OPERATION AND EXPLOITATION OF THE REACTOR

José Gonçalves Marques

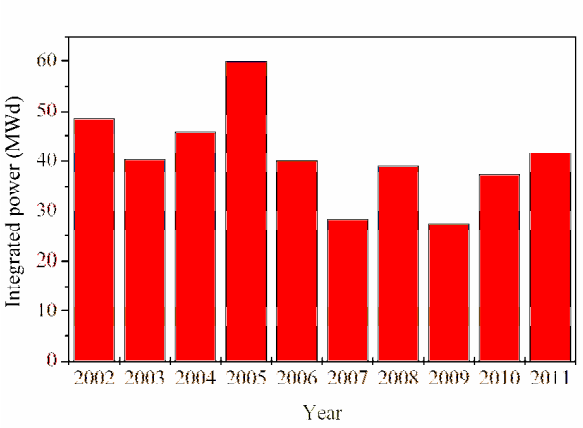
The main objective of the Operation and Exploitation of the Portuguese Research Reactor Group is to be able to satisfy the users' needs while conducting all tasks with the assurance that the reactor is operated in a safe and reliable manner by a highly competent and motivated staff. The implementation of such objectives demands a variety of activities, some of which are repetitive in objective and variable in content, while others address specific aspects of the same end situation.

User	Area	Time (%)
URSN	NAA	51.0
	Tomography	19.0
	Radiation effects	10.5
	Dosimetry and detector development	5.3
	Education and training	1.2
UCQR	NAA	6.6
U. Lisboa	Isotope Production	0.5
	Detector development	0.5
IVIA	Radiation Effects	0.2
UPV	Isotope Production	1.6
U. Heidelberg	Dating	3.6

The main users of the reactor are described in the Table above. The largest sustained activity supported by the RPI is neutron activation analysis (NAA) in the URSN and UCQR Research Units of ITN. Most other activities suffer large fluctuations.

Education and training is very dependent on the number of students that attend courses using the reactor in practical sessions. This activity had a significant boost in 2011 from the ICARO intensive course organized at ITN for 21 European students.

Activities using neutron beams are currently restricted to neutron tomography and irradiation of electronic components and systems. These two activities accounted for 30-40% of the reactor utilization in the last two years. A setup for Prompt Gamma Neutron Activation Analysis is being optimized. It is expected that this setup will contribute significantly to new activities in the RPI.



The integrated power in 2011 increased again, as shown in the figure above, marking this year as the best since 2005. The total irradiation time in 2011 was 1518 hours, corresponding to an average of 1.5 irradiations performed simultaneously during the normal working hours of the RPI.

Research Team

Researchers

J.G. MARQUES, Princ.
A. FALCÃO, Princ.
N.P. BARRADAS, Princ. (85%)
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A.P. FERNANDES, Aux
A.R. WAHL, Aux. (85%)
D. BEASLEY, Aux.
M. PEREIRA, Aux.

Reactor Operators

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Technical Personnel

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Students

M.A.F. COSTA, Ph.D. Student UNL, FCT grant

Collaborators

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Neutron tomography activities at the RPI

M.A. Stanojev Pereira, J.G. Marques

Objectives

The neutron radiography (NR) and Neutron tomography (NT) are very efficient tools to inspect the internal structure of materials. An equipment for neutron tomography was installed in the RPI under project POCI/FIS/59287/2004, funded by FCT, in the horizontal access of the thermal column and provides a parallel beam having 5 cm in diameter at the sample irradiation position. Since 2010 this equipment is operational and for the present conditions, the irradiation time to obtain an image is 90 seconds and the spatial resolution is about 300 μm.

Results

Imaging techniques can be classified according to the penetrating radiation type, such as X – ray, gamma – ray, and neutron and because of their attenuation characteristics, in many cases, they are complementary methods.

Neutrons are strongly attenuated by H-rich substances even when wrapped by thick metal layers while for X rays the inverse occurs. Hence neutrons are commonly used to inspect, e.g., o-rings, components of refrigerators, fuel cells, aeronautical devices and cultural heritage objects.
For neutron tomography it is necessary to obtain about 200 single 2D images over 180 degrees. In our setup these images are captured using a Peltier-cooled CCD camera.

The figure 1 shows an example of a 3D image obtained at the RPI. This object is a tile treated with the consolidant Paraloid B-72 and shows clearly the penetration of the resin. The main conclusions of this study are published[1] and also discussed in a contribution from the Chemical and Radiopharmaceutical Sciences Unit.

The technique also allows to inspect mineral veins. The figure 2 shows preliminary data for a copper ore, from the Department of Mineralogy of the Faculty of Science at the University of Lisbon. The figure 2a is a photography and 2b and 2c are tomography images of the metal, highlighted in red.

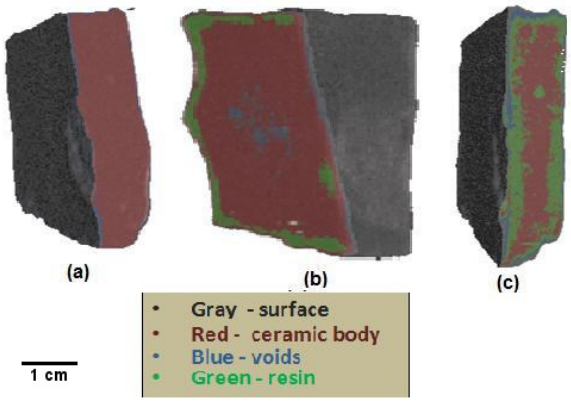
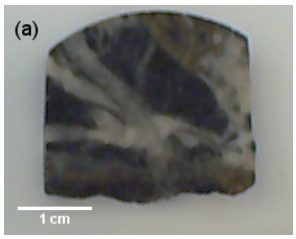
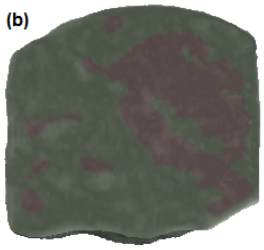


Fig. 1. Fragment of glazed tile (16th century) from Museu Nacional do Azulejo: (a) untreated; frontal (b) and angular (c) neutron tomography images and after resin treatment.





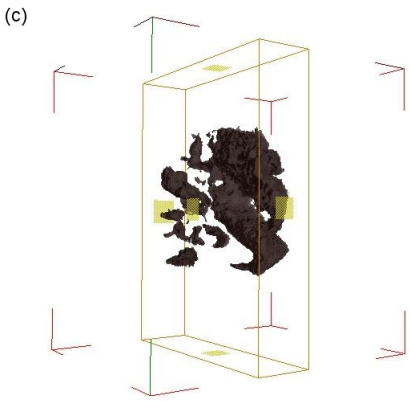


Fig 2. (a) Photography of a Cu ore; (b) tomographic image 1 mm from surface; (c) detailed distribution of Cu.

[1] Prudêncio, M.I., Stanojev Pereira, M. A., Marques, J.G., Dias, M.I., Esteves, L. Burbidge, C.I., Trindade, M.J., Albuquerque, M.B.. Neutron tomography for the assessment of consolidant impregnation efficiency in Portuguese glazed tiles (16th and 18th centuries). Journal of Archaeological Science (2011), doi:10.1016/j.jas.2011.11.010.

Fast neutron irradiation of GaN HEMT transistors
Q. Vinckier[1], J.G. Marques, C. Cruz

Gallium nitride (GaN) High Electron Mobility Transistors (HEMT) are fast becoming adopted for high power amplifier applications. The key advantage of these transistors is their operating power density, which is significantly higher than the one of Si-based transistors. However, not much is known about the behaviour under radiation of GaN-based transistors, which only became commercially available in recent years. A methodology was developed to simulate the defects introduced by neutrons using the MCNPX and SRIM Monte Carlo codes, linked by a custom-made FORTRAN program. HEMT GaN transistors from two manufacturers (Cree and EPC) were irradiated with fast neutrons in the RPI, with fluences up to $2x10^{14}$ n/cm^2 (E> 1 MeV). Si based MOSFET transistors were irradiated at the same time for comparison. Characteristic curves were obtained during irradiation using a custom-made test platform, able to supply the required high drain current. The results show significantly different behaviours for the two HEMT transistors based on similar materials and general geometrical arrangements. Detailed results were presented in the M.Sc. thesis of Q. Vinckier at ISIB, Brussels.

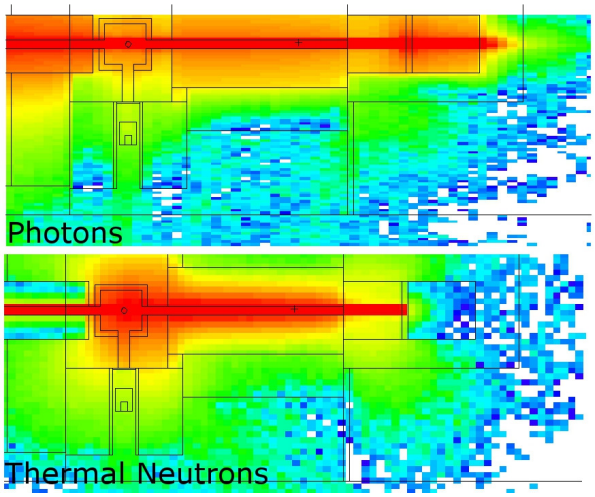
[1]M.Sc. student from ISIB, Belgium

Intensive course on accelerator and reactor operation (ICARO)
J.G. Marques, E. Alves, P. Vaz

ITN hosted for the second time the "Intensive Course on Accelerator and Reactor Operation" (ICARO), from 6 to 19 March 2011 for the CHERNE (Cooperation for Higher Education on Radiological and Nuclear Engineering, http://www.upv.es/cherne/) network, with financial support of the Erasmus Intensive Program. Twenty four students from the Applied University of Aachen, University of Bologna, University of Catania, University of Coimbra, University of Palermo, University of Prague, University of Valencia, ISIB (Institut Supérieur Industriel de Bruxelles), POLIMI (Politecnico di Milano), and XIOS (eXpertisecentrum voor Industrie, Onderwijs en Samenleving) attended the course in 2011. The course included 16 theoretical classes and 34 practical classes on radiation protection, accelerator operation and applications, as well as research reactor operation and applications. Two round tables were also organized on the topics "Nuclear as Part of Sustainable Development?" and "Ethics and the Principle of Justification: The Case of Nuclear Technology Assessment".

Modelling of a proposed beam line extension for multi-elemental Prompt Gamma Neutron Activation Analysis
D.G. Beasley, A.C. Fernandes, J.G. Marques, A.R. Ramos Wahl, J. Santos

Prompt Gamma Neutron Activation Analysis (PGNAA) is seen as a technique with added value to the activities based on the RPI. However, the background at the Ge detector position is too high, preventing the practical use of this technique. A proposal to extend the beam line and build a new detector port and sample chamber was simulated. Grids of foils (Au, Ni, Al and In) were placed in the existing installations to verify and normalize simulations performed using MCNPX. TLDs were placed inside the chamber to measure the photon dose. The simulations allowed for the model to be optimized, the shielding requirements to be determined and for a significant drop in background at the new detector position. Expected flux at the detector positions were calculated from simulations to assist in planning the experimental parameters. The work is expected to be completed in early 2012.



Implementation of a radiological surveillance scheme for the supervised areas at URSN
A. Kling, A. R. Ramos, J. G. Marques

While an extended monitoring for the radiation levels in the controlled area of URSN (the reactor hall) has been operational for many years, a systematic surveillance scheme for the four supervised areas (the annex for radioactive effluent tanks and three laboratories in the main building) was lacking. Based on information provided by the Radiation Protection Technicians (effluent tanks) and the laboratory users for each area, suitable points have been selected and marked for the control of the gamma radiation level and the surface contamination. The surveillance is performed weekly in the early afternoon of Monday. This corresponds to the time period at which, due to the established work schedules, the largest number of radioactive samples and the maximum cumulated activity is present at the laboratories. The procedures and maps containing the designated measuring points have been included in the Radiation Protection Plan of URSN. The measured data are collected on a dedicated form, evaluated by the Responsible for the Radiological Protection of URSN and reported in an adequate form in the annual radiological control report.

Study on the reactor production of 163Ho needed in the search for neutrinoless double Beta-decay
A. Kling, M.R. Gomes[1], F. Gatti[2]

In the neutrinoless double beta decay two neutrons decay simultaneously within a nucleus into two protons and two electrons – a process that is forbidden in the Standard model due the law of lepton number conservation. The proof of the existence of such a decay scheme and consequently the neutrino being a Majorana particle (i.e. particle and antiparticle are identical) is therefore of highest interest. Various approaches with suitable isotopes (e.g. ^{3}H, ^{76}Ge, ^{130}Te, ^{187}Re) and detection techniques (e.g. electrostatic spectrometers, enriched HPGe detectors, cryogenic calorimeters) have been made so far. A very promising candidate is ^{163}Ho due to its low Q-value (2.80 keV) and relatively short half-life (4570 y) to be used with a cryogenic detector developed by a group in Genoa. A reactor-based production of this isotope is possible through the ^{162}Er(n,γ)^{163}Er reaction with subsequent β-decay to ^{163}Ho. However, it is found that the low natural isotopic abundance of ^{162}Er (0.14%) makes it impossible to use natural Er as target. On the other hand, calculations showed that with commercially available targets enriched to 40% in ^{162}Er specific activities of about 2 kBq/mg, Er can be achieved at RPI after 120 hours of irradiation. Furthermore the radiocontamination in this case will be basically restricted to ^{165}Er which decays with a half-life of ca. 10 hours to stable ^{165}Ho and therefore does not impose any limitations in the decay experiments.

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The SIMPLE dark matter search project
M. Felizardo, T.A. Girard[1], A.C. Fernandes, A. Kling, A.R. Ramos, J.G. Marques, M. Auguste[2], D. Boyer[2], A. Cavaillou[2], C. Sudre[2], J. Poupeney[2], H.S. Miley[3], R.F. Payne[3], J. Puibasset[4], F.P. Carvalho, M.I. Prudêncio, R. Marques

SIMPLE project activity in 2011 centered on the analysis of the previous Stage 2 dark matter search data from the underground site (Laboratoire Souterrain Bas Bruit, LSBB). New radioassays of the various shielding materials were completed and incorporated into the previous MCNP neutron background estimate. A re-analysis of the data obtained at the RPI yielded an improved detector nucleation efficiency. The Stage 2 results were reported at the 2011 TAUP meeting in Munich, Germany, and submitted to Phys. Rev. Lett.; combined with those of Stage 1, the results provided the current most stringent limits against a spin-dependent WIMP coupling (overlapping for the first time with limits obtained by indirect means), and eliminated a large part of the recent CoGeNT claim for a light mass WIMP discovery. New single-detector neutron and α calibration measurements were performed, confirming the results of the 2010 Phys. Rev. Lett. obtained with separate detectors. Publicized critiques by J. Collar and by E. Dahl et. al (COUPP Collaboration) were publicly responded to. Measurements of the unshielded neutron background in the GESA site of the LSBB were initiated by the team of V. LaCoste (IRSN) in November, using a set of 13 Bonner spheres.

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