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Centre de Cadarache, 13108 Saint-Paul-Lez-Durance, France

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Advanced solid state detectors for neutron detection and monitoring in fusion and fission environments

Nom du responsable (ou codirecteur) de thèse :		
Michael Houry (CEA/IRFM) Christophe Destouches (CEA/IRESNE)	**e-mail :**	Michael.houry@cea.fr Christophe.destouches@cea.fr
	page web :	
	téléphone :	+33 (0)4 42 25 44 16
	secrétariat :	+33 (0)4 42 25 65 44
Équipe de Recherche :		

Nom du Directeur de thèse :		
Abdallah Lyoussi CEA/IRESNE; Co-Directeur : Laurent Ottaviani (AMU/IM2NP)	**e-mail :**	Abdallah.Lyoussi@cea.fr
	page web :	
	téléphone :	+33 (0)4 42 25 75 88
	secrétariat :	+33 (0)4 42 25
Équipe de Recherche :		

Description détaillée du sujet :

8 000 caractères au maximum.

Plasma and fusion reactions in tokamaks are a source of neutrons which arouse great interest for several reasons. First, they are the primary source of energy that must be recovered to ultimately produce electricity, while allowing the production of the Tritium essential for deuterium-tritium fusion reactions. On ITER machine, elements of the wall, called Test Blanket Module (TBM), will be dedicated to demonstrate the in-situ Tritium production from neutron-Lithium reactions. Second, from the safety side, neutrons are considered as a source of material activation. They induces operating constraints on the machine, especially for research facilities which are undergoing changes as a result of scientific programs, as well as for waste treatment and dismantling operations.

The fusion reactions involving deuterium and tritium mainly produce neutrons of 2.45MeV and 14MeV respectively. However other transient phenomena linked to plasma (disruption, ELM[1], ...) or to plasma heating systems (neutral injection) can produce higher energy neutrons. A background of scattered neutrons is also present. Thus the neutron spectrum extends from low energies to several tens of MeV with flux levels covering several orders of magnitude

Accurate knowledge of these neutron fluxes and associated spectrums is crucial for the experiments that are expected on ITER through real-time monitoring systems embedded in TBMs. Actually, the tokamak vessel is a harsh environment (very high temperature, ultrahigh vacuum, high magnetic and electric

1 Edge-Localized Modes

fields, thermomechanical, high radiation levels), which requires specific and dedicated monitoring/measurement systems. If the choices of concepts are preliminary identified (solid sensors, photoconductive or other carbon semiconductors for example), R&D and qualification needs remain essential before integration into a TBM.

Consequently, the thesis research works proposed here will be dedicated to study, test and qualify solid-state miniaturized neutron detectors based on ad-hoc semiconductor materials such as silicon-carbide (SiC) or/and diamond CVDs for neutron detection and monitoring in a representative nuclear fusion environment.
Furthermore, regarding the high-level fluxes that are expected in ITER (fusion spectrum/flux up to 10^{14} $n.cm^{-2}.s^{-1}$ on the surface of the 1st wall) a representativeness studies should be carried out during this thesis. These studies will deal with the testing and qualifying such detectors under 2 MeV high neutron flux (fission spectrum/flux up to 5. 10 14 $n.cm^{-2}.s^{-1}$) and "extrapolating" the results to the fusion spectrum (mainly 14 MeV) by using advanced modeling tools.

The CEA/IRFM's WEST Tokamak facility that the main aim is to support ITER in these R&D activities in parallel with its construction is the ideal platform for testing neutron detectors in a fusion machine environment (neutron spectrum and environmental integration constraints). In the meantime the WEST platform will benefit for the first time from means for, on the one hand, experimental physics studies on neutron spectra and flux as a function of plasma scenarios and transient phenomena, and on the other hand relevant information on the activation of the machine for the waste management and future dismantling operations.

The CEA/DES JHR (Jules Horowitz Reactor) is a new Material Testing Reactor (MTR) reactor currently under construction at CEA Cadarache research center. JHR will represent a major Research Infrastructure for scientific studies regarding material and fuel behavior under high irradiation levels (up to: 5. 10^{14} $n.cm^{-2}.s^{-1}$, $20W.g^{-1}$, 16 dpa/y). This research reactor will offer a real opportunity to perform R&D programs that will crucially contribute to the selection, optimization test and qualification of innovative materials and fuels as well as new advanced on-line instrumentation and associated measurement methods.
Therefore, the neutron detectors developed and tested during these thesis works in WEST Tokamak machine under nuclear fusion conditions particularly neutron fusion spectrum will be proposed to be tested in JHR reactor under a higher neutron flux and strong radiation conditions following a specific and dedicated representativeness approach (from fission spectrum to fusion spectrum). This will lead JHR and CEA/DES/IRESNE instrumentation team proposing an experimental irradiation-testing program/device for fusion neutron detectors qualification.

These R&D studies will be carried out across the strong partnership between CEA (IRFM, IRESNE) and Aix-Marseille University through the LIMMEX joint Lab.
Indeed for more than ten years, the CEA and Aix-Marseille University have been conducting joint research works in the frame of the LIMMEX lab. on various programs (IN-CORE, I-SMART, CALOR-I, Nanogamma) in order to design, miniaturize, characterize and qualify innovative sensors/microsensors and detectors (SiC/diamond semiconductor detectors, calorimeters, fission chambers, SPNDs, dosimeters, photodetectors). The aim of such R&D works is to lead to accurate on-line measurements of key parameters in nuclear environments and particularly in the field of nuclear fission research reactors (neutron/photon fluxes, absorbed radiation dose rate). The AMU and CEA involved teams have a scientific expertise, recognized nationally and internationally, which is conducive to the launch of new works to meet the challenges across two major scientific instruments: the Jules Horowitz Reactor in fission and the WEST Tokamak in fusion. Indeed, the measurement of neutron flux by high-performance hardened detectors, more and more miniaturized, is essential for these two facilities.

Collaborations scientifiques et/ou partenariats industriels envisagés :

- Nom du collaborateur: *Aix-Marseille Université, Laboratoire IM2NP*
- Organisme/Société:
- Raison de la collaboration: