DEVELOPMENT OF FLNR JINR HEAVY IONS ACCELERATOR COMPLEX (DRIBs III)

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Abstract

The status of the FLNR JINR cyclotrons and plans of their modernization are presented. At present time, three isochronous cyclotrons: U400, U400M and IC100 are under operation at the JINR FLNR. The new isochronous DC-280 cyclotron is being created at the FLNR JINR for the new Super Heavy Element Factory.

INTRODUCTION

The Flerov Laboratory of Nuclear Reactions of Joint Institute for Nuclear Research (FLNR JINR) scientific program on heavy ion physics consists of experiments on synthesis of heavy and exotic nuclei using ion beams of stable and radioactive isotopes and studies of nuclear reactions, acceleration technology and applied research.

Presently, the FLNR JINR has four cyclotrons of heavy ions: U400, U400M, IC100, that provide performance of the basic and applied researches. Total annual operating time of the U400 and U400M cyclotrons is more than 10000 for many years (Fig. 1). The old U200 cyclotron is out of operation now.

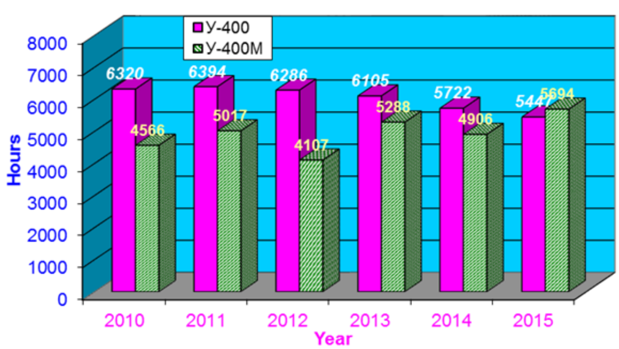

Figure 1: U400 and U400M operation in 2010-2015.

At present time the project of Super Heavy Element Factory is being performed at the FLNR JINR [1]. The project implies design and creation of the new DC280 cyclotron which has to provide intensities of ion beams with middle atomic masses (A~50) up to 10 pμA. The FLNR JINR facilities are shown in Fig. 2.

U400 CYCLOTRON

The isochronous U400 cyclotron has been in operation since 1978 [2]. The cyclotron produces ion beams of atomic masses 4-209 with energies of 3-29 MeV/nucleon. The main parameters of the U-400 are presented in Table 1. About 66% of the total time has been used for acceleration of $^{48}Ca^{5+}$ ions on the U400 cyclotron for synthesis of superheavy elements. New prospects for the synthesis of superheavy elements may appear to be connected with the usage of the intense beam of neutron-rich ^{50}Ti. The beam of ^{50}Ti ions has been accelerated into the U400 cyclotron. The extracted beam intensity of the of ^{50}Ti ions was about 0.5 pμA [3].

In 2014 the cyclotron was equipped by a dedicated channel for SEE testing of electronic components for ROSCOSMOS [4].

The U400 modernization is planned. The aims of the modernization are increasing the total acceleration efficiency and possibility to vary ion energy fluently at factor 5 for every mass to charge ratio (A/Z). The width of ion energy region will be 0.8-27 MeV/nucleon. The project of U400 modernization intends decreasing the magnetic field level at the cyclotron center from 1.93-2.1T to 0.8-1.8T, see Tab.1 (U400R). The axial injection and ion extraction systems will be changed. For the ion extraction both the stripping foil and the deflector methods are considered. Moreover, the project intends changing the U400 vacuum, RF and power supply systems. The expected ion beam intensities will be at least 2.5 times more than U400 ones [5].

Table 1: Comparative Parameters of U400 and U400R

	U400	U400R
Parameters	**Value/Name**	
Magnet weight	2100 t.	2100 t.
Magnet power	850 kW	200 kW
RF system power	100 kW	100 kW
Magnetic field level	1.93-2.1 T	0.8-1.8 T
The A/Z range	5-12	4-12
The frequency range	5.42-12.2 MHz	6.5-12.5 MHz
Harmonic modes	2	2-6
The max extraction radius	1.72 m	1.8 m
Vacuum level	$(1\text{-}5)\cdot10^{-7}$ Torr	$(1\text{-}2)\cdot10^{-7}$ Torr
Ion extraction method	Stripping foil	Stripping foil Deflector
Number of ion extraction directions	2	2

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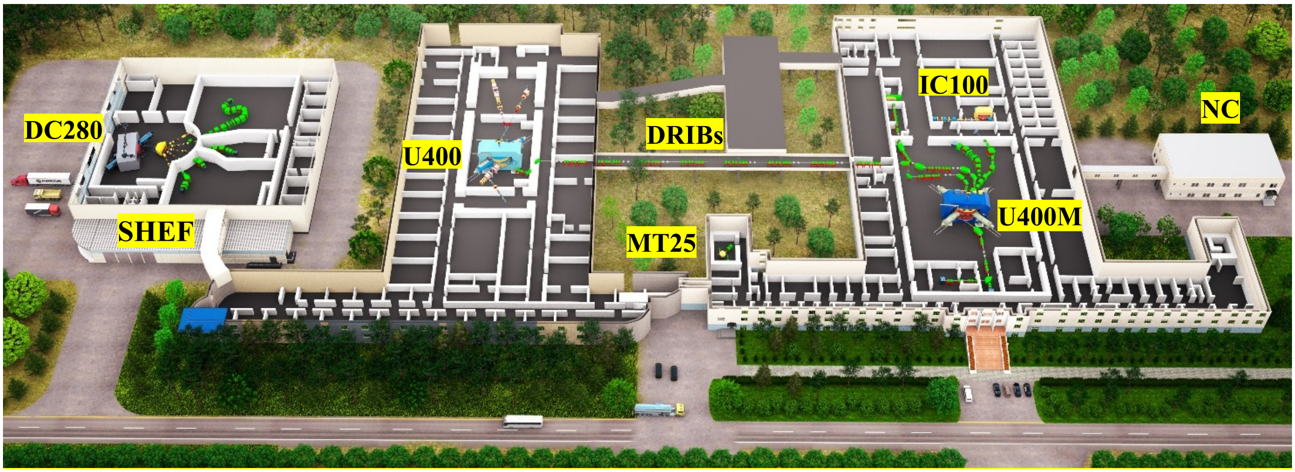

Figure 2: Layout of the Flerov Laboratory buildings, where: U400, U400M, IC100, DC280 are heavy ion cyclotrons, MT25 is the microtron, SHEF is the Super Heavy Element Factory, NC is the Nanotechnology Centre.

The cyclotron ion beam extraction system will be equipped with an electrostatic deflector and a passive focusing magnetic channel (Table 1).

The U400 experimental hall will be essentially modernized. The total experimental building will be extended to about 2000 m^2. New halls will be attached to the old building from sides (Fig. 3). The new experimental area will consists of six separated halls located on two floors. Every hall will be radiation shielded.

Figure 3: A sketch of the new U400 experimental hall.

U400M CYCLOTRON

The isochronous U400M cyclotron has been in operation since 1991. The cyclotron was originally intended for acceleration ion beams with A/Z=3-3.6 (A- atomic weight of the accelerated ion; Z - ion charge when accelerated) at energies of 34-60 MeV/nucleon. The beam extraction method is performed by ion stripping method. In 2008 the U400M possibilities have been extended by addition of the ion beams with A/Z=8-10 at energies of 4.5-9 MeV/nucleon. The additional ion beams intended to carry out physical experiments on synthesis the new super heavy elements and applied researches. The new axial injection system of the U400M was put into operation in 2006.

Two types of spiral inflectors are used to inject ions into the cyclotron centre for low and high energy regimes. At present, the U400M has two opposite directions of ion extraction with corresponding ion beam transport lines. To produce required ions the 14 GHz ECR ion source DECRIS-2 and the superconducting 18 GHz ECR ion source DECRIS-SC2 are being used [6]. Switching from one ion source to another is carried out by rotating the analysing magnet (Fig. 4).

In the period from 2010 to 2015 the cyclotron was equipped by two dedicated channels (low and high energy) for SEE testing of electronic components for ROSCOSMOS [4]. Acceleration of $^{84}Kr^{20+}$ to energies of 27 MeV/nucleon, $^{132}Xe^{30+}$ to 24 MeV/nucleon and $^{209}Bi^{37+}$ to 15 MeV/nucleon has been realized for SEE testing.

In 2016 the new channel for the ACCULINA 2 experimental setup has been created.

In the nearest future we plan to increase the energies of light ions to 60-80 MeV/nucleon by using ion extraction by an electrostatic deflector from ultimate cyclotron radiuses.

IC100 CYCLOTRON

The isochronous IC100 implanting cyclotron was put into operation the in 1985 with PIG internal ion source.

Due to the upgrade in 2003 IC100 was equipped with external axial beam injection system and the superconducting ECR ion source (DECRIS-SC [6]) which allowed to produce intensive beams of highly charged ions of Xenon, Iodine, Krypton, Argon and other heavy elements of the Periodic Table with A/Z=5,545,95 at energies of 0.9-1.1 MeV/nucleon. The focusing system of injection line consists of a solenoidal lens and a quadrupole lens situated between the ECR and the 90°magnet, also three solenoids placed in the vertical part of the injection channel. Spiral inflector is installed into the center of the accelerator. The accelerated beam extraction system consist of electrostatic deflector and two focusing magnetic channels. In routine operation IC100 provides intensities of the $^{86}Kr^{+15}$ and $^{132}Xe^{+23}$ ion beams up to 3 μA.

Special-purpose beam transportation line with polymer film irradiation unit and beam scanning system has been created as well as a box for heavy ion beam research.

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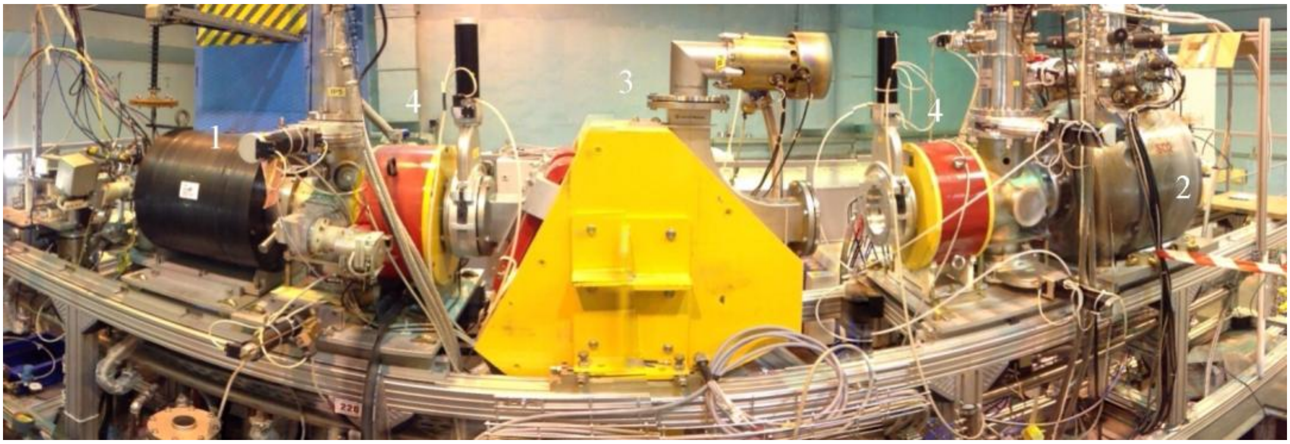

Figure 4: DECRIS-2 (1) and DECRIS-SC2 (2) ion sources at the U400M injection, where (3) is the analysing magnet, (4) is the focusing solenoids.

DC280 CYCLOTRON

The new accelerator will significantly increase the potential of the existing accelerator complex of the FLNR. The DC280 cyclotron designed at the Flerov Laboratory of Nuclear Reaction of the Joint Institute for Nuclear Research in Dubna (FLNR, JINR, Dubna) is intended for carrying out fundamental and applied investigations with ions from He to U (masses from A = 2 up to 238) produced by ECR sources (Fig. 5).

The DC280 will be the basic facility of the Super Heavy Element Factory (SHEF) that is being created at the FLNR. The energy of the ions extracted from the cyclotron may vary from 4 up to 8 MeV/amu. The expected intensity of extracted beam at DC280 is 10 pμA for ions with masses up to 50 [5]. In according to FLNR plans the cyclotron has to be assembled in the period from 2016 to 2017. The cyclotron commissioning will be in the end of 2017 [7].

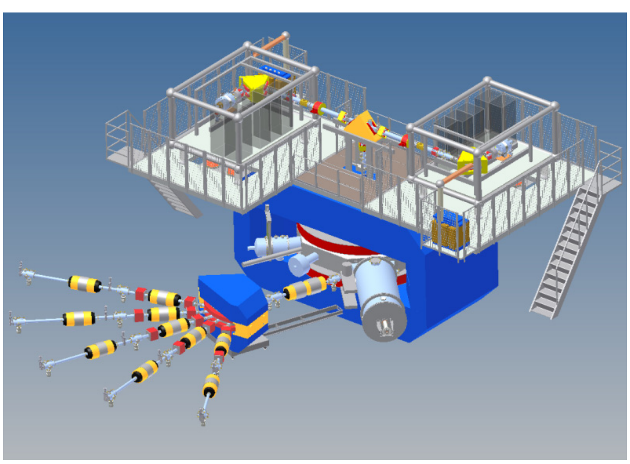

Figure 5. Layout of the DC-280 assembling.

CONCLUSION

The Flerov Laboratory plans implies essential development of the cyclotron complex to 2023.

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