# 19PA-058

# Developments of a JT-60SA Thomson scattering diagnostic
JT-60SAトムソン散乱計測開発の進展

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Progress in developments of a JT-60SA Thomson scattering system is shown. A conceptual design of a laser image relay system (~ 50 m) is performed. Tracing the marginal ray of the laser object shows that the maximum laser width is ~ 30 mm. Thus, energy losses due to laser diffractions can be suppressed. A design of collection optics for the core measurements has been modified so that all lenses are radiation resistant. Designs of the lens-barrel and its supports are also completed. Use of insulting materials enable avoiding high eddy currents due to plasma disruptions. A cover glass to be placed in front of the vacuum window is utilized to shut heat flow from the plasma to the vacuum window.

## 1. Thomson scattering system in JT-60SA

Spatial profiles of electron temperature and density will be measured by an incoherent Thomson scattering diagnostic in JT-60SA[1]. A YAG laser is tangentially injected to the plasma to the toroidal direction on the equatorial plane. The scattered light is measured from three collection optics for the core plasma, edge plasma on the low-field side, and edge plasma on the high-field side. Use of the system enables obtaining whole radial profiles with enough spatial resolutions and dynamic ranges, e.g., 20 – 30 mm and 0.1 – 30 keV for the core measurements. In this presentation, recent progresses of the system design are shown: a laser image relay system, collection optics, a cover glass, and a vacuum window. The systems near the plasma should overcome and/or suppress severe environments in JT-60SA such as harsh radiation environment, severe heat flux from the plasma, electro-magnetic forces.

## 2. Laser relay system

The YAG laser [2] used in JT-60U will be transferred from a laser room to the machine room (~50m). In such a long laser delivery, profile distortions due to diffractions cause energy losses. Fluctuation due to airflow destabilizes the beam profile. In order to cope with these problems, a conceptual design of an optical image relay system has been performed. Figure 1 presents a simple schematic of the system. The vertical axis is the position of the ray on the lateral direction. Use of vacuum pipes prevents airflow and laser break down. Multiple lenses are employed so that the beam width which can be inferred from the position of the marginal ray is maintained within ~ 30 mm in the diameter. The image of the laser at the last amplifier in the laser room is projected at the last lens before the plasma. Note that the thicknesses of the lenses and vacuum windows were ignored in this estimation. Detailed evaluations of aberrations using true thicknesses of the lens and windows remain as a future work.

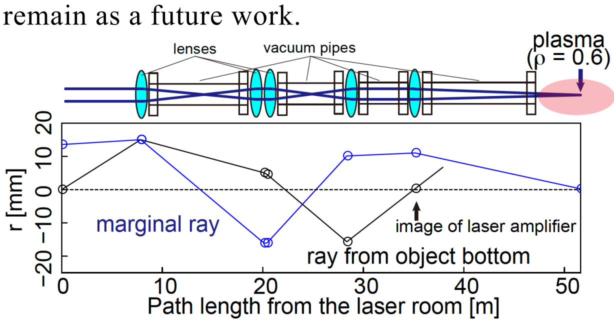


Fig.1 Positions of estimated marginal ray and ray from the bottom of the object.

## 3. Collection optics design

For the core measurements, the collection optics was designed. A modified Ernostar type with four lenses was employed for a wide viewing angle [3].

However, the glass materials of the lenses were BK7 (Schott), S-LAH53, and S-TIH14 (OHARA); intense radiation expected as ~ 1 MGy for 13 years in JT-60SA easily degrade their transmissions. In order to suppress such degradations in lenses, use of radiation resistant materials is an effective way. In the new system shown in Fig. 2 (a), all materials of the lenses are radiation resistant: BK7G18 and F2G12 (Schott). One lens was newly added at the back so that refraction power could be shared among the lenses otherwise strong spherical aberration appeared. Since the glass parameters such as refraction indices and Abbe numbers are different from the previous materials, the thickness and curvatures of the lenses are optimized for obtaining good spatial resolution. Resultant spatial resolution defined as a spatial scale of the encircled energy, is the same as the previous design (~ 0.6 mm).

A lens-barrel consisting of multiple lens mounts and their position adjusting system has also designed as shown in Fig. 2 (b). Plasma disruptions resulting in sudden termination of the poloidal magnetic field (1.4 T/4 ms on the vertical direction) generate large eddy current. Coupling with the toroidal field may cause huge electro-magnetic force (EMF). Especially, eddy current is expected in a rotation about the vertical axis. Use of insulting materials, i.e., glass epoxy substrate and machinable ceramics enable suppressing the EMF. The Lens-barrel is made of stainless steel but the surrounded components are made of the insulting materials. Thus, the maximum stress in the lens-barrel is suppressed as ~0.46 MPa, which is far from the limited stress.

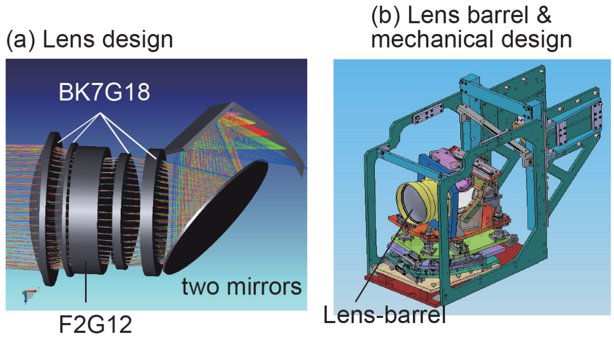


Fig.2 (a): optical design using radiation resistant lenses. (b): Lens-barrel and mechanical design.

## 4. Cover glass and vacuum window

The collection optics will be installed in a port-plug, which accesses the vacuum vessel from the cryostat. Inside of the port-plug is atmospheric. At the head of the port-plug, a large vacuum window (silica) is utilized and the effective window size is 350 mm in a diameter to ensure a wide field of view of collection optics and the large pupil size. However, heat flux from the plasma estimated as 40 kW/m$^2$ may cause heat stress and displacements in the window and may break the high-vacuum seal. Thus, a cover glass which receives the heat flux but dose not require any vacuum seals is planned to be installed in front of the vacuum window.

Figure 3 shows the design. Since the cover glass should endure the EMF generated in the port-plug, rubber O-rings, which are radiation resistant (D0270, NIPPON VALQUA INDUSTRIES, LTD.), are used to hold it with some elasticity. Enough tolerance was confirmed by an estimation assuming a system of mass points of the port-plug and a cover glass. A solution of the equation of motion shows the maximum stress on the glass was only 0.6 MPa, when EMF ($1.2 \times 10^5$ N for 4ms on the port-plug) is added on the radial direction. Adhesion of carbon compounds and/or metal impurities on the vacuum windows significantly degrades the transmission [4]. The vacuum window and the cover-glass are all-in-one and can be installed from the inside of the port-plug: thereby making frequent replacements and sustainment of high transmission possible.

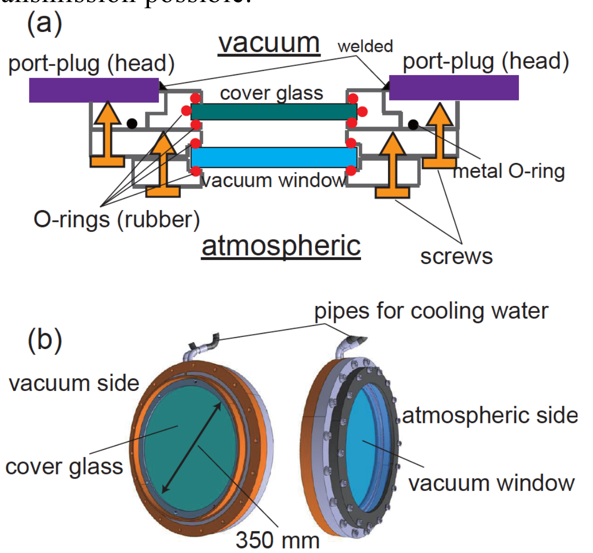


Fig.3 Schematic of a cover glass and a vacuum window. (a): The cross-section view. Space between the two windows is in vacuum. (b): Design from two different views, the vacuum side and atmospheric side.

**References**

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[2] T. Hatae et al., Review of Scientific Instruments **77** (2006) 10E508.

[3] H. Tojo et al., Review of Scientific Instruments **84** (2013) 093056.

[4] H. Yoshida et al., Review of Scientific Instruments **68** (1996) 256.