COMMISSIONING OF THE mVINIS ION SOURCE

A. DOBROSAVLJEVIĆ, I. DRAGANIĆ, S. ĐEKIĆ, T. STALEVSKI

Vinča Institute of Nuclear Sciences, P. O. Box 522, 11001 Belgrade, Yugoslavia

A. EFREMOV, V. KUTNER, N. YAZVITSKY

Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

The mVINIS Ion Source is the part of the TESLA Accelerator Installation whose construction has been going on in the VINČA Institute of Nuclear Sciences in Belgrade, Yugoslavia. It is an ECR ion source designed to be an injector for the VINCY Cyclotron as well as a stand-alone machine for low energy experiments. The main parts of mVINIS have been designed and manufactured in the Joint Institute for Nuclear Research, in Dubna, Russia. It was assembled and initially tested in the Vinča Institute, in the second half of 1997. After completing its safety and control system, and improving the ion beam diagnostics we have started the commissioning of mVINIS in March 1998. This paper presents the recent results obtained for nitrogen, oxygen, neon, argon and xenon ion beams.

1 Introduction

The TESLA Accelerator Installation is an ion accelerator facility consisting of an isochronous cyclotron (VINCY), a heavy ion source (mVINIS), a light ion source (pVINIS) and a number of low energy and high energy experimental channels [1]. When the VINCY Cyclotron will be in operation, it will share the operational time between light ion beams from the pVINIS Ion Source and heavy ion beams from the mVINIS Ion Source.

The mVINIS Ion Source is a complete heavy ion injector, consisting of an ECR ion source, focusing and analyzing magnets along the beam transport line, vacuum system, ion beam diagnostic system, as well as safety and control systems. Its major parts are presented in Fig. 1. mVINIS is not only planned to operate as an injector for the VINCY Cyclotron but also as a stand alone machine, providing beams for low energy experiments.

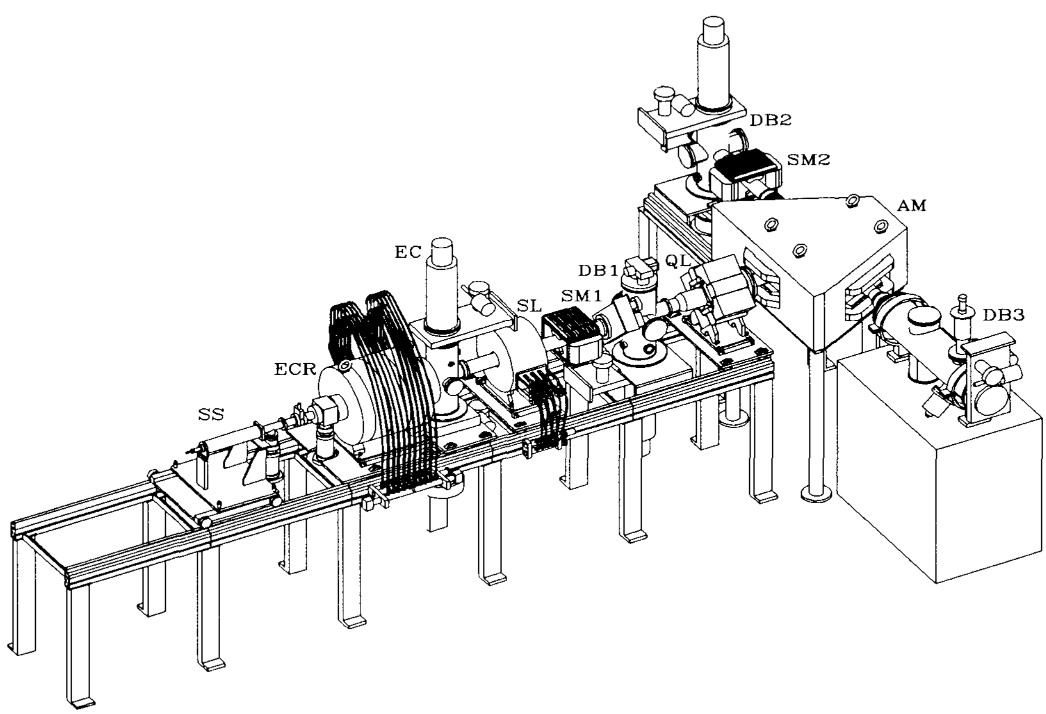

Figure 1: mVINIS Ion Source as a complete heavy ion injector. (ECR – ECR ion source; SS – solid substance inlet system; EC – extraction chamber; DB1, DB2, DB3 – diagnostic boxes; SL – solenoid lens; SM1, SM2 – steering magnets; QL – qudrupole lens, AM – analyzing magnet)

Table 1: Schedule of construction of the mVINIS Ion Source.

Contract between JINR and Vinča	July 26, 1995
Calculation and engineering design	January 1996 - December 1996
Manufacturing of the elements	June 1996 - May 1997
Tests of the beam line in Dubna	April 1997
Assembling of the beam line in Belgrade	May 1997
Tests of the ECR ion source in Dubna	June 1997-July 1997
Assembling of mVINIS in Belgrade	August 1997
First beam in Belgrade	September 7, 1997
Commissioning of mVINIS	March – May, 1998

The main parts of mVINIS (ECR ion source, focusing elements, analyzing magnet, etc.) have been designed and manufactured in the Joint Institute for Nuclear Research (JINR), in Dubna, Russia. The TESLA Project team was responsible for the vacuum equipment, power supplies, ion beam diagnostic system, safety and control system and all utility systems (water cooling, compressed air, etc.). Major events regarding the realization of the mVINIS Ion Source are given in Table 1.

2 Description of the mVINIS Ion Source

The mVINIS Ion Source is a heavy ion injector producing multiply charged ion beams from gases and solid substances. It consists of an ECR ion source, beam transport and analyzing system including the focusing lenses, steering magnets and analyzing magnet, vacuum system, ion beam diagnostic system, safety and control systems [2]. The analyzing magnet is used to direct the ion beams either towards the VINCY Cyclotron or towards the low energy experimental channels and to select the ions of required charge states. The diagnostic boxes are equipped with the movable slits, Faraday cups and the beam profile monitor. Three turbomolecular pumps and three cryogenic pumps provide initial vacuum in the region of 10^{-8} mbar. The beam transport efficiency from the ECR ion source to the diagnostic box situated behind the analyzing magnet is about 70% for the He^{1+} ion beam.

The major part of mVINIS is the ECR ion source. It is an advanced version of DECRIS-14-2 ion source [3], constructed in Joint Institute for Nuclear Research, in Dubna, Russia. The cross section of the ECR ion source is presented in Fig. 2. It shows the ion source structure including solenoid coils and iron yoke, permanent hexapole magnet, double wall plasma chamber, microwave injection box with microwave input, and simple two electrode extraction system. While the overall design of the ECR ion source is similar to its predecessor, there are some significant differences between them. The magnetic system of the source takes into account the well-established fact that a high axial mirror ratio as well as a strong radial magnetic field inside the plasma chamber are very important parameters for providing better plasma confinement [4]. Therefore, it was decided to upgrade the ECR source by increasing its axial magnetic field. The source axial length was shortened for 5 cm. Comparing to DECRIS, it has in each coil only 5 (instead of 6) double-layer pancakes made from smaller hollow copper conductor. Nevertheless, the number of turns in each pancake was increased. The shape of the magnetic field shaping plugs was also slightly changed. As a result the maximum axial magnetic field has been increased from 0.86 to 1.08 T at extraction stage, and from 1.14 to 1.29 T at injection stage, without increasing the overall power consumption. Figure 3 shows the comparison between the axial magnetic field distributions for DECRIS and mVINIS.

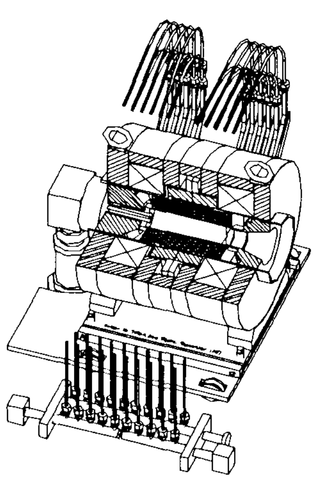

Figure 2: ECR ion source.

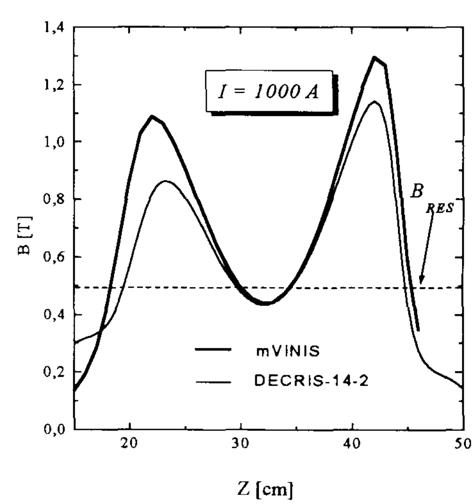

Figure 3: ECR ion source axial magnetic field distribution.

Table 2: Main parameters of the ECR ion source.

MAIN PARAMETERS		
Operating frequency	14.5 GHz	18 GHz
Total power consumption	68 kW	120 kW
B_{inj}	1.29 T	1.45 T
B_{min}	0.46 T	0.58 T
B_{extr}	1.08 T	1.25 T
L_{mirror}	20 cm	20 cm
Source length	40 cm	40 cm
Source diameter	44 cm	44 cm
Plasma chamber diameter	6.4 cm	6.4 cm
COILS		
I_{max}	1000 A	1300 A
U_{max}	34 V	45 V
ΔP	≤ 10 bar	≤ 15 bar
ΔT	25 °C	32 °C
Cooling water consumption	2.5 m^3/h	3.5 m^3/h
HEXAPOLE		
Material	NdFeB	NdFeB
Internal diameter	7 cm	7 cm
Hexapole field on the chamber wall	1.0 T	1.0 T

The mVINIS Ion Source is designed to allow future upgrade from 14.5 GHz to 18 GHz microwave heating. The main parameters of the ECR ion source for both cases are presented in Table 2.

3 Performance of the mVINIS Ion Source

The preliminary testing of the mVINIS ECR ion source was carried out in Dubna in June and July 1997. Then, the ion source was transported to Belgrade, and after completion of its mechanical assembly, the first beam of Ar^{8+} was obtained in the beginning of September 1997. It is interesting to note that during the early tests the performance of the source similar to the performance of its predecessor was easily reached applying comparatively low microwave power (< 200 W). The first phase of commissioning of mVINIS was carried out mostly in March and April 1998.

Table 3: Ion currents for some gases (eμA).

Ion	N	O	Ne	Ar	Xe
5+	470	660			
6+	87	432	290		
7+		37	115		
8+			48	660	
9+				340	
11+				130	
12+				36	
18+					44
19+					43
20+					41

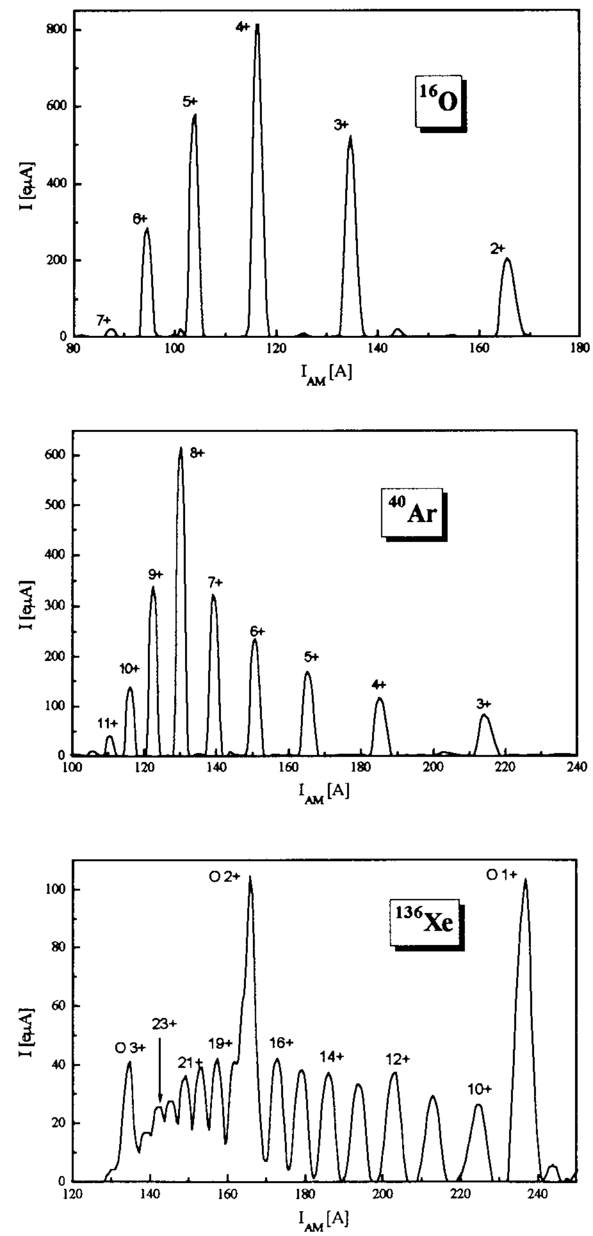

Figure 4: Oxygen, argon and xenon spectra.

It comprised obtaining the currents for nitrogen, oxygen, neon, argon and xenon ion beams that were given in the contract. In spite of some initial problems with the ECR main insulator situated around the hexapole, and safety and control systems, we have succeeded to exceede almost all currents from the contract and obtain encouraging results. The obtained ion beam performance of the mVINIS Ion Source is summarised in Table 3. All these results were obtained with comparatively low UHF power (< 400 W) at 15 kV extraction voltage.These measurements were oriented

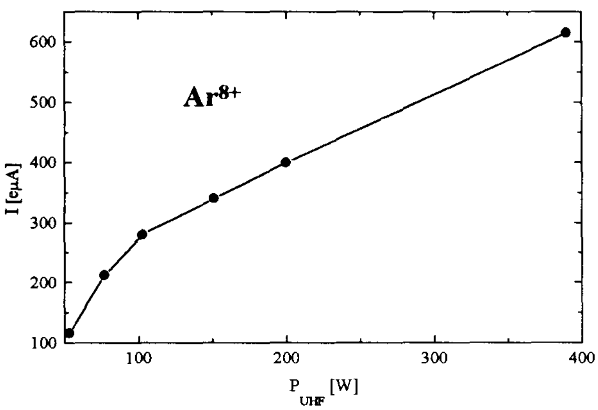

Figure 5: Ar^{8+} ion current vs. microwave power.

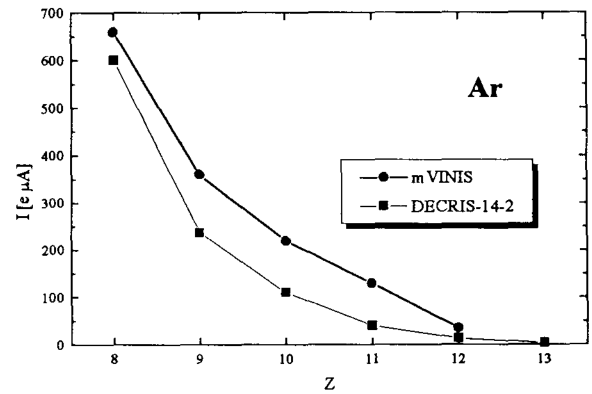

Figure 6: Comparison of the mVINIS and DECRIS-14-2 ion sources in case of argon ion beams.

towards obtaining moderate charge state high intensity ion beams (e.g. N^{5+}, O^{6+} or Ar^{8+}) that were required by the low energy experiments scheduled for the second half of this year. Typical spectra for oxygen (source tuned for O^{4+}), argon (source tuned for Ar^{8+}) and xenon (source tuned for Xe^{19+}) are shown in Fig. 4. Dependence of Ar^{8+} beam intensity on the UHF power is shown in Fig. 5. The comparison between mVINIS and DECRIS-14-2 in the case of Ar ion beams is presented in Fig. 6.

4 Conclusions

Results obtained during the first phase of commissioning of the mVINIS Ion Source are encouraging. mVINIS has shown good performance, especially for the moderate charge state ions. In the nearest future we have to check its operation on 25 kV extraction voltage, and measure the emittance for different ion beams. Also we have to obtain some results for the high charge state ions like Ar^{14+} and Xe^{24+}. We are also planning to finish its solid substance inlet system and to obtain ion beams of Pb, Mo or Zn, required by the researchers. Finally, we are planing to improve the extraction system in order to obtain even better beam properties.

The mVINIS Ion Source is already working at the experimental channel for modification of materials by ion beams. The first physical experiment was performed in May this year, using Ar^{8+} beam to irradiate some polymers and investigate increase of their surface hardness. Several other experiments are already scheduled for the second half of the year. It is already clear that mVINIS will be capable to satisfy complex experimental requirements and supply different ion beams from gaseous and solid substances. It could supply the ion beams whose energy can be easily changed in a broad range by choosing the adequate charge state of the ions: from 100 keV up to 600 keV for Xe ions, for example. It is also capable to fulfill experimental requirements for high beam currents delivering several hundreds eμA of N^{5+}, O^{6+} or Ar^{8+} ion beams. We could say that mVINIS is a powerfull and reliable machine that would supply broad range of high quality heavy ion beams for the whole TESLA Accelerator Installation.

References

[1] N. Nešković et al., Proc. of the 14th Int. Conf. on Cyclotrons and their Applications, Cape Town, 1995, (World Scientific, 1996), p. 82.

[2] A. Efremov et al., Proc. of the 7th Int. Conf. on Ion Sources, Taormina, 1997.

[3] A. Efremov et al., Proc. of the 13th Int. Workshop on ECR Ion Sources, College Station, Texas A&M University, 1997, p.128.

[4] T. A. Antaya and S. Gammino, Rev. Sci. Instr. 65 (1994) 1723.