UPGRADING OF DC-40 CYCLOTRON

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Abstract

The DC-40 cyclotron was upgraded over the last years to serve as a machine for the routine application with heavy ions. The cyclotron was extensively equipped with a new instrumentation and computer control as well as a new irradiation set-up. This paper gives a brief description of some modified cyclotron subsystems, focuses on the commissioning procedure and reports first experimental results.

INTRODUCTION

The DC-40 heavy ion cyclotron [1,2] was in operation since 1985 for acceleration of ions from C to Ar with fixed energy about 1.2 MeV/nucl on accelerating at 4th harmonic mode. For generation of such ions the PIG ion source was used. Experiments in the field of the solid-state physics and industrial applications need to use heavy ions having the mass up to Xe. In order to fulfill these demands superconducting (SC) ECR ion source (ECRIS) [3] was built together with a new axial injection line. The created cyclotron allows one carrying out irradiation of different polymer materials by such heavy ions as Ar, Kr and Xe.

ION SOURCE

In order to get ions heavier than Ar with given energy we need a powerful ion source able to generate highly charged intense heavy ions (e.g. Kr^{15+} and Xe^{23+}). For fulfillment of these demands SC ECR ion source was created. The mean feature of the ECRIS is using of a small refrigerator for cooling the solenoid coils down to 4.2 K. Small Gifford-McMahon refrigerator cools the solenoid coils. It maintains the superconductivity of the solenoid coils without using liquid He. The hexapole magnet consists of permanent magnets made of NdFeB with high residual magnetization (B_r ~ 1.3 T). The maximum induction of the mirror magnetic field is 2 and 3 T at the beam extraction and microwave injection side respectively. The magnetic field induction at the inner surface of the plasma chamber is equal to 1.2 T. The injected microwave frequency is 18 GHz, the maximum microwave power is 1.5 kW. One of the first spectra of Kr ions, obtained with Sc ECRIS, is given in Fig. 1.

AXIAL INJECTION LINE

The beam transport line from SC-ECRIS to the cyclotron center is about 4 m long (see Figure 2). It contains 2 focusing solenoids, 2 steering magnets, one correcting quadrupole,

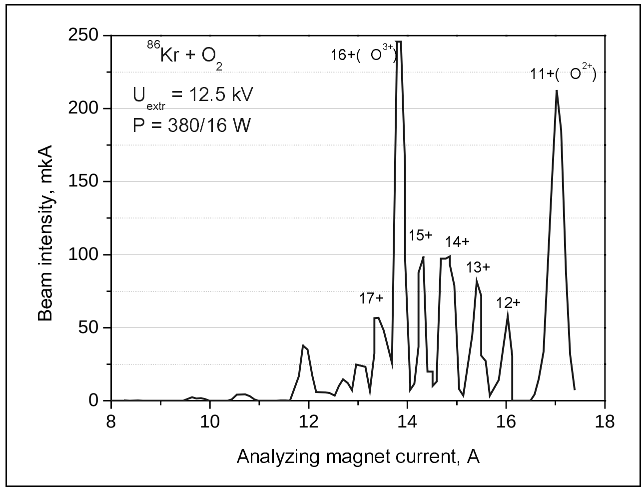

Figure 1: The spectrum of Kr ions from SC ECRIS.

and 3 diagnostic boxes. The ion beam is deflected down axially through the upper yoke by means of 90^0 bending magnet, which serves simultaneously as an analysing magnet for the beam extracted from the ion source [3].

The vacuum pumping in the injection line with diameter of 100 mm is done by means of 5 turbomolacular pumps with the pumping speed of 150 l/s each and 3 cryogenic pumps with the speed of 800 l/s each. Those pumps can produce the operating presser of $5 \cdot 10^{-8}$ torr (when SC-ECRIS is switched off) and $(1–2) \cdot 10^{-7}$ torr when the ion source is switched on.

VACUUM SYSTEM

The vacuum equipments of the cyclotron are changed completely. Instead of oil diffusion pumps we have installed the new ones. Two cryogenic pumps with the pumping speed of 3200 l/s each have been installed in the vacuum chamber while two turbo-pumps with the speed of 450 l/s each are used for pumping the RF resonators. These pumps can produce the operating presser in the vacuum chamber of $(1\text{-}2) \cdot 10^{-7}$ torr.

BEAM EXTRACTION

The beam extraction is performed by an electrostatic deflector (28^0, 58 kV/cm) placed in the valley. In order to compensate the radial beam defocusing caused by the high gradient of the frigging magnetic field (~50 T/m) two passive magnetic channels (20^0, 12 T/m and 50^0, 35 T/m), located in two neighboring hills, are used.

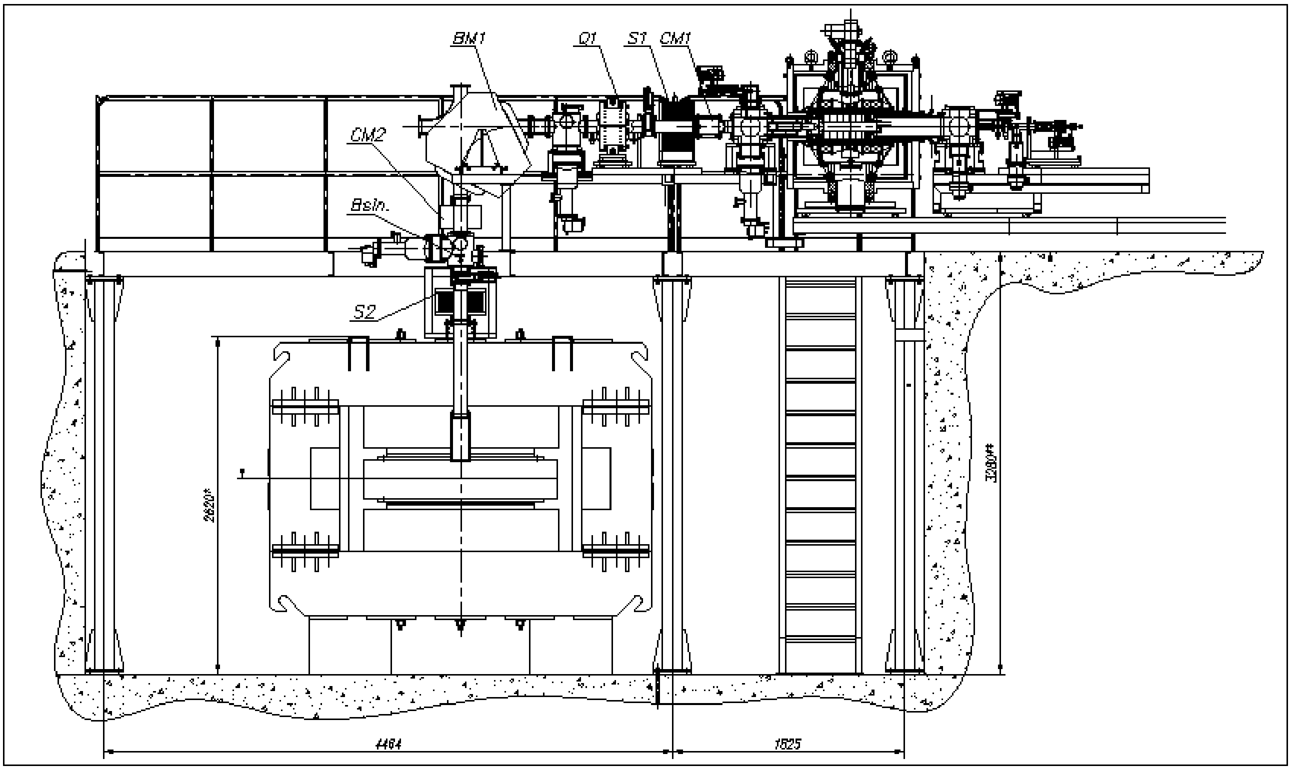

Figure 2: Layout of the axial injection line. BM1 is an analyzing magnet; S1 and S2 are solenoids; Q1 is a correcting quadrupole; CM1 and CM2 are correcting dipole magnets; DBE, DB1, DB2 are blocks for instrumentation and vacuum pumping; B_{sin} is a sinusoidal buncher.

BEAM TRANPORT LINE

The ion transportation from the extraction point to the target is carried out by means of the steering magnet and two magnetic quadrupoles. In order to irradiate rather large area (300 mm × 600 mm) by heavy ion beams with uniform density (± 5%) two magnetic scanners (creating horizontal and vertical scanning) will be used [4]. These beams are intended to irradiate targets made of different polymer materials on the industrial level.

CONCLUSION

At present all main cyclotron systems have been tested and given good results. Recently the cyclotron was commissioned and first accelerated beam of Kr^{15+} was extracted.

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