IAEA
International Atomic Energy Agency

Nuclear Science and Instrumentation Newsletter

ISSN 1020-7120

No. 01, February 2021

Contents

Editorial

The Nuclear Science and Instrumentation Laboratory (NSIL) is integrated into the Physics Section, Division of Physical & Chemical Sciences, Department of Nuclear Sciences and Applications. It provides expertise, training and support in the effective utilization of nuclear instrumentation and analytical techniques in a broad range of applications, with a focus on mobile radiation monitoring, X-ray spectrometry, accelerator technologies, and more recently on compact neutron generators.

For 20 years our laboratory has issued the X-ray Fluorescence - XRF Newsletter with the objective to exchange knowledge and competencies with nuclear analytical laboratories in the IAEA Member States on developments in fundamentals and applied aspects of X-ray spectrometry.

With the broadening of NSIL activities, and also of the Physics Section, the scope of the Newsletter is being enlarged to cover the full scope of NSIL activities. For this reason, the name is changed to *Nuclear Science and Instrumentation Newsletter*. This new version of the newsletter is longer than usual, as it covers the breadth of NSIL activities and capacity and gives reports from Member States.

Capacity building for Members States is one of the major activities of the laboratory. NSIL is a leading training hub on topics related to nuclear instrumentation, XRF analysis, mobile radiation monitoring techniques, accelerator technology and applications, as well as radiotracers and radiation technology applications.

Key areas of development and application of the laboratory include mobile radiation monitoring, elemental analysis using XRF and accelerator technology and applications further detailed in this issue.

NSIL staff (from left to right): First row: Mr Francois Foulon (Lab Head), Mr Roman Padilla (NI Physicist), Mr Petr Sladek (NI Specialist), Mr Natko Skukan and Ms Haifa Ben Abdelouahed (NI Specialists), and Mr Steven Mellard (Ass. Project Officer). Second row: Ms Ragdaa Attia (Team Assistant), Mr Alessandro Migliori, Mr Mladen Bogovac and Mr Milan Matos (Senior Laboratory Technicians) and Mr Farhad Memarzia (Electronics Technician)

Collaboration agreements with the Elettra Sincrotrone in Trieste (Italy) and the Ruđer Bošković Institute (RBI) in Zagreb (Croatia) provide opportunities for hands-on training and research activities, with facilitated access to these facilities for international users with emphasis on developing countries. Furthermore, with the current development of the Neutron Science Facility (NSF), the NSIL will soon offer capacity-building opportunities relevant to neutron physics and related techniques, such as neutron activation analysis, neutron radiography/tomography and radiotracer applications.

The Laboratory provides assistance in addressing quality management challenges and offering proficiency test services for the effective operation of instrumentation and XRF laboratories.

NSIL also operates the *Nuclear Science and Instrumentation Portal*:

nucleus.iaea.org/sites/nuclear-instrumentation

providing an update on the Laboratory activities and to foster information exchange and knowledge preservation in the technical areas of the laboratory, and much more.

NSIL's staff come and go due to the rotational policy, but the team remains strong and committed to respond to the IAEA Member States' needs. Current team is in shown on the first page of this Newsletter.

NSIL looks forward to receiving both contributions and feedback from different Member State counterparts and stakeholders to this Newsletter, to help the laboratory to best continue supporting projects, fellowships, scientific and technical visits, and addressing research & development needs by national facilities worldwide.

Figure 1 Virtual siblings of NSIL rooms are available in a Virtual Tour to the NSIL at

https://my.matterport.com/show/?m=27SbAzwypzW

1. Laboratory Projects and Activities

NSIL provides practical and experimental tools to foster the effective use of nuclear instrumentation and related capacity building.

It helps Member States to establish, operate, maintain, and utilize nuclear instrumentation and spectrometry techniques in support of a wide range of applications that includes health care, food, agriculture, environment, forensics, cultural heritage and material science. Key areas of adaptive research and applications of the laboratory are described in the following.

Mobile radiation monitoring

The laboratory develops instrumentation and related methodology, and regularly organizes technical workshops and demonstration missions on radiation dose rate and activity concentration determinations using mobile radiation monitoring instruments and in-situ characterization techniques, in particular using backpacks and drones.

In-situ measurements provide the means for performing fast screening of the spatial distribution of contaminants needed for environmental evaluation of radioactive and industrial pollutants, as well as for emergency preparedness/response, remediation and mitigation activities. The laboratory also contributes to the studies of using mobile radiation monitoring techniques in the area of nuclear security.

Elemental analysis using X-ray fluorescence

The laboratory hosts and operates several standalone commercial, in-house developed, and portable XRF devices and related instruments. These facilities are used for research and provision of analytical services but are mainly used for capacity building, with emphasis on hands-on training.

NSIL also organizes periodic proficiency testing exercises by offering samples and post-measurement analysis capabilities. Elemental analysis can be performed at NSIL either non-destructively or with minimal sample preparation.

Additionally, the laboratory has instruments to determine the spatial distribution of chemical elements by using Scanning Electron Microscopy, Micro and Confocal XRF or by using Full Field XRF technique

NSIL has also operates a multipurpose chamber that replicates the one installed at Elettra Sincrotrone, which is used to provide basic demonstrations for operation and training of scientists before measurement campaigns are executed at Elettra of near surface analysis techniques.

Accelerator technology and applications

Through technical guidance or assessment missions, NSIL supports Member States in optimal operation and utilization of accelerator technology, including ion sources, vacuum systems and end-stations equipped with specific instrumentation. The Laboratory also conducts and facilitates scientific experiments in this area under agreements with Elettra and RBI, including hands-on training of future users of such facilities.

Applications of neutron generators

NSIL is currently implementing a Neutron Science Facility (NSF) based on the use of two neutron generators, which through D-D and D-T reactions produce respectively 2.45 and 14 MeV neutrons.

This project aims to establish a state-of-the-art facility in Seibersdorf to cover Member States' needs for training scientists and engineers in neutron science and to further expand applications of neutron applications. The facility, planned to be commissioned in 2021, will be used for training and R&D activities related to:

- Neutron activation analysis (NAA),
- Dual neutron/X-ray radiography and tomography,
- Radiation protection with neutron and gamma fields,
- Neutron instrumentation (including equipment relevant to research reactors),
- Demonstration of radiotracer production and usage,
- Operation & maintenance of neutron facility based on DD/DT generators.

Ion beam accelerator project in Seibersdorf

To enhance its in-house capacity and complement experimental probes available for irradiation and analysis using X-rays and neutrons, the Physics Section intend to install a small-scale Ion Beam Accelerator Facility (IBF), to be hosted and operated by NSIL in Seibersdorf.

High interest in such a facility was flagged by results of a potential IBF user survey of different stakeholders (both Member States and internal stakeholders) conducted in 2018. A comprehensive feasibility study showed that a Tandem accelerator, a 3 MV machine providing wide-ranging capabilities, would he most optimal and cost-effective technology option and best match the stakeholders needs.

Establishing an IBF facility in Seibersdorf would provide:

- training on ion beam analysis (IBA) techniques, accelerator technologies and effective maintenance of such facilities,
- facilitation of applied research to scientists and engineers from Member States without accelerators, and
- provision of specialized analytical and irradiation services both to internal and external users.

A call for extrabudgetary support from Member States for this facility was launched at the end of 2018. A call for in-kind contributions for different facility components and equipment was renewed in 2020. The project will also be listed under the Major Capital Investment Plan for the new 2022-2023 project and budget cycle.

1.1 Nuclear Instrumentation

NSIL traditional supports Member States in the field of nuclear instrumentation through transfer of expertise, on-site system installations, hands-on training activities, including long term fellowship opportunities.

The Laboratory pays also systematic attention to development trends in the field of nuclear instrumentation and associated electronics. In addition, NSIL conducts development activities related to programmatic and Member State needs.

Current activities include development of an integrated multiprobe spectroscopy data acquisition system and an ultralight radiation monitoring system based on a digital pulse processor and Silicon Photo-Multiplier (SiPM) detector.

Data Acquisition System for Sediment Tracing and Radiotracer Industry Applications

The data acquisition system is designed to process the data provided by up to 12 gamma radiation detectors based on NaI(Tl) scintillation crystal. The signal from each detector is processed with one Artix-7 Field-Programmable Gate Array (FPGA), data packed by associated W7500P ARM Cortex-M0 processor using TCP-IP protocol and sent via up to 100 m long ethernet cable to the central computer. The detectors are powered over ethernet cable.

A FPGA design features a versatile digital pulse processor (DPP) and softcore Xilinx MicroBlaze processor. The DPP can be set-up to collect data in several modes depending on the targeted radiotracer application. It also features pile-up rejection, base-line restoration, and Gedcke-Hale live time clock to improve the quality of measurements at high counting rates. The system can be operated in three modes.

In the Tuning Mode, the DPP collects a standard Pulse Height Spectrum in a dual port memory block and transfers the data to a central computer. In this mode the user can also observe the signal forms at the inputs and outputs of the internal digital filters. This allows to optimize the pulse processing step and the selection of various regions of interest (ROIs) in the collected spectra.

In the *Industrial Application Mode,* the DPP counts the number of pulses in user selected ROIs and dwell times that can be set down to the millisecond range. The data, i.e. the counts in ROIs, are transferred to the W7500P via a fast serial link and then streamed via TCP/IP to the central computer.

In the *Sediment Tracing Mode*, the DPP collects spectra in two dual port block RAMs alternately, the switching time being defined by the user. When one block is collecting, the other is streamed to the central computer.

Each mode of operation exhibits a specific graphical user interface on the central computer. The application, which can handle up to 12 probes in parallel, enables the user to collect, visualize and store the measured data.

Development of an ultralight gamma spectroscopy system based on SiPMs

SiPMs are a convenient replacement for traditional photomultiplier tubes (PMTs), as they are smaller and lighter, need lower bias voltage and exhibit higher electromagnetic interference immunity. Coupled to various scintillators,

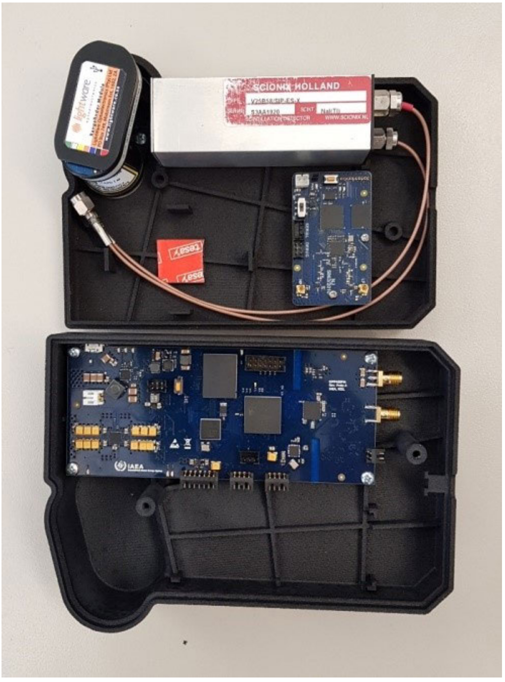


Figure 2: Example of a compact radiation detection module, developed by NSIL and based on NaI SiPM detector. This module was further adjusted for use with instrumented drones

SiPMs allow gamma spectroscopy in harsh environments with resolution and speed that is comparable to that of PMT based systems.

NSIL has developed a battery-powered hardware platform for processing signals from SiPM at high speed and in real-time. The platform is completed with additional hardware for measuring the GPS position and the altitude, as well as for radiofrequency transmitting the data. The expanded platform associated with a combined scintillator - SiPM detector gives rise to an ultralight gamma spectrometry system (less than 500 g) for aerial radiation monitoring and mapping.

This system, developed in the framework of a project with the Fukushima Prefecture (Japan), is a perfect tool for radionuclide identification in low to high contaminated areas.

The power supply for the SiPM detector is generated with an on-board, digitally controlled, low noise switching power supply (MAX1932). The analogue front-end features a fast-trans-impedance amplifier converting the SiPM current pulse into voltage pulses.

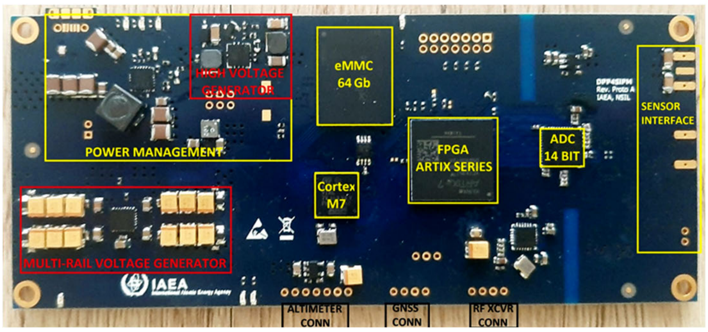


Figure 3: Pulse processing board developed by NSIL for the ultralight gamma spectrometry system based on scintillator-SiPM detectors.

The single-ended voltage signal is processed by a 14-bit Analog-to-Digital Converter (ADC) ADS4149 accommodating up to 250 MHz sampling rates.

The sampled data is transmitted to the Artix-7 FPGA versatile digital pulse processing in real-time. The ADC and FPGA are both clocked with a low power I2C programmable clock generator. The FPGA is connected to a micro-controller unit (MCU) based on the ARM Cortex-M7 core. It is aimed to run a real-time operating system (RTOS) and perform several tasks such as FPGA configuration and parametrization, data storage, real-time data transmission and capturing, SiPM power supply temperature compensation, and some others.

A 64Gb on-board flash memory with an eMMC controller is used for data storage. An external computer or device can be connected to the platform by using the UART port on the FPGA or the USB OTG of the microcontroller.

Optionally, for wireless data transmission, an external, custom-made module based on Semtech SX1276 modem is foreseen. A dedicated external module is also being developed for measuring the position when required. It features a GNSS receiver (NEO-M8P) that can utilize 4 different satellite constellations: GPS, GLONASS, Galileo, and BeiDou. An interface for an external altimeter is also provided.

1.2 X-ray Fluorescence

NSIL is a leading training hub on topics related to XRF. The Laboratory is equipped with a wide variety of instruments for in-situ inspection of valuable objects and for determining the elemental concentration and spatial distribution in samples of diverse origin.

The Laboratory recently installed a wavelength dispersive XRF spectrometer, thus adding to the portfolio of techniques available at NSIL.

An investigation was carried out as part of an internship program to assess the feasibility of determining the effectively probed volume in confocal XRF using uranium micro-particles.

The method relies on measuring the x-ray fluorescence from the particle, as it is translated through the confocal volume defined by the intersection of the excitation beam focus with the volume of fluorescent signal reaching the detector. The beam focus is provided by a poly-capillary lens and the volume of fluorescent signal demarcated by a half-conical lens mounted in front of the detector.

By scanning laterally (x,y directions) and translating the sample through the confocal volume (z direction), the measurement results can render a 3D representation of elemental distributions.

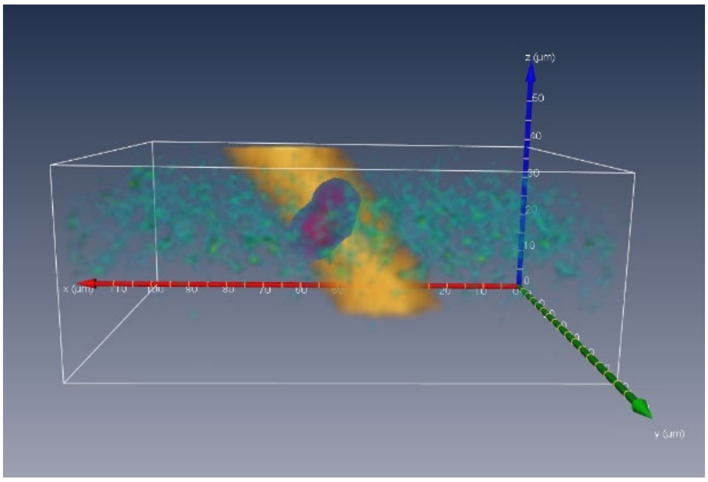


Figure 4: 3D representation of the confocal volume (violet) and the excitation beam path (yellow)

The volume highlighted in violet in Fig. 4 corresponds to the confocal volume or the fluorescent intensities reaching the detector in an experiment in confocal geometry; the yellow volume corresponds to the fluorescence signal measured with a micro-XRF set-up with no focusing element mounted on the detector. The yellow volume clearly depicts the path of the excitation radiation. In this particular case, the confocal volume can be described as a prolate sphere with 12 x 12 x 17 cubic-micron dimension.

A technical report addressing identification of common needs in restoration of cultural heritage artifacts that can be supported by different XRF techniques was prepared as part of another internship. The report contents include the description of handheld, micro-XRF and full-field XRF spectrometers used in the work, as well as valuable information on historical pigments.

Figure 5: Ms Masa Nicic, restorer and graduate of Nuclear Physics, inspects a mural painting at the Vienna Institute of Conservation and Restoration (photography reproduced by courtesy of Old Gallery of the Universalmuseum Joanneum, Graz, Austria)

More recently, a study was started to assess the feasibility of using full-field XRF analysis for the characterization of gunshot residues to ascertain the shape of the residues and the elemental composition of both projectiles and explosive residues as well as to identify correlations with ammunition and explosive type and the distance and angle of shooting.

The results obtained so far are promising and deem further measurements to study different scenarios and materials of deposition (fabric, leather).

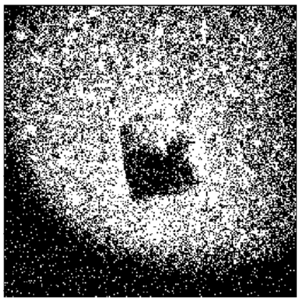
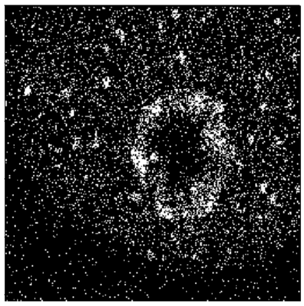
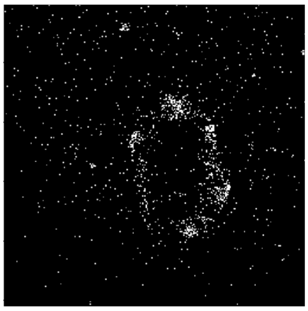
 5 cm	 20 cm
 50 cm	Projectile: 9mm Remington, Impacted material: Cotton fabric Angle of shooting: 90°

Figure 6: Changes in distribution and intensity of Pb-La with increase of the shooting distance

1.3 In-situ Radiation Monitoring

NSIL has long-standing experience in development and application of instrumentation techniques for in-situ measurements, especially mobile monitoring such as field portable gamma spectrometers mounted on backpacks or unmanned aerial vehicles (UAVs) for aerial monitoring.

The field of radiological mapping is challenging for number of applications, such as environmental monitoring, remediation activities and radiation protection as well as nuclear security, and in-situ techniques can offer tailored solutions.

Two recent examples as NSIL major events using backpack radiation detectors (BRDs) are described in the Meetings & Conference Reports Section.

Statistical processing of measurement data, data interpolation and quality control, as well as visualization of the radiation situation on a map are provided by our newly developed application for post processing data based on the R-code platform (www.bit.ly/rcodemapping).

Recent rapid development of the UAV technology allows new applications, such as aerial radiological monitoring. NSIL, together with the Fukushima Prefecture in Japan, is one of the first teams active in this area. After developing an ultra-light radiation detector to be mounted on UAVs, an entire radiation detection system with gamma spectrometry capabilities has now been further developed.

NSIL is developing the electronics for scintillation gamma spectrometry (see page 3). This development allows using various detectors for mobile gamma spectrometry with a broad range of detection efficiency or energy resolution, and consequently optimal signal processing for spectrometric purposes.

NSIL is also employing commercial detection systems, combined with a state-of-the-art drone system or backpacks (see Figs. 7 and 8).

NSIL is working on further development activities in this area. The latest one is connected to the application of photogrammetry for UAV radiation monitoring. This join technology will enable effective flight planning, selection of safe routes, consideration of terrain objects for radiation measurements as well as visualization of the radiation situation on a 3D terrain model (Fig. 7).

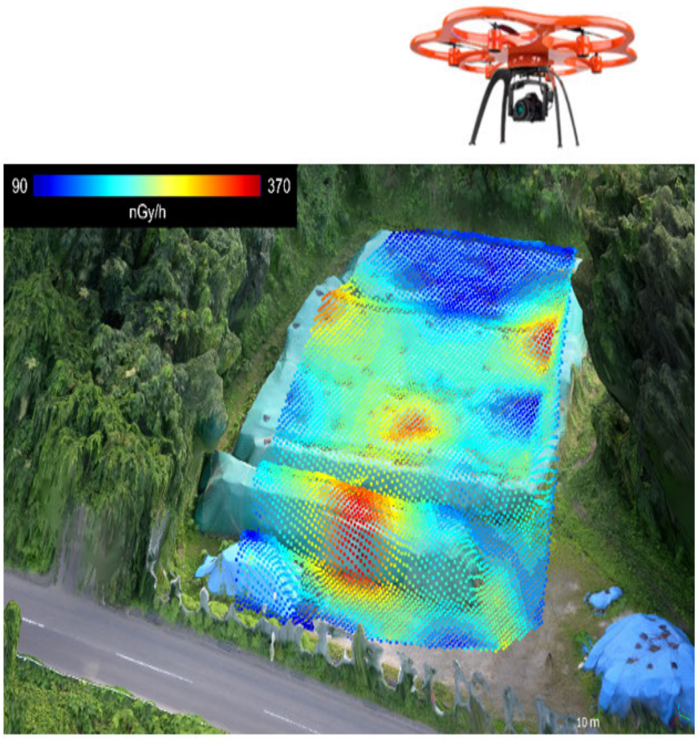


Figure 7: Full 3D aerial photogrammetry superimposed with a radiological map was obtained using the same UAV in two consecutive flights. Image courtesy of the IAEA and Fukushima Prefecture.

Figure 8: Testing of backpack spectrometer within the train ing

The application of photogrammetry can be focused on radiation monitoring of smaller areas, industrial localities and urban objects, where details play an important role. The main benefit of this approach is the ability to work with the most up-to-date map base for radiological mapping.

Efforts are being made to accurately calibrate UAV and backpack detectors and determine the equivalent dose rate of gamma radiation, with the possibility in obtaining metrological certification in the future.

Calibration for the analysis of the concentration of natural radionuclides (U-238, Th-232 and K-40) will also be performed using the calibration plates of the state enterprise DIAMO s.p. (Czech Republic). These activities will further increase the level of quality of the measured data and bring the opportunity to participate in comparative measurements or organize proficiency exercises.

NSIL also provides recommendations and support for the Members States in UAV radiological technologies and in-situ gamma spectroscopy through technical meetings and webinars on use of UAVs for radiation detection and surveillance.

1.4 Accelerator Technology and Applications

Collaboration with Elettra Sincrotrone, Trieste

The IAEA Physics Section operate jointly with Elettra Sincrotrone Trieste (EST) a multipurpose X-ray spectrometry end-station at the X-ray Fluorescence beamline of EST. The collaboration developed thanks to a Partnership Agreement signed in 2014 between the two Institutes. That agreement was extended in 2019. The multipurpose X-ray spectrometry end-station is available to external users since the beginning of 2015 through the EST peer-review process. Through this collaboration, the IAEA supports and promotes synchrotron radiation-based research and training activities for various research groups from the IAEA Member States, especially those who have limited previous experience and resources to access a synchrotron radiation facility.

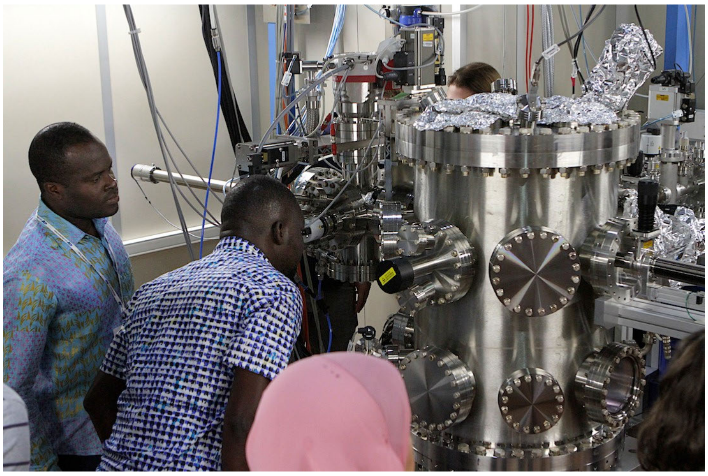


Figure 9: Researchers attending hands-on-training at the IAEA X-ray spectrometry end-station at the X-ray Fluorescence beamline of EST. Courtesy of Elettra Sincrotrone Trieste, photo by Massimo Goina

Access to the Elettra Sincrotrone in Trieste, also an IAEA Collaborating Centre since 2020, can be obtained by submitting research proposals:

https://www.elettra.trieste.it/userarea/apbt.html

Collaboration with RBI, Zagreb

Ion Beam Analysis (IBA) is a group of modern analytical techniques aimed to probe the composition, depth profiles and other characteristics of materials. IBA techniques are usually performed using energetic ion beams from electrostatic accelerators.

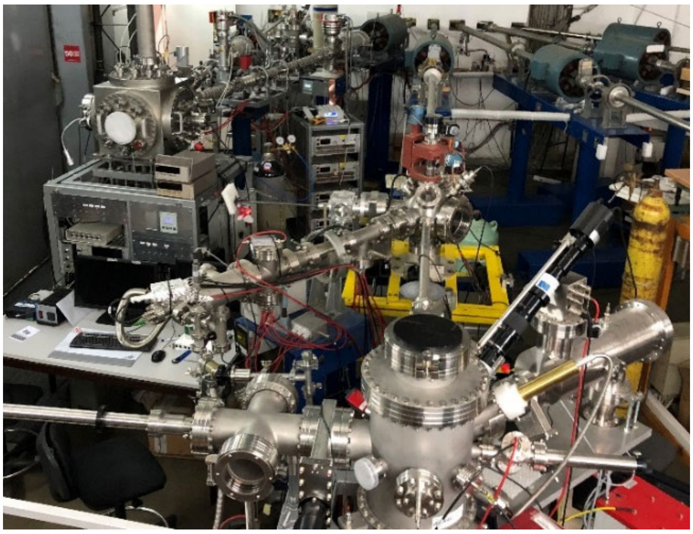


Figure 10: Beamlines at the RBI accelerator facility. Photo courtesy of RBI.

The IAEA has a long-standing collaboration with the ion beam accelerator facility at the Ruđer Bošković Institute (RBI), Zagreb, Croatia. This collaboration has been running since 1997 in the framework of a bilateral agreement.

The RBI ion beam facility consists of two tandem electrostatic accelerators (Tandetron 1 MV and Van de Graaff 6 MV) and several different beamlines, which include, among others, two microbeams and a dual beam line, where beams from both accelerators can be injected in the experimental chamber simultaneously. The collaboration agreement with RBI allows both NSIL and international users to use all the beamlines of the RBI ion beam facility 30 days per year for research and training purposes.

NSIL support to accelerator laboratories

NSIL provides technical advice and expertise on operation, maintenance, troubleshooting, error rectification and possible upgrades in ion beam accelerator technologies to different laboratories within IAEA Member States. NSIL staff are involved in the support of accelerator activities either through Technical Cooperation projects or following direct request for assistance from Member State laboratories, either financed by the requesting organization or through the standard IAEA mechanisms.

Expressions of interest for performing experiments at RBI as well as requests for technical support in accelerator technologies can be addressed by sending an email to nsil@iaea.org.

Facilitating Experiments with Ion Beam Accelerators Worldwide

The G42008 Coordinated Research Project “Facilitating Experiments with Ion Beam Accelerators” aims at facilitating researchers from countries not having IBA facilities to perform experiments in such facilities abroad, with emphasis on regional capabilities if available. Ten accelerator facilities distributed across all continents are the beam providers within this CRP.

Researchers interested in IBA experiments are encouraged to check the CRP web pages and consider submitting their research proposal to obtain beamtime. More information: https://nucleus.iaea.org/sites/accelerators/Pages/beam-time.aspx

Trainings in accelerator technologies

Joint ICTP-IAEA Workshop on Electrostatic Accelerator Technologies, Basic Instruments and Analytical Techniques, held at ICTP, Trieste, on 21-29 October 2019.

Eighteen young scientists, six of them females, were selected to attend the workshop out of total of 115 applications from the Member States. The lectures were given by five external and two IAEA experts.

The following topics were covered in the workshop:

- Introduction to electrostatic accelerators and their operation,
- Ion sources and vacuum systems at electrostatic accelerators,
- Ion-beam optics, beam focusing, and monitoring devices,
- Introduction to low energy nuclear reactions,
- Ion-beam analytical techniques,
- Selected ion-beam based applications,
- Modern detector technologies,
- Basic software for data analysis and accelerator control,
- Safe use of ion accelerators.

Visits to two accelerator facilities were included: a visit to Institut "Jožef Stefan" (JSI), Ljubljana, Slovenia, where participants had hands-on training in PIXE measurements and data analysis, and a visit to Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro (INFN-LNL), Legnaro, Italy, where participants were introduced to the characteristics of six different types of accelerators. As a bonus, participants also visited the JSI TRIGA research reactor.

Figure 11: Visit of the participants and trainers to the LNL-INFN accelerator facilities. Photo taken next to HVEC Tandem-XTU, 14.5 MV electrostatic tandem accelerator

Training Workshop on Operation and Maintenance of Low Energy Electrostatic Accelerators, held at RBI, Zagreb, on 9th to13th of December 2019.

This was the first edition of a new type of training activity organized by NSIL, focusing on the operation and maintenance (O&M) of electrostatic accelerators. Such trainings are planned to be held annually, alternating between O&M and complementary training in IBA techniques every second year.

This very first training workshop included theoretical lectures as well as hands-on exercises in the following topics:

- Accelerator controls and stabilization,
- Ion sources,
- Vacuum and leak detection,
- Ion beam optics including microbeams,
- Accelerator energy calibration.

Eight participants, two females, from eight Member States attended this very successful training workshop.

1.5 Neutron Science and Applications

NSIL is currently establishing a Neutron Science Facility (NSF) based on two portable compact neutron generators: Deuterium-Deuterium resulting in 2.45 MeV neutrons and Deuterium-Tritium resulting in 14 MeV neutrons, with source intensities of 5 $x10^6$ n/s and 4 $x10^8$ n/s over 4π, respectively.

These electrically controlled neutron sources of low and medium intensity are an attractive alternative to isotopic neutron sources and low power research reactors. More than thirty countries currently own and operate D-D and/or D-T neutron generators.

Having been used for decades in oil and mining industries, for exploration and on-line analysis, neutron generator applications has expanded. Their applications include neutron activation analysis (NAA) both with thermal and fast neutrons, digital neutron radiography/tomography (complementary to X-ray radiography); radiotracer production for industrial applications; as well as investigations related to security and safeguard applications.

This new facility will help Member States acquire knowledge and experience in the use of neutron applications to meet their development goals

A specific application of interest is neutron radiography and tomography (also called neutron imaging), that can complement X-ray radiography for non-destructive testing (NDT). Neutron imaging is used for material testing, detection of internal flaws in cast or advanced manufactured parts, corrosion, humidity and water inclusion in civil constructions or electronic components.

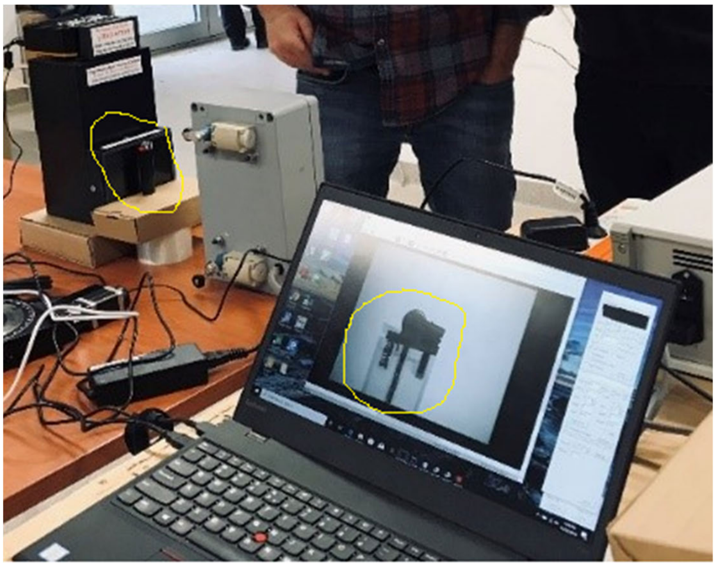


Figure 12: The commissioning of NSIL neutron radiography/tomography instrument with both neutron and X-ray imaging capabilities

Combining data from X-ray and neutron radiographic images is particularly advantageous for gaining a better understanding of the inner characteristics of complex components. The dual neutron/X-ray imaging system recently commissioned at NSIL exhibits such imaging capabilities.

1.6 Support to Radiation Technology Measurements

In cooperation with the Radioisotope Products and Radiation Technology (RPRT) section, NSIL is ensuring and supporting the innovative Radiation Technology for Measurements (RTM) techniques aimed at maximizing Member State benefits from nuclear technology applications for sustainable management of natural resources and ecosystems. NSIL is contributing to RTM development and implementation, including related hands-on training specifically for radioactive tracer and sealed radiation source methods applied to exploration and exploitation of natural resources and environmental monitoring.

Figure 13: NSIL supported training on radiotracer and sealed source methodology and technology as applied to industry and environment

Member States industries can benefit by improving the quality of their products, increasing the productivity, and reducing pollution and cost of production. Relevant target areas are defined in priority industrial sectors, such as oil and gas production, mining and mineral ore processing, environmental monitoring, cement, and civil engineering industries, where the benefit is enormous and radiation technology competes well with conventional techniques.

The main RTM activities, covered by NSIL and RPRT in close cooperation with the International Society for Tracer and Radiation Applications (ISTRA), are training and certification of specialists on radiotracer and sealed source methodologies and technologies as applied for troubleshooting, diagnosing and modelling industrial and environmental processes. Several modules of training are prepared and implemented on radiotracer residence time distribution (RTD), computer fluid dynamics (CFD) experimental simulation, flow rate measurement, leak testing, gamma scanning of pipes and columns, gauging based on neutron back-scattering, gamma and X-ray computed tomography (CT) and nucleonic control systems (NCS). Several training courses were conducted at NSIL premises in Seibersdorf and dozens of specialists have received the qualification certificate of level 1 and 2, accredited by ISTRA.

The demand from Member States for training and qualification of specialists is increasing; this is reflected through the IAEA Technical Cooperation programs, where three regional projects RAF1008, RAS1022 and RER1020 are dedicated to RTM activities. While the IAEA assists Member States in promoting and implementing radioisotope and radiation techniques to industrial end users, further support is given in human capability development, training and qualification of proper specialists and certification of methods. Standardization of RTM procedures are progressively ongoing to ensure good practice and reliable measuring results, to facilitate the expansion of best practice RTM activities.

1.7 NSIL Capacity Building Activities

The successful use of nuclear technology depends on reliable instruments, monitoring and diagnostic equipment that allow accurate measurements of both natural and man-made radiation in a very broad range of applications. Capacity building is essential to provide users and practitioners with the appropriate knowledge, competences and skills to conduct their activities in a safe and reliable way.

NSIL organizes and offers a broad range of training activities, starting from basic level training courses to advanced and specialized trainings in nuclear instrumentation. Most of these activities are organized in the framework of the Technical Cooperation program, addressing various techniques applied to a wide range of topics, including customized instruments design, environmental monitoring, soil erosion, food traceability, and use of various analytical techniques for characterization of materials and cultural heritage objects. Additional activities are carried out in projects in response to specific needs and requests by Member States or other organizational units within the IAEA.

A number of training activities are organized in cooperation with the International Centre for Theoretical Physics (ICTP, Trieste, Italy), the Ion Beam Accelerator at Ruđer Bošković Institute (RBI, Zagreb, Croatia), the Elettra Synchrotron (Trieste, Italy), as well as other IAEA units.

Capacity building opportunities offered by NSIL, grouped by key topical areas, are given hereafter. A more detailed description of the training offered and the announcement of the corresponding training events can be found at https://nucleus.iaea.org/sites/nuclear-instrumentation/ .

Nuclear Instrumentation

Training activities in the field of nuclear instrumentation encompasses various topics such as radiation detection, signal processing, radiation spectrometry, standard instruments and their applications, covering both basic and specific trainings, such as:

- ***Introduction to operation and use of radiation detectors, measurement systems and their applications***; basic level, 2 weeks, generally organized with partner institutions, in cooperation with NSIL at regional level.
- ***Training in nuclear instrumentation***; intermediate level, 8 to 10 weeks, organized at NSIL in Seibersdorf and covering various aspects including the basic principles of radiation detection, analogue and digital electronics, nuclear spectrometry and standard applications.
- ***Training in nuclear electronics, maintenance and repair***; intermediate level, 4 to 5 weeks, generally organized with partner institutions, in cooperation with NSIL at regional level.
- ***Advanced trainings;*** dedicated to the development, interfacing and utilization of nuclear instrumentation systems, through joint ICTP-IAEA training courses (2 weeks), or in the form of fellowship training (individual or in a small group, lasting for 1 to 6 months) hosted at NSIL or in a state-of-the-art partner institution.

Additional and specific trainings, including train-the-trainer courses, can be tailored and designed according to the needs expressed by Member States.

Mobile Radiation Monitoring

Training courses and workshops (from 1 to 2 weeks, from basic to intermediate level) in the field of radiation monitoring and mapping, by means of mobile gamma spectrometry systems using backpacks or unmanned aerial vehicles (drones), are organized by NSIL, frequently in cooperation with the ICTP or other IAEA units involved in environmental measurements, nuclear security, decommissioning and environmental remediation. Topics covered include:

- ***Rationales and strategies of in-situ measurements approach***: specifics of field measurements, measurement strategies in respect of the cause scenarios, quality control actions and practical recommendations, comparison with laboratory measurements.
- ***Selection of instrumentation configuration***: radiation detectors and monitoring systems, signal/data processing, GPS sensors, data synchronization and transmission, data post processing and analysis tools.
- ***Practical demonstration using instrumented backpacks or unmanned aerial vehicles***: conducting a survey, data

- acquisition, control of measurements, compilation of results and data treatment, including interpretation.
- ***Introduction to geo-statistics interpolation and production of maps*** using the R-code platform, developed by NSIL.

The following training material is readily available on-line, while others are under development: In-situ techniques for radiological characterization of sites https://elearning.iaea.org/m2/mod/scorm/view.php?id=11876

Advanced and specific trainings in the form of fellowship training (individual or in a small group, for a duration of 4 to 6 weeks) can be organized and tailored to the needs expressed by Member States.

X-ray Fluorescence Analytical Techniques

Training activities in the field of XRF, which provide a general overview of this analytical technique as well as specific aspects of it and diverse applications, include:

- ***Training in XRF techniques and applications***, intermediate level, 8 weeks group fellowship course, organized at NSIL.
- ***Training in XRF with a focus on analysis of samples of specific nature, method validation or quality control***, intermediate to advanced level, 1 to 2 weeks, organized through joint ICTP-IAEA training or at regional level with partner institutions in cooperation with NSIL.
- ***Introduction to spatially resolved measurements: Micro-, Confocal- and Full Field--XRF analysis***, intermediate level, 1 to 2 weeks, organized at NSIL.
- ***Advanced trainings dedicated to the utilization and applications of XRF analytical techniques***, in the form of fellowship training (individual or in a small group, for a duration from 1 to 6 months), performed at NSIL or in a state-of-the-art partner institution.

The following training materials are readily available on-line, while others are under development:

- Introduction to X-ray emission spectrometry, https://elearning.iaea.org/m2/course/view.php?id=607 , and

- Introduction to total reflection X-ray fluorescence, https://elearning.iaea.org/m2/course/view.php?id=680
- Quality Assurance of X-ray Fluorescence Analysis of Airborne Particulate Matter,
https://elearning.iaea.org/m2/course/view.php?id=757.

Additional and specific trainings can be tailored and designed according to the needs expressed by Member States.

Accelerator Technology and Utilization

Training courses and workshops related to ion beam accelerator and synchrotron light facilities and their utilization are mainly performed in cooperation with the partner institutions such as ICTP, Elettra and RBI. They are based on both lectures and hands-on-training, using state of the art infrastructure, and include:

- ***Operation and maintenance of low energy electrostatic accelerators***, intermediate level, 1 week, organized in cooperation with RBI.
- ***Ion beam analytical techniques and their applications***, intermediate level, 1 week, organized in cooperation with RBI.
- ***Synchrotron-based beam lines and associated instrumentation, including operation and maintenance aspects***, basic to intermediate level, 1 week, organized in cooperation with Elettra.
- ***Applications of synchrotron analytical techniques and formulation of research proposals for beam line access***, basic to intermediate level, 1 week, organized in cooperation with Elettra.
- ***Advanced trainings dedicated to Ion Beam Accelerator Operation or Analytical Techniq***ues, in the form of individual or small group training, for a duration of 1 to 2 months, can be performed at RBI or another state-of-the-art partner facility.

Additionally, ICTP-IAEA joint workshops are organized in Trieste, Italy, typically every two years. Specific trainings can be tailored and designed according to the needs expressed by Member States.

The following training materials are available on-line, while others are under development:

- The Application of Ion Beam Analysis to Forensic Sciences,
https://elearning.iaea.org/m2/course/view.php?id=582

- Introduction to electrostatic accelerators: from basic principles to operation and maintenance,
https://elearning.iaea.org/m2/course/view.php?id=582.

Radiation Technologies for Measurements

The demand from Member States for training and qualification of specialists in the field of Radiation Technology for Measurements (RMT) is increasing. Training courses (generally lasting 2 weeks) are organized in cooperation with the Radioisotope Production and Radiation Technology Section. They include an important hands-on training component. The main fields covered by RTM trainings are:

- ***Radiotracer conventional methodologies and technologies*** applied to industry and environment.
- ***Radiometric and related methods for non-destructive investigations and process visualization***, such as Nucleonic control systems (NCS) and Computed Tomography (CT).
- ***Modelling approaches*** including residence time distribution (RTD) and computer fluid dynamics (CFD), to assist in the parametrization of the measurements, data analysis and results validation.

All RTM trainings are performed in collaboration with the International Society for Tracers and Radiation Applications (ISTRA), the international certification body for practitioners in these fields. Successful participants receive from the certification body the qualification certificates (level 1+2) relative to Radioactive Tracers Method, Residence Time Distribution Technique (RTM/RTD) and Sealed Sources Method, as well as Column Scanning Technique (SSM/CST).

1.8 Proficiency tests organized by NSIL

Provision of reliable results is one of the main missions of analytical laboratories. Many of them in the International Atomic Energy Agency (IAEA) Member States (MSs) carry out research aimed at improving the performance and extending the applicability of different nuclear and related analytical techniques (NAT).

The IAEA assists its MSs laboratories to maintain their readiness by producing reference materials, by developing standardized analytical methods and by conducting inter-laboratory comparisons and proficiency tests as tools for quality control. To achieve this aim and ensure a reliable worldwide, rapid and consistent response, the IAEA NSIL organizes proficiency tests annually for interested NAT laboratories.

The main objective of these tests is to enhance capability of interested MSs in effective utilization of nuclear and related analytical techniques and analytical services in industry, human health, agriculture, and in monitoring and evaluation of environmental pollution. Indeed, proficiency tests are designed to identify analytical problems, to support IAEA MSs laboratories to improve the quality of their results, to maintain their accreditation and to provide a regular forum for discussion and technology transfer in this area. The type of samples and the concentration levels of the analytes are designed and chosen in a way to better enable identification of potential analytical problems. Since 2001, the NSIL has organized sixteen proficiency test exercises.

Review of the most recent exercises

The proficiency test (PT) organized by NSIL involve an increasing number of laboratories and different analytical techniques. In the first tests, most laboratories employed XRF; recently, many laboratories specialized in other analytical techniques, mainly NAA, but also PIXE, ICP and AAS, joined the tests. In some of these cases this was to allow their participation involved in IAEA Technical Cooperation (TC) Projects. Since 2018 NSIL also co-organizes with other colleagues of IAEA Physics Section specific proficiency tests for NAA laboratories. In 2018 and 2019 two tests per year were organized, one open to all NAT and the other one only to NAA. In 2020 the decision was made to organize only one test, targeting a subgroup of participants, e.g. XRF or NAA laboratories.

Table 1: List of the last six exercises organized by NSIL

Proficiency test	Analytical techniques	Time frame	Sample	No. of laboratories	No. of MSs
IAEAPTXRF12	NAT	May 2015-Dec. 2015	Plant sample	37	30
IAEAPTXRF13	NAT	Nov. 2016 - Nov. 2017	Clay	47	36
IAEAPTXRF14	NAT	Mar. 2018 - Aug. 2018	Urban Dust Loaded on Air Filters	43	33
PTNAAI-AEA15	NAA	Jul. 2018 - Feb. 2019	Marine Sediment Animal Tissue	41	29
PTNATIAEA16	NAT	Mar. 2019 - Oct. 2019	Cereal Grain	53	37
PTNAAI-AEA17	NAA	Jul. 2019 - Mar. 2020	Land-plant sample Siliceous material	32	24

A list of the last exercises, including analytical techniques involved, time frames, sample type, number of participating laboratories and number of MSs is reported in the table below. Since exercise IAEAPTXRF14 in 2018, NSIL proficiency tests use a new web-based platform (http://www.pt-nsil.com/) to facilitate and improve the processes and actions for test organization and efficiency for both participants and coordinator. Only laboratories registered in the NSIL database can take part in the tests. Such registration can be initiated by sending a request via email to support@pt-nsil.com.

The organization of the PT exercises is structured according to the guidelines of ISO 17043 (general requirements for proficiency testing) and the statistical methods for data evaluation have been upgraded to full compliance with ISO 13528.

All PT reports can be downloaded from www.pt-nsil.com.

2. Support to Technical Cooperation Projects

NSIL staff provide technical backstopping and support for more than 40 Technical Cooperation (TC) projects listed in the table below, particularly on the themes of "Capacity building, human resource development and knowledge management", "Marine, terrestrial and coastal environments", "Radioisotopes and radiation technology for industrial, health-care and environmental applications" and "Nuclear Instrumentation".

For the development of concepts and designs for IAEA TC projects, support can be provided informally to individual organizations considering proposing projects to their National Liaison Officers (NLOs). More substantial assistance is available for Member State endorsed projects in the conceptual design and design review phases.

Project Title	**Region/ Country**
Supporting Radiation Technologies in Industrial Applications and Preventive Maintenance of Nuclear and Medical Equipment (AFRA)	Africa
Establishing and Improving Air Pollution Monitoring	Africa
Investigating Atmospheric Particulate Matter and Pollution Source Contributions in Urban Environments Using Nuclear Analytical Techniques (ARASIA)	Asia & Pacific
Studying Characterization, Source Apportionment and Long-Range Transport of Air Pollution within the Regional Network (ARASIA)	Asia & Pacific
Enhancing the Capabilities of Radiocarbon Dating in Archaeological Applications (ARASIA)	Asia & Pacific
Strengthening Nuclear Instrumentation Capacity in the Areas of Nuclear Sciences and Applications	Asia & Pacific
Enhancing Utilization and Safety of Research Reactors	Europe
Enhancing the Inventory of Aerosol Source Profiles Characterized by Nuclear Analytic Techniques in Support of Air Quality Management	Europe
Determining Long Term Time Trends of Air Pollution Source Tracers by Nuclear Techniques	Europe
Applying Nuclear Analytical Techniques to Forensics for Analysing Firearms Crime Evidence	Latin America and Caribbean
Strengthening Capabilities for the Utilization of Nuclear and Radiation Technology to Characterize, Conserve and Preserve the Cultural Heritage (ARCAL CLXVII)	Latin America and Caribbean
Assessing Atmospheric Aerosol Components in Urban Areas to Improve Air Pollution and Climate Change Management (ARCAL CLIV)	Latin America and Caribbean
Strengthening Capacity Building of Human Resource Development and Knowledge Management	Afghanistan
Increasing National Analytical Capacities through Upgrading of Nuclear Analysis Laboratories	Algeria
Strengthening the Engineering of Nuclear Facilities and the Management of Radioactive Waste	Algeria
Enhancing Analytical Capabilities for Improved Environmental Monitoring	Bahrain
Strengthening Capacity in the Maintenance and Utilization of the Tandem Accelerator Facility	Bangladesh
Estimating Sedimentation Rates and Reconstructing Sedimentary Processes in Hydroelectric Power Plants, Water Dams and Reservoirs	Columbia

Project Title	Region/Country
Enhancing the Capacities of Nuclear Emergency Response by Source Term Estimation and Unmanned Aerial Survey of Radioactivity	China
Strengthening Human Resources Capacity, Nuclear Knowledge, Skills Preservation, and Expertise in Relevant Fields of the Peaceful Use of Nuclear Energy	Czech Republic
Establishing a National Training Centre and Developing Information and Communication Technology Materials to Build Technical Skills in the Field of Nuclear Science and Technology	Egypt
Developing Human Resources Capacity to Support Education, Research and Training at the Graduate School of Nuclear and Allied Sciences	Ghana
Exploiting Mining and Petroleum Resources through Effective Characterization	Guatemala
Building Capacity on Advanced Non-Destructive Evaluation and Nuclear Analytical Techniques for Product Quality Improvement and Environmental Risk Assessment	Indonesia
Promoting and Developing Ion Beam Analytical Techniques and Archaeological Dating	Iran
Strengthening the Competence in Radiation Technologies and Safety for Biomedicine and Materials Science	Latvia
Enhancing Analytical Capabilities for the Valorisation of the National Cultural Heritage	Lebanon
Upgrading the Surface Chemical Characterization Laboratory to Support Research and Development in Small Local Paper, Plastic and Paint Industries	Lebanon
Strengthening Central Level Capacities to Reduce Air Particulate Matter	North Macedonia
Enhancing National Nuclear Analytical Laboratory Capacities	Myanmar
Developing Capacity for Nuclear Physics and Nuclear Chemistry Teaching Programs at Tribhuvan University	Nepal
Strengthening National Capacity for Nuclear Instrumentation, Repairs and Maintenance	Nigeria
Developing Nuclear Power Infrastructure for Education and Training and National Capacity for Radioactive Waste Management	Nigeria
Designing and Developing a National Ambient Air Quality Monitoring Network for Potential Mega Cities	Nigeria
Strengthening Capacity to Enhance the Use of Nuclear Applications for Development	Panama
Establishing a Graduate Program in Nuclear Science, Engineering and Management for Accelerated Utilization of Nuclear Applications	Philippines
Strengthening National Human Capacity and Research in Nuclear Sciences and Technology	Rwanda
Sustaining Nuclear Instrumentation Maintenance Capabilities (Medical and Scientific Equipment)	Sudan
Building National Capacity in the Protection, Conservation and Restoration of Historical Objects and Documents Using Radiation Processing of Monomers/Polymers	Syria
Strengthening Capacities for Multipurpose Radiation Technologies in Material Applications	Thailand
Establishing a Graduate School of Nuclear Science and Technology at the Nelson Mandela African Institution of Science and Technology	Tanzania
Establishing a Modern Nuclear Sciences and Technology Teaching Laboratory	Zambia

3. Reports from NSIL Events

Training Course on Environmental Monitoring and Mapping

Pecs, Hungary, May 6-10, 2019

The advanced training course was jointly organized jointly by NAEL/TEL and NAPC/NSIL on in-situ characterization of contaminated sites for environmental radioactivity, in Pecs, Hungary, during 6-10 May 2019. The course was attended by 40 participants from 29 countries with previous experience in environmental radioactivity monitoring.

This event covered all relevant practical aspects of characterizing a potentially contaminated site, from field surface scanning by backpack systems, in situ gamma-ray spectrometry and object measurements to gamma dose rate measurements, including aerial exploration by helicopter (with the support of the Hungarian Army). Also, the data measured by six individual teams were evaluated and maps depicting the spatial distribution of the surface contamination were produced, with findings presented by the teams on the last day. The course thus provided comprehensive training on the entire process of environmental contamination monitoring.

To ensure a realistic in-field scenario, the training was conducted on a partly remediated uranium mining area, and at a working yellow cake production facility. The local organizers were the Mecsekerc Laboratory and Mine Property Utilization LTD with the coordination of the National Food Chain Safety Directorate (Hungary) as Collaboration Centre of the IAEA.

Technical Meeting on Data Acquisition Systems Used for Nuclear Instrumentation at Particle Accelerator Facilities

Vienna, Austria, 26-30 May 2019

The objectives of this meeting were to highlight, review and discuss the current state and recent evolutions of data acquisition systems (DAQ) in the field with respect to both Ion Beam Analysis (IBA) and Nuclear Physics facilities. The identification of issues and problems encountered by the participants in their DAQ development and operation was also an important aspect, as well as receiving feedback and recommendations for future improvements and programs.

The meeting was attended by 21 participants from 17 Member States who shared their work experiences and knowledge relevant to the scope of the meeting. The presentations resulted in technical discussions on:

- The development and operation of DAQs at IBA facilities,
- Frameworks for the control of Ion Beam Accelerators,
- The development and operation of DAQs at Nuclear Physics facilities,
- Comparisons between digital and analogue DAQs,
- Development and operation of software for DAQs and control,
- The use of open source and proprietary software and hardware.

The participants concluded that the objectives of the meeting were accomplished through the wealth of information exchanged in presentations and discussions.

Technical Meeting on Advanced Techniques for Equipment Testing Under Field Conditions

Seibersdorf, Austria, 10-14 June 2019

The primary objective of this meeting was to exchange information and best practices on the development of test plans and methods for backpack radiation detectors (BRDs) with the emphasis on building capacity within Member States to conduct tests and train others through Nuclear Security Support Centres (NSSC) and other regional centres. Additional objectives included:

- Develop performance test methods that are related to field environments,
- Create a data set and results that can be used to update international standards,
- Share lessons learned and current best testing practices,
- Provide demonstrations and exchange testing and analysis software and tools.

Participants from 14 countries attended the meeting and delivered presentations, performed hands-on tests with a variety of BRDs, and identified potential improvements that could be made to test plans and methods.

Consultancy Visit on Use of UAVs Equipped with Portable Equipment for Radiological Mapping

Seibersdorf, Austria, 26 June – 05 July 2019

The consultancy visit aimed at discussing the present status and progress of a joint project with Fukushima Prefecture NA9/3 "Rapid Environmental Mapping with UAV Phase II: Operational support".

It focused on good practices as well as issues and challenges in using UAVs equipped with portable equipment for radiological mapping. It included hands-on exercises on calibration of detectors, data collection and data reduction, data analysis and interpretation of results.

Technical Meeting on Non-destructive Testing Using Muon Radiography: Present Status and Emerging Applications

Vienna, Austria, from, 9 to 12 September 2019.

The meeting introduced and discussed in detail muon radiography as a non-destructive technique, which is based on cosmic rays as an alternative or complementary source to a man-made source and thus without regulatory constraints. Muons can penetrate hundreds of meters of rock and thus can be used as a highly penetrating non-destructive probe. The technique of muon transmission/attenuation, which needs long measuring time, is applied to static situations for applications ranging from archaeological studies, volcanology, and geological imaging. More recently, muon scattering tomography, where amount of scattering of incident muon and transmitted muons is measured, is subject of intensive development for numerous applications ranging from geology, industry and civil engineering to security and safeguards.

The Technical Meeting was attended by 29 participants from 14 Member States. It served as a forum for participants to discuss and share recent advances in muon radiography, as well as to evaluate the status and current trends regarding practical applications of muon radiography, both in developed and developing IAEA Member States. Following this meeting an IAEA technical document is under preparation with the objective to disseminate the knowledge and experience related to muon radiography and facilitate further technical advancement of this techniques and its applications.

Technical Meeting on Advanced Radiation Portal Monitor Testing and Configuration Techniques

Seibersdorf, Austria, 28 - 31 October 2019

The meeting focused on testing procedures and evaluation methods for Radiation Portal Monitors (RPMs) that are not currently covered by the standards (including the new IEC62244:2019). It also contributed to a larger IAEA effort to aid Member States in assessing an RPM's minimum detectable activity (MDA).

Participants from 19 countries attended the meeting, delivered presentations, performed hands-on tests with a variety of RPMs, and discussed potential improvements to the technique. The following topics were addressed:

- Overview of the types and models of Radiation Portal Monitors,
- Different uses of these detection systems,
- General requirements that RPMs must meet or be tested against,
- Challenges users' organization faces related to deployment, maintenance and support of RPMs.

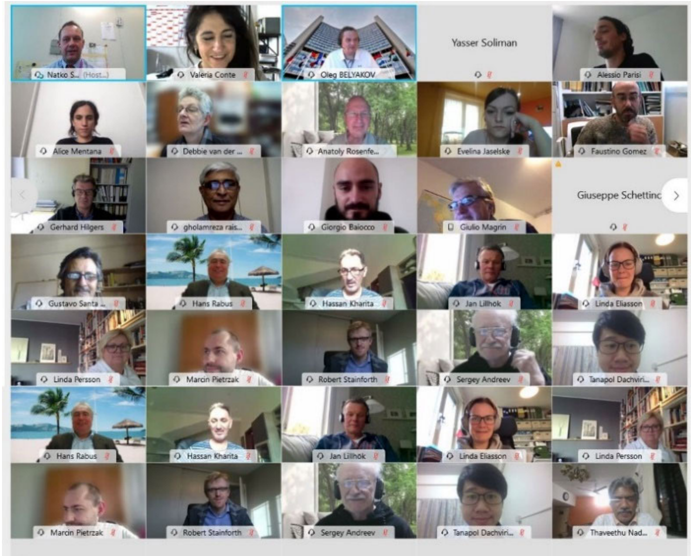
Technical Meeting on New Trends and Advances in Micro-dosimetry and its Applications

27–30 October 2020

The meeting was organized jointly by NSIL and Division of Human Health (NAHU).

The meeting was virtually attended by seventy participants, including eighteen females, from thirty-eight Member States (MS), who shared their work experiences and knowledge relevant to the scope of the Meeting.

Micro-dosimetry is the subfield of radiation physics involving the systematic study of the spatial distribution of the absorbed energy in microscopic structures within irradiated matter. Although it originated more than 60 years ago, micro-dosimetry is still attracting significant scientific interest in radiation medicine, radiation protection, radiation biology and other fields such as space research.



The presentations were organized in five main topics:

- Ion Beam Applications,
- Radiation Protection Applications,
- Biology modelling,
- Nano-dosimetry,
- Needs and challenges in standardization of micro-dosimetry measurements.

The Agency can play a strategic role in providing the multi-disciplinary expertise and environment required in this area. Directions for future research were identified during the Technical Meeting. Those directions will be used to guide the Agency's related research and development work in the coming program cycles.

List of Meetings in 2021

Due to COVID-19 restrictions, meeting plans and their nature (physical versus virtual) are changing constantly. Therefore, the most accurate and up-to-date event calendar can be accessed through the IAEA Meetings webpage at: https://www.iaea.org/events

You might also consult the scientific calendar of events managed directly by the ICTP in Trieste, including the joint IAEA-ICTP meetings: https://www.ictp.it/scientific-calendar.aspx

4. Reports from Member State

Rwanda

This is Dr Joseph Ntahompagaze, a lecturer from Physics Department, College of Science and Technology, University of Rwanda. From end of January to mid-March 2020, I had a chance to participate into the Group Fellowship Training (GFT) on Nuclear Instrumentations, we were ten participants from Africa. It was my first time to be at Seibersdorf IAEA laboratories. I met a very well-trained staff team with a warm welcoming but also with very focused introductions to what is all about to be covered in the training. The spirit of the training was at the level that no one would want to leave the training room, especially while in the experimental sessions and soldering practices, tough one had to rush for the bus to take us to Vienna in the evenings. The training was very intensive with expert lecturers and I can list a couple of training activities of high interest for me. We were trained on the use of the different nuclear instrumentation such as Geiger Muller (GM) detectors, different scintillators, like NaI (Tl), photomultipliers, preamplifier multichannel analysers, alpha spectrometers and gamma spectrometers.

Figure 14: GFT Training organized by NSIL was focused on supporting sustainable industrialization and upgrading capabilities using modern radiation instrumentation and associated techniques

Experiments conducted during the training included the high voltage characteristics of GM detectors, absorption of gamma radiation in materials, in-situ gamma spectroscopy, techniques to amplify the signal using pre-amplifier and amplifier in instrumentation. We also had a chance to use state-of-the-art software such as TI-software and LabVIEW software. The introductory course to micro-controller was valuable, developing my knowledge of possible applications of recent technology to nuclear instrumentation. The course on troubleshooting for nuclear instrumentation was very useful since it provided key steps on how to identify the faulty part of a given nuclear instrument so that the reparation can be made easier with component replacement or block-replacement of the instrument under reparation. After the training, my knowledge was improved in my ways of teaching courses related to nuclear physics and in my research activities in nuclear sciences at the University of Rwanda.

Contributor

Dr Joseph Ntahompagaze
Lecturer, Physics Department
University of Rwanda,
College of Science and Technology
Error! Hyperlink reference not valid.

Indonesia

Research and Development at Pusat Sains dan Teknologi Nuklir Terapan (PSTNT), BATAN, is especially directed to implement analytical methods to determine various elements in support of research in various fields, which include environment, health and industry-related studies. Various national as well as international collaborations have been established with the academic society, R&D institutions and government institutions.

Application of ED-XRF for characterization of airborne particulate matter in monitoring Indonesian urban air quality

Air pollution is one of the serious problems faced by Indonesian cities. Identification of air pollutants is an important step to overcome the problem of pollution and can only be done comprehensively through characterization various elements contained in air particulates.

With support from the IAEA, BATAN in collaboration with Ministry of Environment and Forestry (MoEF) and the local Environmental Protection Agency (EPA) in 17 urban sites covering Java, Sumatra, Kalimantan, Sulawesi, Bali, Nusa Tenggara, Maluku and Papua. The local EPA staff change the filter cassettes weekly and ship them back to BATAN laboratory, where the analyses are performed. Our laboratory is equipped with two PANalytical Epsilon5 ED-XRF spectrometers. BATAN laboratory follows ISO/IEC 17025 standard and was accredited by the national accreditation body.

The results obtained have been compared with other related methods such as PIXE and NAA, and the laboratory has been actively participating in various proficiency testing exercises to ensure and guarantee the validity of the results. The collaboration is not only limited to national scale, but our laboratory also collaborates in the analysis of airborne particulate matter samples from Malaysia, Myanmar, Sri Lanka and Pakistan.

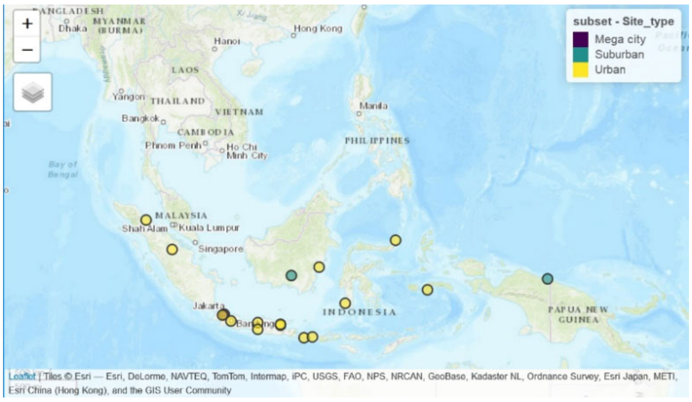


Figure 15: Sampling locations in 17 urban sites in Indonesia.

The air quality research has produced a time series data set of ambient air particulate and the specific results from each city were used as an early warning, baseline data, and identification of pollutant sources. Some important results indicated that the PM2.5 concentrations in several cities in Java island generally exceeded the air quality standard; forest fires and volcanic eruptions have raised the PM2.5 concentrations to 10-100 times above average, and the heavy metal concentrations such as Pb were significantly higher in Surabaya and Tangerang. These results can be used as a reference in formulating strategies and policies considering that Indonesia is in the ring of fires and episodes of forest fires occur regularly, especially in Kalimantan and Sumatera. These results have also contributed to the city of Bandung receiving an award for having the cleanest air quality among other large cities in ASEAN in 2017, as well as encouraging the revisions of ambient air quality standards.

Application of nuclear analytical techniques for micronutrient analysis in food

In Indonesia, the malnutrition status of children remains at a very high level. Stunting is a sign of chronic malnutrition and Indonesia ranks third in the Southeast Asia Region based on WHO data 2018. These problems provide lifelong consequences. Therefore, an assessment of micronutrient status is needed to assess their daily intake. Nuclear analytical techniques (NATs) including NAA, ED-XRF and TXRF have been applied to determine the content of micronutrients in food. By applying these techniques, the micro and macro elements in various foodstuffs from more than 90 cities/districts in Java Indonesia, and in the duplicate diet samples from stunted children have been identified.

The contents of nutrients in foodstuffs is highly needed, since the database related to micronutrients in Indonesia is incomplete and not up to date so that the determination of nutritional status and nutrient intake levels is estimated using secondary data from other countries. To get an accurate picture of nutritional status, it is necessary to have nutritional composition data derived from local food consumed by the Indonesian people. The micronutrient database from BATAN laboratory was considered in the updating of the Indonesian Food Composition Table 2018. The data is a scientific-based reference for related institutions in formulating, taking appropriate and directed actions and policies to deal with community nutrition issues and to support the improvement of the health status of the Indonesian people.

Besides that, since 2018 BATAN laboratory have been involved in national research of stunting problem by identification of micronutrient in duplicate diet and mother breast milk from stunted children in area of stunted high prevalence, East Nusa Tenggara. This research is conducted in collaboration with Southeast Asian Ministers of Education Organization Regional Centre for Food and Nutrition (SEAMEO RECFON), and Research and Development Centre of Biomedical and Basic Health Technology, Ministry of Health. The work is still on going, expanded to other area and designed to be conducted from 2020-2024. In the future, the application of stable isotopes to analyse its bioavailability in human body is promising and expected to be applied.

NATs application have also been used in the characterization during reference materials (RM) development, especially for environmental matrices. This activity will be a contribution of BATAN to Indonesian RM program and to support the National Metrology Institute in Indonesia.

Figure 16: PSTNT BATAN Laboratory Researchers

Outlook

Our laboratory has a long trajectory in the field of multi-element characterization. During this time, the number and variety of research problems addressed has been very diverse. This fact has allowed us to acquire a broad, real and dimensioned perspective of the potentialities and drawbacks of the NATs. With this background in our hands, our lab is always open to collaborate with the international community. In the future we propose to expand our NATs capability by introducing the IBA facility, thermal/optical absorption (EC-OC analyser), and stable isotope analysis.

Contributors

Muhayatun Santoso, Diah Dwiana Lestiani
PSTNT-BATAN Laboratory
National Nuclear Energy Agency of Indonesia (BATAN)
hayat@batan.go.id; diahdwi@batan.go.id

Croatia

Dual Beam irradiation capability at Ruđer Bošković Institute

The Ruđer Bošković Institute Accelerator Facility (RBI – AF) consists of two accelerators: a 6.0 MV EN Tandem Van de Graaff accelerator and a 1.0 MV Tandetron accelerator. These provide ion beams to 9 experimental end stations, forming together the largest research infrastructure in Croatia. The facility is operated within the Division of Experimental Physics of the RBI, and today serve both national and international users.

The DiFU facility

Following the advantage of the RBI-AF to have two accelerators, one of the obvious application possibilities of this facility is dual beam irradiation. Dual beam irradiation is primarily intended to simulate environment in fusion reactors by simultaneous irradiation by H or He (from 1.0 MV Tandetron) and heavy ions such as Fe, Cu, W, I, Au etc. (from 6.0 MV tandem) that simulate neutron irradiation of fusion materials made of these elements.

The E4 end station, also referred as the dual ion beam for fusion materials research (DiFU), was developed as a part of the H2020 EUROfusion project and with an assistance of several other projects funded by European Union, Ministry of science of Croatia and IAEA. The chamber was commissioned in 2019. Inaugural Ceremony, gathered among other representatives of IAEA, Ms. Melissa Denecke, Director of the Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications and Mr. Tony Donne, EUROfusion Programme Manager [1].

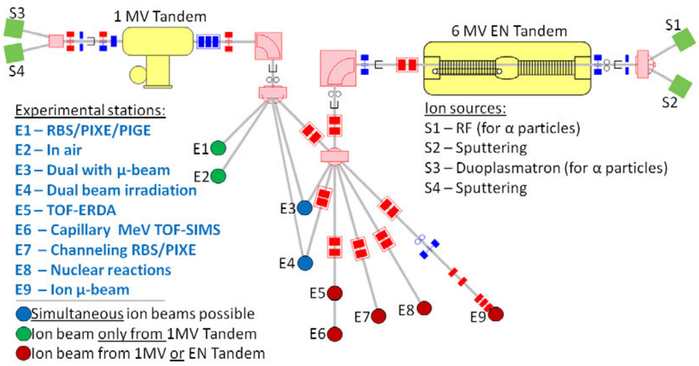


Figure 17: Layout of the RBI accelerator facility. The E4 is the DiFU end station.

During the last one year, many different tests has been performed, primarily to confirm reliability of the system for irradiation by external users.

Irradiation fluence is controlled by several systems. Two sets of electrostatic scanners (one for each beam line) homogenize the beam over the certain surface of sample. Surface area to be irradiated is defined by sets of adjustable slits. One of the special features is also possibility to modify the scanning pattern and as such create different dose gradients on the same sample. Quantification of the fluence is done by two Faraday cups that are automatically inserted into the beam in certain time periods. Furthermore, beam current is monitored continuously on all 8 XY slits that define the irradiation size.

To provide homogeneous irradiation along the sample depth, the irradiation ion energy should be also changed simultaneously during irradiation. For this purpose, beam degrader, that consist of set of metal foils that intercept the ion beam prior to the sample, have been constructed.

However, the first tests showed that the irradiation time by each of the degraders should be adjusted in order to counterbalance the effects of multiple scattering of ions in degrader foils.

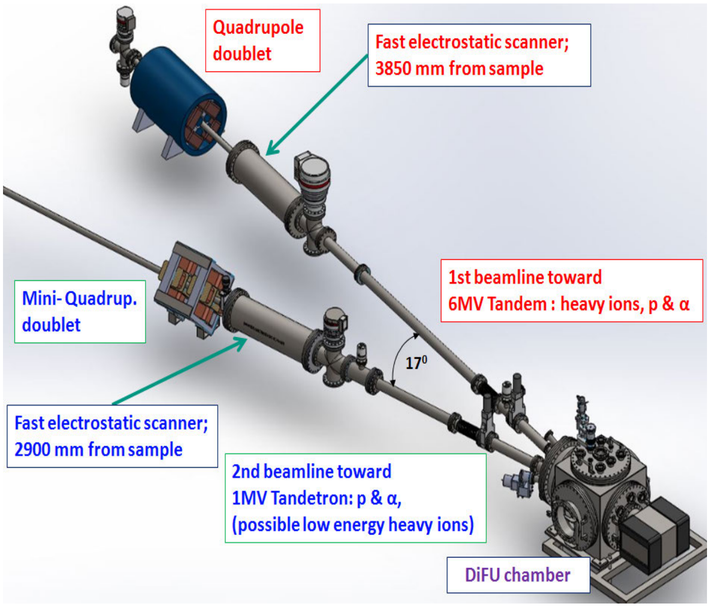


Figure 18: Layout of the dual beam irradiation system at RBI.

The sample holder is motorized to enable proper positioning of the sample. It is also equipped with a resistive heater, tested so far up to 750 degrees Celsius. The sample temperature is monitored both by thermocouples and an IR camera. Alternatively, in one of the upper ports of the scattering chamber, users' sample holders can be also placed. One of these, that provided the temperature gradient on the small space scale of the single sample, has been already used in one of the previous single ion irradiation campaigns by external users [2].

Finally, one of issues related to ion irradiation of fusion materials is deposition of hydrocarbons at irradiated area of sample surface, as well as implantation of carbon (as well as nitrogen and oxygen) in layers below the surface. These effects change chemical composition of irradiated sample and may produce wrong results during post-irradiation evaluation of the sample.

For this purpose, special attention has been given to the vacuum system, which provides now vacuum in the chamber of the 10-8 mbar order. Furthermore, a LN2 cooled cold trap has been also placed close to the sample to reduce deposition during the irradiation. Diagnostics experiments to quantify this effect are now underway.

Users access

The access to the RBI-AF DiFU end station as well as to other beam lines, is now possible through several channels, namely, the IAEA CRP on Facilitating Experiments with Ion Beam Accelerators G42008 [3], CERIC-ERIC consortium [4] and EU Horizon 2020 project RADIATE [5].

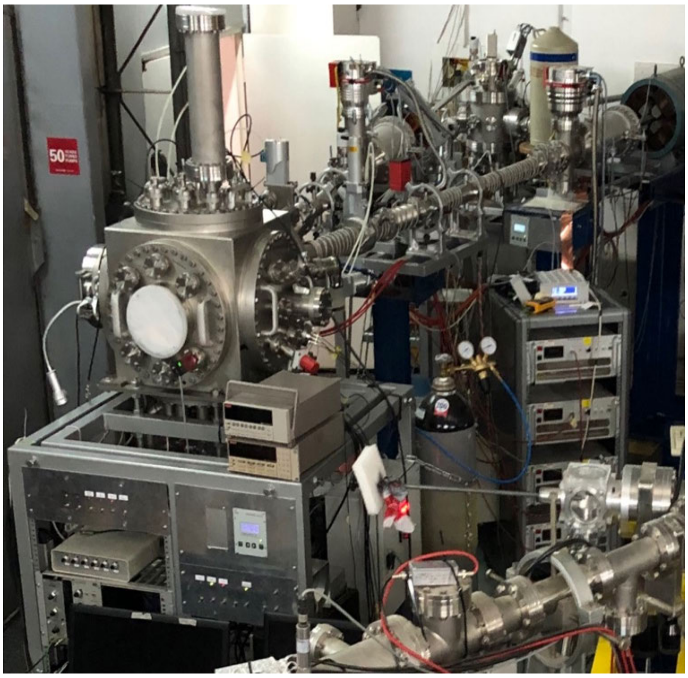


Figure 19: DiFU end station at RBI

Contributors

Tonči Tadić
Laboratory for ion beam interactions, Division of experimental physics, Ruđer Bošković Institute, Zagreb, Croatia
ttadic@irb.hr

Milko Jakšić
Head, Laboratory for ion beam interactions, Division of experimental physics, Ruđer Bošković Institute, Zagreb, Croatia
jaksic@irb.hr

References:

[1] https://www.iaea.org/newscenter/news/a-new-player-in-fusion-research-croatia-launches-dual-ion-beam-facility-with-iaea-support
[2] M.T. Lessmann, et al., The effects of ion irradiation on the micromechanical fracture strength and hardness of a self-passivating tungsten alloy, J. Nucl. Mat. 486 (2017) 34-43
[3] https://www.iaea.org/projects/crp/g42008
[4] https://www.ceric-eric.eu
[5] https://www.ionbeamcenters.eu/radiate/radiate-transnational-access/

Selected recent NSIL publications

Here after a selection of recent NSIL publications:

- *Experimental assessment of effectively probed volume in confocal XRF spectrometry using micro-particles*, P. Poths E. Chinea-Cano, N. Dzigal, I. G. Darby, J. Osan, R. Padilla-Alvarez; X-Ray Spectrometry, Volume48, Issue5.
  https://doi.org/10.1002/xrs.3045
- *IAEA Nuclear Science and Instrumentation Laboratory: Support to IAEA Member States and Recent Developments*, F. Foulon et. al., EPJ Web of Conferences 225, 10005 (2020), ANIMMA 2019.
  https://doi.org/10.1051/epjconf/202022510005
- *IAEA activities in support of nuclear physics research and applications*, D. Ridikas for Physics Section, Journal of Physics: Conference Series, Volume 1643 (2020), 27th International Nuclear Physics Conference (INPC2019) 29 July - 2 August 2019, Glasgow, UK.
  https://iopscience.iop.org/article/10.1088/1742-6596/1643/1/012206
- *Three-Year Long Source Apportionment Study of Airborne Particles in Ulaanbaatar Using X-Ray Fluorescence and Positive Matrix Factorization*, G. Gunchin et.al., Aerosol and Air Quality Research, 19 | 5 (2019) 1056-1067.
  https://doi.org/10.4209/aaqr.2018.09.0351
- *Use of geochemical fingerprints to trace sediment sources in an agriculture catchment of Argentina*, Torres Astorga, R. et al, International Soil and Water Conservation Research 2020.
  https://doi.org/10.1016/j.iswcr.2020.10.006
- *Ambient particulate matter source apportionment using receptor modelling in European and Central Asia urban areas*, Environmental Pollution, Available online, 15 July 2020.
  https://doi.org/10.1016/j.envpol.2020.115199
- *IAEA activities in support of research reactor and nuclear analytical techniques*, N. Pessoa Barradas, A. Migliori, A. Simon, F. Foulon, H. Ben Abdelouahed, I. Swainson, N. Skukan, P. Sladek, R. Padilla Alvarez, S. Charisopoulos, D. Ridikas, Arab J. Nucl. Sci. Appl., Vol. 53, 3, 267-275 (2020).
  web link

Back Scatter

Upcoming Events

Updated information on the Events organized by the NSIL is available on the IAEA Nuclear Instrumentation Portal

(https://nucleus.iaea.org/sites/nuclear-instrumentation/)

and also through the IAEA Meetings webpage at

https://www.iaea.org/events.

Contributions to our Newsletter

Materials for consideration for publication in our Newsletter should be submitted in MS Word only.

Short article submissions should be no more than 800 words with up to 2 high quality figures/pictures (including captions) and, if needed, a maximum of 3 most relevant references.

Submissions for "Laboratory Portrait" articles, a future rubric in the Newsletter, should be no more than 1500 words with up to 4 figures/pictures and, if needed, a maximum of 6 most relevant references.

Impressum

Nuclear Science and Instrumentation Newsletter No. 1, February 2021

The Nuclear Science and Instrumentation Newsletter is prepared twice a year by the IAEA Nuclear Science and Instrumentation Laboratory (NSIL).

International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Printed by the IAEA in Austria, February, 2021

21-00298E