FSUE "D.V. Efremov Scientific Research Institute
of Electrophysical Apparatus"
(NIIEFA)

Saint-Petersburg, Russia

NIIEFA Accelerators for Industry and Medicine

M.F. Vorogushin

vorogushin@luts.niiefa.spb.su

RuPAC-2012

NIIEFA is a leading enterprise in Russia involved in designing and manufacturing of applied and medical charged particle accelerators, as well as electrophysical systems based on these accelerators.

Since the foundation of the Institute, we have designed, manufactured and delivered to Russian customers and abroad more than three hundred accelerators of different types, in particular, cyclotrons, high-frequency linear electron accelerators, high-voltage accelerators and neutron generators.

The activities of the Institute in the field of accelerating engineering encompasses all the stages of an accelerator manufacturing, starting from R & D works to manufacturing, installation, adjustment and maintenance of the equipment delivered.

Nuclear Medicine

Among the present-day methods of medical examination, the radionuclide diagnostics presents the most complete information on available pathologies. The method is characterized with a high sensitivity.

Cyclotron is the most proper accelerator allowing necessary ultra and short-lived isotopes to be produced in the most cost-effective way.

NIIEFA has been involved in designing and production of cyclotrons since the day of its foundation. More than forty different models of cyclotrons have been delivered to Russian customers and abroad, and the majority of these machines have been operated until now. Recently, a series of compact cyclotrons has been designed specially for production of medical isotopes.

Main Parameters of Cyclotrons for Medicine

Parameters	CC-12	CC-18/9	MCC-30/15
Accelerated ions	H^-	H^- / D^-	H^- / D^-
Ion energy, MeV	12	18 / 9	18…30 / 9…15
Extracted beam current, μA	50	100/50	200/70
Electromagnet:			
- pole diameter, cm	90	115	140
- supply power, kW	5	7	12
- mass,t	10	20	41
Frequency of RF oscillations, MHz	76.4	38.2	40.68
RF generator power, kW	15	20	25
Energy consumption, kW	30	70	100

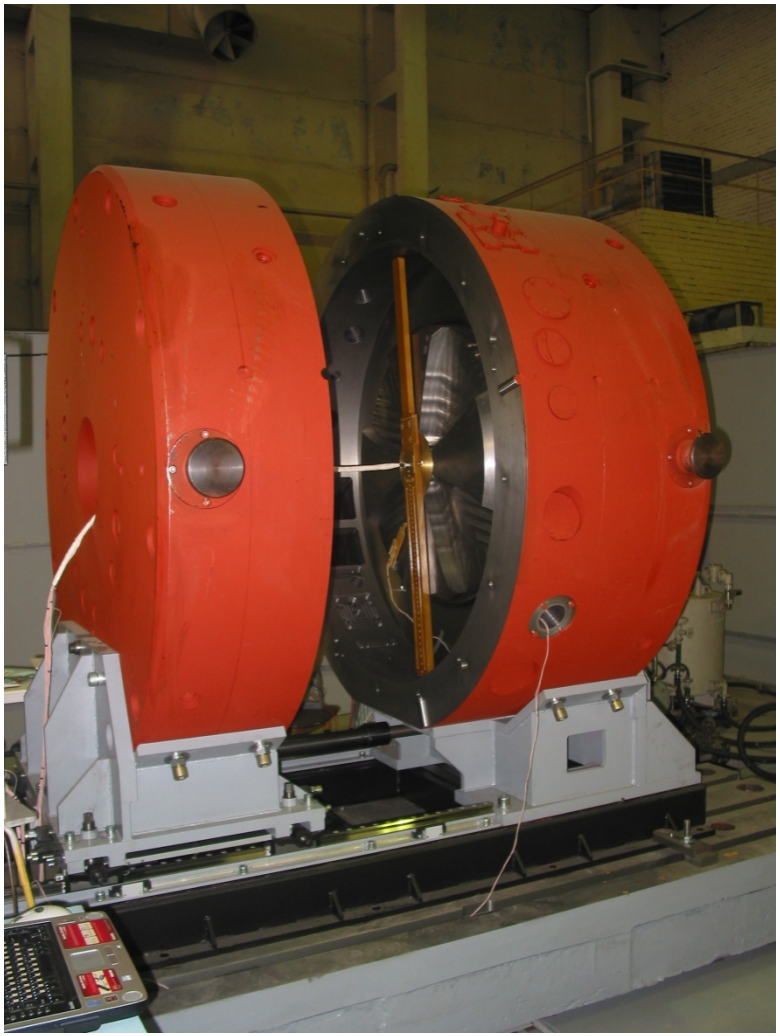
The external injection of hydrogen negative ions, beam extraction by stripping negative ions on carbon foils, the main electromagnet of shielding-type with the vertical median plane, the same principle of construction of the RF-power supply system, vacuum system and automatic control system.

The major part of a cyclotron is a cylindrical electromagnet with four pairs of sectors located on poles. The middle part of the iron core serves as a casing for the vacuum chamber.

The accelerating system consisting of two rectangular coaxial resonators is located completely inside the vacuum chamber. Diagnostic probes, beam extraction devices, RF-power in-feeding device and trimmer for frequency tuning are fixed on the vacuum chamber casing.

To give an access to in-chamber components, the iron core is made as a fixed part and a movable part. The movable part is fixed on a support and can be moved apart for a distance up to 800 mm.

CC-12 Cyclotron



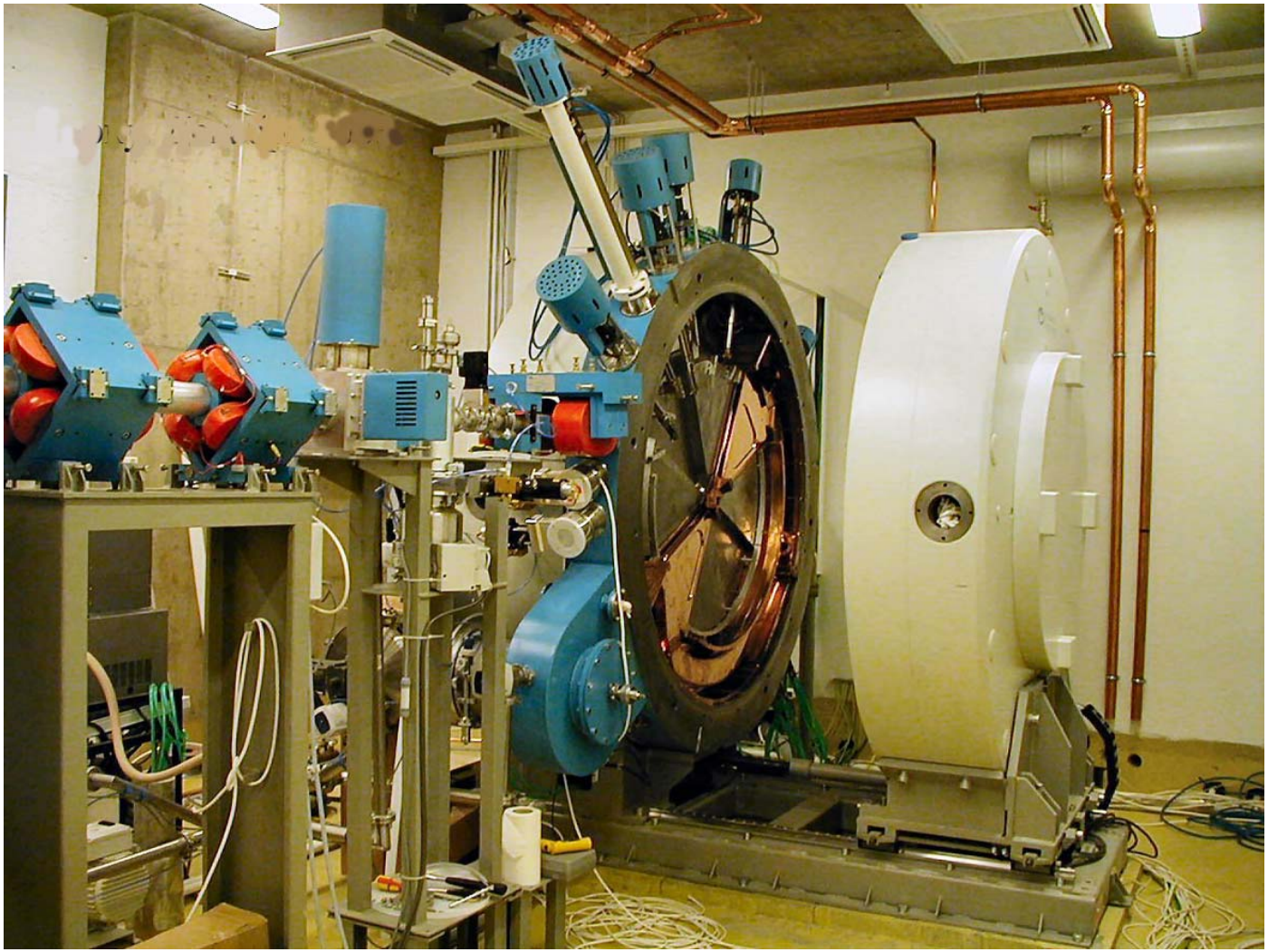
The cyclotron electromagnet at a test facility

The CC-12 compact cyclotron is intended for production of ultra short-lived isotopes directly in medical diagnostic centers.

The cyclotron electromagnet with the external injection system

CC-18/9 Cyclotron

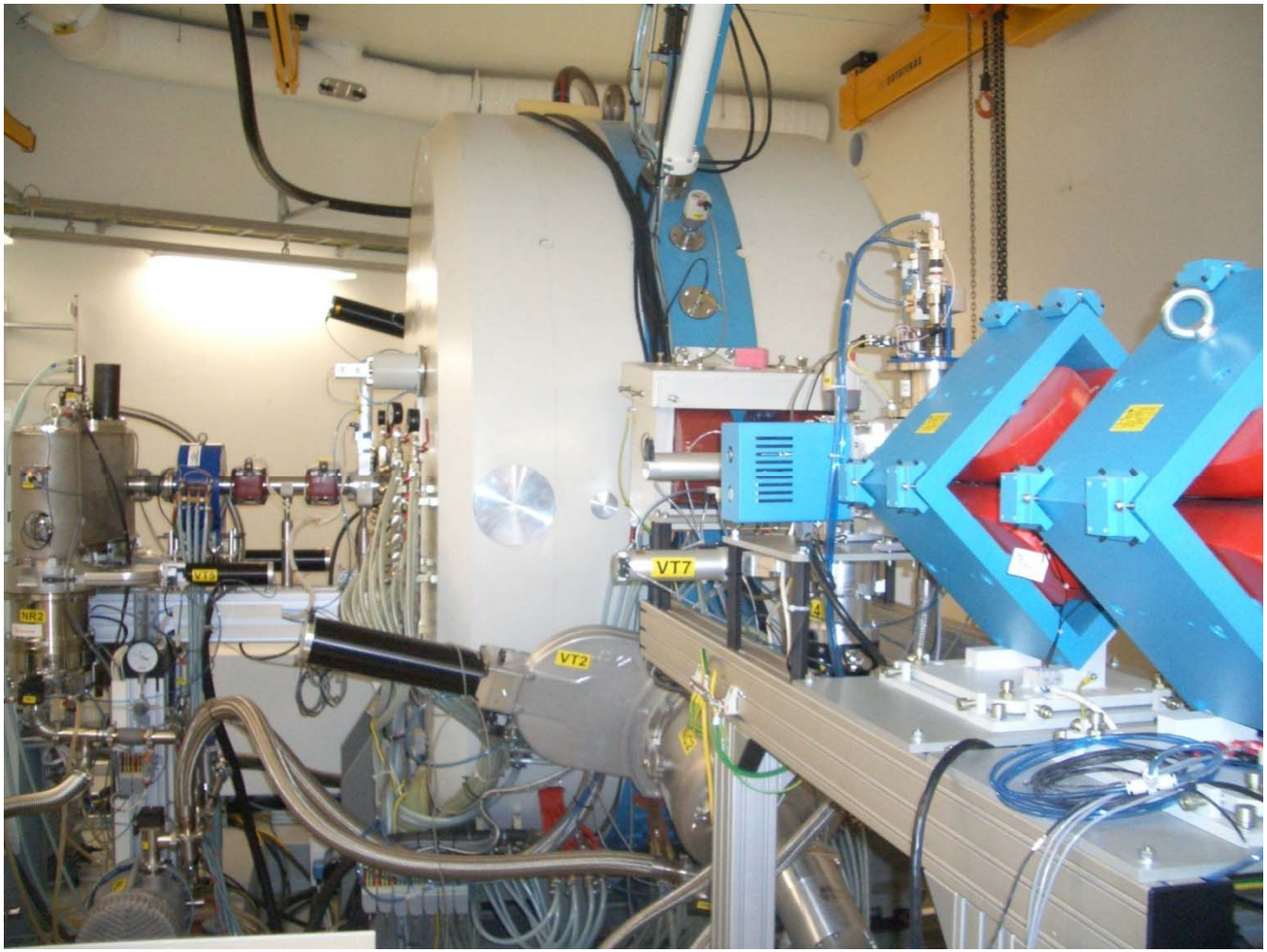
The CC-18/9 cyclotron allows both ultra short-lived isotopes and short-lived isotopes to be produced.



The CC-18/9 cyclotron installed in Turku (Finland)

CC-30/15 Cyclotron

The MCC-30/15 cyclotron with the variable ion energy provides production of ultra short-lived, short-lived and long-lived isotopes for nuclear medicine.



The CC-30/15 cyclotron installed in the University of Jyvaskula (Finland)

Radiotherapy and Neutron Therapy

The D.V. Efremov Institute is the only national designer of linear electron accelerators for radiation therapy, and therefore designing and production of electrophysical equipment for medicine is one of priority fields of its activity.

The fist linear electron accelerator for medical purposes rated for 5 and 25 MeV were developed in Institute more four decades ago.

Over the years of the D.V. Efremov Institute existence, several generations of medical accelerators have been designed and manufactured. About one hundred machines have been delivered to oncologic clinics of Russia and CIS countries.

The SL75-5MT Accelerator for Medicine

The SL-75-5MT accelerator is intended for X-ray radiation therapy with an energy of 6 MeV in the static and arc modes. About sixty machines have been manufactured and delivered to clinics of Russia.

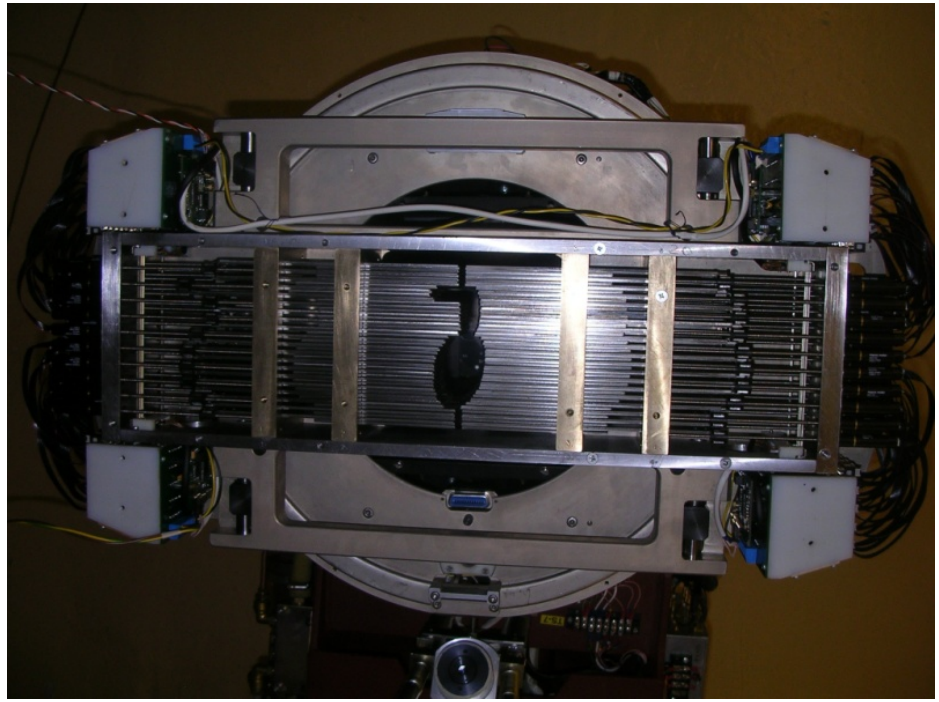
Work center for assembly of SL-75MT irradiators

The SL-75MT accelerator. General View

The «ELLUS-6M» Accelerator for Medicine

The new medical accelerator «ELLUS-6M» with an electron energy of 6 MeV have been designed with the additional medical equipment

The «ELLUS-6M» accelerator in the N.N. Petrov Institute of Oncology, St. Petersburg



Multi-Leaf Collimator (MLC)

NG-12-I neutron generator

The NG-12-I neutron generator provides the neutron yield up to $3 \cdot 10^{12}$ n/s and is used in the system of the Ural Center of Neutron Therapy.

Non-Destructive Testing

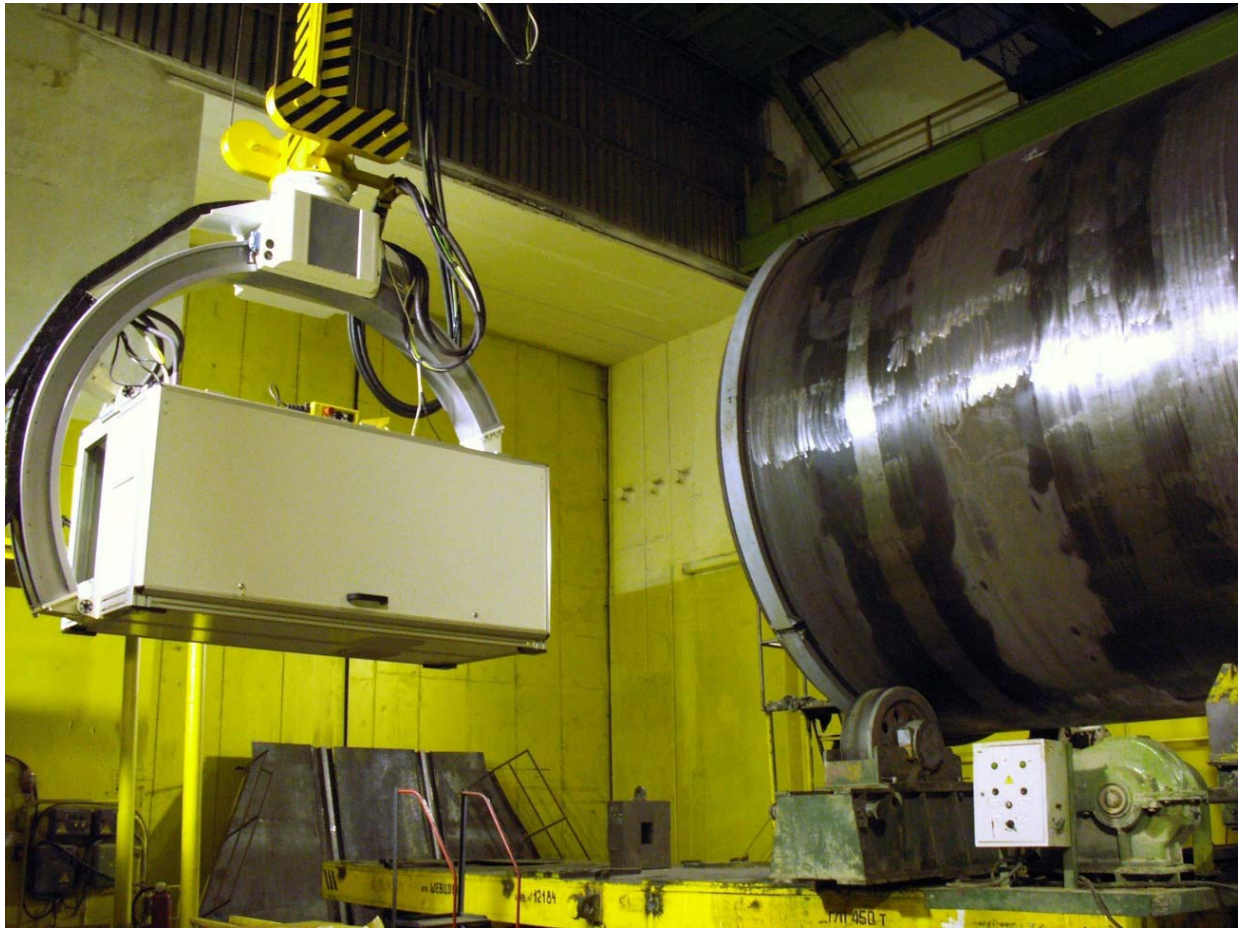
The most important line of activities of NIIEFA in the field of accelerating engineering is designing and construction of systems for non-destructive testing of large-scale products based on linear accelerators with energy ranging from 3 to 15 MeV. NIIEFA has delivered more than thirty similar machines both to industrial enterprises in Russia and abroad.

New accelerators, UEL-10-D and UEL-6-D, have been designed and manufactured especially for non-destructive inspection of products of atomic, chemical and shipbuilding industries.

Use of the latest technologies in the sphere of electronics, creation and software realisation of a powerful mathematical apparatus of signal processing and digital image reconstruction have enable one to implement a spatial resolution of such system up to 1 mm, the density resolution 0.5% for large-size items with steel- equivalelent thickness 300 mm at electron energy 10 MeV.

UEL-10-D Accelerator

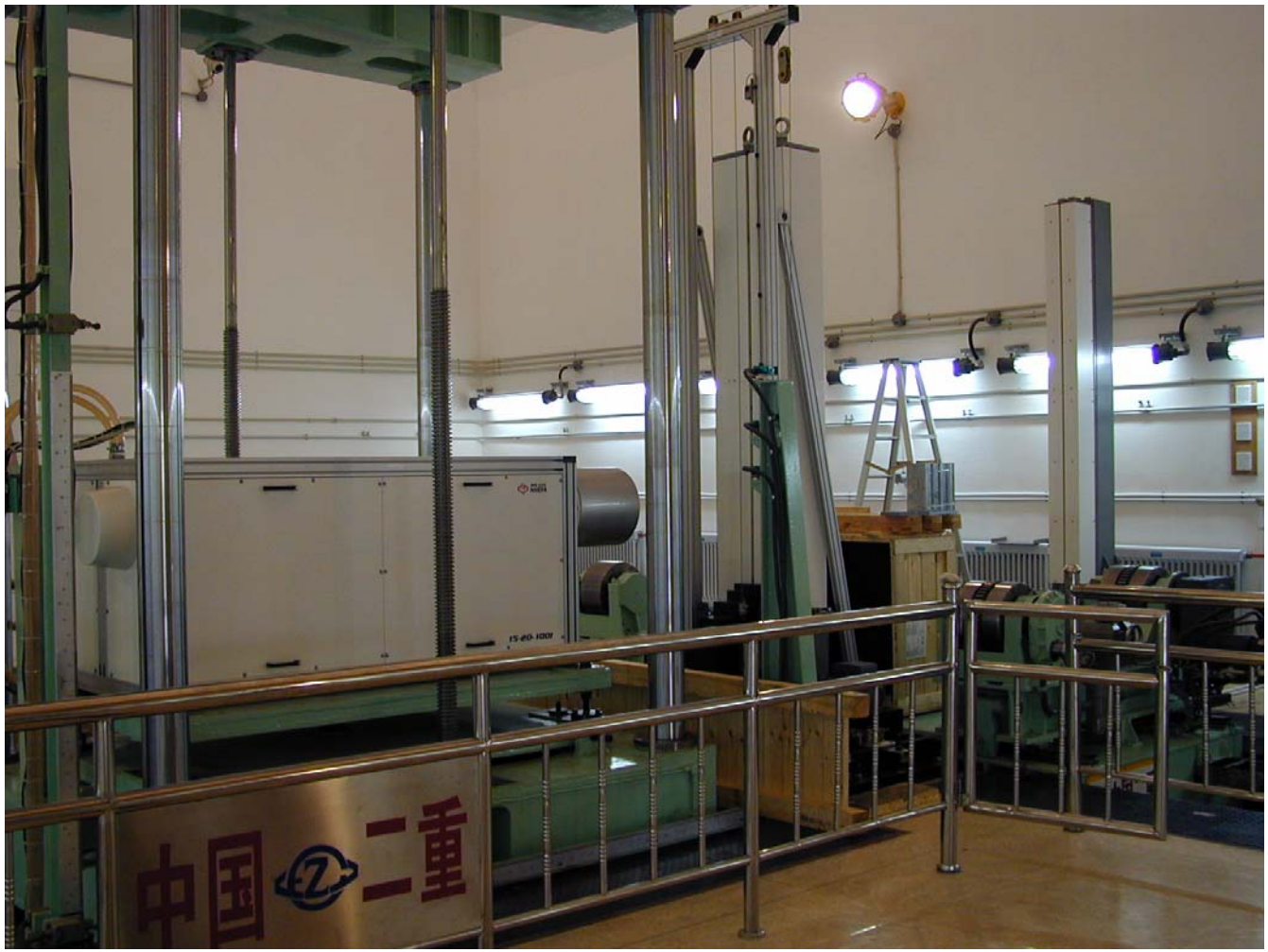
Radiation characteristics of UEL-10-D accelerator: energy of accelerated electrons is 10 MeV, maximum average dose rate 1 m from target on the central axis is 30 Gy/min, asymmetry of the X-ray field is no more than 5%.



The UEL-10-D accelerator at the Izhorskie Zavody, St. Petersburg

UEL-15-D-100I Accelerator

Radiation characteristics of UEL-15-D accelerator: energy of accelerated electrons is 15 MeV, maximum average dose rate 1 m from target on the central axis is 100 Gy/min, focus spot effective diameter on target is no more than 2 mm.



The UEL-15-D-100I accelerator installed in China

The LINAC-4 accelerator

A new design of a series 1.9; 2.5; 4.0 MeV small-sized linear accelerators of electron with the local radiation shielding carried out at the NIIEFA.

The accelerators are intended for mobile systems for radiation customs monitoring of cargo.

The LINAC-4 accelerator in the SMITH HEIMAN system, Germany

System with dual energy of X-ray beam provides discrimination of groups of materials according to their average atomic number.

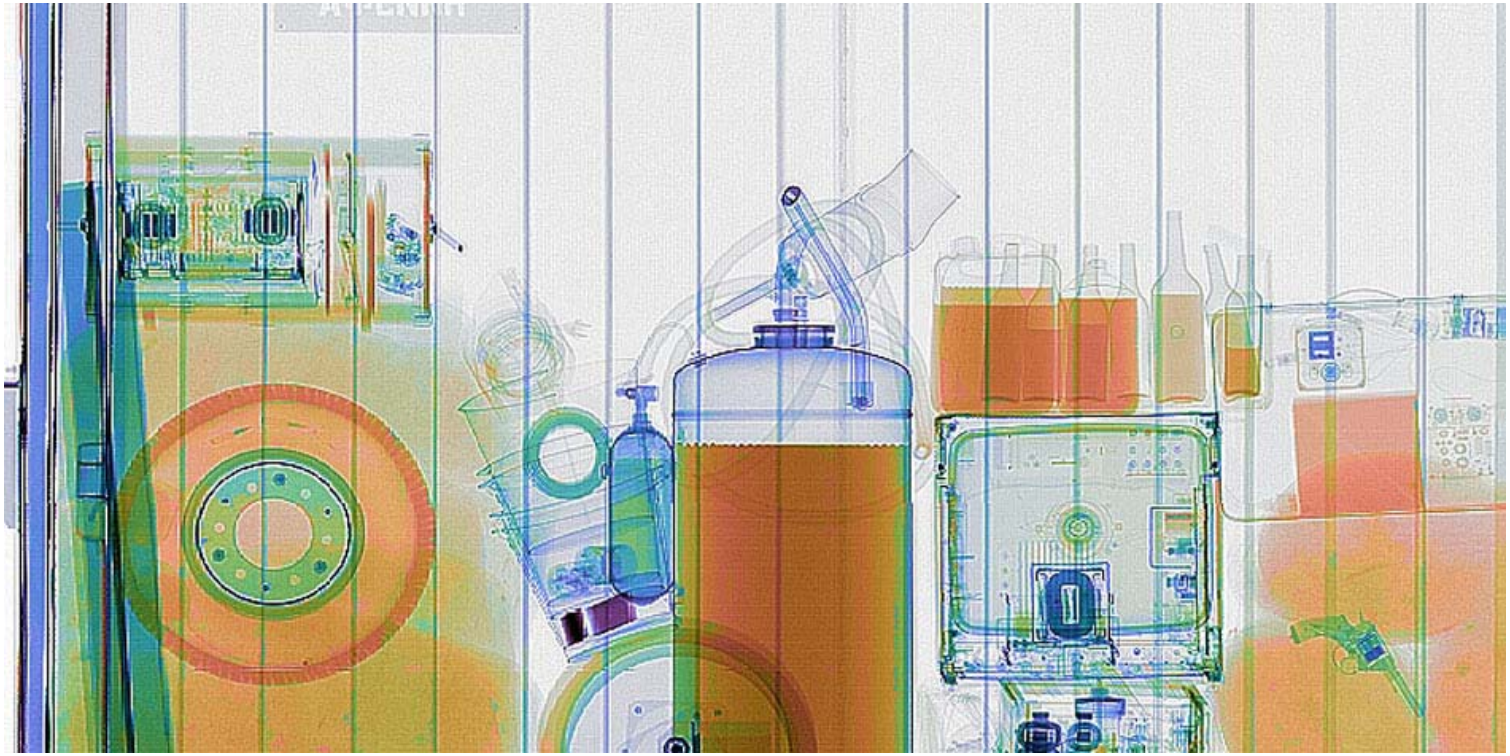


Image of cargo container in material-color encoding:

- ***organic and light materials are orange colored;***
- ***metals are shown in blue;***
- ***overlapping of organic and inorganic substances is in green;***
- ***heavy metals - in lilac.***

High-Voltage Accelerators for Radiation Processing

High-voltage charged particle accelerators are ranked high in the line of the accelerating equipment designed and manufactured in NIIEFA. By now, more than one hundred and thirty high-voltage electron and ion accelerators for various purposes have been delivered to Russian customers and abroad.

Further, radiation processing of different materials and products with an electron beam to modify their molecular structure and impart new properties becomes one of the most promising fields of practical application of high-voltage accelerators with a charged particle energy of up to 1 MeV.

To introduce radiation processing on industrial enterprises, a series of high-voltage accelerators with an electron beam power of up to 50 kW has been designed in NIIEFA.

«Electron-10» Accelerator

The main parameters of the accelerator are: the energy in the 500÷750 kV range, maximum current of accelerated electrons – 70 mA, non-uniformity of the current linear density along the scanning length of 1200 mm is not more than 5%.

The «Electron-10» accelerator at the plastic materials production plant, Izhevsk

«ELECTRON 23» Accelerator

The «ELECTRON 23» with an electron beam power of up to 400 kW and an energy of 1 MeV in the NIIEFA

RF Accelerators for Radiation Processing

Several models of linear accelerators with the electron energy ranging from 3 up to 15 MeV and average beam power up to 15 kW have been designed and manufactured in NIIEFA for high-energy radiation processing.

The accelerators are equipped with horn scanning chambers.

Thickness of objects under processing depends on the electron energy; the velocity and throughput depend on the beam power.

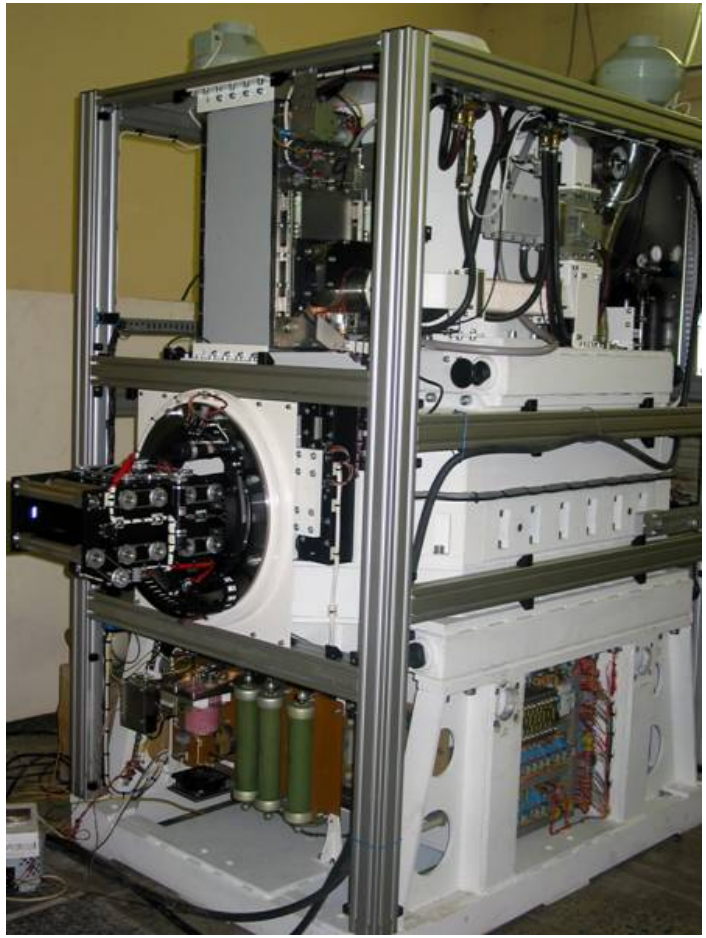
To generate a directed X-ray beam, an accelerator is equipped with a tungsten-nickel target.

The accelerators may be used in conveyer lines and are designed for round-the-clock operation.

The irradiators may be installed either vertically or horizontally depending on particular radiation technology.

UELV-3-3S Accelerator

For the “in-line” processing of products in standard industrial premises, a 3 MeV UELV-3-3S accelerator with a beam power of up to 3 kW equipped with a local radiation shielding has been designed.

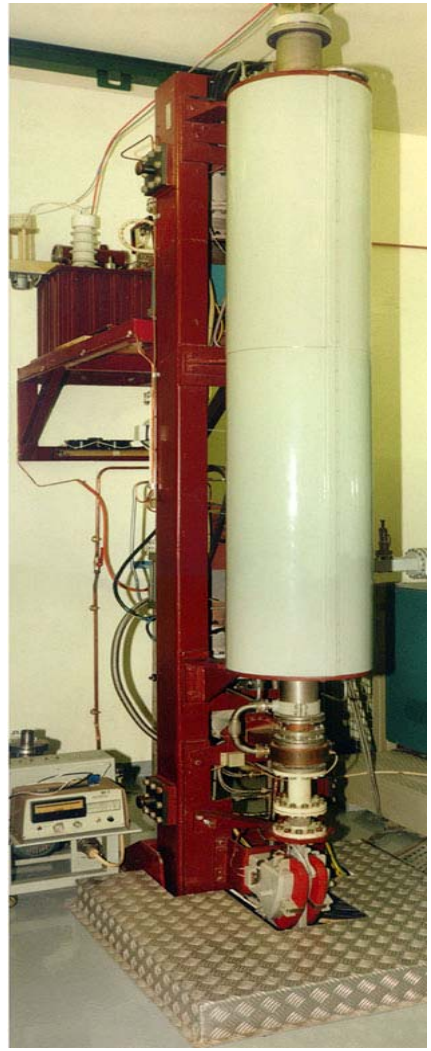


The UELV-3-3S accelerator in NIIEFA

UELR-10-10S and UELV-8-5S Linear Electron Accelerators

The UELR-10-10S accelerator installed in the Chinese National Institute of Metrology, Beijing

Irradiator of the accelerator in the assembly area of NIIEFA



The 8 MeV accelerator installed in France at the "RADIENT Nord" facility for sterilization of medical utensils

UELR-10-10S accelerator characteristics	Parameters
Energy of accelerated electrons, MeV	10
Max output power of the accelerator in the nominal mode, kW	10
Irradiation field size 200mm from the output window foil, mm²	800 x 20
Uniformity along the scanning length, %	5

Conclusion

Technical characteristics of the accelerating equipment designed and manufactured in NIIEFA are on a par with their foreign analogs and in some cases are even superior to their competitors.

Taking into account expenditures for transportation, customs duties, intermediary firms, warranty/after-warranty servicing (especially in case of no foreign service centers), delivery of spare parts, etc., the total cost of the equipment is much lower.

Nowadays, the demand for applied accelerators round the world increases rapidly.

Proper activities towards marketing, promotion and patent right protection as well as the organization of serial production of the accelerating equipment being at present in ever-growing demand can ensure the competitiveness of national projects.