Overview of progress with ITER spectroscopic systems

IAEA, Daejeon 15-19 December 2014

Robin Barnsley and ITER team

- Status overview
- Generic activities
  - Emission modelling
  - Stray light modelling
  - Neutronics modelling
- Outlook

A Q=10 scenario with (ELMy H-mode):

\[ I_p = 15\,\text{MA}, P_{aux} = 40\,\text{MW}, H_{98}(y,2) = 1 \,\text{T} \]
\[ T_e, T_i, n_{e,10}\,\text{He}, Z_{eff} \]
\[ q/g_60/g_3/g_70/e_{keV} \]

Current Ramp-up Phase

Project Requirement on Diagnostics is for Measurements

Interfaces are one of the great challenges of ITER, both in design and in assembly. Many components; space tight and harsh environment

Port Integration Activities

- Joint team working closely together to integrate diagnostics and services
- Port integration very important driver for diagnostics – 2014 big progress
- Driver for all port systems - Interfaces

Port Plugs: Final Design Reviews Completed

- UPP Assembly: GUPP+DFW+DSM
  - FDR completed

All Diagnostic Port Plugs have

- Common Design and shared Procurement
- This saves costs and time for the project
  - Tender started
  - Modular structures
  - Welded (Electron Beam mainly)
  - ESPN
- EPP Assembly: GEPP+DFW+DSM
  - FDR completed

Magnetics and In-Vessel Wiring Looms

- Fundamental to the operation of ITER and
  - Needed early in the assembly phase
- Showing CER (FDR), flux loops (PDR) and prototypes

We are in the construction phase

Needs the best scientists, engineers and project expertise etc
Plasma emission modelling

- Impurity emission modelling is essential input to designs – sets requirements for instrument:
  - Sensitivity
  - Spectral range and resolution
  - Field of view and spatial resolution
- Atomic data from ADAS – Atomic Data and Analysis Structure (open.adas.ac.uk).
- Plasma emission modelling with SANCO impurity transport code

Continuously refined and expanded
- Wide range of plasma scenarios
- Wide range of impurities
- Impurity radiated power – line and continuum
- Input to all spectroscopy CDRs
- Input to Bolometry CDR

Range of plasma scenarios for emission modelling

Te profiles

Ne profiles

ADAS/SANCO Modelled spectral emission

Sight-lines and viewing fans can be generated for any location

Modelling of emission along lines of sight for imaging VUV spectrometer

VUV lines 10 – 100 nm mostly in the outer plasma

The three ITER x-ray spectrometer subsystems

Subsystem
Main plasma X-ray survey
X-ray Core imaging
X-ray Edge imaging
Function
Impurity species identification and monitoring
Core ion temperature, rotation, impurity profile
Edge ion temperature, poloidal rotation, impurity profile
Wavelength range (nm)
0.05 – 10
0.2 – 0.4
0.2 – 0.5
Receiving power (l/sA)
Below 2.5 nm – 1000
Above 2.5 nm – 100
-8000
-8000
Implementation
Shot in E11 port-plug, Deflecting optics in port-cell
Shot(s) in E09 port-plug, Deflecting optics inside port-plug
Shot in U99 port-plug, Deflecting optics behind the port-plug

First Measurement of KSTAR Plasma Impurity

- Impurity lines of initial plasmas at KSTAR 2012 Campaign (2012.08.08)

KSTAR VUV Spectrometer – ITER Prototype
CR Seon, MS Cheon, S Pak & HG Lee

 charities without ABN

NCR/LFD - 2012 Strengths

- Powerful X-ray
- high resolution
- high sensitivity

Korea KSTAR VUV Spectrometer

- X-ray imaging
- ion temperature diagnostics
- impurity profiles
Views for Core Imaging X-ray Spectrometer

Three sub-views with imaging crystal spectrometers
Toroidal component ~25 deg.
The views projected onto flux surfaces

ADAS/SANCO modelling of impurities relevant for the Core X-ray Spectrometer

Fractional abundance of relevant ions
Line-integral intensities of W +64
For the three x-ray views

Stray light modelling

- In-vessel reflections are important for all visible systems
- LightTools is now well-established
  - Quantitative results
  - Sources built based on plasma modelling
  - Surface reflectivities can be modelled or measured
  - Directly uses CAD models of in-vessel components
  - Generates image-quality results
  - Benchmarking comparison with JET in progress

Stray light modelling with LightTools

Strategies for stray light mitigation led to re-design of H-alpha system

Neutronics modelling

- Major design driver for all systems
- Challenge for direct-viewing diagnostics – X-ray, Neutron, NPA etc
  - Use internal collimation to sub-divide views
    - NPA
    - Core x-ray spectrometer
  - Sub-divide into discrete views
    - Radial x-ray camera
    - Core x-ray spectrometer
    - Radial x-ray camera
  - Tight collimation inside port plug to keep direct neutrons away from sight-tube components as much as possible
    - All systems
    - Minimize activation of sight-tube for maintenance
    - Use aluminium where possible
    - Stop direct neutrons in beam-dump
Fan array for Radial X-ray Camera divided into sub-views
- Large improvement in neutronics
- No loss of x-ray sensitivity
- Practical first wall slots

![Image of Fan array](image1)

Discrete sub-views

First wall slots Slit location Detector location

Neutronic analysis of shielding is a major design driver

Core imaging x-ray spectrometer

MCNP model

Under study – Human factors
- Direct neutrons closely collimated in sight-tube
- Minimize sight-tube activation
- Maximum use of low-activation components – eg Aluminium
- Beam-dump to stop direct neutrons

X-ray Camera - Fan view divided into several sub-views
Results in improvement in neutron flux at port flange

![Image of X-ray Camera](image2)

Initial Neutronic Model
Improved Model

1.3x10^10
n/cm^2/s

1.72x10^11
n/cm^2/s

Long-term outlook

General
- PDR phase through to FDR
- R&D ongoing
- Prototypes already - eg VUV on KSTAR

Stray light
- Goal – operation model of vessel, plasma and diagnostics

Neutronics
- Large effort – almost always on critical path for design progress
- Required throughout operation

Plasma modelling
- Goal – continuously updated data for all impurities, scenarios, diagnostics etc
  - Concept design
  - Detail design
  - Analysis code development
  - Analysis support throughout operations
  - Requires long-term availability and updating of
  - Data
  - Experts

Present Global planning for ITER Diagnostics
Atomic data and modelling requirements

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IAEA meeting on data for fusion, Daejeon, 15-19 December 2014, R Barnsley