TU WIEN
Atominstitut
Institute of Atomic and Subatomic Physics
ATOMINSTITUT

# Vienna University of Technology

# Institute of Atomic and Subatomic Physics

As the common nuclear research institute of all Austrian universities, the Institute of Atomic and Subatomic Physics is situated in the Austrian capital's second district near the Prater.

Its **official address**, **telephone and fax number**, respectively, are

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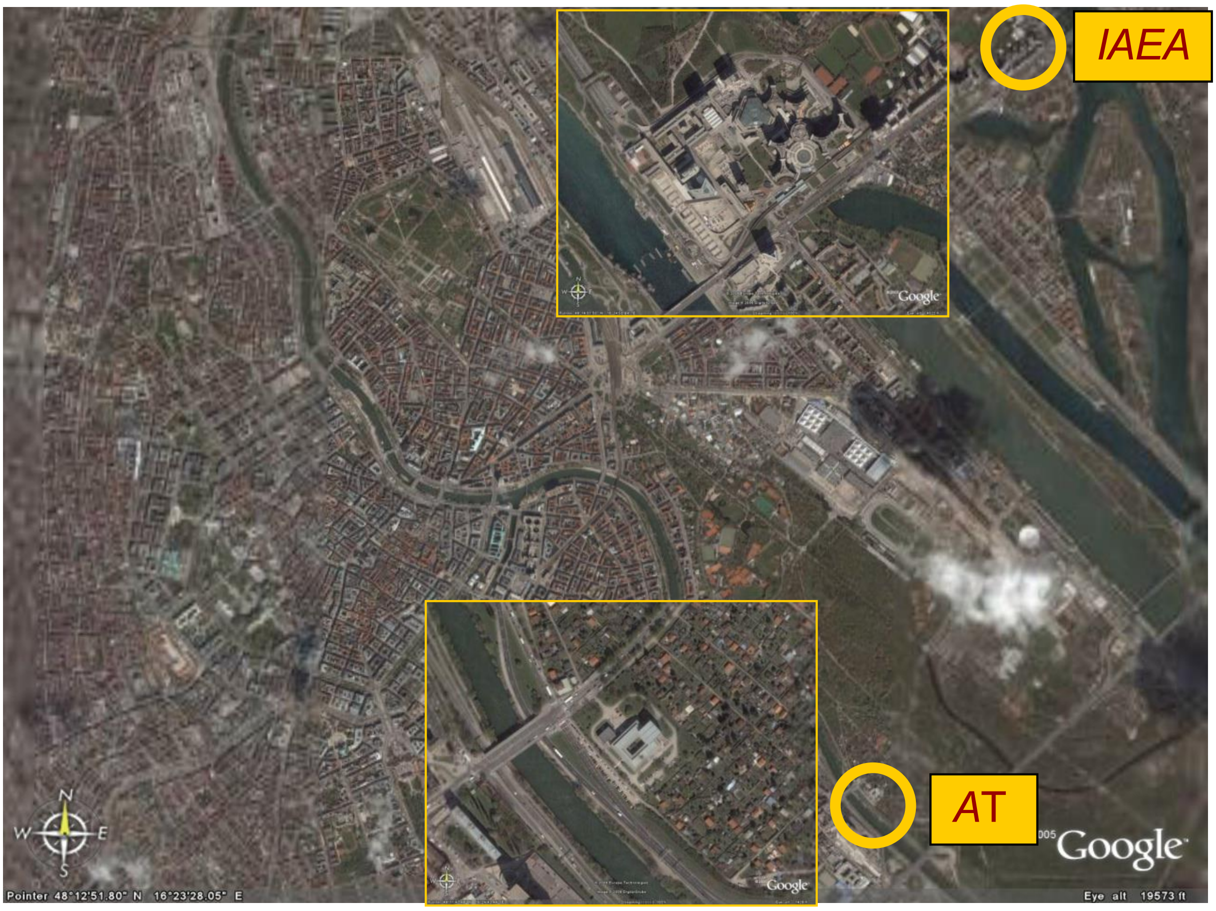


# THE TRIGA MARK-II REACTOR

# OF THE ATOMINSTITUT, VIENNA, AUSTRIA

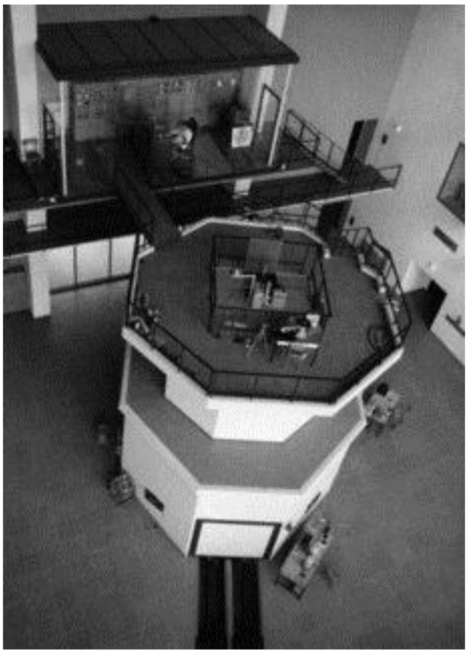
The Atominstitut (ATI) was established in 1958 as an inter-university institute, and in 1962 opened at its current location on the Prater with the commissioning of the TRIGA Mark II research reactor. As part of the reform of the university system, the Atominstitut was integrated 2002 into the Faculty of Physics at the TU Wien and is now dedicated to today's broad range of research and education ranging from very fundamental questions about symmetries and interactions in nuclear and particle physics to neutron-, atomic-, quantum-physics and quantum optics to radiation- and reactor physics to applied tasks such as environmental monitoring, radiation protection or for example the radiation resistance of modern materials.

A central facility thereby is the TRIGA Mark II research reactor and the connected teaching and research infrastructure, which allow us to educate and work with radioactive materials and ionizing radiation. An important contribution thereby is the training of international experts for the International Atomic Energy Authority (IAEA).

Currently, the Atominstitut has a scientific staff of 32 as well as 29 technical staff. In addition, third-party-funded project assistants (currently 75) have been increasing in number over recent years, which is important to be able to fulfill the research and training activities of the institute. In addition the Atominstitut has about 70 students working on their bachelor, master or doctoral thesis.

The educational opportunities offered by the institute cover all areas of research and are fully integrated into the curriculum of the Faculty of Physics.

## Reactor Description



**The TRIGA Mark-II reactor was installed by General Atomic (San Diego, California, U.S.A.) in the years 1959 through 1962, and went into operation for the first time on march 7, 1962. Operation of the reactor since that time has averaged 220 days per year, without any long outages.**

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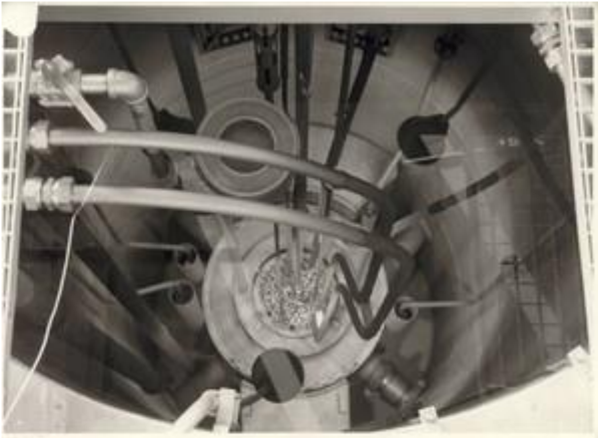
The TRIGA-reactor is purely a research reactor of the swimming-pool type that is used for training, research and isotope production (**T**raining, **R**esearch, **I**sotope Production, **G**eneral **A**tomic = TRIGA). Throughout the world there are more than 39 TRIGA-reactors in operation, Europe alone accounting for 10 of them. The TRIGA-reactor Vienna has a maximum continuous power output of 250 kW (thermal). The heat produced is released into a channel of the river Danube via a primary coolant circuit (deionized, distilled water at temperatures between 20 and 40 °C) and a secondary coolant circuit (ground water at temperatures between 12 and 18 °C), the two circuits being separated by a heat exchanger.

## Reactor core



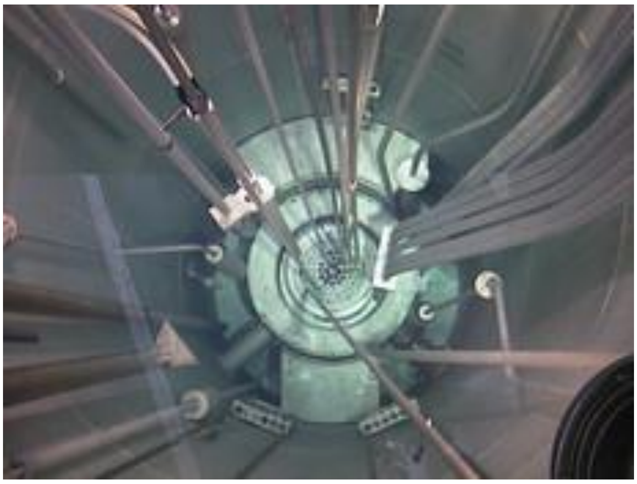
The reactor core consists of some 80 fuel elements (3.75 cm in diameter and 72.24 cm in length), which are arranged in an annular lattice. Two fuel elements have thermocouples implemented in the fuel meat which allow to measure the fuel temperature during reactor operation. At nominal power (250 kW), the center fuel temperature is about 200 °C. Because of the low reactor power level, the burn-up of the fuel is very small. Should these fuel elements ever become unserviceable, they will be sent back to the United States.

## Fuel elements

Inside the fuel element cladding (aluminum or steel), the fuel is in the form of a uniform mixture of 8 wt% uranium, 1 wt% hydrogen and 91 wt% zirconium, the zirconium-hydride, being the main moderator. Since the moderator has the special property of moderating less efficiently at high temperatures, the TRIGA-reactor Vienna can also be operated in a pulsed mode (with a rapid power rise to 250 MW for roughly 40 milliseconds). The power rise is accompanied by an increase in the maximum neutron flux density from $1x10^{13}$ $cm^{-2}s^{-1}$ (at 250 kW) to $1x10^{16}$ $cm^{-1}$ (at 250 MW). This negative temperature coefficient of reactivity, as it is called, brings the power level back to approximately 250 kW after the excursion, the maximal pulse rate is 12 per hour, since the temperature of the fuel elements rises to about 360 °C during the pulse and, therefore, the fuel is subjected to strong thermal stress.

Reactor Core

## Reactor control



The reactor is controlled by three control rods which contain boron carbide as absorber material. When these rods are fully inserted into the reactor core, the neutrons continuously emitted from a start-up source (Sb-Be photoneutron source) are absorbed by the rods and the reactor remains sub-critical. If the absorber rods are withdrawn from the core (two of them by an electric motor and one pneumatically), the number of fissions in the core and the power level increases. The start-up process takes roughly one minute for the reactor to reach a power level of 250 kW from the sub-critical state. The reactor can be shut-down either manually or automatically by the safety system. It takes about 1/10 of a second for the control rods to fall into the core

## Reactor Instrumentation

**The reactor is controlled by four nuclear channels their signals are displayed both at a colour graphic-monitor and at bar graph indicators.**

a) The auto-ranging wide-range channel NM-1000 controls the reactor power from the source level (around 5 mW) up to nominal power of 250 kW. It uses a Campbell fission chamber, the signal is controlled by a microprocessor.

b) Two independent linear channels, NMP-Ch and NMP-Ph control the reactor power from the source level up to nominal power. The signals pass over a range switch which selects the power range. If the signal of one of these two channels exceeds the selected power range for more than 5%, the reactor is shut down automatically. Both channels use compensated ionisation chambers as sensors.

c) For the control of reactor pulse operation an uncompensated ionisation chamber is used. This chamber measures the shape of the reactor pulse which is displayed on the graphic monitor. Further pulse data like integrated power are calculated from this signal.

## Irradiation devices

**In accordance with its purpose as a research reactor, the TRIGA Mark-II is equipped with a number of irradiation devices:**

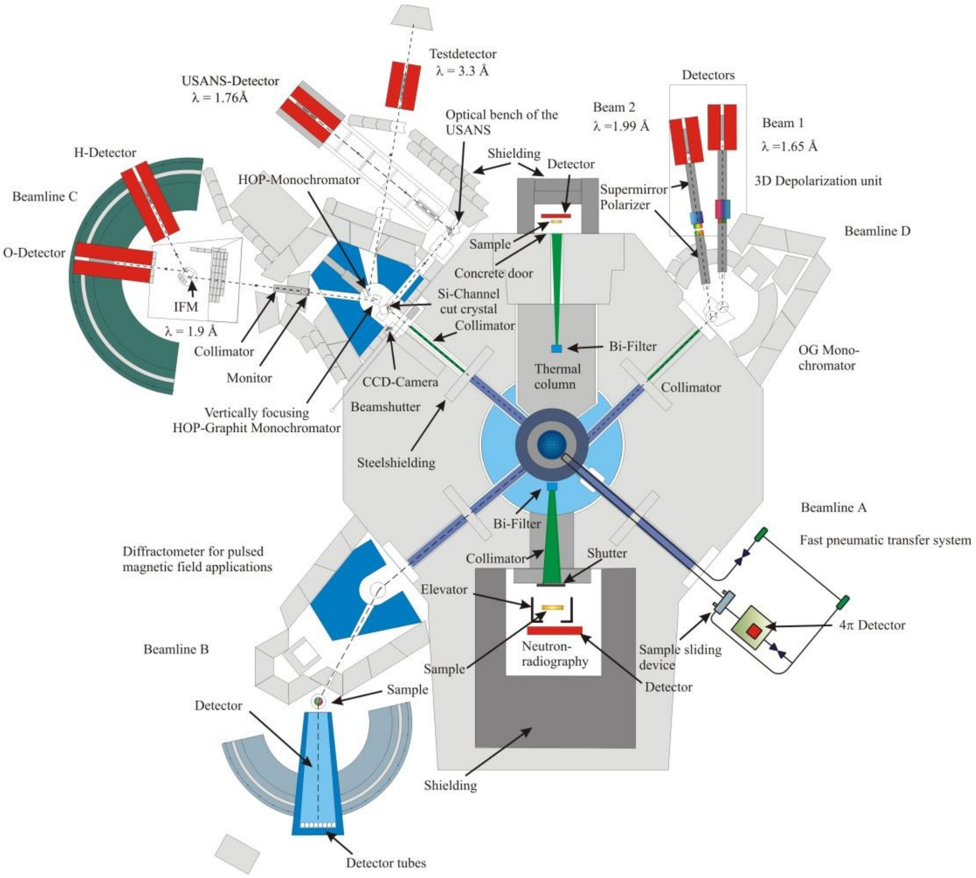
- 5 reflector irradiation tubes
- 1 central irradiation tube
- 1 pneumatic transfer system (transfer time 3 s)
- 1 fast pneumatic transfer system (transfer time 20 ms)
- 4 neutron beam holes
- 1 thermal column
- 1 neutron radiography facility

In the reflector irradiation tubes 10 containers can be irradiated simultaneously. In the central irradiation tube samples up to 38.4 mm in diameter can be exposed to neutrons at a neutron flux density of $10^{13}$ $cm^{-2}s^{-1}$, while the pneumatic transfer system allows to transfer the materials to be activated into the reactor from a chemistry laboratory and back again after the required period of irradiation, without the experimentalist having to leave his working place.

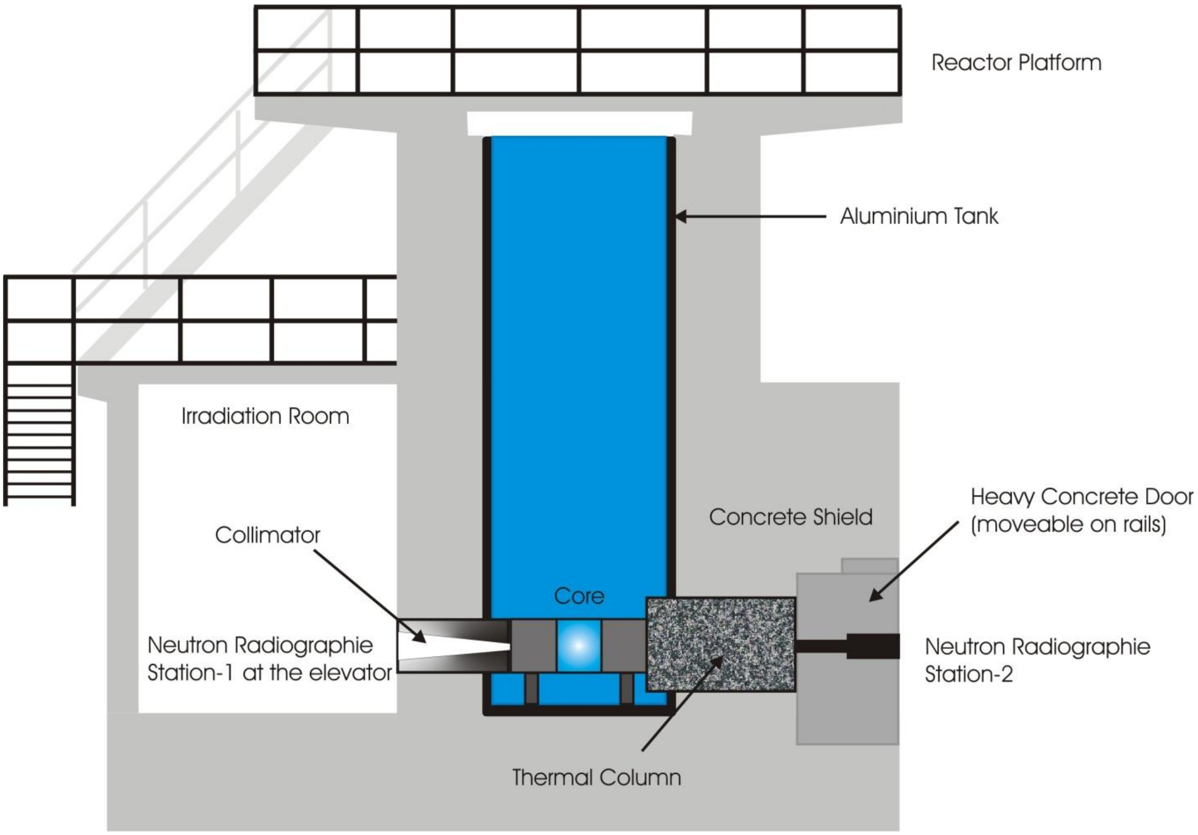
## Beam tube experiments

The four neutron beam tubes permit extraction of neutron beams of all energies into the reactor hall for the purpose of neutron and solid-state physics experiments. The thermal column is used to extract with a thermal spectrum into the reactor hall, unlike the beam holes, the space between the reactor core and the hall is in this case filled with graphite to slow down the neutrons.

The neutron radiography facility is used to investigate components by neutron irradiation similar to X-ray radiography. However, neutrons show especially hydrogen or neutron absorber material in solid matter.



Horizontal Cross Section



Vertical Cross section

# Technical Data

## 1. REACTOR CORE

| | |
|---|---|
| fuel-moderator material | 8 wt% uranium<br>91 wt% zirconium<br>1 wt% hydrogen |
| uranium enrichment | 20% Uran-235 |
| fuel element dimensions | 3.75 cm in diameter<br>72.24 cm in length |
| cladding | 0.76 mm aluminum or 0.51 mm steel |
| active core volume | max. 49.5 cm diameter, 35.56 cm high |
| core loading | 3 kg of uranium-235 |

## 2. REFLECTOR

| | |
|---|---|
| material | graphite with aluminum cladding |
| radial thickness | 30.5 cm |
| top and bottom thickness | 10.2 cm |

## 3. CONSTRUCTION

| | |
|---|---|
| reactor shielding construction | heavy and standard concrete<br>6.55 m high, 6.19 m wide, 8.76 m long |
| reactor tank | 1.98 m in diameter<br>6.40 m in depth |

## 4.SHIELDING

| | |
|---|---|
| radial: | 30.5 cm of graphite;<br>45.7 cm of water and at least<br>206 cm of heavy concrete |
| vertical: | above the core 4.90 m of water and 10.2 cm graphite;<br>underneath the core 61.0 cm water, 10.2 cm graphite and at least 91 cm standard concrete |

## 5. IRRADIATION DEVICES

(1) four beam holes 15.2 cm in diameter
(2) one central irradiation tube (center of core)
(3) five reflector irradiation tubes
(4) one pneumatic transfer system (near core edge)
(5) a thermal column with cross section 1.22x1.22 m and length 1.68 m
(6) experimental tank with surface area 2.44x2.74 m and depth 3.66 m;
connected to the reactor by means of a neutron radiography collimator
0.61x0.61 m in cross section and 1.22 m long.

## 6. CONTROL SYSTEM

- Two boron carbide control rods with electric motor and rack and pinion drive.
- One boron carbide pulse rod with compressed air drive (5 bars).
- Maximum reactivity insertion rate - time rate of change (excluding pulse operation ): 0.04% δk/k per second
- Total rod worth about 4.8% δk/k.

## 7. CHARACTERISTICS IN CONTINUOUS OPERATION

| | |
|---|---|
| Thermal power output: | 250 kW |
| Fuel element cooling: | natural convection of the tank water below 100 kW, pump circulation cooling above 100 kW |
| tank water cooling: | heat exchanger |
| thermal flux: | central irradiation tube: $1x10^{13}cm^{-2}s^{-1}$<br>in the irradiation tubes: $1.7x10^{12}$ $cm^{-2}s^{-1}$ |
| prompt temperature coefficient: | $-1.2x10^{-4}$ δk/k°C |
| mean prompt neutron lifetime: | $6.0x10^{-5}$ s. |

## 8. CHARACTERISTICS IN TRANSIENT OPERATION

| | |
|---|---|
| peak power | 250 MW |
| prompt pulse energy yield | 10 MW s |
| prompt pulse lifetime | 40 ms |
| total energy yield | 12 MW s |
| minimal period | 10 ms |
| maximum reactivity insertion | 1.6% δk/k = 2$ |
| maximum repetition frequency | 12/h |
| number of fissions during a pulse | $3x10^{17}$ |
| maximum fuel temperature: | during the pulse 240 °C<br>9 seconds after the pulse 360 °C |

## 9. BRIEF STATISTICAL DATA

average during last 5 years

| | |
|---|---|
| power produced (MWh) | 300 |
| irradiation experiments | 200 |
| beam hole experiments | 15 |
| number of reactor pulses | 10 |
| number of visitors | 2500 |

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