Participation of the Stellarator Heliotron community in the ITPA Integrated Operation Scenarios Topical Group

E. Ascasíbar
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ITPA IOS scope

-Establish operational scenarios in burning plasma experiments, particularly candidate scenarios in ITER, by means of international collaboration on experimental, code development and modelling activities.

-Tasks:

- Develop safe and reliable ITER operation scenarios:
  - plasma break-down, current ramp-up and ramp-down, plasma termination, sustainment of the current flat-top
- Evaluate capabilities of actuators — heating and CD, fuelling, particle exhaust, etc— for achieving the identified scenarios
- Develop integrated plasma control procedures: steady-state operation in ITER (emphasis on real time control)
- Plasma development for ITER: consistency between scenario development and hardware status for each phase of machine operation
- Promote integrated modelling activities for ITER scenarios: validating the available scenario modelling codes and exploring the operational boundaries

Participation of SH in ITPA IOS (so far)

2009-2011: Joint Experiment IOS 2.1: ECRH-assisted plasma breakdown in ITER

- TJ-II and Heliotron J (Stober et al, Nuclear Fusion 2011)
- Contributions at the ITPA IOS3 (Frascati), IOS6 (Culham) and IOS7 (Kyoto) by E. Ascasíbar and K. Nagasaki

2011: LHD contributions at the ITPA IOS7 Kyoto meeting:

- Recent Results of High temperature mode, EC/ICRF heating and Steady state operation in LHD (T. Mutoh)
- Integrated transport code development and its application to LHD (M. Yokoyama)

Recent very relevant development

Establishment of a new Steady State Operations Coordination Group (SSOCG) to strengthen and coordinate the programmes on science and technology issues of SSO of Implementing Agreements and national laboratories.

- Approved at the last IEA Fusion Power Coordinating Committee on January 2013.
- Group co-chaired by T. Mutoh (NIFS) and G. Sips (Chair of ITPA IOS TG).
- Organizational process is under way. Nomination of a member of the SH Executive Committe and experts of the SH Implementing Agreement is being agreed these days.
- The 2nd meeting of SSOCG will be held at 7th IAEA TM on SSO (Aix-en-Provence, May 2013).

Quick review of Proposed Terms of Reference

[Extract from IEA/CERT/FP/CC(2013)2 Annex 1]

Objectives

To gain experience with SSO in actively cooled devices* as they are essential to the ITER experiment and beyond by sharing best practice and coordinating experiments between the fusion-related IEA Implementing Agreements.

*SC devices — Tore Supra, LHD, EAST, KSTAR (in operation)
SST-1, W7-X, JT-60SA (in construction)

Term

The initial term of the SSOCG will be set as two years, from 1 January 2013 to 31 December 2014. Thereafter, requests for extension of the mandate of the SSOCG will be for periods of three years.

Membership

FPCC Delegates will nominate the Chair, Co-Chair and additional members as deemed relevant. Each fusion-related IA carrying out relevant SSO work is expected to nominate one member and experts as required to the SSOCG at the beginning of each term.

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Quick review of Proposed Terms of Reference (cont'd) [IEA/CERT/FP/CC(2013)2 Annex 1]

Work Programme

A primary concern of SSO research is the precise distribution of plasma on various first wall components which impacts on their design concepts and fabrication.

- ●First wall materials choices,
- ●operation with SC coils,
- ●additional heating systems,
- ●diagnostics and real-time plasma control methods for very long pulse operation

are equally important issues.

The integration of physics and technology constraints is particularly challenging.

Having these concerns in mind, SSOCG members will establish a joint work programme that will endeavour to:

- ●Identify the most urgent topics related to SSO technology/physics in support of ITER and beyond;
- ●Ensure that these key areas are considered in the fusion-related IEA Implementing Agreements and will propose actions for stimulating joint work in this area; and
- ●Establish strong links with the ITPA working group on Integrated Operation Scenarios (IOS-TG) in the area of physics engineering for SSO and long pulse operation.

Courtesy from Prof. T. Mutoh

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Key Physics areas for SSO

Actuators

- Define the physics requirements for long pulse heating systems (core heating, peripheral, current drive)
- (Novel) heating and current drive methods
- Current drive actuators (Tokamaks)
- MHD control by H&CD actuators
- Long pulse: RF coupling and LHCD at high plasma density

Particle fuelling and particle inventory

- Fuelling methods
- Wall content and wall fuelling
- Hydrogen (T_2) inventory control for SSO
- Pumping requirements and options for pumping
- Vacuum systems leak rate tolerances (minimum leak rate?)

Courtesy from Prof. T. Mutoh

Key Physics areas for SSO (cont'd)

Long pulse performance optimisation

- Candidates for Tokamak (including STs) and Stellerator-Heliotron operational scenarios
- Reliable and robust operation
- Modelling and forecasting of SSO regimes
- Possible SSO scenario validation/tests on ITER (ITER → DEMO)

Energy and power loads

- Power exhaust from the plasma
- Materials options for the wall compatible with plasma operation
- Loads to magnets and heating systems of SS devices

Control

- Burn control and simulating burn control in current devices
- (Tokamaks) Current profile control in burning plasmas

Courtesy from Prof. T. Mutoh

Key Technological areas for SSO

(With special emphasis relation to physics)
[Ref: Interim Report for Study Group on SSO in 2006
by R. Haange and T. Mutoh]

- A number of technological aspects are vital for SSO machines
- In the case of ITER, being a nuclear machine, this covers the full spectrum
- Most developments are also required for the present generation of SC Tokamaks and Stellarator-Heliotrons, except that the neutron fluence is much smaller compared to ITER.

The main areas where further developments are required are:

1. **Superconducting Coils**
2. **Cryogenics**
3. **Plasma Facing components**
4. **Heating and Current Drive Systems**
5. **Instrumentation, Plasma Control and Diagnostics**
6. **Others**

Courtesy from Prof. T. Mutoh

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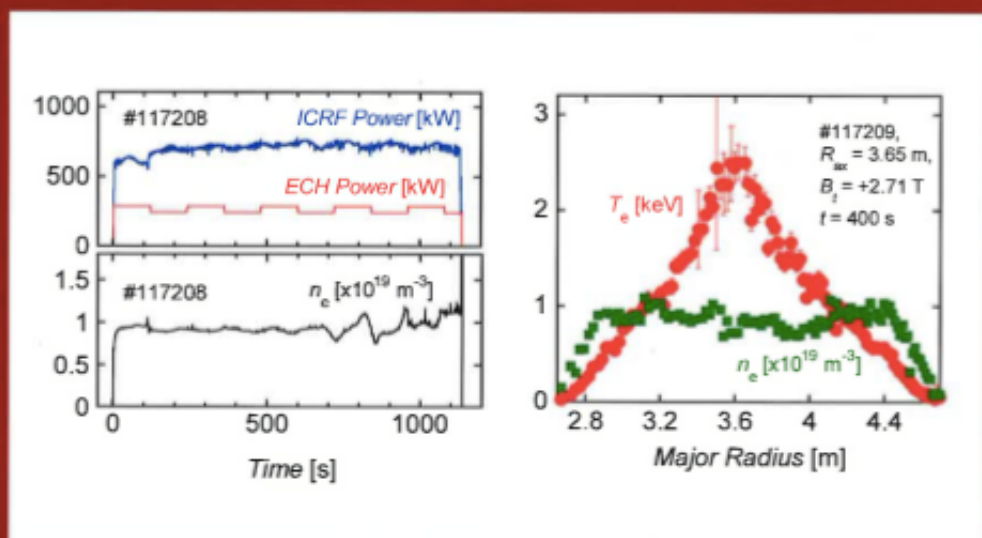
Summary

- Possibilities of collaboration between SH and ITPA IOS in a few specific areas:
  - -Actuators: Heating and CD, ….
  - -Integrated modelling activities
  - -……

- Major role to be played by LHD and (in a few years time) by W7-X in the development of the Steady State Operation physics and technology programs : SSOCG



Steady-state discharge with the total RF power of 1 MW in LHD. Plasma with n_e ~1x10^{19} m^{-3} was successfully maintained for 19 minutes.