Outline

- Plasma Control
  - EFIT
- H&CD
- Pellet Fueling, Cryopumping, Wall Conditioning
- Remote Participation
- Diagnostics
- Experiments

KO Request for Plasma control

- A thorough review on the magnetic diagnostics (including electronics and engineering aspects) - *2009*
- Design a set of vacuum field measurement experiments applicable to *2009* campaign to understand the effects of the ferromagnetic material in the TF/CS coils
- Figure out how to measure the non-axisymmetric fields in the full SC tokamaks (*2010/11*)
  - Room-temperature experiment would be very difficult because of the large ferromagnetic materials in the TF
- A schematic approach of In-vessel control coil research collaboration would be essential to speed up machine upgrades and controllability (*long term*)
  - VDE stabilization research is ongoing in NFRI / GA
  - Existing research activities of the rest of coils (IRC / ELM / RWM) should be connected to the NFRI for the system requirements to make it work

DIII-D Plans for FY2009 Campaign

- Analysis of vertical control growth rates for PS specification
- Support of magnetics analysis
  - Embedding Yoon FE tools into TokSys
- Algorithms for dealing with current cross-over in real-time control
- Physics operator training/discharge preparation using simserver simulations
  - New operators gain experience in programming a discharge
  - Experienced operators develop and evaluate shape estimator data and feedback control gains
- Other Possibilities ...
  - Evaluation of passive plate shielding and controllability
  - Participate in magnetic materials experiment design and analysis
  - Participate in planning of control experiments

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DIII-D Plans for FY2010 Campaign

- Development and evaluation of vertical control algorithm in PCS
- Development and implementation of isoflux control
  - Verify proper execution and good reconstruction of RTEFIT
  - Development of feedback control gains
  - Verify implementation in PCS with simserver simulations
- Magnetics characterization - non-symmetric configurations
  - Finer control requires more detailed understanding of magnetics
- Other possibilities (develop control models, controllers, simulation) ...
  - Beam control feedback (beta control)
  - ICRF coupling control
  - Real-time control of ECH deposition by plasma position
  - Puff and pump density control

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Columbia Plans for 2009-2010

- Equilibrium reconstruction / support
  - Multi-year addition of diagnostics, improvement of models is usual
  - Columbia group proposes to continue support in this evolution, working with K-I. You, S.W. Yoon, S.G. Lee, J.G. Bak, etc.
  - Talks given at this workshop show several key near-term needs (several researchers are working on these):
    - Incoloy compensation, r/t magnetic correction, wall current measurement, etc.
- Multi-purpose IVCC use / passive stabilizer design
  - Passive stabilizer circuit options (effect of current bridges, desire to change plate electrical connections)
  - IVCC performance for n = 1 RWM control; power supply needs
  - Plasma rotation control analysis using n = 2 magnetic braking (rotation control during NBI = better connection to ITER operation)
  - ELM mitigation capability studies, optimal IVCC electrical circuits; analysis determining improved mitigation via IVCC upgrades
- Experimental proposals to support this work (incl. stability)

PPPL Plans for Startup Experiments ‘09, ’10

- Explore range of breakdown parameters
  - –Prefill pressure (from too low to too high) (E/p)
  - –V_{loop} (lower V means easier control, but too low can waste V•s)
  - –ECH power; 1st and 2nd harmonic comparison
  - –Field Null/ configuration
- Experiments to explore the range of ramp-up parameters
  - –dI_p/dt, high enough to not waste V•s, low enough to avoid MHD
  - –Gas fueling (too much->density limit, too little-> locked modes, failure)
  - –R(I_p), shape(I_p) choice: ~ constant q growth which gives high l_i; full aperture gives lower l_i and more easily shaped plasma
  - –Auxiliary heating power expected to save V•s

Results may be influenced by wall conditions, need to compare 2009 and 2010 (after bakeout), as well as pre/post boronization

KSTAR Request for H&CD

- **Loan of 110 GHz gyrotron System from GA**
  - 500 kW Gycom gyrotron tube, magnet system, MOU
  - All other T/L components for 110 GHz
  - Full participation for system set up & conditioning
- **170 GHz, 1 MW ECCD launcher development (PPPL)**
  - 1 beam, 1 MW (300 s) two mirror antenna (similar launcher as Bay N launcher, the laminated mirror, active water cooling channels)
  - Design with PPPL
  - Fabrication by PPPL, or by Korean company **to get faster track??**
- **5 GHz, 1 MW LHCD launcher prototype development (PPPL)**
  - 16 x 4 front coupler (grill) with 16 power inputs from two 500 kW klystrons (one klystron feeds 8 inputs)
  - Maximum 2 s pulse duration (no active cooling needed!)
  - **Design by PPPL, Fabrication by NFRI**
- **Gyrotron conditioning support from GA**
  - 84 GHz gyrotron is now under repair at CPI
  - Initial conditioning support from GA
- Application of DIII-D ECH setup tools (ECHRES, Toray code, EFIT viewer for EC launcher mirror settings) to KSTAR

- **Co-experiment on NB injection in CY10 (PPPL?)**
  - If the 1st NBI is comes in 2010, we need helps from experts.
  - Test stand for R&D in KAERI and the KSTAR is different.
  - Co-experiment for NB injection into the tokamak can be greatly helpful to the KSTAR research center.

PPPL Proposal for H&CD

- CY09
  - Electric motor upgrade for Bay N-m startup launcher
  - Mirror upgrade for Bay N-m launcher
  - Long-pulse mirror development
  - Pre-conceptual and conceptual design of SS 170 GHz launcher
  - LH launcher design support
- CY10
  - Design/fabricate of SS 170 GHz launcher
  - Complete development of SS mirror and cooling
  - LH launcher design support
- CY11
  - Design/fabricate SS 170 GHz launcher
- CY12
  - Complete fabrication of SS 170 GHz launcher

– A ~10 sec launcher ~ $1.2M
– A steady-state launcher ~$1.8M

DIII-D – 110 GHz Gyrotron

- Exploring sending existing gyrotron to KSTAR.
  - Evaluating potential export control issues

KSTAR Request for Fueling, Pumping and Wall Conditioning

- **Design & Loan of HFS Pellet Injector System (ORNL)**
  - Technical Support for Eng. Design of Pellet Guidance Tubes (Urgent)
  - Loan of Injector & every related ancillary system
  - Participation in the system commissioning & injection experiments
- **Technical Supports & Co-experiment for In-vessel cryopump (GA)**
  - Technical discussion & support on the DIII-D's cryopump (Feb. 2009)
  - Review on Engineering Design in NFRI (end of June? early July? In 2009)
  - Co-experiments in CY11
- **Wall Conditioning & Boronization (GA)**
  - Technical support for the design of Boronization Plan
  - Review on Engineering Design in NFRI (Apr. 2009)
  - Co-experiment in CY09 for wall conditioning and Boronization
- **Engineering Design for In-vessel Control Coil (GA?)**
  - Technical support on design of power cabling system from PS to coil

DIII-D Plans

- Supporting design of the:
  - boronization system
  - Cryopump systems

KSTAR Request for Remote Participation Tools

- Tools for operation control such as EFIT viewer, RDBRM, e-log

- Policy review for remote operation

DIII-D and PPPL Proposals for Effort on Remote Participation Tools

- **Data Storage and availability**
  - EFIT data storage in MDSplus
  - MDSplus data replication
  - Relational database installation and operation

- **Tools**
  - EFITViewer and ReviewPlus fully operational
  - Electronic Logbook deployed
  - Webportal for KSTAR deployed
  - Remote PCS client installed and securely operational

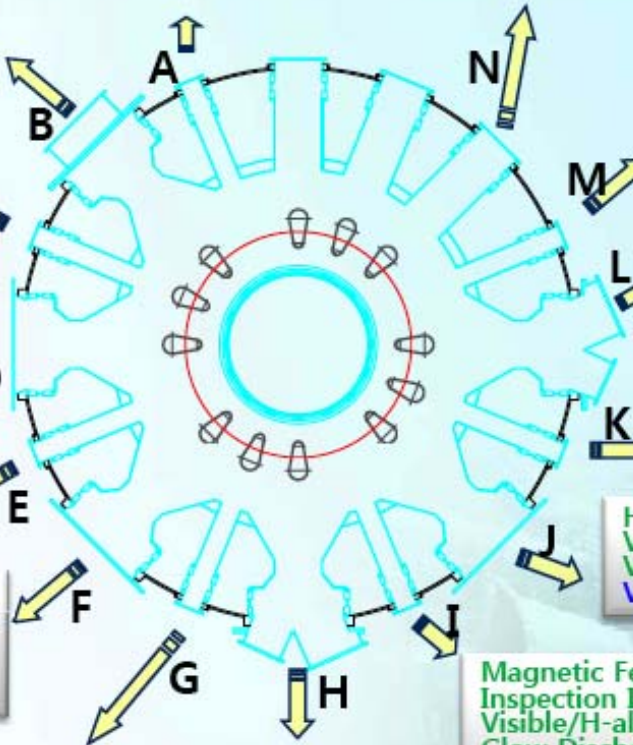
- **Network and Access**
  - Test network throughput, diagnose as required
  - File required paperwork for access: Video, data, computers
  - Test Gatekeeper security model and access

- **PPPL support for TRANSP and PTRANSP using the Fusion Grid**

Status and Plan KSTAR Diagnostics

NFRI
http://www.nfri.re.kr

Basic Diagnostics (2008)
2009 New Diagnostics
Next Diagnostics



Magnetic Feedthrough
Inspection Illuminator
Visible/H-alpha TV
Glow Discharge Probe
Survey IR TV
CES (Background)

Torus Ion Gauge
RGA
X-ray Crystal Spec.
Fast Neutral Pressure Gauge
Thomson S.(Beam Dump)

Thomson Optics
Div. Thomson Optics

Magnetic Feedthrough
Inspection Illuminator
MSE
CES
BES

Reciprocating Langmuir Probe
Bolometer Array
X-ray Pinhole Camera

Soft X-ray Array
Survey IR TV
Visible/H-alpha TV
X-ray PHA
Multichord Vis. Spec.
X-ray Pulse Height Anal.
Impurity Pellet Injector

Bolometer Array
Fast Neutral Pressure Gauge
Thomson S. (Laser Input)
CX-NPA

ECE Radiometer(110~162GHz)
ECE GPC
Diagnostic Neutral Beam
LIF (Optics)

Magnetic Feedthrough

H-alpha Monitor
Visible Survey Spec.
Visible Filterscope
Visible Brems. Array

Torus Ion Gauge
RGA
X-ray Crystal Spec.
Soft X-ray Spec.
VUV Survey Spec.

Magnetic Feedthrough
Inspection Illuminator
Visible/H-alpha TV
Glow Discharge Probe
Survey IR TV
MSE(II)

mm-Wave
Interferometer
Reflectometer
MIR
ECEI

Fast Neutral
Pressure Gauge
Tan. FIR Int.
(Laser Input)

Revised Version: Dec. 2008

PPPL Proposals for Diagnostics

- **Magnetics: error field measurements and corrections**
  - application of techniques from NSTX
  - IPEC code – focus on error field corrections
  - Loan of probe drive for e-beam measurements
- **X-ray Crystal spectrometer collaboration**
- **Design support of diagnostic windows and shutters**

Visualization Data Analysis

Tobin Munsat, U. Colorado

- KSTAR will have a suite of imaging diagnostics very early on (SXR, BES, ECEI/MIR, etc.)
- Data is very dense and rich!
- Analysis methods can be developed and shared between measurements

- *Qualitative information in graphical images*
- *Correlation and coherency*
- *Frequency/wavenumber visualization*
- *Bispectral analysis*
- *Velocimetry*

ORNL Plans for Diagnostics

- ORNL participation in first plasma on KSTAR June & July 2008
  - ORNL filterscope used to monitor H-alpha and impurities (He, C, O, VB) during first plasma operation
  - Filterscope already capable of 10 minute pulse lengths with automatic gain control
- ORNL continuing support for KSTAR Operation in 2009-2010
  - ORNL labsphere purchased to perform absolute calibration of H-alpha and filterscope channels in July 2009 (preparation for next KSTAR experimental campaign Oct - Nov 2009)
  - Obtained additional Visible Bremstraahlung filters for measuring Zeff profile on KSTAR with filterscopes- Fall 2009
  - Obtained fiber splitters to permit simultaneous He, C, O, and VB measurements on current K STAR H-alpha channels using ORNL filterscope - Fall 2009
- ORNL preliminary design of divertor filterscope system for monitoring impurities and recycling in KSTAR divertor - probably 2011, maybe 2010
- ORNL proposing “Ohmic H-mode” experimental campaign as a research thrust during near term circular plasma operation (led by J-W Ahn - ORNL post-doc) - begin Fall 2009
  - Will need major wall conditioning (will need anyway for later shaped and diverted plasmas)
    - H glow, He glow, boronization, etc.
  - Should be obtainable within next 2 years before divertor ready, will utilize existing diagnostics
  - ORNL filterscope will be one of first diagnostics to see H-mode
- ORNL & PPPL & U. of Wisconsin have prepared preliminary design for CER/MSE/BES diagnostic for KSTAR (Bay M).
  - have preliminary design - need budget & 3 years to implement. If started today would be available late 2011
  - Maybe need an initiative to begin soon
- ORNL can provide support for pellet fueling and disruption mitigation on KSTAR
  - ORNL can provide support for design and testing of KSTAR inside pellet launch

UC Davis Proposal for ECEI and MIR Collaborations

- ECEI and MIR diagnostics for KSTAR in a good position, due to a long but productive development period on TEXTOR and ongoing work for a new ECEI system on DIII-D to begin operation in Oct. 2009
  - Strong simalarities between DIII-D and KSTAR system designs
- Conceptual designs exist for both low field (1.5-2.0 T) and high field (3.0-3.5 T) operating conditions
  - Low field operation to consist of a two array (each 24x8) ECEI system
  - High field operation to consist of simultaneous one array (14 element) multi-frequency MIR and two array (each 24x8) ECEI system
- Close collaboration with Dr. H. Park of POSTECH
- Development plans worked out for development of the 2.0 T system for the FY2010 campaign (assuming sufficient funds become available in the next few months) and the 3.0-3.5 T system beginning in FY2012
- DIII-D will begin a ~1 year shutdown period in May 2009, freeing up UC Davis personnel with experience on DIII-D to install and commission a low field ECEI system for the FY2010 campaign on KSTAR

Proposed Control and Operations Experiments

- Axisymmetric magnetic control (2009/10)
  - Assess and improve magnetic diagnostics, reconstruction capability
  - Quantify fundamental PF capabilities and controllability
  - Validate axisymmetric plasma response models

- MHD control (2010)
  - NTM suppression/control island size, locked mode studies
  - RWM control: model validation, stable plasma response

- Disruptions (2009/10)
  - VDE, major disruption physics
  - Varying post-TQ plasma conditions
  - Mitigation by gas injection, nonaxisymmetric fields
  - Off-normal and fault detection/response: begin developing modules for ONF management, pursue operations solutions for disruption-free operation

Potential ITER Support Experiments

Controllability studies
- In-vessel coil operation with SC PF coils (2010)
- Fundamental controllability limits, quantify role of noise/disturbances (2009/10)

SXR tomography for magnetics-free reconstruction: (2010)
- Correlation with magnetic topology
- Accuracy assessment
- Methods for dealing with emissivity variation

Startup/shutdown scenarios: (2009/10)
- Input to ITER operations plan: develop and document commissioning process
- Demonstrate/quantify aspects of ITER startup/rampdown scenarios with SC coils
- Inboard/outboard startup comparisons, quantify accessible operating space and tradeoffs for startup
- Demonstrate methods for dealing with magnetic materials, error fields
- Rapid controlled shutdown scenarios: non-terminating mitigation methods, neutral point, control of runaway channel, nonaxisymmetric fields…

Disruption characteristics and mitigation: (2009/10)
- Prediction of post-thermal quench plasma conditions
- Validate and expand models for scaling of forces, halo currents
- Runaway electron generation physics, rapid uncontrolled shutdown/mitigation strategies appropriate for ITER
- Useful disruption diagnostics: halo currents, force/displacement, photodiodes for radiation accounting, scintillators for runaway electron detection

ORNL Proposed H-mode

- Study Ohmic H-modes

CATEGORIES	KSTAR	US
EFIT	•Algorithm understanding and development of way to include ECH and ECE •How to include the Incoloy effect •Validation of magnetic analysis and participation in the measurements	•Find way to include Incoloy compensation in EFIT –Preprocess of inputs •EFIT reconstruction of high beta plasmas in KSTAR •Inclusion of additional kinetic diagnostic signals such as TS and ion pressure •Support for magnetic analysis and measurements
Operation Tools	•Tools for operation control such as EFIT viewer, RDBRM, e-log •Policy review for remote operation	•Full EFITViewer •Relational DB for run management •E-log •Webportal •Gatekeeper for PCS •Data storage in MDSPlus

CATEGORIES	KSTAR	US
Real Time Control	•Identification and control of plasma shape-part of PCS improvement •Non-symmetric error field study and design of measurement tools •Support for IVCC operation and PS design	•Improve TokSys capability •Improve KSTAR PCS • Analysis supports for current cross-over, vertical control growth rates for PS, etc specification •Physics operator training/discharge preparation using simserver simulations •Analysis on IVCC-flexibility, PS requirements, future upgrade, capabilities of RWM, ELM stabilization • Characterization of non-symmetric configurations – measurements and code

CATEGORIES	KSTAR	US
Others	•Code support – TRANSP, other physics codes •Support for diagnostic developments, operation participation, loan of experimental components, training and education and development of physics issues in KSTAR for unique niches	•Fusion Grid for TRANSP •Loan of XCS detector, 110 GHz gyrotron. •Operation participation