HORIZONTAL THOMSON SCATTERING SYSTEMS FOR DIII–D AND SSPX

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DISCLAIMER

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DIII–D –Three of the seven existing core Thomson scattering laser beams were redirected to probe the previously unmeasured central region of the DIII–D plasma. Modifications to the existing collection optics system and support tower were made to inject the lasers and collect scattered light in this new extended region. Stray light levels were reduced to acceptable levels to permit Rayleigh scattering calibration on five of the six new channels, inticating that the new in-vessel dump operates well. Measurements of the plasma temperature and density from the plasma edge to the center are now possible. Peaked density profiles are now observed in this new measurement region.

SSPX – We have completed the design and installation of a 10-spatial channel Thomson scattering system to measure the plasma temperature and density profile on SSPX. A single-pulsed YAG laser operating at 0.7 J and 8 ns is used to scatter photons into a 7-element collection optic that provides a spatial resolution of 1.5 cm at the outer plasma edge and 7.5 cm at the inner edge of a .5 m radius spheromak plasma. The collected light is then analyzed by a 4-channel interference filtered polychromator which has been optimized to measure temperatures between 2 eV and 2 keV and densities as low as 1×10^{12} cm^3. We use an in-vessel beam dump and a series of entrance and exit baffles to reduce the stray laser light and provide for an absolute density calibration by Rayleigh scattering in argon gas.

1   DIII–D — Introduction

Recent advances in high-confinement discharges on the DIII–D Tokamak produce plasmas with steep density profiles in the core region. It is, therefore, crucial to determine the temperature and density profile all the way to the magnetic axis. Over 50% of the neutrons are produced from a major radius of 165 cm to 195 cm in these plasmas, which was outside of the measurement region of the previous Thomson scattering system (Fig. 1). We have extended this measurement region to a major radius of 165 cm (ρ=0) by re-routing three of the seven laser beams to probe horizontally across the plasma in front of the existing collection optics. The same collection optics are used to view the new region. Six existing viewing channels were repositioned in the image plane of the horizontal laser beams.
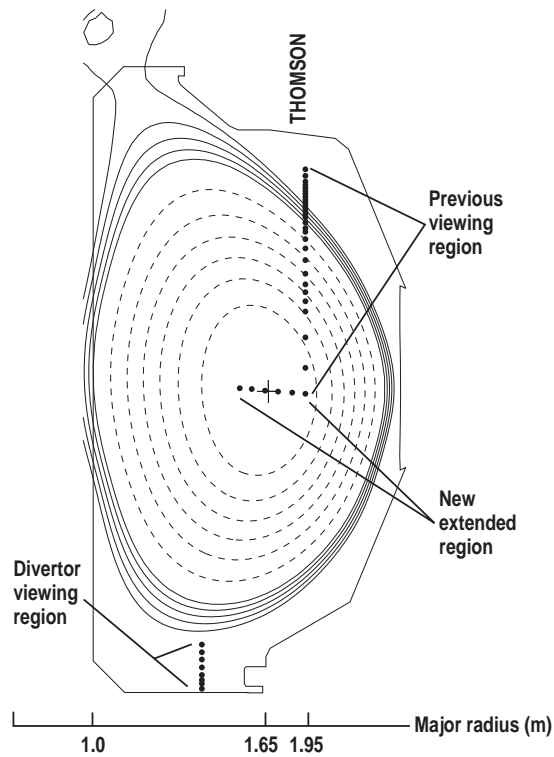
Fig. 1. Six new Thomson channels provide a view from a major radius of 165–195 cm .

2   DIII–D — System Design

The existing Thomson system uses eight closely packed laser beams that are transported 35 m from a remote laser room to the DIII–D vessel where they probe the divertor, central, and edge regions of the plasma.[1,2] Each of these 1.06 μm laser beams operate nominally at 20 Hz with 1 J per pulse. One beam is directed to the divertor region as shown in Fig. 1. Three of the remaining seven laser beams are redirected at the laser room so that they diverge several centimeters from the remaining four beams when they reach the DIII–D vessel area.[3] Here, a series of mirrors direct the beams onto a platform containing the focussing lens, an adjustable aperture, and beam position and energy monitoring instruments (Fig. 2). The beams are then directed through a series of cone shaped baffles which help reduce stray light. The beams focus to a 3.5 mm spot in the viewing region and then strike an absorbing glass beam dump located on the far wall of the vessel. A HeNe alignment laser beam passes through the 3 mm thick KG-2 dump glass and a vacuum window where it is captured on a CCD camera that is used to monitor the system alignment.

The collection efficiency along this new beam path only varies about 10%, even though the magnification decreases from 0.25 at the 194 cm position to 0.15 at the 165 cm position. This is
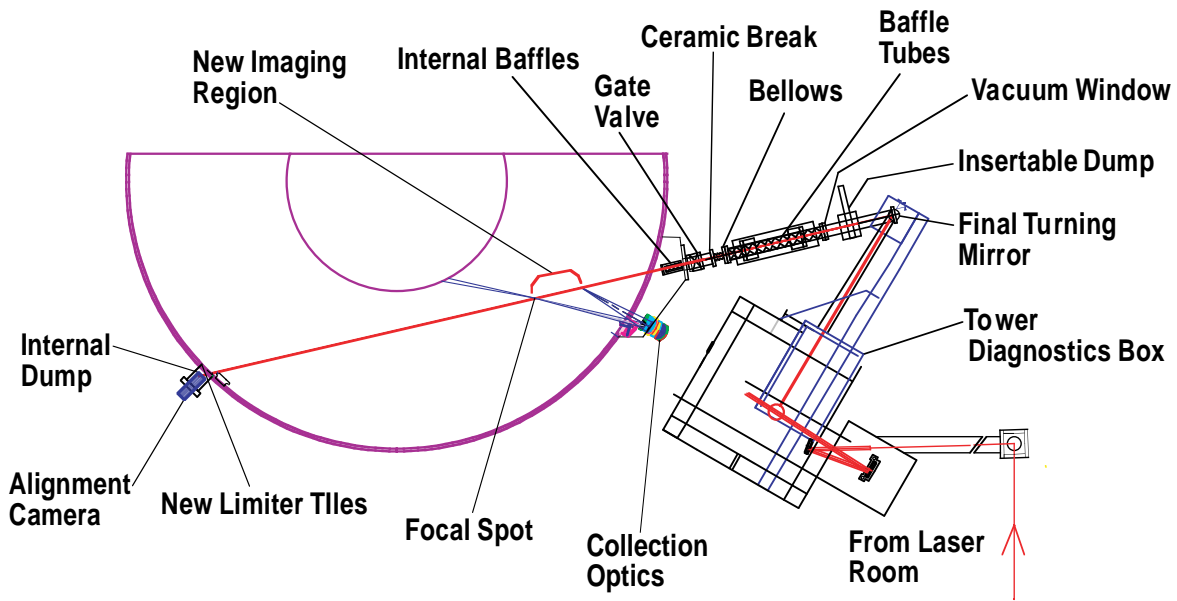
Fig. 2. A new horizontal beam probes the DIII–D core region.

because the increased signal from the magnification change is balanced by the reduced signal from the smaller collection solid angle.

3   DIII–D System Operation

A coherent fiber bundle provides initial HeNe alignment feedback from an insertable dangling target which is used at the start of each run day. Alignment is maintained throughout the run day by using a five-fiber array that provides *in-situ* alignment information from the scattered signal.

The initial stray light levels were a factor of two higher than that needed to perform an acceptabledensity calibration in argon gas. An IR sensitive CCD camera was employed to determine the source of the stray light.[4] The first camera images of the dump and entrance cones indicated that they were both large stray light sources. However, by slightly moving the beams away from the nearby wall tiles at the dump entrance and blackening some of the more reflective surfaces of the entrance cones, we reduced the stray light to acceptable levels on five of the six new viewing channels. Having reduced the initial stray light problem, the in-vessel beam dump now performs as expected. We have limited the dump exposure to 6 s to avoid any glass rupture or out-gassing problems due to excessive temperatures. The stray light level is stable, indicating an absence of any significant glass coatings that could scatter light.

During the last six months of physics experiments on DIII–D, this extended viewing region has allowed the Thomson diagnostic to provided significant new information, particularly for

high density discharges above the electron cyclotron emission (ECE) cutoff densities. For lower density plasmas, the new Thomson data complements the existing ECE temperature data very well. There is also good agreement at the 194 cm radial location where the existing core Thomson system and new tangential system overlap.

4   SSPX — Horizontal Thomson System

The new Sustained Spheromak Physics Experiment (SSPX) at LLNL is now operational. We are ready to study particle control due to the expected high densities of these spheromak plasmas, and are, therefore installing a Thomson scattering diagnostic to measure plasma densities between 1×10^{12}–5×10^{14} cm^3, and plasma temperatures between 2 eV and 2 keV. This instrument design is based on the DIII–D Thomson scattering system which has demonstrated it can produce reliable and accurate n_e and T_e profiles.[1] These parameters are expected to have a considerable radial variation requiring multiple spatial channels across the minor diameter. It will be important to reduce the stray light levels since the density measurement will be absolutely calibrated by Rayleigh scattering in argon gas.

5   SSPX — System Description

A single pulsed Nd:YAG laser (Quanta-Ray DCR-2) operating at 0.7 J and 8 ns, is located in a temperature controlled room on the ground floor of the SSPX building. We first monitor the energy and position of this 1 cm diameter beam on the laser optical table, and then direct it up two floors to the SSPX vessel area. Here, the beam is apertured, focussed, and turned horizontally towards the vessel (Fig. 3). It then passes through a vacuum window located at the end of a 1.5 m long horizontal tube containing the entrance baffle cones. As the beam converges to a 2.5 mm diameter spot in the vessel, it maintains a 4 mm radial clearance from the edge of the entrance baffle set. After passing through the viewing region and an exit baffle set, the beam is extinguished by an absorbing glass dump. The alignment HeNe passes though the KG-2 dump glass and vacuum window and is viewed with a CCD camera.

The Thomson scattered signal is collected with a 7-element optic that is mounted behind a vacuum window located inside a re-entrant tube which is adjacent to the laser entrance port. The optic is positioned near the 5 cm tall diagnostics slot to obtain a full radial view of the plasma. An insertable shutter provides protection for the vacuum window during glow discharge cleaning. Ten spatial channels are located in 13 possible positions along the 48 cm long radial path extending across the plasma minor diameter. The scattered laser light is imaged onto 10 incoherent fiberoptic bundles, each with vertical and horizontal dimensions of 1.5 mm and 3 mm respectively. Due to the viewing geometry constraints, the optic collects at f/4 in the outer edge
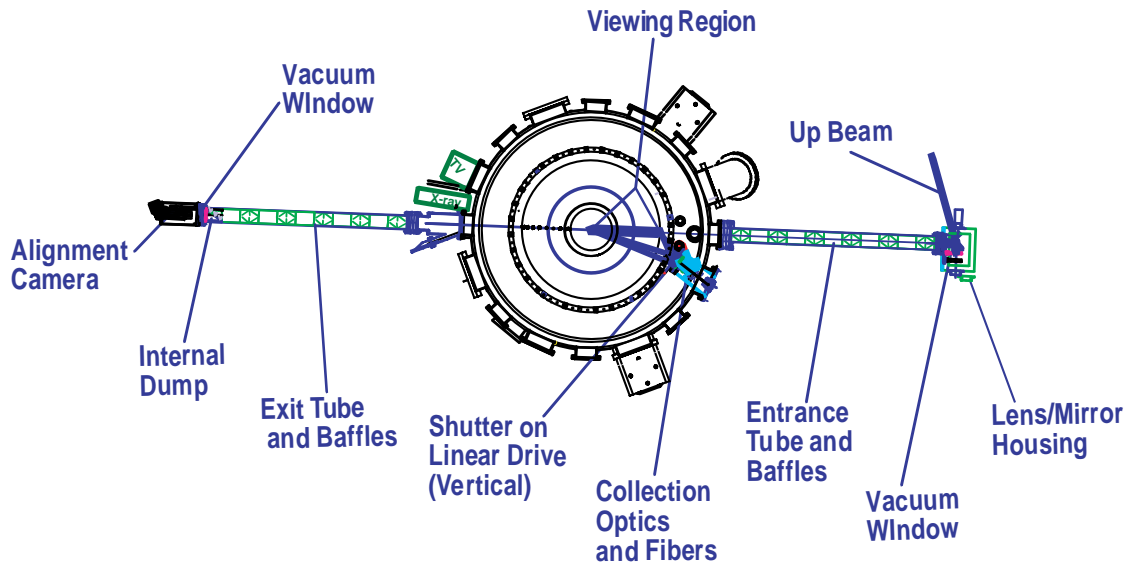
Fig. 3. The SSPX experiment uses a radial Thomson scattering system.

of the plasma and $f/21$ at its inner edge. However, the photon collection efficiency remains nearly constant across this profile due to the radial magnification change. Unfortunately, this change in magnification causes the radial spatial resolution to increase from 1.2 cm at the outer edge to 7.5 cm at the inner edge.

The collection fibers transport the collected light back to the laser room to a set of 4-channel filtered polychromators that use avalanche photodiode detectors (APDs).[5] One of the four filtered channels contains the laser wavelength at 1064 nm which is used for density calibrations. Simulations indicate that temperature measurements as low as 2 eV are possible with only a 10% error with these polychromators.

The fiberoptic bundles are aligned using an insertable flag to scatter the a colinear HeNe alignment laser into the collection optics. This is done by rotating the flag past a diagnostics slot post and across several of the outer spatial channels. The fiber optics holder is then positioned so that an image of the HeNe laser is centered on a coherent fiber bundle located adjacent to the incoherent collection fibers.

6   Data Acquisition and Controls

The shot control computer, a Macintosh with Labview, operates the flashlamp and supplies a microsecond resolution Thomson trigger synchronized to the other machine systems. This triggers a nanosecond resolution timing module that fires the Pockels cell and a Camac gate generator. The APD outputs are gated into two banks of LeCroy 4300B FERA digitizers: the first

measures the plasma background 100 ns before the laser pulse, and the other acquires the scattered laser light. After the shot, the data acquisition system reads the single pulse data directly from the FERA's with no auxiliary memory hardware.

Acknowledgements

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