First IMSci-Nu School

February 27th - March 3rd, 2023
Campus St. Jérôme, Marseille, France
Contact person: christelle.carette@univ-amu.fr

Date	Time slot	Lecture	Lecture mode
February 27	9 :15 - 9 :30	CHRISTELLE REYNARD-CARETTE (AMU, IM2NP, LIMMEX, ISFIN, France)	No place available (IMSci-Nu Students only)
	9:30 - 12:00	Course of JANE DUNPHY Finalization of the student poster preparation (GLS, MIT, USA)	
	12:00 - 14:00	Break	
	14:00 - 15:30	IVANA CAPAN Junction Spectroscopy Techniques for Studying the Radiation Induced Defects (RBI, Croatia)	Limited number of participants Person to contact to attend: christelle.carette@univ-amu.fr
	15:45 - 17:15	ADRIEN VOLTE The challenges associated with the thermal property characterization for the study of the response of calorimeters dedicated to the nuclear heating rate measurement in research reactors (AMU, IM2NP, LIMMEX, ISFIN, France)	
February 28	9:00 - 10:30	GORDON KOHSE Introduction to the MIT Research Reactor (NRL, MIT, USA)	
	10:45 - 12:15	JARED WIGHT AND LUDO VERMEEREN Major nuclear facilities at SCK CEN and associated instrumentation: BR2 and MYRRHA (SCK-CEN, Belgium)	
	12:15 - 14:00	Break	
	14:00 - 15:30	ŽIGA ŠTANCAR Overview of JET science facilitated by nuclear instrumentation measurements and modelling (UKAEA, UK)	
	15:45 - 17:15	VLADIMIR RADULOVIĆ Research and education activities at the Jožef Stefan Institute TRIGA research reactor (JSI, Slovenia)	
March 1	8:30 - 17:30	Visit (CEA, France)	No place available (IMSci-Nu Students only)

March 2	9:00 - 10:30	BRUNO SOARES GONÇALVES High availability control and data acquisition systems in Fusion environments (IPFN, Portugal)	Limited number of participants Person to contact to attend: christelle.carette@univ-amu.fr
	10:45 - 12:15	MASSIMO MORICHI Nuclear Measurements for Nuclear Safeguards and Nuclear Security (CAEN S.p.A., Italy)	
	12:15 - 14:00	Break	
	14:00 - 15:30	SYLVAIN GIRARD Fiber-based Dosimetry: from Ground applications to the International Space Station (Laboratoire Hubert Curien, France)	
	15:45 - 17:15	JEAN-MICHEL RUGGIERI SMR: Challenges and opportunities (CEA, France)	
March 3	9:00 - 10:30	MALCOLM JOYCE Characterising nuclear materials across the sensitivity range with radiation detection and accelerator mass spectrometry (University of Lancaster, UK)	
	10:45 - 12:15	Poster session	No place available (IMSci-Nu Students only)
	12:15 - 14:00	Break	
	14:00 - 15:30	IGOR JOVANOVIC Advanced radiation detection research at the University of Michigan (University of Michigan, USA)	Limited number of participants Person to contact to attend: christelle.carette@univ-amu.fr
	15:45 - 17:15	FRANCESCO D'ERICCO Radiation detection and dosimetry in nuclear medicine (Univ. Pisa, Italy / Yale, USA)	
	17:15 - 18:00	Conclusion	

IVANA CAPAN (RBI, Croatia)

Title: Junction Spectroscopy Techniques for Studying the Radiation Induced Defects

Abstract: Junction spectroscopy technique is a term describing measurements performed on a semiconductor junction using electrical or electro-optical techniques. The role of the junction is to create a depletion region, as its usage brings an important advantage over other bulk techniques. The advantage is that it is much easier to manipulate the occupancy of defects producing energy levels in the bandgap within the depletion region than in bulk region. The most common junction spectroscopy technique is deep-level transient spectroscopy (DLTS). DLTS can detect defects in concentrations around 1010 cm−3. It provides information regarding the activation energy for electron and hole emission, capture cross-section, and concentration of defects. However, the main problem associated with DLTS is the lack of energy resolution (i.e., it is almost impossible to resolve two closely spaced deep energy levels). An improvement came in another junction spectroscopy technique called Laplace DLTS (L-DLTS), which brought an order of magnitude better energy resolution (meV). While DLTS is mostly used for studying the electrically active defects associated with majority charge carrier traps, minority charge carrier traps have been much less investigated. In principle, it is possible to investigate minority charge carrier traps using DLTS by applying forward bias, but more reliable results can be obtained by using minority carrier transient spectroscopy (MCTS).
The main aim of this presentation is to provide a basic description of junction spectroscopy techniques supported by examples from different studies on radiation induced defects in semiconductors.

ADRIEN VOLTE (AMU, IM2NP, LIMMEX, ISFIN, France)

Title: The challenges associated with the thermal property characterization for the study of the response of calorimeters dedicated to the nuclear heating rate measurement in research reactors

Abstract: In order to support the research and development work of the nuclear field, major international research facilities are essential to generate and establish representative extreme conditions and specific nuclear environments in order to perform experiments to understand phenomena from nominal to accidental conditions on materials and fuels.
For instance, in the case of the nuclear fission, the future Jules Horowitz Reactor under construction (JHR, CEA Cadarache, France) will have characteristics unequalled in Europe, such as a nominal thermal power of 100 MW, intense mixed fields of neutrons and photons, high accelerated aging damage under irradiation and a nuclear absorbed dose rate (also called nuclear heating rate) of 20 $W.g^{-1}$ in aluminum. This last physical quantity, which represents the energy deposited by radiation/matter interaction per unit of time and mass, is a crucial parameter in thermal, thermohydraulic, mechanical purposed and damage in the reactor channels from the dimensioning of online experiments to their interpretation. This important energy deposition leads to a significant temperature rise allowing a quantification with non-adiabatic calorimeters divided into two families: single-cell or differential (composed of at least two cells) calorimeters.
These two families of sensors have a similar physical principle based on thermal exchanges

and require a preliminary calibration under appropriate laboratory conditions. A comprehensive approach coupling experimental, numerical and analytical work is necessary to design these sensors, interpret their results and quantify the nuclear heating rate. The work presented will focus on the challenges associated with the thermal property characterization as a function of temperature for the experimental and numerical studies of the response of these calorimeters under laboratory conditions and real conditions in order to reduce associated measurement uncertainties. Key thermal properties as well as the associated equipment and measurement methods will be highlighted and detailed.

JARED WIGHT AND LUDO VERMEEREN (SCK-CEN, Belgium)

Title: Major nuclear facilities at SCK CEN and associated instrumentation: BR2 and MYRRHA

Abstract: Currently the major nuclear facility at SCK CEN is the BR2 reactor, a Material Testing Reactor offering opportunities for fuel, material and instrumentation testing, but mainly focusing nowadays on the production of radioisotopes for medical applications (diagnostic and therapeutic) and silicon doping. With the MYRRHA project, a next generation nuclear facility is being developed. It will consist of a lead-bismuth cooled core, which can be operated in critical or subcritical mode; in the latter case it will be coupled to a 600 MeV proton accelerator, creating source neutrons via spallation reactions in the lead-bismuth coolant in the center of the core.

The course will be split in two parts. The first part will start with a concise description of the BR2 reactor and its main applications. Some elements on the operational and non-nuclear instrumentation will be discussed. During the past decades, an extensive program on the development and testing of on-line in-core nuclear instrumentation has been conducted in the BR2. This will be treated in some more detail, covering information on self-powered neutron detectors, sub-miniature fission chambers, a Pu-242 fission chamber based system for fast neutron monitoring, and gamma monitoring via gamma thermometers and self-powered gamma detectors.

In the second part, the MYRRHA project will be highlighted, including its envisaged applications and the stepwise approach for the realization of the project. Some aspects of the related instrumentation will be discussed, including instrumentation for the proton accelerator, nuclear in-core instrumentation and instrumentation for monitoring the lead-bismuth coolant.

ŽIGA ŠTANCAR (UKAEA, UK)

Title: Overview of JET science facilitated by nuclear instrumentation measurements and modelling

Abstract: The Joint European Torus (JET) has undergone four decades of scientifically rich plasma operation and remains the world's largest tokamak fusion device. It has the unique capability to operate with deuterium-tritium fuel – this enabled the successful completion of the 2021 DTE2 campaign, which broke the world record of total fusion energy produced, and exhibited sustained performance over a period of five seconds.

We will open the talk with a short description of JET and a summary of the team's recent

scientific achievements in deuterium-tritium plasmas. We will continue with an overview of the rich variety of nuclear instrumentation installed at JET, followed by examples of how various detectors are used in supporting plasma operations or aiding with our understanding of plasma physics. In the final part we will draw the connection between instrumentation measurements and theoretical physics work, through a description of recent advancements in integrated modelling and development of synthetic diagnostics models.

VLADIMIR RADULOVIĆ (JSI, Slovenia)

Title Research and education activities at the Jožef Stefan Institute TRIGA research reactor

Abstract: The Jožef Stefan Institute is the leading research institution in Slovenia, covering all the fields of science, including the peaceful use of nuclear energy. Since 1966 the Institute operates a TRIGA research reactor, located approximately 12 km NE of Ljubljana. The JSI Reactor Centre represents the epi-centre of Slovenian research and development in nuclear science and engineering as well as education, training and competence building, and thus plays a vital role in supporting the operation of the Krško Nuclear Power Plant and governmental bodies. This talk presents the Jožef Stefan Institute and the JSI TRIGA research reactor and gives an overview on the research and education activities it supports.

BRUNO SOARES GONÇALVES (IPFN, Portugal)

Title: High availability control and data acquisition systems in Fusion environments

Abstract: Real-time control of magnetically confined plasmas is a critical issue for the safety, operation and high performance scientific exploitation of the experimental devices on regimes beyond the current operation frontiers. It is essential to ensure the reliability of the plasma discharge by controlling the plasma dynamic over long times while avoid deviations from the reference scenario and hence ensuring reproducibility. Furthermore, it is crucial for machine protection the avoidance or mitigation of instabilities and disruptions. To guarantee a steady state burn of fusion plasmas on future reactors will be necessary a significant increase in the amount and sophistication of feedback control with respect to present day experiments. High availability (HA) is a key requirement of next generation Fusion devices, targeting steady-state operation. HA is demanded in mission-critical systems, as is the case of experimental Fusion devices and future Fusion power plants, where safety of people, environment, infrastructure and investment is primordial. The biggest challenge is providing robust and fault tolerant control systems able to fulfill requirements for RAMI (Reliability, Availability, Maintainability, Inspectability). This lecture will address some of these issues and challenges and provide practical examples of solutions based on the Advanced Telecommunications Computing Architecture (ATCA), developed at IPFN (Institute of Plasma and Nuclear Fusion, Lisbon – Portugal).

MASSIMO MORICHI (CAEN S.p.A., Italy)

Title: Nuclear Measurements for Nuclear Safeguards and Nuclear Security.

Abstract: The evolution of the nuclear activities is rapidly growing both for new installation as well as for decommissioning activities and is requiring more and more particular attention to the way that nuclear material is handled, stored and processed in all operations and consequently Nuclear Safeguards are requested to enhance methods and simplify methodology for inspections. In this scenario particular attention is also
dedicated to nuclear security followed by many institutions (Ministry of Interior, Ministry of Health, Civil Protection and CBRN Corps) that are all requiring new instrumentation to address effectively unforesee situation such as orphan source, accidental radioactivity dispersed in the environment, scenarios of nuclear material smuggling or potential terrorist attacks with Radioactive Dispersal Device (RDD) or RID.

The seminar will offer a comprehensive understanding of the problems and the required approach of the nuclear measurements with real examples and explaining the typology of nuclear instrumentation for the different cases.

SYLVAIN GIRARD (Laboratoire Hubert Curien, France)

Title: Fiber-based Dosimetry: from Ground applications to the International Space Station

Abstract: This talk will present the different types of dosimeters that can be developed exploiting the radiation effects in silica-based optical fibers. Ionizing or non-ionizing radiations can create in the pure or doped silica core and cladding of the fiber some microscopic point defects that are optically active. Under irradiation, the fiber attenuation increases with the dose through the so-called radiation-induced attenuation (RIA) phenomenon, the amplitudes and kinetics of RIA depend on many parameters intrinsic and extrinsic to the fibers. The defects are not only associated with absorption bands, some of them are also light emitting centers under irradiation or laser exposure. These defects lead to the radioluminescence (RL) phenomenon that corresponds to the generation of light within the waveguides under irradiation. For most of the application, researchers elaborate radiation hardening strategies to limit the impact of RIA and RL on the fiber-based application: data transfer, diagnostics, sensors. But, those effects can also be used to build radiation detectors and even dosimeters with the most promising optical fibers for a variety of environments from fusion-devoted facilities, nuclear industry, accelerators, space or medicine. Exploiting the RIA in phosphosilicate optical fibers, one can build point or distributed dosimeters. After explaining their operation principle, two main examples of recent progresses will be described: the development of a distributed radiation dosimeter, today implemented along all the CERN's accelerators and part of the LHC and the development of a punctual dosimeter for space application. This latter dosimeter, called LUMINA, has been recently (08/2021) implemented in the international space station by Thomas Pesquet in the framework of its ESA Alpha mission and is still today acquiring data. After that, the recent advances regarding RL-based sensors will be presented through two of the many possible applications: the first will concern the measurements of a very large range of dose rates (more than 12 decades) as those

encountered in fusion-devoted facilities, the second one will show how those fibers could serve in the proton therapy and Flash medical fields. Finally, future perspectives will be discussed for this particular class of optical sensors.

JEAN-MICHEL RUGGIERI (CEA, France)

Title: SMR: Challenges and opportunities

Abstract: The purpose of the presentation is to make you understand what lies behind these 3 SMR letters for designers of nuclear systems and what are the ambitions for these concepts? The international panorama that will be made will help to draw the extent of this initiative and to make an inventory of it.
The main challenges for these concepts will also be discussed throughout the presentation.

MALCOLM JOYCE (University of Lancaster, UK)

Title: Characterising nuclear materials across the sensitivity range with radiation detection and accelerator mass spectrometry

Abstract: Nuclear materials often require characterisation so that we can determine what they are, what they comprise of, what they might be derived from or what they might be used for. Uranium is a specific example, where the enrichment, isotopic composition and level of impurity can be very important. For macroscopic quantities, it is often possible to discern these properties from measuring the radiation that a substance emits. For example, the alpha-particle emission can yield energy-related distributions for specific isotopes, the gamma-ray emission can yield isotope-specific lines and the neutron emission (if present) can yield quantitative information concerning components in the material susceptible to fission, either passively or interrogatively. For smaller quantities of nuclear materials, and especially trace quantities in the environment, the radiation yield can be too small to be measurable and we have to resort to mass spectrometry, where individual atoms are counted to yield a given isotopic ratio, and therefore signature, for a given material. This presentation will review these approaches to understanding the variety of nuclear materials that exist.

IGOR JOVANOVIC (University of Michigan, USA)

Title: Advanced radiation detection research at the University of Michigan

Abstract: The Department of Nuclear Engineering and Radiological Sciences at the University of Michigan is the leading research and educational nuclear engineering program in the Unites States, featuring fission systems and radiation transport, radiation measurements and imaging, nuclear materials, plasmas and fusion, and nuclear policy. The faculty lead several outstanding research laboratories, including the Neutron Science Laboratory, the Michigan Ion Beam Laboratory, and the Gérard Mourou Center for Ultrafast Optical Science, which includes ZEUS, the most powerful laser in the United States. Strategic research priorities of

the department include (1) clean, affordable, and reliable nuclear-inclusive energy systems, (2) nuclear security and homeland defense, (3) environment and health, and (4) scientific discovery.

FRANCESCO D'ERICCO (Univ. Pisa, Italy / Yale, USA)

Title: Radiation detection and dosimetry in nuclear medicine

Abstract: Among all the diagnostic imaging techniques relying on ionizing radiation, nuclear medicine is the one requiring the most advanced detection instrumentation and the most sophisticated analyses. Indeed, for a complete and correct interpretation of the data, physicians specializing in nuclear medicine must have a deep understanding of the radiation interaction and detection physics underlying the image acquisition. Likewise, patient and personnel radiation protection dosimetry require dedicated experimental and computational techniques. This lecture will review the design fundamentals of the devices utilized in Single Photon Emission Computed Tomography (SPECT) and in Positron Emission Tomography (PET), of the devices utilized for ambient and individual monitoring in nuclear medicine, and of the MIRD internal dosimetry methods used for patient radiation safety.