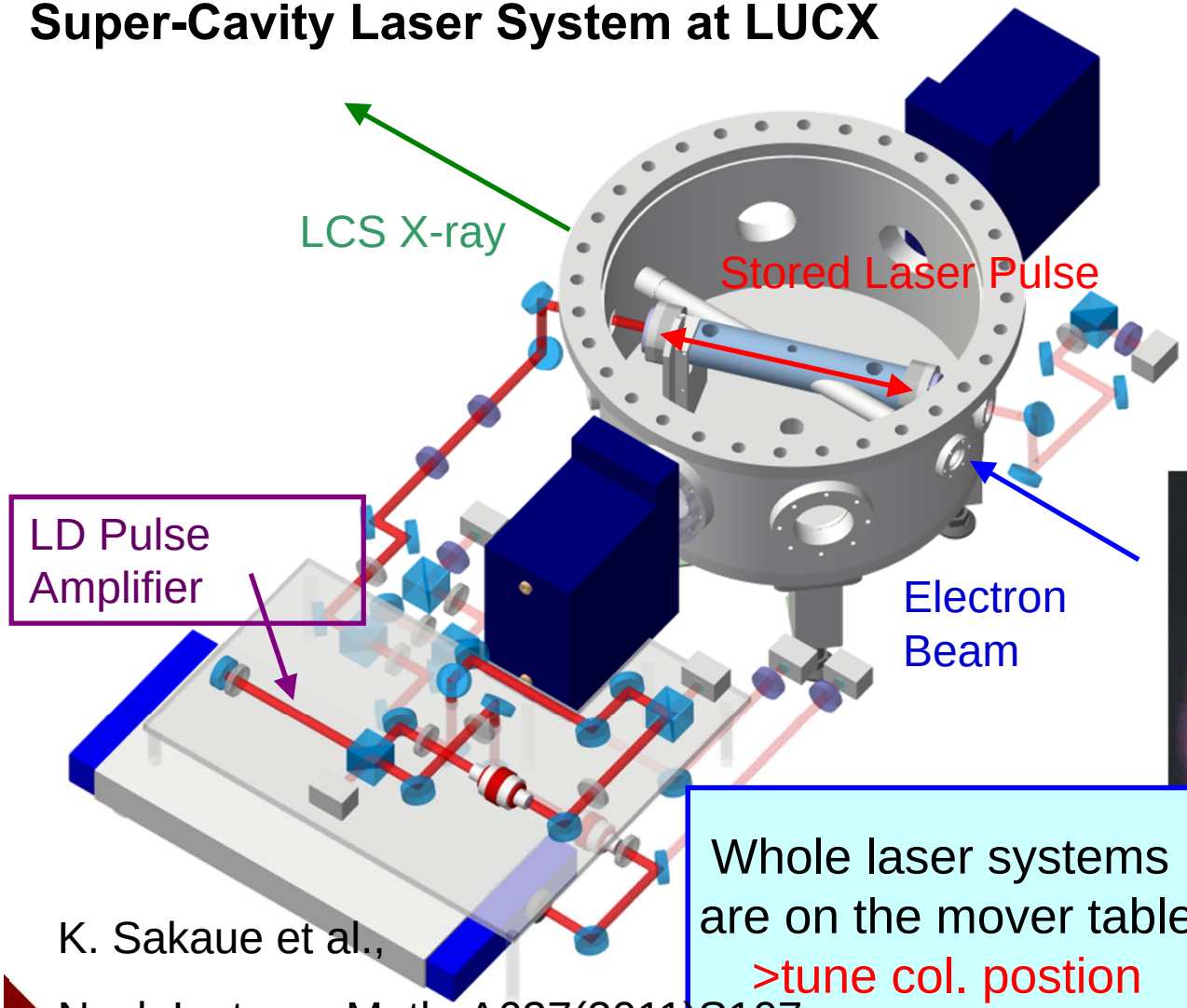


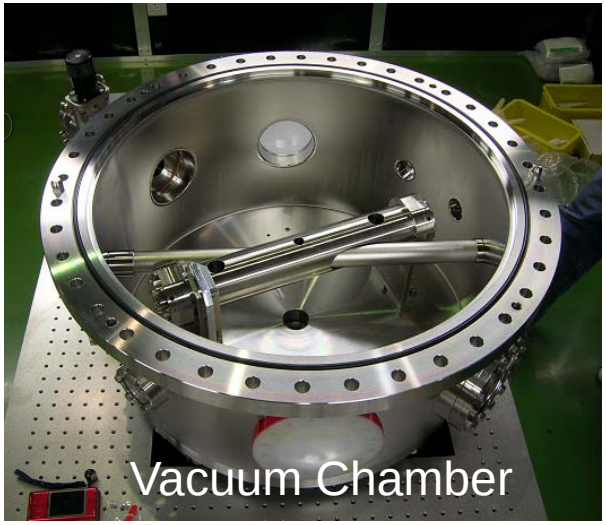


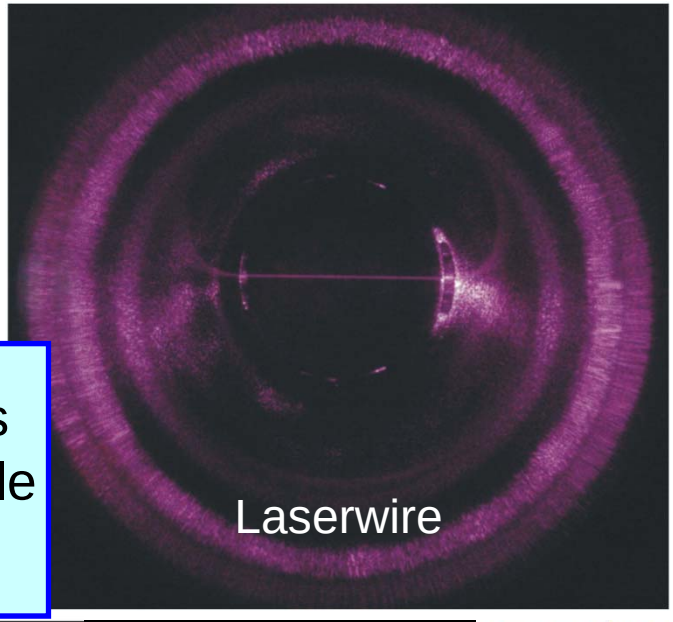
Electron Beam
30/40MeV
400pC/bunch
100bunch/train

Laser Storage Cavity System

Super-Cavity Laser System at LUCX







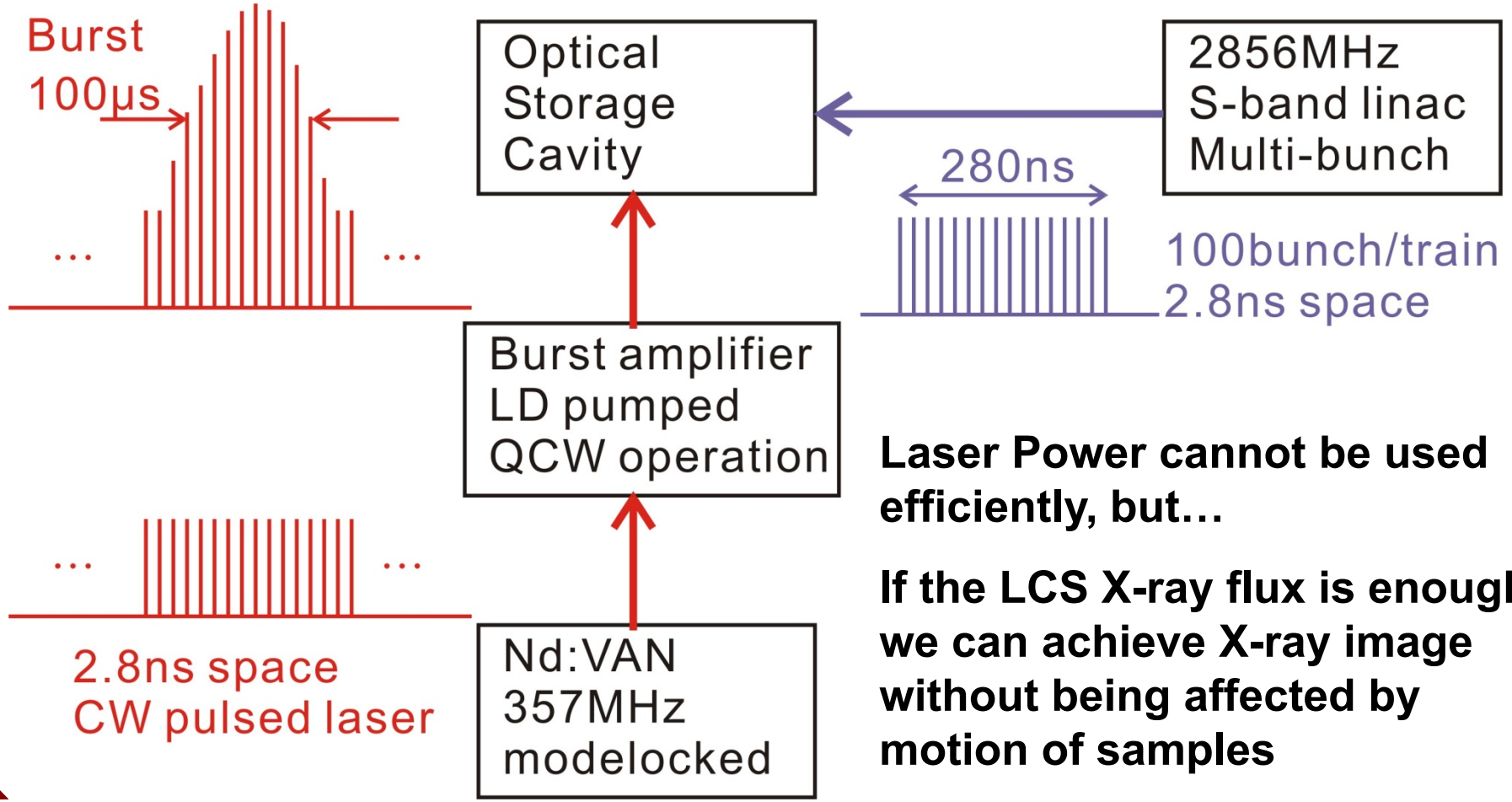
Whole laser systems are on the mover table
>tune col. postion

K. Sakaue et al.,
Nucl. Instrum. Meth. A637(2011)S107

Burst operation of optical cavity

Burst operation of optical cavity

>suitable for S-band pulsed Linac



Laser Power cannot be used efficiently, but…

If the LCS X-ray flux is enough, we can achieve X-ray image without being affected by motion of samples

Electron-Laser Parameters

Electron Laser Parameters at Interaction Point

Electron Beam			Laser		
Energy	Charge	N Bunch	Wavelength	Pulse Energy	
30/40MeV	400pC	100bunch/train	1064nm	400μJ/pulse	
Beam size (H)	Beam size (V)	Bunch length	Waist size	Pulse duration	Col. Angle
200μm (1σ)	53μm (1σ)	4.3ps (rms)	30μm (1σ)	3ps (rms)	20deg
Bunch space	Repetition		Pulse rep.	Burst rep.	
2.8ns	12.5Hz		2.8ns	12.5Hz	

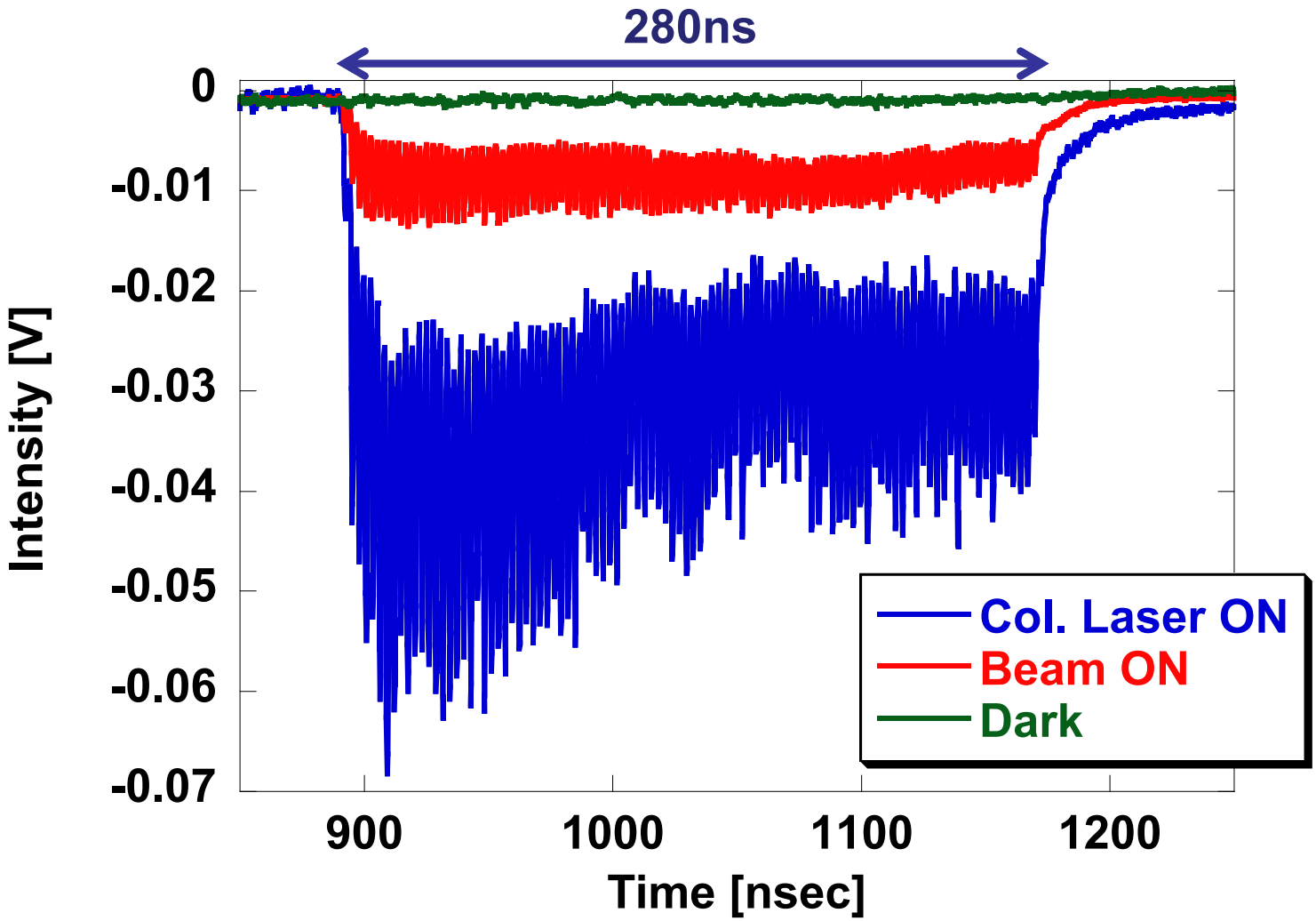
Electron Energy: 30MeV X-ray Energy >15keV X-ray

40MeV >28keV X-ray

LCS Signal by MCP

Raw waveform of MCP

K. Sakaue et al., RSI 80(2009)123304



LCS Signal by MCP

X-ray flux by MCP observation

1.8×10^4Photon/10%b.w.

- **> 1.6×10^4Photon/train**
- **> 2.1×10^5Photon/sec in Total bandwidth**

(Calculated by MCP detection efficiency of 5%)

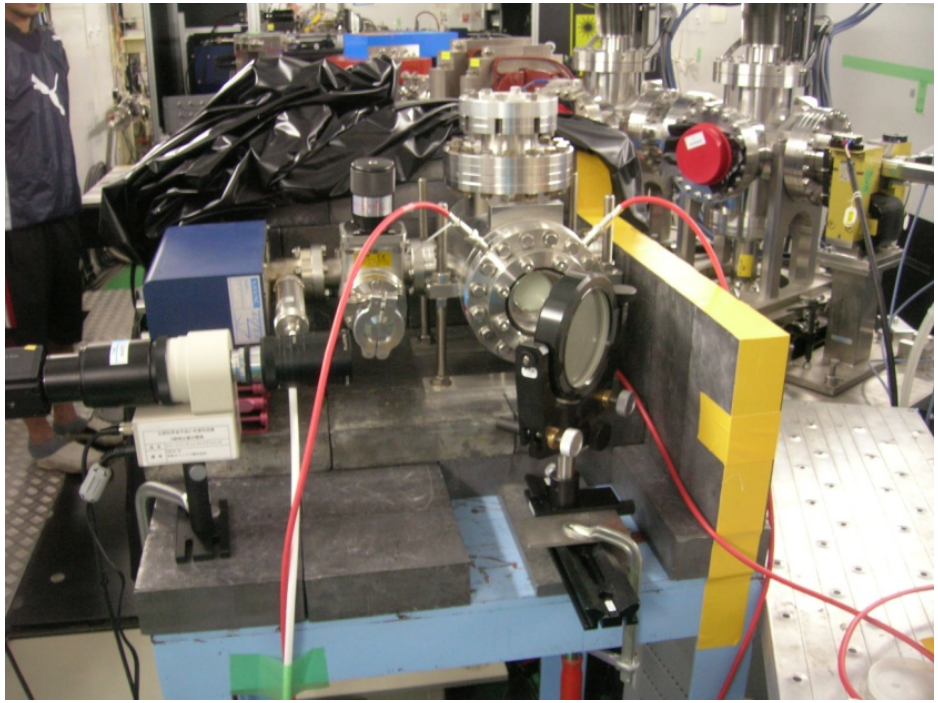
X-ray flux was not enough but…
Enough for X-ray imaging test by accumulating the images

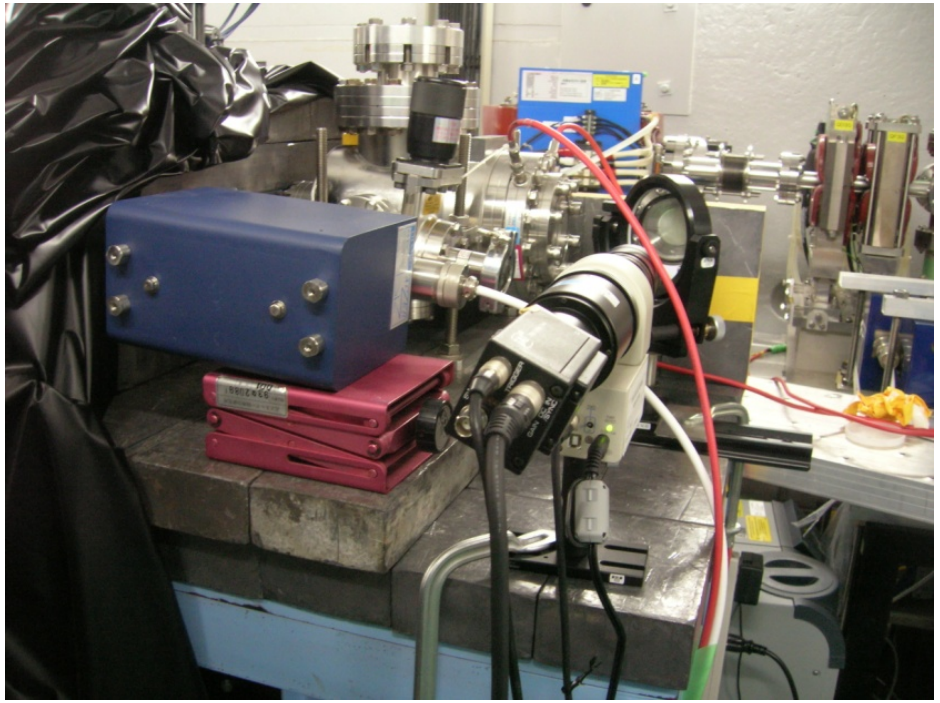
>move on to LCS X-ray imaging test

Imaging Setup

X-ray Imaging Setup

MCP with fluorescent screen + Image Intensifier





Imaging Setup

Properties of our imaging detector

Using MCP + fluorescent screen

>MCP was the highest S/N detector

Image Intensifier

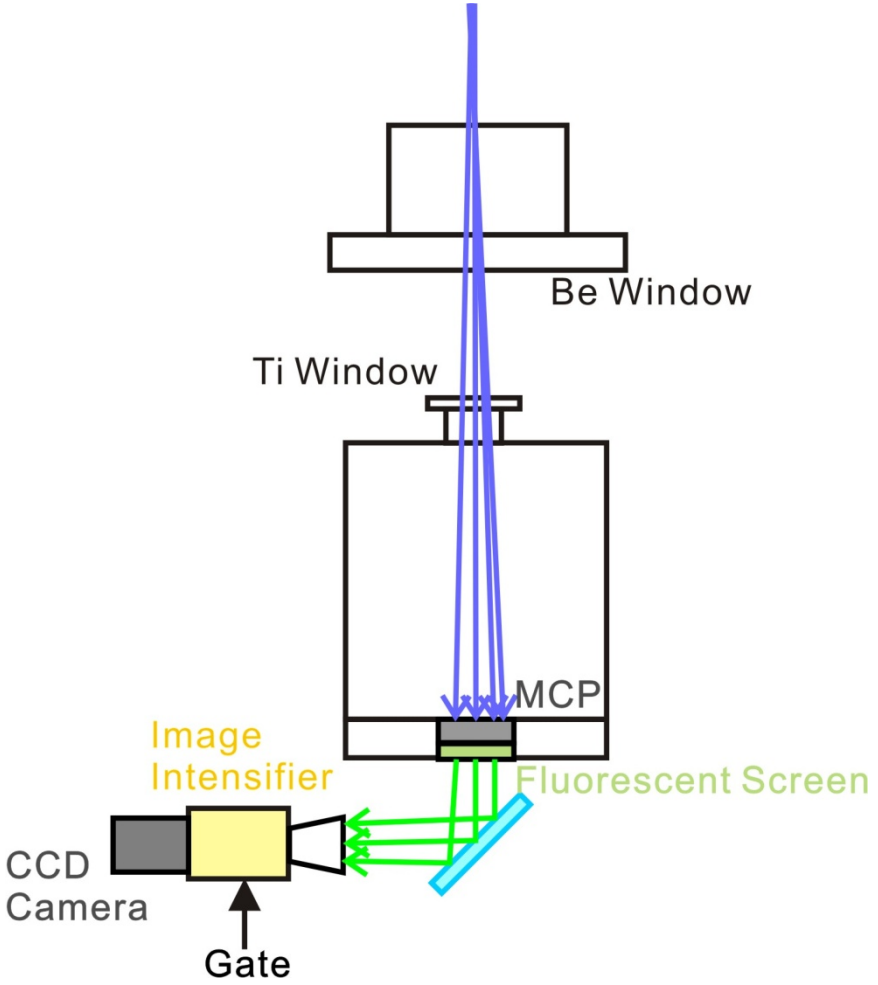
>apply the timing gate on X-ray beam

MCP and I.I

>amplify the X-ray signal (～10^9)

Disadvantage

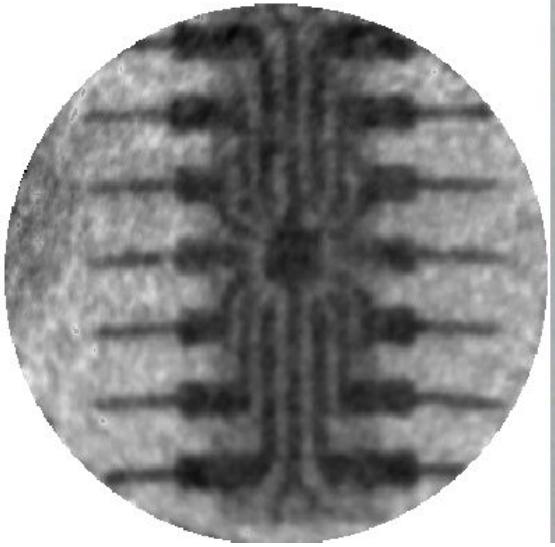
>Spatial resolution get worse

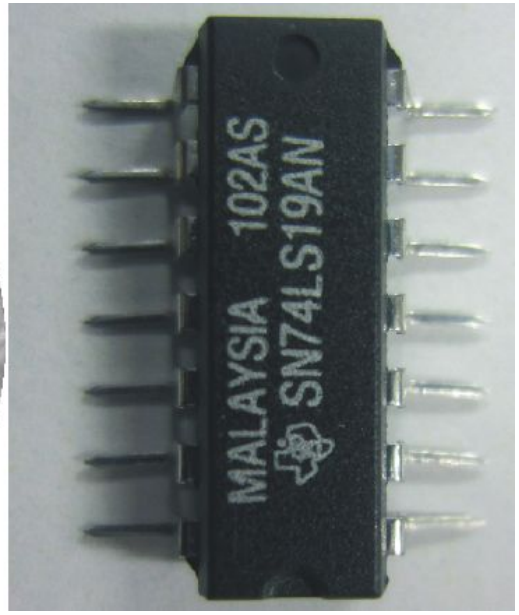


28keV Imaging Test by LCS

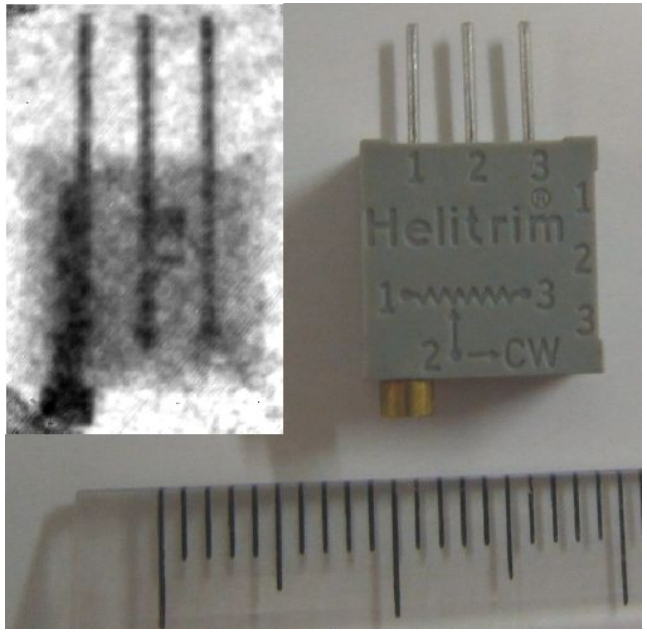
Imaging test by 28keV LCS X-ray

IC





Adjustable resister



15keV Imaging Test by LCS

X-ray see through image of peanut by 15keV LCS X-ray

15keV Imaging Test by LCS

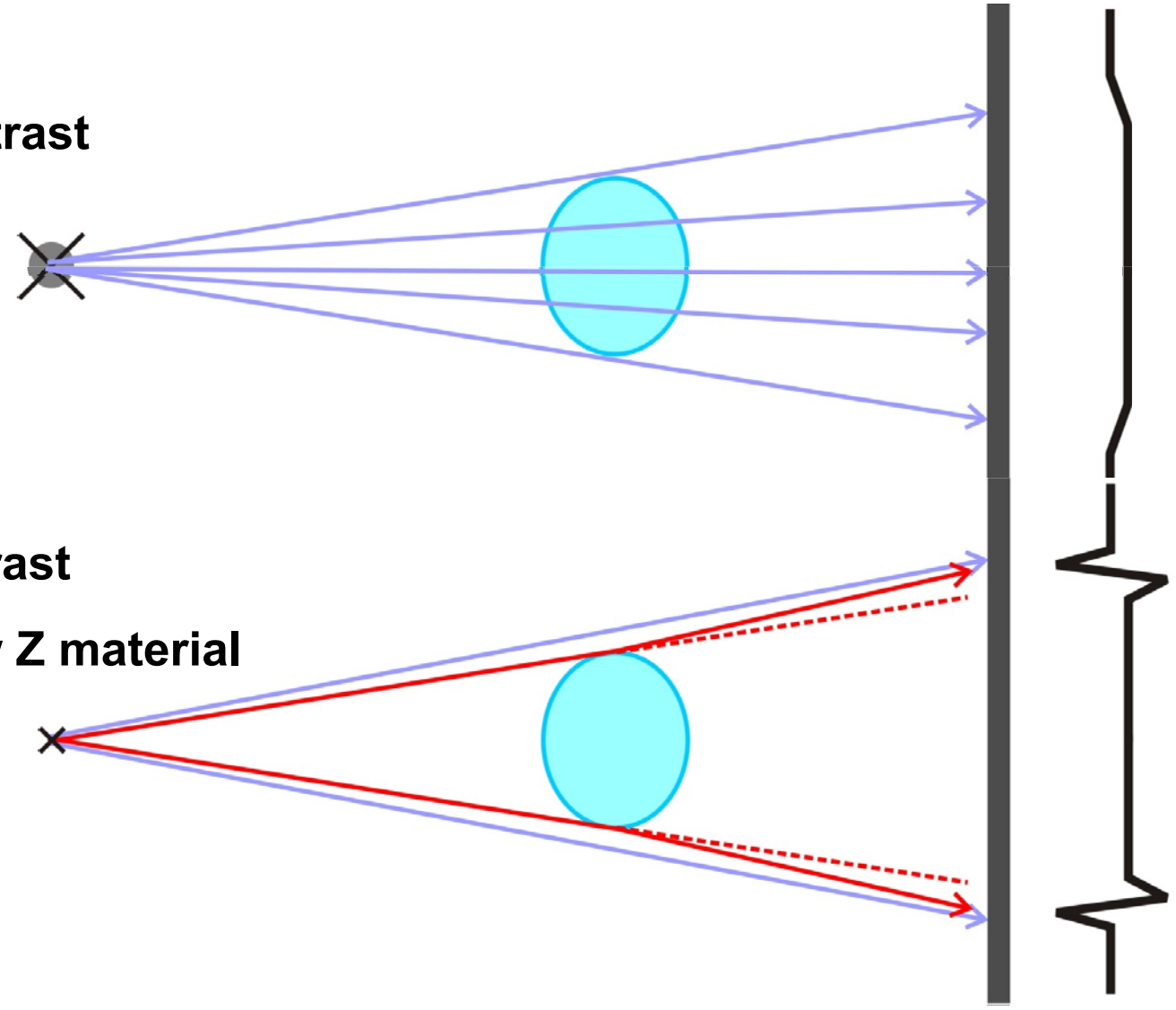
Fish backbone image by 15keV LCS X-ray

Accumulate 2700shot of images >Stable during 2700shot

Refraction Contrast

X-ray Imaging

Absorption Contrast

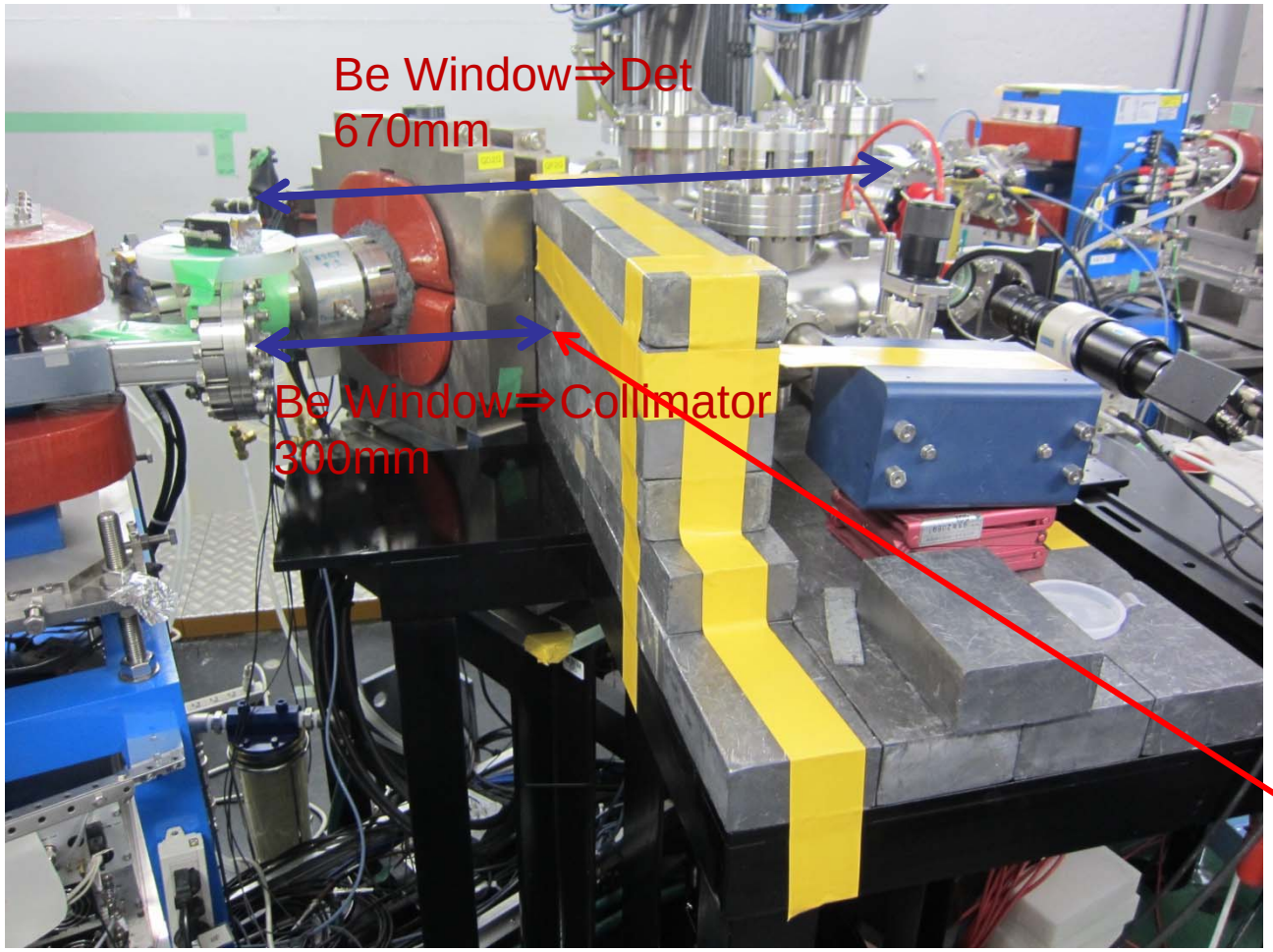


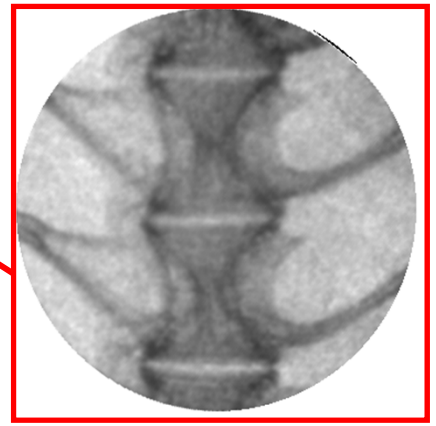
Refraction Contrast

>suitable for low Z material

Refraction Contrast

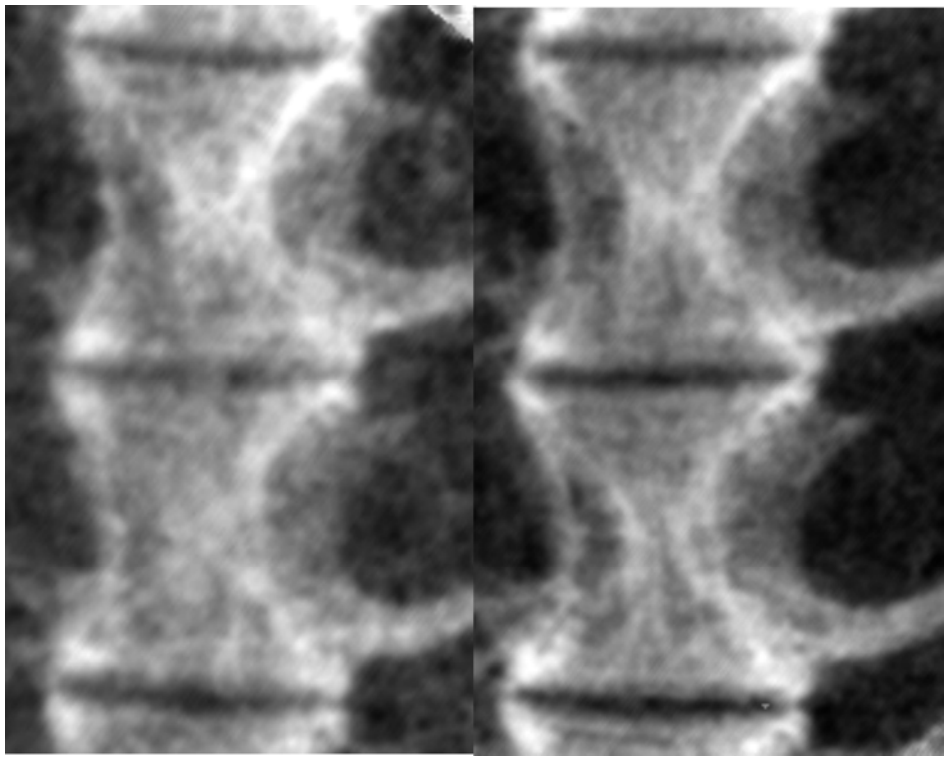
Setup of Refraction Contrast imaging test





Refraction Contrast Image

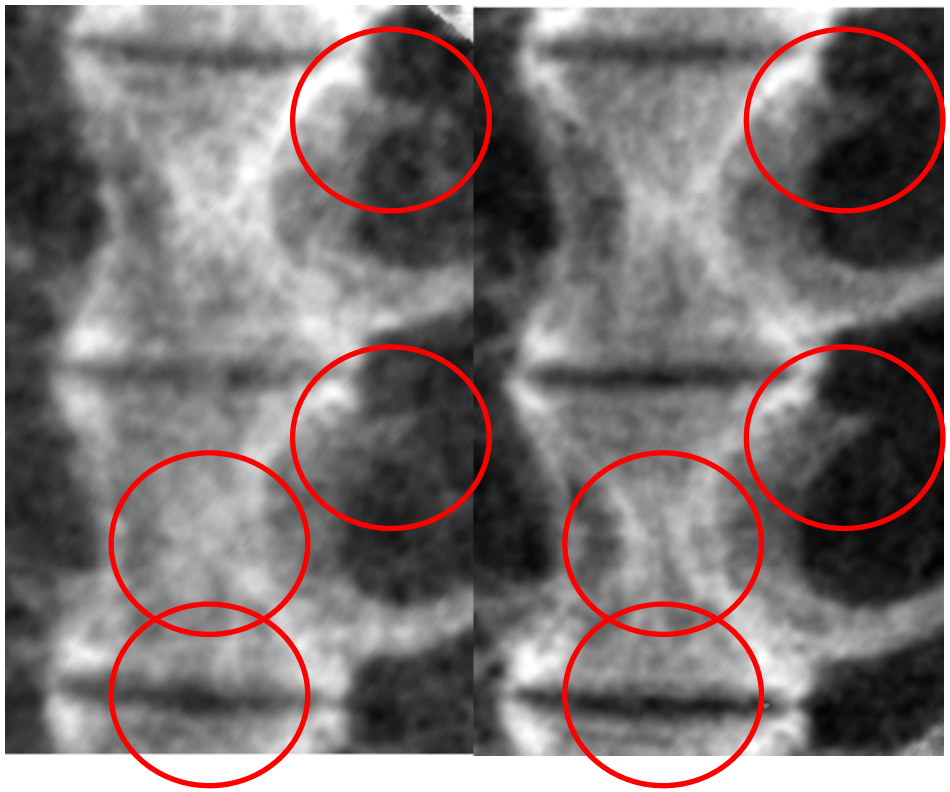
2 X-ray images by different distance from sample to detector



Distance **370mm** **670mm**

Refraction Contrast Image

2 X-ray images by different distance from sample to detector

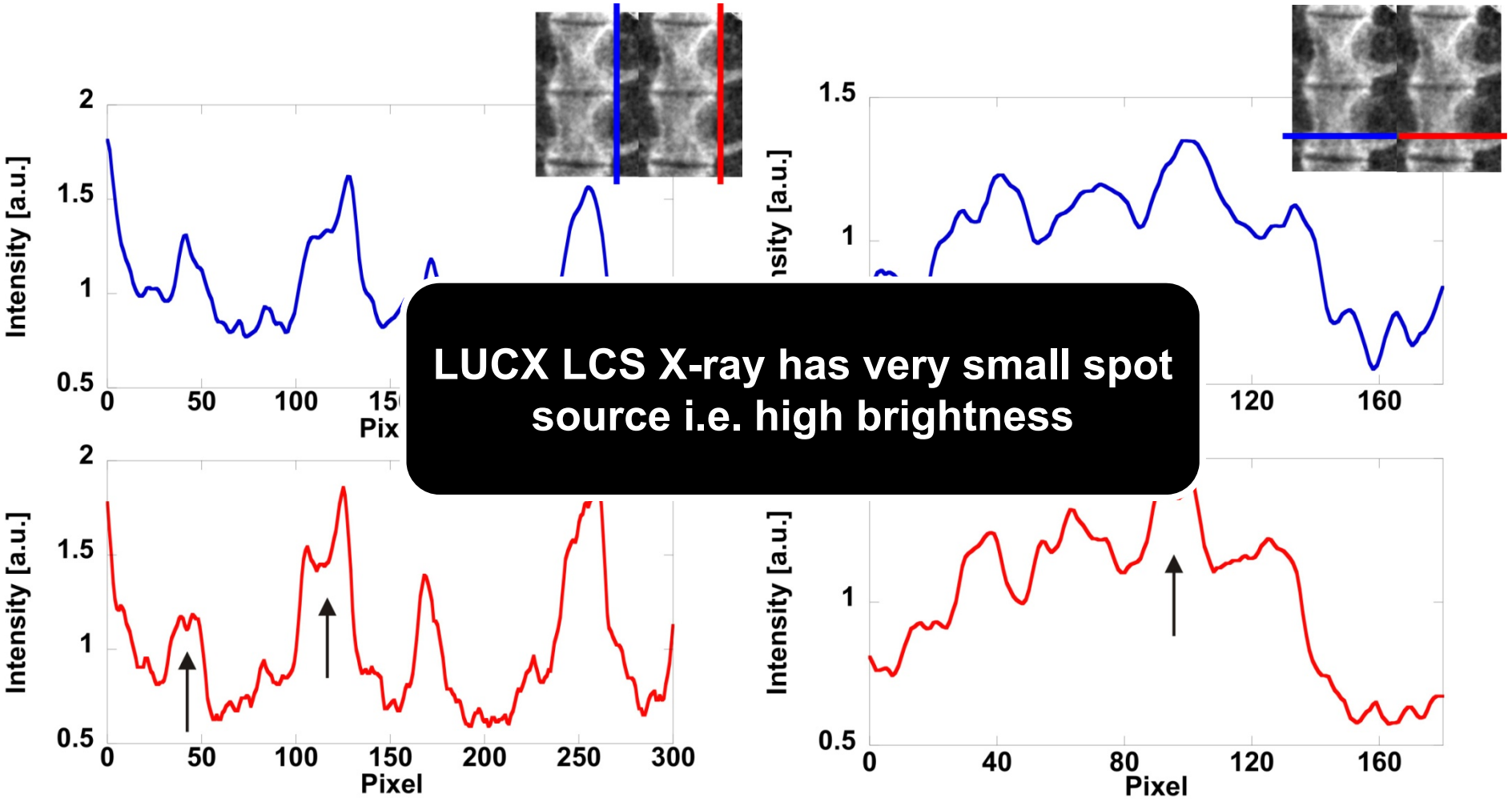


Distance **370mm** **670mm**

Large distance image (670mm) has large contrast

Refraction Contrast Image

Line profiles of each X-ray images



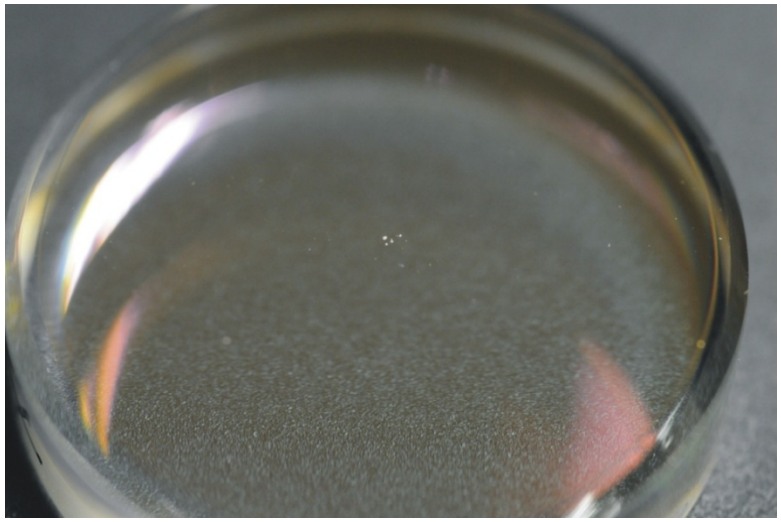
Mirror Damage Limitation

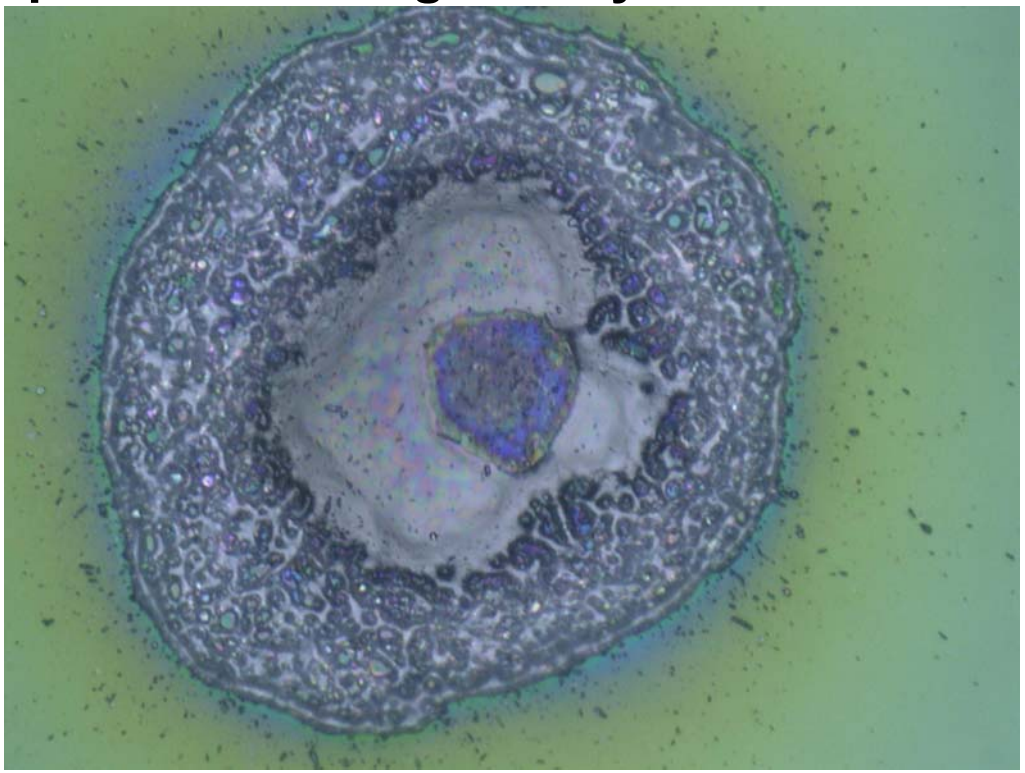
Limit of our LCS X-ray is by optical storage cavity mirror damage

~5GW/cm^2

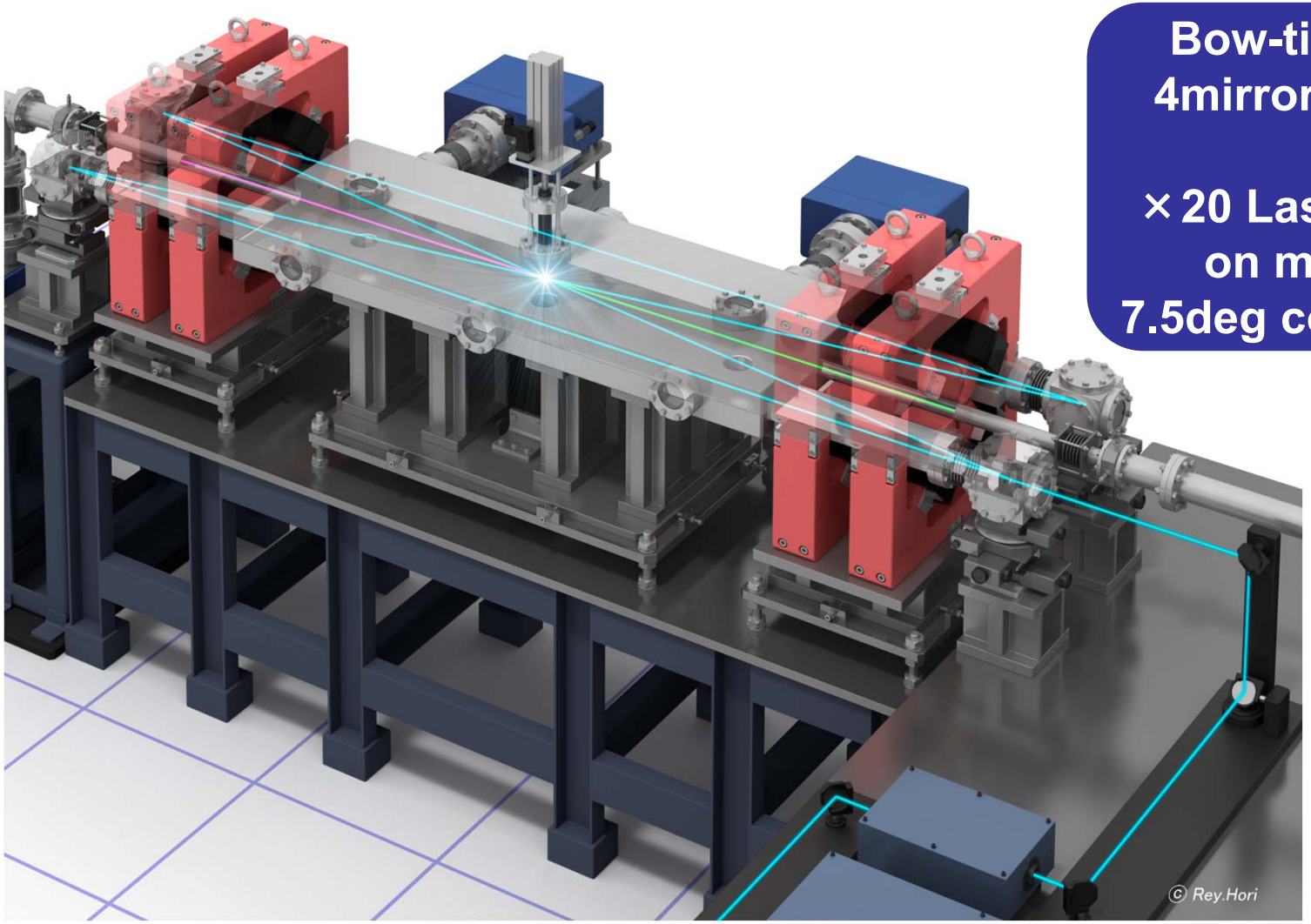
>~1mJ pulse energy with 1mm spot on mirror

We are now concentrating to improve the storage cavity





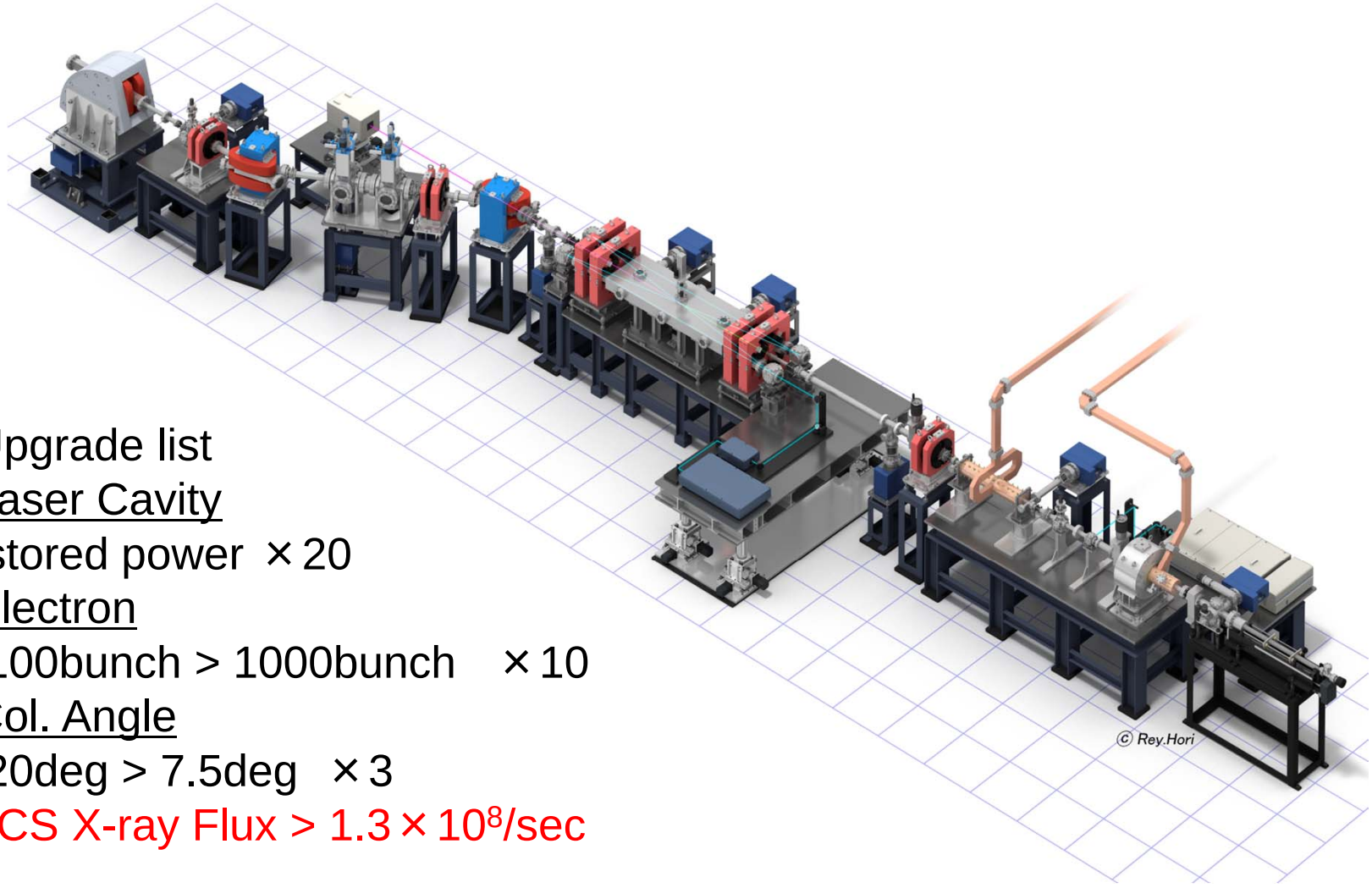
Upgrade Plan of LUCX Super-cavity



Bow-tie type 4mirror cavity

×20 Laser spot on mirror 7.5deg col. angle

Upgrade Plan of LUCX Super-cavity



Upgrade list

<u>Laser Cavity</u>

stored power ×20

<u>Electron</u>

100bunch > 1000bunch ×10

<u>Col. Angle</u>

20deg > 7.5deg ×3

LCS X-ray Flux > 1.3×10^8/sec

Summary

We are developing a Laser-Compton scattering X-ray source

using S-band linac system and optical storage cavity

X-ray flux is 2.1×10^5Photon/sec in Total bandwidth

We performed X-ray imaging test and refraction contrast observation

>refraction contrast was observed

>our LCS X-ray is “High brightness”

In this summer we will upgrade our LCS system

>X-ray flux :1.3×10^8/sec X-ray image can be obtained by several shots

Thank you for your attentions