KHARKOV COMPACT CYCLOTRON CV-28: PRESENT AND FUTURE STATUS

Yuri Petrusenko[1], Dmytro Barankov[1], Sergii Shkyryda[1], Denys Irzhevskyi[1], Rainer Hoelzle[2]
1 - CYCLOTRON Science & Research Establishment, NSC KIPT, 61108 Kharkov, Ukraine,
2 - Institut für Festkörperforschung, FZJ, 52425 Jülich, Germany

Abstract

Reported are the present and future statuses of the Kharkov Compact Cyclotron CV-28 donated to the National Science Center - Kharkov Institute of Physics & Technology (NSC KIPT) by the Forschungszentrum Juelich (Germany). The cyclotron configuration and special features of new installation at the NSC KIPT are described. Consideration is given to the use of the cyclotron beam as a promising means for investigation and development of materials for fusion reactors and generation-IV nuclear reactors, investigation and production of medical radionuclides, possible applications of a high-energy neutron source based on a deuteron beam and a thick beryllium target.

INTRODUCTION

A compact isochronous cyclotron CV-28, supplied by Cyclotron Corporation (USA) to the Jülich Research Center (Germany) provides the generation of light ion beams (H^+, $^2H^+$, $^3He^{++}$, He^{++}) in the continuous mode of operation with output energies adjustable in a sufficiently wide range [1].

Table 1 gives the performance characteristics of cyclotron CV-28.

Table 1: Cyclotron CV-28 performance characteristics

Particles	Beam energy range	External Current at Minimum Energy	External Current at Maximum Energy	Internal Current
H^+	2-24 MeV	70 μA	70 μA	500 μA
D^+	3-14 MeV	100 μA	100 μA	500 μA
$^3He^{++}$	5-36 MeV	15 μA	70 μA	150 μA
He^{++}	8-28 MeV	10 μA	50 μA	100 μA

It should be noted that the above-mentioned advantages of the cyclotron are supported by the fact that it can be readjusted for ion production with different energies or for acceleration of ions of other species more than once per working shift, i.e., sufficiently promptly.

The cyclotron is really operated as a multi-particle and variable-energy machine, as it is common practice with it to have several different beams a day, mostly on different targets, too. The general view of the compact cyclotron CV-28 is shown in Fig. 1.

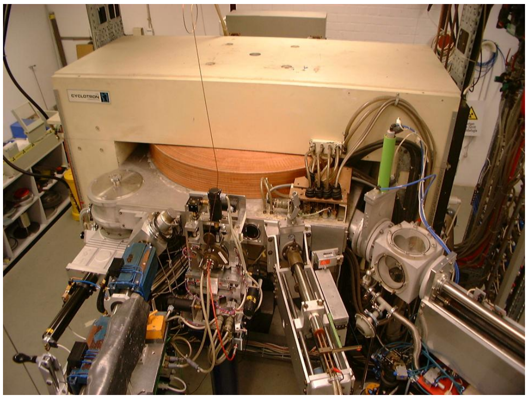

Figure 1: View of cyclotron

An accelerated beam can be guided to the target located inside the acceleration chamber, and can be extracted by means of the deflector and the magnetic channel outside the acceleration chamber.

The ion guide with ion-optical elements arranged on it directs the beam to the switching electromagnet.

PRESENT STATUS OF CV-28

In 2006, the cyclotron complex CV-28 equipment (except ventilation and water-cooling systems) was dismantled, packed and, by the end of 2006, was brought to the NSC KIPT. The layout of the cyclotron complex equipment is shown in Fig. 2

We have designed a new scheme of locating the cyclotron in a specially assigned building at the NSC KIPT. This scheme follows the German version of the equipment arrangement in many ways. The main feature consists in the ejection of the accelerated ion beam to three radiation-isolated target rooms, which accommodate five channels altogether. Two more ion beam channels are located in the cyclotron room.

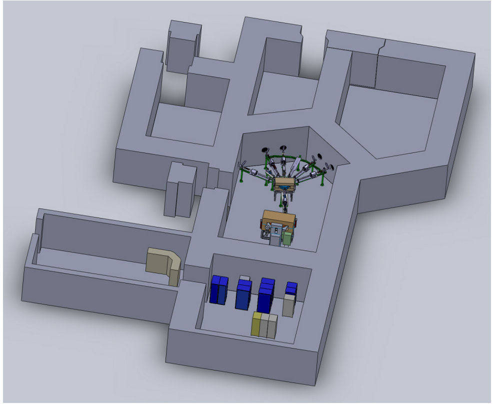

Figure 2: Layout of the cyclotron complex equipment

Currently, the work on installing the components and units of the cyclotron is under way. The cyclotron chambers with main magnetic coils as well as the switching magnet are installed in their working places. Assemblage of the major ion channel has been started. Installation of service cables and air channels is carried out. The work is in progress on the preparation of the main and backup power supply of the cyclotron. The 3D picture of the cyclotron and switching magnet is presented in Fig. 3.

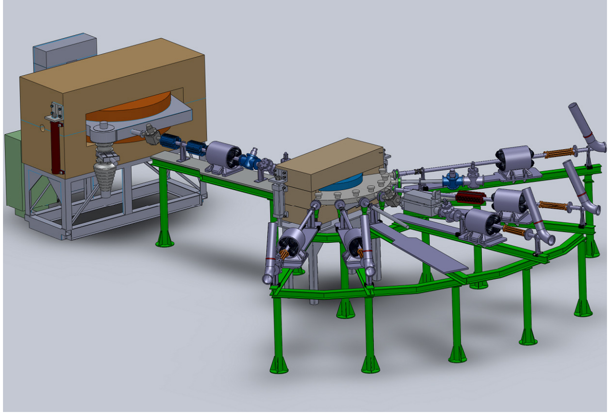

Figure 3: The cyclotron with switching magnet

FUTURE STATUS

The main lines of research at the NSC KIPT with the use of cyclotron CV-28 include: nuclear physics, production of medical isotopes, investigation of radiation damages in structural materials of nuclear power reactors [2].

Medical Radionuclide Production

The cyclotron CV-28 offers the challenge of producing isotopes for PET and SPECT diagnosis, as well as for radionuclide therapy of cancerous growths (brachytherapy, radioimmunotherapy, targeted alpha therapy, Auger-therapy) [3]. The possibility of production of medical radionuclides ^{123}I, ^{124}I, ^{125}I at the cyclotron CV-28 with the use of Te targets has been investigated

The Neutron Source

As regards the creation of a neutron source on the beam of deuterons with a thick beryllium target, it has been shown that with a deuteron beam having energy of 14 MeV and current of 100 mA, one can obtain neutron beams with a maximum density of $10^{12}\cdot$n/sm^{2}sec. The calculated energy spectrum of neutron flux is shown in Fig. 4.

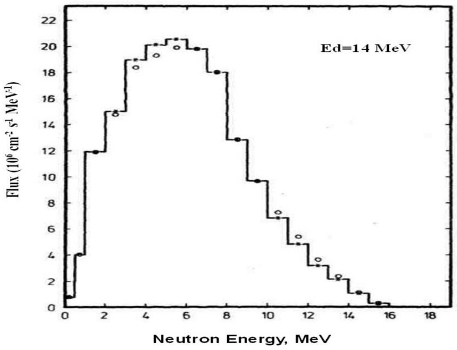

Figure 4: The energy spectrum of neutron flux

The main areas of application of the neutron source based on the cyclotron are as follows:

- development and testing of neutron detectors;
- element analysis;
- neutron effects on biological materials.

The neutron collimator is shown in Fig.5.

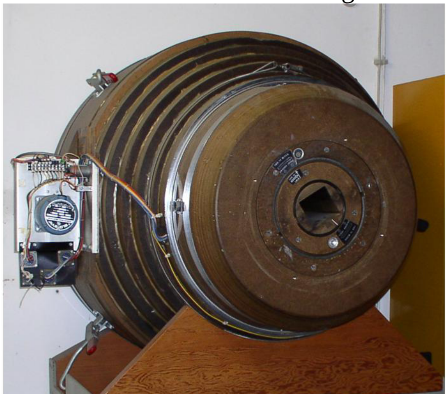

Figure 5: The neutron collimator

Study of Radiation Damage in Structural Materials of Nuclear Power Reactors

The main research areas are: radiation creep, high-temperature radiation embrittlement; effects of implantation of H, He; vacancy swelling; the role of nuclear reaction products in the change of mechanical and other properties of reactor vessel and fuel cladding. The maximum doses and dose rates attainable for different ion beams were calculated and are presented in Table 2.

Table 2: Calculated maximum damage by different particles

Particles	Max Beam Energy	Average Current	Max Dose Rate	Max Dose
H^+	24 MeV	50μA	~$5\cdot10^{-6}$ dpa/sec	~0.25 dpa
D^+	14 MeV	50μA	~10^{-4} dpa/sec	~5.0 dpa
$^3He^{++}$	36 MeV	50μA	~$2\cdot10^{-4}$ dpa/sec	~10 dpa
$^4He^{++}$	28 MeV	50μA	~10^{-3} dpa/sec	~50 dpa

The depth of proton penetration into nickel has been calculated (see Fig. 6).

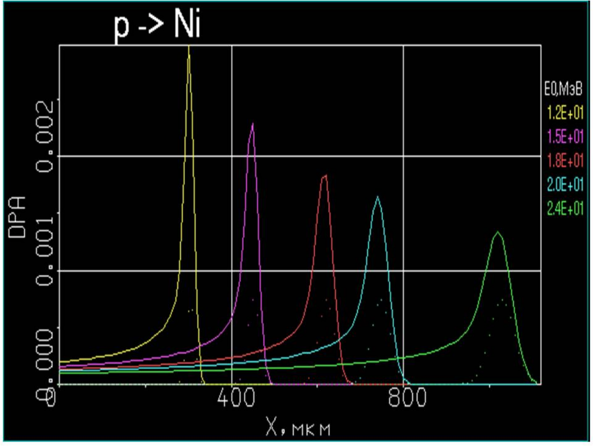

Figure 6: Profiles of defect accumulation in nickel irradiated with a proton beam.

ACKNOWLEDGEMENTS

We thank V. Gann at National Science Center – Kharkov Institute of Physics & Technology for calculation of damage profiles in nickel irradiated with a proton beam.

REFERENCES

[1] J. Hemmerich, R. Hoelzle,W. Kogler. The Juelich compact cyclotron – a multi – purpose irradiation facility // Kerntechnik. 1977, No 2.

[2] A.M. Yegorov, A.G. Lymar, I.M. Nekludov, Yu.T. Petrusenko. Compact cyclotron CV-28 and prospects its usage //Problems of atomic science and technology, 2008. No 5. Series: Nuclear Physics Investigations (50), p.12-15.

[3] V.V. Sotnikov, V.A. Voronko, Yu.T. Petrusenko, D.Yu. Barankov // The Potential of medical radioisotopes production by cyclotron CV-28, Problems of atomic science and technology. 2010. No 3. *Series:* Nuclear Physics Investigations (54), p.168-172.