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13th INTERNATIONAL STELLARATOR WORKSHOP

HSX HARDWARE, CONTROLS AND DIAGNOSTICS

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Abstract:

The HSX Helically Symmetric Stellarator has been operational for the last year, making plasmas at 0.5T using 28 GHz ECH. During this phase of operation, hardware, machine diagnostics, and plasma diagnostics have been continually implemented to improve machine operation and control, and plasma diagnostic capabilities. This paper will provide and overview of the basic machine control concepts, some details of the He glow discharge cleaning methods used to provide density control under plasma operation, and some details of the LabView^R (National Instruments) and SLC interfaced machine control, timing and diagnostics. Low-level machine operation (coil deflection, ground currents, vacuum base pressures and contaminants, etc.), motor generator, Gyrotron, coil cooling and temperature monitoring is also performed using the LabView/SLC combination; more of which is planned for the ensuing months.

Diagnostic implementation, from 288 GHz microwave interferometer, diamagnetic loop signals, optical and x-ray diagnostics, probes, etc., are primarily interfaced using LabView A/D, digital and analog I/O, and timing cards controlled by PC computers: all of which save the data to a PC based data storage site. A ten-chord fir Thomson Scattering system and a multichannel ECE system are under construction for operation in the near future, again with primary control and data interface planned for incorporation into the PC based system.

A SQL database is currently under implementation to improve overall data searching capabilities and accessibility, and to facilitate data backup and protection. Both MatLab^R and IDL^R are currently used for data analysis and presentation, which will be maintained through the database implementation.

Introduction

HSX plasma operation has begun in earnest over the last year, using second-harmonic ECH at 28 GHz to produce and maintain stable and controlled discharges at 0.5 Tesla. The primary experimental thrust to date has been confirmation of the production of closed nested magnetic surfaces and their harmonic content through electron beam magnetic surface mapping experiments, and confirmation of the effects of helical symmetry on the plasmas produced by second harmonic ECH at 28 GHz. These experiments are detailed in other presentations at this 13-th International workshop.

During this period, hardware, diagnostic control, and database storage and interface have been continually undergoing both implementation and improvement to provide a stable platform for plasma physics experiments. This paper outlines the basic diagnostic capabilities current in the HSX device operation, its basic magnet-coil and plasma control systems, and the interfaces required to initiate, correlate, store and retrieve the plasma diagnostic and status signals. Also discussed are diagnostics and rf capabilities either under construction, or planned for near-term implementation, and improvements or modifications planned in the HSX controls and database.

Diagnostics and controls

Current HSX diagnostics are outlined in Table I, and provide a reasonable basis for plasma experimentation, with the notable exception of a reliable or credible electron or ion temperature diagnostic. A ten-channel Thomson Scattering system has been designed, and the bulk of the components necessary for its assembly are in hand. The system is based on the DIII-D Divertor Thomson system, optimized for 10 eV through 2keV, and will cover the plasma half radius in ten intervals. Capabilities to perform both in a rapid dual-pulse and a 50 Hz mode, for tracking of both rapid and longer-term variations of plasma temperature and density profile effects, are included in the design. Also soon to be installed is the first channel of a planned 5-channel ECE system, which should provide a continuous Te monitor and initial plasma fluctuation data.

Along with these plasma diagnostics, machine operations require a set of base diagnostics and controls for the various components in use; motor generator spin up controls (armature currents and flywheel speeds, etc.), magnet coil currents and voltages and ground-fault monitors, 28 GHz gyrotron system monitors and controls (cfc cooling system, power supplies, tube vacuum status, tube currents and voltages, etc.), HSX coil cooling systems, coil temperatures, coil deflections under operation, vacuum system and gas puffing, and safety interlock systems. The glow discharge cleaning (GDC) system used daily before HSX operation is controlled by a SLC.

Most low-level controls and monitoring in critical systems is performed with SLC's, with separate SLC systems for each relevant group (MG control, gyrotron, vacuum, safety/GDC) interconnected through optically isolated IEE488 lines. The SLC systems are also in communication with the basic PC-based machine control and operation system, which operates using the National Instrument LabView^R program to control HSX firing and plasma diagnostic data gathering and storage. Timing is initiated from a motor generator spin-up/ready status signal, which then hands off control to the fast timing card of the master control computer. This control PC arms the relevant data taking PC systems for plasma data-taking using http port protocols, and then provides a master timing sequence as needed through optically isolated hardware timing signals. Each data PC either uses the master timing signal or fans out timing signals as required using secondary timing cards. Plasma discharges are then taken, and the data stored locally on each PC, until further http port commands initiate data transfer to the main data storage computer, and any post-shot processing required for data interpretation. This basic interconnect system is shown in figure 1.

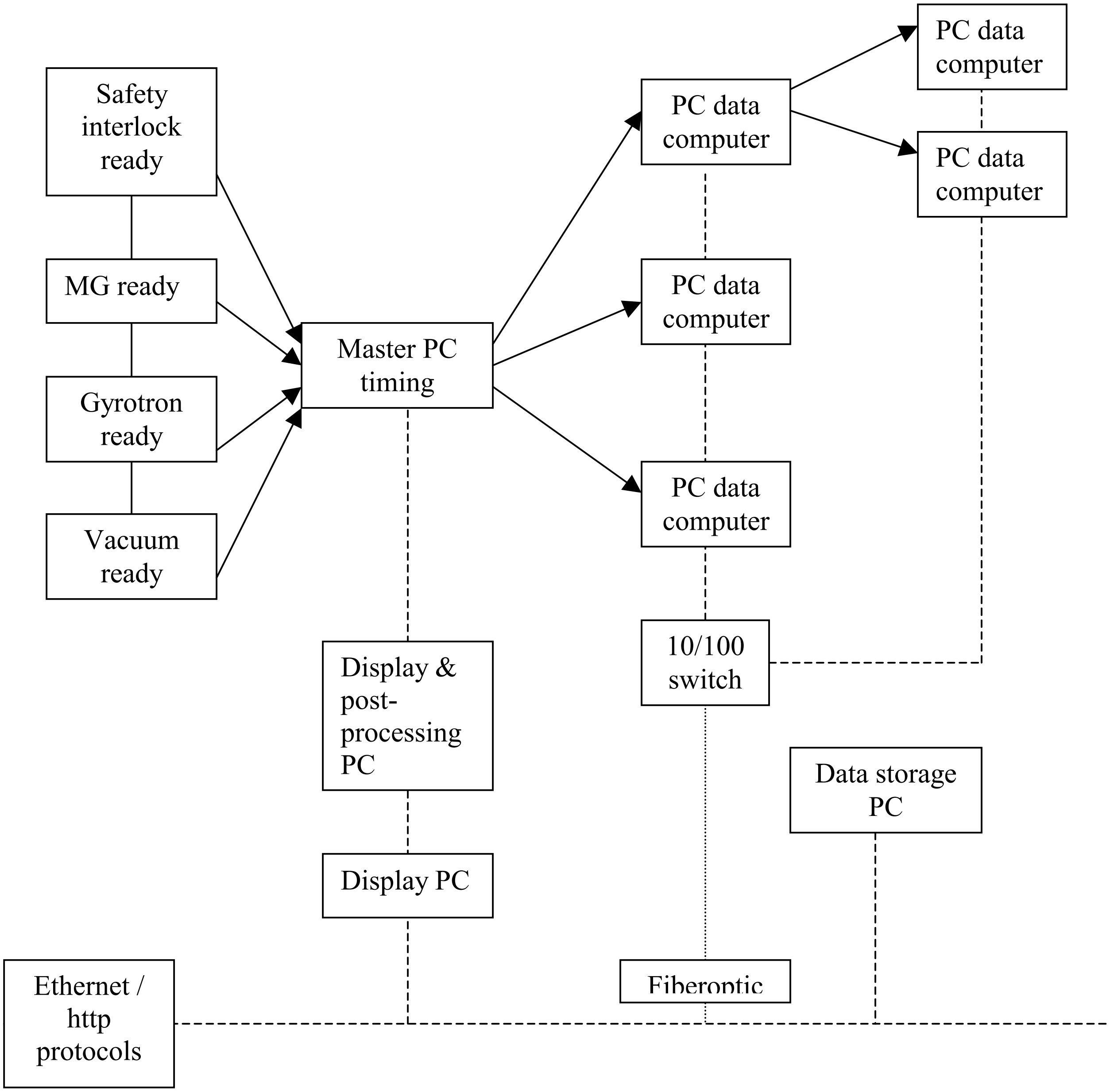
Glow Discharge Cleaning (GDC)

Plasma density control has been established in HSX through the continued use of GDC techniques. Initial chemical cleaning and electropolishing of the stainless steel HSX vacuum vessel established a leak-tight vessel but which still had significant surface contaminants which the evolved during plasma operations. Initial vacuum levels in the high 10^{-7} torr range were provided with 2 turbomolecular and one cryogenic pump, but RGA traces showed very significant impurity levels; predominantly H_2O, O and O_2, CO_2, CO, N_2, and H_2 and H. Plasmas at this stage showed immediate electron density runaway, and no significant levels of stored energy, H-alpha or X-ray signals, and strong impurity radiation signals.

Initial GDC attempts were made using a single anode, with 400 V and 2Amps, in hydrogen at about 2 mtorr. Many hours of GDC showed a significant reduction in the base impurity levels, a reduction in the base vacuum to high on the 10^{-8} torr range, but very significant H and H_2 levels were present. The glow did not however reach all around the HSX vessel, being primarily confined to the half nearest the anode. Plasma produced at this stage were improved in providing low levels of plasma stored energy, and reduced impurity radiation, but density control could not be obtained; electron density continued to rise uncontrollably during the discharge reaching cut-ff ($\sim 5 * 10^{12}$ / cc), while stored energy signals dropped during the discharge. A second anode inserted at this stage 180^0 toroidally from the first improved overall impurity cleanliness but exacerbated the density runaway problem with increased hydrogen adsorption on the vessel walls.

Helium GDC was then initiated which had both the effect of further reducing the impurity levels, and also removing the adsorbed hydrogen from the vessel walls. Base pressures low on the 10^{-8} torr level were obtained, and plasma density control, from $1 * 10^{11}$ /cc through $2 * 10^{12}$ /cc was now routinely obtained. These plasmas also exhibited strong stored energy signals (up to 50 J, and rising throughout the duration of the ECH pulse), strong X-ray signals, and long density decay times (>10 – 15 msec). Plasma density could now be maintained flat over a full 50 msec discharge, or made to rise or fall as desired through control of the hydrogen gas puff – up to 20 units of pulse width modulated bursts capable of separately controlling up to 4 piezo-electric puff valves provide fine control of the gas puff sequence.

Figure 1



Safety interlock ready
MG ready
Gyrotron ready
Vacuum ready
Master PC timing
PC data computer
PC data computer
PC data computer
PC data computer
PC data computer
10/100 switch
Display & post-processing PC
Display PC
Data storage PC
Fiberoptic
Ethernet / http protocols

Table I

Diagnostic	**Parameter(s)**	**Capabilities**
288 GHz microwave interferometer	$n_e$dl along 9 chords	$n_e(r)$ through Abel inversion
Soft X-ray monitors	5 chords with filter x-ray discrimination	T_e possibly primarily of tail
H-alpha monitor	Neutral hydrogen line integrated	Edge or plasma neutral components
Diamagnetic loop	ΔB_t through the loop	Plasma Stored energy
Hard X-ray monitors	3 chords with high-energy x-ray discrimination	Tail electron energies
1 meter spectrometer	Impurity line emissions – 2 opposing chord views	Impurities, and impurity ion rotations
Edge Probes	I_{sat}, V_{float}, swept probes, biased probes, multi-faceted collectors	T_e, V_{float}, plasma flows, electric fields, fluctuations and fluctuation driven transport
Divertor probes/plates	Collection and bias plates	Divertor fluxes and potentials