REPORT (SUMMARY) OF THE 10TH INTERNATIONAL CONFERENCE ON ION SOURCES

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Abstract

In this paper, I will report the summary of the 10th International Conference on Ion Sources (ICIS'03). The topics were ECR; EBIS/T; Ionic Physics; Radioactive IS and Beams; Laser IS and MEVVA; Ion Extraction, Beam Emittance and Transport; Negative IS; High Current, Novel & Miscellaneous IS; Ion Acceleration Systems; Fusion; and Industrial Application. The number of papers related to ECR IS was 27%, which means ECR IS is most enthusiastically investigated in the world. Outstanding topics are the followings. New high performance ECR IS (superconducting type: Venus and Ramses/Shiva) have started. With improvement in both frequency and confinement, new generation ECR IS can produce much higher currents of highly charged ions. As for EBIS/T, the performance of EBIS/T has been greatly advanced in these two years, especially in EBIS developed in BNL. As for Negative IS, although ion production mechanism as well as ion extraction mechanism had not yet been fully understood, a new multi-component plasma sheath theory for H^- extraction was proposed at this conference.

INTRODUCTION

The 10th International Conference on Ion Sources (ICIS'03) was held in Dubna, Russia, on September 8-13, 2003. The series of this conference were biennially held in the world. The number of the participants at this conference was 214 from 23 countries. The conference was composed from 20 scientific sessions, and 184 papers were presented as oral and poster papers. The topics and these percentages of presented papers were as follows: ECR(27%), EBIS/T(6%), Ionic Physics(1%), Radioactive IS and Beams(5%), Laser IS and MEVVA(5%), Ion Extraction(2%), Beam Emittance and Transport(9%), Negative IS(18%), High Current and Novel & Miscellaneous IS(14%), Ion Acceleration Systems(4%), Fusion(5%) and Industrial Application(4%).

ECR ION SOURCES

The number of the papers related to ECR ion source was the largest and its percentage was counted as 27% of total number of papers. Therefore, it can be said that ECR ion source community is largest of ion source world.

Followings were the topics in ECR ion source sessions: 1) new high performance ECR ion sources (superconducting type: Venus and Ramses/Shiva) have started; 2) with improvement both frequency and confinement, new generation ECR ion sources could produce much higher currents with higher charges; 3) some remarkable effects such as afterglow, gas mixing and biased probe, were investigated; and 4) diagnostics techniques for ECR ion source were steadily proceeding..

Superconducting Devices

In ECR ion source, various kinds of frequency (6.4, 10, 14, 18 and 28 GHz) and confinement condition (mirror ratio: R<1.3, 1.3<R<1.8 and 1.8<R<2.5) were used[1]. Recently the frequency was increased in order to obtain high plasma density, and then the high magnetic field is necessary for electron cyclotron resonance. In the last conference, many superconducting device projects were proposed. In this conference, the performance of these devices has been reported.

One of the superconducting devices was VENUS[2] (Versatile Ecr for NUclear Science) as shown in Fig.1. From this ion source they could obtain high current beams with very high charge state ions for metal element as well as noble gases as shown in Table 1 and Fig.2.

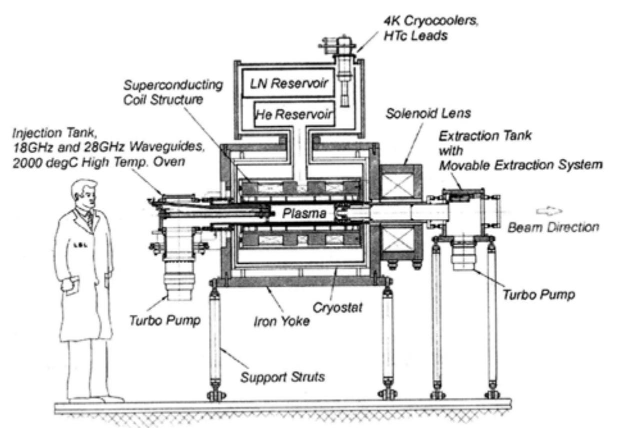

Figure 1: VENUS ECR ion source.

Table 1: Ion currents for noble gases with VENUS operating at 18 GHz. Currents in e μ A.

Ar^{11+}	Ar^{12+}	Xe^{20+}	Xe^{27+}	Xe^{30+}	Xe^{31+}	Xe^{32+}	Xe^{33+}
290	180	164	84	28	15	9	3

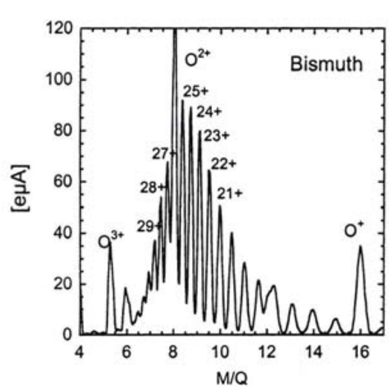

Figure 2: Charge state distribution for bismuth from VENUS.

The other superconducting device was RAMSES and SHIVA sources as shown in Fig, 3[3]. Actually this source is hybrid type, permanent magnet and superconducting coils without liquid He. From these devices, high charge sate ions could be obtained as shown in the Fig.4.

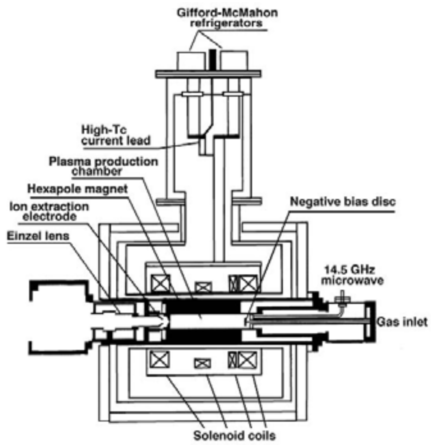

Figure 3. Structure of SHIVA source.

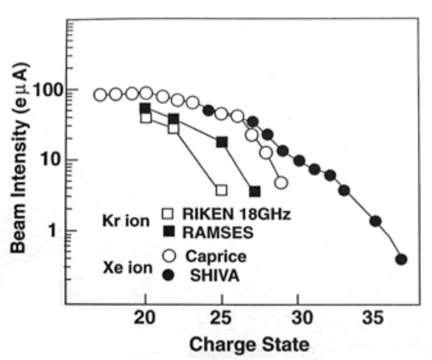

Figure 4. Beam intensities of Kr ions from RAMSES (closed square) and Xe ions from SHIVA (closed circle).

Room Temperature ECR Ion Sources

GTS(Grenoble Test Source)[4] is a room temperature ECR source, and has been designed according to magnetic scaling laws defined with the Serse source. GTS could deliver high charge state metal (Ta) ions as shown in Fig.5 as well as 1 mA of medium charge states ions (Ar^{8+}).

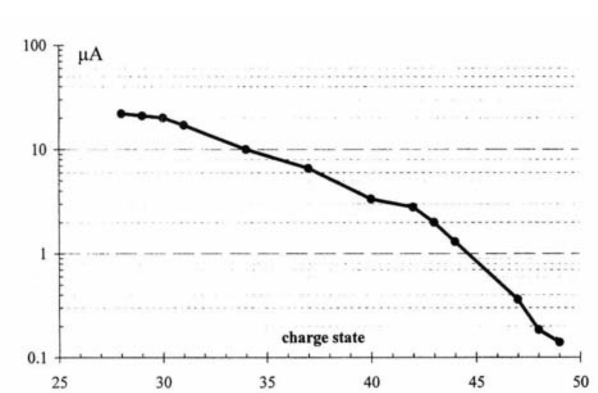

Figure 5 Tantalum beam intensities obtained with the sputtering technique (GTS 18 GHz).

Remarkable Effects in ECR Ion Sources

In ECR ion sources, some remarkable effects were found such as afterglow, gas mixing and biased probe.

In the afterglow, high charge state ions could be produced. The current was increased by a factor of 2 or 3[5,6].

Gas mixing effect that production of high charge state ions were enhanced, was observed when typically oxygen gas was introduced[4,6]. This effect was also observed in the afterglow mode.

When a biased probe was inserted into the ion production chamber, production of high charge state ions was enhanced. Instead of a probe[6], a special shape cylinder; Comb-shape cylinder could be used for this purpose[7].

Diagnostics technique for ECR plasma such as X-ray pinhole camera was proceeding[8]. Distribution of high charge state ions in the ion production chamber could be observed. It can be very helpful to understand production mechanism of highly charged ions.

EBIS/T

The performance of EBIS/T has been greatly advanced in these two years, especially in EBTS developed in BNL. String mode EBIS developed in JINR was steadily proceeding.

Figure 6 shows the structure of EBIS Trap Source. Source length is not so different from conventional EBIS, but electron current was dramatically increased[9].

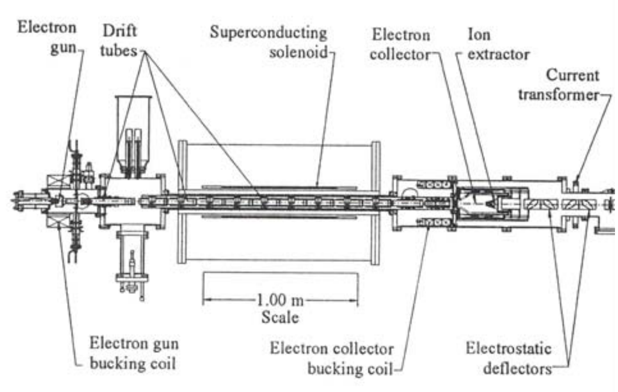

Figure 6. Structure of EBIS Trap source[10].

EBTS performance represents more than an order of magnitude improvement over past EBIS sources. The key features of this ion source are as follows:

1) A novel electron gun design: a convex LaB_6 cathode
2) Large bore (32mm) drift tubes have been used

The experimental results were:

1) 10 A electron beam. 10 time of improvement over previous EBISs
2) 55 nC pulses of ion was extracted.
3) Au^{32+} will be produced in only 30 ms.

String mode EBIS in which the electron beam moves back and forth was investigated in JINR, and high charge state of iron ions such as Fe^{+24} were obtained[11].

RADIOACTIVE ION SOURCE AND BEAMS

Recently radioactive ions are strongly required, and then at the various Institutes in the world radioactive ion source development projects have started.

Figure 7 shows the SPIRAL 1 project at GANIL. They use a nanogans configuration and already 36 isotopes were available[12,13].

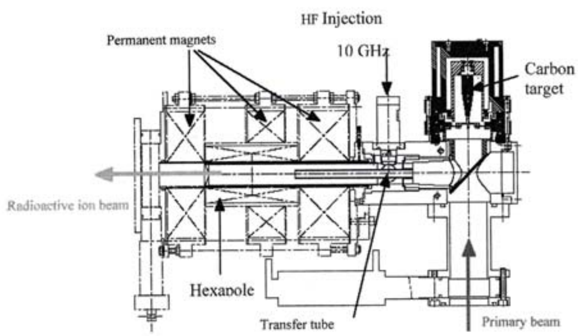

Figure 7. ISOL (Isotope Separator On Line) type radioactive ion source.

Radioactive ions could be produced by using a laser ion source as shown in Figure 8[14].

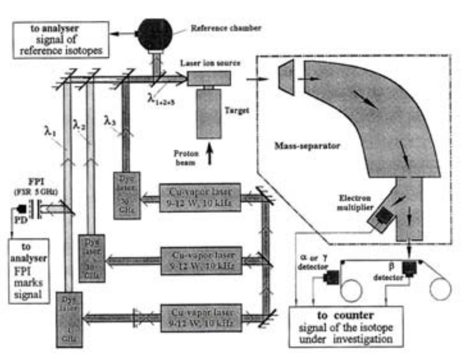

Figure 8. Laser ion source modification (ISOL type).

And at many other laboratories, such as LPSC[15], ORNL[16] etc, radioactive ion sources were under development.

LASER ION SOURCE

PALS (Prague Asterix Laser System) iodine laser has a large power output of about 1 kJ. Therefore, this pulse irradiation on the metal surface causes the production of very high charge state metal ions. Ta ions of charge state more than 50 could be obtained as shown in Figure 9. And highly charged ions have MeV class energies, so by using these ions high energy ion implantation application could be performed[17].

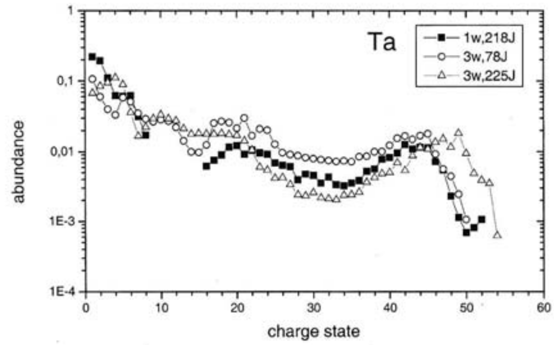

Figure 9. Charge state distribution of Ta by PALS.

ION EXTRACTION, BEAM EMITTANCE AND TRANSPORT

Extracted ion currents from ECR ion source have been increased by two orders of magnitude in past twenty years. And now the beam currents reach emA order. 3D simulation is needed for efficient ion extraction and beam transport.

By using 3D simulation, the electron trajectory as well as the H^- ion trajectory could be calculated[18], and it was very helpful to design the extraction electrodes.

As for the emittance measurement, noise would cause an error in emittance estimation. In order to reduce an error, a new method of self-consistent, unbiased, exclusion-based emittance analysis has been developed[19].

NEGATIVE ION SOURCES

Fundamentals

In the negative ion sources, ion production mechanism as well as ion extraction mechanism, were not yet fully understood. In this conference, a new multi-component plasma sheath theory for H^- extraction as shown in Figure 10 was proposed[20]. It is very helpful to understand negative ion extraction from plasma. And electrode structure for negative ion extraction was also calculated.

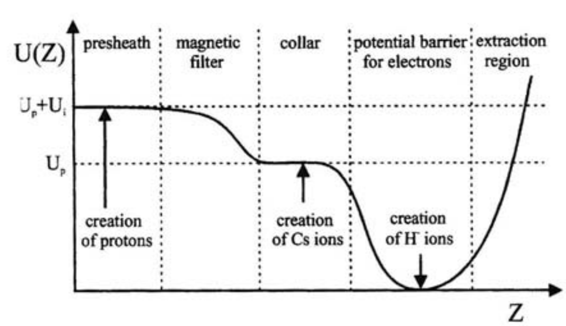

Figure 10. Collisionless electrostatic model for the sheath theory for negative ion extraction.

In the negative ion production mechanism in volume production, many processes are concerned in it. So, various effects were observed. Wall material strongly affects negative ion density in plasma, and then the extracted ion current[21].

Beam Transport

As for the transport of negative ion beam, there were not so many investigations. Space-charge lens was effective even for the negative ion beam focusing[22]

H^- Source for Neutron Production

Hydrogen negative ion beams can be used for neutron production for neutron therapy. For this purpose, a negative ion source which could deliver several mA H^- ion beam was developed[23].

H^- Source for High Energy Accelerator

Hydrogen negative ion beams are commonly used for high energy accelerators. The source current is around a few tens mA. Many Institutes have developed various kinds of negative ion sources as shown in Figure 11[24].

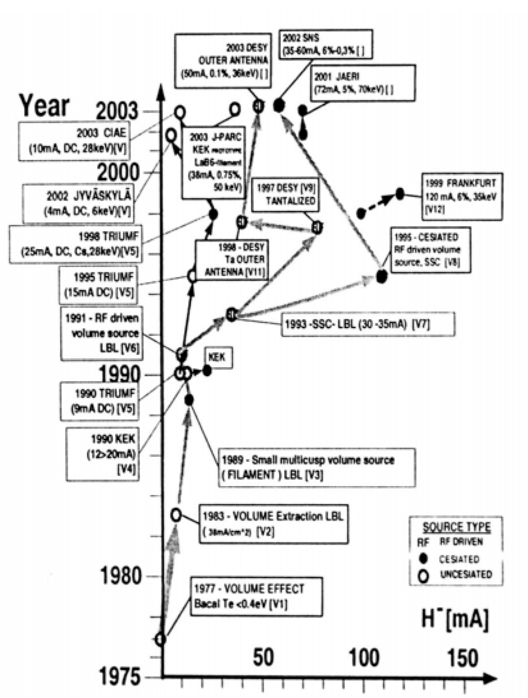

Figure 11. History of negative ion source development for high energy accelerator.

As typical sources, there were negative ion sources developed in DESY and KEK. The ion source in DESY was RF-discharge type source with a changeable frequency[24]. The ion source in KEK is cesium-free type[25].

H^- Source for Fusion

In the neutral beam injection system for fusion reactor, very high current ion sources which can deliver a few tens amperes are needed such as H^- source developed in NIFS as shown in Figure 12[26]. Lifetime of filament was an important factor in this kind of ion source.

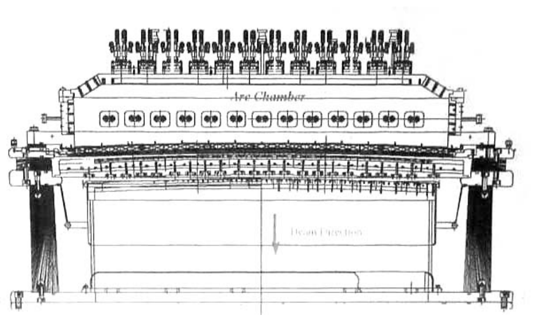

Figure 12. Negative ion source for neutral beam injection developed in NIFS. Output :25A-180 kV.

In order to investigate the fusion plasma, diagnostic neutral beam injector is necessary. For this purpose, several kinds of ampere class hydrogen negative ion sources were developed[27].

In the neutral beam injection, neutralization efficiency of negative ion is very important. For the neutralization of H^- ion beam, the efficiency of plasma neutralization is much higher than that of gas neutralization. At JAERI they proved the effectiveness of plasma neutralization by using a practical scale experimental device as shown in Figure 13[28].

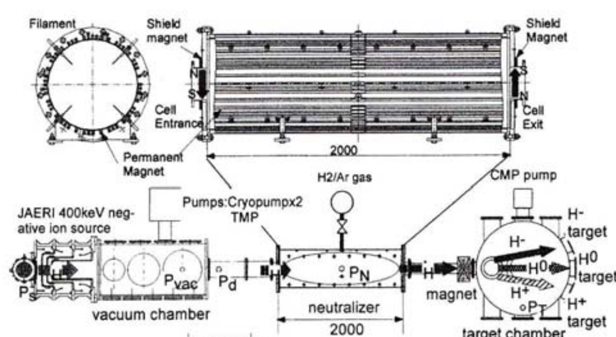

Figure 13. Plasma neutralization experimental system at JAERI.

INDUSTRIAL APPLICATION

About the topic of industrial application, developments of new type of cluster ion source (Corona discharge assisted selenium cluster ion source[29]) and boron negative ion source (sputter type)[30] were interesting.

ICIS2003 BRIGHTNESS AWARD

The last topic at this conference was Brightness Award which has started from this conference. This time, Drs Beebe and Pikin wined the Award.

CONCLUSIONS

Many impressive results have been reported from ECR, EBIS, Negative IS etc. communities.

Especially the performance of EBTS (EBIS community) is outstanding.

Brightness Award have started from this conference.

This conference ICIS2003 was very active and very successful.

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