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Analysis of baffles for stray light reduction in the Thomson scattering diagnostic on EAST

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HIGHLIGHTS

- A stray light analysis model of baffle was built.
- Stray light suppression effect of installed double edged baffle was analyzed.
- A new corrugation baffle with 33.3% less stray light than the old one was designed.
- An EAST TS diagnostic system simulation model was built.
- Stray light suppression effect of the system with the two type baffles was analyzed.

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ABSTRACT

Baffle is a critical technique to suppress stray light. In order to reduce stray light of EAST Thomson scattering (TS) diagnostic system, a 60° cone angle double edged baffle array was installed for the system. Recently the 45° cone angle corrugation baffle was designed based on double edged baffle and simulation results indicate that the new design can reject 33.3% more stray light than the old one. Based on the mechanical structure and surface property of EAST TS diagnostic system, a stray light analysis model has been built, and using the model, stray light of the system was simulated with the two types of baffles added to the system respectively. Results show that the installation of 60° cone angle double edged baffle array in input tube can cut 92.1% of the stray light to the system, while using 45° cone angle corrugation baffle array in input tube and three 45° cone angle corrugation baffles in exit tube, additional 74.1% of the stray light will be removed.

1. Introduction

Electron temperature and density are both significant parameters in physical research of fusion plasma. Thomson scattering (TS) diagnostic system can precisely measure the profiles of electron temperature T_e and density n_e simultaneously and has been exploited widely in fusion devices [1–7]. For the system, massive stray light is introduced due to optical elements, some mechanical parts of the system, suspended dust and other sources, and the intensity of stray light is very high in comparison with the TS signal. So it leads to some difficulty in system calibration and measurement. Based on the characteristics of different TS diagnostic systems, some stray light analysis and suppression methods have been used. For DIII-D TS diagnostic system, D.G. Nilson used a CCD camera to analyze stray light produced in DIII-D vessel interior, and then reduced stray light to an acceptable level, compared to the Rayleigh signal, through combined methods of image relaying, exit window tilting, entrance and exit baffle modifications, and a beam polarizer [1]. Through simulating ETE TS diagnostic system, L.A. Berni found the main source of stray light generated in the system, and then by changing the design of the beam dump, the stray light was reduced up to 60 times [2]. Additionally, high energy beamlet generated in laser oscillator cavity is a dominant stray light source in HBT-EP TS system. In order to reduce stray light of the system, J.P. Levesque designed a high-power spatial filter which used a focusing lens to focus the laser beam through a pinhole aperture to remove spatial irregularities or high-k components of the laser beam and obtained a good effect [3].

EAST TS diagnostic system is a complex optical system which includes laser, laser propagation path, signal collection system, polychromator, and data acquisition and analysis system [8,9]. Fig. 1 shows the laser propagation path and signal collection sys-

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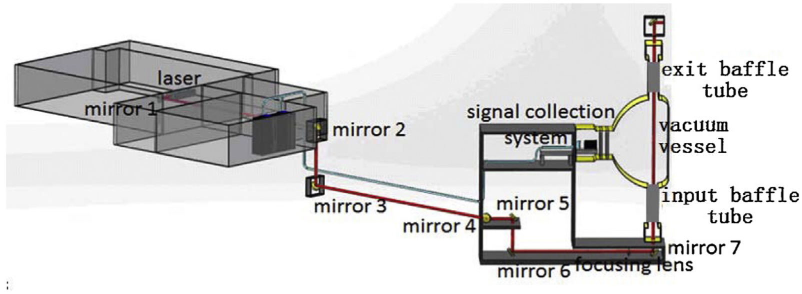

Fig. 1. Diagram of laser propagation path and signal collection system of EAST TS diagnostic system.

tem of EAST TS diagnostic system. Laser beam propagates through seven reflection mirrors with total optical path over 40 m. A 6 m focal length lens was inserted in the beam path to focus it down to 3 mm diameter in the middle of the plasma column inside the vacuum vessel. Collecting system, including collecting lens and signal collecting fiber, was installed in the horizontal viewing port (side window) to collect 90° Thomson scattering signals. For the system, the structure and position of the collecting system are easy to introduce stray light into signal collecting fiber if stray light enters vacuum vessel. The scattering light of optical elements and backward scattering light of outgoing laser are two primary sources introducing stray light into vacuum vessel. So, two baffle tubes were installed after the entrance and before the exit window of vacuum vessel used for laser beam propagation to suppress stray light respectively. Raman scattering density calibration result shows that the influence of stray light on Raman scattering density calibration is very small [10]. However, the intensity of stray light isn't yet reduced to a level small enough to realize Rayleigh scattering density calibration, as signal-to-stray ratio is still about 1%–10%. So, it needs to reduce stray light much more for the system to meet Rayleigh scattering density calibration in the future. In the paper, the structure of baffle already installed in the system was analyzed firstly. And then a new corrugation baffle was designed based on the analysis of old baffle. At last, a simulation model of EAST TS diagnostic system was built and stray light of the system was analyzed with the two types of baffles added to the system.

2. Baffle analysis

Referring the baffle installed in DIII-D TS diagnostic system [1], a tube including five circular double edged baffles with 60° cone angle has been designed and installed in EAST TS diagnostic system between entrance window and vessel bottom. It is called input tube with total length 3.37 m and tube aperture diameter 119 mm. It provides a maximum aperture 32 mm diameter baffle near entrance window, three baffles with aperture 25 mm diameter distributed in the middle and a minimum aperture 12 mm diameter baffle in the end of the tube for laser beam to enter vacuum vessel. Fig. 2 shows the structure of 60° cone angle double edged baffle. The other tube including eight rectangle baffles with aperture 32 mm × 182 mm was installed between the vessel top and exit window, which is called exit tube. The total length of the tube is 2.98 m.

For double edged baffle, the cone angle is an important factor to suppress stray light. In order to compare stray light suppression effects of double edged baffles under different cone angles, 60° cone angle was modified to other cone angles to form corresponding cone angle double edged baffles, and a simulation model was built by using TracePro® software to analyze stray light suppression effects of the baffles. Fig. 3 shows the simulation model, which includes a light source, a mirror, a baffle installed in a tube and a detection surface. In the simulation model, the light source generated a 1 mm radius laser beam (red light rays) that was composed of 10,000 rays with each ray of 1 W flux first, and then the laser beam was reflected by a mirror with surface specular reflection coefficient 0.995 and scattering coefficient 0.0011 to generate stray light (blue light rays). Different cone angle edged baffles with the same aperture and surface property were added to the tube for the simulation respectively, and the detection surface was placed

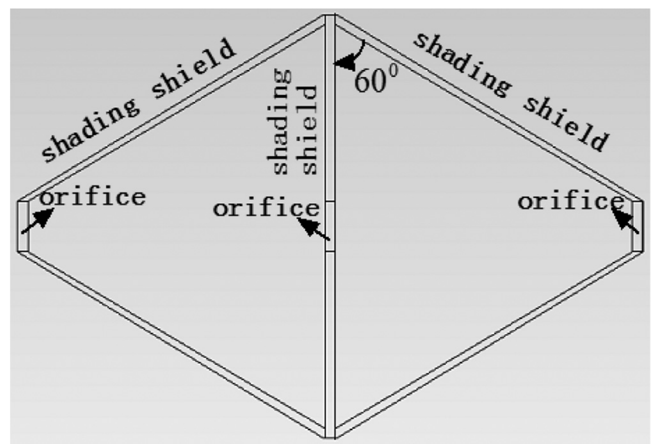

Fig. 2. Structure of the double edged baffle.

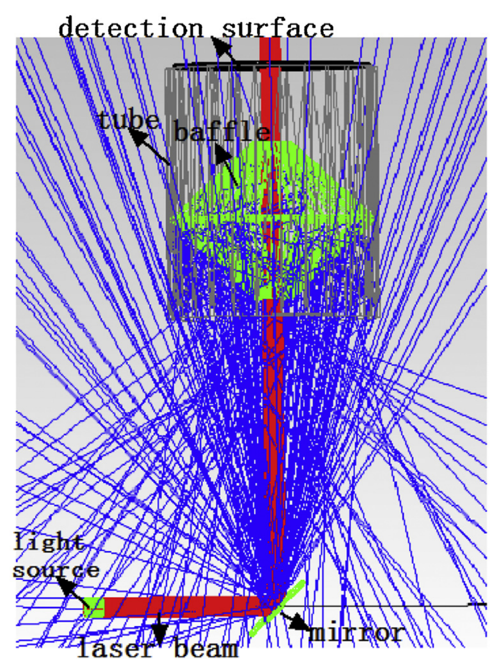

Fig. 3. Simulation model for comparing stray light suppression effects of double edged baffles under different cone angles.