UTILISATION OF THE RESEARCH REACTOR TRIGA MAINZ

G. HAMPEL, K. EBERHARDT
Johannes Gutenberg-Universität Mainz,
Mainz,
Germany
Gabriele.hampel@uni-mainz.de

1. INTRODUCTION

Founded in 1477 and named after the famous fifteenth century printer who revolutionized printing with movable letters, the Johannes Gutenberg Universität Mainz, with about 35 000 students from more than 130 nations, is one of the largest universities in Germany and is one of the main research centres of the Federal State of Rheinland-Pfalz. About 500 professors and 2300 academic staff members are involved both in research and teaching in eleven departments with 150 different institutes. The university offers a wide research area including the natural sciences, humanities, social studies, law, economics and medicine. The campus also hosts the research reactor of type TRIGA Mark II. It was built on the initiative of Fritz Strassmann, at that time the director of the Institute for Anorganic Chemistry and Nuclear Chemistry at the Mainz University.

On 3 August, 1965, the TRIGA Mainz reached its first criticality with the insertion of the 57th fuel element in the reactor core. Two years later, in April 1967, the Nobel Prize Laureate Otto Hahn initiated the first of now more than 17 000 pulses at the official inauguration.

Since this time the TRIGA Mainz has operated failure-free during an operation cycle of about 200 days per year, with one short break for a complete refurbishment of the cooling and purification circuits and the cooling tower in 1995. In recent years, approximately 80% of the time has been used for reactor operation at the nominal power of 100 kW_{th} and the rest for pulses.

In the steady state mode of operation, TRIGA reactors offer a broad range of applications for commercial irradiations, research and training. This includes neutron activation analysis, radioisotope production and a variety of neutron beam applications for physical, chemical, biological and medical research. Due to the high flexibility of TRIGA reactors they can be used very effectively for special commercial applications, as well as for exotic projects in basic research in physics and chemistry. In addition, however, the capability to produce a pulsed burst of neutrons provides an additional area of research applications. This includes the production of very short-lived radionuclides for radiochemistry and nuclear physics studies, the production of ultra cold neutrons (UCN) and a setup for mass spectrometry and laser spectroscopy known as TRIGA-SPEC.

2. THE TRIGA MAINZ

The TRIGA Mark II reactor at the University of Mainz is a swimming pool reactor with a graphite-reflected core placed inside an aluminium tank with a diameter of 2 m and a height of 6.25 m (Figure 1). The surrounding concrete biological shield and the demineralised water in the pool provide the required radial and vertical radiation shielding. The fuel-moderator elements are fixed in the core with a top and bottom grid plate containing 91 positions loaded with the fuel-moderator elements, control rod guide tubes or irradiation channels, and graphite dummy elements. Currently, the reactor core is equipped with 75 fuel elements, each containing about 36 g of ^{235}U. Under typical operation conditions, the burn-up of fuel elements is of the order of only 4 g of ^{235}U per year, giving the TRIGA core a long lifetime. In order to overcome the slow decrease of reactivity with time, a fresh fuel element is introduced about every four years.

For irradiations the TRIGA Mainz has a central experimental tube, three pneumatic transfer systems and a rotary specimen rack with 40 positions which allows the irradiation of 80 samples at the same time. In addition, the TRIGA Mainz includes four horizontal beam ports (A, B, C and D) penetrating the concrete shielding and extending inside the pool towards the reflector. A graphite thermal column provides a source of well-thermalised neutrons suitable for physics research or biological and medical irradiations. Figure 2 shows a horizontal cross section view of the TRIGA Mainz, indicating the core-reflector configuration and the position of the four beam tubes that penetrate the concrete shielding.

In the steady state mode the reactor can be operated at power levels ranging from about 100 mW_{th} up to 100 kW_{th}, depending on the requirements of different experiments. Pulse mode operation is also possible. The operation licence allows the insertion of an excess reactivity up to 2 δk^1, corresponding to a pulse peak power of 250 MW_{th} [1, 2]. Under these conditions, the pulse width (FWHM) is about 30 ms. Up to now, more than 17 000 pulses have been carried out without any fuel failure.

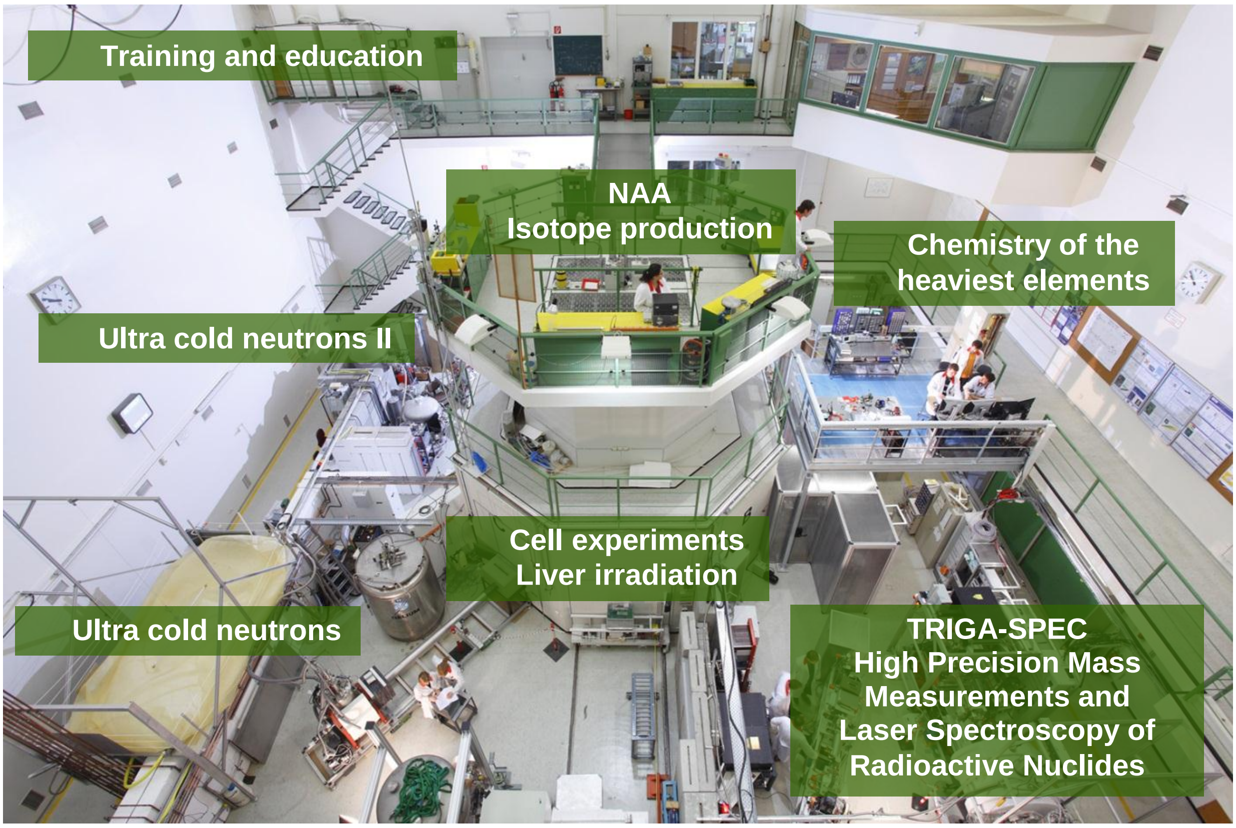

Fig. 1. View of the TRIGA Mainz and its applications.

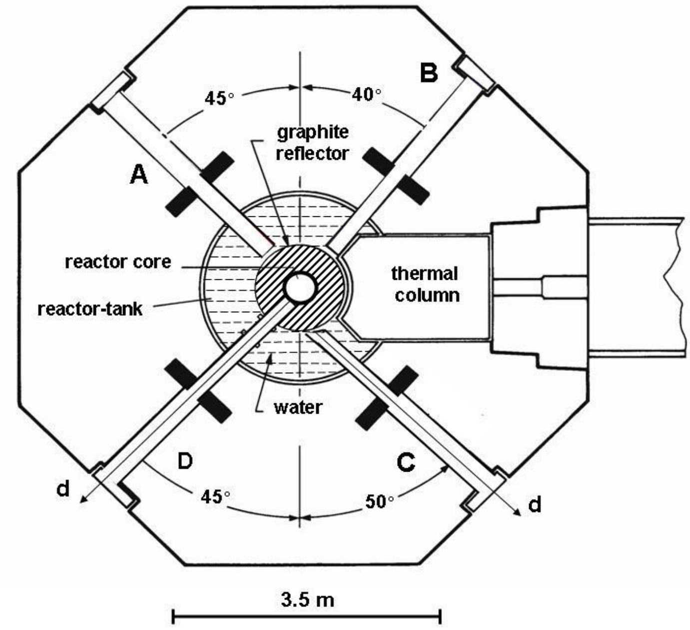

Fig. 2. Horizontal section view of the TRIGA Mainz indicating the positions of the three radial beam ports (A, B and D) and the tangential one (C) as well as the thermal column.

3. EDUCATION AND TRAINING

Training is, and will be even more so, a main utilisation of the TRIGA Mainz for engineers and technicians, teachers, researchers and especially as training tools for university students studying nuclear engineering or physics, where there is a growing demand today [3].

Various courses in nuclear and radiochemistry, radiation protection, reactor operation and physics are held at the Institute for Nuclear Chemistry:

- **Reactor operation and reactor physics:** This course consists of a lecture in reactor physics and practical training in reactor operation at steady state power as well as in the pulse mode. The course is focused on education and practical training to understand the general behaviour of a nuclear reactor. The main object of this course is to introduce the basics for reactor operation, reactor techniques and physics in practical examples at the research reactor TRIGA Mainz. The participants receive practical experience in operation of a nuclear reactor which can be perfectly executed at the TRIGA Mainz. The main part of the course includes:

  - The daily and monthly inspections at the reactor;
  - Operation of the reactor in the steady state and pulse mode;
  - Neutron flux measurements at different irradiation positions;
  - The influence of test samples to the reactor operation;
  - Calibration of the control rods;
  - Fuel inspections;
  - Function and sensitivity of the compensated ion chamber;
  - Reactivity measurements; and
  - Error diagnostics.

— **Neutron activation analyses:** This course is performed as part of the basic course in nuclear chemistry to demonstrate the capabilities of this method for trace analysis of various materials. As part of the experimental programme of the course in radiation protection, measurements of the neutron and gamma dose rates at the biological shield and near the surface of the reactor pool water are carried out. Here, the reactor is operated at different power levels from a few Watts to 100 kW_{th}, and the dose rates are monitored as a function of reactor power.

4. IN-CORE APPLICATIONS: NAA AND ISOTOPE PRODUCTION

The classic applications of TRIGA reactors are radioisotope production and radio-analytical techniques, such as NAA, which is a very useful method to determine trace elements in different various materials. At the TRIGA Mainz instrumental neutron activation analysis is applied to a variety of commercial and scientific disciplines to determine trace elements in different sample matrices such as silicon for solar applications [4], limestone, reverse paintings [5], hematite and other materials in archaeological research as well as brick stones [6, 7], as well as glass and hair in forensic investigations. In addition some special applications have been carried out such as the analysis of wine, ivory [8] or gemstones [9]. Irradiations can be performed in the steady state mode of the reactor at a power of 100 kW, using the central irradiation tube with a thermal neutron flux Φ of 4.2×10^{12} $cm^{-2}s^{-1}$, the pneumatic transfer system with $\Phi = 1.6\times10^{12}$ $cm^{-2}s^{-1}$ or the rotary specimen rack with $\Phi = 0.7\times10^{12}$ $cm^{-2}s^{-1}$. The samples are analyzed using gamma spectroscopy.

4.1. Solar grade silicon

Due to the boom in the solar industry, the availability of high purity silicon, which is also needed in the semiconductor industry, is limited due to increasing costs. An alternative can be given by so-called solar grade silicon (SG-Si). SG-Si is defined as silicon with acceptable purity grades, especially of the 3d transition metals since the energetic efficiency of solar cells is affected by these impurities. The 3d transition metals perform as recombination centres and reduce the lifetime of the charge carriers produced by light irradiation. In order to investigate the different purification procedures NAA is used to determine the 3d metal content for solar grade silicon.

4.2. Forensic investigations

In forensic investigations, building materials such as brick stones can be used as evidence to associate, e.g., one scene of crime to a suspect or to another scene of crime. To this end, elemental analysis can be a useful tool to characterize brick stones or fragments of them in order to compare these stones with each other. Therefore, brick stones collected from different production facilities were studied for their elemental composition using INAA. The method was compared with laser ablation — inductively coupled plasma — mass spectrometry (LA-ICP-MS) and X ray fluorescence analysis (XRF) [6, 7].

4.3. Archaeological materials

Since the histories of many archaeological materials are unknown, NAA is of interest for museums and art historians. The compositional characterization of archaeological materials by NAA can be used in conjunction with stylistic and petro-graphic criteria to infer geographic origin and attribute the materials. Compositional data answers questions about groups of materials belonging together, since a common origin relating materials of unknown origin to a region or a quarry that may have furnished the raw material for its production gives information about trade relations in the archaeological time period [10]. NAA is one of the best methods presently for the analysis of many archaeological materials for several reasons: its precision and accuracy allows the testing of very small samples; it determines many elements simultaneously and its sensitivity permits the determination of constituents present in very small concentrations. The TRIGA Mainz collaborates with museums and archaeological institutions to determine the concentrations of elements in archaeological samples, such as haematite probably used as pigment for colouring the body since the Lower Palaeolithic era (300 000 BC in Terra Amata, South France). First traces for digging of haematite led back to South Africa in 45 000 BC, and it was used regularly by Neanderthals.

An actual project involves the analysis of spoil with unknown origin produced by limestone from the Roman period in Rhineland-Palatinate, and which were installed in other buildings before and later re-used, for example, in grave stones. NAA is carried out using the rabbit system and the irradiation roundabout of the TRIGA Mainz. The analysis permits the determination of more than 30 elements (Al-28, Mg-27, Ti-51, V-52, Ca-49, Mn-56 and Sr-87m from the irradiation in the rabbit system and Na-24, K-42, Ga-72, As-76, La-140, Sm-153 and W-187, as well as Sc-46, Fe-59, Cr-51, Co-60, Zn-65, Rb-86, Zr-95, Sb-124, Ba-131, Cs-134, Ce-141, Nd-147, Eu-152, Tb-160, Yb-169, Lu-177, Hf-181, Ta-182, Pa-233 and Np-239 using the roundabout) of which the Lanthanides seems to be especially useful in distinguishing among limestone from different sources.

Other applications include reverse paintings of glass which present an important part of the middle European cultural heritage [5]. Since materials changed rapidly in the 18th and 19th centuries, pigments as well as glass materials were analysed to find out if there are differences in the properties of materials in different areas or in different periods. To get an answer to the principal question of whether different kinds of glass from reverse paintings can be analytically distinguished, 20 paintings from different European areas have been analysed by INAA. Their supposed period of origin was the middle of the 18th century to the end of the 19th century.

Mainz is Germany‘s wine capital. Directly situated in the heart of Rheinhessen, it is one of Germany´s largest wine growing areas with a lot of small wine restaurants and wineries. Therefore, a high quality of wine is important for trade in this region. It is known that the quality of wine is affected by interruptions in fermentation, which can be caused by trace elements. With the aim to produce a wine with high quality a systematic determination of the element and trace element concentration independent of the fermentation time for the grapes and the wine was carried out using NAA. One important result is the determination of the level of Zn concentration in the pure yeast injected to start the fermentation of Riesling wine.

At low flux reactors, such as the TRGA Mainz, radioisotopes with short decay times can be produce easily. For the analysis of chemical-technical processes radiotracers such as ^{24}Na, ^{41}Ar, ^{56}Mn, ^{113m}In, ^{82}Br and ^{140}La are applied in fluid flow, dwell time and volume measurements.

In another project the efficiency of toothpaste is being determined. Therefore, teeth are irradiated in the roundabout, then cleaned with toothpaste and the total amount of activity in the toothpaste is measured.

5. MEDICAL AND BIOLOGICAL APPLICATIONS (THERMAL COLUMN)

5.1. Enhanced liver tumour therapy

The thermal column of the TRIGA Mainz is being used very effectively for more direct medical and biological applications. Similarly, at the TRIGA in Pavia, Italy, patients with liver metastases have been treated successfully, a project which will be applied also at the TRIGA Mainz [11, 12]. Extended incursion of the liver by primary and secondary cancer is life limiting even if the tumour is confined to this organ. So far in this situation, only palliative treatment using chemotherapy is applicable. At the moment, a multinational research consortium conducts research in boron neutron capture therapy (BNCT) to explore the possibilities of a curative treatment of the liver.

BNCT is a biologically targeted form of radiotherapy, which uses the ability of the isotope ^{10}B to emit ^{4}He particles and ^{7}Li recoil ions following the capture of thermal neutrons with a very high probability (cross-section: 3837 b). The fragments produced in this reaction ($^{10}B(n,\alpha)^{7}Li$) have high linear energy transfer (LET) properties and a high relative biological effectiveness (RBE) as compared with photon irradiation. The range of these particles in tissue is limited to 8 and 5 µm, respectively, thus confining the destructive effects to about one cell diameter. Therefore, if the ^{10}B atom can be selectively delivered to cancerous tissue, the short range of the high LET charged particles offers the potential for a targeted irradiation of individual tumour cells, while the healthy liver parenchyma would be spared [13].

The condition for this effect is a sufficient concentration of ^{10}B inside the relevant cells or tissue. Such a concentration is achieved by a ^{10}B carrier that shows a high uptake rate in the specifically targeted cells when administered to the patient. The uptake of the tumour cells has to be higher (≥ 3) compared to the uptake in the surrounding healthy tissue, which causes the dose to the tumour to be much higher than the dose to the healthy tissue. Only in this case a lethal damage is inflicted on the tumour while the healthy tissue remains intact. For the task of delivery, the boron compound 4-borono-phenylalanine (BPA) is a suitable choice. During a study in Pavia, Italy, the enrichment in several tumours was confirmed with patients who suffered from colorectal carcinoma. In Pavia, the possibility of using BNCT for the treatment of colorectal liver metastases has been explored in the case of two patients [11]. Follow-up examinations of both patients showed that the liver was fully purged of cancer. The first patient died 44 months after the BNCT treatment due to recurring intestinal tumours; the second patient died after 30 days of dilated cardiomyopathy.

In cases of liver treatment, the irradiation must be performed outside of the body, or else too much damage is inflicted to the surrounding organs and tissues by neutron and gamma radiation from the neutron source. To perform the treatment, the organ is explanted after the infusion of BPA in the operation theatre and then irradiated in a suitable facility, such as the thermal column of a research reactor. Monte Carlo simulations have demonstrated the potential for an effective BNCT treatment for extracorporeal livers irradiated in a modified thermal column, since the simulation of the gamma dose has shown the necessity of shielding the organ from all sides due to the secondary gamma photons induced within the graphite of the thermal column, which contribute considerably to the total gamma dose [14, 15].

For a successful treatment it is necessary to identify the kind of tissue or cell where the ionised radiation is generated. Furthermore, knowledge of the differences of the boron concentration in cancerous and healthy tissue is required to calculate the correct dose released by ionising radiation in the relevant tissue.

The two successful treatments in Pavia in 2001 and 2003 gave rise to the assumption that BNCT could be a beneficial option for a large number of patients suffering from primary and secondary cancer. Taking also into consideration the treatment possibilities of hepatocellular carcinoma and intrahepatic cholangiocarcinoma, about 12 000 patients per year in the European Union could profit from this kind of treatment.

Preparatory work is currently carried out performing a pharmacokinetic study with 15 patients at the Department of Transplantation Surgery of the University of Mainz, to investigate the uptake of boron carriers under conditions identical to the proposed therapeutic situation in prospective patients [16].

During surgery, blood and tissue samples are taken to assess the pharmacokinetic behaviour of the BPA. Blood and urine samples are measured with inductively coupled plasma mass spectroscopy (ICP-MS), prompt gamma ray analysis and quantitative neutron capture radiography (QNCR). While PGRA and ICP-MS are spectroscopic methods that cannot perform locally selective analysis, radiography is a method to visualize the distribution of particular isotopes by image analysis. This can be done qualitatively and quantitatively using adequate standard reference materials. These images are obtained from the irradiation of a particular solid state detector, more specifically, a polyallyl-diglycol-carbonate polymer film (TASTRAK, CR-39), which is sensitive only to charged particle radiation. On such films, cryosections are mounted from cut samples. Upon irradiation, the fragments produced during the $^{10}B(n,\alpha)^{7}Li$ reaction leave so called “latent tracks” on the surface of the films, which are made visible by etching. Hence, a precise image of the concentration distribution inside the tissue slices is created. With this method it is possible to determine the boron concentration on the millimetre scale, and this is a great advantage compared to other methods in BNCT, which very often include bulk analysis of tissue samples in which local information inevitably is lost.

5.2. Neutron irradiation of cell cultures

Cell cultures may be irradiated at different fluxes in very homogeneous thermal neutron fields, which is a unique possibility for research involving a variety of diseases. The investigation of radiation resistance, intrinsic repair mechanisms for radiation damage or genetic properties of cells is of great importance for medical research, especially for oncology. As only a relatively small number of cells are needed for these kinds of experiments, only mild activation induced radiation results, which makes for quick and efficient experimental procedures with low risk for the scientific personnel.

Currently, at the TRIGA Mainz experiments with human hepatoma cell lines are carried out to expand the research on the treatment for liver cancer in the BNCT project. To estimate an organism’s or complex organ’s reaction to therapeutic radiology, either animal or alternative cell experiments are required. In particular, results of experiments with human liver cells correlate more with results of human *in vivo* analyses than with animal experiments. For this purpose, the cell line Huh7 is selected, which stems from a well differentiated hepato cellular carcinoma. The cells’ media were treated with p-boron-phenylalanine enriched with 99% ^{10}B before the cells were irradiated in the thermal column. The aim of the cell experiment is to calculate the survival of cells given different doses, incubation times and boron concentration. The survival curves allow the determination of a relative biological effectiveness (RBE) specific to the liver, values which are important parameters to evaluate the subsequent radiotherapy.

5.3. Dosimetry in mixed neutron and gamma fields

For dosimetry monitoring in the mixed neutron and gamma field in the thermal column, an alanine detector system is being established and tested [17]. The alanine pellets have a diameter of 5 mm and a thickness of 2 mm, consisting of 90% finely grained crystalline alanine powder. When alanine is irradiated with ionizing radiation, it forms the stable radical CH3–CH–COOH. Using an electron spin resonance (ESR) reader, the radical electron at the carbon atom can be detected. The value of the ESR signal correlates to the amount of absorbed dose.

The dose in each pellet correlates to an equivalent gamma dose by a factor called relative effectiveness (RE). To determine the RE values and to predict the dose for each pellet, the Hansen & Olsen alanine detector response model is used together with FLUKA, a multipurpose transport Monte Carlo code, able to treat particle interactions up to 10 000 TeV. The only information needed for the calculations is the neutron and gamma spectrum for the TRIGA Mainz and the description of the thermal column.

6. APPLICATIONS AT THE BEAM PORTS

The beam ports of the TRIGA Mainz are used for some special applications which are unique in the world in the experiments carried out. Beam port A is used for the development of fast chemical separation procedures which will be applied for chemical and physical studies of the heaviest elements in the periodic table. At beam port B, an experiment for high precision mass and laser spectroscopic measurements of neutron rich radioisotopes is currently under construction. At beam port C, a source for ultra-cold neutrons (UCN) is installed, and at beam port D, a new UCN source for the production of higher UCN densities is currently in progress.

6.1. Transactinide research at the TRIGA (Beam port A)

The heaviest elements known in the periodic table are the transactinides or so-called superheavy elements. Up until now, the transactinides 104 to 118 have been produced in nuclear fusion reactions. From the liquid drop model, it would be expected that superheavy elements cannot exist, but due to nuclear shell effects, their half-lives are in the range of milliseconds to minutes. For chemists, these elements are really exciting. Relativistic effects might be visible in the chemical behaviour of these elements, so their chemical behaviour might be significantly different from the chemistry of their lighter homologues.

Superheavy elements can only be produced at ion accelerator facilities. An intense ion beam is shot onto a thin target foil. The production rate of the transactinides is between a few atoms per hour down to one or two atoms per month. Due to these low production rates and the short half-lives, there are special requirements for a transactinide chemistry experiment. The chemistry system must be as fast as possible, fully automated, and the decay of the superheavy elements must be detected with high efficiency [18].

The TRIGA reactor gives us a unique possibility to develop and test chemistry setups. Short-lived isotopes of the lighter homologues of the superheavy class can be produced in the neutron induced fission of actinides and used for experiments. Systems to study single atoms with ion exchange chromatography and electro-deposition on various metals [19] have been invented in Mainz. Currently, the synthesis of new volatile compounds of transactinides is under development.

6.2. TRIGA-SPEC: A facility for high precision atomic mass measurements and laser-spectroscopic investigations of short–lived fission products (Beam port B)

High precision measurements of nuclear ground state properties are fundamental for the improvement of nuclear models and a better understanding of the nucleo-synthesis process. The research reactor TRIGA Mainz is an ideal facility to provide neutron rich nuclides with production rates sufficiently high for mass spectrometric and laser spectroscopic studies. Nuclear mass directly reflects the binding energy in the nucleus, and thus precise mass measurements can provide important data for astrophysical calculations of the so-called rapid neutron capture process, or r-process, and also serve as test cases for nuclear mass models in the heavy mass region. Independent of a particular nuclear model, laser spectroscopy yields information on properties such as nuclear moments and charge radii of neutron rich nuclides far from stability, which are extracted from the observed hyperfine structure and isotope shift.

The TRIGA-SPEC experiment [20] currently being installed at beam port B consists of two branches: (i) the Penning trap mass spectrometer TRIGA-TRAP, and (ii) a setup for collinear laser spectroscopy called TRIGA-LASER. Currently, TRIGA-SPEC is worldwide the only facility of this type installed at a nuclear research reactor. Short-lived nuclides are produced by neutron induced fission of an actinide target located in a specially designed recoil chamber near the reactor core. For extraction of fission products from the production site to the TRIGA-SPEC setup, a gas jet transport system is used. The target chamber is continuously flushed with a carrier gas containing aerosol particles made of, for example, metal halides or carbon clusters [21]. The fission products, attached to the aerosols, are flushed out and guided through the biological shield of the reactor by means of a thin capillary. Transport times of less than 500 ms and transport efficiencies up to 70% have been achieved with this technique [21]. In a skimmer unit the transport gas is removed and the aerosol particles containing the activity enter a low pressure region. In an ECR ion source, attached to the skimmer unit, the aerosol particles are destroyed, and a beam of radioactive ions is extracted at kinetic energies of 30-60 keV. In a subsequent magnetic separator, the nuclides of interest are selected and then enter an electrostatic deflector which guides the ion beam either to TRIGA-TRAP or to TRIGA-LASER.

The main components of TRIGA-TRAP are a cylindrical purification trap for beam preparation and a hyperbolical precision trap for the mass measurement. Both are located in the bore of a 7 T superconducting magnet and are kept at cryogenic temperatures of 77K. For mass measurements, two different methods can be used: The destructive time-of-flight ion-cyclotron resonance (TOF-ICR) technique is used for short-lived nuclides and the non-destructive Fourier transform ion-cyclotron resonance (FT-ICR) method for rarely produced but rather long-lived species. It is our intention to apply this technique for the first time at a radioactive beam facility.

At TRIGA-LASER, the fast beam of singly charged ions is overlapped with a continuous wave laser beam in collinear or anti-collinear geometry. This technique allows studying short-lived nuclides, since they are investigated in-flight. Here, a fixed frequency laser can be used, since the frequency scanning is achieved by means of tuning the velocity either from the ion beam or from atomic species after charge exchange and therefore changing the frequency of the laser light in the rest-frame of the atom due to the Doppler shift. Resonance fluorescence is then observed inside a light collection region.

6.3. Production of UCN (Beam port C and D)

The pulse mode operation of the TRIGA is advantageous for the production of so called ultra-cold neutrons). Such neutrons have very low kinetic energies (<10 m/s) and hence are storable in certain material bottles or in magnetic fields. UCN can be stored over hundreds of seconds in such traps and their fundamental properties can be measured with ultra-high precision. Experiments with UCN aim to measure, among others, the neutron lifetime, to detect a non-zero permanent electric dipole moment or even a non-zero electric charge of the neutron. Experiments, such as the neutron lifetime, will be conducted at the TRIGA UCN source in the near future. The possibility to pulse the reactor every 10 minutes and to produce a high amount of UCN can be adapted in an ideal way to the requirement of such a storage experiment where the trap has to be filled in similar periods in time. The physical background of UCN experiments is strongly connected to fundamental questions of astro-particle physics like the primordial synthesis (i.e., the production of the lightest elements directly after the Big Bang) or the absence of antimatter in the universe.

Since January 2006, a UCN source has been in operation at beam port C using the pulse mode as well as the steady state mode with 100 kW for different experiments [22, 23].

For UCN production, an in-pile part, which houses a 3.5 m neutron guide made from polished stainless steel, is inserted in the beam tube. The thermal neutrons are down-scattered into the ultra-cold neutron range (<250 neV) in a solid deuterium (5 K) converter which is located at the beginning of the in-pile part close to the reactor core. About 200 000 UCN per pulse can be produced at beam port C. At beam port D, a new source with enhanced properties is under development using a higher neutron flux of the order of 4×10^{13} $cm^{-2}s^{-1}$ for a 2 δk pulse.

7. SUMMARY

The TRIGA Mainz is one of only three research reactors that are currently in operation in Germany. It is intensively used for basic research, applied science and educational purposes. Important projects for the future of the TRIGA Mainz are the UCN experiment, fast chemical separation, mass measurements on neutron rich isotopes, medical applications and the use of the NAA, as well as the use of the reactor facility for training and education in the fields of nuclear chemistry, nuclear physics and radiation protection.

When taking into account the past and future operation schedule and the typically low burnup of TRIGA fuel elements (~4 g ^{235}U/a for an operation at a power of 100 kW), the reactor can be operated for at least another decade. Due to its experimental programme, the TRIGA Mainz will be in operation until at least 2020.

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