Improved application beam line and recent experiments on the NIJI-IV DUV/VUV FEL

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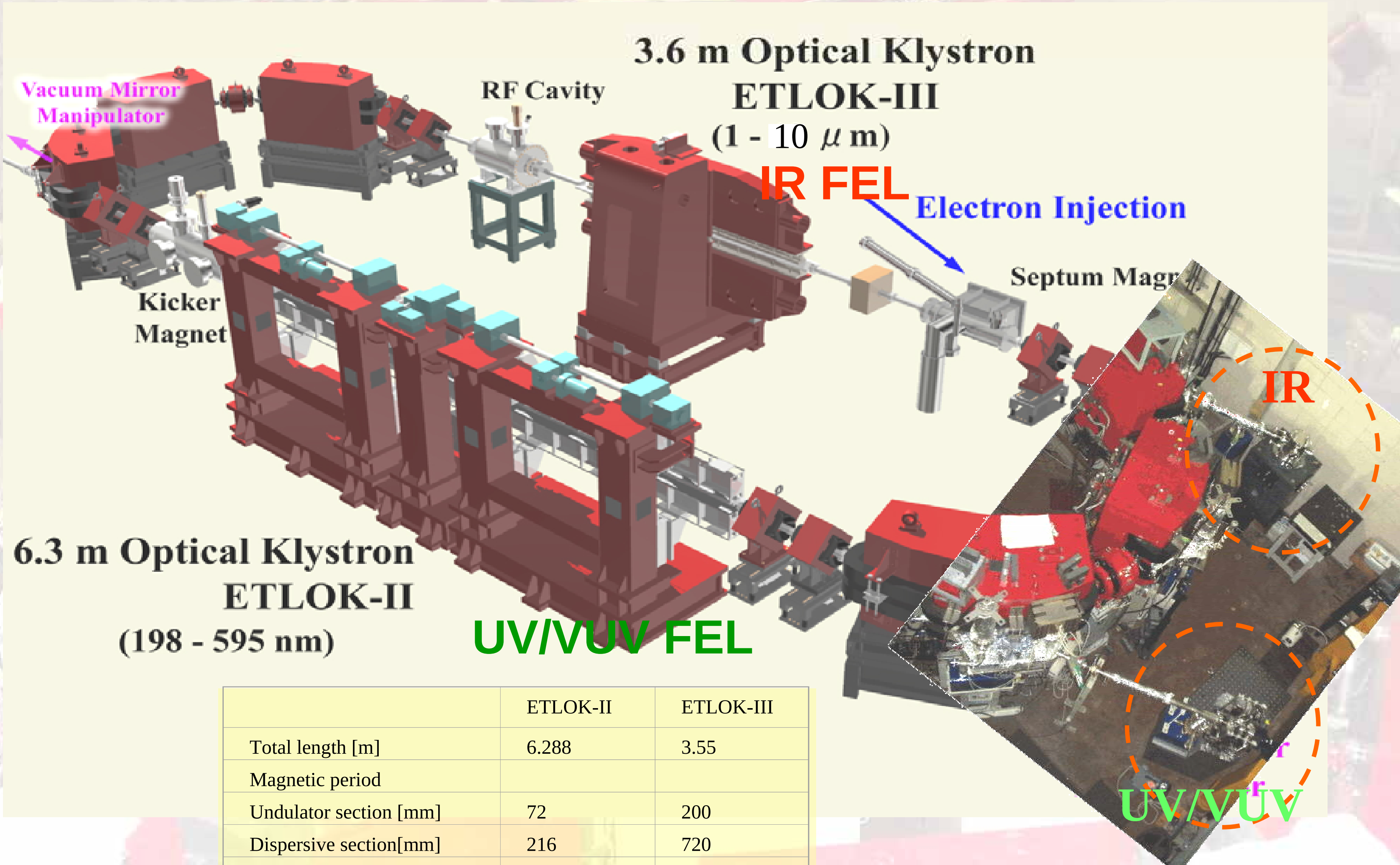
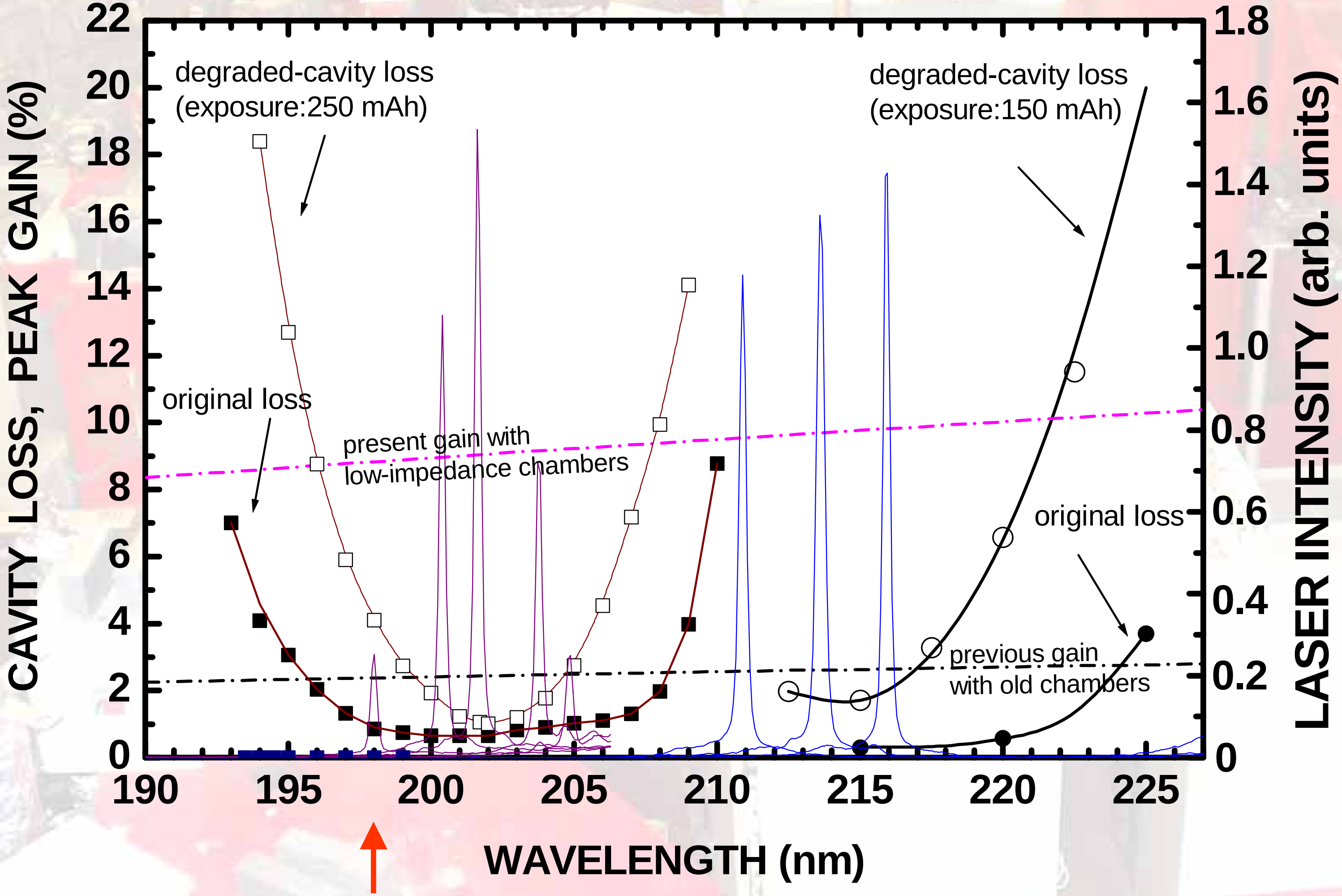
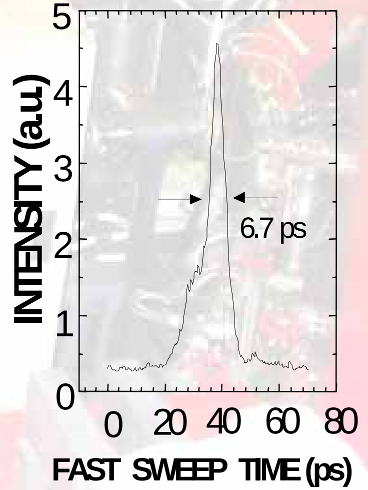
NIJI-IV FEL



	ETLOK-II	ETLOK-III
Total length [m]	6.288	3.55
Magnetic period		
Undulator section [mm]	72	200
Dispersive section[mm]	216	720
Number of period N_u	42×2	7×2
Deflection factor K	<2.29	<10.04
Wavelength [μm]	0.198-0.595	(0.4-10)

Lasing in the NIJI-IV FEL

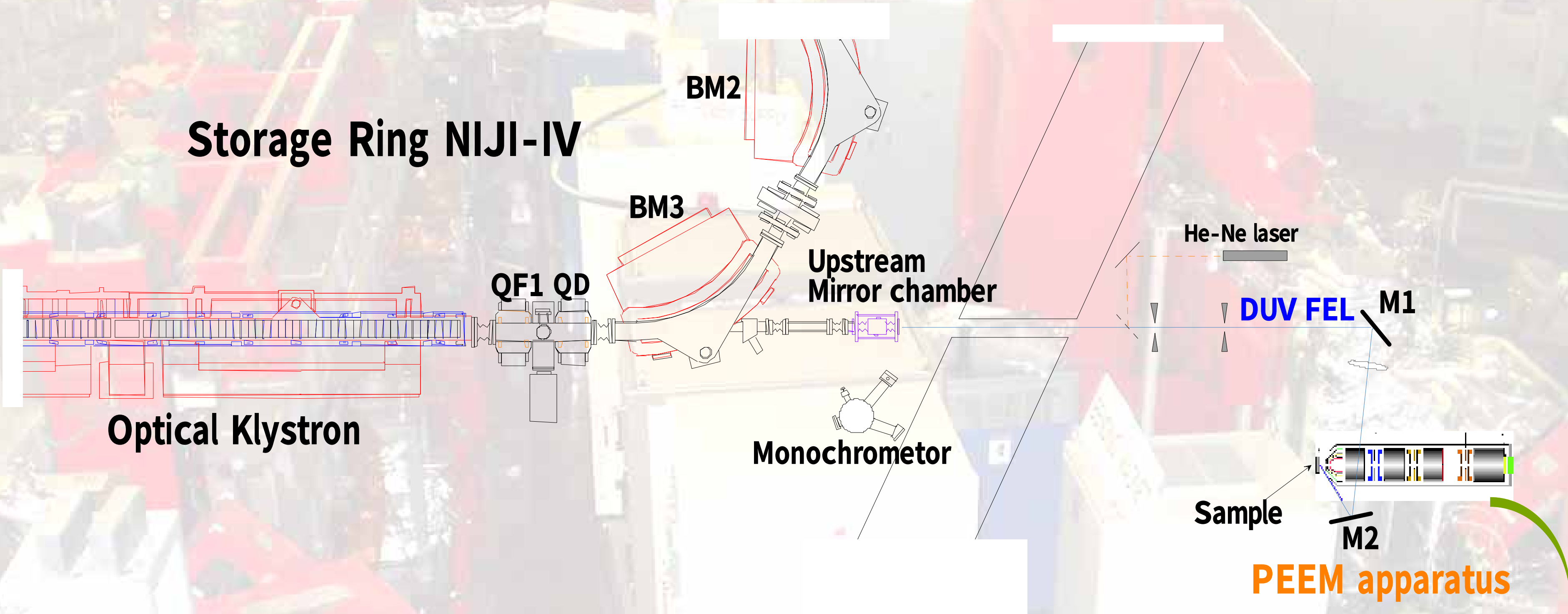




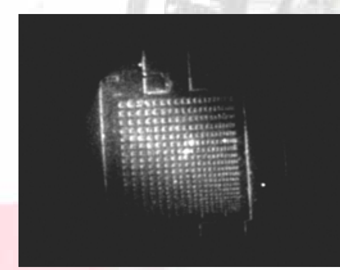
Lasing down to 198nm (~ 595nm)

Line width: 0.07nm

DUV/VUV Beam line for FEL-PEEM(Photoelectron emission microscopy)



An FEL at a wavelength of 202nm emitted from a 6.3-m optical klystron ETLOK-II was transported to the experimental room through air and was reflected by a flat aluminium mirror and focused onto the sample surface.



Optical cavity system for DUV/VUV FEL

Robust optical cavity sytem

Old system

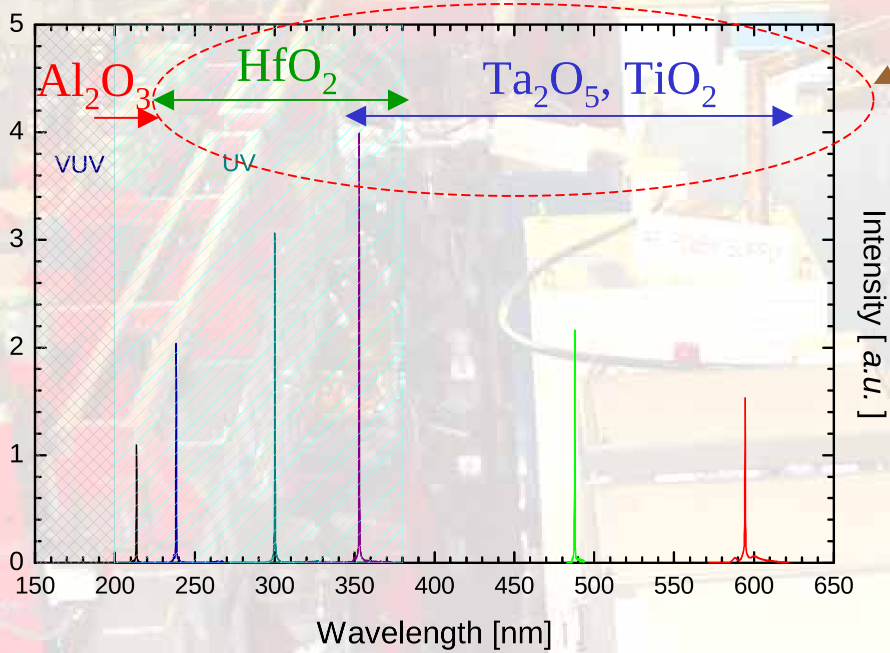
Slender structure

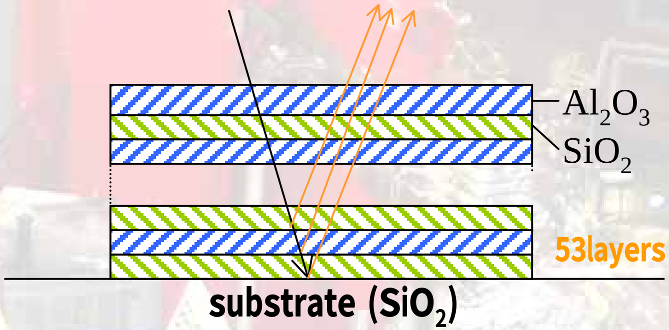
The mirror manipulators were composed of five-axis stages with gimbal mounts containing a high-vacuum mirror chambers each of which has interchangeable two in-vacuum mirrors to extend FEL tuning range.

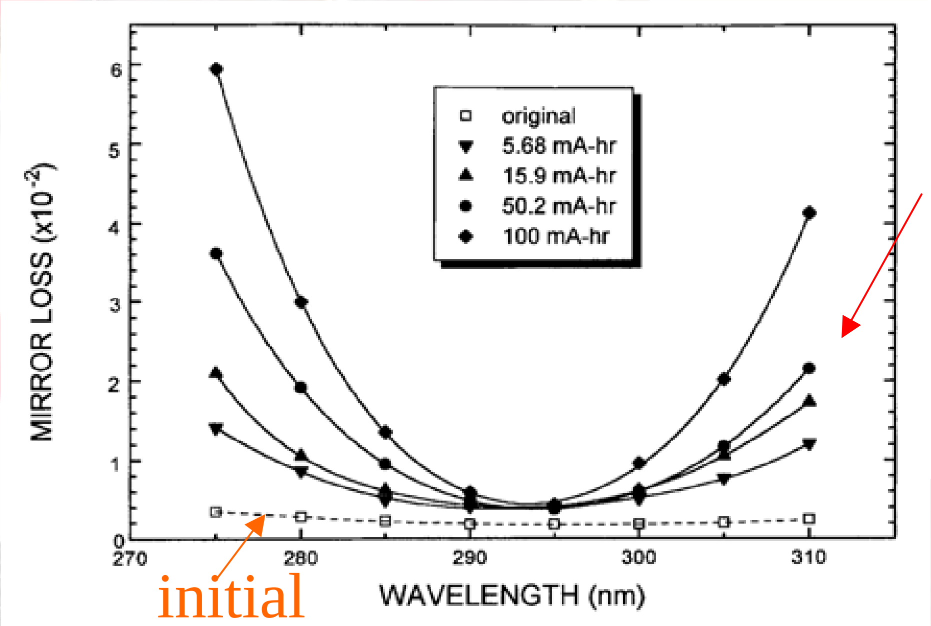
heavy granite stone(2 ton)

Resolution: $\Delta z = 0.1\mu m$, $\Delta\theta = 0.8\mu rad$

Degradation of dielectric mirror in the visible and UV regions







The mirror bandwidth was narrowed due to deposition of carbon atoms onto the mirror surface.

→ O_2 plasma treatment

K.Yamada: NIMA393(1997)

O_2 plasma treatment in the visible and UV regions

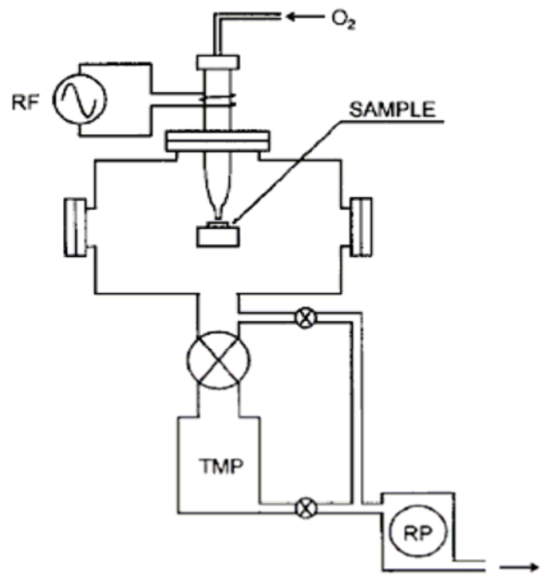


Fig. 2. Schematic drawing of the reaction chamber for the plasma treatment.

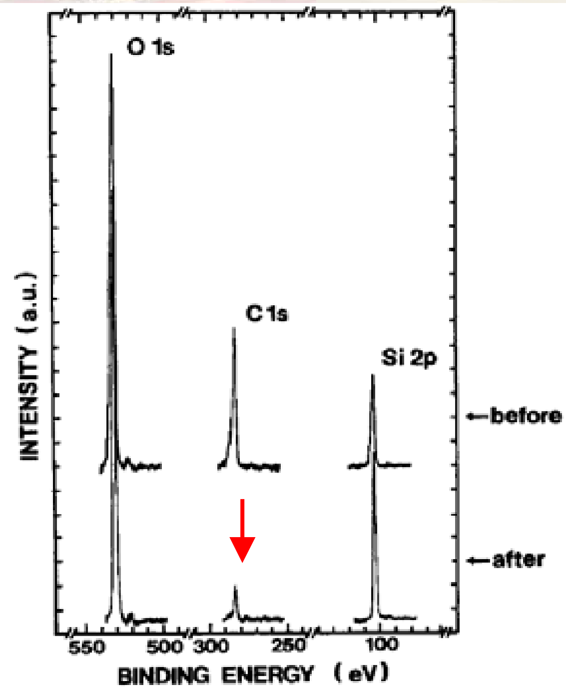


Fig. 5. Typical x-ray photoelectron spectra before and after plasma treatment.

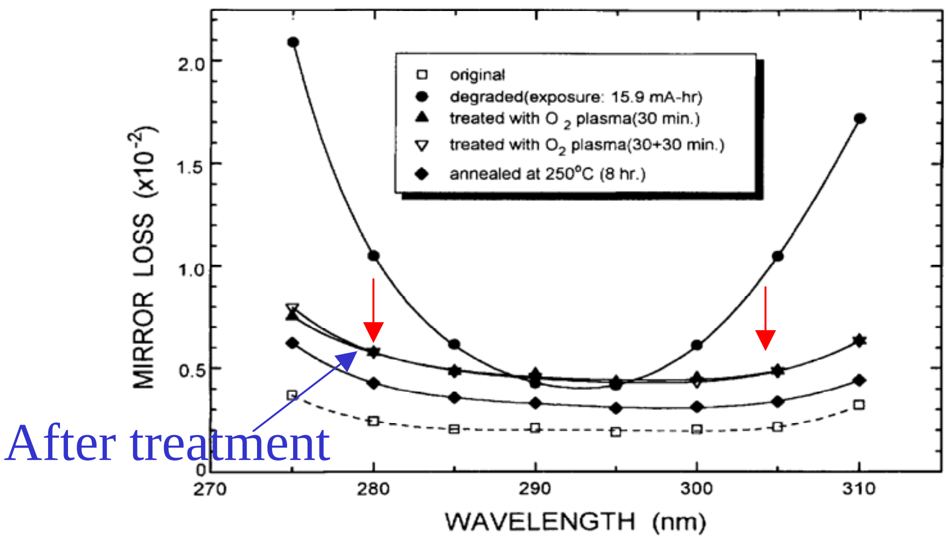


Fig. 2. Restoration of a degraded IBS mirror with plasma treatment and thermal annealing. Exposure dose to the sample was 15.9 mA h.

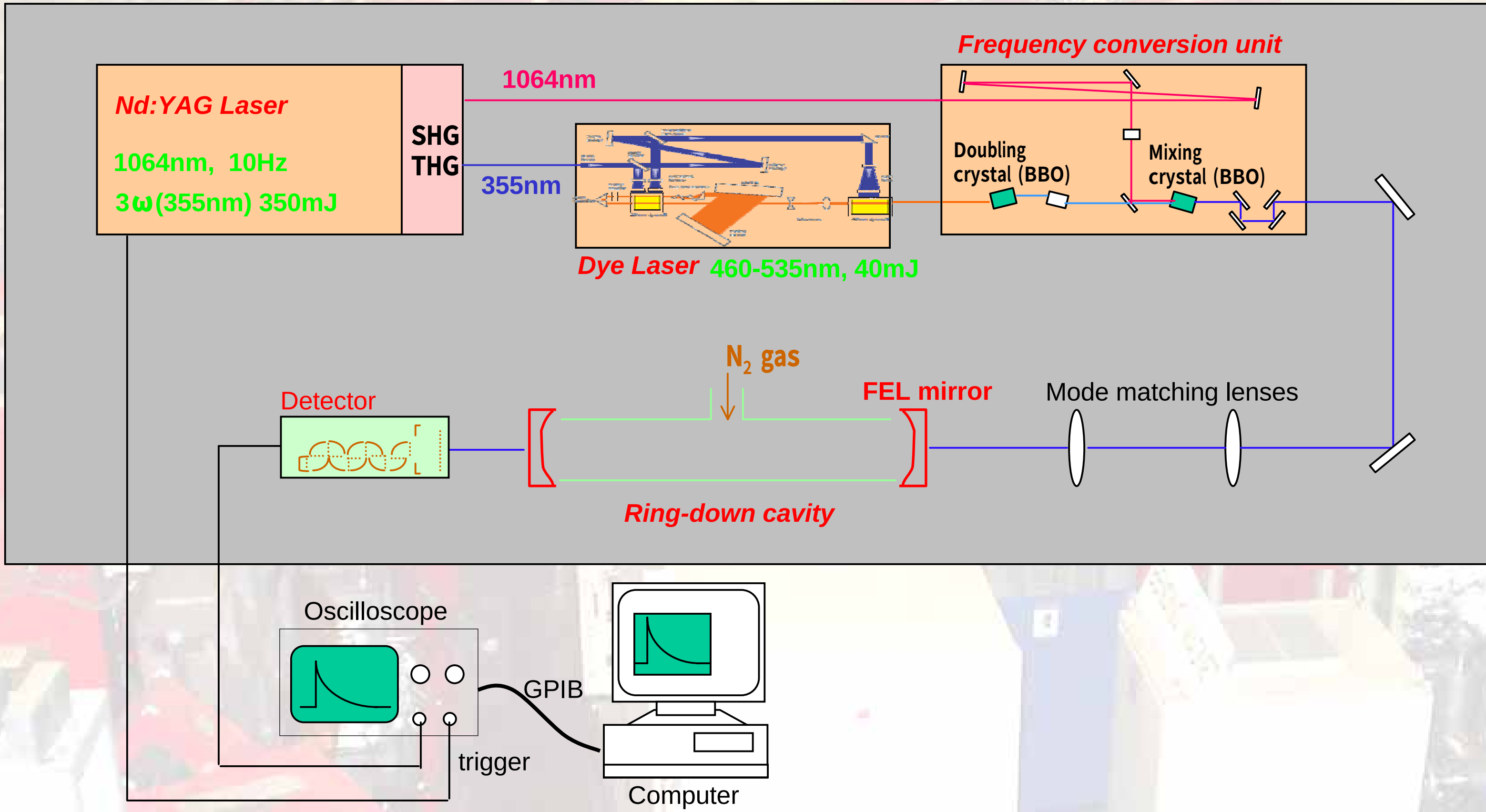
Reduction of carbon contamination after plasma treatment was confirmed by XPS analysis.

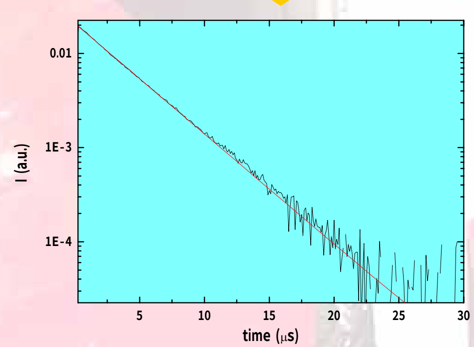
We already demonstrated to TiO_2/SiO_2, Ta_2O_5/SiO_2, HfO_2/SiO_2.

K.Yamada Appl. Opt. 34 (1995)

Mirror Loss Measurement — Cavity ring-down method

193 – 210 nm





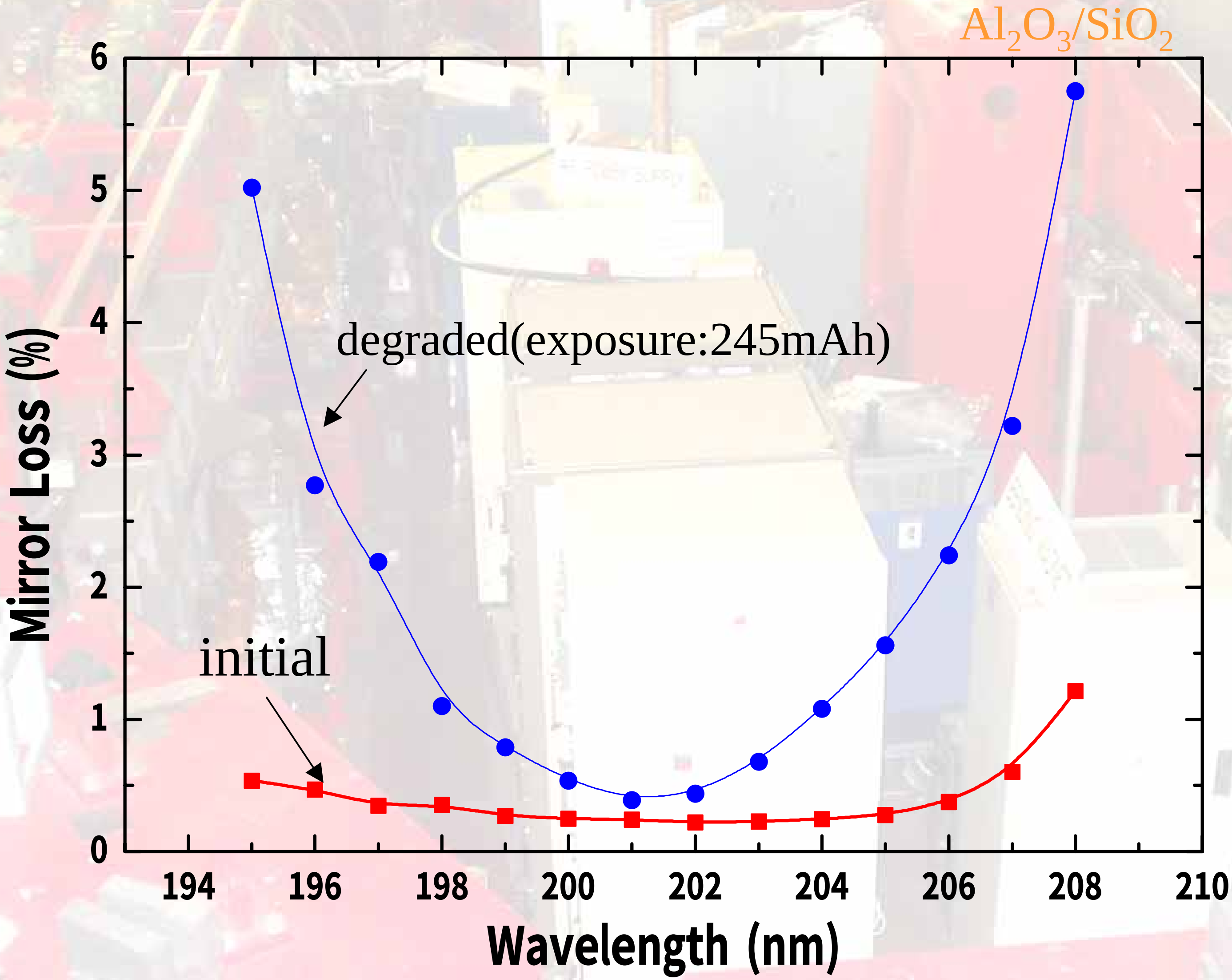
$$I(t) = I_0 \exp\left(-\frac{t}{\tau_c}\right)$$

cavity decay time

$$\tau_c = \frac{2nl_c}{cL}$$

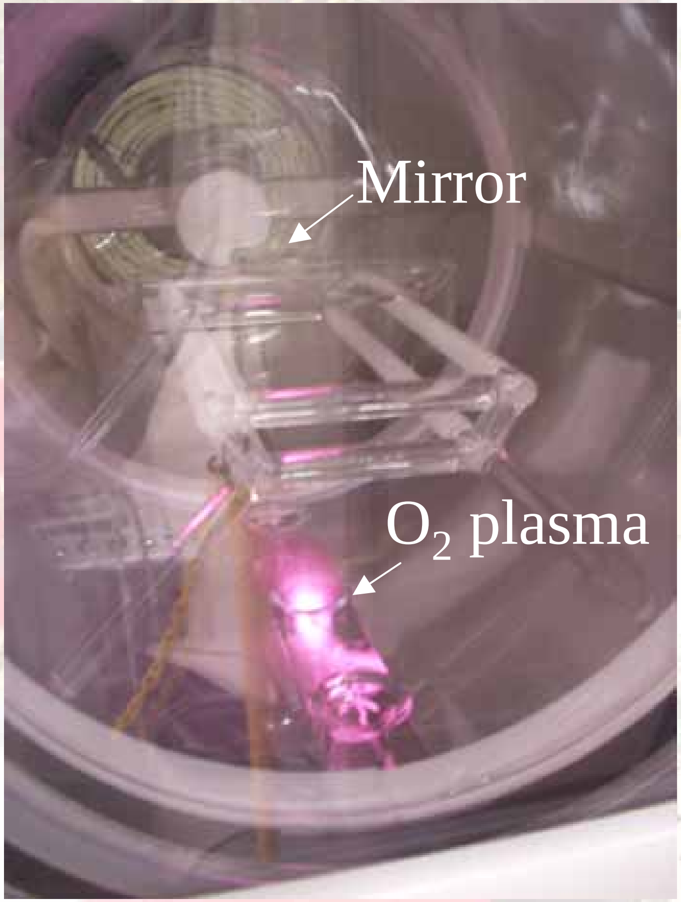
Mirror Loss

Mirror degradation around 200nm



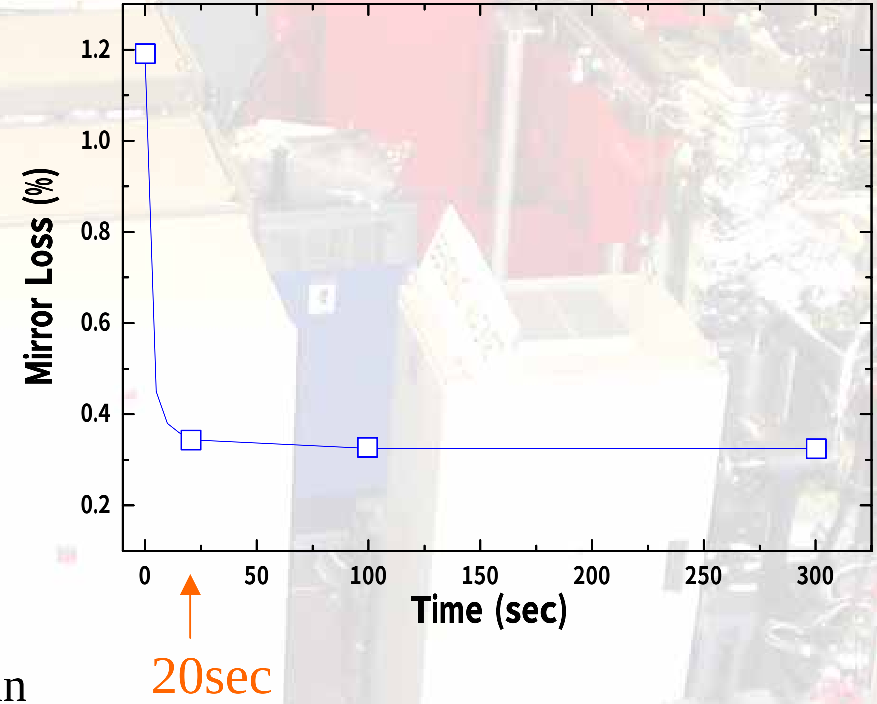
The mirror bandwidth was narrowed. → O_2 plasma treatment

RF-induced O_2 plasma treatment



To remove surface carbon contamination, the surface was treated with O_2 plasma.

Restoration of degraded mirror



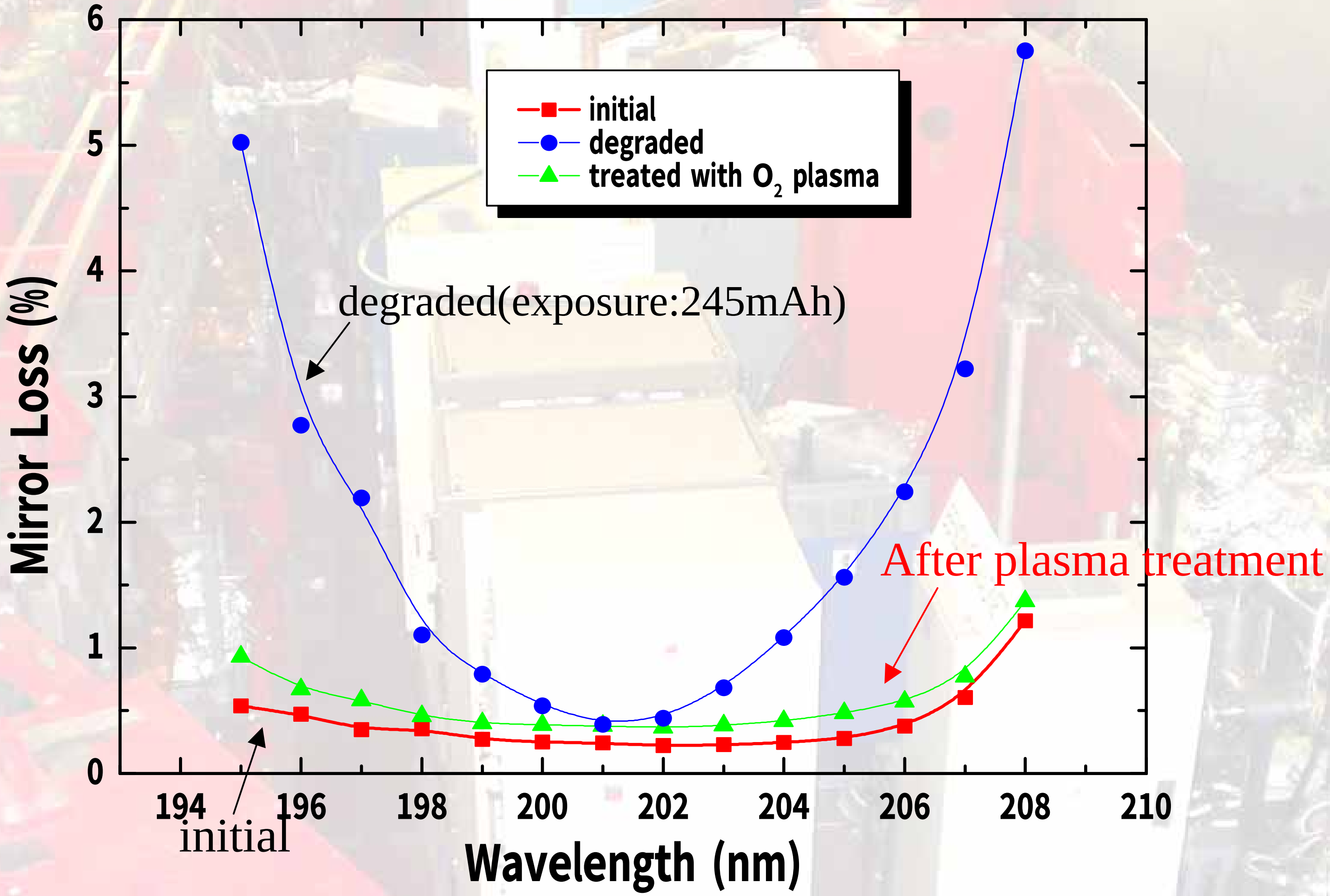
O_2 gas : flow rate of 100ml/min

60Pa

RF: 13.56MHz, 300W

The treatment time of at least 20sec is enough to restore the degraded mirror.

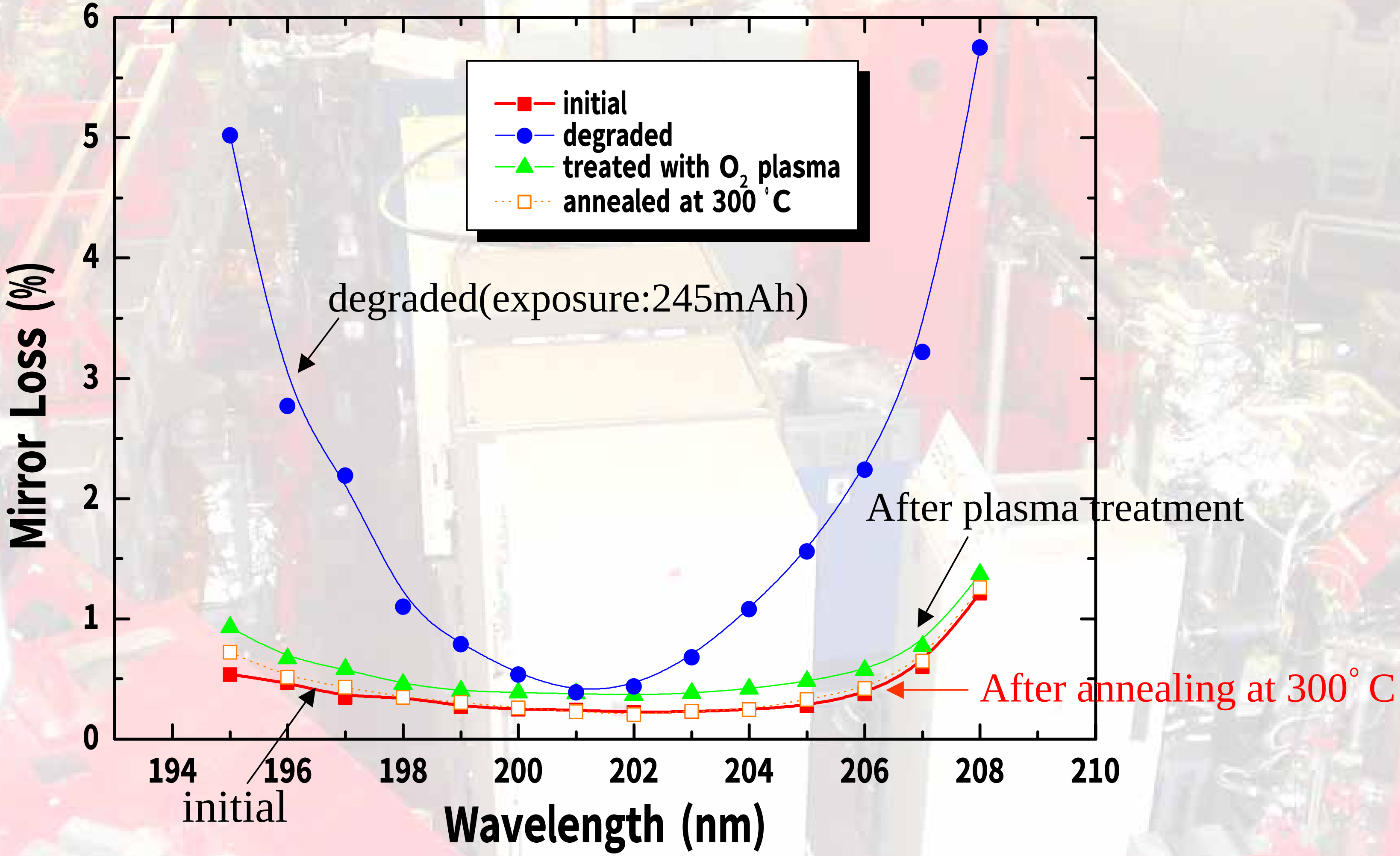
After O_2 plasma treatment



The narrowing of the mirror bandwidth disappeared and the shape of mirror loss curve was repaired, while the absolute value was still larger.

- volume degradation through defect formation inside the dielectric layers.
- thermal annealing treatment

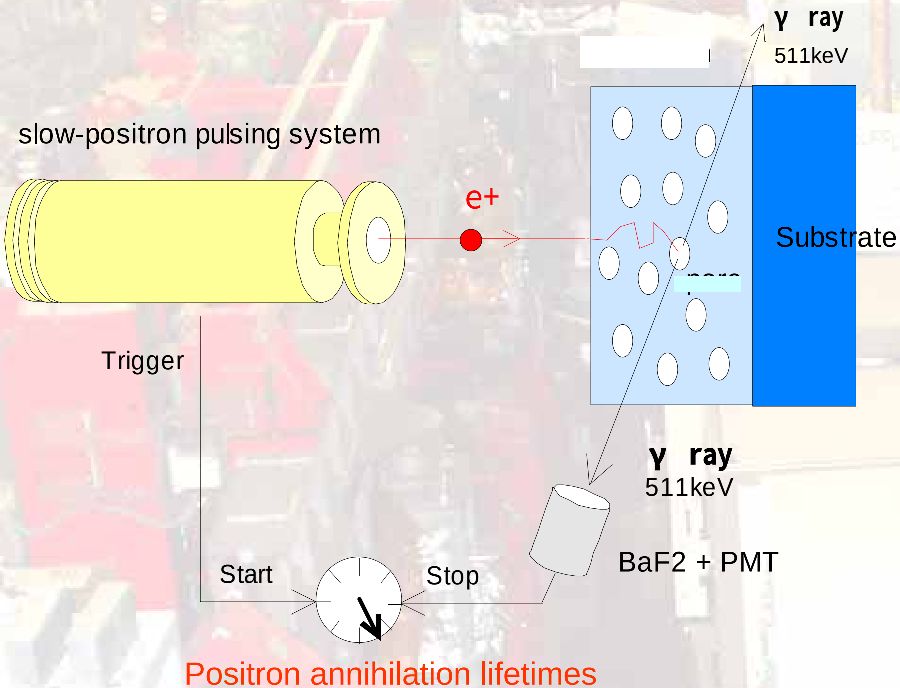
After thermal annealing treatment



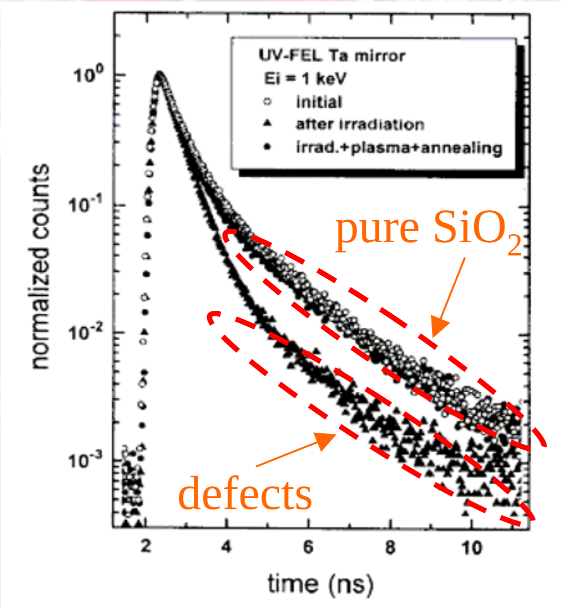
Degradation was almost restored.

To examine the degradation mechanism due to inner defects, we performed positron lifetime experiments.

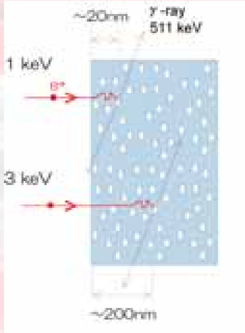
Depth-selective PALS(Positron Annihilation Lifetime Spectroscopy) system

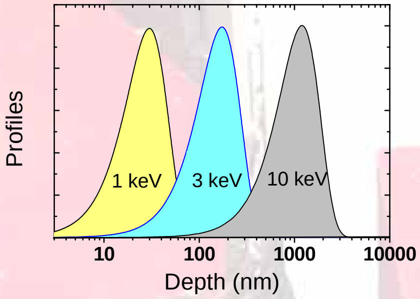


Depth-selective PALS system at AIST



- *Measurable pore-size range* : mono-vacancy – 100 nm.
- *Observation depth* : surface to ～3 μm (E=0.3～30keV).

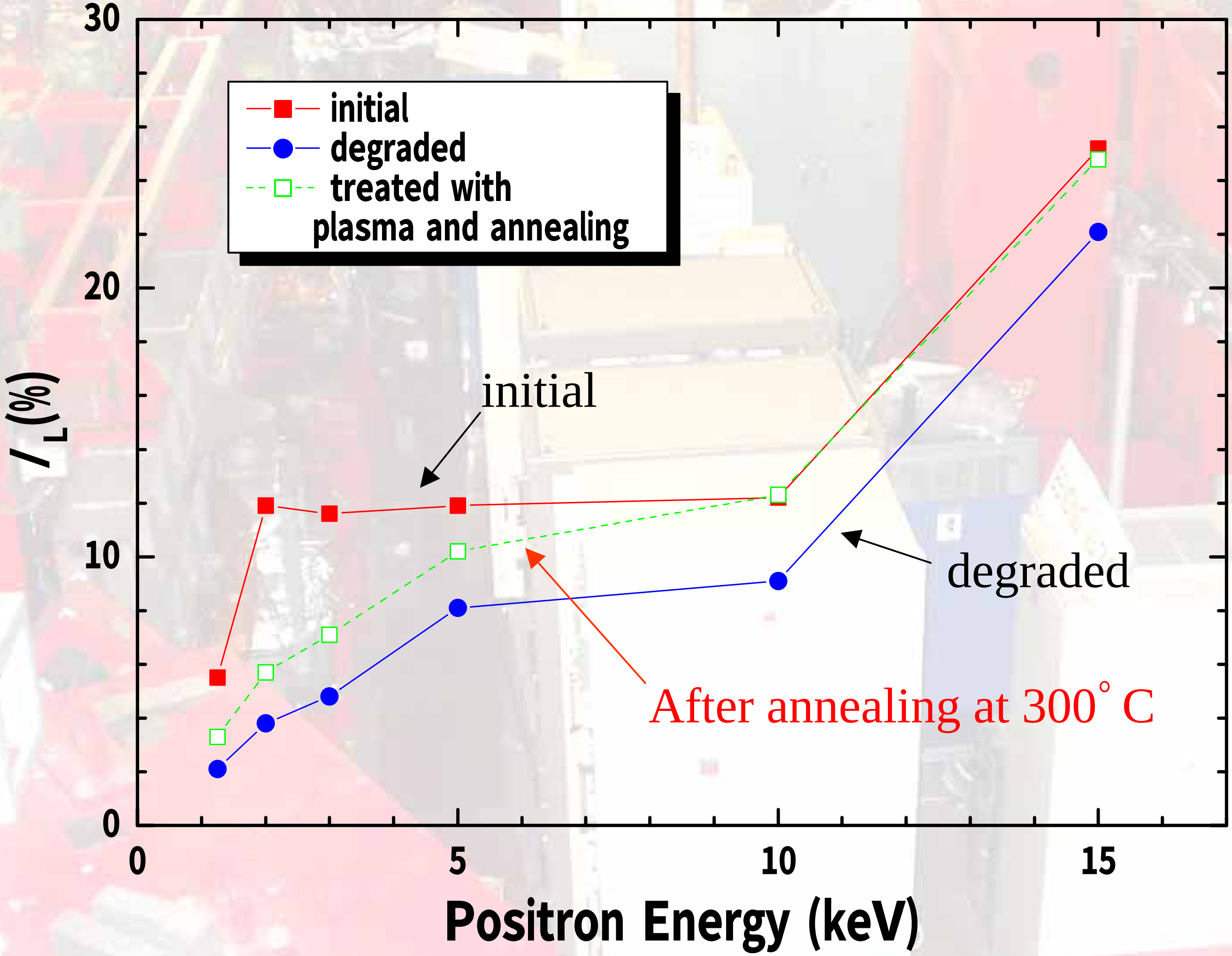




bond-like-type defects Si×O

→ Long-lived component is reduced.

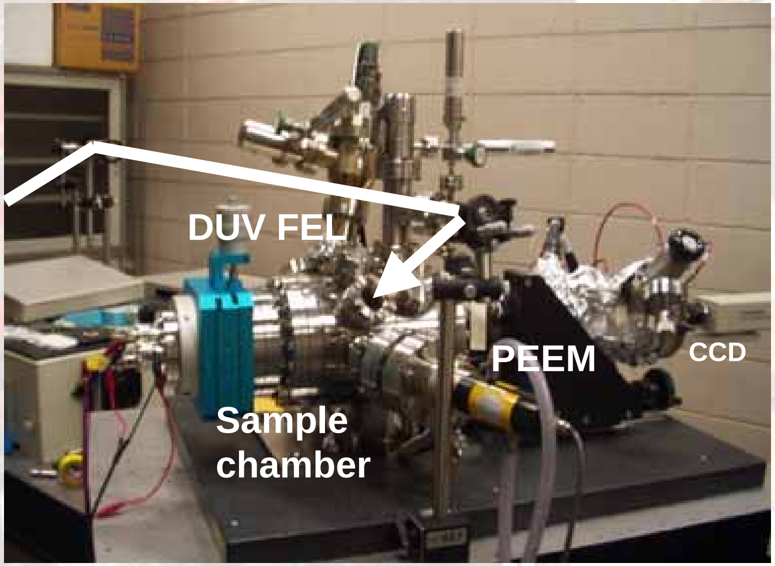
Result of Positron experiment

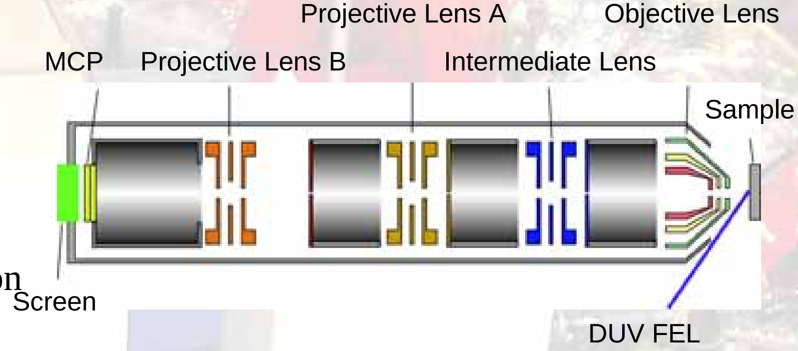


In the UV and visible regions, the defect was completely repaired with 230-250° C annealing

In the DUV/VUV, annealing should be more higher temperature to repair completely.

NIJI-IV FEL-PEEM (photoelectron emission microscopy) system





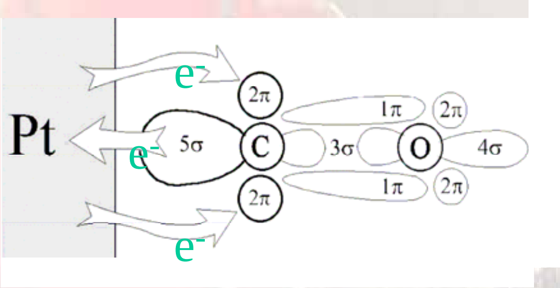
NIJI-IV DUVFEL was applied to surface observation, in combination with a PEEM system (STAIB Instrumente, type 350). This PEEM system has three sets of electrostatic electron lenses and a micro channel plate (MCP) equipped with a fluorescent screen. By viewing the focused images on the fluorescent screen with a CCD camera, transient phenomena, such as chemical reactions on transition-metal surfaces, can be monitored with video-rate time resolution. Since the spatial resolution of this system is 80 nm and our FEL intensity is large enough to extract sufficient amount of photoelectrons to recognize the surface contrasts within 33.3 msec, we can examine real-time physical and chemical information on transition-metal surfaces in a sub-micron scale.

Magnification	200-2000
Field of View	20 µm-200 µm
Guaranteed Resolution	100nm
Limited Resolution	80nm

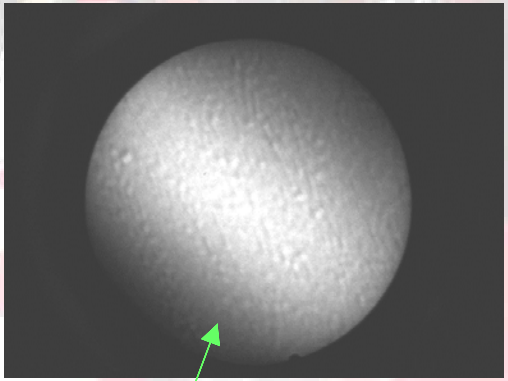
Catalytic CO oxidation ($2CO + O_2 \rightarrow 2CO_2$) on a Pd(111) surface

In case of Pt(110)

	Workfunction ϕ
Pt(110)	5.5eV ←FEL
Pt(110) ⊕ CO	5.8eV
Pt(110) ⊕ O	6.5eV

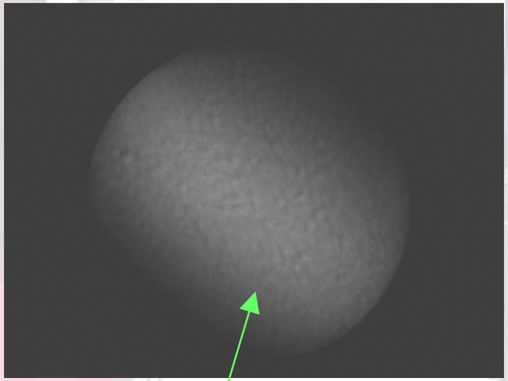


pure Pd(111) surface



bright surface

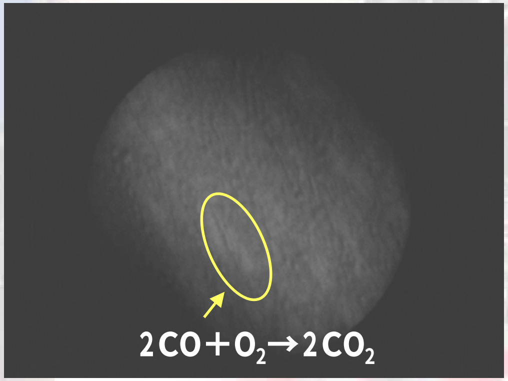
Pd(111) ⊕ CO



Exposed to CO gas

dark surface

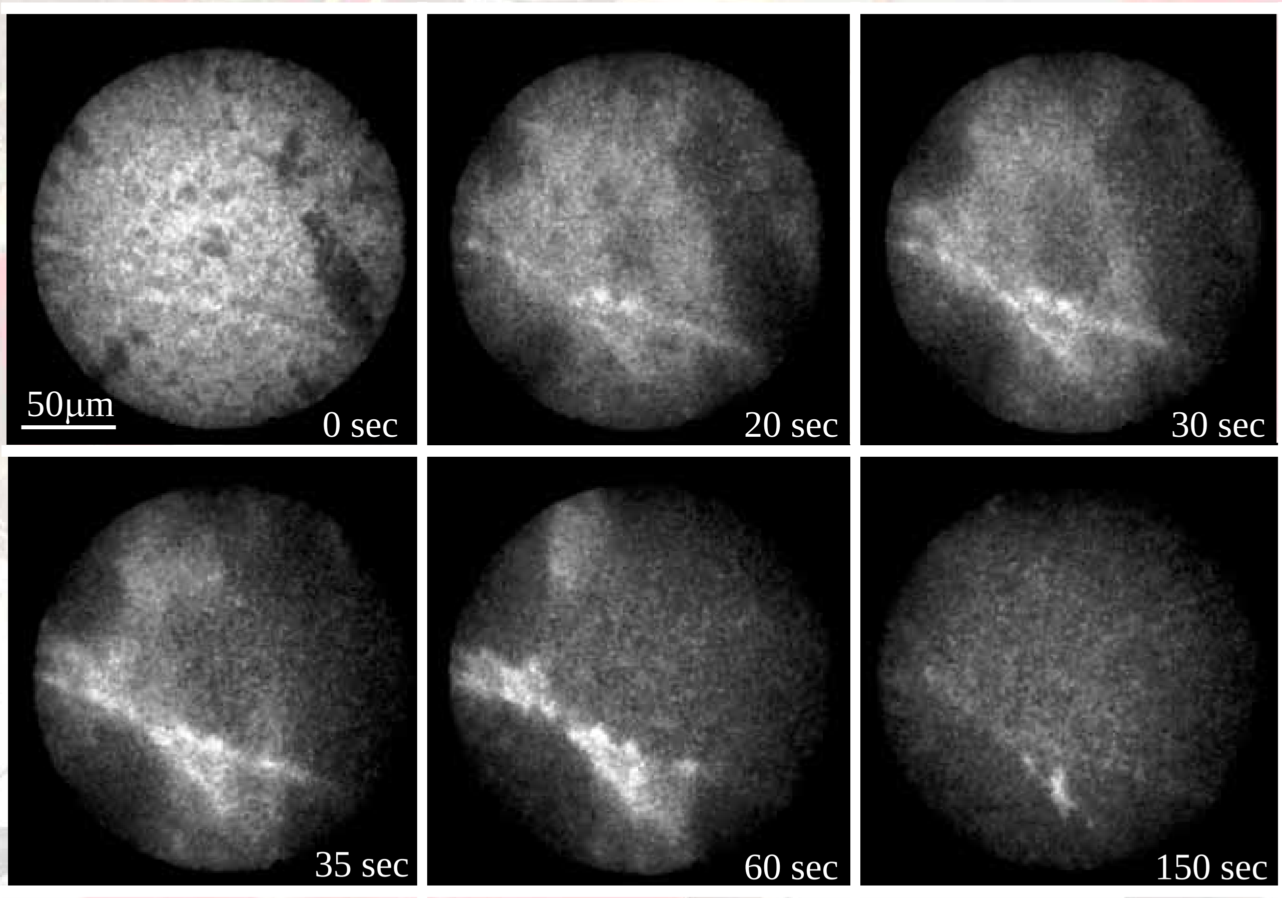
Produced CO_2 gas desorbs immediately.



Exposed to O_2 gas

K.Yamada: FEL Conf. 2004

Expansion of CO domain on a Pd(111) surface



Exposure

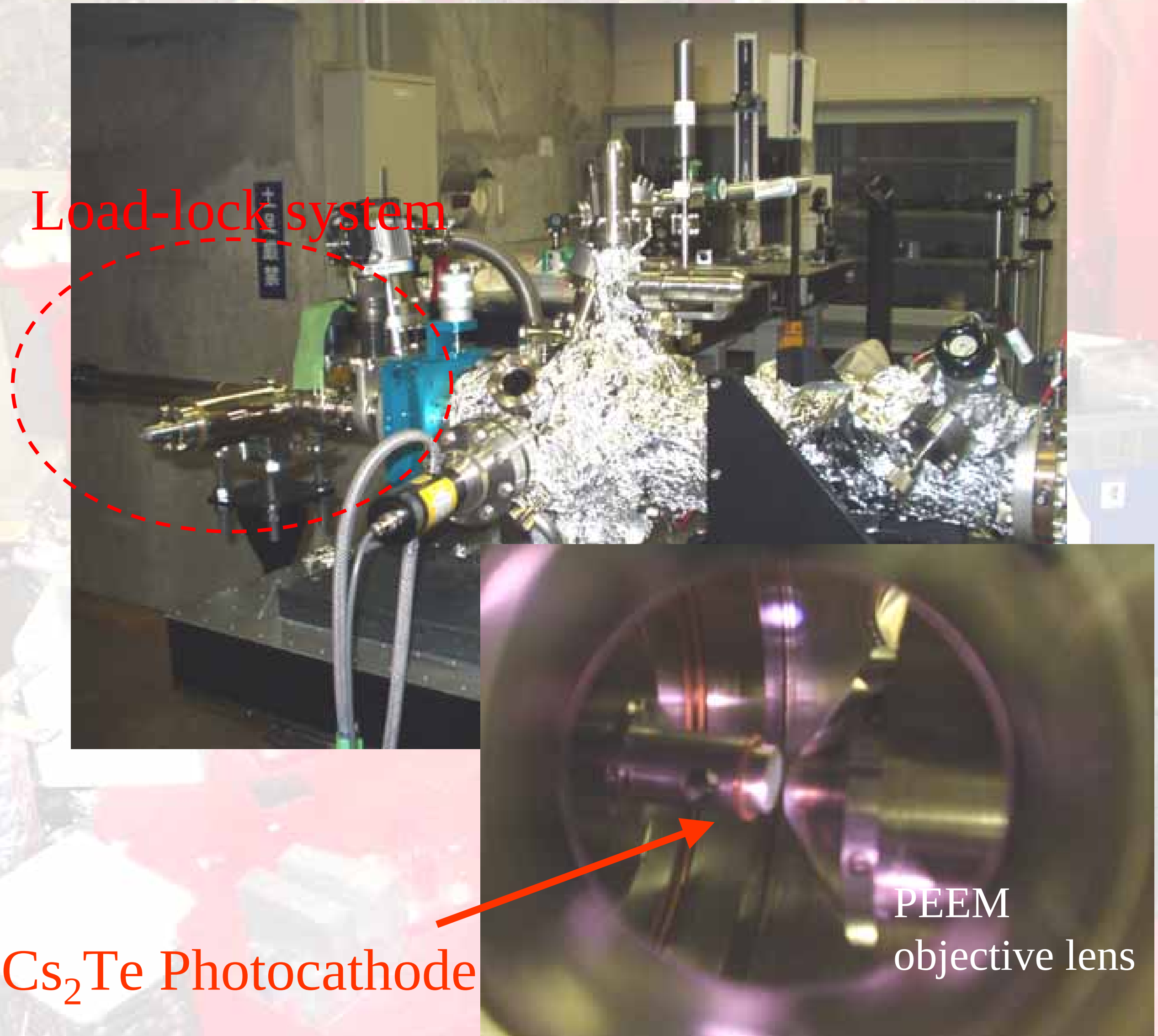
CO $(5 \times 10^{-6}$ Pa)

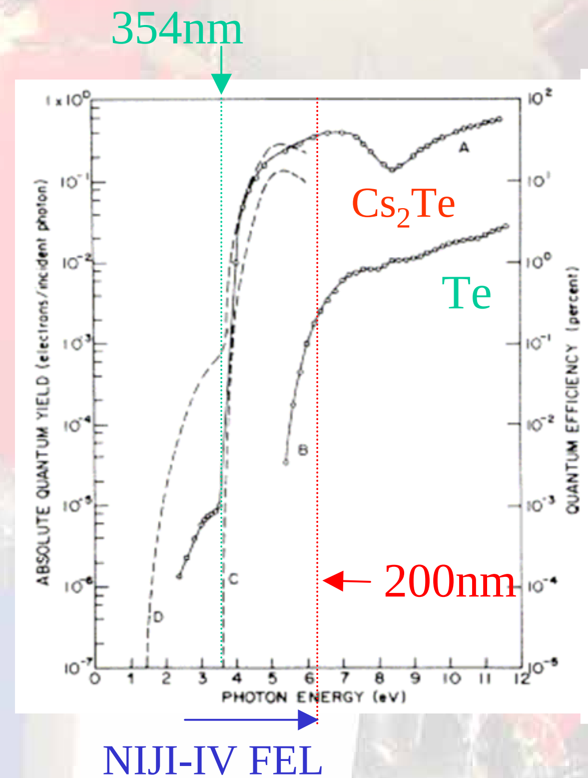
O_2 $(4 \times 10^{-5}$ Pa)

T = 360K

It is supposed that the oxygen play a role in preventing a speed of CO expansion.

Observation of Cs_2Te Photocathode





talk on Wednesday by Kuroda

Observation is now proceeding

Summary

- Stable optical cavity system was installed for DUV/VUV and IR FEL.

- Degradation in Al_2O_3/SiO_2 mirror was studied around 200nm. The degraded mirror was successfully restored by treatment of O_2 plasma and thermal annealing.

- As for FEL application study, a real-time imaging of chemical reaction was performed with PEEM and Cs_2Te photocathode observation is now proceeding .