EFDA WORKPROGRAMME 2011

Call for Participation

Dust and Tritium Management

Deadline for Responses: 21. Apr 2011

EFDA CSU contact person: Artur Malaquias

This Call for Participation aims to implement the Emerging Technologies - System Integration Work Programme for 2011 under Task Agreements as foreseen in the new EFDA Art. 5

Introduction

In a Tokamak, Plasma Wall Interaction phenomena induces tritium trapping and dust production/deposition in the Vacuum Vessel and plasma facing components. Due to radiological and explosion risks pointed out by safety evaluation studies, the accumulation of dust and tritium in the VV could significantly impact the operation of ITER. In view of ITER licensing and operation requirements there is an urgent need to further develop and mature techniques allowing the monitoring of dust and tritium inventories in the VV and also mitigation techniques allowing detritiation and dust removal. Such techniques are also needed in a longer perspective for future fusion reactors such as DEMO. The safety limits under which ITER has to operate are 1000Kg of cold dust, 6 kg of hot dust each of Be, C, W and 1Kg of T, all in-vessel.

In order to provide control on the inventories ITER is developing the systems presented in Table I and II below.

Measurement

	Main system / method	**Supporting**
Dust	Measurement of erosion by PFC metrology • IVVS • Fixed laser • Other diagnostics: spectroscopic measurements	• Local dust monitor, • Dust removable samples, • Dust production rate model • Tracking and characterization of removed dust
Tritium	• Tracking tritium (difference between tritium injected and tritium recovered) • Gas balance • Characterization of material removed from the VV	• LIBS/LID • Models – Retention model – Tritium process model – Gas balance • Removable samples • Desorption via laser mounted on IVVS (under consideration)

Table I: Main ITER systems to provide inventory measurements

Removal

	Main method	**Supporting methods**
Dust	• Vacuum cleaner via the Multi- Purpose Deployer	• Vacuum cleaner via other RH systems • CTM, CMM, • IVT
Tritium	• Divertor baking at 350°C • Dust removal • PWM cleaning & conditioning techniques	• Baking of Blanket and VV • PFC removal

Table II: Main ITER systems to provide removal action (CMM - cassette multifunctional mover, CTM - cassette transport mover, IVT - in-vessel transporter)

Ongoing research in this topic is being covered by several organizations. A research programme has been running by Fusion for Energy (F4E) which included three systems: the Divertor Erosion Monitor system, Capacitive Diaphragm Monitor and Hot Dust measurement using water vapour injection. The JET programme on dust and tritium management provides also valuable results on the processes of dust generation and distribution as well as for tritium retention maps throughout post mortem analyses of tritium depth profile in PFC, and measurements of erosion, deposition and characterisation of co-deposits. During 2009/10 EFDA has also implemented a programme to cover feasibility studies on laser based techniques that presented some potential to perform the inventory and removal of dust and tritium.

Programmatic Background

Dust and Tritium management are in the high priority list of ITER topics in order to satisfy safety and operation limits. Several organizations including ITER, F4E, EFDA, and to some extent JET are implementing programmes in this topic. The necessity to streamline the on-going programmes and optimize the resources led to the realization of a coordination meeting held on the 11th of February 2010 in Cadarache gathering the Dust and Tritium Management working group experts and representatives of EFDA-EMT, EFDA-PWI, F4E, ITER (first wall, safety, operation and diagnostics) and ITPA, with the aim to prepare the 2011 EFDA-EMT programme guidelines. In June 2010 a PWI and EMT joint progress meeting was held and in a dedicated session the important activities to be included for 2011 on a Dust and Tritium EFDA programme were discussed for the PWI and EMT programmes under EFDA. The present programme was prepared taking into account the output of these meetings and the results of the EFDA 2009/2010 programmes related to this topic. In the present planning it has also been recognized that any techniques being presently developed would most probably require testing on medium to large tokamaks such as TEXTOR, ASDEX, JET, etc. in order to demonstrate the required level of reliability and measurement capability for their integration into ITER.

1. :

Task Agreement WP11-ETS-DTM-01:
Dust and Tritium Management

1.1 Introduction

This task agreement aims to complete the experimental studies leading to the qualification of laser and arc discharge techniques for deposited layer removal and in vessel fuel inventory measurements for ITER. It is expected that by the end of this work all information required for ITER to take-on on the integration of the systems, if so decided, is completed. The description of each activity is detailed hereinafter taking into consideration that the ITER requirements must be accomplished by the technique as a whole. The ITER guideline requirements are presented in the table III.

MEASUREMENT	PARAMETER	COVERAGE	TIME / FREQUENCY	SPATIAL RESOLUTION	ACCURACY
Divertor Operational Parameters	erosion rate	1-10 x 10^{-6} m/s	2 s	10 mm	30%
	net erosion	0-3 mm	per pulse	10 mm	12x10^{-6} m
Dust monitoring	accumulation rate	10^{-4}-10^{-2} kg/m^2/pulse	per pulse	several positions	50% abs 20% repr
	concentration	10^{-2}-10 kg/m^2	daily	several positions	50% abs 20% repr
Tritium Monitoring	H, D, T accumulation rate	2.10^{19}-2.10^{21} atoms/m^2/pulse	per pulse	several positions	50% abs 20% repr
	H, D, T concentration	10^{20}-2.10^{24} atoms/m^2	daily	several positions	50% abs 20% repr

Table III - ITER measurement requirements

1.2 Objectives

The EDFA work programme for 2011 under Emerging Technologies will focus on advancing two potentially useful technologies (in addition to other techniques and studies on this topic that will be covered under EFDA Diagnostics and PWI programmes):

- Advance feasibility studies of arc-based techniques operating at atmospheric pressure to remove and control locally the layer composition and trapped tritium on places of higher retention (in particular at the top of the vessel)
- Advance and qualify LIDS, LIAS and LIBS techniques on a ITER port plug relevant set-up in tokamaks or relevant experiments (optical paths and tests on ITER like materials) for performing tritium wall inventory.

For the purposes of the present call the development of the arc-based techniques at atmospheric pressure shall take into consideration that the concept and the configuration of the system must allow for integration into the ITER remote arm, i.e. shall be able to clean the sample by scanning over its surface and shall allow to include components that are in line with the application on a remote arm (weight and size), feeding cables and optical fibres (radiation hard, acceptable diameter, flexibility), etc.

1.3 Work Description and Breakdown

Structure

There are two main activities foreseen in the present call regarding deposited layer removal and four activities related to laser based techniques for trapped fuel measurements.

One common aspect of the tasks here presented is that they are to be developed keeping in mind their application for ITER. Therefore all relevant aspects that impact on the performance of the system in ITER have to be considered on every aspect of the design if otherwise the end result is not applicable in ITER. In particular, defining the spatial coverage with respect to available ports and/or Remote Handling systems, defining relevant performances achievable for the diagnostic/system (accuracy, depth resolution, spatial resolution, time resolution, spatial coverage, etc…), and estimating, taking into account ITER conditions (T, radiation effects, vibration, deposition, erosion, etc...), the impact on performances.

All tasks herein proposed based on laser techniques will be developed under coordination of a leading Association to be selected from the quality of the proposals and level of experience. Proposals which includes strong collaboration with other Associations are expected.

Work Breakdown

WP11-ETS-DTM-01-01

Arc-discharge method at atmospheric pressure

One of the priorities for ITER is the development of methods for collecting dust and perform inventory accounting (e.g. dust collectors for in-situ and ex-situ accounting). Non-invasive methods based on the photonic principle to mobilize dust have been tested in the laboratory with some relative success. However the spatial coverage offered by an ITER port-plug system might be very limited requiring usage of several ports to cover the whole divertor. There is therefore the need to develop additional methods making use of the Multiple Purpose Deployer arm operating under a controlled atmosphere. Additionally to the problem of dust inventory removal/mobilization and accounting one needs to develop methods for removing deposited layers accumulating not only on the divertor but also on the top of the vessel. To that end the use of arc based cleaning systems seems a promising technique. During the previous EFDA programme the potential of this technique to clean deposit layers on a laboratory environment under vacuum has already been demonstrated.

The present task calls to advance this system aiming at demonstrating cleaning efficiency under atmospheric pressure (simulating the vent conditions on ITER) and define the parameters to build a compact unit that can be integrated on a remote arm. In addition, the potential of these techniques to work in parallel with spectroscopic systems allowing to perform in-situ measurements of film composition and fuel content will be exploited in another task.

It shall demonstrate experimentally the capability to clean deposit layer from SS, W and Al surfaces under ITER vent conditions and pressures and evaluate efficiency of the method for ITER like composite deposits of Al and W on Al, SS and W (determine how much volume can be cleaned and perform parametric studies vs. area.thickness/min). Measure the roughness of the surface after cleaning and determine the efficiency on re-deposit cleaning. This would simulate the behaviour of ITER walls after successive cleaning and plasma operation cycles. Roughness of the cleaned and re-cleaned samples shall be characterized and compared with virgin samples. The tests are to be made on a relevant mimic experiment or on a real tokamak.

Define a work plan with costs, resources and time frame and input required for developing a prototype for application on the Multiple Purpose Deployer arm.

WP11-ETS-DTM-01-02

Arc-discharge spectroscopic system

The system is foreseen for application in parallel with the arc discharge method and foreseen for implementation on the same ITER robotic arm (MPD).

A conceptual study must be developed compatible with the arc discharge system to be developed in Task DL1.1. In a following phase the spectroscopic system must be constructed, installed and qualified as part of this task. Elemental analysis of H and D doped layers of Al and W on several relevant substrates must be conducted in a laboratorial experiment and relevant parameter scans and optimization to achieve the accuracy target of 20% on relative concentration measurements and 50% absolute on H and D must be performed. The following activities need to be explicitly included in a proposal

- Procurement, installation and optimization of the light-collection and spectroscopic system (type of spectrometer, collection optics needed, characterize resolution of the spectrometer). The light transport system shall be preferentially fibre optic based
- Modelling and experimental demonstration for characterization of when the surface has been cleaned
- Modelling and experimental demonstration for determination of the composition of the deposited layers
- Modelling and experimental demonstration for determination of the fuel concentration of the deposited layers (20% accurancy, 50% absolute)
- Presentation of a work plan with costs, resources and time line required for developing a prototype for the Multiple Propose Deployer arm

WP11-ETS-DTM-01-03

Laser Induced Desorption Spectroscopy

This activity aims to install and operate LIDS on an ITER relevant setup taking into account equivalent optical system layout and throughput. Determine the influence of the plasma on the measurements and experimentally establish the accuracy for different plasma and sample conditions and perform H, D and T inventory surface measurements on Al and W doped films and a range of mix of these materials.

The main goals for this task are: i) to develop H, D and T retention diagnostics for study of the retention issue during the early phases of ITER operation and for later operation with T and ii) the identification of hot spots (higher concentration of T). Once identified, it may be possible by applying specific detritiation techniques on those spots to reduce locally the tritium inventory.

Three main types of potentially port plug based laser techniques for tritium inventory measurements have been developed and tested in laboratory:

- Laser induced desorption spectroscopy (LIDS)

- Laser induced ablation spectroscopy (LIAS)

- Laser induced breakdown spectroscopy (LIBS)

LIDS experiments on a real tokamak environment shall provide detailed information and test of integration solutions for ITER (using equivalent relevant optics and lasers) and on the accuracy, time resolution, spatial resolution, 2D and in depth resolution.

As for LIAS and LIBS the present laboratory relative accuracies of circa 50% do not provide yet the ITER required accuracy (20%) for fuel inventory. Dependences on substrate material and laser characteristics must be better clarified and supported by experimental and physics model. This activity in particular will also be addressed by arc based systems that have the potential to produce relatively high releases and stronger spectral emissions from the deposits. However, the latter is not a port plug candidate therefore it will be considered only under the invasive methods. The advantage of Laser based systems remains on their non-invasive capability.

WP11-ETS-DTM-01-04

Laser Induced Ablation Spectroscopy

Perform H, D and T inventory surface measurements on mix deposits of Al and W and on Al and W substrates and determine composition of the ablated layer. Determine the influence of the tokamak environment on the measurements and experimentally establish the accuracy for different plasma vs. sample mix and concentrations.

The following results shall be obtained:

a) Qualify the operation of LIAS on a ITER relevant experimental set up on a tokamak (ASDEX, TEXTOR, etc…) for performing H, D and T inventory (20% accuracy) in depth measurements on the wall and on deposited layers and determine composition of the ablated layer.

b) Compare LIDS and LIAS measurements obtained with running plasma and LIBS measurements on the same samples and determine the reproducibility of the signals.

c) Establish a solid base for calibrating the diagnostic by advancing the technique under different substrates and irradiation conditions. Develop predictive model for diagnostic operation under several substrates (W, AL (or Be) single and mix layers) and irradiation conditions (power, pulse length, etc) in order to determine H, D and T contents as well as ablated layer composition.

d) Characterise operation under magnetic field and develop a modell for data retrieval from the plume signal to concentration depth profile: characterise plume dynamics in the different discharge conditions and identify optimum conditions to collect the light and validate the measurement including any contributing masking effects and presence of different species, as a function of surface type, laser pulse duration and power, and magnetic field strength; quantify depth of ablation (compare model with experimental results by ranging laser power and pulse duration vs. material and material mix and determine total material ablated for H and D concentration determination),

- Test and optimise relevant ITER optical layout for LIAS
- Elaborate tests on calibrated samples in a mix of W and Al samples dopped with controlled amounts of H and D
- Estimate the S/N level in ITER for an optimized configuration of the diagnostic on an equatorial port plug for an ITER DT burning plasma reference scenario

WP11-ETS-DTM-01-05

Laser Induced Breakdown Spectroscopy

Advance and qualify the operation of LIBS on a ITER relevant experimental set up on a tokamak for performing H, D and T inventory surface measurements on Al and W substrates (single and mix materials). The following results shall be provided:

a) Qualify the operation of LIBS in a ITER relevant experimental set up in a tokamak (ASDEX, TEXTOR, etc…) for performing H, D and T inventory (20% accuracy) in depth measurements on the wall and on deposited layers and determine composition of the ablated layer.

b) Compare LIDS and LIAS measurements obtained with running plasma and LIBS measurements on the same samples and determine the reproducibility of the signals for ns and ps laser duration.

c) Establish solid base for calibrating the diagnostic by advancing the technique under different substrates and laser irradiation conditions. Develop predictive model for diagnostic operation under several substrates (W, AL (or Be) single and mixed layers) and irradiation conditions (power, pulse length, etc) in order to determine H, D and T contents as well as ablated layer composition.

d) In particular the following activities shall be considered:

- characterise operation under magnetic field

- develop a model for data retrieval from the LIBS plasma signal to concentration depth profile: characterise LIBS plasma dynamics in the magnetic field and identify optimum conditions to collect the light and validate the measurement including any contributing masking effects and presence of different species, as a function of surface type, laser pulse duration and power, and magnetic field strength; quantify depth of ablation (compare model with experimental results by ranging laser power and pulse duration vs. material and material mix and determine total material ablated for H and D concentration determination)
- Test and optimise relevant ITER optical layout for LIBS
- Elaborate tests on calibrated samples in a mix of W and Al samples doped with controlled amounts of H and D
- Estimate the S/N level in ITER for LIBS for an optimized configuration of the diagnostic on an equatorial port plug for an ITER DT burning plasma reference scenario

WP11-ETS-DTM-01-06

Coordination

The leading Association will be responsible for the coordination of the activities on laser based techniques.

The coordination of the experiments shall be performed aiming to accomplish the deliverables timely and with the required level of development. In particular a time plan for the task covering the design of components, installation, modelling activities and experimental studies shall be presented taking into account the need to synchronize all task activities in several Associations. A final report shall be produced containing a concise and scientifically sound discussion of the results to point clear directions of future development if required. The report shall include a conceptual design for ITER with a detailed breakdown of activities, costs and resources and a time plan for developing and integrating the Laser based system techniques in ITER (LIDS, LIAS and LIBS).

JET related activities

none

Resources

The indicative resources and hardware support for implementing the Dust and Tritium Management programme are given in the following Table

Task	BS (ppy)	PS (ppy)	EU Hardware contribution (k€)
DTM-01-01 - Advance and improve the arc based method for application on the MPD for film coating removal and collection of waste	1	1.2	50
DTM-01-02 - Develop a spectroscopic system for application in parallel with an arc discharge method for performing extraction monitoring and layer composition analysis	1	0.4	10
DTM-01-03 - Advance and qualify the operation of LIDS on a ITER relevant experimental set up on a tokamak for performing H, D and T inventory surface measurements on Al and W substrates	0.5	0.5	0
DTM-01-04 - Advance and qualify the operation of LIBS on a ITER relevant experimental set up on a tokamak for	1	0.5	0

performing H, D and T inventory surface measurements on Al and W substrates			
DTM-01-05 - Advance and qualify the operation of LIAS on a ITER relevant experimental set up on a tokamak for performing H, D and T inventory surface measurements on Al and W substrates	2	1	10
DTM-01-06 – Coordination of LIAS, LIDS and LIBS activities	0.2	0.2	0
Totals	**5.7**	**3.8**	**70**

1.4 Scientific and Technical Reports

Progress reports

At the end of the Task Agreement during the final monitoring meeting, the Task Coordinators shall present a report on all activities (under baseline and priority support) under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable.

The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the Task Coordinators and submitted to the EFDA Leader. Each participating Association will have to report in one subsection on the degree to which the deliverables of their Tasks have been achieved and shall include a breakdown of expenditure. The Task Coordinator will collect the individual subsections into the final report for Priority Support activities addressing the associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

Milestones and Deliverables

Milestones:

Progress Meeting 6 months after the start of the Task Agreement

Final Meeting by the end of the Task Agreement

Deliverables:

The deliverables consists of an intermediate and final report presenting the results as per required in the Task Agreement with a critical view on the status of the research and developments obtained. A further detailed and complete assessment of a programme to implement the technique in ITER shall be provided based on a work breakdown project oriented approach including costs, man power and time frame to deploy the technique in ITER.

Activity	*Priority Support Deliverables*			*Due Date*
WP11-ETS-DTM-01-01	**Time (month)**		**Deliverables**	30. Apr 2012
	T0+5		Short report containing results of the cleaning and re-cleaning efficiency of deposits with mix of Be or Al, C and W. Conceptual design of a scanning system.	
	T0+6	Monitoring Meeting	Presentation of work done, experimental results, links to other related ongoing research and future plans for development.	
	T0+11		Full report containing detailed results on the experiments. The report shall contain: the estimated performance and indicate capacity of cleaning area/min, efficiency under vacuum and non vacuum; assess a strategy for complete coating extraction in ITER; results of experiments and studies under controlled atmosphere (N2, air at optimal pressures near atmospheric); contain results on the concentration measurement accuracy of the extraction of H and D content on Al and W deposits.	
	T0+12	Final Meeting	Presentation of work done, links to other related ongoing research. Presentation of a work plan with costs, resources and time line required for developing a prototype for the Multiple Propose Deployer arm	
WP11-ETS-DTM-01-02	**Time (month)**		**Deliverables**	30. Apr 2012
	T0+5		Short report including the conceptual design of the optical system.	
	T0+6	Monitoring Meeting	Presentation of work done, experimental results, links to other related ongoing research and future plans of development.	
	T0+11		Full report presenting the results of concentration measurements for different mixing percentage combinations of coatings with traped H and D (accuracy, time resolution, etc). Conceptual design for integration of the system in the ITER MPD arm.	
	T0+12	Final Meeting	Presentation of work done. Presentation of a work plan with costs, resources and time line required for developing a prototype for the Multiple Propose Deployer arm	
WP11-ETS-DTM-01-03	**Time (month)**		**Deliverables**	30. Apr 2012
	T0+5		Short report including new results of testes on samples under several plasma conditions. Estimate accuracy for ITER design conditions based on experimental results and modelling.	
	T0+6	Monitoring Meeting	Presentation of work done, links to other related ongoing research and future plans for development.	
	T0+11		Full report presenting the results of analysis for different material combinations and percentage mixtures	
	T0+12	Final Meeting	Presentation of work done, links to other related ongoing research and future plans	
WP11-ETS-DTM-01-04	**Time (month)**		**Deliverables**	30. Apr 2012
	T0+5		Short report on the design and implementation of the ITER relevant LIAS system.	
	T0+6	Monitoring Meeting	Presentation of work done, links to other related ongoing research and future plans for development.	

	T0+11		Full report presenting the new results of analysis for different material combinations and percentage mixtures of coatings under different plasmas. Provide accuracy for ITER design conditions based on experimental results and modelling.	
	T0+12	Final Meeting	Presentation of work done, links to other related ongoing research and future plans	
WP11-ETS-DTM-01-05	**Time (month)**		**Deliverables**	30. Apr 2012
	T0+5		Short report on the design and implementation of the ITER relevant LIBS system in a tokamak. Reporting on measurements calibration procedures and results.	
	T0+6	Monitoring Meeting	Presentation of work done, links to other related ongoing research and future plans for development.	
	T0+11		Full report presenting the new results of analysis for different material combinations and percentage mixtures of coatings under different plasmas. Results of comparison of LIBS and LIAS. Results and establishment of calibration of LIBS and LIDS. Provide detailed diagnostic design and integration for ITER. Establish accuracy and coverage for ITER conditions based on experimental results and modelling.	
	T0+12	Final Meeting	Presentation of work done, links to other related ongoing research and future plans	
WP11-ETS-DTM-01-06	**Time (month)**		**Deliverables**	30. Apr 2012
	T0+5		Short combined report	
	T0+6	Monitoring Meeting	Presentation of overall work done, links to other related ongoing research and future plans for development.	
	T0+11		Full combined report including an executive summary. The report shall include the individual reports of each task and a cover report providing a critical analysis and discussion of the results obtained in view of the objectives of this task agreement.	
	T0+12	Final Meeting	Presentation of overall work done with discussion of results and the extend of accomplishment of the objectives. Provide a work plan following a project management approach (resources, timeplan, work breakdown) for integrating a LIAS,LIDS and LIBS systems in ITER.	