A Short-Pulse Hard X-ray Source with Compact Electron LINAC via Laser-Compton Scattering for Medical and Industrial Radiography

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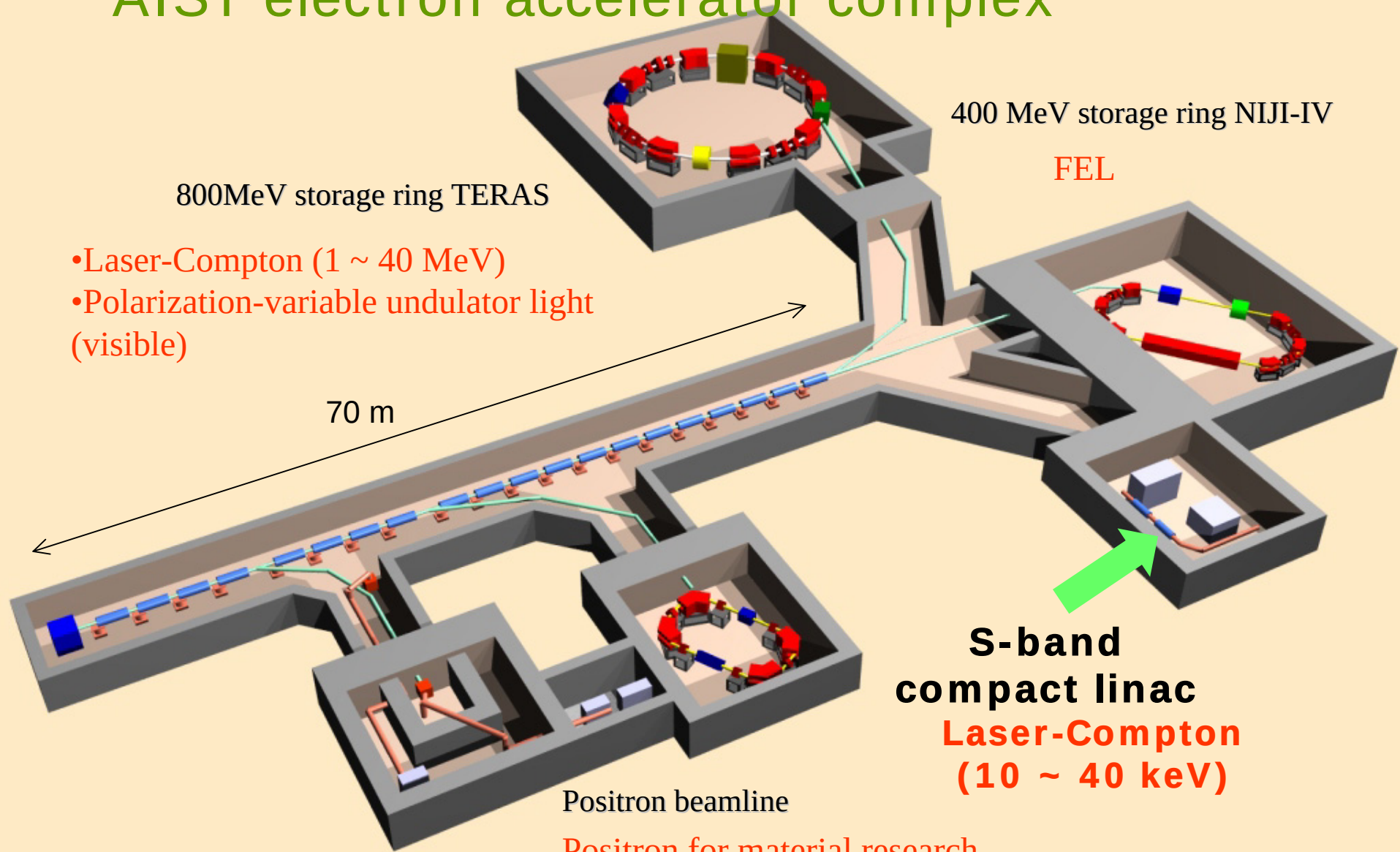
Introduction

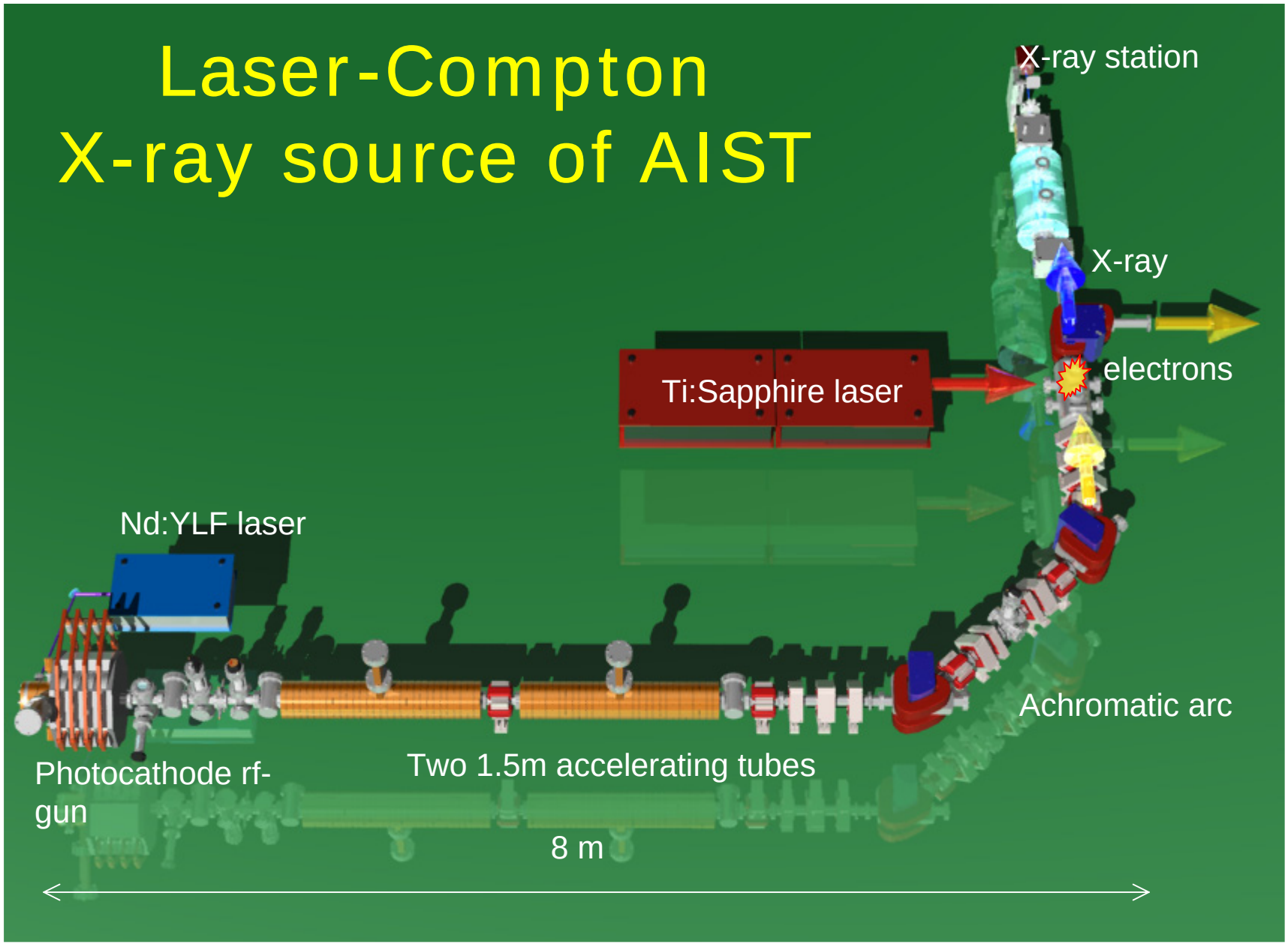
- Sumitomo Heavy Industries Ltd. and AIST, under the Femtosecond Technology Association (FESTA) have developed a laser-Compton x-ray source in FY2000, in the Femtosecond Technology Project.
- We succeeded to generate 150 fs x-ray pulse in FY2004.
- As the project is over in FY2005, it was moved to AIST Tsukuba for further improvements and modifications, in collaboration with users in physics, industries, and medical sciences.

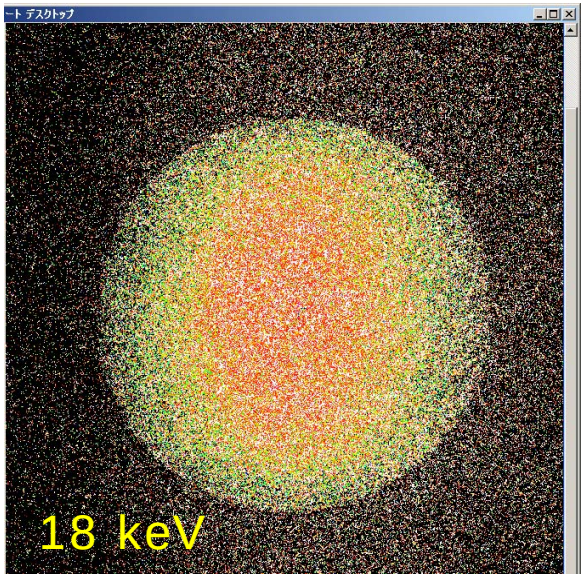
Description of x-ray source

AIST electron accelerator complex

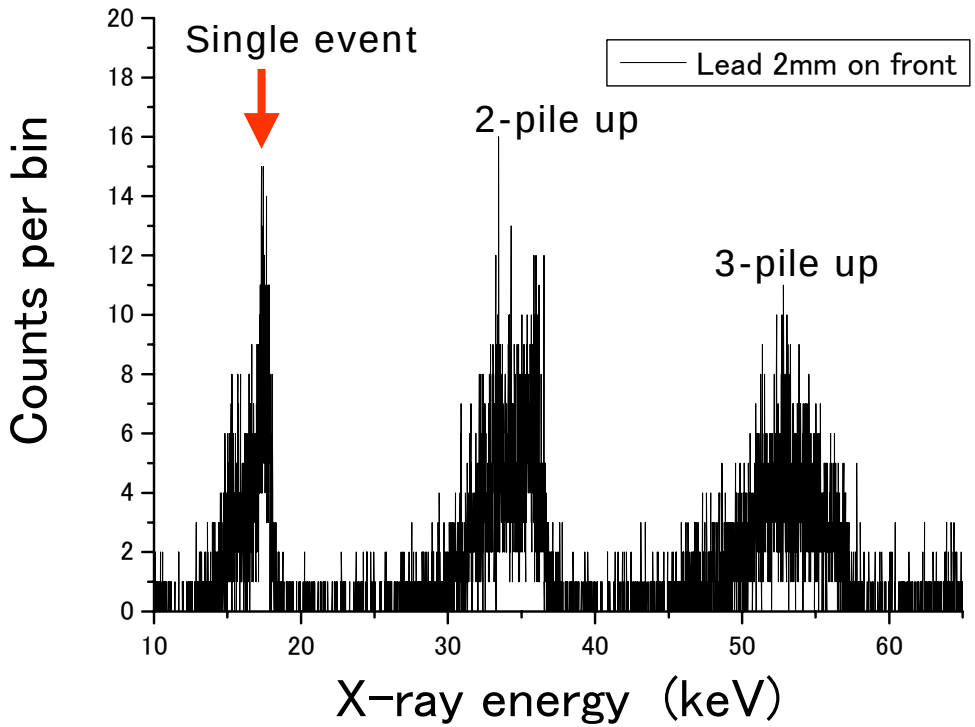


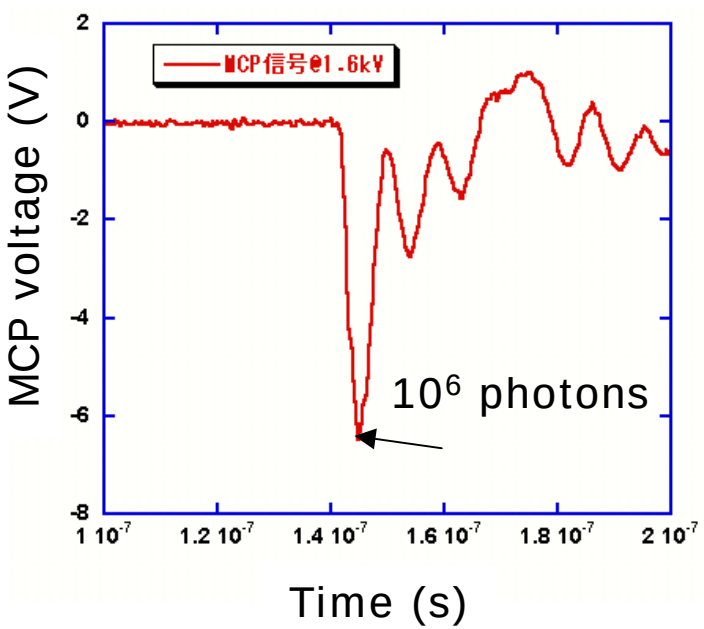
Laser-Compton X-ray source of AIST





Current status





Electron energy: 27.41 MeV
X-ray energy: 17.56±0.37 keV
Solid angle: 0.3 mrad

Specifications

Electron beam

Electron energy	20 ~ 40 MeV
Energy spread	0.2%
Bunch charge/bunch	0.8 nC
Bunch length (rms)	3 ps
Beam size (σ_x/σ_y)	40/30 μm

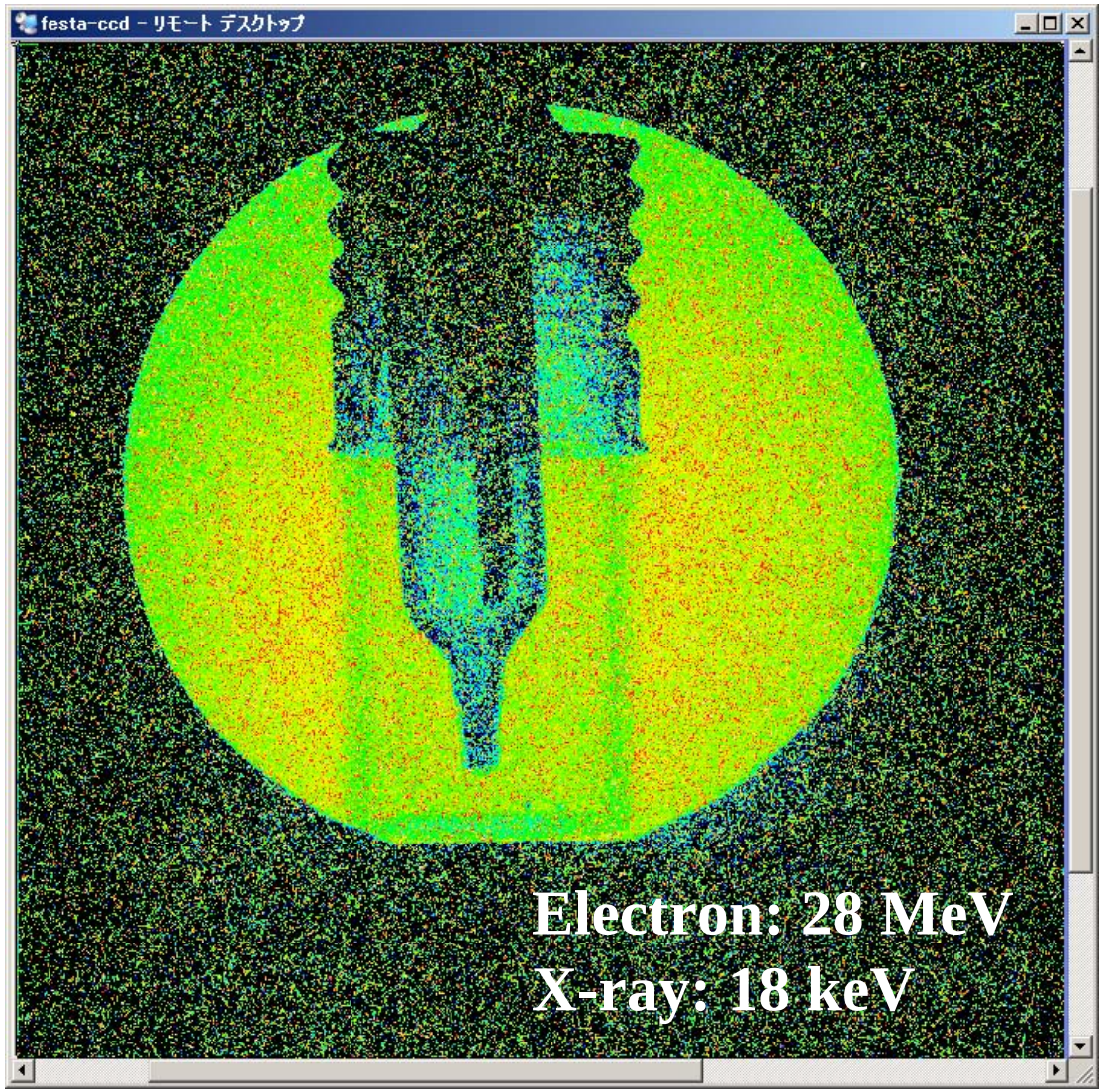
Ti:Sapphire laser

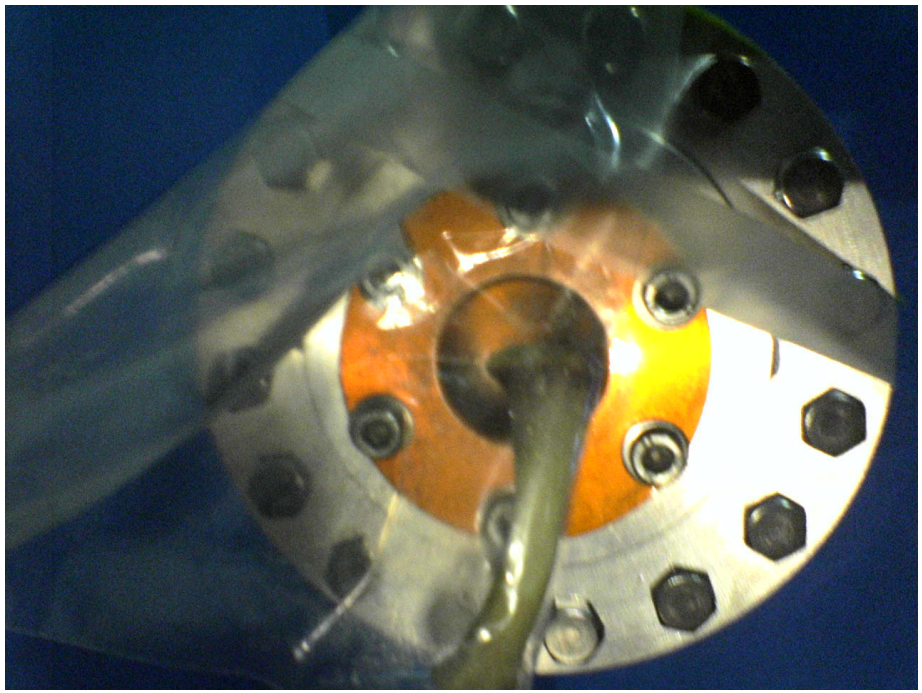
Wave length	800 nm
Energy/pulse	140 mJ
Pulse length (rms)	100 fs
Beam size (σ_x/σ_y)	30 μm

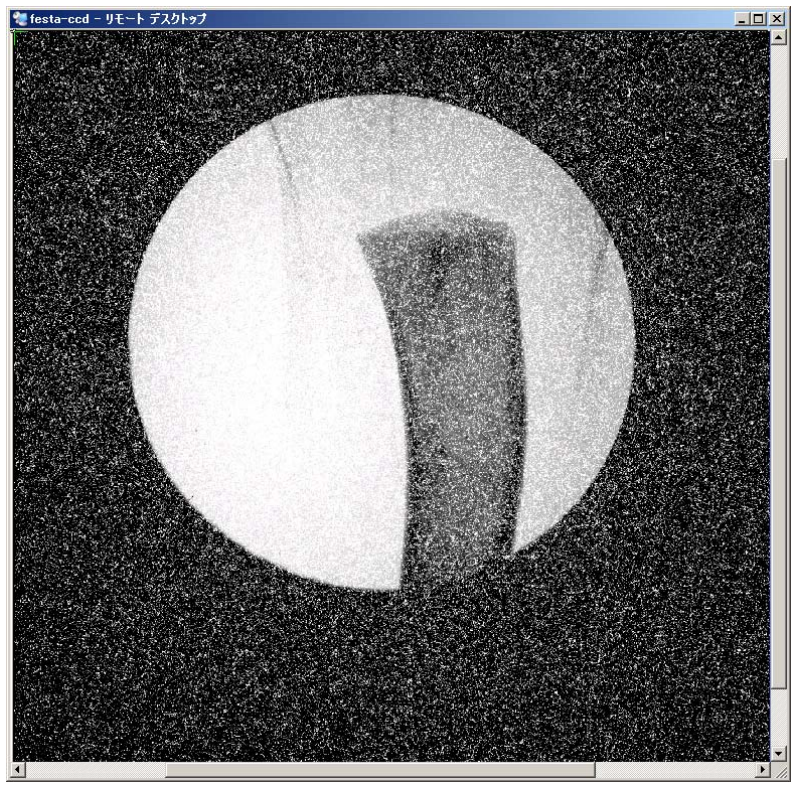
X-ray

Collision angle (ϕ)	photon energy	Pulse width (rms)	Number of Photons
90	20 keV	150 fs	~10^6 /s (max) @10Hz
165	10 keV ~ 40 keV	3 ps	~10^7 /s (max) @10Hz

Recent activities


festa-ccd - リモート デスクトップ
Electron: 28 MeV
X-ray: 18 keV



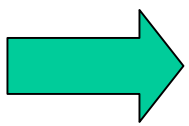


Electron: 30 MeV
X-ray: 21 keV

I don't know why, but most of the users say…

*"Very nice and unique x-rays, but will you increase **a bit**…?"*

a bit …



10^9 photon/s,

Two orders…

OK, let's do it.

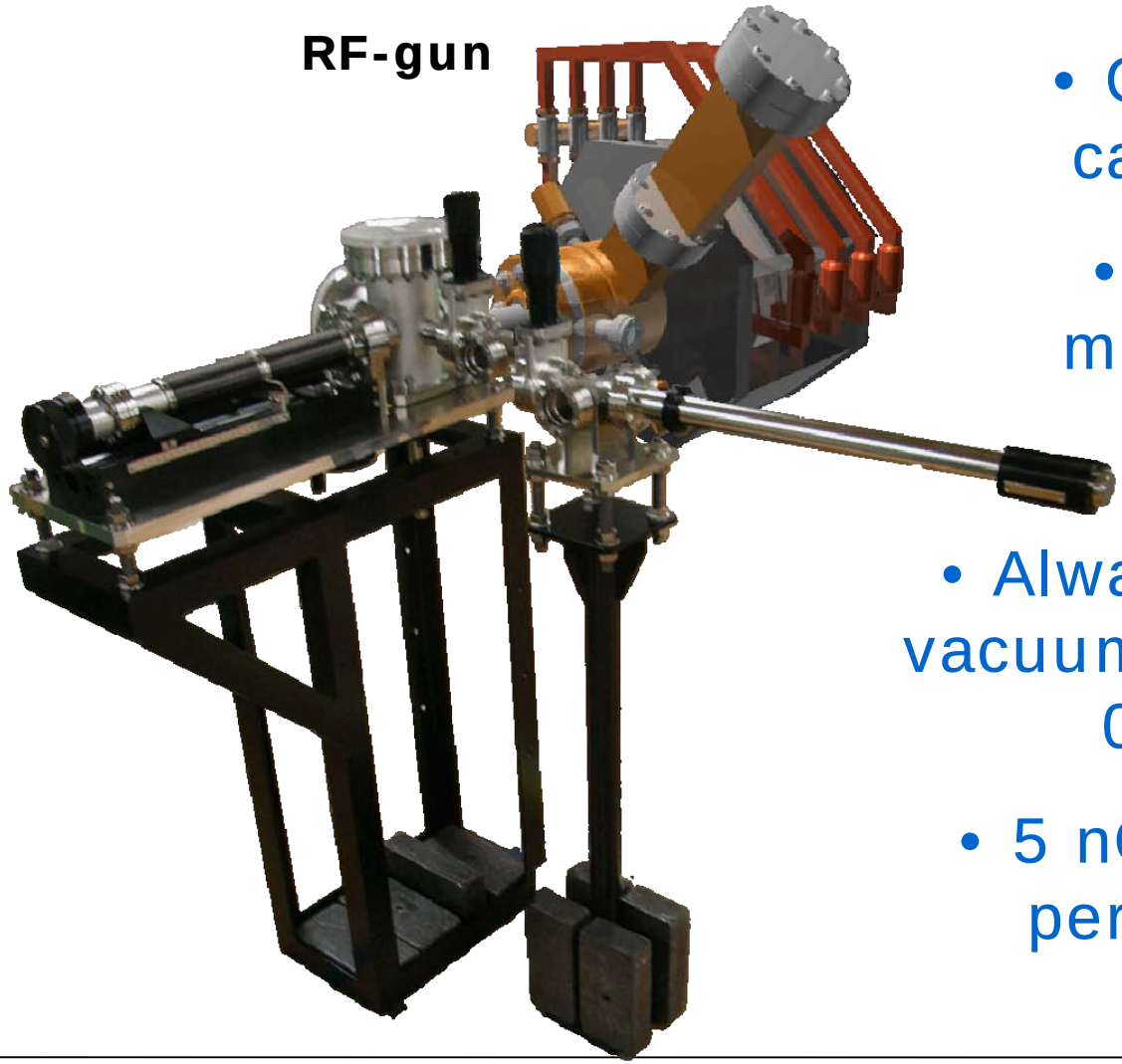
1. Generation of a high-charge electron bunch with Cs-Te cathode.

2. Multi-bunch generation and acceleration with beam loading compensation, and a multi-pulse UV laser development.

3. Picosecond-pulsed laser-Compton scattering within a cavity of a regenerative amplifier.

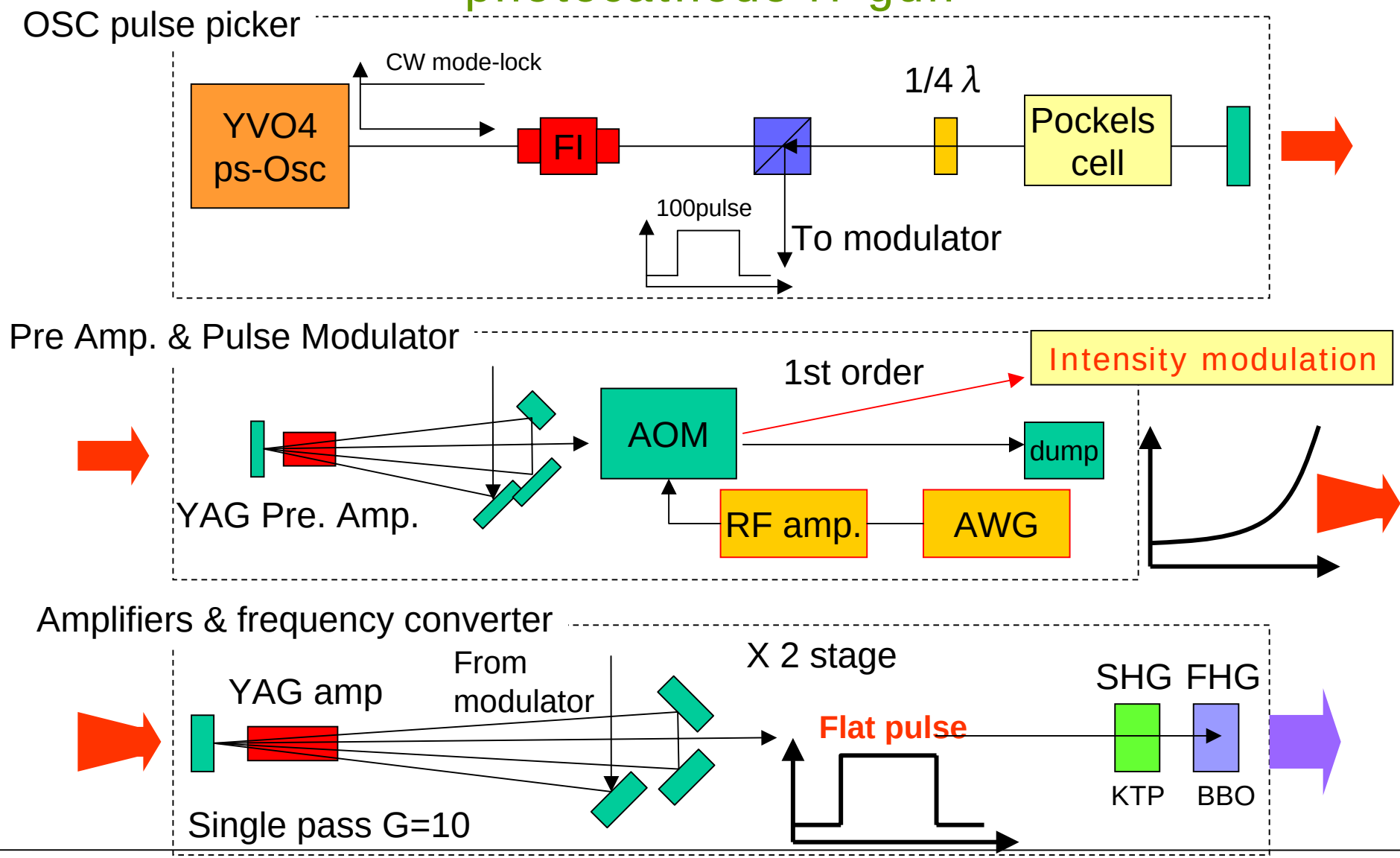
4. Strongly-focused electron beam at the collision point

A compact cathode load lock system



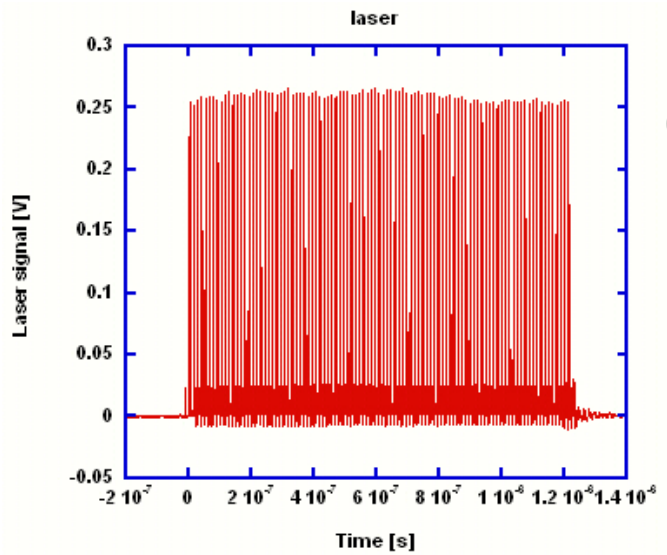
- Compact (guide to cathode 1 m or less)
- Various cathode medium (Cs-Te, etc.)
- Always keeps cathode in vacuum,(quantum efficiency 0.1% or higher)
- 5 nC per bunch, or 1nC per bunch times 100 bunches

Intensity pre-modulated multi-pulse laser for photocathode rf-gun

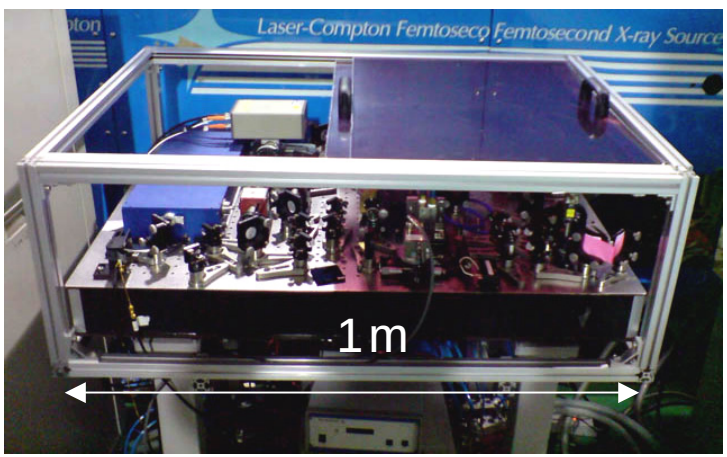


Multi-bunch electron beam

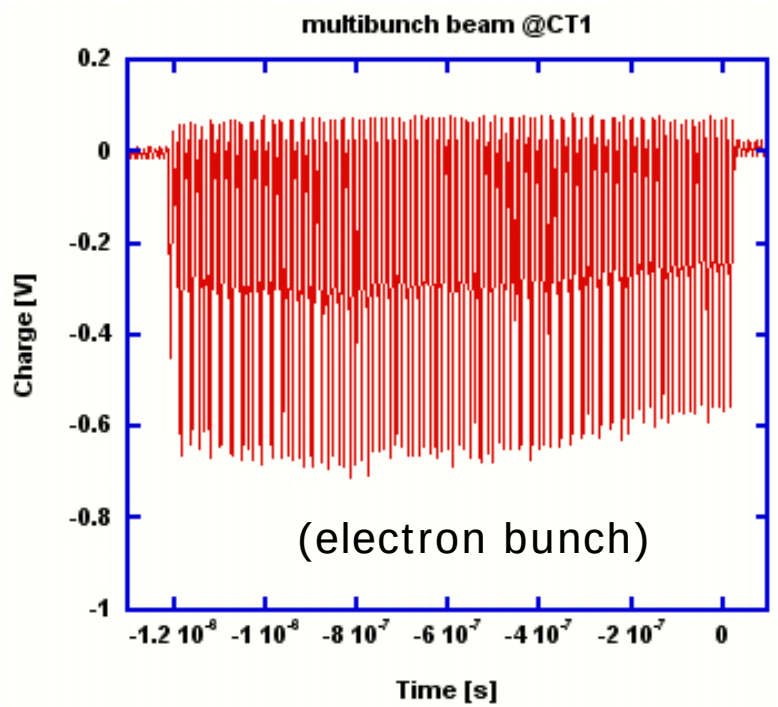
All solid LD pumped Nd:YVO4 laser, 8 μJ × 100 pulses/ macropulse@UV



(laser pulse)

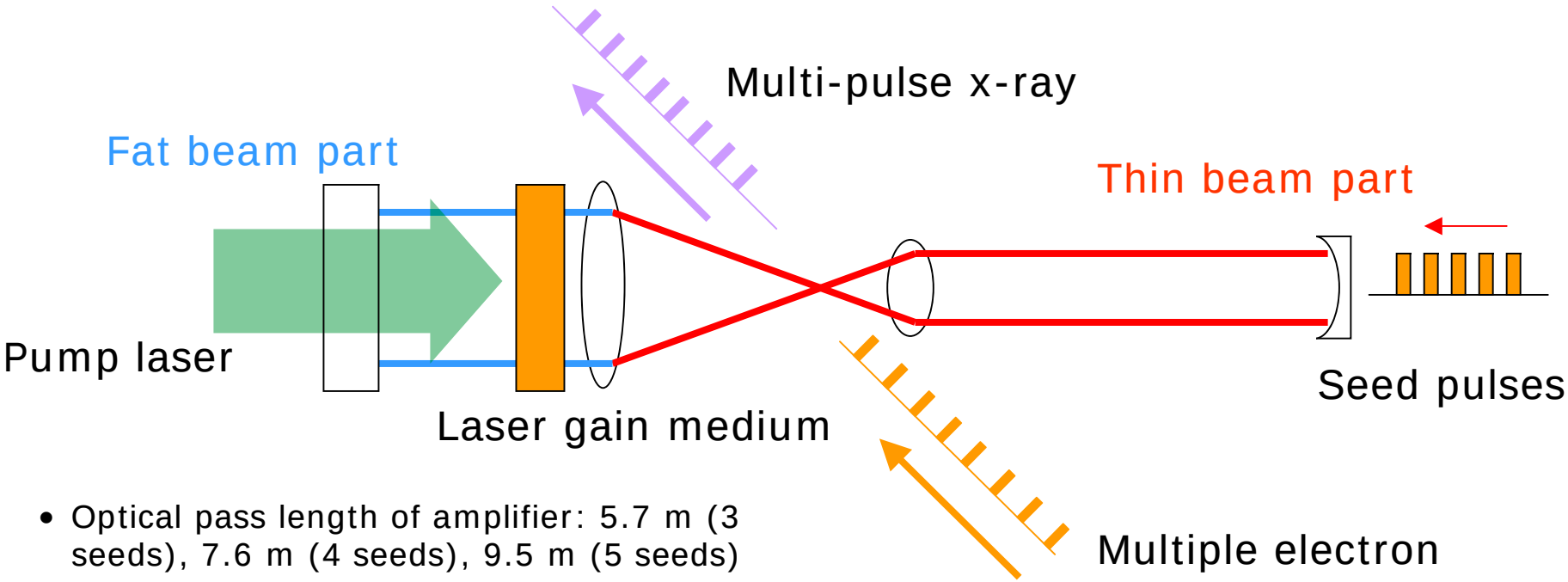


0.6 nC × 100 bunches/ macro pulse with Mg cathode



(electron bunch)

Multiple laser-Compton scattering within a cavity (regenerative amplifier)

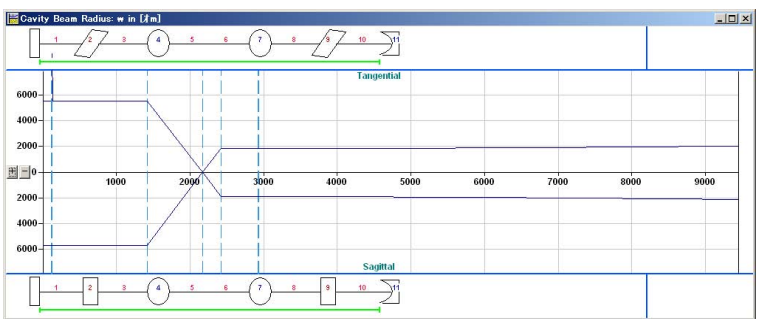


- Optical pass length of amplifier: 5.7 m (3 seeds), 7.6 m (4 seeds), 9.5 m (5 seeds)
- Laser wavelength: 800 nm
- Intra cavity power: 100 mJ × 100 pulses (total power of 10 J)
- Pulse width: 10 ~ 20 ps
- Focal spot size: 40 ~ 50 μm

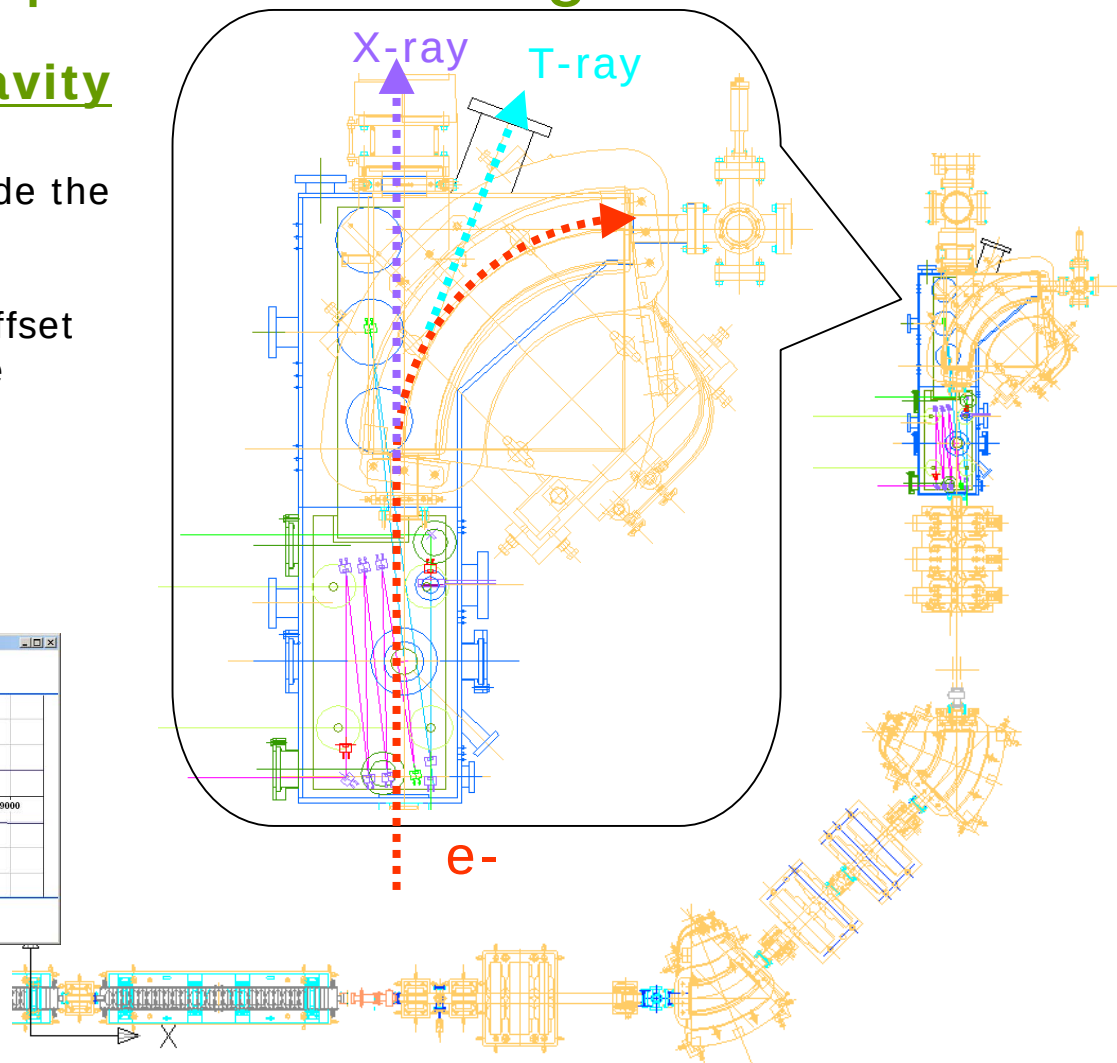
Main cavity for multi-pulse laser for laser-Compton scattering

Regenerative amplifier cavity

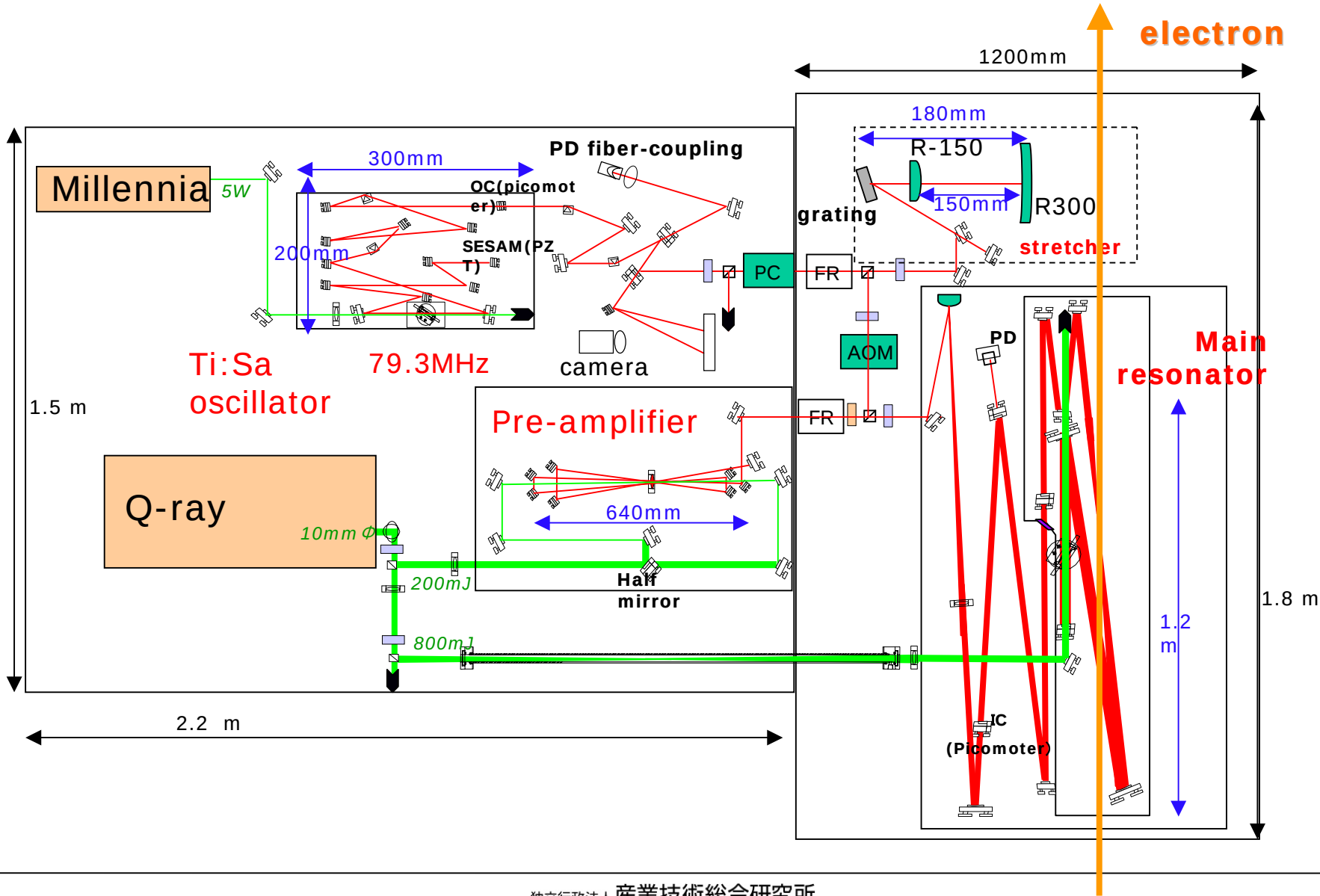
- 1×3 beam expansion telescope inside the cavity
- Fat beam 6 mm, thin beam 2 mm
- Residual astigmatism for angular offset by concave mirrors of the telescope



Cavity optics calculated with Winlase



Laser system for multiple laser-Compton scattering



Summary

Done
On going
To be achieved

Current status:

- X-ray energy : 10 ~ 40keV (electron beam energy: 20 ~ 40 MeV)
- Photon yield : $>10^7$ photos/s @ 10Hz
- Transmission, refraction-enhanced imaging

Injector modification:

- Multi-pulse laser of 8 μJ × 100 pulses @UV was generated
- 600 pC × 100 bunches with magnesium cathode was generated
- Cs-Te cathode and load-lock system, will be installed soon.
- 5 nC/single bunch and 1 nC × 100 bunches

Multi-pulse laser-Compton scattering:

- Optics design, is almost done
- Main cavity design, is almost done
- Main cavity vacuum chamber is on a factory line
- Intra cavity power of 100 mJ × 100 pulses = 10 J
- PMQ for strong focus, is still under discussion, but probably we need it