NON-DESTRUCTIVE EXAMINATION BENCHES AND ANALYSIS LABORATORIES IN SUPPORT TO THE EXPERIMENTAL IRRADIATION PROCESS IN THE JULES HOROWITZ REACTOR

Dr Daniel P. Parrat [a]*
P. Kotiluoto[b], T. Jäppinen[b], C. Roure[a], B. Cornu[a], B. Berthet[a], C. Gonnier[a], S. Gaillot[a]
***(*) Main author mail*: daniel.parrat@cea.fr**
P: +33-442-257-572
F: +33-442-254-747
[a]CEA/Nuclear Energy Division
***Main author address*: DEC/SESC - Building 151**
CEA Cadarache
F – 13108 Saint Paul lez Durance
[b]VTT Technical Research Centre of Finland
P.O. Box 1000
02044 VTT, Finland

1. THE IRRADIATION PROCESS IN MTR: A NECESSARY STEP FOR THE DEVELOPMENT OF A NUCLEAR PRODUCT

The development process of a fuel product or a material before using it at an industrial scale in a power reactor generally comprises several steps, from the characterization of the material itself under neutronic flux up to the qualification in accidental conditions. These steps have been presented for the nuclear fuel domain at the previous IGORR 12 conference [1].

For that aim, several experimental infrastructures are used to reproduce or to simulate the irradiation effects:

- Gamma or X-ray sources to produce intense gamma fluxes at high energy,
- Electron or ion accelerators to simulate either the particles effect or the evolution of the material under neutron flux (ageing process) by means of component activation or creation of fission products placed in interstitial location in the crystalline structure,
- Fundamental research reactors (RRs), in which a small size sample is placed into an experimental chamber in a neutronic guide,
- Material test reactors (MTRs) and dedicated reactors (e.g. for safety tests) to irradiate a large scale experimental sample by neutron and gamma fluxes,
- Industrial reactors either at a prototypical or at a mature scale. In this case, the tested sample is a fuel product at the same scale than the other standard products and irradiated at a small number as “precursors”.

Only the two last types of infrastructures are capable to welcome large or instrumented specimens. Moreover, thanks to their design, the industrial reactors are the only ones which respect strictly all the environment parameters applied to the sample in normal conditions for which it is designed for (thermal-hydraulics, neutronic level and spectrum etc.) For this reason one could think that this development method, supported by results obtained thanks to “surveillance programs” regularly carried out during the life of the product thanks to post-irradiation examinations (PIEs), is the reference. However these industrial facilities present several limitations and this qualification method cannot be applied when:

- The sample design and structure is not optimized for the characterization or qualification objective, or when heavy instrumentation is necessary,

- The sample has to be tested at the design or reactor operating limits (high dpa value or burn-up increase, …),
- Specific power time histories not compatible with a reactor standard operation have to be applied (intermediate power operation, cycling, soliciting transients, power ramps…),
- Specific environment parameters shall be applied (controlled stress, higher temperature or volumic power, neutronic spectrum, coolant chemistry…),
- Specific constraints or solicitation could induce a non-acceptable risk of sample integrity loss (geometrical change, rupture, clad failure),
- Reactor is not adequately designed, especially if the experimental program is related with safety criteria (fuel central melting research, continuous irradiation in a failed mode, fuel rod lift-off study…),
- The sample aspect or properties observed or measured through post-irradiation examinations are no more representative or cannot be transposed to the sample status during irradiation,
- The industrial reactor simply doesn't exist.

For all these reasons, irradiations in MTR are mandatory and are in practice the basis of the whole development process (selection, characterization and qualification). Dedicated reactors play also an important complementary role for some specific integral tests (e.g. LOCA or RIA test for fuels). Finally irradiations of precursors in power reactors are limited to products which present a slight design evolution (clad alloy, microstructure optimization, doped fuel…) and which ensure an expected behavior quite comparable to the standard product. They are also used when a statistical approach is useful.

In a nutshell, experiments in MTRs aim to study [2]:

- Evolution of material and fuel properties under neutronic flux, versus the flux level and the dose:
    - Mechanical properties (densification, creep, thermal expansion, gaseous swelling…),
    - Thermal properties (conductibility, heat capacity…),
- Thresholds versus the fast neutrons integrated dose, the burn-up or the temperature (e.g. MOX agglomerate restructuration, fission gas release, clad or neutronic absorber swelling…),
- Unexpected or insufficiently modelled phenomena (e.g. fuel cracking network, pellet-cladding contact, He behavior),
- Distribution and thermal-chemical behavior of fission products other than noble gases,
- Quantification of margins versus safety criteria or versus the loss of the product reliability or robustness. This service offer is essential in support to the qualification file of the product [3].

Moreover, experiment objectives are now strongly related to the modeling needs, which will become progressively the driving force for implementing such tests. Among other interests, the main aims of the modeling is i) to gather experimental results in a database for the simulation tool validation, and ii) to set up a reliable knowledge and understanding of the activated phenomena through models and laws.

2. INTEREST OF NON-DESTRUCTIVE EXAMINATIONS FOR THE IRRADIATION PROCESS IN MTR

The experimental process in a Material Test Reactor (MTR) mainly consists in the irradiation of an experimental sample (nuclear fuel or material) in a specific device reproducing as much as possible the power reactor environment conditions (thermal-hydraulics, neutronic flux level and spectrum, coolant chemistry etc.). The key parameter time history requested by the customer (e.g. nuclear power, temperature, stress) is applied to the sample by means of various in-situ or out-of-pile systems (e.g. distance to the MTR core, neutron absorber movement, electric or gamma heating, isolating gas gap, internal pressure or bellows).

The sample itself is generally instrumented in order to monitor or quantify the effect of the environment variation on the sample behavior. When it is technically feasible this instrumentation is on-line (thermocouple, pressure gauge, LVDT, neutron detector etc.). If not, it plays the role of an integrator (e.g. neutronic fluence or melting wire). Other on-line sensors monitor the environment of the sample. A lot of information are gained from this type of instrumentation (close sample behavior follow-up, identification of behavior thresholds or non reversible turn points), which are of great interest for characterization, or qualification of the irradiated fuel or material sample. After that the sample is classically sent to hot cell laboratories for supplementary non-destructive and destructive examinations. This process represents a dramatic progress compared to the “cook and look” irradiations, which were implemented before the generalization of reliable on-line instrumentation and associated instrumentation and control channel. New irradiation devices are designed to embark a lot of instrumentation and to transmit the various signals properly [4], [5].

However, supplementary and valuable scientific information can also be gained within the MTR process, thanks to intermediate non-destructive examination (NDE) on the sample and to specific laboratories that can welcome and analyze fluids in contact with the sample. When these facilities are available in a research reactor, a considerable improvement of the experiment scientific quality can be offered to the end-user, often with no specific handling (no supplementary risk for the sample) and with a limited time consumption which doesn’t jeopardize the experiment unfolding.

NDE methods can be implemented during the reactor intercycle on underwater benches that are able to gain information on the sample still mounted on the sample-holder and connected. X-ray radiography and tomography, gamma scanning and tomography, or neutronography are the more common techniques encountered in MTRs. At the end of the irradiation process, sample is unloaded from the device and disconnected from the sample-holder. Examinations are then performed in MTR hot cells depending on the available equipment: precise X-ray radiography and tomography, gamma scanning and tomography can be applied directly to the sample.

The main support offered by implementation of NDE is:

- Initial checks of the sample and confirmation of its acceptable status before starting the irradiation:
    - Handling possible effects (e.g. after transportation or reparation, or after insertion in the device),
    - Precise positioning of sample or sample-holder instrumentation,
- Help to manage the irradiation time history by gaining first results on the sample behavior and adjusting experimental protocol:
    - Power time history fine tuning (after a short experimental run at reduced power),
    - Detection of unexpected sample behavior,
    - Detection of specific elements offering a large contrast with some examination techniques (light elements, neutron absorber…)
- Gain of data not accessible by classical PIE in hot cells:
    - Maintain of a stress or an atmosphere applied to a sample
    - Quantitative measurement of short half-life fission products,
    - Slow geometrical transformations after irradiation,
- On the spot monitoring of the sample status after a soliciting test:
    - Handling limitation to preserve the “as tested” sample geometry,
    - Geometrical changes after an off-normal transient,
- Final check to define the “reference status” before transportation to hot cells.

Regarding analysis laboratories, such as a fission product laboratory or a chemistry laboratory, the objective is to be able to analyze fluids in contact with the sample:

- Loop coolant (gas or liquid) for measuring concentrations of corrosion, activation or fission products:

  - Corrosion test in normal operation,
  - Failed fuel test in normal operation,
  - Rewatering water after quenching at the end of a safety test,
- Gas blanket of a device when the coolant is not compatible with a transfer towards an out-of-pile part (e.g. Na, NaK, molten metal, stagnant water…):
  - Monitoring of a fuel-coolant interaction kinetics after a clad failure,
  - Balance of gaseous and volatile fission products released in the gaseous phase during an accidental sequence
- Sweeping gas of a capsule containing the sample, or of the inner free volumes of a rod:
  - Fission gas and helium release,
  - Gaseous chemical or radiolytical interaction products (H_2, T_2, CO, CO_2, CH_4, NH_3…).

Measurement systems comprise gamma, beta and alpha spectrometry for radioactive atoms, and gas chromatography, mass spectrometry, UV and IR spectrophotometry … for stable isotopes. These measurements can be applied on-line to the fluid coming from the in-pile part of the device, or after delay on a sample or from a trapping media.

A dosimetry laboratory is also of interest for quantifying doses of various types received by a material, a component or a sample. Specimens are of very small size and need a specific process to be recovered and routed to the laboratory.

One can also mention other laboratories which support indirectly the experimental process. Some of them have an operational objective because they are devoted to:

- Reception, final assembling or checking of new components or devices, outside the controlled area,
- Interventions on already slightly irradiated materials (maintenance, calibration…) in controlled area. However, if the dose rate or the contamination risk in not negligible, the work has to be done in the large material and fuel hot cells of the facility.

3. MAIN FEATURES OF THE NDE BENCHES AND ANALYSIS LABORATORIES IN THE FUTURE JULES HOROWITZ MTR

The global status of the Jules Horowitz Reactor (JHR) MTR is presented at this conference in [6].

3.1 Jules Horowitz Reactor (JHR) underwater NDE benches

The non-intrusive scanning systems will involve two sets of benches. They concern examinations on the experimental sample still within the test device. These NDE benches will be therefore underwater and located in the pool of the reactor and in a storage pool:

- 2 photon imaging stands will be located in the reactor pool for the first one and in the component storage pool for the second one (see figure 1). These 2 stands will be equipped with both gamma emission and X-rays transmission imaging systems set on a same mechanical bench and using a shared feed-through. The gamma photons used will be those self-emitted by the radioactive object since X-rays will require a dedicated generator as a Linac (Linear Accelerator) for instance installed behind the pool wall,

- A neutron imaging system using the neutrons escaping from the core at the mid-plane level. A picture of the analyzed object will be reconstructed from the attenuation of neutrons through the scanned object. This test stand would be located on the reactor pool flooring. However, the final decision to install it is not taken.

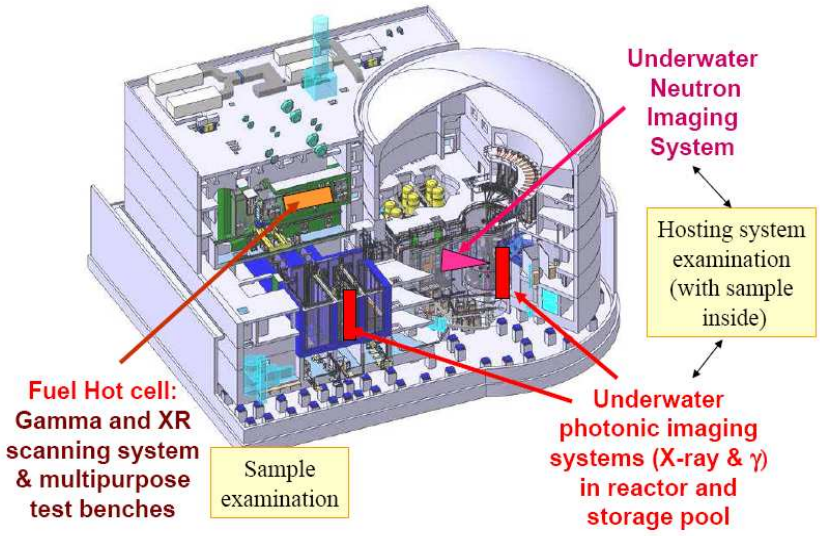


Figure 1: Location of NDE benches in the future Jules Horowitz MTR

3.2 NDE benches in JHR hot cells

The second set of benches concerns the examinations on the experimental sample itself after having been removed from the test device. These NDE benches will be placed into two “examination hot cells” dedicated respectively to fuel and to material sample handling and checking. These hot cells are located in the auxiliary building, and their sizes are 3.4 x 2.5 x 4.2 m^3 and 4 x 2.2 x 4.2 m^3 for respectively material samples and fuel samples examinations (see figure 2). They are connected to the JHR large hot cells welcoming irradiation devices and large irradiated components.
The objective of such examination hot cells is to collect the standard set of data obtained by non-destructive testing which i) are valuable for the scientific aim of the program and ii) can be obtained largely earlier than for the classical irradiation process (transportation in a hot cell laboratory):

- External aspect: visual inspection, macroscopy, open cracks,
- Metrological techniques: dimensions, growing, creep, density evolution,
- Oxidation and corrosion: weight increase, corrosion layer thickness,
- Internal flaws detection and characterization using ultrasonic (US), X-ray and Eddy Current techniques,
- Distribution of radioactive emitters by gamma scanning and of sample internal density by X-ray tomography imaging.

For that aim, study of several benches is in progress. One can mention in the fuel examination cell a coupled X-ray – gamma vertical bench, and a multipurpose horizontal NDE bench.

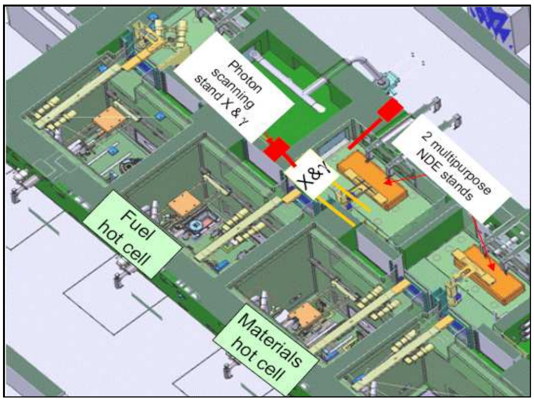


Figure 2: Multipurpose NDE benches for fuels and materials expected in JHR hot cells

These on-site PIE programs will be of course completed by destructive examinations programs in hot cell laboratory, which participate also strongly to the success of the experimental process.

3.3 Fission product laboratory

The fission product laboratory (FP Lab.) will be solely devoted to the on-line and delayed measurement of radioactive and stable fission products, their temporary trapping for further measurements, and their purification and storage as a waste. This infrastructure will be based on shielded cells connected either to irradiation devices or to experimental cubicles, or to the both. Depending on the device and the type of fluid to monitor, the measurement can be carried out either on the fluid coming directly from the in-pile part (e.g. the coolant or the upper gas blanket) or on fluid present in the cubicle (e.g. for sampling). Equipment study of this laboratory is still in progress, and so far four main components are planned:

- A shielded cell devoted to measure radioactive and stable fission gases by on-line gamma spectrometry and on-line mass spectrometry (this new device is under development). This cell will also contain a set of traps coolable until liquid nitrogen temperature to retain xenon and krypton,
- A shielded cell capable to welcome coolant routing an elevated fission product concentration. Measurements on the passing fluid will be based on on-line gamma spectrometry, delayed neutron detection (DND) and sampling,
- A third shielded cell connected to the two previous ones will welcome the samples taken and will deal with the delayed counting and the short-term storage between two measurements
- A ventilated glove box for counting gas coolant or sweeping gas with low concentrations of radioactive and stable noble gases (Xe, Kr), or other gases (He, CO, CO_2…).

These components will be progressively installed in the FP Lab., depending on the expressed needs for programs coming from future end-users.

3.4 Chemistry laboratory

This laboratory will deal mainly with the experimental part of the JHR. Its role will be:

- To verify that the chemistry characteristics of the various coolant used in the loops are within the specifications,
- To welcome samples taken in the fission product laboratory or in the experimental cubicles, and to quantify isotopes or elements, relevant for the scientific objectives of an experiment, thanks to specific measurement systems,
- To analyze gaseous and liquid wastes released by the experiments,
- To support the operation of the JHR.

So far the scientific equipment of this infrastructure is not completely defined. However a first set of recommendations regarding the type of valuable techniques to install in a modern MTR has been released at the European level thanks to the European program “MTR+ I3” (6^{th} Framework programme) [7].

3.5 Dosimetry laboratory

The dosimetry laboratory aims to analyze dose integrators (mainly for neutronic fluence and spectrum tailoring) placed either in experiments or in JHR components near the core, previously recovered and packed in a hot cell. This infrastructure will take benefit from the large know-how gained at CEA on the dosimetry surveillance program in French power reactors.

Sample-holders containing dosimeters will be unloaded from the irradiation device in the material or the fuel hot cell, depending on the program. Then dosimeters will be extracted in the material examination hot cell. After that, they will be sent to the analysis laboratory thanks to a pneumatic transfer channel.
The general process to recover the dosimeters has been defined. The equipment of the dosimetry laboratory is being studied.

4. DEVELOPMENT STATUS OF THE JHR UNDERWATER GAMMA - X-RAY BENCH

This paragraph is focussed on the underwater gamma-X-ray bench (UGXR bench), for which the study is the most advanced among the set of imaging benches planned for the JHR. Basic and detailed design is currently realized by the Finnish research institute VTT as an in-kind participation to the JHR facility building, with CEA collaboration, as well as later on the manufacturing, mounting and calibration on the JHR site. For that aim a bilateral agreement has been signed between VTT and CEA. Concerning the specific high level imaging components or technologies, VTT also subcontracts design and development work from specialized Finnish companies, such as Oxford Instruments Analytical Oy (OIA) for the X-ray imaging.

4.1 Main experimental specifications expressed by the end-users and technological constraints

The X-ray imaging system (radiography and tomography) by transmission and the gamma tomography system by emission are mainly characterized by the objective to check with a high spatial resolution the irradiated experimental sample when it is present in the irradiation device and still connected to the sample-holder. This implies strong technological constraints:

- To go through a considerable thickness of metal (mainly stainless steel or Zircaloy) constituted by the irradiation device pressure tube. The total wall thickness to penetrate can reach several centimeters,
- To have a spatial resolution largely smaller than the size of the object to check, to identify valuable details (fuel cracks or inter-pellets, dense material grains or chips, sensor heads, connectors…). For example, as the outer diameter of a LWR fuel rod is typically near 1 centimeter, the targeted geometrical resolution performance on the object is near 100 micrometers. This request has strong consequences on:
    - The thinness of the detected gamma or X-ray beam,
    - The elementary displacement step of the mechanical bench supporting the checked object (translation, rotation angle, vertical axis conservation during a rotation, etc.),
- To produce if necessary the requested results during the JHR intercycle period, during which benches are accessible (JHR handling means availability…). This means with a limited acquisition time and consequently a quick separation signal/background. This necessitates, for the X-ray imaging system, the use of a linear accelerator (6-9 MeV range),
- To protect the X-ray detectors from the intense gamma emission supplied by the experimental fuel sample itself.

Moreover, regarding the gamma imaging system, some additional issues shall be taken into account: the sample can present:

- A wide range of radionuclide inventory that necessitates a relevant choice for the pre- and post-collimation system design, the set of screens and the detector. Experimental programs will deal from fresh fuel with a short irradiation period (e.g. to quantify beginning of life properties of an innovative fuel material) up to high burn-up rods coming from power reactors and refabricated. Moreover one can also face to the more difficult case of a high burn-up rod re-irradiated at low linear power, the aim consisting in the detection of short half-life fission products of interest among a high Compton background coming from long half-lives isotopes emitting gamma rays at higher energy,

- Various decay time before starting the examination, according to the program objectives. The target can be to measure short half-life fission products, to gather the maximum of information. In this case the first spectrum can be gained a few hours after the end of the irradiation (e.g. after a safety test). Another case can be to select a few radionuclides of interest and to start the examination at the optimum detection decay time. For that it can reach several days and consequently the radionuclide inventory in the sample is much lower.
- A wide range of sample shapes that imposes a suitable pre-collimator geometry set with a change system operated easily. For example, the pre-collimator geometry can range from 0.5*5 mm (for gaining a gamma emission tomography) to very narrow slits (e.g. 13*0.5 mm for a standard gamma scanning on a single rod or even 40*0.5 mm if a rod cluster has to be checked). The collimation principle is given on figure 3.

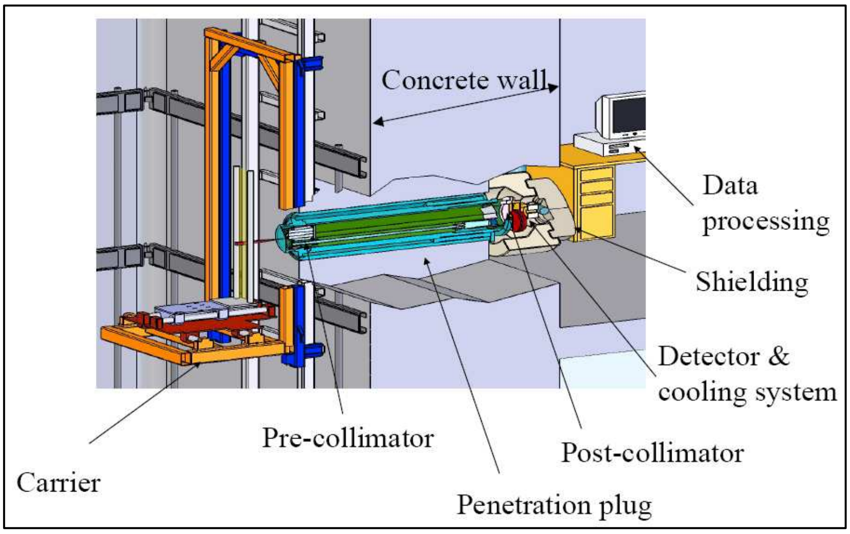


Figure 3: Main components of a standard underwater gamma spectrometry bench (The post-collimator includes the possibility for screen insertion)

4.2 Mechanical design of the underwater benches

The choice was to duplicate the same design for the both UGXR benches (in reactor pool and in the component storage pool) in order to simplify the study and to offer the same complete service offer at the highest measurement quality level. This strategy integrates a convincing experimental feedback showing that this type of bench is very demanded at the MTR intercycle and that often one exemplary cannot face to all requests.
The bench located in the reactor pool will be mainly devoted to irradiation management, and will carry out short examinations during the intercycle, in order to continue the irradiation during the following cycle. However the both benches will be also used during the JHR cycle for longer checkings (e.g. tomography).
As an example a global and simplified view of a standard UGXR bench is given on figure 4.

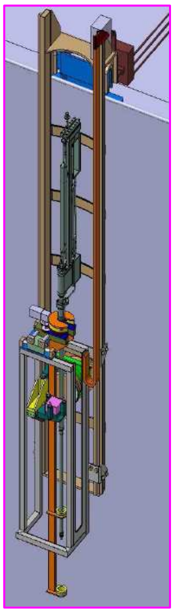


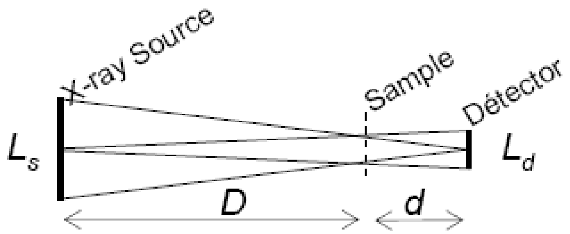
Figure 4:
Example of a mechanical bench 3D view

The mechanical design of the bench is in progress and integrates:

- A high displacement accuracy and positioning reproducibility despite important device masses to welcome and an important vertical stroke to cover (800 mm and 1100 mm respectively above and under the sample mid-height plane, and 200 mm on horizontal axis),
- A robustness regarding the seismic risk, with a satisfactory behavior versus the safety criteria,
- The mastering of the bench frame handling inside the JHR facility, in regards of the security and the safety,
- The sizing of the biological protections around the accelerator and the irradiation device,
- An instrumentation and control system compatible with the JHR facility requests.

4.3 R&D work on X-ray imaging at high resolution

To perform X-ray imaging at high resolution with an underwater bench in nuclear environment represents a real challenge. The first step consists of defining an objective in terms of spatial resolution that is ambitious but feasible technologically. This objective can be expressed as a final geometrical resolution of the system called the "geometrical blur" LF, which is defined by the following formula given on figure 5:



$$LF \equiv \sqrt{L_s^2 \times \left(\frac{d}{d+D}\right)^2 + L_d^2 \times \left(\frac{D}{d+D}\right)^2}$$

Figure 5: Definition of the geometrical blur in an X-ray imaging system

With:

- L_s: Size of the focal spot of the accelerator. Accelerator model choice will lead to a size of about 300 micrometers.
- D: Distance between the X-ray source and the centre of the checked object. In the JHR UGXR configuration, this distance will be about 2.7 m.
- d: Distance between the centre of the checked object and the X-ray detector. An optimisation of this parameter is necessary. Technological constraints exist (size of the irradiation device, place to handle it…) but also the effect of the gamma rays emitted by the sample on the X-ray detector has to be taken into account.
- L_d: Size of the elementary detector. Strong technological difficulties are related to this parameter, which necessitates a significant R&D work at VTT and OIA.

Two parameters are input data fixed by the JHR design and the mechanical design of the bench: D and d. The two others parameters are manageable (L_s and L_d) and require an important R&D work to reach the best values accessible with the current state of the art. So far a final target about 100 micrometers for LF is considered as reachable, and will drive the continuation of the JHR UGXR bench study.

The second step is to define the optimized shape for the X-ray beam by collimation. As represented on figure 6, a first horizontal slit in a pre-collimator allows obtaining a thin horizontal beam (about 2 mm in height) with an aperture capable to cover the total width of the irradiation device (up to 100 mm). After traversing the object, a post-collimator provokes a supplementary decrease of the height of the beam in order to reach the targeted spatial resolution.

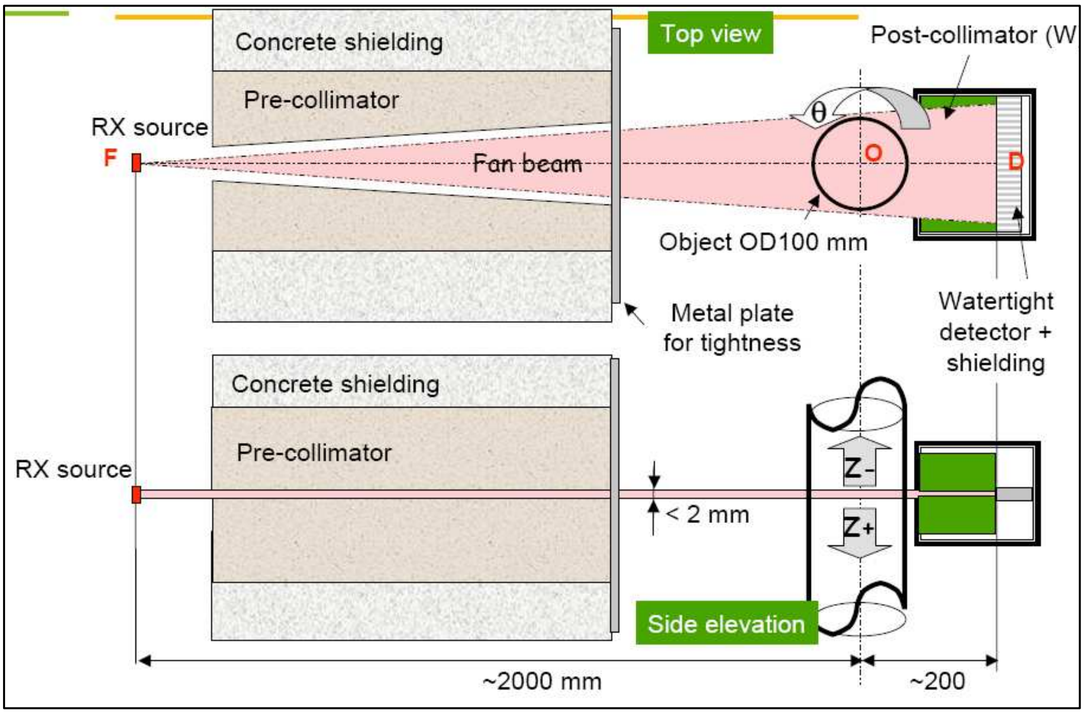


Figure 6: Basis principle for obtaining a thin X-ray beam on an object located far from the X-ray source

Finally, a third step consists of listing the parameters influencing the high resolution and consequently the performances of the X-ray tomography system. These parameters come from limitations of the components constituting the system: mechanics, electronics, signal sampling and numerating, photonic noise, photon-material interaction etc. An important work is currently carried out at VTT to model the system and to make the suitable technological choices.

4.4 Current status of the X-ray tomography system studies

Technical exchanges between VTT, OIA and CEA allowed converging on first technological choices summarized as follow:

- A narrow post-collimator (about 50 micrometers) in order to reject emission photons diffused by the sample and to discriminate the direct photons,
- A thin X-ray detector in form of a horizontal slice (target of thickness and pixel width of about 50 micrometers), but having a depth sufficient for an efficient X-ray photon-atoms interaction (several centimeters). This interaction can induce recoil electrons if the detector is made of a semi-conductor, or light if it is made of a scintillating material. In both cases high temporal resolution electronics shall be used for detecting these emerging particles. So far a semi-conductor material based on the GaAs technology is preferred and proposed by OIA and VTT. One shall notice that such targeted detector is totally innovative when used with a far X-ray source. It will require a strong effort on basic research about radiation-material interaction and a suitable process for the prototype qualification.

Other studies are still in progress to optimize the system. One can mention in particular:

- Modeling of the detector size in height, which shall be a compromise between the geometrical resolution and the detection scattering by photonic noise,
- Integration in the modeling of the non parallel shape characteristics of the X-ray beam,
- Image reconstruction work with a lot of adjacent elementary X-ray detector pixels,

- Parallel reviewing of all the system components and design choices in order to find permanently the best compromise between the performance target and the technological difficulties (manufacturing, handling, operation, maintenance) that could provoke a dramatic and unacceptable system cost increase.

4.5 Current status of the gamma imaging system studies

Even if such a system is less innovative than the previous one and currently more used in nuclear facilities, some adaptations and optimizations shall be carried out taken into account the JHR facility design and the specificities of the checked samples (mainly geometry and activities). For that aim, current studies concern:

- The definition of the pre- and post-collimator set, according to various sample types to accept (rods, plates…), the counting rate at the detector level, the type of scientific information requested and the allowed examination planning,
- The choice of the detector type and sensitivity according to the activity range to be measured and detailed in § 4.1. For that aim, several radionuclide inventory cases have been selected as input data for pulse height and rate calculations and gamma spectrum reconstruction.

An example of gamma spectrum reconstruction with the MCNP code is given on figure 7 below.

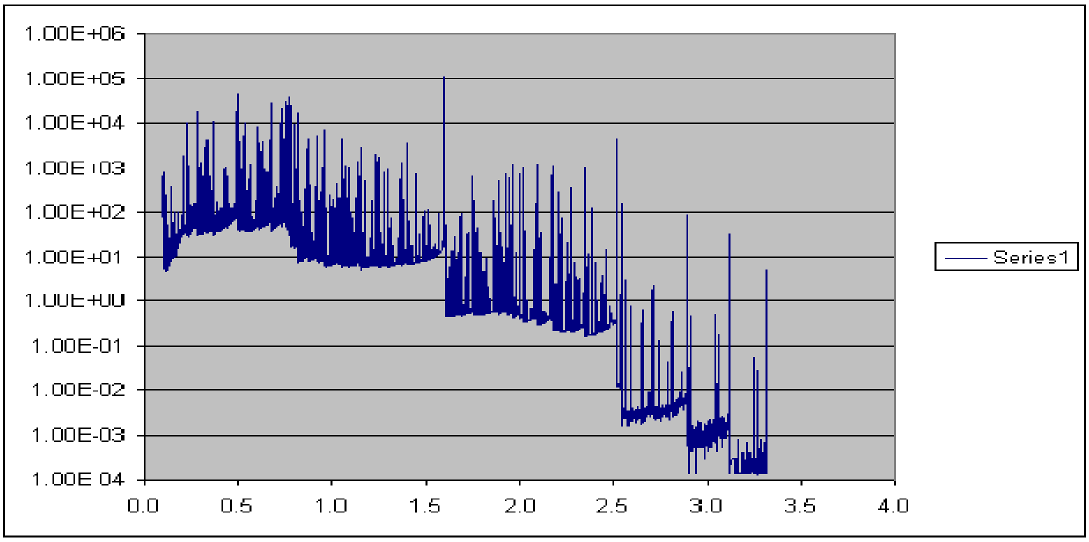


Figure 7: Example of gamma spectrum reconstruction with the MCNP code for a LWR rod present in an irradiation device (counts versus the gamma energy in MeV)

5. CONCLUSION

The work carried out on the non-destructive examination benches and the analysis laboratories of the JHR presented in this paper is driven by identified and expected future experimental requirements. The design work of the whole park of these infrastructures, and the associated priority, is dependent from:

- The type of support offered and its place in the experimental process,
- The requested performances versus the complexity of the component and of its integration in the JHR facility,
- The maturity of the program demand, from the scientific community and from utilities and the industry,
- The associated development and manufacturing cost.

As a consequence, the current work selected firstly the type of infrastructures necessary for a good experiment quality, and to optimize the requested performances versus the JHR operation planning and the cost. Future evolutions or development of new benches will likely occur, and equipment of analysis laboratories will be progressively completed.

The international collaboration for designing the performances of the JHR irradiation devices and associated measurement laboratories and non-destructive examination benches is of major importance. This collaboration has already taken place within the European Community thanks to the Integrated Infrastructure Initiatives Program “MTR+ I3”, which ended at the end of September 2009. It will progressively take a more significant place by identification of future irradiation market evolutions, and by the strategy applied by the JHR Consortium members and the Jules Horowitz International Program (JHIP) driven by OECD/NEA. To participate to these organizations now is a relevant opportunity for a win-win approach, gathering needs and developing suitable scientific infrastructures to fulfil them, and before technical choices have been finalized to respect the JHR facility operational starting planning.

REFERENCES

[1] Irradiation facilities and examination benches for implementing fuel programs in the future Jules Horowitz Material Test Reactor
D. Parrat, M. Tourasse, C. Gonnier, S. Gaillot, P. Roux
12th International Group on Research Reactors (IGORR 12)
Beijing, P.R. China, October 28 – 30, 2009

[2] Development status of irradiation devices for the Jules Horowitz Reactor
C. Gonnier, D. Parrat, S. Gaillot, J.P. Chauvin, F. Serre
ENS Research Reactor Fuel Meeting (RRFM 2008), 02-06 March 2008, Hamburg, Germany

[3] Safety experiments in the Jules Horowitz Reactor: Dedicated loops within a modern experimental facility
S. Gaillot, D. Parrat, C. Gonnier, J.P. Chauvin
International Conference on the Physics of Reactors (PHYSOR 2008)
Interlaken, Switzerland, 14-19 September 2008

[4] The ADELINE irradiation loop in the Jules Horowitz MTR:
Testing a LWR fuel rod up to the limits with a high quality level experimental process
S. Gaillot, D. Parrat, G. Laffont, C. Garnier, C. Gonnier
12th International Group on Research Reactors (IGORR 12)
Beijing, P.R. of China, October 28 – 30, 2009

[5] The MADISON experimental hosting system in the future Jules Horowitz Reactor
P. Roux, C. Gonnier, D. Parrat, C. Garnier
13th International Group on Research Reactors (IGORR 13)
Knoxville, Tennessee, USA, 19-23 September, 2010

[6] The Jules Horowitz Reactor: A new European MTR open to International collaboration, Description and status
G. Bignan, D. Iracane, X.Bravo
13th International Group on Research Reactors (IGORR 13)
Knoxville, Tennessee, USA, 19-23 September, 2010

[7] Integrated Infrastructure Initiatives for Material Testing Reactors Innovations (MTR+ I3)
Final report
European Project FI6O 036440 – 01/10/2006 – 31/09/2009
www.mtri3.eu