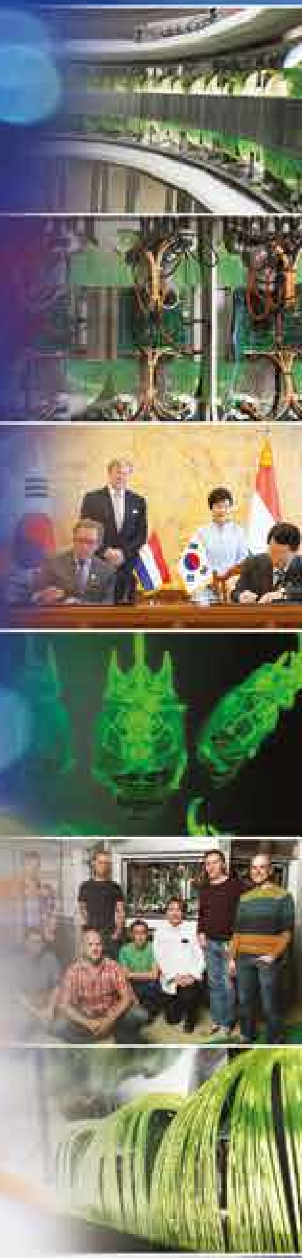
2014
OYSTER
Annual Report
Building Pearl and concluding the tender



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Foreword

We are very proud of our first OYSTER beam instrument, PEARL, which is about to be taken into operation. PEARL will permit the unravelling of the crystal structure of (energy) materials, such as lithium batteries, hydrogen storage materials and magneto caloric devices. The PEARL-team started the 'hot commissioning phase' of this neutron powder diffractometer in 2014. The experiments to-date show that they are building a competitive instrument with very promising results. The instrument will be calibrated in the first half of 2015. It will enable scientists to perform experiments in Delft and not at other neutron sources such as in France or the UK.

In addition to this, our scientists have built the science case for attracting external funding for another beam instrument called FISH. FISH refers to First Imaging Station Holland and is a neutron instrument by which a very versatile way of looking in the inside of objects becomes possible without having to destroy them. It will serve a broad community of users from industry, material science, cultural heritage to biology.

The funding we attracted for our positron instrument PALS will enable us to get a better understanding of how very small defects in materials are created through prolonged exposure to humidity and light. This technique is, among other things, very important in developing production methods for improved long-term stability of solar cells.

We have finalised the European tendering process for selecting the main contractor who will be responsible for building a cold neutron source in our reactor. This will allow us to increase the intensity of low-energy neutrons which will improve the sensivity of our instruments. Following an intensive and careful selection process with the pre-selected suppliers the contract agreement with consortium KHC; KAERI, Hyundai Engineering and Hyundai Engineering & Construction was signed on November 3. His Majesty the King of the Netherlands and the President of the Republic of Korea attended the ceremony. We are happy to notice that the Korean companies are highly motivated to introduce their innovative nuclear designs to the European market. The current annual report provides an update to all these areas along with more OYSTER related issues of interest.

This third OYSTER year was a very rewarding year enabling us to look with confidence to the future. For next year we will continue building and expanding our instruments and irradiation facilities. And, it goes without saying that the necessary preparations for the reactor modifications are being continued.

Prof. dr. Bert Wolterbeek
Director of the Reactor Institute Delft
Head of the Department on Radiation Science & Technology

Contents

OYSTER in short

An introduction (pages 4-7) to the OYSTER programme and RID.

The OYSTER programme (Optimized Yield - for Science, Technology and Education - of Radiation), co-funded by the Dutch government, TU Delft and a number of commercial parties, is to expand the potential of the research reactor by improvements and expansions of the RID infrastructure (reactor, instruments, facilities).

This expansion will enable current and future educational, scientific and societal questions to be better addressed. RID also contributes in-kind, through OYSTER, to the ESS (European Spallation Source in Lund, Sweden), by means of the development of neutron instruments.

The Reactor Institute Delft

The Reactor Institute Delft (RID) of TU Delft is a knowledge centre for nuclear issues. It operates the reactor, the irradiation facilities and laboratories, as well as neutron- and positron instruments. In conjunction with the Department of Radiation Science & Technology (RST) of the Faculty of Applied Sciences, RID accommodates resident and visiting scientists and other users from a variety of (scientific) disciplines. RID educates students, professionals and scientists, and serves as an independent source of information for society on radiation- and nuclear-related issues.

The technique

The installation of a Cold Neutron Source (CNS), which will cool neutrons from room temperature to -250 ºC and will therefore increase the intensity of low-energy neutrons by more than an order of magnitude. This will improve the sensitivity of existing top-class instruments.

The design and construction of new research instruments.

The (re-) design and construction of (new) irradiation facilities, which permit the (development of) production of radioisotopes with unprecedented purity and which will increase the sensitivity and opportunities of research with isotopically enriched stable isotopes.

The design and installation of a miniature hot-cell/decanning facility for submerged access of irradiated samples from the irradiation facilities. The hot cell serves mainly as a decanning facility of canisters containing samples, irradiated for the research programme by innovative production methods of (medical) radioisotopes, and for subsampling of these samples to study radiation damage effects.

The design of irradiation facilities positioned in the tangential beam tube of the reactor, to undertake research into alternative production methods for e.g. Molybdenum-99 (99 Mo).

Our five main goals

1 To further develop RID as a coordinating centre for the application of neutron, positron and radiochemistry science and techniques, as well as radiation detection and reactor technology, thereby supporting and uniting the Dutch scientific community.

2 To create a home base for neutron scattering and mobilize the scientific community to secure Dutch collaboration with major international neutron sources.

3 To establish RID as a knowledge centre and training institute in Europe, and therefore a coordinating partner in European research networks.

4 To stimulate ground-breaking innovations in the field of neutron, positron, reactor and radiochemistry science.

5 To sustain RID's leading role in the use and knowledge of world-class instruments, such as continuous positron beams, as well as the development of new routes for radioisotope production and the ISO 17025 accredited laboratory for Instrumental Neutron Activation Analysis.

Participation in large international and national collaborations

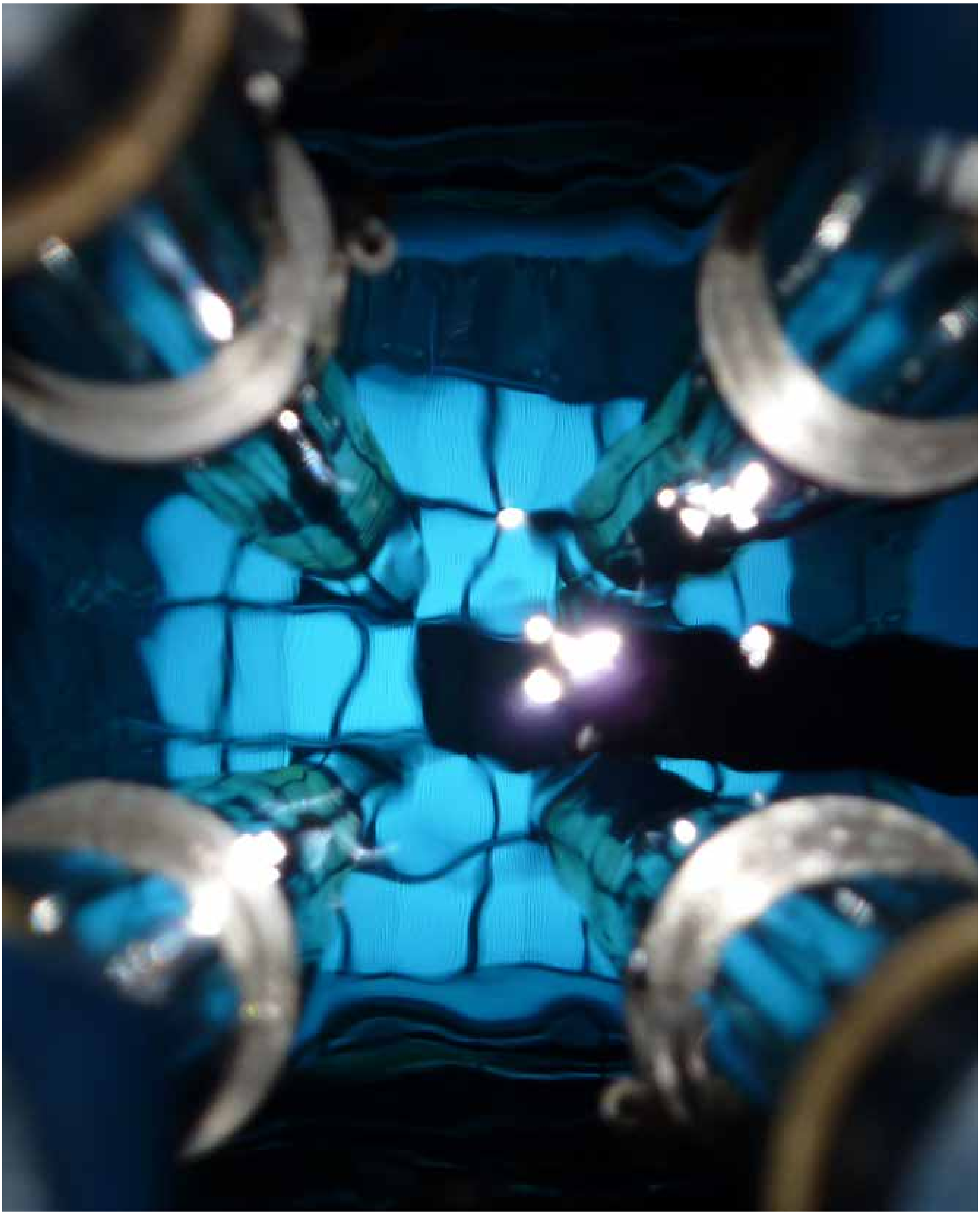
RID participates in the development of the European Spallation Source (ESS, www.EuropeanSpallationSource.se) in Lund, Sweden, which is an international collaborative facility for materials research using neutron scattering techniques. The Dutch contribution to the pre-construction phase of the ESS is partly financed through OYSTER. For this purpose RID works on the development of novel instrumental concepts for the ESS and in close collaboration with the ESS scientists.

RID participates in the R&D of Holland Particle Therapy Centre (Holland PTC, www.HollandPTC.nl) dedicated to innovative radiation treatment of cancer, using proton beams, as well as in a collaborative R&D program at TU Delft, the Leiden University Medical Centre (LUMC) and the Erasmus University Medical Centre Rotterdam (Erasmus MC). HollandPTC is under construction and will be located on the RID premises.

OYSTER research also strengthens the role of RID in supplying innovative ideas towards the envisioned PALLAS reactor (www.pallasreactor.com), which is to become one of the world's leading production sites for medical isotopes.

The OYSTER-initiated new irradiation facilities enhances RID's position in DIVA (Dutch Isotope Valley). This is an R&D collaboration set up between URENCO, RID and NRG/PALLAS, aimed to optimize efforts to develop, engineer and produce the best possible medical isotopes for clinical use in both (radio)diagnostic and (radio) therapeutic hospital protocols.

Finally, OYSTER highlights the role of TU Delft's RID as an International Atomic Energy Agency (IAEA) Collaborating Centre by demonstrating the many innovative scientific opportunities in the utilization of a medium-sized university research reactor.



Reactor & Utilities

The modification of the reactor deals with a modification of the connection between core and instrument facilities in order to allow the installation of a Cold Neutron Source (CNS). The objective of this modification is to increase the cold neutron flux in order to realize the best conditions for experiments connected to the neutron beam.

Cold Neutron Source Utilities consist of the installation of all utility systems to the CNS which will be located outside the reactor building. This includes a new CNS Utility building with a cryogenic installation next to the Reactor hall and all associated equipment required to produce cooling capacity for cooling the Cold Neutron Source.

Closing out the EU competitive dialogue tender

Photo: Signing of contract agreement in South Korea (Robin Utrecht Fotografie)

In Q2 2014 all pre-selected parties presented their final tenders for the realisation of the OYSTER project. Many technical discussions took place between RID and the potential suppliers as part of the tendering process. In order to support the decision process our External Expert Team (see Box) was consulted. A major contribution by the expert team was made to the evaluation of the various contractor designs during the European tendering procedure. The team's conclusions were used as an important background to independently support the decision making process. Further involvement of the Expert Team is foreseen after the final supplier selection to support the engineering and construction phase (from Q2 2015 until 2018).

After this intensive and careful selection process, the clear decision could be made to select the consortium KHC; KAERI, Hyundai Engineering and Hyundai Engineering & Construction, as the winning contractor to implement the OYSTER Engineering, Procurement & Construction (EPC). On November 3 the contract agreement between TU Delft and consortium KHC was signed in South Korea attended by his Majesty King of the Netherlands and the President of the Republic of Korea.

As part of the OYSTER contract, a Go/No-Go decision based on a total cost estimate and a fixed project schedule is planned after receiving the basic engineering design. This milestone was included as during the time of contract award the impact of the DSR legislation on the original scope as well as the final cost of the OYSTER project was not known.

The external expert team

Toni Scheuer
Nuclear Technology Consultant for TUV Rheinland Group. Specialized in licensing issues, and material- and component qualification.

- Welding procedures, Materials, Codes & standards

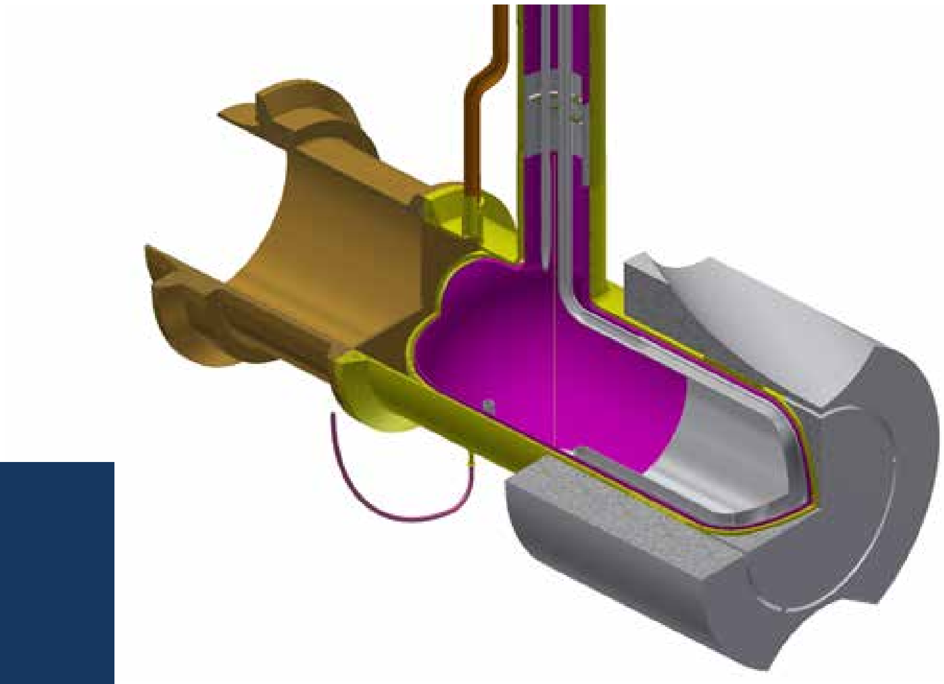
Stephan Welzel
Chief coordinator reactor upgrade Helmholtz-Zentrum Berlin specialized in CNS process technology and operational aspects

- CNS process technology

Stuart Ansell
During 2014 scientist at ISIS STFC (UK) specialized in Cold Neutrons equipment design for research reactors.

- Leading specialist for optimization processes neutronics

Besides the involvement of the expert team, Nuclear Research and consultancy Group (NRG) was hired for the preparation of the Safety Analysis Report and the environmental impact assessment. In a joint effort between RID, the supplier and the Regulator, the DSR will be further worked out to a final status.



Start of the basic engineering design

The basic design phase of the Reactor Modifications and CNS Utilities started in 2014.

Figure: Cross section of the Cold Neutron Source (KAERI)

The main issues were the sizing of the thermosyphon as part of the In-Pool-Assembly for the Reactor Modifications. The basis for this is the correct simulation of our core performance together with the new CNS equipment.

The basic safety philosophy for the CNS has already been established, including the safety classes, quality classes and the codes and standards to be used. This resulted in a document that has been discussed with the Regulator.

The choice of cryogenic unit became the most important challenge for the CNS Utilities package. Firstly, given it had to be located near the reactor in a separate building as yet to be designed, this was also partly due its size. The simulation also plays a crucial role here in determining the total cooling capacity.

The cost estimate based on the above detail of the original OYSTER Scope of Work will become available in Q2 2015 together with the best estimate of extra costs related to the new Dutch Safety Requirements (DSR). However this extra cost will remain uncertain as long as the final DSR legislation is not established.

Licensing

'Environmental Impact Assessment' (MER)

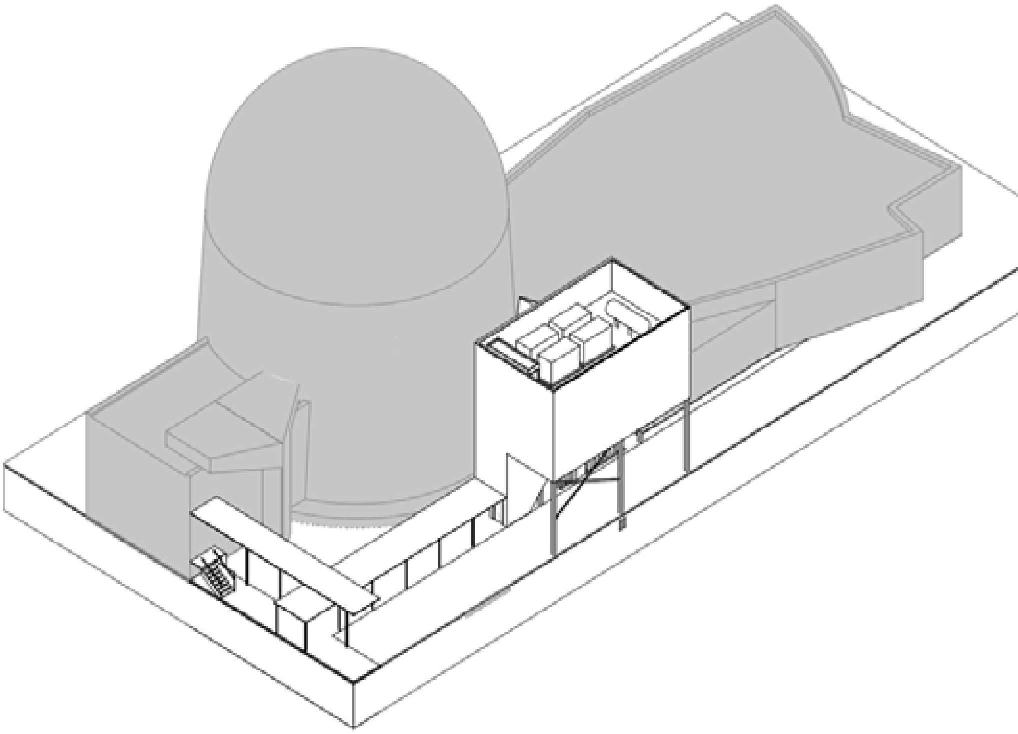
One of the conditions for obtaining a new operating permit for the RID reactor is to describe the impact of the OYSTER modification project on the environment, through a so-called Environmental Impact Assessment (milieueffectrapportage, MER). The Ministry of Economic Affairs issued a detailed set of MER guidelines for the OYSTER project ('Notitie Reikwijdte en Detailniveau') in 2013. An elaboration of the study has been started since this point. The MER preparations will take until the end of 2015.

Dutch Safety Requirements (DSR)

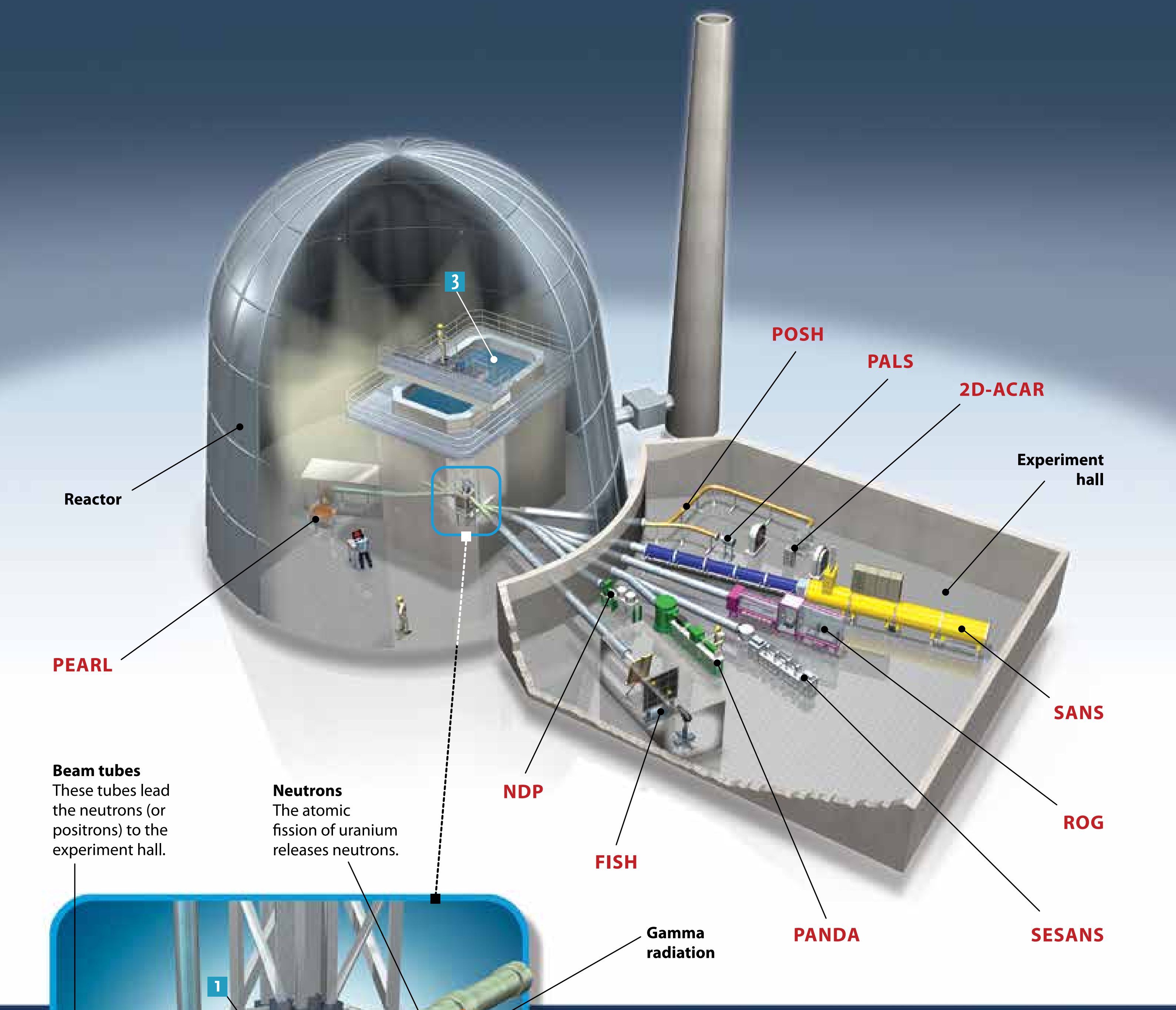
The OYSTER project necessitates a renewal of the existing license for the RID reactor. From the start of 2013 onwards the required licensing procedures and the associated review schedules for the OYSTER project approach have been discussed with the regulator at the Ministry of Economic Affairs.
In June 2013, new and more stringent Dutch Safety Requirements (DSR) for new nuclear reactors were presented at a workshop and the Dutch nuclear community was invited to participate in the discussion with the Dutch regulator for advice and comments regarding the further development of these new requirements.

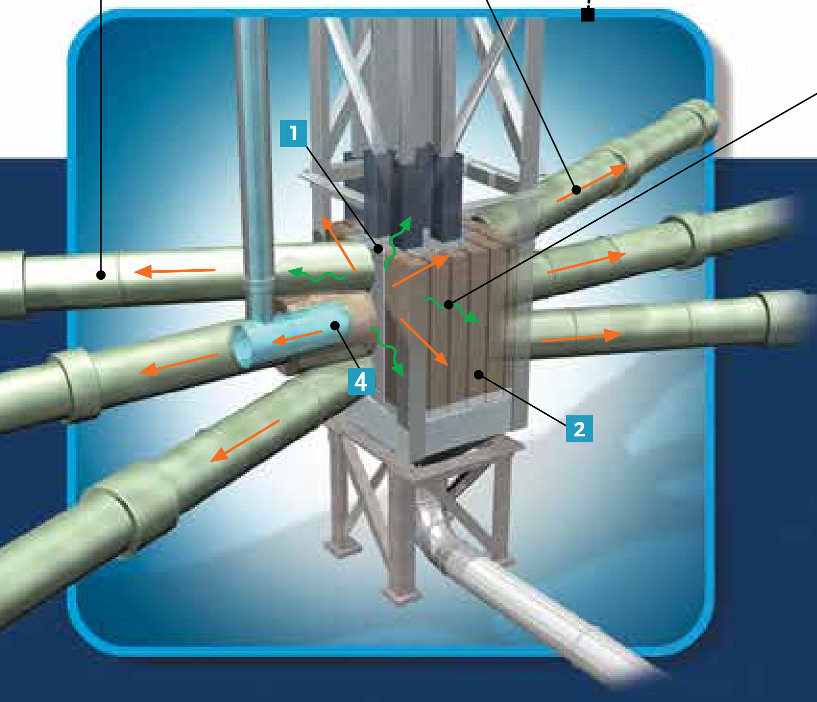
As presented during the workshop in June 2013 a draft version of the DSR was expected mid-2014. In December 2013 the Ministry of Economic Affairs reported that the draft version of the DSR would be ready for internet consultation by mid-2014 and the implementation would follow at the end of 2014. However, in December 2014 the ministry issued notice that the formal publication of the DSR had been postponed to mid-2015. Therefore the original overall delay due to the DSR impact estimated at one year might increase.

Figure: View of the building with future modifcations (Kaan Architecten)



Measurement instruments
around the research reactor





1 Fuel element
This element (8 x 8 x 60 cm) comprises 19 airtight aluminium boxes each enclosing a thin plate of uranium silicide.

2 Reflector elements
Beryllium (a metal that absorbs almost no neutrons) elements are used to reflect neutrons that do not fly directly into the beam tubes back to the fuel elements.

3 Water pool
The water slows down fast neutrons and cools the reactor core.

4 Neutron cooler

Instruments

The instruments: developments during 2014

- PEARL – a neutron powder diffractometer (under construction)
- FISH – a new multi-purpose neutron imaging facility, unique within a radius of 500 km. from RID (first preparations to attract external funding)
- POSH-PALS – positron annihilation lifetime spectroscopy, using positrons from POSH (external funding granted, first preparations for execution)
- SANS – a new small angle diffractometer with a dedicated cold beam line (under construction)
- NDP – neutron depth profiling spectrometer (first results)
- MÖSSBAUER SPECTROSCOPY – a new in-beam Mössbauer facility (first preparations to attract external funding)

Commissioning PEARL: a competitive neutron powder diffractometer

The neutron powder diffractometer PEARL will unravel the crystal structure of materials, for example, energy materials such as batteries and hydrogen storage materials. To achieve that, PEARL reflects neutrons of a particular wavelength from the reactor core to the sample. The neutrons scattered by the sample are measured by the detector, which is located around the sample. The distribution of the intensity of scattered neutrons around the sample (i.e. the resulting diffraction pattern) is the 'fingerprint' of crystal structure inside the sample.

Photo: Fibres of the PEARL instrument (Herman Kempers Fotografie)

The 'hot commissioning phase' of the PEARL neutron powder diffractometer started in 2014. The PEARL team built prototypes of the detector and the monochromator to be able to perform those first experiments. The design and construction of the final detector and monochromator was continued in parallel during the year.

By the end of the year 18 out of 24 monochromator crystals had been aligned and installed and the design of the detector was finalized in collaboration with the detector experts of the ISIS neutron facility at the Rutherford Appleton Laboratory in Oxfordshire (UK). All the main

hardware parts had been ordered. The in-house construction of the 11 128-pixel detector banks was finalized and all of the 1408 pixels had been calibrated in a neutron beam. This final detector will be installed in the beginning of 2015.

The 'hot commissioning' started off with copper foil measurements at the monochromator position and the sample position, which confirmed the thermal neutron fluxes simulated in 2011 and 2012. Using the prototype detector of 64 pixels in 2Θ, diffraction data was collected 'manually' to inspect the performance of the new concept as proposed by Leo Cussen in 2010[1]. Those experiments demonstrated that PEARL will be a competitive medium resolution diffractometer, despite the relatively low core brilliance.

In the first half of 2015 all major components of PEARL will be installed and the instrument will be calibrated. The first experiments will then be performed on energy materials, such as magneto-caloric, battery and hydrogen-storage.

1. L. D. Cussen, Nuclear Instruments and Methods in Physics Research A 583 (2007) 394–406.

Photo: Topview of the PEARL instrument (Herman Kempers Fotografie)

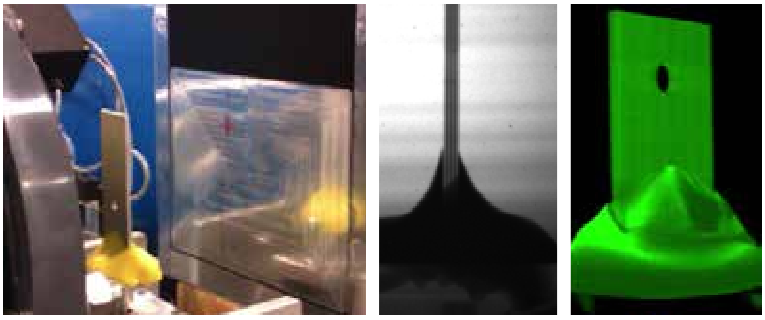
Photo: PEARL-team
(Herman Kempers Fotografie)

First Imaging Station Holland – FISH

Neutron imaging is a very versatile technique to reveal secrets inside materials without the need to destroy the object. Water or air bubbles inside concrete while it's hardening or plastic parts trapped in steel housing can be seen with neutron imaging, whereas this is not possible with X-ray imaging. FISH refers to First Imaging Station Holland and is a neutron imaging station that will be unique within a 500 km radius from Delft. This instrument is designed for neutron radiography and tomography, which given the nature of neutron radiation is complementary to X-ray imaging.

A pilot investigation entitled “Paving the way for a neutron imaging setup Delft” was undertaken to study the possibilities of a neutron imaging station in Delft. This pilot was designed to support the science case within an upcoming proposal to attract external funding. Potential users were selected and the researchers decided what could already be achieved using an improvised setup in the RID experimental hall. Several approaches to obtain the best images and best reconstructions were studied at the ‘state of the art’ imaging station at the Paul Scherrer Institute (PSI) in Switzerland. This resulted in many improvised imaging experiments with neutrons and X-rays, new reconstruction software and a new neutron camera.

The conclusion of the pilot investigation was that a Delft neutron imaging station would be a very powerful neutron application and serve a broad community of users from industry, material science, cultural heritage to biology. The instrument will be designed to be very flexible to cope with all the potential sample environments.

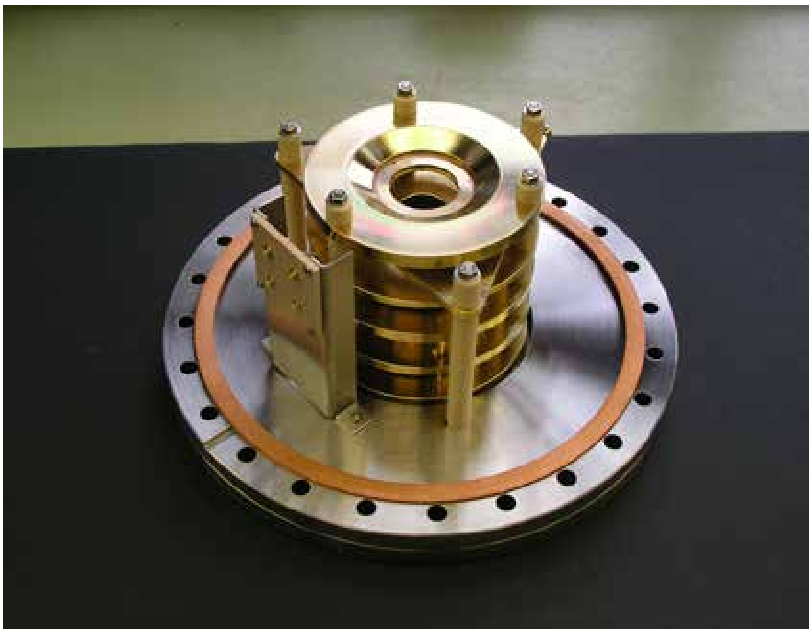


A piece of Glare (used on Airbus A380) mounted on a stepper motor to make 400 projections and the shiny surface of the neutron camera. The possible internal damage around the small hole is the focus of the investigation (left). One of the images where the laminated structure of the glare is clearly visible (middle). Tomographic reconstruction where we can make virtual cuts in the material so damage around the hole can be detected (right).

An example of a biological sample, a rhino Beetle, where the thickness of the protective armour was investigated without destroying the specimen (left). Several views of the tomographic 3D reconstruction of the sample (middle). A virtual cut can be made with ease to measure the armour thickness (right).

Positron Annihilation Lifetime Spectroscopy - POSH-PALS

Photo: Positron re-moderation lens system in the B to E convertor section



Positron Annihilation Lifetime Spectroscopy (PALS) is a unique method for identifying defects and their concentrations in materials. These defects, ranging from atomic vacancies to nano-voids, have a significant influence on the properties of many materials, but are usually too small to be made visible (e.g. with electron microscopy). An understanding of how such defects are created through prolonged exposure to humidity and light is therefore very important in developing production methods for improved long-term stability of solar cells. These are an important building block for future renewable energy supply in the Netherlands. Recent research into solar-cell materials shows that the presence of defects significantly affects the performance of promising thin-film solar and amorphous silicon solar cells.

In 2014, the proposal “Thin-film positron annihilation lifetime spectrometer POSH-PALS for advanced characterization of defects and nanostructures of thin film solar cell layers” was approved in the second phase of the ADEM (A green Deal in Energy Materials) programme. This includes a budget for the components required to construct the POSH-PALS positron lifetime spectrometer.

As of the beginning of February 2015 we will start working on computer simulations to optimise the POSH

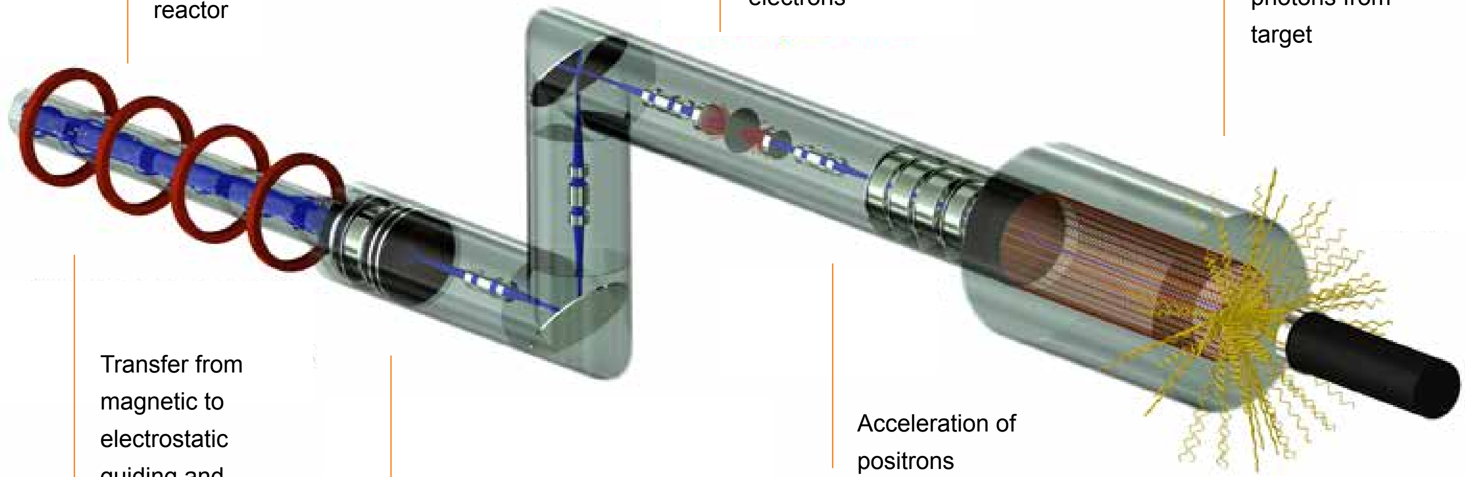


Figure: Schematic representation of the working of the POSH-PALS instrument

beam for a first detailed design for the POSH-PALS spectrometer. In POSH-PALS, the magnetically guided positron beam will be converted into an electrostatically guided beam with a sub-millimetre focus diameter. By generating secondary electrons as a starting signal for measuring the time that elapses between positron implantation and positron annihilation, the expectation is that a time resolution of 100-150 pico-seconds (ps) will be achieved developing an ultra-fast annihilation-radiation detector.

The depth resolution of the POSH-PALS spectrometer (10 nanometer to several microns) corresponds one-to-one to the thicknesses of the solar-cell layers. With a time resolution of 150 ps it will also be possible to investigate the behaviour of defects in self-healing metal alloys and in materials with applications in fusion and fission reactors, and to study their thermal stability. In addition, POSH-PALS will be an excellent instrument for studying the free volume in polymers.

The POSH-PALS spectrometer will be constructed and set up in 2015, and the expectation is that the first experiments will start in 2016. Solar cell materials, amorphous silicon, transparent conducting oxides and doped layers for silicon wafers will be researched in the coming years in collaboration with various universities, the Netherlands Organisation for Applied Scientific Research (TNO), the Energy Research Centre of the Netherlands (ECN) and Dutch solar-cell technology companies.

Small-Angle Neutron Scattering instrument - SANS

Photo: View of the SANS instrument under construction (Marc Blommaert)

The small-angle neutron scattering instrument (SANS) allows the user to investigate structures with particles of sizes from 1 up to a 100 nanometres. For larger particles neutrons scatter under smaller angles. This allows for a direct characterization of the particle size distribution within the material. Using this technique typically proteins, micelles, polymers, porous media and precipitates are investigated. These are of interest for the development of new products in the field of polymer science, colloids, emulsions, food science and metal alloys.

In 2014, the separate components of the SANS instrument were mechanically positioned in the experimental hall, aligned and fixed in their final position. The velocity selector was tested successfully and its software control was modernized.

In 2015, the 2D detector will be tested and the calibration of the instrument will be performed using the thermal neutrons of the current reactor source. The period before the installation of the cold source the instrument gives the opportunity to study strongly scattering samples and will enable preliminary neutron imaging studies. After the installation of the CNS the instrument will be able to perform at full capacity.

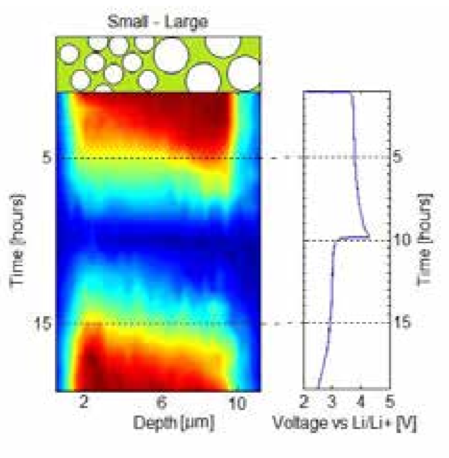
Neutron Depth Profiling – NDP

The Neutron Depth Profiling setup at the RID has recently started delivering its first results on working Li-ion batteries, which are nowadays so popular in smartphones, cars etc. One of the key challenges of Li-ion electrodes is the enhancement of (dis-) charge rates. This is severely hindered by the absence of a technique that allows direct and non-destructive observation of lithium ions in operating batteries.

Direct observation of the Li-ion concentration profiles using Neutron Depth Profiling reveals that the rate-limiting step is not only dependent on the electrode morphology, but also on the cycling rate itself. In the LiFePO4 electrodes phase nucleation limits the charge transport at the lowest cycling rates, whereas electronic conductivity is rate-limiting at intermediate rates.

It is only at the highest rates where ionic transport through the electrodes is rate limiting.

This novel insight in electrode kinetics is imperative for the improvement of Li-ion batteries and demonstrates the significant value of Li-ion battery research and development using the NDP capability to observe the inside structural changes.



In-situ NDP spectra during C/10 cycling of a Li-ion battery electrode that contains a double layered electrode with different particle sizes (small (70 nm) particles at the current collector side and large (140 nm) particles at the electrolyte side. The evolution of the Li-ion distribution during a full charge discharge cycle shows that Li-ions preferentially react with smaller particles, giving direction to future high performance electrode design for Li-ion batteries.

MÖSSBAUER
SPECTROSCOPY

Catalysts are used abundantly in the chemical and oil industry for synthesizing, e.g. ammonia, natural gas, hydrogenating oil fractions, etc. Our globally unique state-of-the-art facility for combined Mössbauer/ infrared spectroscopy has proven to be very valuable for the studies of heterogeneous catalysts under realistic industrial conditions. The high penetrating power of the gamma rays makes Mössbauer spectroscopy a very versatile technique to study catalysts while they are at work, providing promising information to develop a better understanding of the catalytic sites and opening ways to synthesize novel or improved catalysts.

Producing and using Mössbauer-sensitive nuclei in-beam will largely increase the number of nuclei usable for industrial experiments. Neutrons capture prompt-gamma nuclei for in-beam excitation. Continuously activated prompt-gamma Mössbauer nuclei will be used in catalysis, high-temperature superconductors, magnetic layers and nuclear waste research studies.

The first Mössbauer-business plan was drafted in 2014. This includes these new ideas, and has been used as the basis for the expression of thoughts and approaches on how to fund these new developments.

Developments in the irradiation facilities

The irradiation facilities of the RID reactor are used to irradiate various materials with neutrons or other types of radiation in a well-controlled environment. Their major application is related to research focusing primarily on production of radioisotopes, and for analytical purposes such as Neutron Activation Analysis (NAA)

Radioisotope research and decanning (hot) cell

Nuclear reactors are essential in producing radioisotopes for diagnostics and therapy, such as Molybdenum-99 (99Mo), and increasingly also for the production of radioisotopes such as Holmium-166 (166Ho) and Lutetium-177 (177Lu). In addition to production, nuclear research reactors play an important role in development of new and the improvement of existing irradiation facilities that can meet the rapidly changing requirements of the medical industry.

For instance, Moybdenum-99 (the mother isotope of the most-used diagnostic isotope 99mTc) is currently mostly produced by fission of highly enriched uranium targets. This is a debated process due to, amongst others, the risk of proliferation of nuclear material. As an alternative, Delft scientists developed a process for the production of similar quality Molybdenum-99 without the use of uranium. In this process, Molybdenum is made radioactive by irradiation with neutrons. An innovative method is applied to separate the produced medical isotope from the chemically identical stable Molybdenum.

In this research, just as the one involving 166Ho microspheres, it has been shown that radiation damage effects occurring during irradiation have tremendous influence on the quality of the product. Therefore more insight is needed into radiation damage effects. Consequently new irradiation facilities are required where the irradiated material can be cooled and shielded against reactor radiation such as gamma-rays.

In addition, in order to show the potential of these production processes at industrial level, it is necessary to at least partly scale-up the production of medical isotopes. For this purpose a decanning (hot) cell for handling highly active materials has been further optimised during 2014. The selected positioning of the decanning cell on the reactor's second platform has been revisited in view of simplifying the logistics of the irradiation, under water transport and handling of the irradiation containers. Alternatives are currently being studied.

Small-target irradiation facilities

Carbon fiber Autonomous Facility for Irradiation and Analysis (CAFIA) is a special system allowing the combination of an irradiation facility and spectrometer into a single instrument. This enables the activity of very short-lived radioisotopes (i.e. half-lives down to 1 second) to be measured without unpacking the irradiation container. As an example, tens of thousands of Selenium measurements – using its short half-life radioisotope Selenium 77m - have been carried out in Delft since the end of the 1970s for epidemiological studies. This research focuses on finding the relation

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>> between this element and the occurrence or prevalence for various forms of cancer, such as prostate cancer.

A pre-design of a new carbon-carbon composite irradiation end, housed in an aluminium encapsulation suitable for mounting on the reactor grid plate has been evaluated in 2014 for further detailing. It is expected that the neutron flux in this facility will increase by a factor 3 to 5. A mechanism is currently under investigation for disconnecting the tubing system in case the reactor bridge has to be moved towards the large reactor pool for maintenance or in emergency situations, including the new CAFIA irradiation end on the grid.

Shielded Irradiation Pneumatic Facility – SIPF and Resonance Irradiation Facility – RIF

The SIPF will facilitate irradiations with shielding against gamma-radiation using lead filters of adjustable size and thickness for optimizing the neutron/gamma-ray intensity ratio. This facility will expand the opportunities of irradiating materials having organic nature, as radiation damage will be reduced.

Alternative Mo99 production route

Medical isotopes are foremost used for early diagnosis of tumours. One of the best-known isotopes is Technetium, which can be obtained by radioactive decay of Molybdenum-99. Molybdenum is produced by nuclear fission of Uranium-enriched plates, which after irradiation in a high flux reactor, are dissolved in an acid. The Molybdenum is then extracted from the solution and fed into so-called generators to be transported to users. This production method is complicated and generates a lot of (radioactive) waste relatively speaking. Research is being conducted on a new production method whereby Molybdenum can be produced continuously in a beam tube running

This facility is especially important for the production of polymeric microspheres containing radioactive Holmium-166 (166Ho) with specific activities of at least 25 GBq (per 100 mg Ho). Radiation therapy with Holmium microspheres is expected to become a major procedure for the treatment of liver tumours. In ad dition, the SIPF will be used for other research projects such as the upscaling of the Molybdenum-99 neutron capture production process.

The facility's design will also provide the opportunity for orientating experiments with target shielding by neutron filters as intended to be used in the RIF. These neutron filters will allow for production of radioisotopes by activation in a neutron energy spectrum with the highest intensity in the region of specific resonance neutron energies. If necessary the reduction of the thermal neutron production of interfering radioisotopes could also be achieved. This will be a world-unique facility and can result in unprecedented improvements to radioisotope purity and specific activity. It is currently being investigated if SIPF and RIF can be designed as a single combined facility.

A research proposal for additional funding for the design, implementation and testing of this facility will be submitted in 2015 to Technology Foundation STW, as a collaboration of TU Delft and the University of Utrecht, supported by NRG and two other industrial partners.

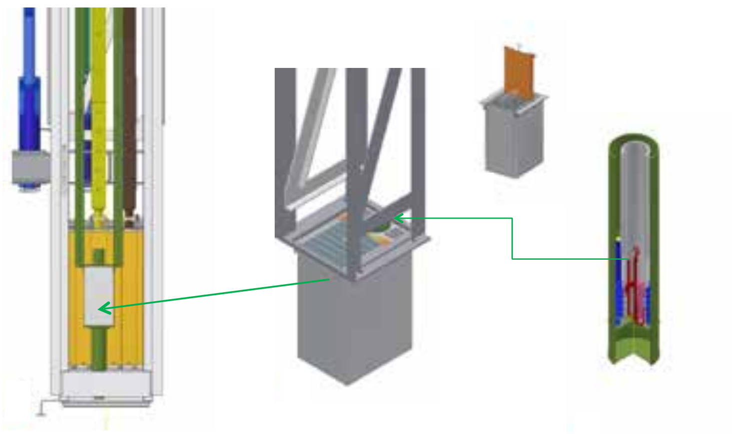

Figure: Near-Core FlexBeBe with cooled sample position

beside the HOR reactor core. This beam tube will be filled with a circulating uranyl-sulphate or a uranyl-nitrate solution, which will have an increased Molybdenum concentration after each core passage. Because of its presence in a solution, Molybdenum is expected to be more easily extracted than in the present commercial processes. About 2% of world production could be produced in such a way. This method could be produced in a reactor like the proposed new reactor PALLAS to increase the production scale.

In 2014 research was undertaken to optimise the Uranium concentration and the liquid flow of the Uranium solution to maximise the Molybdenum production. On top of that a first judgement was made in terms of the relevant safety related items. In 2015 the system will be further optimised and investigations will start to develop the separation chemistry.

The European Spallation Source (ESS)

The European Spallation Source (ESS) in Lund (Sweden) is a new multi-disciplinary research centre based on the world's most powerful neutron source. This new facility will be around 30 times brighter than today's leading facilities, enabling new opportunities for researchers in the fields of life sciences, energy, environmental technology, cultural heritage and fundamental physics. This next generation neutron source will facilitate a large number of neutron instruments enabling scientists to see and understand basic atomic structures and forces. It will allow the study of various materials, from plastics and pharmaceuticals, to engines, and molecules

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Photo: ESS/Team Henning Larsen Architects

Through the OYSTER project RID is able to invest in the ESS pre-construction program with four RID developmental work packages. The RID approach is to play special "tricks" with the spin of the neutron that basically allows scientists to reach a much higher resolution than by conventional methods. This is one of the RID's specialisms and is one of the reasons the ESS likes to have RID on board.

Because of the (financial) size of the ESS project an international approach is needed and many European countries have already partnered up with the host countries Sweden and Denmark. The Netherlands has also expressed its interest, but has not made a formal financial commitment yet and, as a result, has the official status of observer.

A full partnership of the ESS would mean, for instance, the Dutch industry delivering engineers or high tech systems in the construction- and subsequent phases of the ESS, which is currently under construction. In 2014, RID organised a special 'Science Meets Industry day', at which ESS representatives discussed options with a large number of Dutch interested (industrial) companies.

In 2015, RID, together with NWO representing the Netherlands within various ESS consortia, will continue to support and promote Dutch scientific and industrial involvement in the ESS.

Review by NWO

In May 2014 the second review on the OYSTER project was undertaken by the NWO OYSTER Advisory Committee of external experts.

The committee concluded that OYSTER “is replaced a great project with huge potential” and made various recommendations of which the most important ones are summarized on the right:

Recommendations

Locate additional funds for instruments and instrument support as a “guaranteed” part of the OYSTER project.

Implementation

Preparations for external funding applications are ongoing for FISH and Mössbauer instruments, and for the several Irradiation Facilities. The preparations are being funded from OYSTER budget.

The team

Prof. K.N. Clausen
Head of the Neutron and Muon Research Department and vice Director of the Paul Scherrer Institute (Switzerland)

Dr. Dimitri N. Argyriou
Director for Science at the European Spallation Source

Not to enter into any contract with a vendor before the budget for instruments and instrument support has been fixed.	Organisational aspects with respect to a common vision between the various units should be addressed.	More involvement of the RID scientists in the decision making process is advised to strengthen the feeling of joint responsibility for its success.
Contract awards will only be granted with sufficient financial support. Based on our successful fund raising record we believe we will be able to raise the necessary funds to realize the OYSTER instrumentation and irradiation facilities during the coming years.	RID management has published its vision, which has been amply discussed. The 2015 RID activities will be a direct result of this vision. In 2015 a new communication advisor will be assigned in order to support this process.	The involvement of the RID scientists in the OYSTER decision process was already established and will be continued. Senior scientists to act as “champion” have been appointed and plans for both scientific projects and valorisation involving “their” instrument are under development.

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Head of the Department
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Erasmus MC

Dr. Nico Kos
Senior Manager (International) Programme
Innovation at the Chemical & Physical Sciences
Division of the Netherlands Organisation For
Scientific Research (NWO)

Financial overview

OYSTER amounts to € 117 million, covering the initial investments as well as the basic reactor-associated operational costs over a period of 10 years. In 2012 the Dutch government awarded € 38 million for OYSTER. TU Delft contributes € 74 million in kind. Furthermore, TU Delft stands surety for an additional € 5 million. This is part of the co-funding (industrial, scientific etc.) that has to be added to RID/OYSTER to fund the development, commissioning and exploitation of instruments and facilities over the total 10-years OYSTER program period and beyond.

In 2014, a total of € 2.5 million was spent on the license process, tendering process, including reimbursements of tendering parties, the positioning of the OYSTER facility and Dutch Safety Requirements (DSR) related costs. TU Delft contributed € 9.3 million in kind to the OYSTER project in 2014.

For the construction of PEARL the in-kind contribution of TU Delft and OYSTER investment amount to a total of € 1.3 million. In 2014 ADEM Innovation Lab granted € 200,000 for POSH-PALS and in addition external funding of € 165,000 was attracted. SANS is funded by in-kind TU Delft contribution. To further realise instruments and irradiation facilities, plans are being formulated to attract external funding (e.g. for FISH, Mössbauer and Irradiation Facilities).

The KHC consortium has been awarded the contract for the reactor modification in June 2014. Work to be conducted by KHC has been split in two phases. The Basic Engineering Phase, started in August 2014 (contract value € 1.9 million). At the end of Q2 2015 a final cost calculation is expected for the entire reactor modification including the estimation of the extra cost due to the new DSR requirements. Based on these cost calculations a 'Go/No go'-decision will precede the Construction Phase. Assignment of extra funding to cover the DSR items is an essential part of this decision.

Communication

The OYSTER programme will result in improved and expanded infrastructure around the reactor in order to better address current and future educational, scientific and societal questions. This is the key message that we want to share and instil across the relevant research communities and other stakeholders. We want to inform researchers and scientists, whether from academia, SMEs or large companies, as well as non-governmental organizations about the opportunities, instruments, facilities and know-how available at the Reactor Institute Delft.

In 2013, the implementation of the communication strategy was started and focussed mainly on external communication, whereas in 2014 the focus was on the employees of the RID/ RST institute itself. A common vision has been developed and a merged management-team consisting of both the management teams of RID and RST has been established in order to discuss about strategy, instrument/ facilities issues and timelines.

At the end of 2014 it was decided to expand the communication hours for OYSTER. A communications advisor (0.6 FTE) dedicated for the OYSTER project was recruited. The communications advisor will start at the RID in the beginning of 2015. New internal and external communication actions based on the strategy will be formulated for the coming years. New communication tools will be developed and a number of existing communication tools such as the OYSTER website and brochures will be expanded and updated.

Planning

OYSTER REACTOR MODIFICATIONS PROJECT
Construction Phase (Preliminary)

The original project schedule of the OYSTER project was based on terms and conditions as defined during the first half of 2013. After notification of the new DSR legislation in June 2013, the original schedule was adjusted anticipating the availability of the final DSR by the end of 2013. Closing out of the OYSTER project was foreseen for the end of 2016. However, in June 2013 the Ministry of Economic Affairs reported that the earliest date of issuing a draft version of the DSR would be in the middle of 2014 and the implementation of the final revision would follow at the end of 2014. During 2014 it was anticipated that the OYSTER project would be closed out in Q1 2018.

At the end of 2014 however the ministry reported that the date of issuing the DSR had been postponed to the middle of 2015. This might result in a further delay to the project schedule. Because the final DSR requirements are not known yet, it is difficult to predict a fixed closeout date for the OYSTER project.

Activity name
TOTAL INSTALLED COST OVERALL ESTIMATE
FABRICATION EQUIPMENT REACTOR MODIFICATIONS
CONSTRUCTION SECURITY CHECK
SHUT-DOWN REACTOR
START-UP REACTOR
CLOSE-OUT OYSTER PROJECT
GENERAL
TIC OVERALL ESTIMATE
CONSTRUCTION SCHEDULE
CONSTRUCTION SECURITY CHECK
REACTOR MODIFICATIONS
'MILIEUEFFECTRAPPORTAGE' PREPARATION + REVIEW
DUTCH SAFETY REQUIREMENTS DEFINITION
PREPARATION CONCEPT LICENCE
SAFETY REPORT (SAR) PREPARATION + REVIEW
LICENSING PROCEDURE
BUILDING PERMIT
OBJECTION PROCEDURE
BASIC ENGINEERING REACTOR MODIFICATIONS
DETAILED ENGINEERING REACTOR MODIFICATIONS
FABRICATION EQUIPMENT REACTOR MODIFICATIONS
SHUT-DOWN REACTOR AND DISMANTLING CORE
DRAINING REACTOR BASSIN 1ST STAGE INCL. DISMANTLING HANGER ETC.
AS-BUILD CHECK CORE AND BASSIN CONFIGURATION
DRAINING REACTOR BASSIN 2ND STAGE FOR BEAM TUBES DRY
DISMANTLING MIRROR GUIDE SYSTEM BEAM TUBE R2
MODIFICATIONS BEAM TUBE R2 AND REACTOR CORE
MODIFICATIONS REACTOR BASSIN
INSTALLATION HOTCELL, ISOTOPE - AND LOOPSYSTEM FACILITIES
REFILL REACTOR BASSIN 1ST STAGE INCL. INSTALLATION NEW CONTROL RODS
AS-BUILD 0-MEASURING AND REFILL REACTOR BASSIN 2ND STAGE
INSTALLATION INPILE PART
DETAILED ENGINEERING HOTCELL FACILITIES
DETAILED ENGINEERING E&I MODIFICATIONS RELATED TO CNS INPILE PART
MODIFICATIONS E&I RELATED TO CNS INPILE PART
CNS UTILITIES CONTROL ROOM
DETAILED ENGINEERING CNS UTILITIES AND CONTROL ROOM
BUILDING PERMIT
INSTALLATION NEW CNS UTILITIES CONTROL ROOM
DETAILED ENGINEERING CNS COOLING SYSTEM AND COMPRESSOR
INSTALLATION CNS UTILITIES EQUIPMENT
DETAILED ENGINEERING CNS E&I MODIFICATIONS
INSTALLATION PIPING AND E&I
START-UP / COMMISSIONING

Start	Finish	2014				2015				2016				2017				2018			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	31/May/15																				
	31/Dec/17																				
	31/Dec/15																				
	1/Apr/17																				
	1/Jan/18																				
	31/Mar/18																				
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1/Oct/17	31/Dec/17																				
1/Jan/18	31/Mar/18																				

Date	1 Sept 2014	1 Dec 2014	31 Jan 2015
Revision	Rev. 13	Rev. 14	Rev. 15