P2-082

Gamma-ray irradiation effects on optical coatings and polarizers for edge Thomson scattering system in ITER

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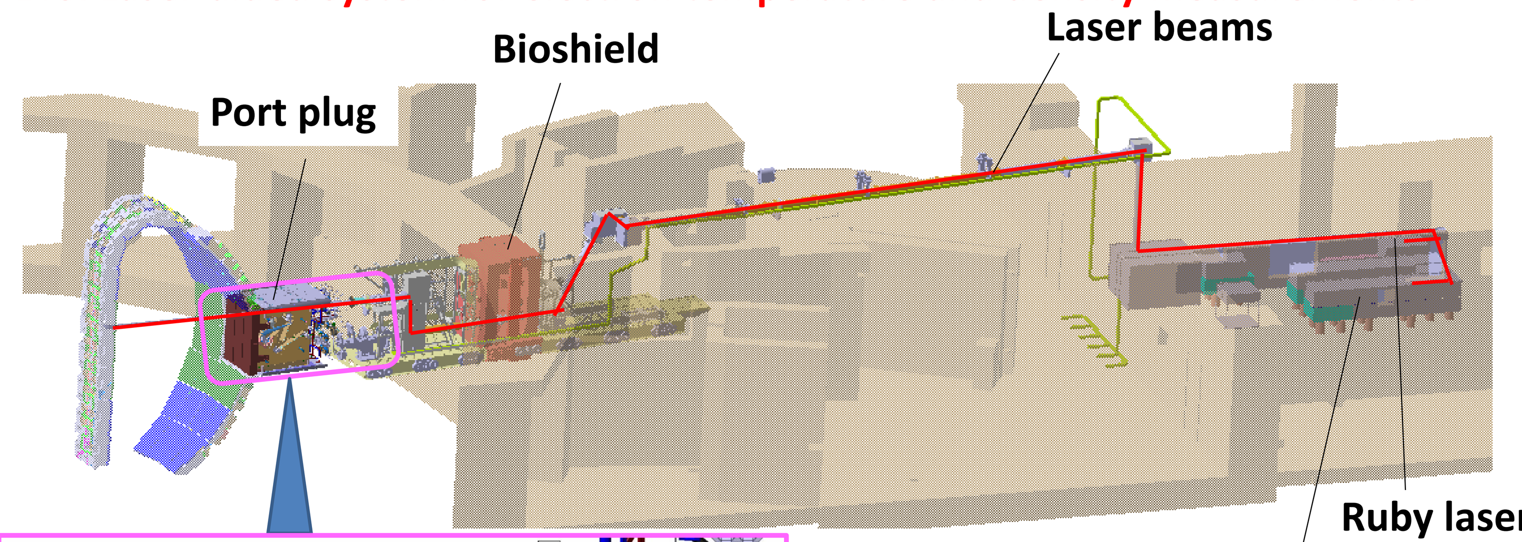
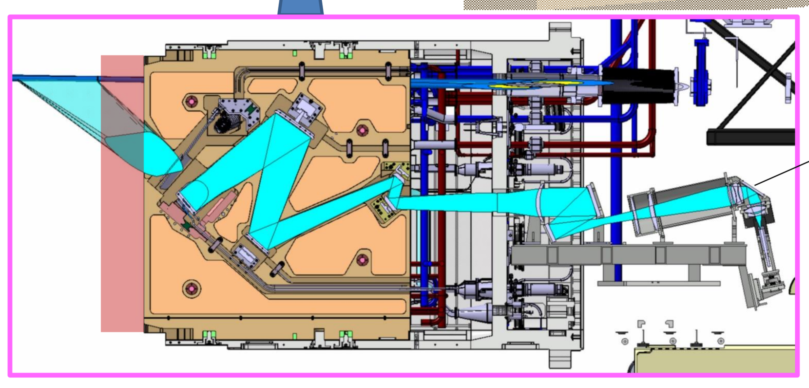
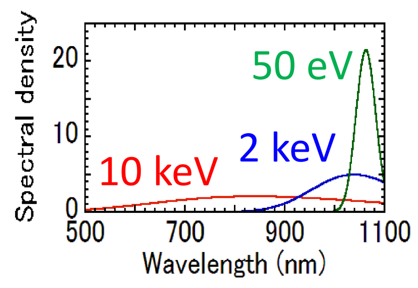
1. Background & Objectives

1.1 ITER Edge Thomson Scattering system (ETS)

ETS: Laser-aided system for electron temperature and density measurements.







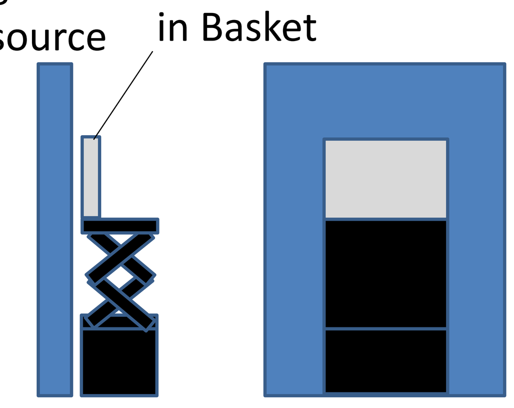
- ✓ YAG laser (λ=1064 nm) is the probing beam and ruby laser (λ=694 nm) is used for *in-situ* calibration of spectral transmission collection optics to detector.
- ✓ Laser beams are produced in the diagnostic building and transferred to plasma with many mirrors.
- ✓ Scattered light with a wavelength of 590-1070 nm are analyzed to determine electron temperature and density.

- ➢ **Optical elements in the Interspace (between port plug and bioshield) should withstand total gamma-ray dose of the order of MGy.**
- ➢ **Radiation hardness of laser injection window must be demonstrated.**
  - **•Vacuum window is confinement barrier for tritium, beryllium, etc.**
  - **•High power laser beam passes through the vacuum window.**
  - **•Laser-induced damage threshold (LIDT) after irradiation was unknown.**

2. Gamma-ray Irradiation

2-1. Irradiation Facility

Configuration



Uniformity of dose rate measured by dosimeter (Radix W, Radia Industry)

- ✓ Gamma-ray (^{60}Co) irradiation facilities of Takasaki Advanced Radiation Research Institute, QST.
- ✓ Dose rate ~ 10 kGy/h and maximum total dose ~ 10 MGy.
- ✓ All samples (typical size: 25 mm) were wrapped in aluminum foil.
- ✓ Temperature and humidity were not actively controlled in this study.

2-2. Specific demand of irradiation tests for ETS

High power laser optics with many kinds [Sec. 3]

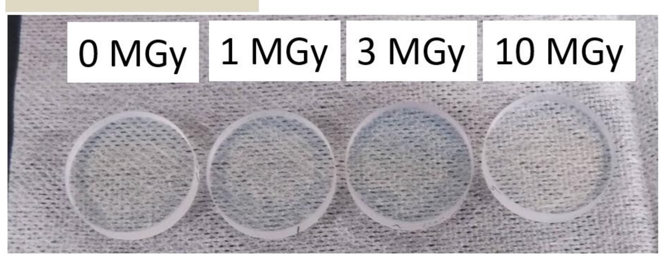
- ➢ **Laser-induced damage threshold (LIDT) after irradiation**
  - **・Anti-reflection (AR) coating for vacuum window**
  - **・High-reflection (HR) coating for laser beam transfer mirrors**
  - **・Beam splitter (BS) for laser beam alignment**

Small intensity and linearly polarized signal [Sec. 4]

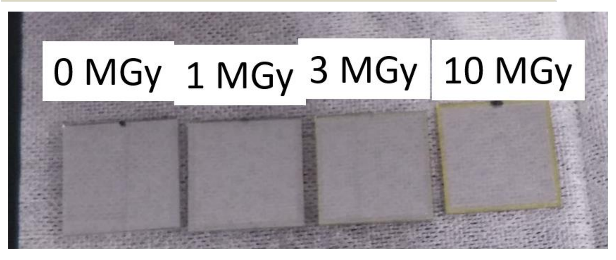
- ➢ **Spectral transmission of broad-band AR coating**
- ➢ **Spectral transmission and extinction ratio of wire-grid polarizer (WGP)**

2-3. Samples irradiated by gamma-ray

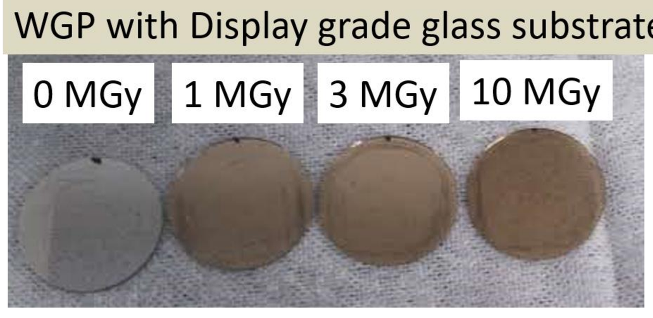
Laser window



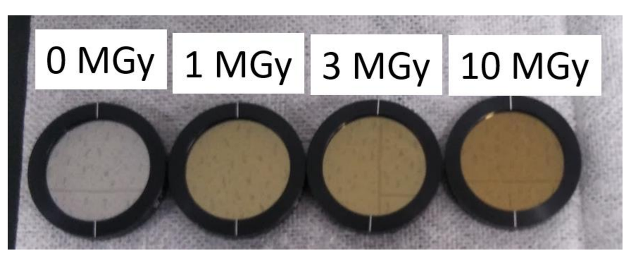
WGP with Fused silica substrate



WGP with Display grade glass substrate



WGP with Borosilicate glass



Conclusions

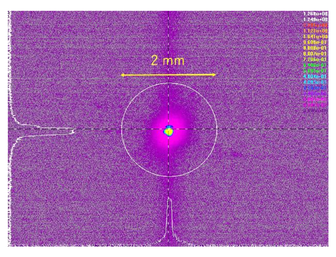
I. Laser-induced damage threshold (LIDT) of AR and HR coatings at the laser wavelengths:
  - A) Contrary to expectation, LIDT of AR coating is more likely higher for the irradiated samples at a wavelength of 1064 nm.
  - B) Regarding HR coatings, LIDT was not noticeably degraded by gamma-ray irradiation.

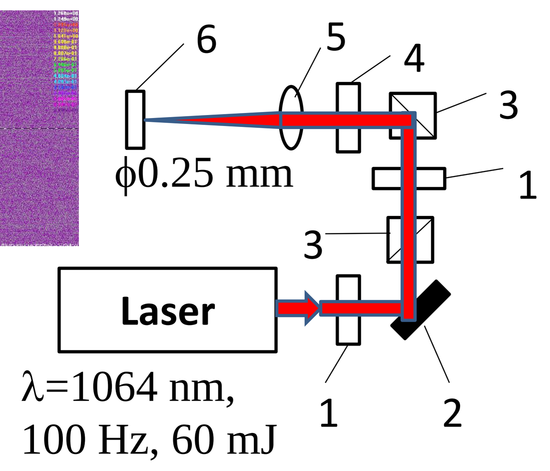
II. Broadband AR-coated windows and wire-grid polarizers for the collection optics:
  - A) AR-coated window decreased monotonously (3% @10 MGy, 600 nm)
  - B) Regarding wire-grid polarizers, no degradation was observed.

3. Laser-induced Damage Threshold (LIDT) after gamma-ray irradiation

3-1. LIDT test methods

Configuration





1: Half-wave plate
2: Mirror
3: Polarizer
4: 90° polarization rotator (for P-polarization injection)
5: Focusing lens
6: Sample

N-on-1 test for vacuum window

- ✓ Incident energy density of 5 J/cm² (6,000 pulses) was injected onto 10 spots of an optical element, and then it is increased by 1 J/cm².

S-on-1 test for dielectric mirrors

- ✓ A certain incident energy density (6,000 pulses) was injected onto 3 spots.
- ✓ If damage occurs, incident energy density was decreased.

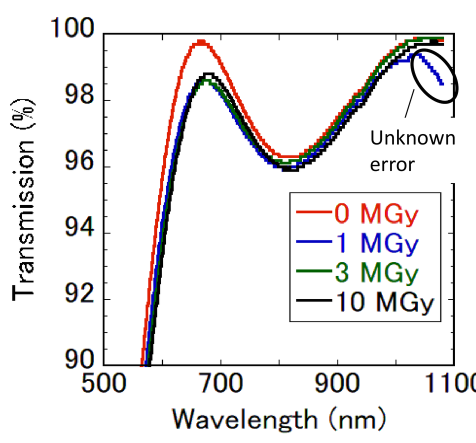
3-2. Consideration on difference between ITER and this study

Item	ITER	This study
Repetition rate	100 Hz	100 Hz
Pulse duration	4 ns	8.4 ns
Beam size	45-58 mm	0.25 mm
Number of pulses	2×10^9	6×10^3
Typical beam energy density	0.3 J/cm²	5-20 J/cm²

- ✓ Pulse duration: Nanosecond laser pulse has LIDT dependence on pulse duration of $\tau^{1/2}$. LIDT decreases by a factor of 0.7 at the pulse duration of laser used in ITER.
- ✓ Beam size: LIDT dependence on beam size disappears when the spot-size exceeds 0.1 mm.
- ✓ Number of pulses: It has been empirically found that the LIDT of the AR coating stops decreasing after several hundred pulses.

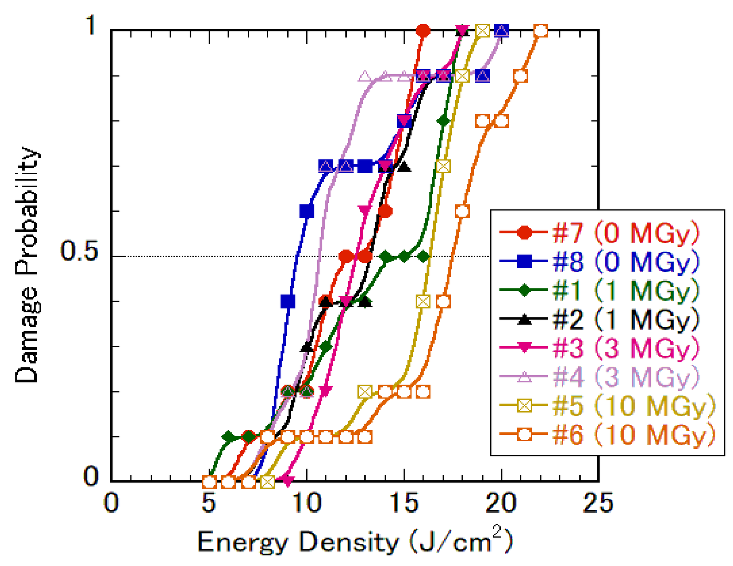
3-3. LIDT of laser window

Spectral transmission



- ✓ No degradation at λ=1064 nm.
- ✓ 1.5% degradation at λ=694 nm.

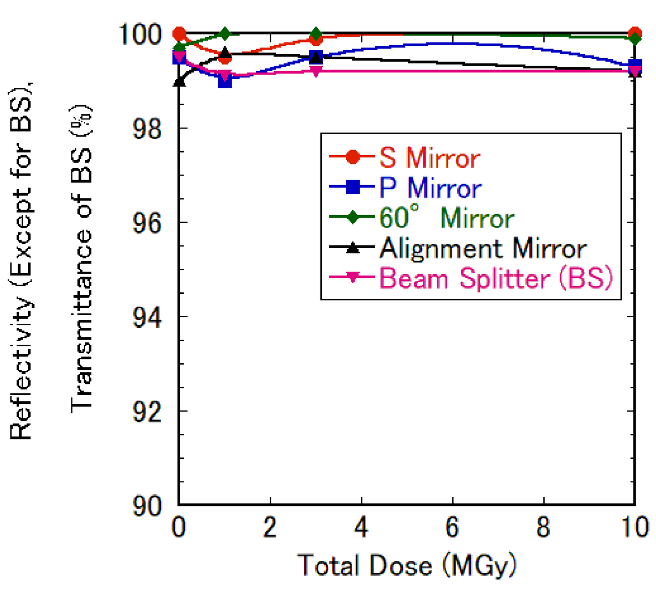
Result of N-on-1 test



- ✓ Although measurement was possible with only a small number of samples, and there was also variation among samples, the measurement result showed that LIDT was higher in the sample irradiated with 10 MGy.
- ✓ LIDT is sufficiently higher than incident beam energy density expected in ITER (0.3 J/cm²).

3-4. LIDT of dielectric mirrors

Reflectivity or transmission at 1064 nm.



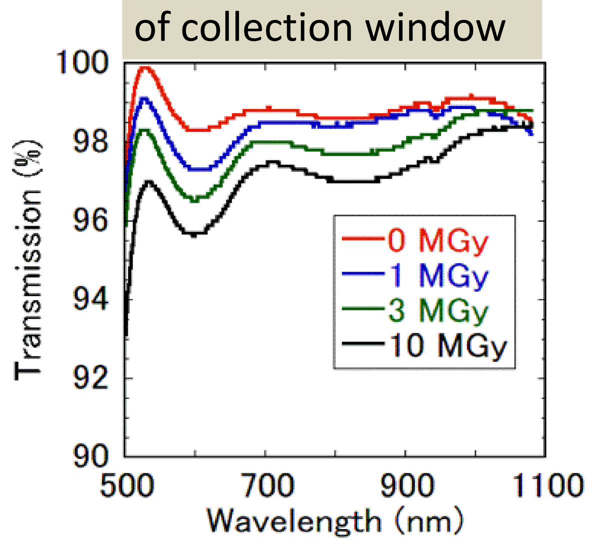
Roughly estimated LIDT values obtained with S-on-1 test

Name	AOI and polarization	Coatings	LIDT (J/cm²) 0 MGy	LIDT (J/cm²) 10 MGy
S mirror	45°, S	HR: 1064 nm HR: 694.3 nm	20	12.5
P mirror	45°, P		8	10
60° mirror	60°, S		9	8
Alignment mirror	45°, S	HR: 1064 nm HR: 694.3 nm 70% reflection: 642 nm	5	10
Beam splitter	45°, P	AR: 1064 nm AR: 694.3 nm 50% reflection: 642 nm	5	4

- ✓ It seems that the gamma irradiation up to 10 MGy does not cause a significant drop in LIDT, except for the "S Mirror".

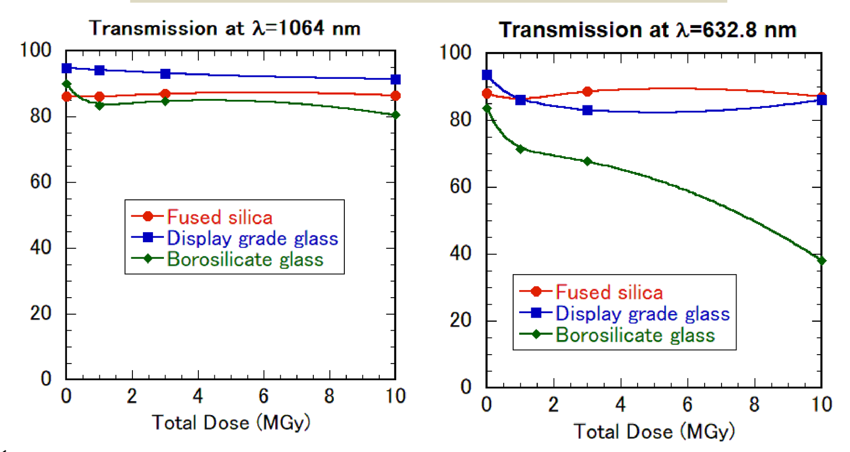
4. Gamma-ray irradiation effects on optical elements for scattered light collection

Spectral transmission of collection window



- ✓ 3% degradation at 600 nm.
- ✓ Collection optics includes 2 windows and 10 lenses.
- ✓ 22% (acceptable) total degradation is expected at 600 nm.

Spectral transmission of WGPs



- ✓ WGP with fused silica substrate maintains performance. S/N improvement is expected.