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| **Relevant field** (choose one main research field from list below) | **F4** |
|---|---|

*F1. Tokamak physics for ITER and beyond*
*F2. Technology for ITER and beyond*
*F3. Stellarator and reversed field pinch research and advanced concepts*
*F4. Plasma-wall interaction and material research*
*F5. Plasma theory and computational plasma physics*
*F6. Diagnostics, plasma control and data analysis*

**Thesis Topic: Understanding plasma detachment through advanced diagnosis**

**Background**:

The fusion reactor ITER will produce 500 MW of fusion power. During operation, as they are exhausted, all particles including helium (a fusion product) and other impurities pass along the scrape-off layer, a two centimetre thick plasma layer at the edge of the confined plasma. Ninety percent of this power is radiated isotropically, but the remainder is transported to the divertor (see Fig. 1) that has to exhaust these particles and corresponding power fluxes.

Consequently, successful operation of future reactors rely on so-called divertor detachment to maintain the involved power fluxes to the divertor surfaces within acceptable limits. Experiments indicate that the detached plasma state can be associated with particle recycling and ion-neutral friction at the near surface plasma, leading to cooling and temperature gradients along the magnetic field lines [1]. However, a precise description of the involved mechanisms is still missing. For predictions of divertor operation under these conditions, plasma and neutral models with radiation transport and particle trapping need to be validated with high-quality data. The high flux linear plasma generator Magnum-PSI can play a critical role in this respect as it associates a relevant high-density plasma with an excellent diagnostic access. Magnum-PSI is already equipped with an advanced incoherent Thomson scattering (TS) system for measuring the electron density and temperature profiles, spectroscopic systems (to determine heavy particle properties), an extremely fast visible light camera and a fast IR camera for surface temperature measurements.

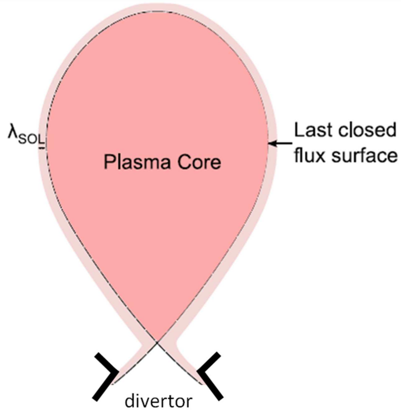


Fig. 1: Schematic presentation of cross section fusion reactor with divertor configuration, adapted from thesis J.R. Harrison, University of York (2010).

To provide a full picture of the plasma properties in front of the plasma facing surface the development of an advanced collective Thomson scattering system is ongoing [2] and the implementation of a so-called tunnel probe [3] is proposed within this project:

1. Collective Thomson scattering (CTS) enables the measurement of scattered light originating from electrons that are correlated with the motion of the ions. It enables unambiguous determination of ion temperature ($T_i$) and macroscopic plasma velocity ($v_{plasma}$). Although a prototype system is being developed, a diagnostic needs to be realized that enables the routine measurement of $T_i$ and $v_{plasma}$ profiles.
2. The tunnel probe will be mainly used to investigate secondary electron emission (SEE) from surfaces at local sheath plasma conditions. The sheath is a transition layer from plasma to surface of a few Debye lengths thickness wherein ions are accelerated to the surface, responsible for the main power load of the surface. New research, using this tunnel probe [3], shows that the contribution of elastically back scattered SEE from the surface is significant, especially for low energy electrons, which will predominate in the divertor plasma. The quantum mechanical basis for this could be the fact that the de Broglie wavelength for low energy electrons becomes very large compared to the lattice spacing of the surface. Elastically backscattered SEE is normally neglected in sheath studies, leading to a possible overestimation of the sheath potential and thus under estimation of the power load on plasma facing components. Remark: In addition the tunnel probe enables to measure the flux of ions hitting the target (ion current density parallel to the magnetic field lines, $J_{//}$). Combined with the axial velocity and density measurements from CTS upstream of the target, it will be possible to measure gradients of plasma pressure and particle flux which give valuable information about the physical processes that govern plasma detachment.

**General objective**:

We propose here to experimentally study the divertor detachment process in the Magnum-PSI with the aim to build a full picture of the plasma properties and their evolution in the last few centimeters from the surface using all the diagnostics at hand with a focus on TS/CTS and probe measurements. The resulting detailed measurements on Magnum-PSI will shed light on the plasma loss channels (volume recombination, radiation etc) and provide an excellent basis to benchmark plasma models such as the SOLPS suite (SOLPS; Scrape-Off Layer Plasma Simulation).

References


1. P.C. Stangeby, *The Plasma Boundery of Magnetic Fusion Devices*, IOP Published, 2000
2. H.J. van der Meiden, *Plasma Phys. Control. Fusion*, **52**, 045009, (2010)
3. J.P. Gunn, *Plasma Phys. Control. Fusion*. **54**, 085007 (2012)

**Objective**:

The project involves the following tasks:
Implementation of a tunnel probe in the Magnum-PSI device, in collaboration with CEA (France) and possibly IPP Prague (Czech Republic):

1. Performing measurements on detached plasmas at Magnum-PSI using the newly developed and available diagnostics.
2. Study the influence of local gas puffing and target orientation on the detachment process
3. Comparison of results with parallel modeling done in-house.

**Time line and mobility scheme (see guidelines summary, research need to be performed for at least six month in two different countries):**

Year 1:
Starting in September 2014, the PhD student will implement the tunnel probe at Magnum-PSI. He will also contribute in the commissioning of the CTS diagnostic. At the end of the first year measurements with the complete diagnostic park will be performed to obtain the required data.

Year 2
Finish measurements. After that, the PhD student will be stationed at CEA and work on modeling required for analysis of the tunnel probe data. Measurements can be performed at CEA (and possibly at IPP Prague) for comparison with data obtained at DIFFER: comparison detached process in Magnum and in a tokamak to identify similarities and determination of the influence of SEE.

Year 3:
Compare results with parallel modeling done in-house. Finalizing analysis, publishing results and writing PhD thesis.

**Home Institution (must be full partner):**
FOM-Institute DIFFER, PO Box 1207, 3430 BE Nieuwegein, The Netherlands

**Responsible person(s) at the home institution**
**(indicate full contact data of promoter and/or mentor):**
Promoter: Prof.dr.ir. Richard van de Sanden, m.c.m.vandesanden@differ.nl, tel: +31 30 6096914

Supervisors:
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Dr. Hennie van der Meiden, h.j.vandermeiden@differ.nl, tel: +31 30 6096944

**if the Home Institution is not a University indicate the**
**University* at which the promoter is affiliated**
Eindhoven University of Technology, The Netherlands

**Second institution (in a different country, can also be associated partner):**

Institut de Recherche sur la Fusion par confinement magnétique, CEA, 13108 Saint-Paul-les-Durance, France

**Responsible person(s) at this second institution**
**(indicate full contact data of co-promoter and/or co-mentor):**

Dr. James P. Gunn, Jamie.Gunn@cea.fr, tel +33 442257902, fax +33 442254990

**if this second institution is not a University indicate the**
**University* at which the co-promoter is affiliated**

| |
|---|
| Université de Provence Aix-Marseille I, France |
| *** note:** if these universities are not both full partner (in which case they have already agreed to provide at least a double degree), both universities have to submit with the submission of the common thesis topic, a letter confirming that they will award at least a double degree. |
| **Other Partners:**<br>IPP Prague is interested to be involved in this collaboration<br>(Contact person : Dr. Renaud Dejarnac, dejarnac@ipp.cas.cz, tel +420 26605 2944) |
| **Remarks:** |

## Annex 1 - Structure of the FUSION-DC network

### FUSION-DC full partners

Universiteit Gent (Coordinating institution), Belgium
Université de Lorraine, Nancy I, France
Universidad Complutense de Madrid, Spain
Universidad Carlos III de Madrid, Spain
Universität Stuttgart, Germany
Università degli Studi di Padova, Italy
Instituto Superior Técnico, Lisbon, Portugal

Institut de Recherche sur la Fusion par confinement magnétique, Saint-Paul-les-Durance, France
Max-Planck Institut für Plasmaphysik, Garching and Greifswald, Germany

### FUSION-DC associated members

CIEMAT, Madrid, Spain
DIFFER, Nieuwegein, the Netherlands
Forschungzentrum Jülich, Germany
ITER Organization, Saint-Paul-les-Durance, France
Fusion for Energy, Barcelona, Spain
IPP Prague, Czech Republic
Université de Provence Aix-Marseille I, France
Technische Universiteit Eindhoven, the Netherlands
Université Libre de Belgique, Brussels, Belgium
Ludwig Maximillian University, Munich, Germany
FUSENET Association, Eindhoven, the Netherlands

University of California Los Angeles, USA
University of California San Diego, USA
University of Wisconsin-Madison, USA

St. Petersburg State Polytechnic University, Russian Federation
MEPhI, Moscow, Russian Federation

Tsinghua University, Beijing, China
Southwestern Institute of Physics, Chengdu, China
University of Science and Technology of China, Hefei, China

Kyushu University, Kasuga-city, Japan