Strategy for Sustainable Utilization of IRT-Sofia Research Reactor

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History

- Pool type, light water cooled and moderated reactor
- First criticality of IRT-2000 was reached on 18 September 1961
- Council of Ministers Decree No.332/May, 1999 to shutdown the IRT-2000

History

- **Council of Ministers Decree № 552 / July, 2001 to refurbish and convert IRT-2000 into a civil reactor with low power up to 200 kW**.
- **Renaissance of Research Reactors, 2000**
- **Global Treat Reduction Initiative (GTRI), 2004**

- US DOE program RRRFR for spent nuclear fuel return back to Russia

- US DOE program RERTR for conversion HEU to LEU fuel

Conversion and Refurbishment

- reactor of thermal power 200 kW
- **LEU fuel U-235 fuel**
- six vertical experimental channels
- seven horizontal experimental channels
- maximal fast neutron flux : 3.10^{12} n/cm^{2}s
- maximal thermal flux: 8.10^{12} n/cm^{2}s

Activities

- 2002: Return of fresh fuel to Russia, RERTR
- 2003 Conceptual Design
- 2005 Detailed Design, IRT-4M (20%)
- 2003-2005: SAR Ed. 3, together with USA ANL
- 2005-2006: LEU Core Performance
- 2007-2009: BNCT LEU Core
- 2005-2010: SAR Ed. 4, together with USA ANL
- 2004-2009: **Return of spent fuel** to Russia, **RRRFR**
- **2007-2009: Report of the Environment Impact Assessment**
- 2003-2010 Integrated Management System – ISO:9001, ISO:14001 and BNRA requirements

Program for utilization

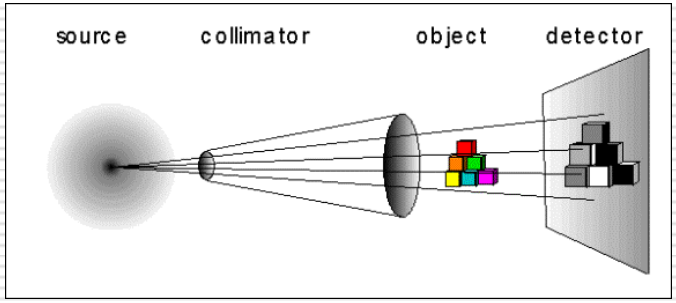
EDUCATION AND TRAINING

- Nuclear Energy
- Radiation protection and radiological engineering
- Physics and biology
- Public education

Program for utilization

APPLICATIONS

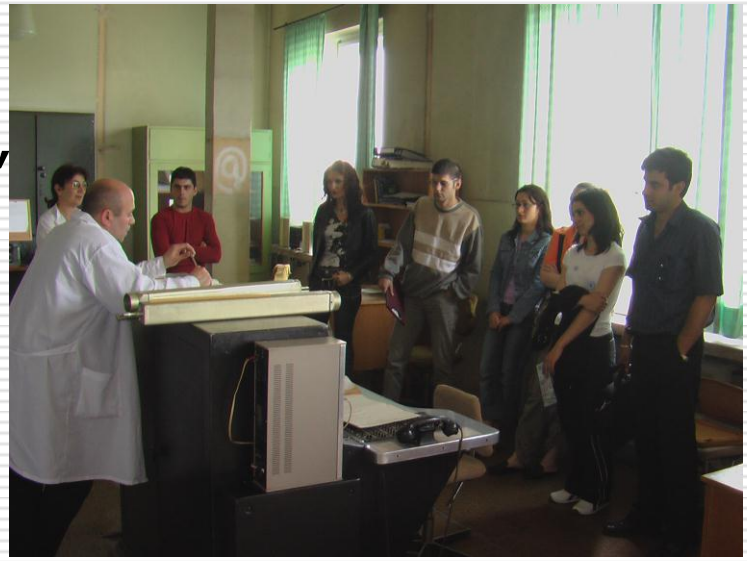
- Boron Neutron Capture Therapy
- Neutron activation analysis
- Radioisotope production
- Radio-pharmacy
- Materials irradiation
- Neutron radiography
- Material structure studies
- Metrology



Recent activities

Education & Training

- 2001-2010: training on “Neutron and Reactor Physics” and “Radiochemistry” of Bachelor, MSc., Ph.D. in collaboration with SU ”Sv. Kl. Ohridski” and TU-Sofia
- 2005-2010: Training of personnel and instructors for identification of commodity with possible double usage
- 2001-2010: Participation in national and international schools and conferences



Recent activities

Research & Development

- 2001-2005: Development of radiopharmaceutical kits for in-hospital diagnostics
- 2007-2009: Development of Scientific Information System to support the establishment of BNCT on IRT
- 2008-now: Development of dosimetry module for BNCT Treatment Planning System

Future utilization

The future utilization of IRT aims to satisfy the society needs for:

- Development and preservation of nuclear science, skills, and knowledge;
- Implementation of applied methods and research;
- Education of students and training of graduated physicists and engineers in the field of nuclear science and nuclear energy;
- Development of BNCT facility.

Training and education 1

- **Extension of the Nuclear Energy Course** for the **Master of Science Degree** of the Technical University in Sofia: types of research reactors, safety, reactor physics and thermo-hydraulic characteristics, accident analyses, fresh and spent fuel management, radioactive waste management
- **Scientific supervising and consulting** the students bachelor and MSc degree during the elaboration of their theses in the frame of collaboration with the SU”Sv.Kl.Ohridski” and TU-Sofia
- **Seminar and practice work** for students MSc degree, TU-Sofia, at the laboratory complex of IRT research reactor

Training and education 2

- Radiation protection training to meet the extremely high nuclear safety and radiation protection requirements as well as to develop a safety culture**.**
- Training of medical physicists in dosimetry technique and skills
- Educating the **PhD students** in "Neutron and reactor physics", and "Radiochemistry", INRNE is accredited for education on these subjects, in process of accreditation for "Nuclear reactors";

Public Education

Lectures and demonstrations to high-school and university students as well as to the general public will provide a media for increasing the public understanding, confidence, and support for nuclear energy.

Applications

Neutron Activation Analysis (NAA)

- NAA is a sensitive analytical method for the determination of elements and their traces (nanograms) in various types of samples and specimens, in metals and inorganic compounds, in animal, plant, and fish products, soil, river waters and sea sand, rain and snow, rocks, cosmic materials, archaeological objects, medicine, and police inquest.
- NAA is the widely used and beneficial application of the research reactors worldwide. It is estimated that approximately 100 thousand specimens are analyzed each year.
- There is constant demand for this service from the Universities

Applications

Isotope Production

There are 4 hot cells available at IRT, that allow the organization of radioisotope production and particularly of some radioisotopes (Na-24, K-42, Br-82) for medical application in vivo and in vitro. The production of short-lived isotopes is important, as in this way the problem with the transport of imported isotopes is diminished.

Applications

Material Structure Studies

- Study of various defects in the crystal metal lattice produced by irradiation of metal specimens will be carried out.
- Investigation on reactor steel embrittlement will be used for development of a model for prognosis of Kozloduy NPP VVER reactor pressure vessels lifetime.

Applications

Positron Source

Positron beam could be obtained from irradiation of appropriate targets with thermal neutrons or hard fission gamma rays. Positrons can be used as particle probes, suitable to detect materials defects with dimensions smaller than a micrometer .

Applications

Neutron-Nuclei Interaction

Measurements of the radiation capture cross sections of different nuclei using monoisotope targets e.g. of Hf, Gd, Sm, etc., can be performed by using 4π-multidetector system **"Romashka"**

Applications

Metrology

The development of a metrological system for testing and calibration of instruments needed for measurements of neutron/gamma fluxes as well as of radiation field monitors for measurements of dose received is planned. Such a metrological system will guarantee uniformity of the neutron/gamma measurements in the country.

Applications

Neutron Radiography

- Neutron radiography is an effective method of non-destructive testing that allows imaging of defects in a variety of objects (electronic, mechanical, military).
- The neutron beam penetrates a specimen, attenuates depending on the element contents, and interacts with a neutron absorbing screen. As a result a secondary radiation is produced from which an image is obtained on a special device.

Applications

Boron Neutron Capture Therapy

- Has good results, and improves during the last decade
- Has the potential to generate income through various sources
- Has extremely good response among the society

Applications

Boron Neutron Capture Therapy

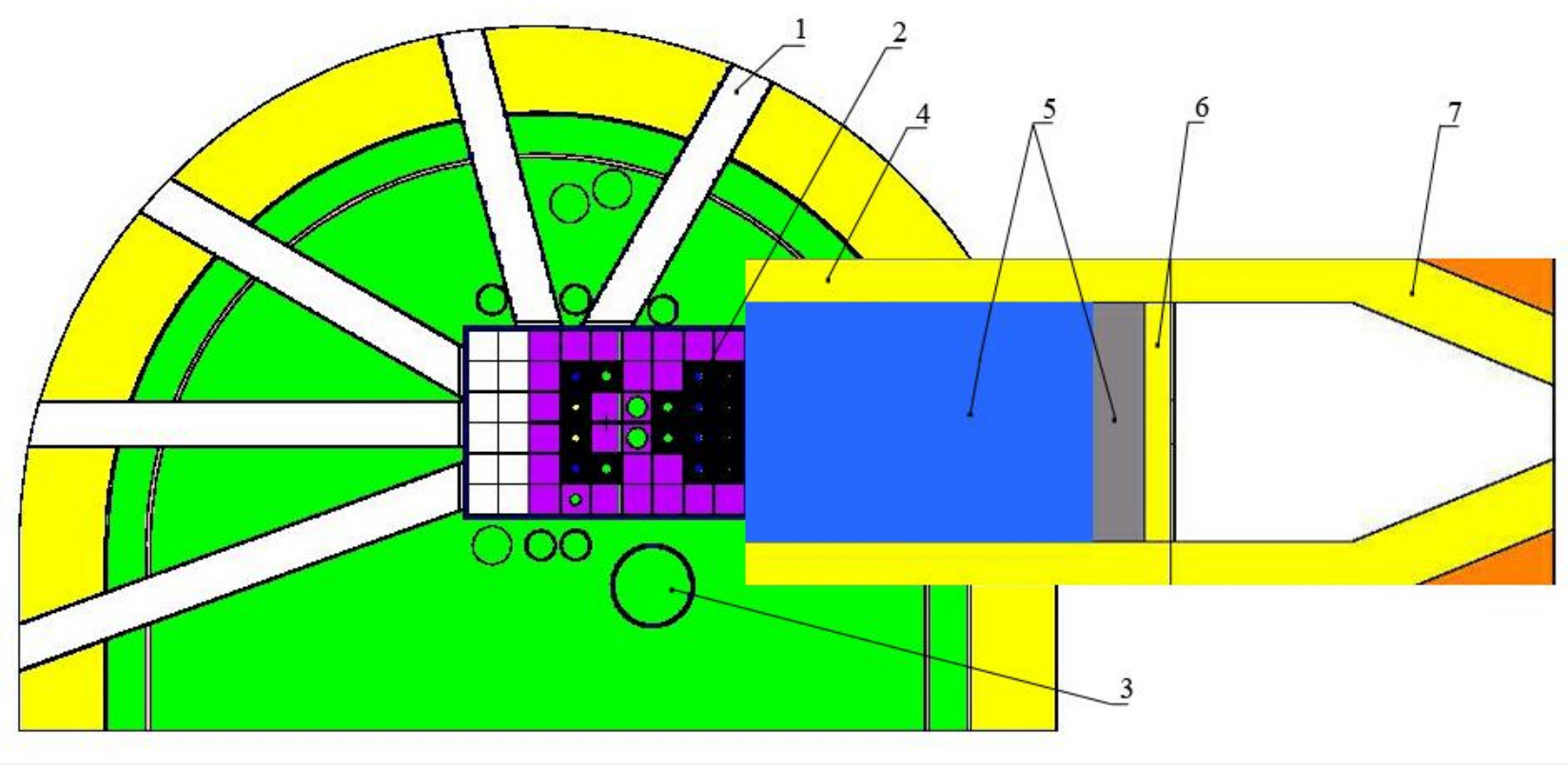
- BNCT is a form of radiotherapy that has the potential to selectively kill the cancer cells embedded within normal tissue. It uses B-10 isotope, which emits two short-lived high-energy particles when irradiated with a beam of thermal energy neutrons. Due to very short (cell dimension) path of the particles the treatment is lethal to cancerous cell containing the B-atoms, but has a much less damaging effect on the surrounding normal tissue.
- Treatment using BNCT is mostly applied on brain tumours and head&neck tumours

Applications

Boron Neutron Capture Therapy

- The current worldwide practice in BNCT is to irradiate the patients with neutron beam from reactor.
- **BNCT Beam Tube Design** as the USA MIT tube design
  - Lead reflector (10 cm)
  - Filter/Moderator: Al(81 cm), PTFE (13 cm), Cadmium (0.05 cm)
  - Lead photon shield (6 cm)
  - Lead collimator (15 cm)

MCNP Calculational Model of IRT with BNCT tube



The MCNP model (MIT tube design): 1. Horizontal channel 2. Fuel cell 3. Vertical channel 4. Lead reflector (10 cm) 5. Filter/Moderator: Al(81 cm), PTFE (13 cm), Cadmium (0.05 cm) 6. Lead photon shield (6 cm); 7. Lead collimator (15 cm);

Beam Parameters

Parameter	IRT	Required
φ_{epi}, E+9 $cm^{-2}s^{-1}$	4.63±0.3%	>0.5
D_{fn}/φ_{epi}, E-11 cGy cm^2	2.10±1.0%	<2
D_{γ}/φ_{epi}, E-11 cGy cm^2	0.55±1.0%	<2
J_{epi}/φ_{epi}	.704±1.0%	>0.7

Applications

Boron Neutron Capture Therapy

- Equipment as shielding, filters, collimators, shutters, etc. is being planned for creating a facility with well-filtered and collimated neutron beam
- The necessary medical equipment for patient preparation, irradiation and monitoring rooms, blood laboratory at the reactor facility are being planned too.
- Good infrastructure connections with the Oncology Hospital (about 3 km)

Collaboration

- **Contacts and Experience Sharing** with EC JRC-HFR, the Netherlands; VTT, Finland and NRI-Rez, the Czech Republic, Massachusetts Institute of Technology (MIT), USA, the MEPhI IRT Reactor, Moscow, Russia, Department of Neurosurgery University of Tsukuba, Japan .
- **National Network** on BNCT with the Medical University in Sofia, the Institute of Experimental Pathology and Parasitology and the Institute of Electronics of the Bulgarian Academy of Sciences, the Faculty of Physics of Sofia University, the National Centre of Radiobiology and Radiation Protection

Integrated Management System

- ISO 9001:2000 for quality, ISO 14001:2004 for environment, Bulgarian Nuclear Regulatory Agency requirements, Governmental requirements for occupational health and safety, and for security.
- Implemented from 2003 and certificated by the Quality Austria.

Support from

- **Bulgarian Government -** budget for reconstruction, from 2001
- **EC PHARE** Program, projects "Innovation of the Radiation Monitoring Systems…" ***and*** "Technical Assistance", 2002-2005
- **IAEA** project BUL/4/014 "Refurbishment of Research Reactor" , 2005-2008
- **National Science Fund** - "Building of Scientific Information System for Supporting BNCT Development in Bulgaria" ,2007-2008 ***and*** "Building Scientific Infrastructure for Development of BNCT in Bulgaria"

Outcome

- The research reactor is a basis for keeping up specialists with researcher's approach and skills, who are able to give adequate responses to the challenges of complex **modern technologies** and the associated **environmental problems**.
- The acquired scientific experience and qualification are a precondition for the equal in rights participation of the country in the **international cooperation.**
- Human, social and economical for patients from Balkan region benefits are expected

Outlook

- Final design and refurbishment of the IRT
- Involve more young physicists and engineers
- Train teams capable to operate the RR, to held application works, to conduct the BNCT
- Strengthen the international collaboration with RRs for sharing good practices
- Establish closer collaboration with national institutions like Universities,hospitals, regulatory agencies
- Development closer connection with the business

Thank You