MECHANICAL DESIGN ASPECTS OF THE ADVANCED TOROIDAL FACILITY THOMSON SCATTERING DIAGNOSTIC*

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Abstract

A two-dimensional (2-D) Thomson scattering system has been designed for the Advanced Toroidal Facility (ATF), a torsatron experiment at the Oak Ridge National Laboratory (ORNL). The system is a modification of the Thomson scattering system used on the Impurity Study Experiment (ISX-B) tokamak. It will provide measurements of electron temperature (T_e) and density (n_e) at 15 points along a vertical chord. With multiple shots, a 2-D T_e and n_e map of a toroidal cross section of ATF can be obtained. The horizontal Thomson scattering viewing port is offset by 15° toroidally from the ports through which the vertical laser beam passes. The modifications to the ISX-B Thomson scattering system are either changes required to adapt the system to the ATF device geometry or changes that result in improvements to the original system. This paper deals with the mechanical design aspects of the laser light baffle plates that reduce the amount of extraneous light entering the plasma, the upper and lower vacuum extensions that contain the baffles and attach to the ATF vacuum vessel, the entrance window assembly, the laser dump assembly, the viewing window and shutter assembly, and the alignment target mechanism and drive used to determine the mapping of data points in the plasma cross section.

Introduction

Figure 1 shows the Thomson scattering system for the ATF [1]. This paper describes the system's main mechanical components, shown in Fig. 2.

In the ATF Thomson scattering system, a ruby laser beam focused to a diameter of 2 mm passes through the plasma. The beam image at the collection optics is one-fourth of the focused beam diameter; this necessitates care in the alignment, and hence the design, of the system. To minimize stray light in the system that could drown the electron scattering signal, baffles are located in the vacuum extensions that allow the laser beam to enter and exit the ATF vacuum vessel and prevent air breakdown by the laser as it is focused. The extensions also allow the entrance window and beam dump to be located far enough from the focused plasma to prevent damage to the glass. Through careful alignment and design, most of the laser beam is absorbed in the dump without reflecting back toward the plasma.

The mechanical design of the Thomson scattering system was constrained by several criteria that were beyond the control of the design team. The location of the system on the machine relative to other diagnostics was determined before mechanical design began. Early in the construction phase, the hole in

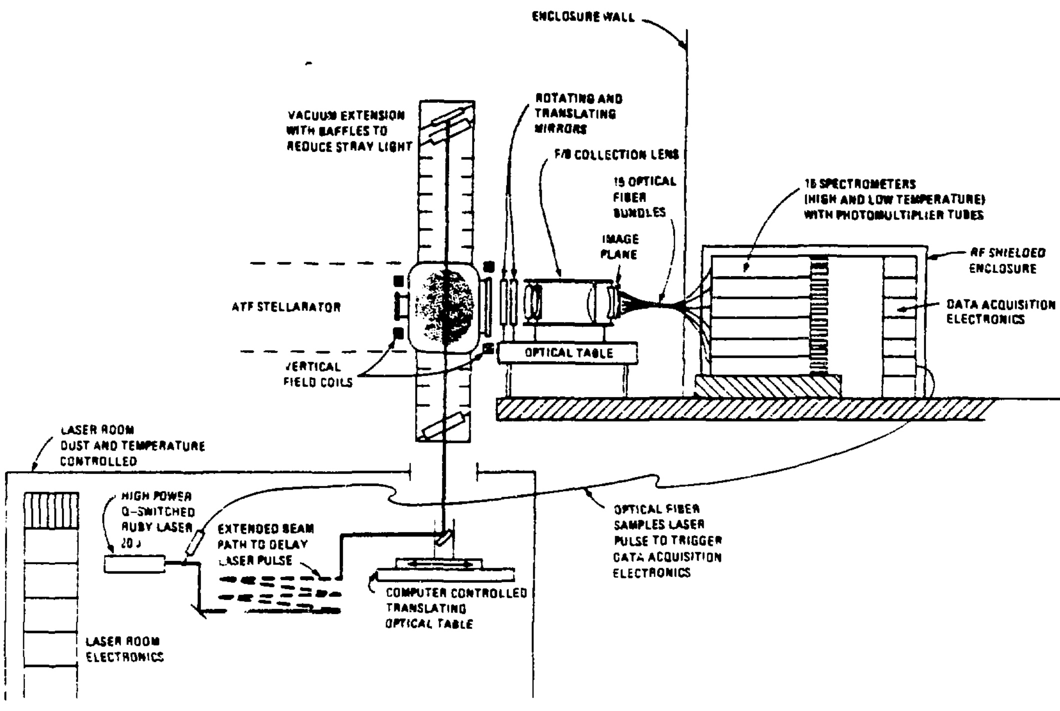

Fig. 1. The ATF Thomson scattering system.

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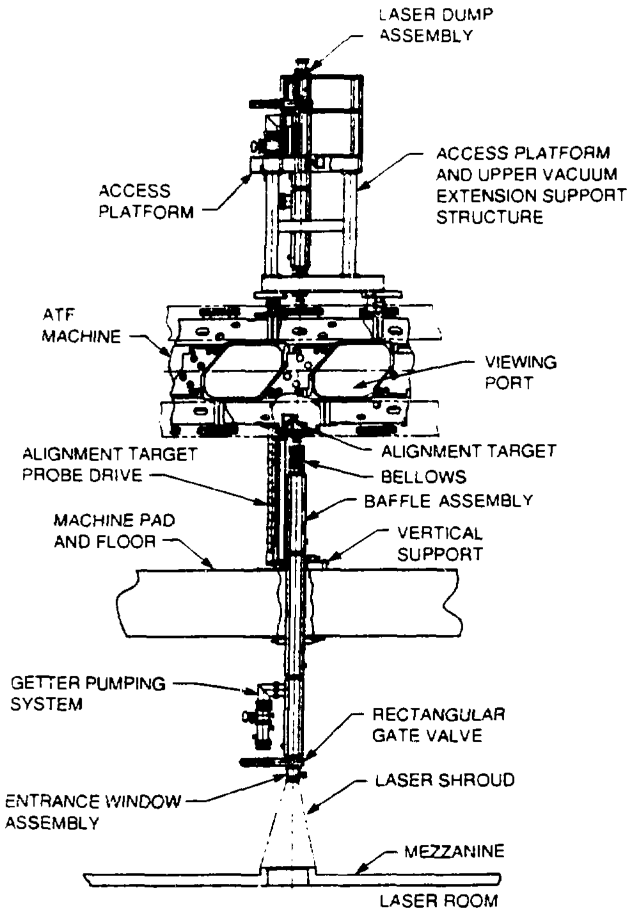

Fig. 2. Elevation view of mechanical equipment for Thomson scattering system.

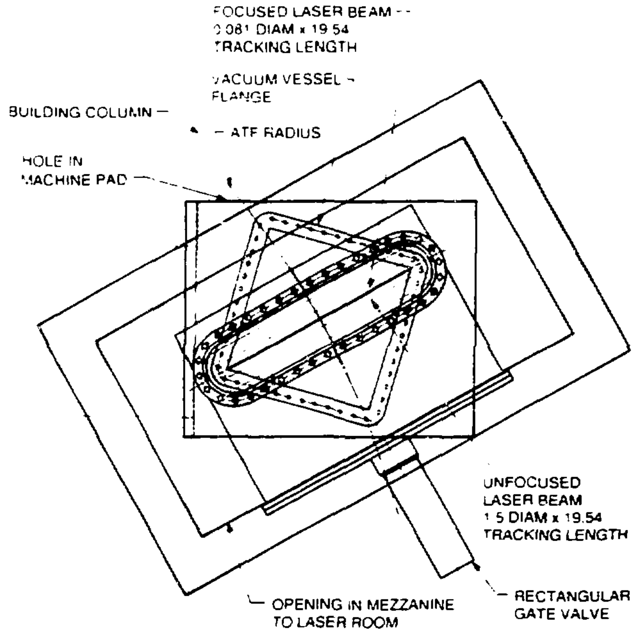

Fig. 3. Relative position of vacuum extensions to ATF.

the machine pad was positioned with reference to the existing ISX-B Thomson scattering laser room and equipment, which were to be reused. As shown in Fig. 3, the hole through which the vacuum extensions pass is narrower than the width dictated by the desired length of laser tracking. Hence, the extensions had to be oval and situated along the diagonal of the hole. The laser tracking is through a radial cross section of the plasma.

Vacuum Extensions

As noted in the introduction, the vacuum extensions have an oval cross section (Fig. 4). The material selected for the extensions was series 304L stainless steel (SST), which is compatible with the rest of the ATF vacuum system and can be baked to 150° along with the main vacuum vessel. The internal dimensions of the vacuum extensions (see Fig. 4) are 5.25 in. by 23.25 in., with 2.265-in.-radius ends and 0.25-in.-thick walls. The extensions are two different lengths—42 and 65 in. long. The 65-in. length was needed to penetrate far enough through the hole in the machine pad to miss an existing building column and to allow access for installing the flange bolts. Stiffeners made of commercially available 2 × 2 × 0.25-in. SST tees are welded to the extensions to limit the deflection of the longest extension to 0.016 in. under vacuum loads. For convenience and consistency of design, tees of the same size were also used on the shorter extensions.

The body of each extension was formed as two identical, elongated U-shapes on a brake press. Then the two halves were joined with two longitudinal TIG welds along the full length. Afterward, the previously machined oval flanges were welded to the ends. The SST flanges are identical, except that the upper

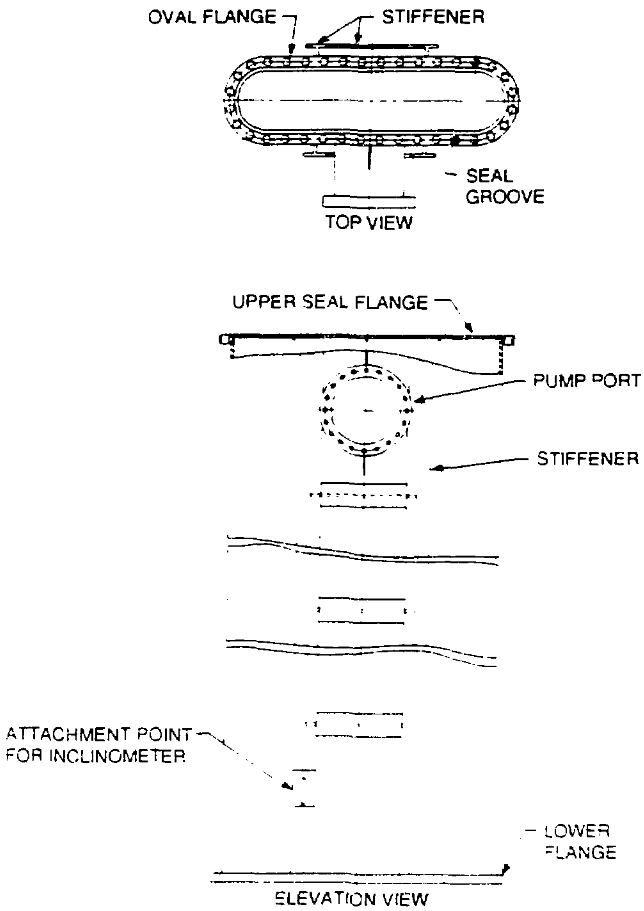

Fig. 4. Vacuum extensions.

flange will later be machined to accept a *Helicoflex metal seal* specifically designed for this application.

After stiffeners and flanges are welded to the body, the extensions are jacked out hydraulically to eliminate weld distortion. Individual pumping ports are welded into three of the five extensions, and the extensions are cleaned internally and stress relieved with an internal inert atmosphere present to limit oxidation. After stress relieving, final machining of the flanges is performed to obtain parallelism across the flanges to within 0.005 in., and machining of the seal groove is completed.

The vacuum extensions are joined to the ATF vacuum vessel with an oval SST welded bellows. The bellows is designed to allow alignment of the vacuum extensions with the laser room below the floor and with each other. It also accommodates the radial motion of the vacuum vessel during bakeout.

Baffles

The baffles, as shown in Fig. 5, are 0.032-in.-thick aluminum sheets with 21-in.-long slots cut into them. The width of the slots varies as the laser beam is focused at the center of the ATF device; it ranges from 1.375 in. at the far end of the baffle assemblies (Fig. 6) to 0.625 in. just before the laser enters the bellows section that joins the baffle assemblies to the device. The slot widths nominally allow ±0.25 in. of clearance for the laser beam. The baffles are black anodized after machining to reduce reflected light and are spaced 9 to 10 in. apart in the baffle assemblies.

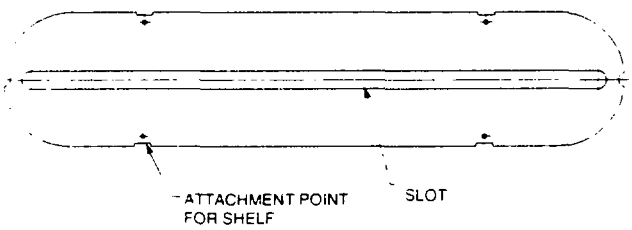

Fig. 5. Baffle.

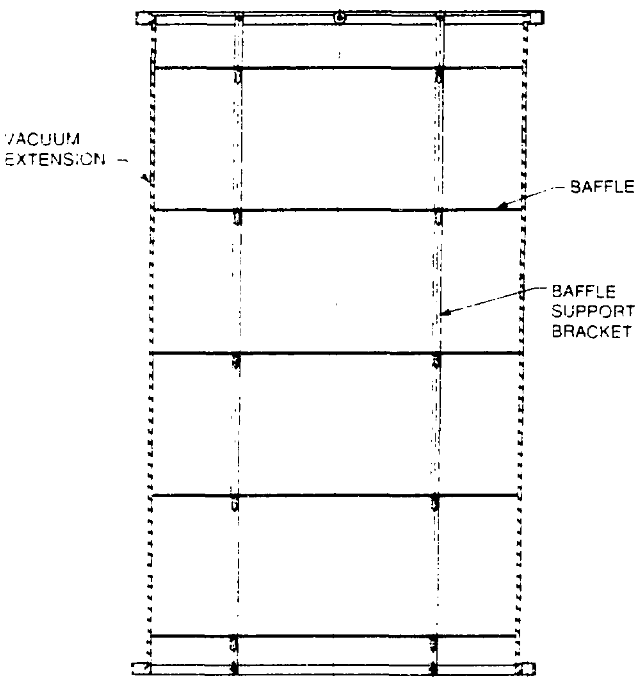

Fig. 6. Elevation view of baffle assembly cross section.

Entrance Window Assembly

The entrance window assembly (Fig. 7) is mounted at the bottom of the lower baffle assembly; the laser beam enters the vacuum system through it. The 1.5-in.-thick window is tilted at an angle of 3° for scattering to allow energy measurement. This assembly contains a shutter mechanism that protects the window glass during discharge cleaning and when the Thomson scattering system is not in use. A commercially available rectangular gate valve (with oval flanges to match the vacuum extensions) was installed between the entrance window assembly and the vacuum extensions so that the glass can be removed for cleaning.

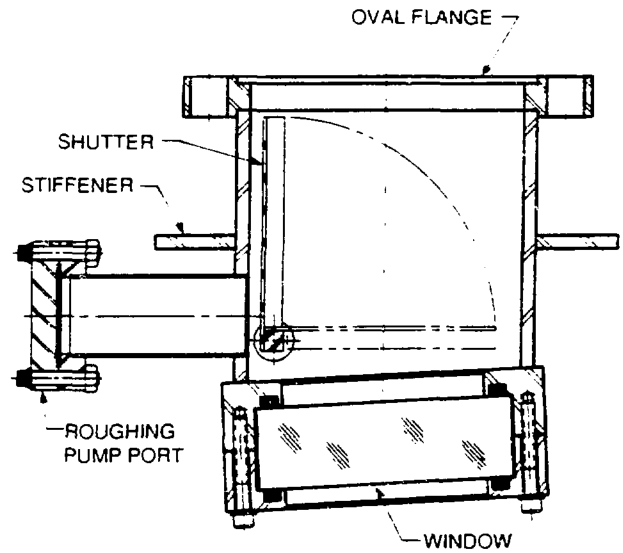

Fig. 7. Entrance window assembly.

Laser Dump Assembly

The laser dump assembly (Fig. 8) serves two functions. A set of fixed and movable blue glasses is positioned at an angle that eliminates reflection of the laser back down the vacuum extensions and into the plasma. One set can be retracted from its normal position to allow alignment and calibration of the system with an He-Ne laser. The top of the laser dump is flanged, with three half-nipples that have viewing windows to allow observation of the system. The movable glass assembly is moved with a linear-motion vacuum feedthrough; it is interlocked to prevent operation of the ruby laser when the glass is retracted.

Viewing Window and Shutter Assembly

A 2-in. piece of BK-7 glass is mounted on the outer port of the vacuum vessel next to the vertical port through which the laser is shot. This window allows collection of the reflected laser light from the plasma. It is positioned to permit maximum collection of reflected light over the full radial movement of the laser through the plasma. The glass has a 60/40 scratch/dig requirement. It is mounted on the outside of the port cover in a frame and is sealed to the vacuum with an elastomer O-ring.

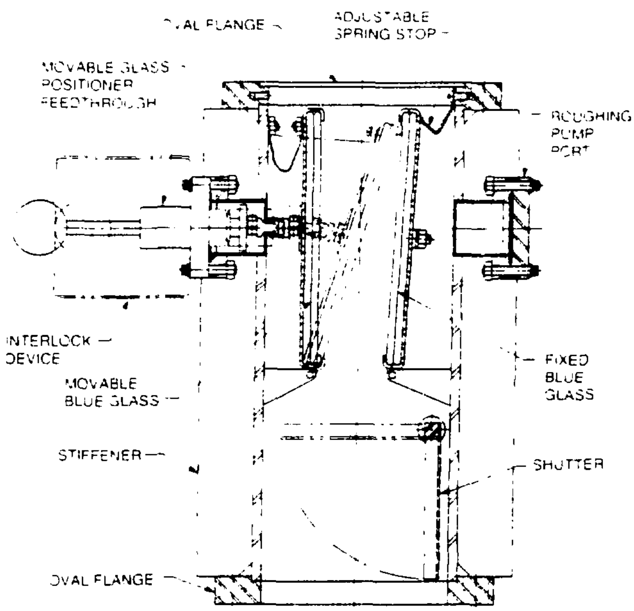

Fig. 8. Side elevation of laser dump assembly.

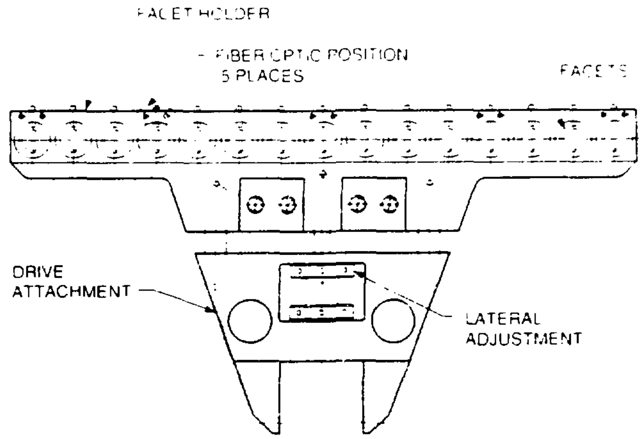

Fig. 10. Alignment target.

The glass is protected during discharge cleaning and when the Thomson scattering system is not operating by a manually driven shutter mechanism (Fig. 9) mounted on the inside of the port cover. The shutter is made of 0.0625-in.-thick SST sheet and was designed so that, when closed, it completely covers the window; when open, it does not obscure the view of the plasma. This design necessitated a two-piece shutter, which is supported by overhead tracks. One portion of the shutter is driven; the other is slaved to the driven portion. The drive is provided by a SST miniature pitch chain, moved by a commercially available rotary-motion vacuum feedthrough. The chain is enclosed in the upper track to protect it during discharge cleaning; a SST shield protects the portion not in the track. The chain can be adjusted with an eccentric bolt. Ceramic rollers attached to the shutters in the upper track prevent relative motion of SST on SST and reduce frictional resistance. A lower track keeps the shutters from swinging and holds them as close to the glass as possible.

Alignment Target and Drive Mechanism

An alignment target (Fig. 10) facilitates alignment of the laser beam and mapping of the cross section through the plasma. It is also used to mount fiber optics that allow calibration of the viewing window to determine when the window needs cleaning. This target must be retractable so that it will not interfere with the laser beam during operation. It is designed to retract completely into the neck of the vacuum vessel. The target is shielded to prevent coating of the fiber optics during discharge cleaning. It has removable cylinders with facets machined at an angle of 45° from the horizontal to reflect the vertical laser beam through the viewing window. The cylinders are angled with respect to each other in the target holder so that light is reflected to the rotating mirror on the optical table. Cross-hairs are scribed on the facets to provide focal points for the He-Ne laser during alignment and mapping.

The alignment target is moved vertically through the vacuum vessel over a 17-in. range with a commercially fabricated, linear-motion bellows-sealed vacuum probe drive, shown in Fig. 2. The probe drive is driven by a standard stepper motor, and an absolute encoder is used to determine the target position. The target can be positioned to within ±0.005 in. of the desired location. At its maximum extension, the target deflects 0.03 in. laterally.

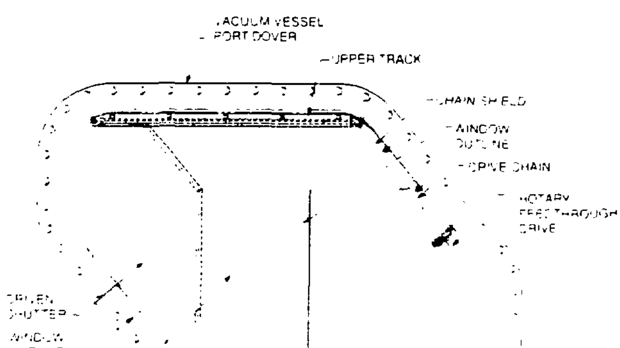

Fig. 9. Viewing window and shutter assembly.

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Reference

1. R. R. Kindsfather et al., "Two-dimensional Thomson scattering system for ATF," *Rev. Sci. Instrum.*, vol. 56, pp. 1816–1818, 1986.

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