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TPX Diagnostics for Tokamak Operation, Plasma Control and Machine Protection.

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Introduction

The Tokamak Physics Experiment (TPX) is planned to be an advanced performance, high beta, steady state, high heat flux, double null divertor tokamak [1, 2, 3, 4]. Machine parameters are: R_0=2.25 m, a_p=0.5 m; A=4.5; κ~2; δ~0.8; B_T=4 T and I_P=2 MA. Operation in both hydrogen and deuterium is planned. The design is required to incorporate end-of-life tritium capability. The experiment includes 8 MW of neutral beam power, 6 MW of ion cyclotron and 3 MW of lower hybrid rf power for auxiliary heating and current drive. Experimental scenarios include non-inductive current drive with an initial 1000 sec long pulse mode and an upgrade to steady state (10^5 sec), divertor heat loads of up to 7.5 MW/m^3 and maximum neutron rates up to 7.5×10^{16}/sec. First plasma is scheduled for mid-2001.

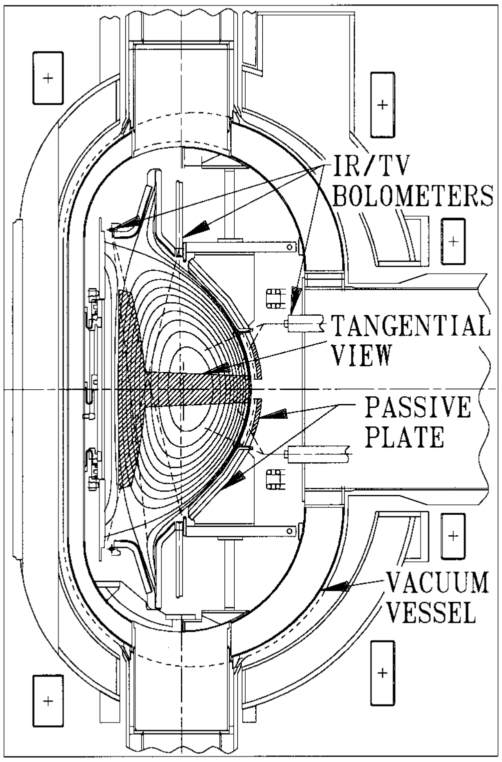

Figure 1. *Elevation View of TPX Core including IR TV locations and view of plasma through stabilizer plates*

Diagnostics are required for real time plasma control, physics measurements and

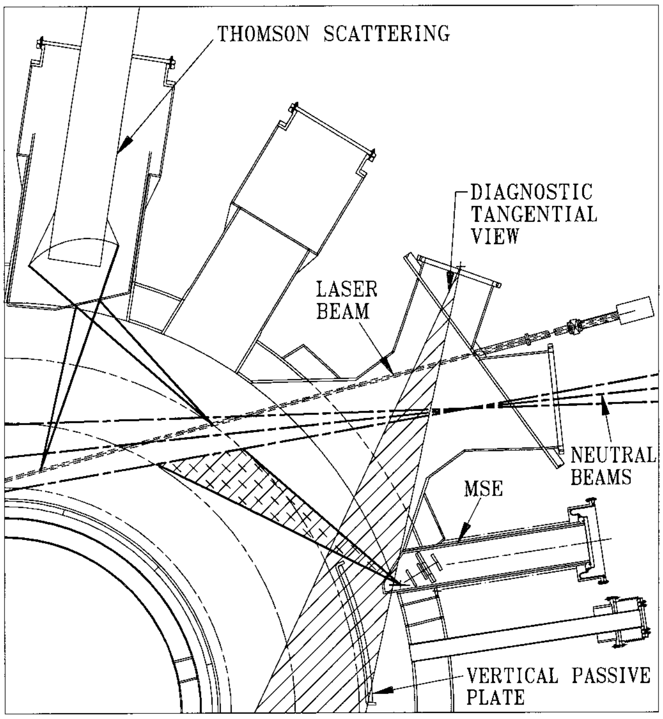

Figure 2. Plan view of TPX quadrant showing representative MSE re-entrant port, NB trajectory, Thomson scattering beam and view lines, and typical tangential mid plane view.

Plasma Parameters	Baseline	Upgrade(a)
$n_e(0)$ (m^{-3})	0.9×10^{20}	2.0×10^{20}
τ_E (ms)	300	400
$T_e(0)$ (keV)	14	21
$T_i(0)$ (keV)	14	23
β_N (%), β.a.B_0/I_p (T-m/MA)	4	5.5
Bootstrap Fraction, F_{BS}	0.72	0.73
Peak DD neutron rate (s^{-1})	$5x10^{16}$	$7.5x10^{16}$

Table I Selected TPX Parameters

machine protection. Fundamental to initial operation are measurements of plasma equilibrium and position, basic plasma properties, current density and pressure profiles, surface heat loads on plasma facing components and provision for disruption avoidance. An extensive set of diagnostics is planned, divided between a baseline set required for the first phase of operation and an upgrade set which includes fluctuation diagnostics as well as those required for extended pulse length operation [5]. Present diagnostic design is concentrated on the first phase diagnostics. Preliminary designs for the magnetics, Thomson scattering, motional Stark effect and divertor infra-red imaging diagnostics are described.

TPX diagnostic design, construction, installation and operation will be a national effort, with participation by National Laboratories, industry and universities under the direction of the TPX project.

TPX Device Description

An elevation view of the TPX machine core is shown in Fig. 1 and a partial plan view in Fig. 2. Stability against MHD modes at high beta requires close fitting stabilizer plates. These consist of upper and lower toroidal rings with a resistive gap and vertical plates located at the four vessel weld planes. These plates will have narrow mid plane slots for tangential viewing. A projection of a representative tangential view is included in Fig. 1. Selected physics parameters for the baseline and upgrade configurations are given in Table I.

The primary neutron shielding will consist of boronized cooling water in the double jacket vacuum vessel, external shields and plugs installed in vessel penetrations will provide further shielding. Remote maintenance will be required for all in-vessel components; this radiation zone includes many diagnostic elements, fiber optics, windows, etc. Where necessary this requirement is included in the diagnostic design. To minimize this need, a design preference is that diagnostics should be robust, redundant and remotely insertable.

The combination of high heat flux and long pulse accentuates the issues of thermal heating and erosion/deposition for plasma facing diagnostic components, such as windows and mirrors and of the degradation of window and fiber-optic transmission quality due to radiation induced absorption and scintillation effects.

TPX Diagnostics Description

Shape, Position and Magnetic Configuration Measurements.

The TPX magnetic set is based on conventional inductive sensors with advanced hybrid integrators [6]. Real time processing of the data for equilibrium reconstruction is needed for plasma profile control and for integration with the MSE and pressure diagnostics for current profile control. Additional sensors will measure currents in the plasma facing, vacuum vessel and other structural components. Remote maintenance of the magnetic diagnostics is unlikely and the diagnostics will be required to survive for the life of the machine.

Current Profile Measurements.

The plasma current profiles will be measured by the Motional Stark Effect (MSE) diagnostic. The diagnostic requires a tangential view intersecting a neutral beam path. The planned installation, shown in Fig 2, provides a spatial resolution of about 2 cm [7]. Each beam line contains three sources, only one is used for the MSE diagnostic, beam modulation will be required to discriminate against signals from the two other beams. For extended pulse length operation (>> 1,000 sec) two beam lines will be utilized for plasma heating and current drive, these will alternate during the long pulse to allow for cryopump regeneration. A second MSE system will be added, viewing the second beam line, to supply continuous current profile information.

Thomson Scattering.

The goals for the Thomson scattering system include a repetition rate of 100 Hz and spatial resolution of 3 cm in the core and 3 mm in the edge. Technical and performance requirements favor imaging systems over LIDAR techniques [8]. The proposed configuration utilizes radial imaging of a tangential laser beam line. A

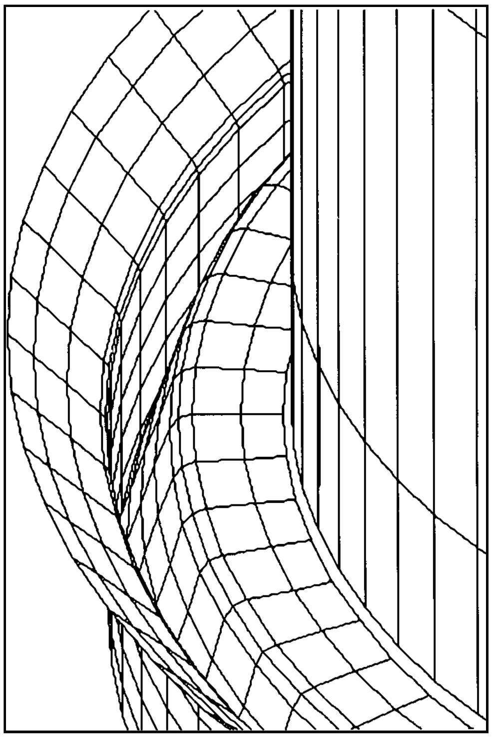

Fig. 3. Non-perspective divertor view from auxiliary port (outboard camera in Fig. 1.)

separate viewing system will be used for the high resolution view of the mid plane edge plasma. The viewing and laser sightlines are indicated in Fig. 2.

Divertor Imaging

The divertor tile temperature will be monitored using visible/IR TV systems. The imaging elements will be located in-vessel at top and bottom locations as shown in Fig. 1. A non-perspective divertor view from the outboard auxiliary port is shown in Fig. 3. Fiber optic and lens/mirror relay optics will deliver the signal to cameras located in a low radiation environment outside the vessel. Beam splitting mirrors will allow simultaneous viewing in the infra-red and visible. Complete coverage of the high heat flux tiles is desired. A preliminary study of the divertor IR/TV diagnostic has been completed [9].

Summary

The diagnostics for TPX are at an early design phase, with emphasis on the diagnostic access interface with the major tokamak components. Account has to be taken of the very severe environment for diagnostic components located inside the vacuum vessel. The placement of subcontracts for the design and fabrication of the diagnostic systems is in progress.

Acknowledgment

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