Progress in development of the KSTAR Thomson scattering system

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Abstract. The design of Thomson scattering system for the Korean Superconducting Tokamak Advanced Research (KSTAR) device is described. The system includes a laser beam guiding system, laser input port, laser beam dump, collection lens, shutter, and cassette system. The laser guiding system has a collimating lens set for reducing the laser power loss. The laser beam dump will be attached inside of the vacuum vessel and hence it has been designed compactly. The preliminary design of collection lens, shutter system, and the cassette were done by PPPL and the engineering design is being executed by NFRI. The collection lens system has two sets of lenses, one set is designed for the core and the other set is designed for the edge. Two sets of pneumatic shutter systems are designed for independent remote control. Most of the KSTAR Thomson scattering system design is already finished and we are planning to install the whole system by March, 2010. We will measure the plasma parameters \((T_e, n_e)\) in KSTAR during the third campaign.

1. Introduction

The Korea Superconducting Tokamak Advanced Research (KSTAR) tokamak [1] achieved the first plasma on the last day of June 2008 at the National Fusion Research Institute, Daejeon, Korea. Thomson scattering has become an important diagnostic for measuring electron temperature and density profiles in most tokamaks. [2][3][4] Therefore we plan to install the KSTAR Thomson scattering system before the KSTAR 3rd campaign in 2010. The goal of the Thomson scattering diagnostic on KSTAR is to provide reliable electron temperature \(T_e\) and density \(n_e\) profiles in both core and edge regions during long-pulse tokamak plasma discharges. To meet this goal, we are designing each part of the KSTAR Thomson scattering system, such as laser beam guiding system, laser inlet system, and laser beam dump system inside the KSTAR vacuum vessel and collection optics systems with a cassette. For the laser system, we will use a commercial Nd:YAG laser (1064 nm, 10 Hz, ~1.5 J, Coherent Co.) for the 3rd campaign. For the KSTAR 4th campaign in 2011 and the next 5 years, a high-power high-performance (> 3 J) high repetition rate (> 50 Hz) Nd:YAG laser system will be used which is being developed by JAEA, Japan. [5] Next year in 2010, the design requirements for parameters to be measured are as follows; time resolution: 100 msec (10 Hz), spatial resolution: 15 mm in the core and 25 mm at the edge, temperature range: 10 eV < Te < 1.5 keV in the core and edge, density range: \(3 \times 10^{18} \text{ m}^{-3} < n_e < 2 \times 10^{20} \text{ m}^{-3}\). [6]

In this paper, we describe the engineering design of the laser beam dump, laser shutter systems etc., and the 1st calibration data for the polychromators.
2. Thomson scattering apparatus on the KSTAR tokamak

The KSTAR Thomson scattering system is configured with 90° scattering optics, including a single tangential beam, as illustrated in Figure 1. The laser beam, transported for a distance of about 40 m and focused by a 5.5 m focal length lens, is directed into the vacuum vessel through the mid-plane port of Bay L (the Lm-port). The focal lens and steering mirror are mounted on an optical bench which is located in front of the Lm-Port. Finally the laser beam reaches the beam dump that is located at the Bm-port wall in the vacuum pumping duct. The collection optics with cassette system is located in the Nm-port and shares that space with the ECH launcher system (Figure 2). Most of the other parts of the Thomson system such as laser, polychromators, and A/D system will be located in the diagnostics room which is well shielded from radiation.

![Figure 1. Top view of the KSTAR Thomson scattering system](image)

![Figure 2. Photograph of the KSTAR Thomson cassette port inside the vacuum vessel. (The ECH launcher system is shown on the right side of the photo)](image)

2.1. Lens design and cassette

The preliminary design of the Thomson collection lenses was done by PPPL [6], but recently we have changed the design using lens design software. PPPL’s design consisted of four lenses for the core and edge collection optics systems and each optics module had the same design. However, we have designed the core and edge parts of the lenses differently because each part of the KSTAR Thomson collection lenses has different viewing angles. Finally, we have obtained the optimum focusing spot size for core and edge lens systems using quartz glass. In our design, the spot size of the core part is around 20 micrometer and the edge part is 500 micrometer. The cassette and shutter were also designed by PPPL. We will finish this cassette system early in 2010 and will test the collection optics positioning and alignment.

2.2. Laser input port and beam dump design

The laser input port of the KSTAR Thomson system is located on the mid-plane Lm-port. The Thomson laser input system shares the available space with the resistive bolometer system. The laser input port contains five parts of the system; an electro-pneumatic operation gate valve, ceramic break, bellows, baffles, and vacuum window.

The laser beam dump design is very simple as shown at Figure 3. This wedge type beam dump is made with SUS316L outside and thick carbon sheet inside. Of course, this beam dump has a baffle and straight knife edges around the edge of a doughnut hole that are located at the front of this wedge dump system. This simple beam dump will be attached at the end of Bm-port because of the limited number of KSTAR tokamak vacuum windows.
2.3. Polychromator and calibration
The KSTAR polychromator was developed by the Japan - Korea nuclear fusion joint cooperation program. This program completed the polychromator design and 25 polychromators with power supplies were made by NIFS, Japan. These polychromators have 5 different wavelength channels (filter combinations in nm): [890, 990], [990, 1030], [1030, 1050], [1050, 1060], [1062, 1066]) (Figure 4), and avalanche photo diodes (APD). Recently we performed calibrations, including detector position, wavelength, light intensity, pulse width, and voltage-out calibration for the 25 polychromators. The detector position calibration used tungsten light and we rotated the x- and y-axis to find the maximum voltage from the APD signals. The next calibrations were the wavelength and light intensity calibrations. In these calibrations, we use a calibrated detector (Melles Griot silicon detector) and a monochromator (CVI Co.). Table 1 shows an averaged central wavelength and Full width at half maximum (FWHM) of wavelength with standard deviation for each polychromator channel from this calibration. Figure 4 is an example of filter combination spectrum data for the polychromator #1 from the calibration of light intensity. For the pulse width calibration, we made a diode laser pulse light source that had a pulse width of ~19 nsec. Table 2 shows the average pulse width with standard deviation for each polychromator channel measured using an oscilloscope. Finally, we measured the output voltage from the APD. From these five different calibrations, we confirmed the performance of the polychromators. From this result, we will measure the KSTAR electron temperature next campaign, 2010, using these polychromators that measuring range will be 10 eV < Te < 1.5 keV. (Figure 6)

Table 1. Filter wavelength calibration data for the polychromators.

|        | Channel 1 | Channel 2 | Channel 3 | Channel 4 | Channel 5 |
|--------|-----------|-----------|-----------|-----------|-----------|
| λc^a   | 1063.6    | 1054.5    | 1043.4    | 1010.5    | 944.4     |
| δb     | 11.24     | 5.32      | 10.8      | 32.8      | 103.2     |
| Avg.   |           |           |           |           |           |
| σ^d    | 0.8       | 0.51      | 0.49      | 0.59      | 1.50      |
|        | 0.66      | 0.48      | 0.48      | 0.44      | 1.37      |

^a Center of wavelength (nm), ^b Full width at half maximum (FWHM) of wavelength (nm)
^c Average wavelength (nm), ^d Standard deviation

Figure 3. Beam dump design for the KSTAR Thomson scattering system.

Figure 4. Polychromator filter combination (example: polychromator #1).
Table 2. Laser pulsewidth(FWHM) calibration data for the polychromators.

| Channel 1 | Channel 2 | Channel 3 | Channel 4 | Channel 5 |
|-----------|-----------|-----------|-----------|-----------|
| Avg. $^a$ | 19.68     | 19.74     | 19.24     | 19.16     | 19.04     |
| $\sigma$$^b$ | 0.69      | 1.35      | 1.23      | 1.25      | 1.4       |

$^a$ Average pulsewidth at FWHM(nsec), $^b$ Standard deviation

3. Installation schedule for the KSTAR Thomson scattering system

To measure electron density and electron temperature profiles on KSTAR using Thomson scattering diagnostics, most of system design has been completed now and the system must be fabricated this year. However the cassette system is actually quite complicated to design for the KSTAR Thomson diagnostics because of the long narrow port size and, in addition, sharing port space with the ECH launcher system. For this reason, the Thomson cassette will be finished next February. The optical fiber and collection lens are designed and these are now undergoing a final check.

The 1st calibration of KSTAR polychromator was successfully finished, and moreover at the end of this year we will perform a 2nd calibration. The 3rd calibration will be performed just before the KSTAR 3rd campaign. These calibrations will give reliable results for the KSTAR plasma electron temperature and density.

The KSTAR Thomson scattering diagnostic system should be installed next year to measure KSTAR 3rd plasma, 10 spatial points for 2010, 25 spatial points for 2011, and 40 spatial points for 2012.

References
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