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First beam from the DECRIS 14-2m ion source for Slovak Republic

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Abstract The ECR laboratory of the Cyclotron Centrum of Slovak Republic (CC SR) in Bratislava, Slovakia, consists of the DECRIS 14-2m ion source and two low energy channels. It is a complete injector, consisting of an ECR ion source, focusing and steering elements, an analyzing magnet, a vacuum system, and an ion beam diagnostic system. The DECRIS 14-2m ion source is a multiply charged heavy ion source based on the electron cyclotron resonance principle. The ECR ion source DECRIS 14-2m and other system have been designed and manufactured at the FLNR JINR. The preliminary testing (magnetic field measurements, vacuum testing and testing of ECR ion source) has been performed at FLNR JINR. The final assembly of the DECRIS 14-2m will be done at the CC SR in Bratislava.

Key words ECR ion source • injector

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Introduction

The Cyclotron Centrum of Slovak Republic is a facility consisting of a few parts including the Complex DECRIS 14-2m named as the ECR laboratory. This complex includes the ECR ion source DECRIS 14-2m (**D**ubna **E**lectron **C**yclotron **R**esonance **I**on **S**ource) and two channels. The first one is a low energy channel and the second one is the post acceleration part [1, 2].

The main parts of the ECR laboratory was designed and constructed at FLNR JINR. In March 2001 all major elements of the complex, including the ion source, were completed and partially tested in Dubna (magnetic field measurements, vacuum testing). The preliminary tests of the DECRIS 14-2m ion source were carried out at the ECR test bench in Dubna from March to July 2001. In September 2001, all elements were packed in and transported to Bratislava. In the near future the whole complex will be completed and put into operation.

Description of the ECR laboratory

The Complex DECRIS 14-2m is a heavy ion injector which can supply, multiply charged ion beams of gaseous as well as solid elements with a beam energy up to $25 \times Q$ kV (where Q is the charge state of ions). The main part of the ECR laboratory consists of the ECR ion source, the beam transport line, the analyzing magnet, the vacuum system, the ion beam diagnostic system, the safety and control systems (see Fig. 1). The main feature of the beam transport and analyzing line is their ability to bend the ion beam towards both the low energy and post acceleration experimental channels. For this reason, the pole face rotation angle of the analyzing magnet (AM) at its entrance is zero and the

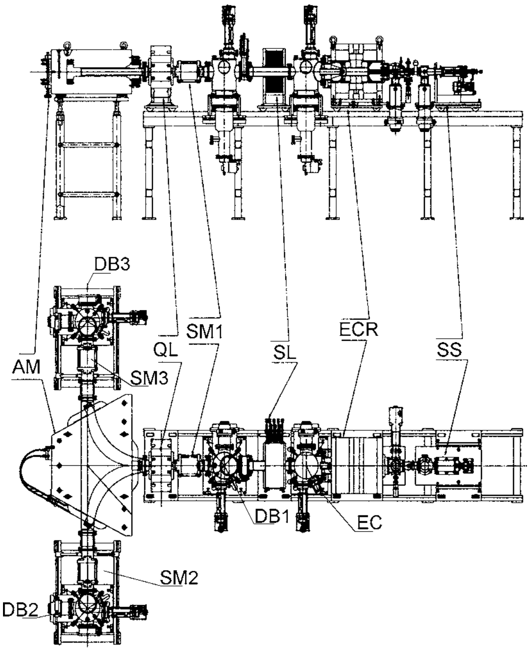

Fig. 1. The Complex DECRIS 14-2m.

ion beam cannot be focused at this pole face in the vertical direction. The additional quadrupole (QL), situated just in front of the analyzing magnet face, focuses the ion beam at the entrance of the analyzing magnet in the vertical direction. The beam transport and analyzing line start at the extraction chamber (EC), and includes the solenoid lens (SL), three (both faces) steering magnets (SM1,2,3), three diagnostic boxes (DB1,2,3) with movable slits, Faraday cups and beam profile monitors (scanners). The main parameters of the magnetic elements of the beam transport and analyzing line are shown in Table 1.

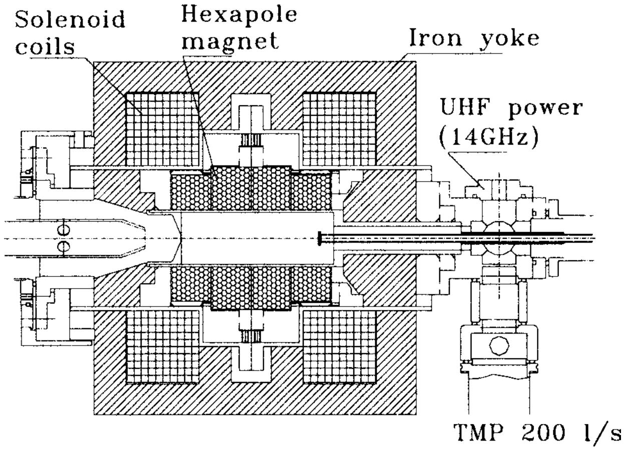

Fig. 2. Magnetic structure of the ECR ion source DECRIS 14-2m.

The vacuum system of the ECR laboratory consists of three cryogenic pumps – 800 l/s and six turbomolecular pumps Pfeiffer TMH/TMU 261 with 200 l/s pumping speed for each one. It provides background vacuum better than 1×10^{-5} Pa in all vacuum chambers.

ECR ion source

ECR ion source is the main part of the ECR laboratory. The design of the magnetic and mechanical structure of DECRIS 14-2m ion source is based on a DECRIS 14-2 [3] ion source. A cross-sectional view of the DECRIS 14-2m ion source is shown in Fig. 2. The axial magnetic field is formed by two separate coils with an iron yoke. A comparison of the calculated and measured axial magnetic field is shown in Fig. 3. All calculations were made for the

Table 1. Magnetic elements of the DECRIS 14-2m beam line.

Parameter		Designed	Measured
		Analyzing magnet	
Aperture	(mm)	70 ± 0.1	70 ± 0.01
Maximal magnetic induction	(T)	0.2	0.214
Magnetic field nonhomogeneity	(%)	<0.15	0.1
Effective length	(mm)	628 + 70	645.8
Bending angle	(deg)	±90 ± 0.5	±90 ± 0.6
Nominal current	(A)	300 ± 5%	300
Nominal cooling water flow	(l/min)	15 ± 5%	15
		Solenoid lens	
Aperture	(mm)	90 ± 0.5	90
Maximal magnetic induction	(T)	0.69 ± 2%	0.6797
Effective lenght	(mm)	134 ± 5%	132.8
Nominal current	(A)	500 ± 5%	500
Cooling water consumption	(l/min)	10 ± 5%	10
		Quadrupole lens	
Aperture	(mm)	100 ± 0.1	100
Nominal magnetic field gradient	(G/cm)	82 ± 1%	80
Magnetic field nonlinearity	(%)	<1	0.85
Nominal current	(A)	4.8 ± 5%	5
Effective length	(mm)	245 ±5%	230.7

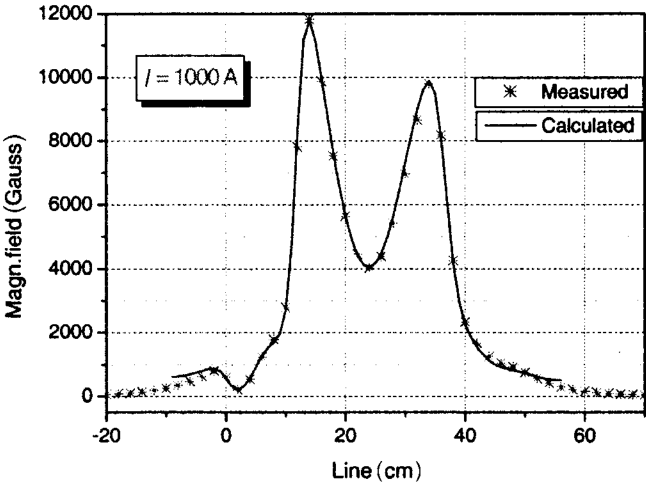

Fig. 3. Calculated and measured axial magnetic field of the DECRIS 14-2m ion source.

nominal current of 1000 A and the water-cooling pressure of 5 bars. The radial magnetic field is created by the NdFeB permanent magnet hexapole with a "Halbach structure". The hexapole magnetic field exceeds 1.0 T on the 32 mm radius which corresponds to the internal radius of the plasma chamber.

The operating frequency of the ion source is 14 GHz. The main parameters of the ion source are presented in Table 2.

Preliminary test

All parts of the complex DECRIS 14-2m, including the ECR ion source, were tested separately in Dubna, while the final assembly and testing will be carried out in Bratislava. During the commissioning of the magnetic elements good agreement between the measured and desired parameters was found. The vacuum system supplied background vacuum of about 1×10^{-5} Pa. Testing of the ECR ion source was carried out at the FLNR JINR test bench in Dubna. The main power supplies were tested for the maximum current up to 1300 A. In this case the water-cooling pressure of about 10 bars was required.

Some preliminary results of the ECR ion source testing are presented in Table 3 and Fig. 4. All these results were obtained with a 16 kV extraction voltage and the extraction aperture 10 mm. These results show that the design of the ECR ion source was correct and that we could expect good

Table 2. Main parameters of the ECR ion source.

Main parameter		
f	(GHz)	14
B_{inj}	(T)	1.25
B_{extr}	(T)	1.05
L_{mirror}	(cm)	20
Source length	(cm)	45
Source diameter	(cm)	50
Plasma chamber diameter	(cm)	6.4
Coils		
Number of coils		2
I_{max}	(A)	1300
ΔP	(bar)	10
ΔT	(°C)	25
Cooling water consumption	(m^3/h)	2.5
W_{total}	(kW)	60
Hexapole		
Material		NdFeB
Internal diameter	(cm)	7
Hexapole field on the plasma chamber (T)		>1.0

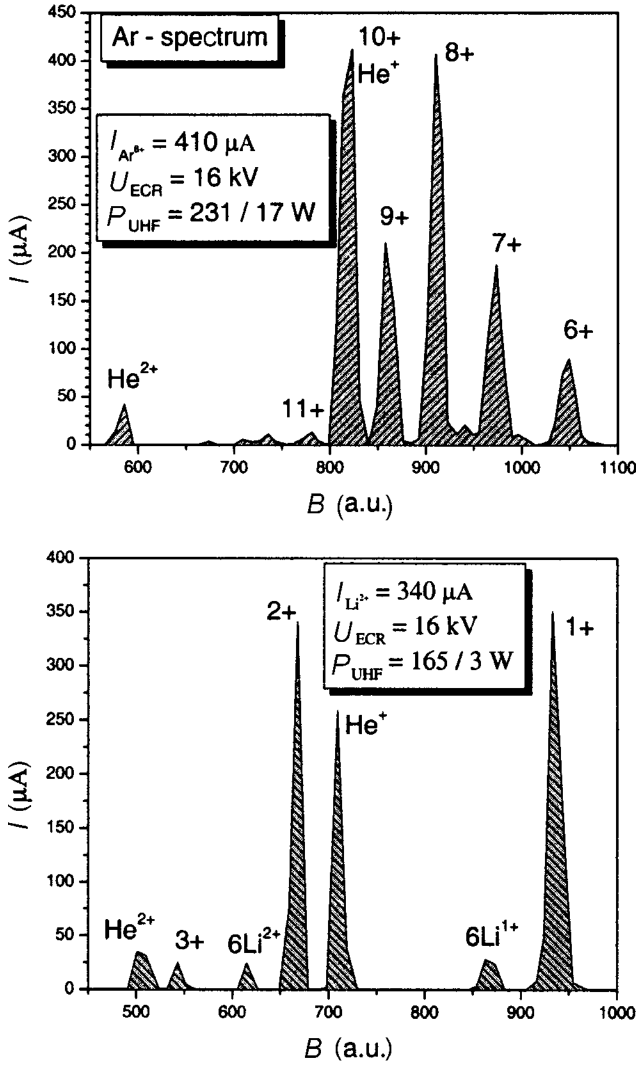

Fig. 4. Ion spectra of Ar and Li.

Table 3. Yields (eµA) of some gases form the DECRIS 14-2m.

Q	4+	5+	6+	8+	9+	12+	18+
^{14}N	450	360					
^{16}O		370	250				
^{40}Ar				410	210		
^{84}Kr					100	110	
^{132}Xe							30

results in terms of ion beam intensities when the source will be in full operation.

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