Development of Cs_2Te photocathode RF gun system for compact THz SASE-FEL

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Outline

- Introduction (THz source, our present system)
- Development of compact multi-pulse laser
- Development of compact Cs_2Te load-lock system
- Multi-bunch electron beam generation
- Surface observation of Cs_2Te cathode with PhotoElectron Emission Microscopy (PEEM)
- Summary

Introduction

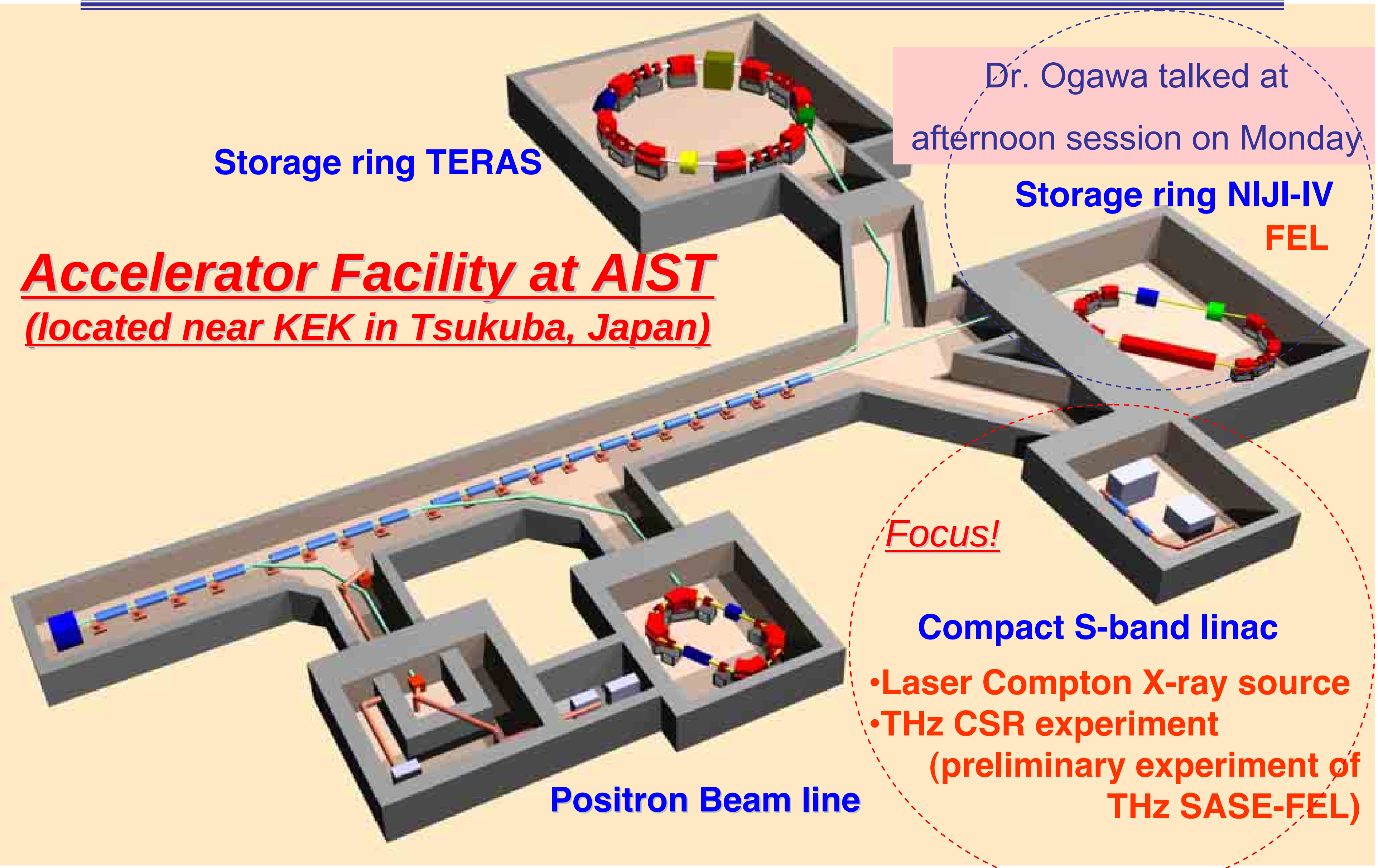
Motivation

THz imaging technique using the laser-driven THz source has been developed at many other laboratories for detection of the illegal medicine, dangerous chemicals and so on.

However, in case of laser based THz source, the output power is very low. The imaging analysis of large illuminated area is not practical.

→ High power THz source based on compact electron linac (within about 1 middle room size) is required and it can perform the total inspections of the sealed letters and the carry-along items.

Introduction



Introduction

Our system have been developed by Sumitomo Heavy Industries Ltd (SHI) and AIST for FESTA project to develop the laser Compton scattering hard X-ray source.

Total system is installed in 1 room which area is about 10m × 10m including all components such as a Klystron, laser systems, a BNL-type S-band photocathode RF gun, two 1.5 m-long accelerator structures, achromatic arc section and beam dump. The LCS hard X-ray source is usually operated for biological observation.

We are originally planning to modify our system to apply to THz SASE-FEL in future. it is designed based on the compact S-band linac.

Image of compact THz SASE–FEL at AIST

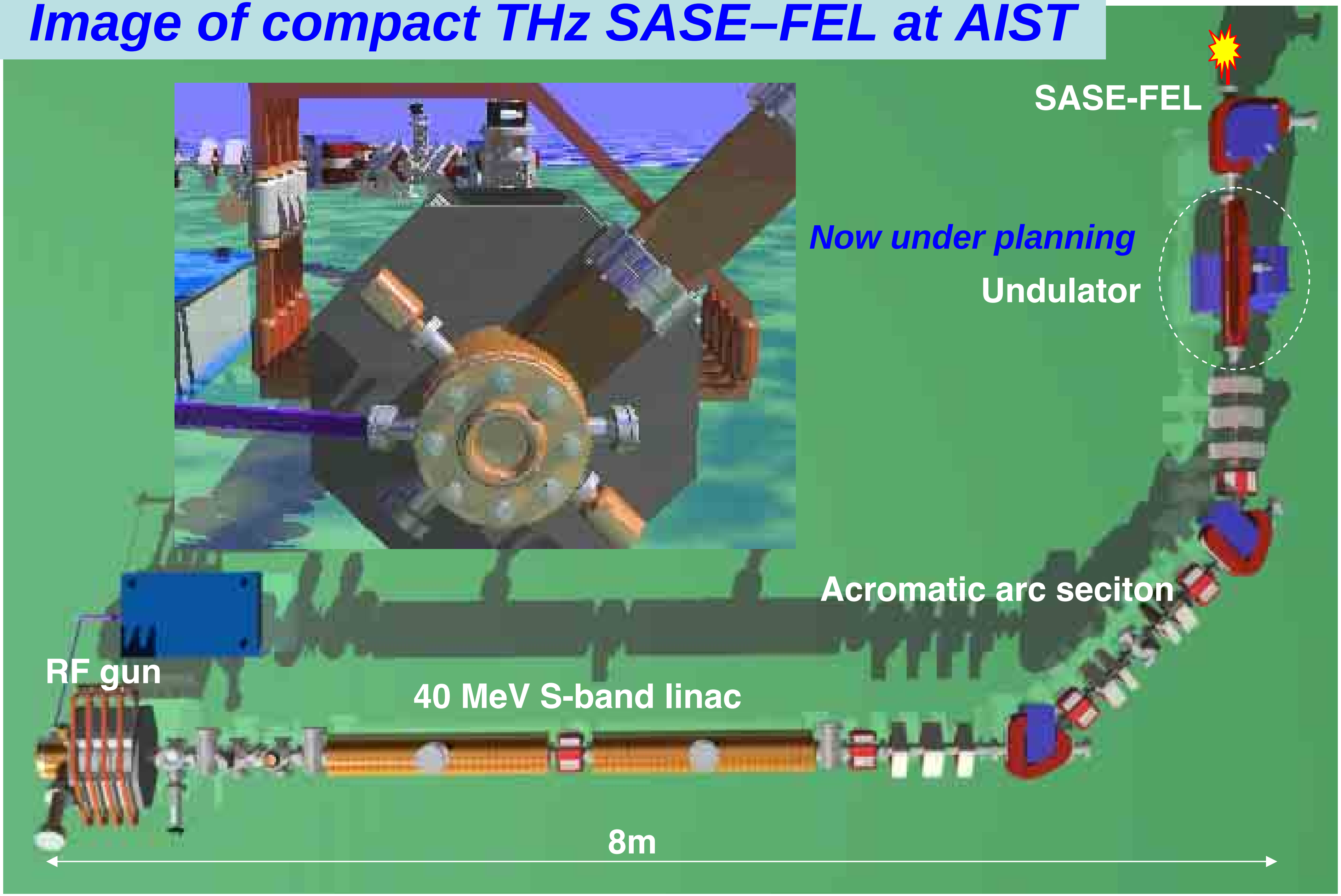
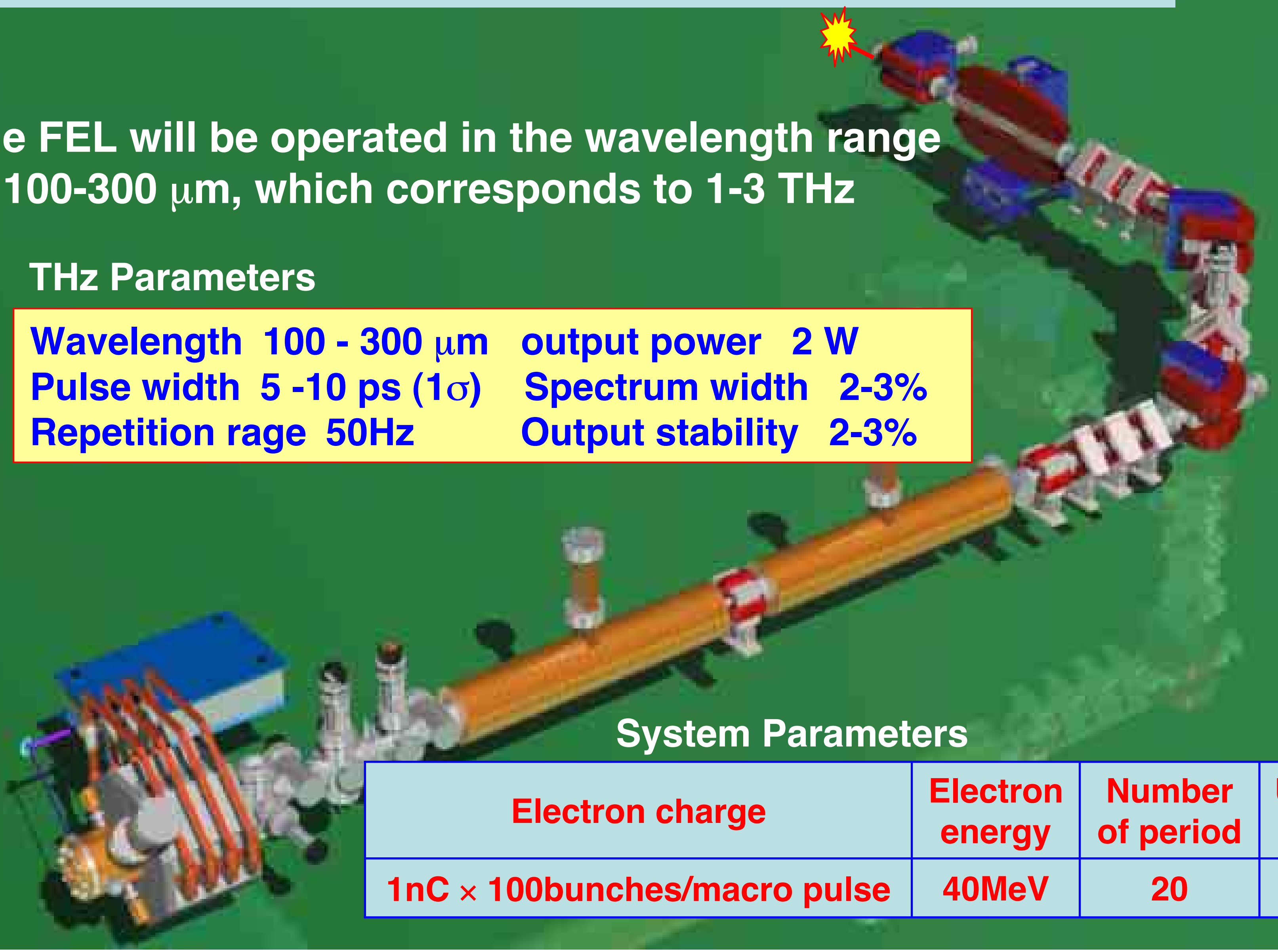


Image of compact THz SASE–FEL at AIST



The FEL will be operated in the wavelength range of 100-300 μm, which corresponds to 1-3 THz

THz Parameters

Wavelength 100 - 300 μm output power 2 W
Pulse width 5 -10 ps (1σ) Spectrum width 2-3%
Repetition rage 50Hz Output stability 2-3%

System Parameters

Electron charge	Electron energy	Number of period	Undulator period
1nC $\times$ 100bunches/macro pulse	40MeV	20	100 mm

Our requirement of electron beam

- 1nC 100 bunches / macro pulse
- Low emittance (already achieve < 5 mm mrad @1nC single bunch)

Improvement

UV laser : commercial single-pulse laser → original multi-pulse laser

Photocathode: Cu, Mg → Cs_2Te

Subject to achieve:

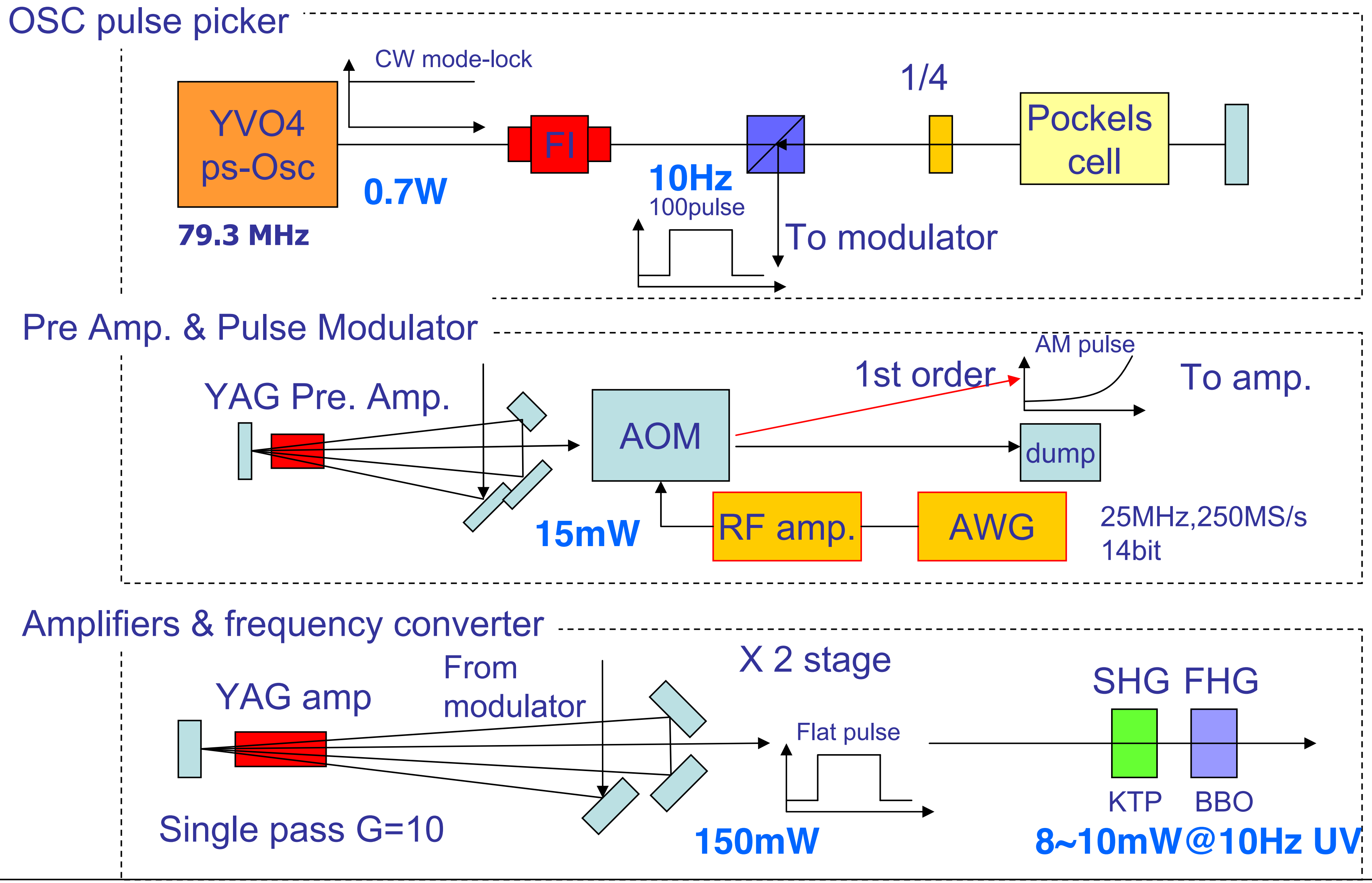
1 Development of compact multi-pulse UV laser

2 Development of compact load-lock system of Cs_2Te photocathode.

3 Multi-bunch electron beam generation

4 Photocathode surface observation with PEEM

Development of Compact Multi-pulse UV laser



Status of multi-pulse UV laser

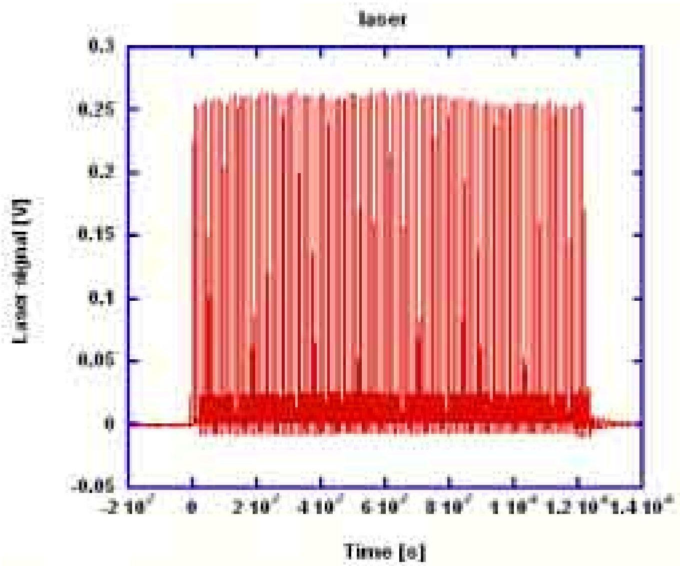
All solid-state and compact

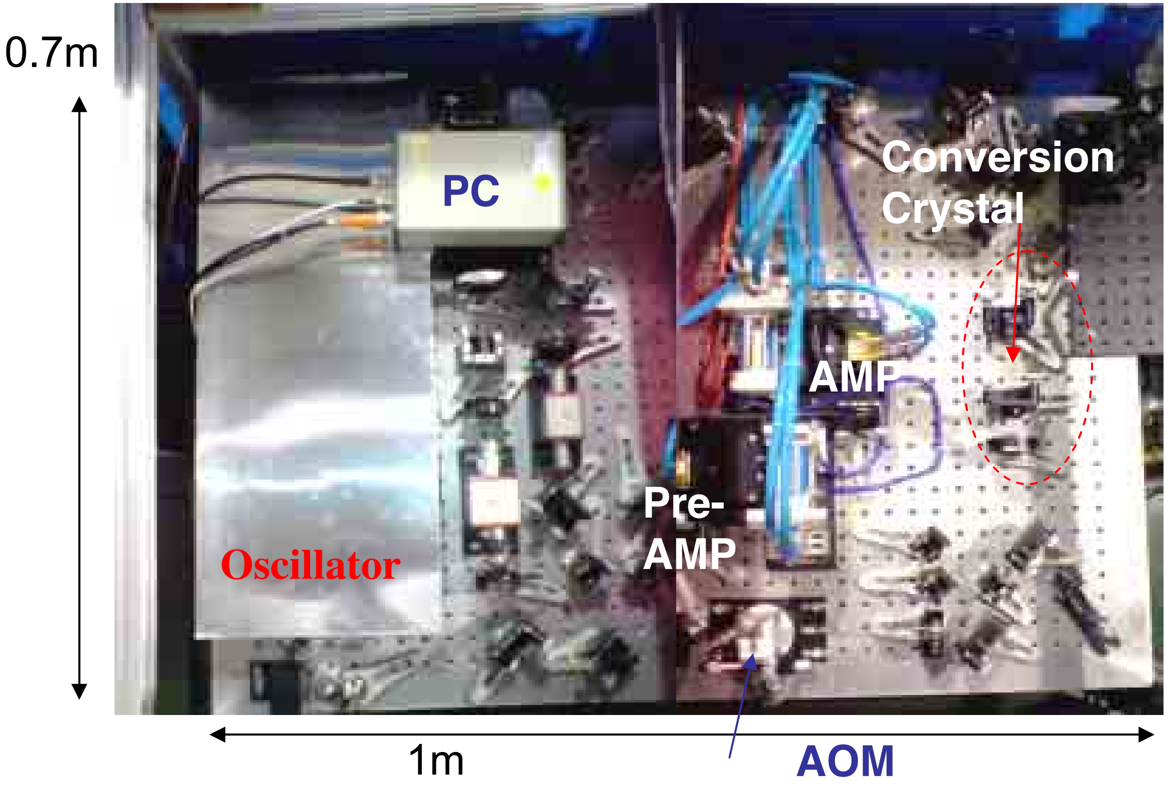
$8\mu J \times 100$ pulse/ macro pulse

Timing jitter is less than 1 ps

Intensity stability is less than 3% (each pulse)

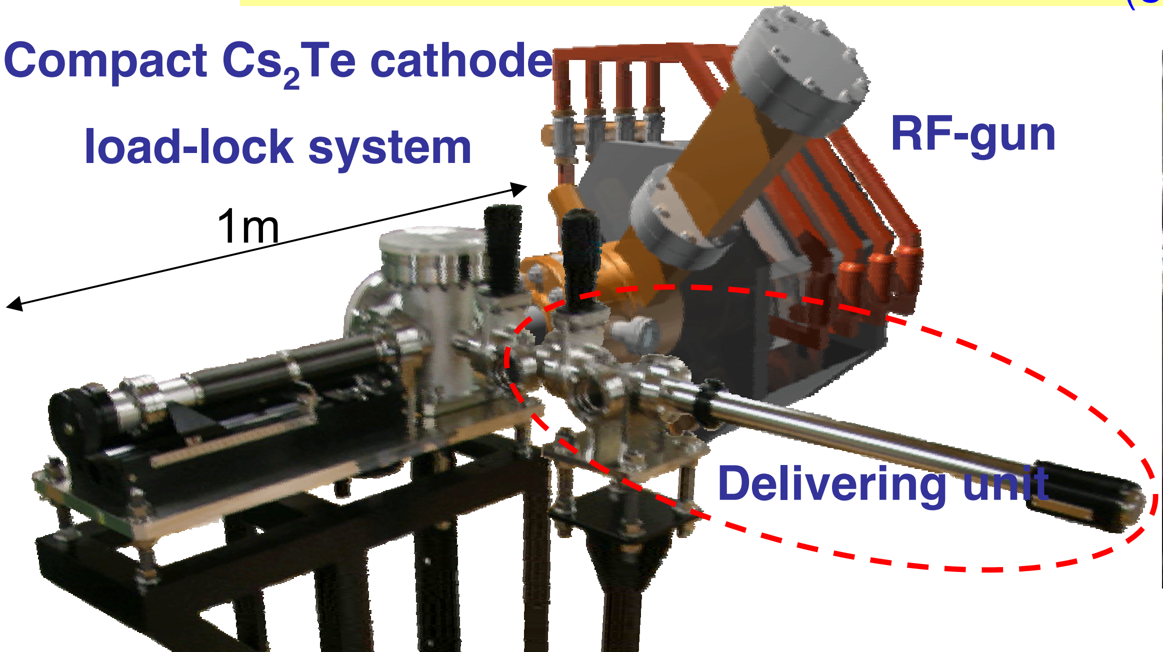
Intensity flatness is less than 5% (macro pulse)

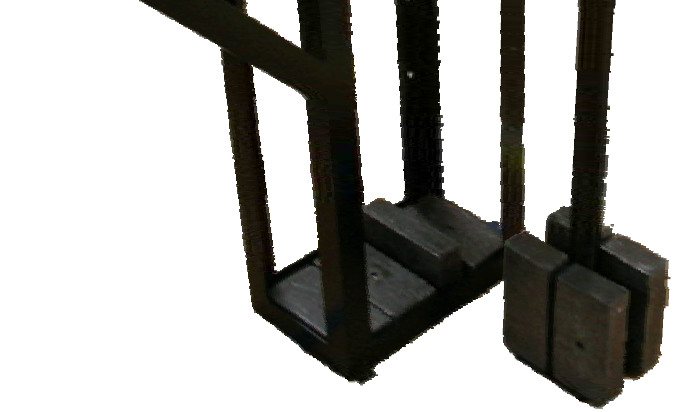




Development of Cs_2Te compact load-lock system for multi-bunch electron beam generation

(Collaborating with KEK, Waseda Univ.)

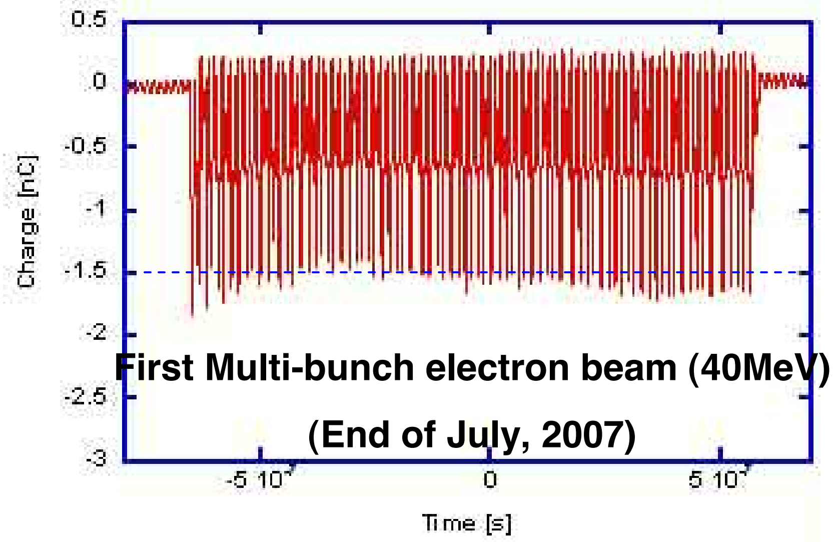




Te 50nm

Cs >10nm

Multi-bunch electron beam generation using Cs_2Te photo-cathode

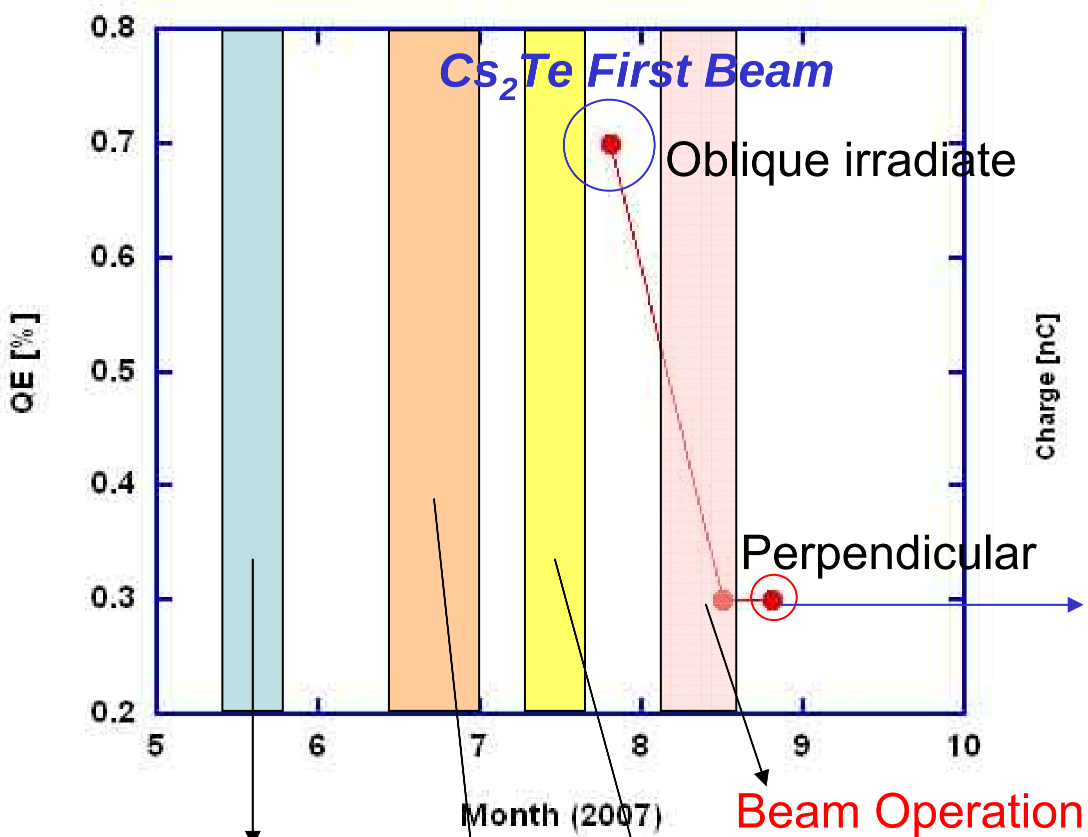


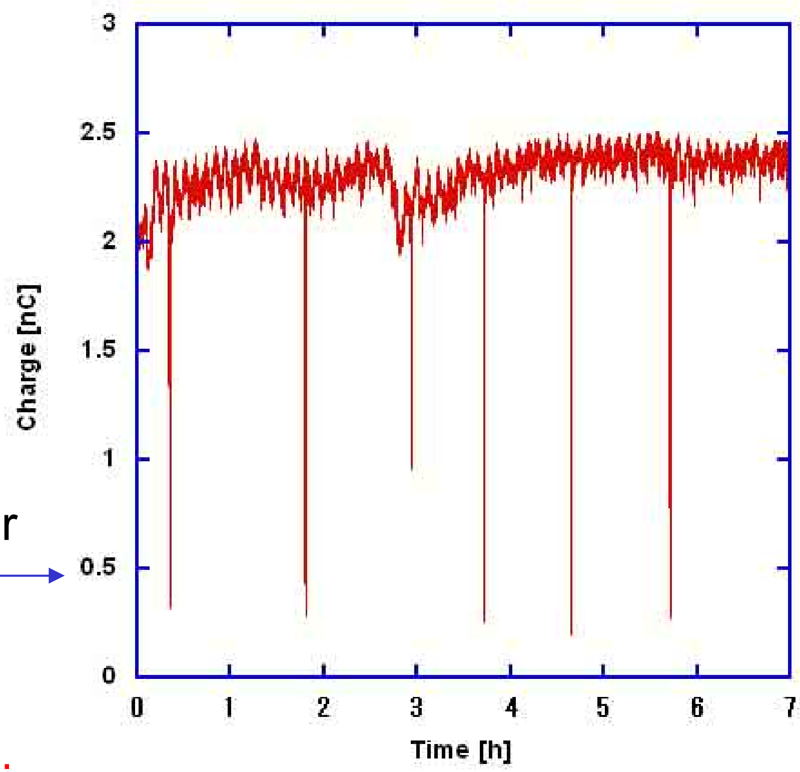
1.5 nC × 100 bunch@40MeV

Bunch spacing: 12.8 ns

Quantum efficiency is about 0.7% MAX)

Cs_2Te operation status





Beam Operation (LCS experiment)

Evaporation

(QE is unknown)

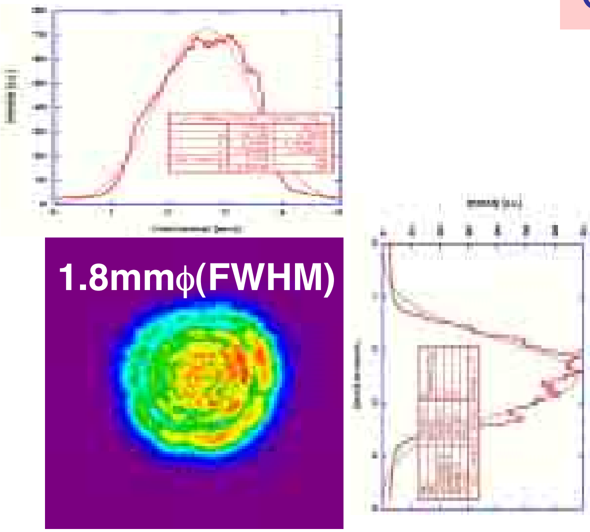
Installation and RF aging

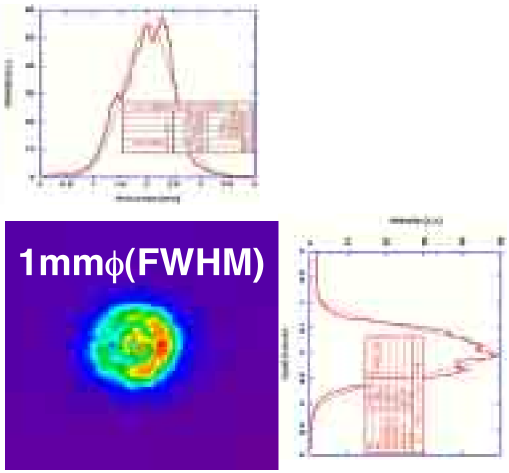
Surface observation with PEEM

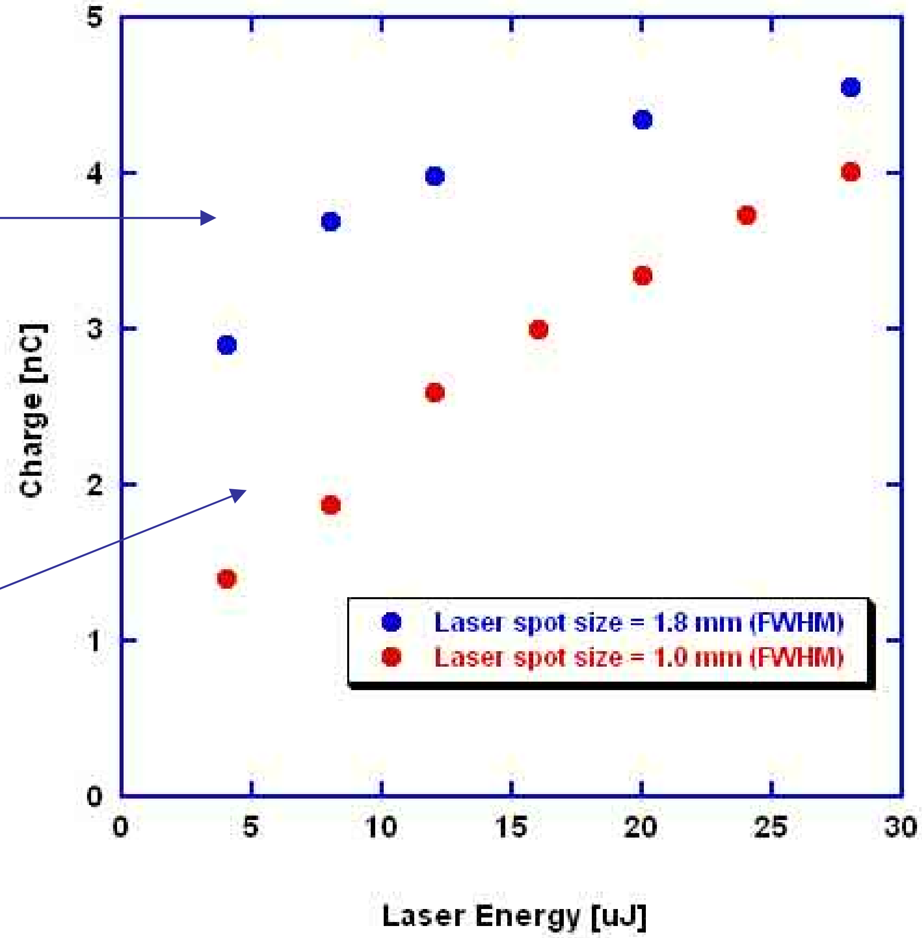
Stabilization of Cs_2Te with RF during 7 hour operation

Laser spot size dependence

Charge saturation appears due to space charge limitation

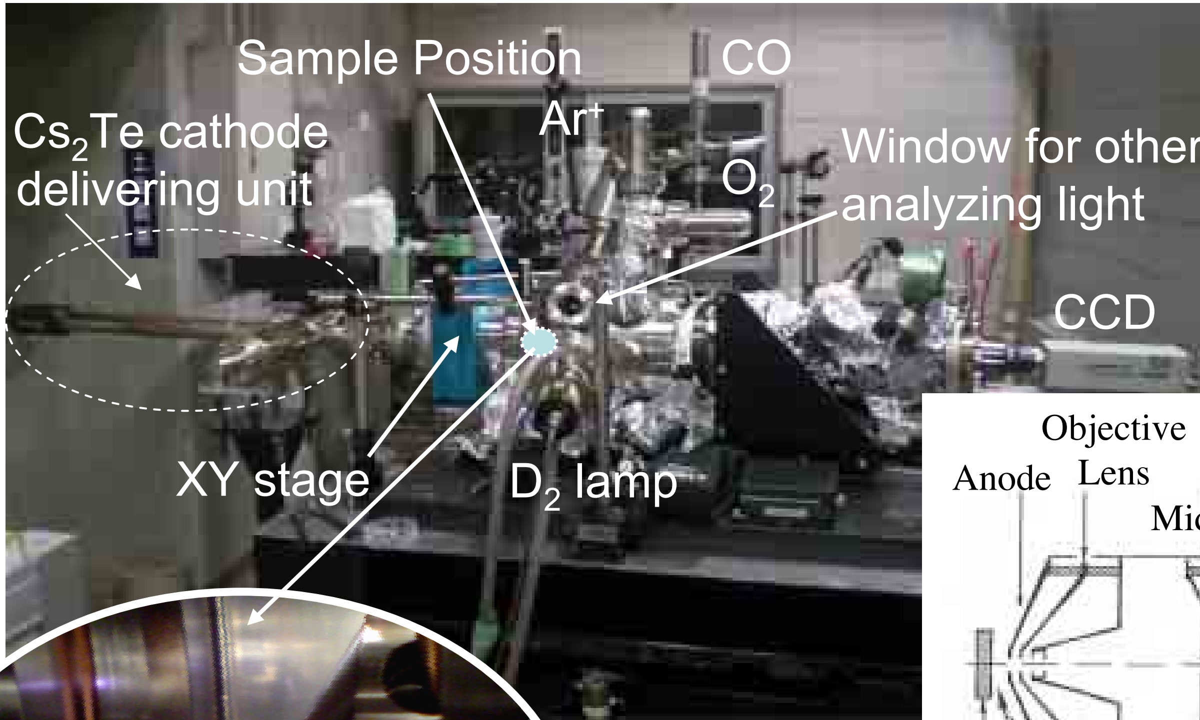






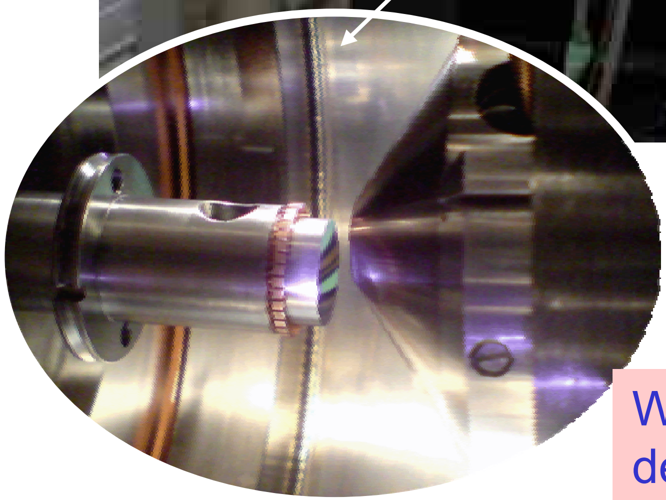
Electron charge vs Laser energy
by changing laser spot size

Compact load-lock PEEM for surface observation

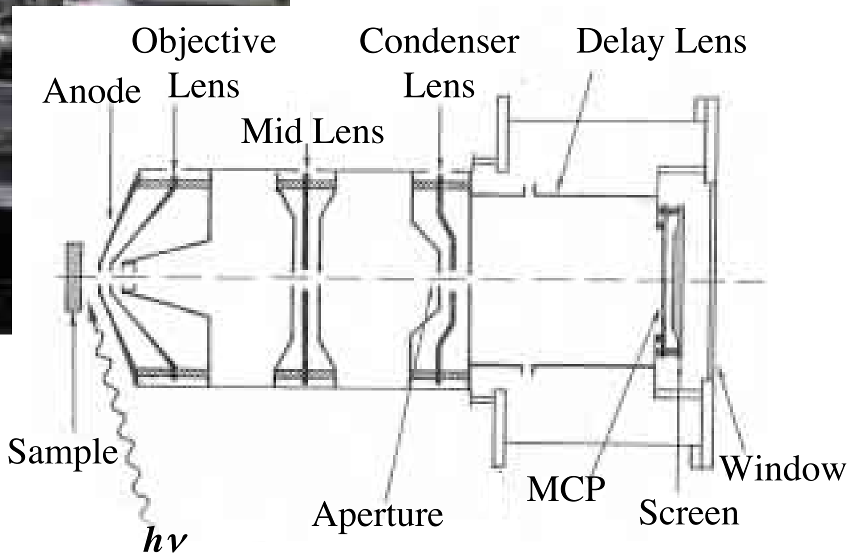


→ Xe lamp, Hg lamp,

FEL(NIJI-IV), Laser … etc

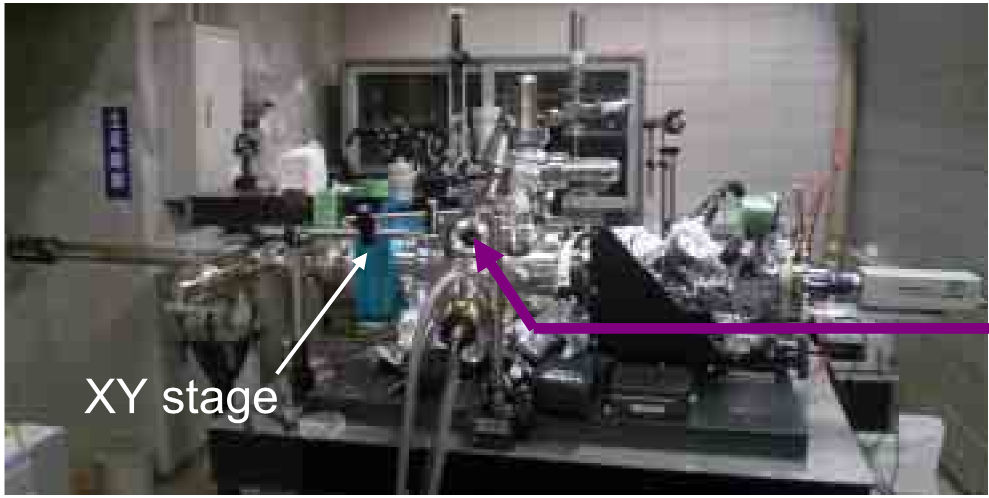


Cs_2Te with Mo plug



We improved photoelectron emission microscopy (PEEM) device to apply to the load-lock system for Cs_2Te surface observation in vacuum (10^{-7} Pa).

First Cs_2Te surface observation with PEEM

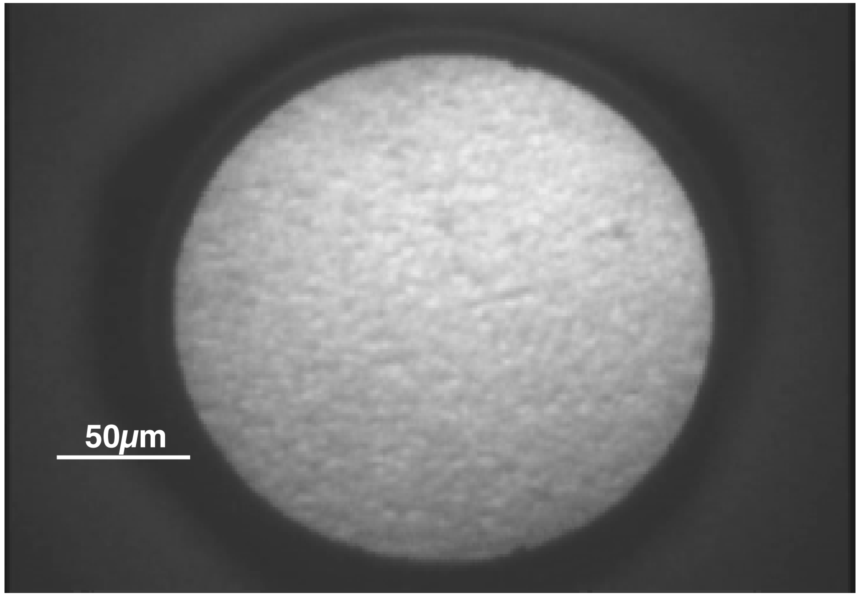


UV filter(239nm, 300nm, 360nm)

Xe Lamp

Field of view: 200 μm

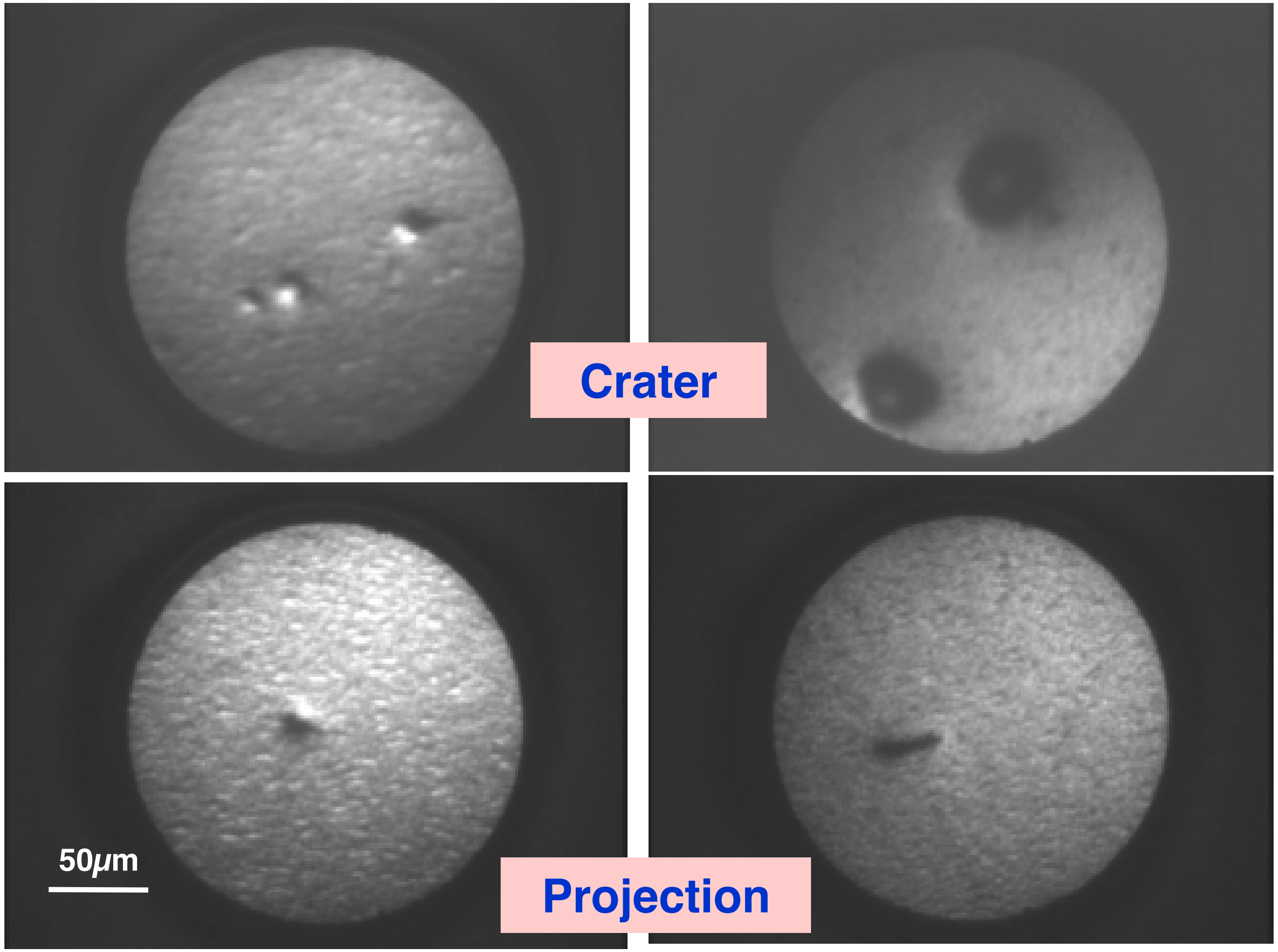
Scanning by XY stage (manual)

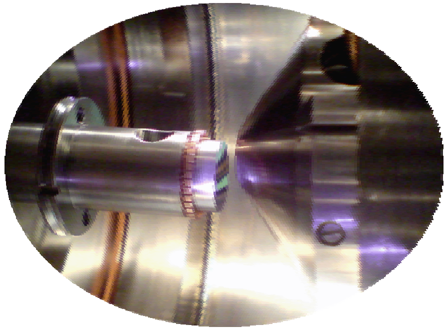


Cs_2Te surface was observed with PEEM right after evaporation.
Mo substrate has small roughness but its surface is practically flat and Cs_2Te is uniformly evaporated.

First Cs_2Te surface observation with PEEM(2)

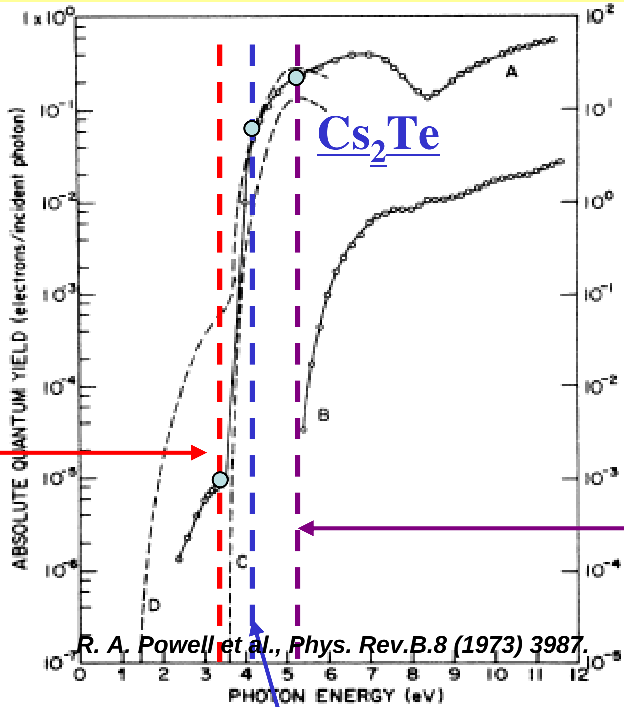
Some craters and projections can be observed on the surface.

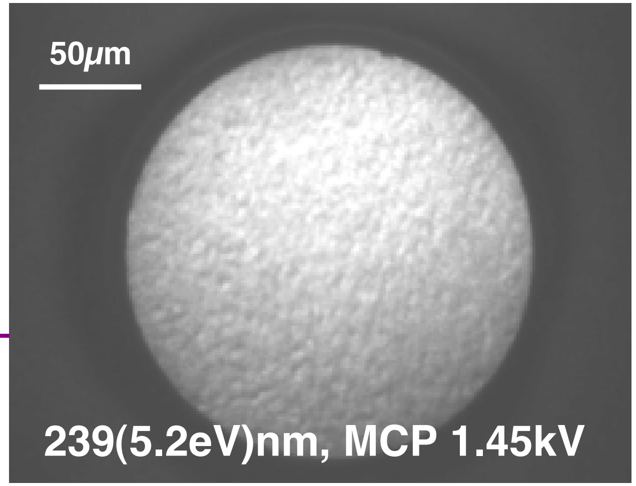




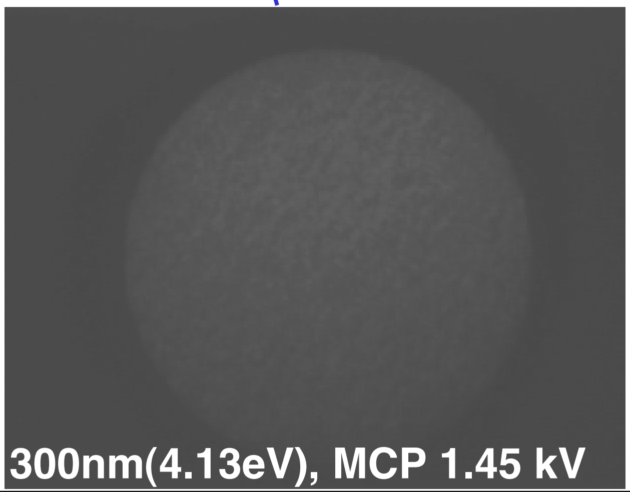
Even if Mo substrate is polished with diamond powder, it has some small craters and projections. So we can observe them with PEEM.

First Cs_2Te surface observation with PEEM(3)



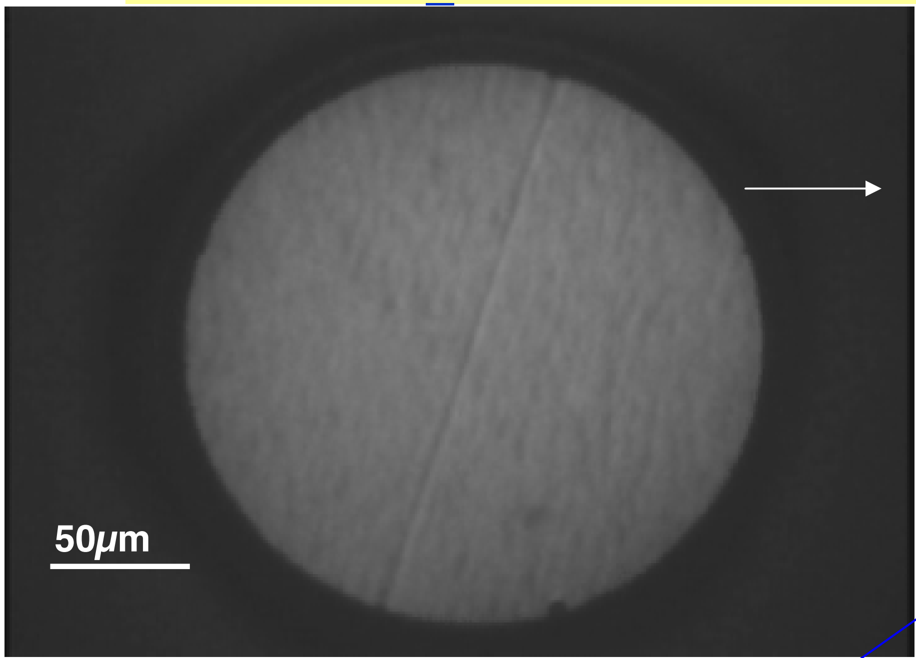


Dependence of different UV filters

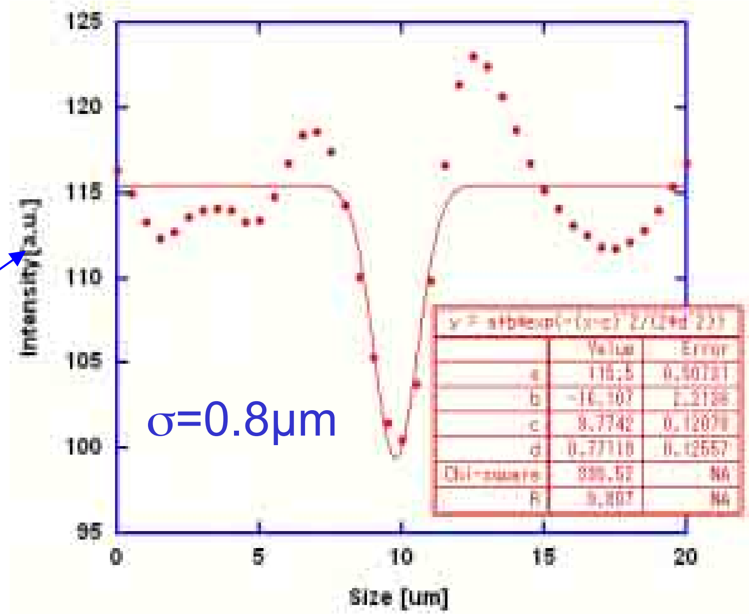


In case of 360nm filter (3.4eV), we cannot observe PEEM image.

First Cs_2Te surface observation with PEEM(4)



Some long scratch on Mo substrate is observed.



Narrow scratch less than 1 μm(rms) can be observed with PEEM.

Summary

Multi-pulse UV laser is almost completed.

Cs_2Te cathode and load-lock system are already operated for LCS experiments and quantum efficiency is achieved about 0.7%(MAX), typically 0.3%.

Multi-bunch electron beam generation is already started and achieved about 1.5 nC × 100 bunches.

Surface observation of flesh Cs_2Te cathode is already started with PEEM.

In near future

Surface observation of Used Cs_2Te cathode will be performed with PEEM

High resolution observation of nm scale will be demonstrated by high magnified optics mode of PEEM.

Modification of PEEM device to combine sample evaporation, substrate baking and element analysis.

Acknowledgement

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