CLOSING REMARKS FOR ECRIS'14

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Abstract

A scientific overview of the ECRIS14 workshop is proposed in this paper. The workshop content demonstrated that the ECR community is still very active and that research is of high interest for future accelerator projects. A selection of new results and development presented during the workshop is proposed.

INTRODUCTION

The XXIst ECR Ion Source conference was hosted by the Institute of Applied Physics of the Russian Academy of Science in Nizhny Novgorod, Russia, from August 24th to August 28th 2014. The number of attendees was 60. The workshop atmosphere was relaxed, studious and suitable to discussion. Many new ion sources have been presented, many new developments were announced and interesting new results shown. The paper proposes selected highlights from the workshop. Because it is not possible to present every single contribution, the author apologies for those works which are not mentioned there.

NEW RESULTS

The know-how on the use of high ECR frequency in superconducting ECR ion sources keeps on improving with new results from MSU, IMP Lanzhou and RIKEN.

At IMP Lanzhou, impressive high intensities Bi beams were produced: 710 μA of Bi^{30+} (1.4 kW 18 GHz+4.7 24 GHz), 100 μA of Bi^{41+} and 10 μA of Bi^{50+}.

The RIKEN 28 GHz SC-ECRIS, demonstrated the production of high intensity U beam using the sputtering method: 225 μA of U^{33+} and 180 μA of U^{35+}.

At MSU, the commissioning of SUSI started at the 24 GHz frequency. 860 μA of Ar^{12+}, 530 μA of Ar^{14+} have been obtained (with 5.5 kW of RF power). It is noticeable that these intensities are equivalent to the records of VENUS (LBNL) obtained at 18+28 GHz, with quite a different plasma chamber volume (7.6 litre for VENUS and 3.5 for SUSI). Another insight from MSU studies is that beam intensities obtained at high power 18 GHz compare with the ones obtained with a pure 24 GHz frequency. The so-called "ECR frequency scaling law" implying a current extracted proportional to the frequency to the square is not quite observed here. Results look like the higher intensities obtained with the 24 GHz emitter for Ar^{11+} to Ar^{14+} could be due to the higher RF power available rather than the frequency change, since the current gain per RF power is very similar for both frequencies. Nevertheless, a net gain in current performance at 24 GHz has been obtained for high charge state (Ar^{16+}). A last interesting information from SUSI comes from the plasma chamber return temperature which happens to be higher at 24 GHz than at 18 GHz for the same RF power level.

At LPSC Grenoble, the first 60 GHz high power pulses have been injected into SEISM, a room temperature magnetic CUSP having a closed ECR resonance. Record beam current densities have been measured up to 600 mA/cm^2 (5 mA extracted from a Ø1 mm extraction electrode). Another very interesting point is that intense afterglow peaks of low charge states have been observed. This implies that such a simple axisymmetric structure features non trivial plasma confinement properties: interesting physics is hidden behind.

NEW DEVELOPMENTS

This workshop edition featured many new ion sources projects or major upgrades of existing ones. Because the detailing all the contributions would be too long to be included in these closing remarks, the reader is invited to look into the proceedings for uncovered new developments.

First ECRIS Plasma and Commissioning

The commissioning of the ECRIS-LECR4 at Lanzhou gave excellent results at 18 GHz : 1.9 mA O^{6+}; 1.7 mA Ar^{8+}, 0.29 mA Xe^{20+} with a radial magnetic intensity at wall of 1T only. The source uses a set of original evaporative cooling coils to generate its axial magnetic field.

The KBSI team of Busan presented the first plasma of their new 28 GHz SC-ECRIS dedicated to the production of Li beam. The SC solenoids reached their nominal current design, while the hexapole coils reached 83% of design so far. Further training of the hexapole is planned.

The Fraunhofer Institute and the Dreebit company presented the development of an original ECR ion source including an inverted cylindrical sputter magnetron to produce intense 1^+ aluminum beams for ion implantation.

New ECRIS Project

IMP CAS is building an upgrade of the SECRAL source named SECRAL II, to be operated at 18+28 GHz. The source has an upgraded cryogenics. The cold mass has been built and the coils ramped together to 90% of the design within 8 quenches.

IMP CAS presented the HIAF accelerator complex project requiring the challenging production of pulsed U^{34+} with a peak intensity of 1.7 mA and a duration of 400 μs. The design of a 4th generation high frequency ECR is under progress in the institute to tackle this objective.

INFN-LNS team reported the design of a new hybrid ion source named AISHa dedicated to hadrontherapy. The source features a permanent hexapole and a set of 3 He-free coils. The talk also included the presentation of

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the ESS microwave 2.45 GHz proton source featuring a flexible axial magnetic field to investigate classical flat, simple mirror and magnetic beach profiles.

JYFL is developing a new room temperature ECRIS named HIISI with a chamber volume and a magnetic field topology very similar to the SUSI ion source. The source has 3 coils for the axial magnetic profile and a refrigerated hexapole including permanent magnets.

Metallic Beam Developments

Several contribution included new developments in metallic beams. The use of dedicated low temperature metallic ovens, initiated by LBNL, spread to other facilities (MSU, IMP Lanzhou). The advantage of such an oven technique is that it is insensitive to the level of power feedback from the plasma (or microwave), providing higher reliability and tunability of the ion source. New ^{50}Ti MIVOC beams (Metal Ions from Volatile Organic Compounds) have been developed at JINR Dubna (82 μA $^{50}Ti^{5+}$) and GANIL (25 μA $^{50}Ti^{11+}$). A technique to produce pure rare earth metal sample from oxydized state has been successfully developed at MSU and used to produce Yb and Sm beams.

PLASMA, BEAMS INVESTIGATIONS, SIMULATIONS

At CERN, the demand to increase luminosity at LHC requires an improvement of the whole LINAC3 performance. As a first step, a Pb beam extraction simulation study was performed on the CERN's GTS-LHC ion source. The IBsimu freeware used was able to reproduce the experimental emittances and characteristic beam shapes.

Systematic emittance measurements of high charge state uranium beam have been performed with the RIKEN 28 GHz SC-ECRIS as a function of its axial magnetic profile intensity. The team measured an emittance decrease by ~50% when the magnetic injection intensity peak Binj was reduced from 3.1 to 1.5 T. This effect was not pointed out in the past: similar measurements in other ECRIS would be of high interest. Another emittance measurement was done as a function of the magnetic extraction peak intensity B_{ext}. The results show that the beam emittance decreases with the B_{ext} intensity. At first sight , this measures looks contradictory with the well-known fact that the emittance in a ECRIS is driven by the magnetic emittance. But, on the other hand, there are evidences that high charge state ions are extracted very close to the ion source axis which limits *de facto* the magnetic emittance contribution. Again, it would be great to cross check this original study in another ion source.

The Jyväskylä team in collaboration with IAP RAS Nizhny Novgorod presented an interesting study on beam current oscillations driven by electron cyclotron instabilities in ECRIS. The study included a careful temporal analysis of microwave reflection, x-ray, light emission and ion beam intensity to capture information on the instability. The study was completed by a theoretical approach by D. Mansfield who presented a theoretical work on the development of kinetic instabilities in ECR plasma due to the anisotropy of the electron energy distribution function.

At LPSC, experimental hot electron x-ray spectrum data from the VENUS source was revisited. The investigation tends to show that the hot energy tail temperature is proportional to the ECR heating frequency. A fact which is of bad omen for future 60 GHz SC-ECRIS which would endure even stronger x-ray flux toward the coils cold mass. A simple ECR heating model developed allows to correlate the change of x-ray temperature (when the B_{med} field is varied) for a given ECR frequency as a direct geometrical change of the ECR surface.

V. Mironov from JINR used a particle in cell code to test the ECRIS scaling laws. Helped with simple assumptions and an effective model, the code can reproduce many features from ECRIS like charge state distribution or some variation of beam current with magnetic field intensity.

CONCLUSION

The ECRIS 2014 workshop demonstrated once again that the ECR community is still very alive. The development of new ECR ion source remains an important activity in many laboratories and the workshop was, as usual, a great place to share valuable information together. The performance and know-how of 3rd generation ECRIS is still improving. The existing projects of future generation accelerators featuring challenging performances require to increase again the performance of ECR ion sources. So ECRIS research and development must go on to explore even higher RF frequencies to improve beam intensities and charge states. The author, on behalf of the attendees, wishes to express his warmest congratulation to the chairman V. Skalyga and to the local organizing committee for organizing such a high quality level workshop. The XXIInd edition of the Electron Cyclotron Resonance Ion Source workshop will be hosted by the Korean Basic Science Institute in Busan, Republic of Korea. Hope to see you all there!

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