Welcome message from the chair

ECRIS2016

Dear colleagues.

It is great pleasure for me to welcome all of you to this workshop, as a chair on behalf of the organizing committee. I would like to deliver our thanks to have all attendees here with us.

The Korea Basic Science Institute (KBSI) is very happy and especially honored to be hosting the 22nd International Workshop on ECR ion sources, ECRIS2016, which is the first workshop held in Korea. Due to the effort on the development of 28GHz superconducting ECRIS, we have been decided a host institution of the ECRIS2016, at the IAC of ECRIS2014. Following that the ignition of the first ECR plasma was generated in 2014; recently, we have successfully extracted the various ion beams from KBSI-ECRIS. For further performance improvement of our system, it is now on the overhaul after 2 years operation. For the optimization of the system, some modification of plasma chamber and so on are ongoing that will be provided better performance of the system.

In welcoming all of you, let me say that I and organizing committees are caring so much to provide the opportunities at the ECRIS2016, place for sharing and exchanging the ideas of latest advances and breakthroughs on ECR ion sources. Under comprehensive discussions with IAC, the sessions are prepared to deal with the topics: Status Reports and New Development, RF Generation and Transport, Plasma Investigations, Beam Extraction & Optics, Charge Breeding, Theory, and Applications. Technologies as well as brand-new results related on ECRIS are freely presented and discussed during the workshop with 82 presentations including 38 oral contributions.

I hope you make the most out of this workshop. And, please do enjoy the beautiful scenery of Haeundae beach and the dynamic activities in the Busan.
Thank you.

Mi-Sook Won,
Chair of the ECRIS2016

Organization

Workshop Chair

Dr. Mi-Sook Won, KBSI

International Advisory Committee

Yong-Seok Hwang, SNU
Ivan Izotov IAP, RAS
Andrey Efremov, JINR
Vadim Skalyga, IAP, RAS
Santo Gammino, INFN-LNS
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Sandor Biri, Atomki
Peter Spadtke, GSI
Takahide Nakagawa, RIKEN
Hongwei Zhao, IMP
Michael Hotchikis, ANSTO
Daniel Xie, LBNL

Local Organizing Committee

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Byoung Seob Lee, KBSI
In Seok Hong, IBS (RISP)
Hyun-Jong You, NFRI
Jang-Hee Yoon, KBSI
Hyun Gyu Kim, KBSI
Seyong Choi, KBSI
Jung-Woo Ok, KBSI

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Korea Basic Science Institute (KBSI)
Rare Isotope Science Project (RISP)
National Fusion Research Institute (NFRI)

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2016 RICHARD GELLER PRIZE

ECRIS2016

In recognition of outstanding contributions to the development of ECR (Electron Cyclotron Resonance) ion sources and to encourage promising young scientists, PANTECHNIK - the world leader in commercial ECR ion sources - awards the "Richard Geller PRIZE" on the occasion of ECRIS workshops.

This prize will be awarded for the fifth time during the 22st Workshop in Busan (2016). An ad-oc Geller Prize Award Committee will choose the winner of the Richard Geller Prize.

PANTECHNIK
Boost Your Physics

PRIZE PREZENTATION

Presentation is on Thursday, September 1, 2016, 09:40 - 10:40, Workshop Oral session room(Manarola).

SELECTION COMMITTEE

Vadim Skalyga, IAP, RAS (Chair)

Santo Gammino, INFN/LNS

Takahide Nakagawa, RIKEN

Thomas Thuillier, LPSC

Mi-Sook Won, KBSI

Daniel Xie, LBNL

Hongwe Zhao, IMP

Schedule

ECRIS2016

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<tr><td>09:00 - 09:40</td><td></td><td>Opening ceremony</td><td rowspan="3">Status reports and new development II (TUAO)</td><td rowspan="3">Status reports and new development III (WEAO)</td><td>Status reports and new development IV (THAO)</td><td>09:00 - 09:40</td></tr>
<tr><td>09:40 - 10:20</td><td></td><td>Special session (MOAO)</td><td rowspan="2">Geller Prize (THBO)</td><td>09:40 - 10:20</td></tr>
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<tr><td>11:00 - 12:00</td><td></td><td>Theory (TUBO)</td><td>Applications (WEBO)</td><td>Closing Remark</td><td>11:00 - 12:00</td></tr>
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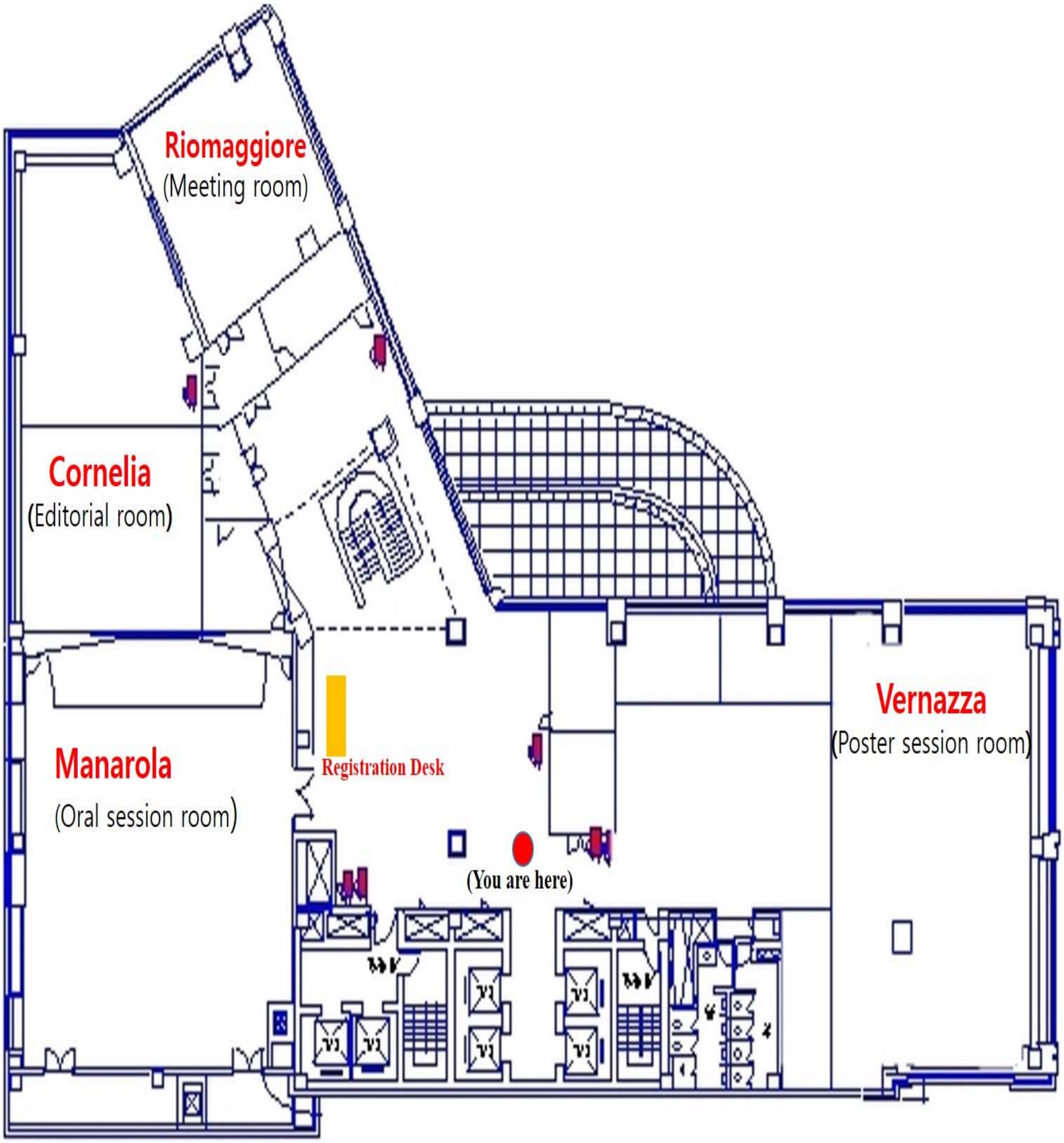
Riomaggiore
(Meeting room)
Cornelia
(Editorial room)
Manarola
(Oral session room)
Registration Desk
(You are here)
Vernazza
(Poster session room)

Presenting session change

ECRIS2016

MOBO01 Presenting session changed from Status reports and new development I to **Status reports and new development Ⅲ (Aug 31, 09:20 - 09:40)**

MOCO01 Presenting session changed from Plasma investigation I to **Status reports and new development Ⅱ (Aug 30, 10:00 - 10:20**)

TUAO04 Presenting session changed from Status reports and new development II to **Status reports and new development I (Aug 29, 10:40 - 11:00)**

WEAO02 Withdrawal

Welcome reception

Location:

Blue Seagull restaurant on the second floor of Hanhwa resort

Date:

18:00 – 20:00, 8/28 (Sunday)

Transportation:

Shuttle bus - Departure from Centum hotel to Hanhwa resort at 17:00

Shuttle bus - Departure from Hanhwa resort to Centum hotel at 20:30

Banquet

Banquet is to be held on a cruise ship (Tiffany 21) along the Gwangan Grand Bridge. All passengers on board the cruise ship are required to submit a report on board. So, **all attendants of banquet must bring their ID card or passport.**

Location:

Cruise Terminal (Tiffany21 Terminal) - 10 minutes walk from the Workshop place

Date:

18:00 – 21:00, 8/31 (Wednesday)

Transportation:

Walk - Departure from Hanhwa resort to Tiffany21 terminal at 18:00

Shuttle bus - Departure from Tiffany21 terminal to Centum hotel at 21:00

Shuttle bus timetable

	Date	Start	Stop	Time
1	8/28(Sun.)	Centum Hotel	Hanwha Resort	17:00
2		Hanwha Resort	Centum Hotel	20:30
3	8/29(Mon.)	Centum Hotel	Hanwha Resort	08:20
4		Hanwha Resort	Centum Hotel	18:00
5	8/30(Tue.)	Centum Hotel	Hanwha Resort	08:20
6	8/31(Wed.)	Centum Hotel	Hanwha Resort	08:20
7		Tiffany21	Centum Hotel	21:00
8	9/1(Thu.)	Centum Hotel	Hanwha Resort	08:20

Program

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ECRIS2016

Monday, 29-AUG, 2016

Special session

Status reports and new development I

Plasma investigations I

MOCO03 14:10 **Cavity Tuning Experiments with the JYFL 14 GHz ECRIS**

Presenting author: Olli Tarvainen - University of Jyvaskyla Department of Physics

MOCO04 14:30 **Recent Bremsstrahlung Measurements from the Superconducting Electron Cyclotron Resonance Ion Source VENUS**

Presenting author: Janilee Yvette Benitez - Lawrence Berkeley National Laboratory

Plasma investigations II

MODO01 15:20 **Structural Information on the ECR Plasma by Spatially Resolved X-ray Imaging**

Presenting author: Richárd Rácz - Hungarian Academy of Sciences Institute of Nuclear Research

MODO02 15:40 **Angular Distributions of Bremsstrahlung X-ray Emission from ECR Plasma**

Presenting author: Mwingereza John Kumwenda - Korea University

RF generation and transport

MOEO01 16:00 **Microwave Power Injection Schemes Study at IMP with Superconducting ECR Ion Source SECRAL**

Presenting author: Junwei Guo - Institute of Modern Physics, Chinese Academy of Sciences

Charge Breeding

MOFO01 16:40 **SPIRAL1 Charge Breeder: Performances and Status**

Presenting author: Laurent Maunoury - Grand Accélérateur Nat. d'Ions Lourds

MOFO02 17:00 **Comparison of Residual Background in an ECR and an EBIS**

Presenting author: Richard Vondrasek - Argonne National Laboratory

MOFO03 17:20 **Simulations of the ECR-based Charge Breeding Process at INFN: Status and Perspectives**

Presenting author: Alessio Galatà - Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Legnaro

Tuesday, 30-AUG, 2016

Status reports and new development II

TUAO01 09:00 **The Proton Source for the European Spallation Source (PS-ESS): Installation and Commissioning at INFN-LNS**

Presenting author: Luigi Celona - Istituto Nazionale di Fisica Nucleare Laboratori Nazionali del Sud

TUAO02 09:20 **The Development of ECR Ion Source for Medical Applications**

Presenting author: Byoung Seob Lee - Korea Basic Science Institute Busan Center

TUAO03 09:40 **Injector Characteristics of 100-MeV Proton Linac at KOMAC**

Presenting author: Han-Sung Kim - Korea Atomic Energy Research Institute

TUAO04 10:00 **SECRAL II Ion Source Development and the First Commissioning at 28 GHz**

Presenting author: Liangting Sun - Institute of Modern Physics, Chinese Academy of Sciences

TUAO05 10:20 **First Plasma of the PHOENIX V3 ECR Ion Source**

Presenting author: Thomas Thuillier - Laboratoire de Physique Subatomique et de Cosmologie Université Grenoble-Alpes, CNRS/IN2P3

Theory

TUBO01 11:00 **Optimization of Magnetic Field Distribution of RIKEN 28 GHz SC-ECRIS for Intense Beam Production**

Presenting author: Takahide Nakagawa - The Institute of Physical and Chemical Research Accelerator Research Facility Cyclotron Center

TUBO02 11:20 **Numerical Studies of the Gas-Mixing Effect in ECRIS**

Presenting author: Vladimir Mironov - Joint Institute for Nuclear Research

TUBO03 11:40 **Simulations of High Intensity Low Mass Ion Sources**

Presenting author: Remi de Guiran - Commissariat à l'Energie Atomique Institute of Research into the Fundamental Laws of the Universe Service des Accélérateurs, Cryogénie et Magnétisme

Wednesday, 31-AUG, 2016

Status reports and new development III

WEAO01 09:00 **Recent Developments with the GTS-LHC ECR Ion Source at CERN**

Presenting author: Ville Toivanen - European Organization for Nuclear Research

WEAO02 09:20 **Preliminary Design of a Hybrid Ion Source for 7Li+3 Generation**

Presenting author: ShiXiang Peng - Peking University Institute of Heavy Ion Physics

WEAO03 09:40 **Practical Comparison of Two-Frequency Heating Phenomena in Different ECRISs**

Presenting author: Atsushi Kitagawa - National Institute of Radiological Science

WEAO04 10:00 **Installation and Commissioning of the 18 GHz High Temperature Superconducting Ecr Ion Source and Low Energy Beam Transport System on a 200 kV High Voltage Platform**

Presenting author: Dr. Gerard Oscar Rodrigues - Inter University Accelerator Centre

WEAO05 10:20 **SMASHI and MeLA ECR Ion Source at NFRI: One for Highly-Charged Ions and the Other for High Current Metal Ions**

Presenting author: Hyun-Jong You - National Fusion Research Institute

Applications

WEBO01 11:00 **An ECRIS Facility for Investigating Nuclear Reactions in Astrophysical Plasmas**

Presenting author: Martin Kreller - DREEBIT GmbH

WEBO02 11:20 **Design of New Compact ECR Ion Source for C5+ Production**

Presenting author: Masayuki Muramatsu - National Institute of Radiological Sciences Division of Accelerator Physics and Engineering

WEBO03 11:40 **In-situ Observation of Phase Transformation During Ion Beam Irradiation**

Presenting author: Jonghan Won - Korea Basic Science Institute Advanced Nano Surface Team

Beam extraction & optics

WECO01 13:30 **Intermediate Commissioning Results of the ECR Injector of IFMIF/LIPAc Required to Deliver 70 mA/50 keV H+ and 140 mA/100 keV D+ Beams**

Presenting author: Benoit Bolzon - Commissariat l'Energie Atomique Institut de recherche sur les lois fondamentales de l'Univers (IRFU) Service des Accélérateurs, Cryogénie et Magnétisme

WECO02 13:50 **Development of a Compact High Intensity Ion Source for Light Ions at CEA-Saclay**

Presenting author: Olivier Delferriere - Commissariat à l'Energie Atomique Institute of Research into the Fundamental Laws of the Universe Service des Accélérateurs, Cryogénie et Magnétisme

WECO03 14:10 **Study of Ion Beam Extraction from an ECRIS: Beam Transverse Coupling and High Order Compensation**

Presenting author: Yao Yang - Institute of Modern Physics, Chinese Academy of Sciences

WECO04 14:30 **Progress of an Intense Ion Source and Low Energy Beam Transport System for Jinping Underground Nuclear Astrophysics Experiments**

Presenting author: Qi Wu - Institute of Modern Physics, Chinese Academy of Sciences

Poster session

WEPP01 15:20 **Acceleration of the SILHI Source Beam at CEA/Saclay**

Presenting author: Raphael Gobin - Commissariat à l'Energie Atomique Direction des Sciences de la Matière Institut de recherche sur les lois fondamentales de l'Univers

WEPP02 15:20 **Commissioning of the High Intensity Proton Injector of the Facility for Anti Proton and Ion Research at CEA-Saclay**

Presenting author: Olivier Tuske - Commissariat à l'Energie Atomique Institute of Research into the Fundamental Laws of the Universe Service des Accélérateurs, Cryogénie et Magnétisme

WEPP03 15:20 **Never Run Your ECR Ion Source with Argon in Afterglow for 6 Months!**

Presenting author: Detlef Kuchler - European Organization for Nuclear Research AB Department

WEPP04 15:20 **Development and Performance ECR Ion Source for Deuterium Ion Irradiation Facility**

Presenting author: Sudhirsinh J Vala - Institute for Plasma Research

WEPP05 15:20 **Status Report on Metallic Beam Production at GANIL/SPIRAL 2**

Presenting author: Christophe Barue - Grand Accélérateur Nat. d'Ions Lourds

WEPP06 15:20 **First Experiments on Applying the Gasdynamic ECR Ion Source for Negative Hydrogen Ion Production**

Presenting author: Vadim Skalyga - Institute of Applied Physics Russian Academy of Sciences

WEPP07 15:20 **H+ and D+ High Current Ion Beams Formation from ECR Discharge Sustained by 75 GHz Gyrotron Radiation**

Presenting author: Vadim Skalyga - Institute of Applied Physics Russian Academy of Sciences

WEPP08 15:20 **Development of Compact H+ ECR Ion Source with Pulse Gas Valve**

Presenting author: Yasuhiro Fuwa - Kyoto University Institute for Chemical Research Advanced Research Center for Beam Science

WEPP09 15:20 **Development of a New Compact 5.8 GHz ECR Ion Source at LPSC**

Presenting author: Julien Angot - Laboratoire de Physique Subatomique et de Cosmologie Université Grenoble-Alpes, CNRS/IN2P3

WEPP10 15:20 **Recent Work of High Intensity Beam Production With LECR4 Ion Source**

Presenting author: Liangting Sun - Institute of Modern Physics, Chinese Academy of Sciences

WEPP11 15:20 **All Permanent Magnet ECRISs for Heavy Ion Medical Machine at IMP**

Presenting author: Liangting Sun - Institute of Modern Physics, Chinese Academy of Sciences

WEPP12 15:20 **ECR Ion Sources Operation for HIRFL**

Presenting author: Xuezhen Zhang - Institute of Modern Physics, Chinese Academy of Sciences

WEPP13 15:20 **Development of a 14GHz Intense Proton Source With Ultra-Low Consumption of Hydrogen Gas**

Presenting author: Qi Wu - Institute of Modern Physics, Chinese Academy of Sciences

WEPP14 15:20 **A New ECRIS Installation at the Argonne Tandem Linac Accelerator System**

Presenting author: Robert Scott - Argonne National Laboratory

WEPP15 15:20 **Design, Construction and Commissioning of the New Superconducting Source AISHa**

Presenting author: Luigi Celona - Istituto Nazionale di Fisica Nucleare Laboratori Nazionali del Sud

WEPP16 15:20 **Beam Profile Measurements of 12C4+ Ion Beam From SMASHI**

Presenting author: Wonil Choo - National Fusion Research Institute

WEPP17 15:20 **Plasma Characteristics of a New High Current Metal Ion Source at NFRI**

Presenting author: Soouk Jang - National Fusion Research Institute

WEPP18 15:20 **Innovative Mechanical Solutions in the Design of the High Intensity Proton Injector for the European Spallation Source**

Presenting author: Luigi Celona - Istituto Nazionale di Fisica Nucleare Laboratori Nazionali del Sud

WEPP19 15:20 **A Study on the Superconducting Magnets for Raon 28 GHz ECR Ion Source**

Presenting author: Jeong Il Heo - Institute for Basic Science

WEPP20 15:20 **Superconducting Magnets Design and Fabrication of 28 GHz Electron Cyclotron Resonance Ion Source for Heavy Ion Accelerator Facility at KBSI**

Presenting author: Jonggi Hong - Korea Basic Science Institute Busan Center

WEPP21 15:20 **Analysis and Design of Impedance Matching Unit for Radio Frequency Ion Source**

Presenting author: Yahong Xie - Institute of Plasma Physics Chinese Academy of Sciences

WEPP22 15:20 **Versatile High Power Microwave System for Frequency Tuning of the CAPRICE ECRIS**

Presenting author: Fabio Maimone - GSI Helmholtzzentrum für Schwerionenforschung GmbH

WEPP23 15:20 **Improvement of the Microwave Ion Source at KOMAC**

Presenting author: Hyeok-Jung Kwon - Korea Atomic Energy Research Institute (KAERI) Korea Multi-purpose Accelerator Complex (KOMAC)

WEPP24 15:20 **Precision Measurement of Lifetime of J + = 5/2 + Excited State of 133 Cs via γ − γ Coincidences using NaI(Tl) Scintillators**

Presenting author: Innocent Jimmy Lugendo - Korea University

WEPP25 15:20 **Development Progress of Large-Area High-Power Rf Ion Source for High-Energy Beam Applications**

Presenting author: Doo-Hee Chang - Korea Atomic Energy Research Institute

WEPP26 15:20 **Current Status of the Control System Development for KBSI 28 GHz ECR Ion Source**

Presenting author: Seongjun Kim - Korea Basic Science Institute Busan Center

WEPP27 15:20 **Fabrication Status of the Radio Frequency Quadrupole for the RISP**

Presenting author: Bum-Sik Park - Institute for Basic Science

WEPP28 15:20 **The Continuous Wave RF Test of an 81.25 MHz Normal Conducting Re-Buncher for MEBT in RISP**

Presenting author: Hye-Jin Kim - Institute for Basic Science

WEPP29 15:20 **Recently Test Results for RISP Prototype RFQ**

Presenting author: Bong Hyuk Choi - Institute for Basic Science

WEPP30 15:20 **Magnet Power Supply at PAL-XFEL**

Presenting author: Ki-Hyeon Park - Pohang Accelerator Laboratory

WEPP31 15:20 **Development of S-band Accelerating Components for PAL-XFEL**

Presenting author: Do Yoon Kim - Vitzrotech Co., Ltd.

WEPP32 15:20 **Magnetic Field Design for 2.45 GHz Negative Hydrogen PMECRIS Chamber using FEM Simulation**

Presenting author: Rajesh Kumar - Institute for Plasma Research

WEPP33 15:20 **Investigation of Electron Trajectories in an Ion Channel Magnetized Free Electron Laser With a Rectangular Hybrid Wiggler**

Presenting author: Masoud Alimohamadi - Farhangian University

WEPP34 15:20 **Recent Beam Dynamics Studies for the SCL Demo of RISP**

Presenting author: Hyunchang Jin - Institute for Basic Science

WEPP35 15:20 **Transverse Four-Dimension Phase-Space Distribution Measured by the Pepper-Pot Type Emittance Meter**

Presenting author: Takashi Nagatomo - RIKEN Nishina Center

WEPP36 15:20 **Effect of Repair for Plasma Chamber System in KBSI ECR Ion Source**

Presenting author: Jin Yong Park - Korea Basic Science Institute Busan Center

WEPP37 15:20 **LEBT System for RISP**

Presenting author: In-Seok Hong - Institute for Basic Science

WEPP38 15:20 **Emittance Measurement for a Low Energy Heavy Ion Beam**

Presenting author: Deok-Min Kim - Korea University

WEPP39 15:20 **The Design of Computer Data Processing System for RF Ion Source on NbI**

Presenting author: Xiaodan Zhang - Qinghai University

WEPP40 15:20 **Fast Sputtering Measurements of Uranium with an 18 GHz ECRIS and Ion Density Simulations with a Kinetic Global Model (KGM)**

Presenting author: Derek Elwin Neben - Michigan State University National Superconducting Cyclotron Laboratory

WEPP41 15:20 **Measurement of Microwave Frequencies Emitted by Instabilities of ECRIS Plasma with Waveguide Filters and Microwave Sensitive Diodes**

Presenting author: Olli Tarvainen - University of Jyvaskyla Department of Physics

WEPP42 15:20 **Investigation of 2.45 GHz Microwave Radiated Argon Plasma under Magnetized Condition**

Presenting author: Rajesh Kumar - Institute for Plasma Research

WEPP43 15:20 **Kinetic Instabilities in ECR Plasmas Under Conditions of Two-Frequency Heating**

Presenting author: Ivan Izotov - Institute of Applied Physics Russian Academy of Sciences

WEPP44 15:20 **Design of a Langmuir Probe for Low-Pressure High-Density Plasma Diagnostics**

Presenting author: Sung-Ryul Huh - Korea Atomic Energy Research Institute

WEPP45 15:20 **Heating of Microwave Plasmas to Further Increase Their Densities**

Presenting author: Dr. Gerard Oscar Rodrigues - Inter University Accelerator Centre

Thursday, 01-SEP, 2016

Status reports and new development IV

THAO01 09:00 **Recent production of intense high charge ion beams with VENUS**

Presenting author: Daniel Xie - Lawrence Berkeley National Laboratory

THAO02 09:20 **Development Status of 28 GHz Superconducting ECR Ion Source for the KBSI Accelerator**

Presenting author: Seyong Choi - Korea Basic Science Institute Busan Center

Geller Prize

09:40 ~ 10:40

Monday

August 29, 2016

Scaling Laws in Electron Cyclotron Resonance Ion Sources

Claude M Lyneis

LBNL, Berkeley, California

In the last 43 years, the performance of high charge state ECRIS has improved dramatically as a result of improvements to the magnetic field confinement, increases in the microwave heating frequency and techniques to stabilize the plasma at high densities. For example, in 1973 15 eμA of O6+ was produced in an ECRIS and now it is possible to produce as much as 4500 eμA. In this paper the parameters and performance of ECRIS are reviewed and compared to empirical scaling laws[*] to see what can be expected when fourth generation ECRIS begin to operate.

Footnote

[*] Geller, Richard. Electron cyclotron resonance ion sources and ECR plasmas. CRC Press, 1996, p 395

FECRAL - a 45 GHz Fourth Generation ECR Ion Source and Its Technical Challenge

Hongwei Zhao, Liangting Sun

IMP/CAS, Lanzhou

A 45 GHz superconducting ECR ion source FECRAL (a Fourth generation ECR ion source with Advanced design in Lanzhou) is going to be built in the next few years as a key technology R&D of HIAF facility. HIAF injector of a superconducting heavy ion linac requests the ion source of delivering 50 pμA of 238U35+ pulsed beam and 25 pμA of 238U35+ CW beam. This presentation will present preliminary technical-design of FECRAL ECR ion source including magnetic field configuration produced by a Nb3Sn superconducting magnet with 6.5 Tesla axial mirror field and 3.5 Tesla sextupole field on the plasma chamber inner wall, 20 kW@45 GHz microwave coupling system and beam transport line. Obviously, to build a 45 GHz FECRAL ECR ion source, there will be many technical challenges, such as engineering and fabrication of the Nb3Sn superconducting magnet with 12 Tesla maximum magnetic field on the conductor, cryogenic system of the magnet, efficient coupling of 45 GHz microwave power, intense beam extraction and transmission to achieve good beam quality, integration of the FECRAL ion source system and analyzing beam line at a high voltage platform.

Optimizations of Existing Magnet Structures for the Next Generation of ECRIS

[1]Daniel Xie, GianLuca Sabbi, Damon Todd, [2]Wang Lu

[1]LBNL, Berkeley, California, [2]IMP/CAS, Lanzhou

Constructing a minimum-B structure with higher magnetic fields is the prerequisite for the next generation of Electron Cyclotron Resonance Ion Sources (ECRIS): ion sources that will operate at substantially higher heating frequencies than those currently in use. There are three leading candidates of Nb3Sn coil structures for use in future ECRISs: a Mixed Axial and Radial field System (MARS) that merges the sextupole racetrack coils and partial end-solenoids into an exotic closed-loop-coil; a classical Sextupole-In-Solenoids design; and a Solenoids-In-Sextupole configuration. Focusing on efficient magnetic field generation, this article briefly reviews the advantages and disadvantages of each of these magnet structures. Though Sextupole-In-Solenoids and Solenoids-In-Sextupole magnetic structures using NbTi conductor have been validated by current ECRISs, improvements of these magnet structures remain possible. Possible optimizations to the two existing magnet structures, such as using a non-conventional sextupole magnet consisting of either V-bend or skew racetrack coils, are discussed. The development status of a MARS NbTi magnet at LBNL for a new ECRIS will be also presented.

Current Status of a SC-ECRIS of the RAON Accelerator.

Yonghwan Kim, Takashi Hashimoto, Jeong Il Heo, Hironobu Ishiyama

IBS, Daejeon

Raon is the heavy ion accelerator being built in Korea. It contains 3rd generation SC-ECRIS which uses 28GHz/18GHz microwave power to extract a heavy ion beam. We prepared and installed beam focusing devices and beam diagnostic devices to characterize the ion source. Now the ion source is in beam commissioning status after maintenance activities. After beam commissioning with oxygen beam, a metal ion beam will be extracted at the end of this year using sputtering method.

Agency

This work was supported by the Rare Isotope Science Project funded by Ministry of Science, ICT and Future Planning(MSIP) and the National Research Foundation(NRF) of the Republic of Korea

Recent Developments of RIKEN 28 GHz SC-ECRIS

Yoshihide Higurashi, Takahide Nakagawa, Jun-ichi Ohnishi

]RIKEN Nishina Center, Wako

In the past two years, we tried to improve the performance of the RIKEN 28GHz SC-ECRIS for production of intense U ion beam. Usually, we used the sputtering method to produce U ion beam. Last year, we produced ~200e micro A of U35+ at the injected RF power of ~2.6kW, when slightly adding the U vapor with high temperature oven. For RIKEN RIBF experiment, we produced ~120 e micro A of U35+ beam with sputtering method longer than one month without break. In this case, we surly need very stable beam to increase the transmission efficiency in the accelerators and avoid the any damage of the components of the accelerator due to the high power beam. In this contribution, we will report the beam intensity of highly charged U ions as a function of various parameters (magnetic field strength, RF power, sputtering voltage etc.) and the effect of these parameters on the beam stability in detail. We also present the experience of the long term operation of the ion source for the RIKEN RIBF experiments.

Innovative Schemes of Plasma Heating for Future Multiply-Charged Ions Sources: Modeling and Experimental Investigation

[1]David Mascali, Carmen Altana, Giuseppe Castro, Luigi Celona, Santo Gammino, Ornella Leonardi, Dario Nicolosi, Giuseppe Torrisi, [2]Francesco Paolo Romano, [3]Maria Mazzaglia, Reitano Riccardo, [4]Gino Sorbello

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Plasma heating methods alternative to direct ECR-coupling may lead to a change-of-paradigm in the design of future ion sources of multiply-charged ions. The modal conversion driving Electron Bernstein Waves (EBW) gives the unique opportunity to largely overcome the cut-off density. In compact magnetic traps, the generation of these waves is still a challenge, requiring advanced modelling and innovative diagnostics. At INFN-LNS clear signatures of modal conversion occurrence have been collected on a test-bench operating at 3.75 GHz, 0.1 T, where the new microwave interferometer VESPRI has measured a plasma density one order of magnitude larger than the cut-off one. Innovative wave launching systems devoted to modal conversion have been then designed for a the new Flexible Plasma Trap now operating at LNS at 7+14 GHz, 0.5 T for double-frequency/ECR-EBW heating mode in flat/simple mirror/beach magnetic configurations. The talk will give an overview about modal-conversion investigation by a theoretical and experimental point of view, including the state of the art of the diagnostics developed to detect plasma emitted radiation in the RF, optical, soft-X and hard-X-ray domains.

Broadband Microwave Emission Spectrum Associated With Kinetic Instabilities in ECR Plasmas

[1]Ivan Izotov, Vadim Skalyga, [2]Dmitriy Mansfeld, [3]Taneli Kalvas, Hannu Koivisto, Jani Komppula, Risto Juhani Kronholm, Janne Laulainen, Olli Tarvainen

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ECRISs are susceptible to kinetic instabilities due to resonance heating mechanism forming an anisotropic electron velocity distribution function. Well-known and frequently observed extracted ion beam current oscillations in case of high heating power and/or low magnetic field gradient are proven to be caused by the instabilities of cyclotron type leading to a notable reduction of highly-charged ion beam intensities. It has been shown recently that heating power level and magnetic field gradient affect the spectrum of microwave emission of plasma related to cyclotron instabilities, being in the frequency range of 8-14 Ghz. More detailed study of microwave emission spectrum of ECR plasma conducted with an improved setup is presented in this work. It was found that frequencies of microwaves emitted by the plasma can be far beyond the primary heating frequency (14 GHz) and up to 25 GHz. Moreover, a threshold transition from periodic pulsed emission to a CW emission has been observed in the experiment for the first time, as was predicted theoretically*. The transition occurs at certain threshold levels of heating microwave power and magnetic field gradient.

Footnote

* A.G. Shalashov et all, JETP Letters, 2006, Vol. 84, No. 6, pp. 314-319 (2006)

Cavity Tuning Experiments with the JYFL 14 GHz ECRIS

[1]Olli Tarvainen, Taneli Kalvas, Hannu Koivisto, Risto Juhani Kronholm, Janne Laulainen, Joose Orpana, [2]Ville Toivanen, [3]Ivan Izotov, Dmitriy Mansfeld, Vadim Skalyga

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Experimental results showing the effect of cavity tuning on oxygen beam currents extracted from the AECR-type JYFL 14 GHz ECRIS are reported. The microwave-plasma coupling properties of the ion source were adjusted by inserting a conducting tuner stub through the injection plug, thus changing the dimensions of the plasma chamber and affecting the cavity properties of the system. The beam currents of high charge state ions were observed to vary up to some tens of percent depending on the tuner position and the microwave frequency.

Recent Bremsstrahlung Measurements from the Superconducting Electron Cyclotron Resonance Ion Source VENUS

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Axial bremsstrahlung from the superconducting Electron Cyclotron Resonance ion source VENUS have been systematically measured as a function of RF heating frequency, and the axial and radial field strengths. The work focuses on bremsstrahlung with energies greater than 10 keV to extract the spectral temperature Ts. The three axial coils and the radial coils in the superconducting VENUS can all be set independently and have a large dynamic range, which makes it possible to decouple Bmin and Bgrad and study their effects on the bremsstrahlung independently. With typical pressure and RF power levels, the measurements show that Ts depends approximately linearly on Bmin and is not correlated with the ∇BECR, the magnetic field mirror ratios or the RF frequency. These results are important for the next generation of ECR ion sources, which are designed to operate at frequencies above 40 GHz and significantly higher magnetic fields where bremsstrahlung is expected to cause a significant cryogenic heat load and increase the radiation shielding requirements.

Structural Information on the ECR Plasma by Spatially Resolved X-ray Imaging

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Precise knowledge on the density distribution of the Electron Cyclotron Resonance Ion Source plasma is needed by several reasons: i) in order to possibly improve the quality parameters of the extracted ion beam (emittance, brightness) strongly linked to the plasma structure, ii) to correctly investigate the recently observed plasma instabilities and/or the implementation of alternative heating methods (e.g. modal conversion) iii) in order to improve the general microwave-to-plasma coupling efficiency, in view of a microwave-absorption oriented design of future ECRIS. The non-destructive spectroscopic diagnostic methods give information always corresponding to an integration over the whole plasma volume. X-ray imaging by pin-hole camera can partly overcome this limitation. We performed volumetric and space resolved X-ray measurements at the ATOMKI ECRIS operated at lower frequencies than usual. The experimental setup in detail and the methods how the working parameters were selected will be shown. The integrated and photon-counting analyses of the collected plasma images show a strong effect of the frequency and magnetic field on the plasma structure and local energy content.

Angular Distributions of Bremsstrahlung X-ray Emission from ECR Plasma

Mwingereza John Kumwenda

Korea University, Seoul

High-energy X-ray emission beyond a critical energy from ECR heating has long attracted much attention and its nature has yet been unsolved. We have measured bremsstrahlung X-rays from the 28-GHz ECR ion source at Busan Center of KBSI. The gamma-ray detection system consists of three NaI(Tl) scintillation detectors placed 55 cm radially from the beam axis at the extraction port, and a NaI(Tl) scintillation detector for monitoring X-ray intensity at the beam axis. Bremsstrahlung X-ray energy spectra were measured at 9 azimuthal angular regions at RF power of 1kW. We also measured bremsstrahlung X-rays by exchanging detector positions for studying systematic uncertainties. Detection efficiency and shielding effect are taken into account for extracting real X-ray energy spectra from measured ones, based on Geant4 simulation results. Preliminary results on the azimuthal angular distributions of bremsstrahlung X-rays with respect to energy region will be presented.

Microwave Power Injection Schemes Study at IMP with Superconducting ECR Ion Source SECRAL

Junwei Guo

IMP/CAS, Lanzhou

The performance of electron cyclotron resonance ion sources (ECRIS) is critically dependent on the resonant absorption efficiency of microwave power. Over-sized round waveguide with a diameter about Ø33.0 mm excited in the TE01 mode has been typically adopted for microwave coupling to the ECR plasma with the superconducting ECRIS operated at 24 or 28 GHz, such as SECRAL and VENUS. However, it should be realized that this is not necessarily the optimal scheme for microwave power injection. In order to study the impact of different microwave power distribution on ECRH efficiency and especially the production of highly charged ions, a set of compact and efficient mode convertors and mode transitions with different diameters applicable to 24 GHz SECRAL has been designed, fabricated and tested.SECRAL has been tested with the different microwave power injection schemes for the production intense highly charged heavy ion beams of Ar and Xe. A general comparison of the performance working at the different injection schemes with SECRAL will be given, and a preliminary analysis will be made in this paper.

SPIRAL1 Charge Breeder: Performances and Status

[1]Laurent Maunoury, Olivier Bajeat, Pierre Delahaye, Mickael Dubois, Romain Frigot, Pascal Jardin, Anthony Jeanne, Omar Kamalou, Patrice Lecomte, Benoit Osmond, Guillaume Peschard, Alain Savalle, [2]Julien Angot, Thierry Lamy, Patrick Sole

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In the framework of the SPIRAL1 upgrade under progress at the GANIL lab, the charge breeder based on a LPSC Phoenix ECRIS, first tested at ISOLDE[*] has been modified as to benefit of the last enhancements of this device from the 1+ / n+ community[**]. Prior to its installation in the middle of the low energy beam line of the SPIRAL1 facility, it has been tested at the 1+/n+ LPSC test bench to validate its operation performances. Charge breeding efficiencies as well as charge breeding times have been measured for noble gases and alkali elements. The experimental results demonstrated that the modifications done were on the right track leading the SPIRAL1 charge breeder to the top worldwide in terms of performances. The experimental outcomes have proved the strong interrelationship between the charge breeding efficiency and the charge breeding times which are still under active discussion.

Footnote

[*] P. Delahaye et al, Review of Scientific Instruments. 77, 03B105 (2006)

[**] R. Vondrasek et al, Review of Scientific Instruments 83 113303 (2012)

Comparison of Residual Background in an ECR and an EBIS

[1]Richard Vondrasek, Clayton Dickerson, Peter Ostroumov, Richard Claude Pardo, Robert Scott, [2]Gary Zinkann

[1]ANL, Argonne, Illinois, [2]ANL, Argonne

An ECR charge breeder was developed some years ago as part of the Californium Rare Ion Breeder Upgrade (CARIBU) program at Argonne National Laboratory. The charge breeding efficiency and high charge state production of the source were at the forefront of ECR charge breeders, but its overall performance as part of the accelerator system was limited by a pervasive stable ion background. Steps were taken to reduce the level of background contamination but met with limited success. As such, the ECR charge breeder was decommissioned in late 2015 and replaced with an EBIS charge breeder. The EBIS has demonstrated good breeding efficiency in an off-line installation, but the critical attribute of stable ion background has only begun to be characterized. We will present a comparison of the background levels from these two devices when coupled to the accelerator complex as well as possible solutions for background reduction in ECR charge breeders.

Agency

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Simulations of the ECR-based Charge Breeding Process at INFN: Status and Perspectives

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Since 2012, the INFN ion source group has been undertaking an intense activity on numerical modelling, in the European context of the EMILIE Project until 2014. The work concerns the study of the two main aspects influencing the performances of an ECR-based charge breeder: on one hand, the interaction of the injected 1+ beam with the ECR plasma; on the other hand, the energy coupling to plasma electrons by the microwave field set-up inside the plasma chamber. The first aspect has been addressed by developing a numerical code in a Matlab environment, able to reproduce the capture and thermalization of an ion beam by the ECR plasma. Equations describing the process have been implemented trough the Langevin formalism, including a plasma model of increasing complexity. The second aspect has been studied with the interplay between the 3D solver COMSOL Multiphysics and Matlab, describing the plasma through its fully 3D dielectric permittivity tensor. This paper describes the state-of-the-art of the work on both the fronts: it will show an overview of the beam-plasma interaction, offering some hints for the optimization of already existing devices or for the design of new ones.

Tuesday

August 30, 2016

The Proton Source for the European Spallation Source (PS-ESS): Installation and Commissioning at INFN-LNS

[1]Luigi Celona, Luciano Allegra, Antonio Amato, Giuseppe Calabrese, Antonio Caruso, Giuseppe Castro, Francesco Chines, Giuseppe Gallo, Santo Gammino, Ornella Leonardi, Alberto Longhitano, Giovanni Manno, Salvatore Marletta, David Mascali, Antonio Maugeri, Lorenzo Neri, Santi Passarello, Giuseppe Pastore, Antonio Seminara, Antonino Spartà, Giuseppe Torrisi, Salvatore Vinciguerra, [2]Maria Mazzaglia, [3]Sandra Di Martino, Paolo Nicotra

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A 2.45 GHz, 0.1 T microwave discharge Proton Source has been designed and assembled at INFN-LNS for the European Spallation Source (PS-ESS) in order to produce pulsed beams of protons up to 74 mA nominal current, at 75 keV of energy, with a transverse emittance containing 99% of the nominal proton current below 2.25 π mm mrad. The challenging performances of the machine have triggered specific studies on the maximization of the proton fraction inside the plasma and of the overall plasma density, including dedicated modeling of the wave-to-plasma interaction and ionization processes. The commissioning of the high intensity beam started recently. The design phase, the construction and the first beam characterization, particularly focused on beam stability at high current intensity, will be presented for different source configurations. A testbench called Flexible Plasma Trap (FPT), installed in the same experimental area of PS-ESS and characterized by rescaled parameters in terms of pumping wave frequency and magnetic field strength up to 7 GHz and 0.5 T, has been used for investigating the microwave-to-plasma matching by means of several diagnostics tools.

The Development of ECR Ion Source for Medical Applications

[1]Byoung Seob Lee, Seyong Choi, Jonggi Hong, Hyun Gyu Kim, Seong Jun Kim, Jung-Woo Ok, Jin Yong Park, Mi-Sook Won, Jang-Hee Yoon, [2]Jungbae Bahng

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Since 2009, the ECR ion source for material researcher was developed at Korea Basic Science Institute (KBSI). From our efforts during 7 years, The service of 28 GHz ECR ion source of KBSI was succeeded in this year. Our new project is started based on developed skills for 28GHz ECR ion source. In this year, we are started proton ECR ion source with high current for medical application that is Boron Neutron Capture Therapy (BNCT), Proton Therapy. The first step is development of proton ECR ion source with beam current of 23mA. In this paper, we will suggest design results and manufacturing status of proton ECR ion source for BNCT. Also, we will introduce the future plan about development of compact proton therapy and will report plans for feasibility study.

Injector Characteristics of 100-MeV Proton Linac at KOMAC

[1]Han-Sung Kim, [2]Yong-Sub Cho, Dae-Il Kim, Hyeok-Jung Kwon, Sang-Pil Yun

[1]KAERI, Daejon, [2]Korea Atomic Energy Research Institute (KAERI), Gyeongbuk

A 100-MeV proton linac at Korea Multi-purpose Accelerator Complex (KOMAC) is under operation and has provided high-intensity proton beam to users since 2013. The injector part of the linac consists of a microwave ion source with 50 keV extraction energy, two solenoids for beam matching to the 3-MeV RFQ and a vacuum box including beam diagnostics and vacuum pump. The design current of the injector is 20 mA with 0.2 pi.mmmrad transverse normalized rms emittance. The injector was characterized through emittance measurement and solenoids operating parameter sweep. The details of the injector characteristics will be presented in this paper.

Agency

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SECRAL II Ion Source Development and the First Commissioning at 28 GHz

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IMP/CAS, Lanzhou

SECRAL II ion source has been successfully designed and developed at IMP. This ion source is a 3rd generation ECR machine optimized for the operation at 28 GHz. As a second superconducting ECR ion source developed at IMP with the identical coldmass design as SECRAL ion source, which has the sextupole coils external to the axial solenoids, the magnet performance is more robust according the training test. After a short time beam test at 18 GHz, SECRAL II has been commissioned at 28 GHz, and some preliminary results have been achieved with high charge state ion beam production. This paper will present the magnet design and test results. The first beam at 28 GHz will also be given.

First Plasma of the PHOENIX V3 ECR Ion Source

[1]Thomas Thuillier, Julien Angot, Laurent Bonny, Josua Jacob, Thierry Lamy, Patrick Sole, [2]Jean Luc Flambard, Laurent Maunoury, [3]Christophe Peaucelle

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The PHOENIX V3 ion source is an upgrade of the PHOENIX V2 ECRIS granted by the CRISP project (EU Grant Agreement 283745). This new ECRIS features a larger plasma chamber and a reduced vacuum pressure under operation. The V3 source is foreseen to replace the V2 one on the SPIRAL2 accelerator in 2018. The first plasma of PHOENIX V3 was achieved on May 9th 2016. The early commissioning of the V3 source will be presented along with a status of the SPIRAL2 injector operation. Depending on the progress of the V3 commissioning, the ability of the V2 and V3 ECRIS to produce Q/A=1/3 beams will be compared and discussed.

Agency

This project was partially funded by the EU Grant Agreement 283745.

Optimization of Magnetic Field Distribution of RIKEN 28 GHz SC-ECRIS for Intense Beam Production

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Optimization of the magnetic field distribution is one of the crucial issue to increase the beam intensity and design the next generation ECRIS with higher frequency. For this reason, we studied this effect on the beam intensity of various highly charged heavy ions (Ar, Kr, Xe and U) with 14,18 and 28GHz, systematically. Using our ECRISs, we observed that 1) Optimum Bmin to maximize the beam intensity was strongly dependent on the gas pressure and biased disc voltage. 2) Optimum field is Binj〉1.6Bext, Br~1.2Bext. 3) Bext strongly affects the beam intensity under the optimum conditions. Based on these results, we produced ~100euA of U35+ with Bext ~1.55T at the injected RF power of ~1.5kW (~150W/L) (28GHz), which is almost same beam intensity for higher Bext. Bext~1.55T was significantly lower than the magnetic field usually used for SC-ECRISs with 28GHz. We also obtained 200euA, 225euA of U35+,33+ with 2.6kW(~260W/L) (Bext~1.78T). In this contribution, we present effect of the magnetic field on the beam intensity of various heavy ions with 18 and 28GHz and the production of intense U ion beam. We also discuss the optimum structure with higher RF frequency based on these results.

Numerical Studies of the Gas-Mixing Effect in ECRIS

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The particle-in-cell MCC code NAM-ECRIS is used to simulate the ECRIS plasma sustained in a mixture of Kr with O2, N2, Ne and He. The model assumes that ions are electrostatically confined in ECR zone by a dip in the plasma potential. Gain in the extracted krypton ion currents is seen for the highest charge states; the gain is maximized when oxygen is used as the mixing gas. A special feature of oxygen is that most of singly charged oxygen ions are produced after dissociative ionization of oxygen molecules with the large kinetic energy release of around 5 eV per ion. Increased loss rate of energetic lowly charged ions of the mixing element requires building up of the retarding potential barrier close to ECR surface to equilibrate electron and ion losses out of the plasma. In the mixed plasmas, the barrier value is large (~1 V) compared to the pure Kr plasma (~0.01 V), with the longer confinement times of krypton ions and with the much higher ion temperatures.

Simulations of High Intensity Low Mass Ion Sources

Remi de Guiran, Antoine Chancé, Raphael Gobin, Olivier Tuske

CEA/IRFU, Gif-sur-Yvette

At CEA/Saclay, in the framework of the HPPA development, the Department of Accelerators, Cryogenics and Magnetism (SACM) has designed and built low mass, high intensity ECRIS for more than 15 years. Such skills are illustrated by the construction of injectors (sources and low energy beam transport lines) for several national and international projects such as, SPIRAL2, IFMIF and FAIR. In order to improve the source performance, a better understanding of the processes involved in the plasma generation is needed as well as an important R&D activity. In this aim, in collaboration with Pantechnik Company, we develop a code based on the numerical method developed by Lampe et al 1998. Using dedicated numerical tools for the description of the electron heating, the ionization and the Coulombian collisions, self-consistent simulations have been performed. The impact of the chamber geometry and the power of the RF wave injected have also been studied.

Wednesday

August 31, 2016

Recent Developments with the GTS-LHC ECR Ion Source at CERN

[1]Ville Toivanen, Giulia Bellodi, Claudio Fichera, Detlef Kuchler, Alessandra Maria Lombardi, Marc Maintrot, Alice Ingrid Michet, Michael O'Neil, Sergey Sadovich, Fredrik Wenander, [2]Olli Tarvainen

[1]CERN, Geneva, [2]JYFL, Jyvaskyla

Linac3 is the first link in the chain of accelerators providing highly charged heavy ion beams for the CERN experimental program. The beams, predominantly lead, are produced with the GTS-LHC 14.5 GHz Electron Cyclotron Resonance (ECR) ion source, operated in afterglow mode. In the framework of the LHC Injector Upgrade program (LIU), several activities have been carried out to improve the GTS-LHC and Linac3 performance, in terms of delivered beam current. The extraction region of the GTS-LHC has been upgraded with redesigned apertures and the addition of an einzel lens, yielding improved Linac3 output. Also, a series of measurements has been performed to study the effects of two-frequency heating on the performance of the GTS-LHC. A Traveling Wave Tube Amplifier (TWTA) with variable frequency and pulse pattern was utilized as a secondary microwave source. The two-frequency effect commonly reported with CW operation of ECR ion sources boosting high charge state ion production was also observed in afterglow mode. Lastly, for studies of metal ion beam production, a dedicated test stand has been assembled to characterize the GTS-LHC resistively heated miniature oven performance.

Preliminary Design of a Hybrid Ion Source for 7Li+3 Generation

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To provide a novel directional fast-neutron via the p(7Li ,n) reaction for prompt fission γ -ray (PFG) spectra study, a hybrid 7Li3+ ion source was designed at Peking University(PKU). It is a combination of a 6.5 GHz ECR (electron cyclotron resonance) ion source and a hot surface ionization source. The surface ionization source locates inside the ECR chamber and a 500 V bias voltage is set between the hot surface and the ECR chamber. Lithium vapor from an oven is guided into the surface source through a heating transfer pipe. Li+ ions generated on the hot surface will be extracted from the surface source and striped into Li3+ with the electron impact ionization. To avoid the lithium vapor attaching on the wall of the discharge chamber, the whole plasma chamber will be heated up to 300 ℃. A four-electrode extraction system will be used for Li3+ ion beam formation. Details will be presented in the paper.

Practical Comparison of Two-Frequency Heating Phenomena in Different ECRISs

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In order to improve highly-charged ion production from the 18GHz NIRS-HEC ECRIS, our group has studied the mixture of two microwaves of which the frequencies were close together each. Our conclusion was that when an additional microwave is added to the primary microwave, the plasma stability is improved. The output current of the highly charged ion beam was proportional to the total power of both microwaves. The dependence on the additional frequency showed the fine structure. Since this structure depended on the magnetic field, vacuum pressure, and so on, the precise frequency adjustment for maximum output was required under each condition. Our interest is whether the above-mentioned phenomenon can be demonstrated using a different ion source where the two frequencies are even far from each other. We installed a 17.75-18.25 GHz microwave system in addition to the 14.3 GHz klystron amplifier of the ATOMKI ECRIS. Argon output currents at various values of the microwave power and frequency were studied. The dependence on the total power shows the similar tendency as at NIRS. The dependence on the additional frequency also shows the fine structure. Detailed data will be presented.

Installation and Commissioning of the 18 GHz High Temperature Superconducting Ecr Ion Source and Low Energy Beam Transport System on a 200 kV High Voltage Platform

Dr. Gerard Oscar Rodrigues, Rajeev Ahuja, Pradip Barua, Dinakar Kanjilal, Ashok Kothari, Achakala Malyadri, Abanimohan Mandal, Yadhuvansh Mathur, Unnam Koteshwar Rao, Ashish Sharma

IUAC, New Delhi

The High Current Injector programme at the Inter University Accelerator Centre is presently in various stages of installation and commissioning. The main objective of the high current injector is to provide higher beam intensities (A/q ~ 6) over a wider mass range as compared to the presently operating 15UD, 16MV Tandem-LINAC combination. The injector is based on a reasonably high performing ECR ion source called PKDELIS. The 18 GHz high temperature superconducting ECR ion source, PKDELIS and the low energy beam transport system has been recently installed and commissioned on a 200 kV high voltage platform. The details of the installation and commissioning results will be presented.

SMASHI and MeLA ECR Ion Source at NFRI: One for Highly-Charged Ions and the Other for High Current Metal Ions

Hyun-Jong You, Wonil Choo, Soouk Jang

NFRI, Daejon

There are two type of ECR ion sources at NFRI. One is SMASHI (Superconducting Multi-Application Source of Highly-charged Ions), and the other MeLA(Magnet-embedded Lisitano Antenna) ion source. They are developed for highly-charged ions(HCI) and high current metal ions(HCMI) generation, respectively. Firstly, SMASHI is a 18 GHz superconducting ECR ion source, which will be dedicated for future application of HCIs and matter interaction. SMASHI is featuring a liquid helium-free SC magnet having fast-excitation capability(〉0.1 A/s) of coils, two frequency heating(18, 18+Δ GHz), remotely-positional variable gap extraction system, and two diagnostic ports for the extraction region. Secondly, MeLA ion source is a scalable high current(〉10 mA) metal ion source. the MeLA*, originally developed for a large-area microwave ECR plasma source for semiconductor processing by our group, is able to generate high density uniform ECR plasma by a waveguide directly-coupled and permanent Magnet-embedded Lisitano Antenna. In this presentation we describe design aspects of the sources in detail, and then their performance results are provided.

Footnote

* H. J. You, S. O. Jang, Y. H. Jung, and B. J. Lee, "Microwave Antenna for Generating Plasma", U.S. Patent 8 648 534, February, 2014.

An ECRIS Facility for Investigating Nuclear Reactions in Astrophysical Plasmas

[1]Martin Kreller, Guenter Herbert Zschornack, [2]Christine Baumgart, [3]A Huke, Goetz Ruprecht, D Wei¿bach, [4]Konrad Czerski, Mateusz Kaczmarski, Natalia Targosz-Ślęczka

[1]DREEBIT GmbH, Dresden, [2]Dreebit GmbH, Großröhrsdorf, [3]IFK Berlin, Berlin, [4]University of Szczecin, Szczecin

Nuclear reactions at low energies can be strongly enhanced due to screening of the Coulomb barrier by the surrounding electrons. This effect was studied for the deuteron fusion reactions taking place in metallic environments as a model for dense astrophysical plasmas. Experimentally determined screening energies corresponding to the reduction of the Coulomb barrier height are much larger than the theoretical predictions. One possible explanation is the excitation of a hypothetical threshold resonance in the 4He nucleus. As the energy dependence of the resonant reaction cross section differs to that of the electron screening effect, one can distinguish between both processes expanding measurements down to the deuteron energies of 1keV. A novel ion accelerator was implemented at the University of Szczecin. Ions are produced by a Dresden ECRIS-2.45M as a high-current, low-Z ion source. The following beam line is designed to work on HV potential for decelerating ions below a kinetic energy of 1keV and combined with a ultra-high vacuum target chamber to reduce target impurities. The ion irradiation facility as well as first experimental results are described and discussed.

Design of New Compact ECR Ion Source for C5+ Production

[1]Masayuki Muramatsu, [2]Keita Fukushima, Taku Suzuki, Katsuyuki Takahashi

[1]NIRS, Chiba-shi, [2]AEC, Chiba

The Heavy Ion Medical Accelerator in Chiba (HIMAC) was constructed as the first medical dedicated heavy ion accelerator facility at National Institute of Radiological Sciences (NIRS). Over 9000 cancer patients have been treated with 140-430 MeV/u carbon beams since 1994. Compact ECR ion source with all permanent magnets, named Kei2, was developed for production of C4+ ions for medical treatment at NIRS. A compact ECR ion source for Gunma University (Gunma University Heavy Ion Medical Center: GHMC), Saga carbon-ion radiotherapy (Saga Heavy Ion Medical Accelerator in Tosu: SAGA HIMAT) and Kanagawa carbon-ion radiotherapy (Ion-beam Radiation Oncology Center in Kanagawa: i-ROCK) facility has been operated for medical use. It is a copy of the Kei2 which was developed by NIRS. In order to reduce operation cost of the injector for next designed carbon ion facility, we start design of new compact ECR ion source for C5+ production. Some dependence (mirror field, microwave power and frequency) were checked for optimal parameter of C5+ production at 18 GHz NIRS-HEC source. Results of experiments and specification of new compact source are described in this presentation.

In-situ Observation of Phase Transformation During Ion Beam Irradiation

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The new method uses reflection high-energy electron diffraction (RHEED) to collect electron diffraction patterns while performing ion irradiation. We use a 50 keV electron beam impinging on a crystalline substrate at grazing incidence. In this presentation, we report on ion irradiations of a single crystal. Irradiations were performed using 100 keV Ar ions at room temperature. Before the single crystal was bombarded with Ar ions, a diffraction pattern with strong diffraction maxima was observed. During the Ar ion irradiation, electron diffraction patterns were collected from the near surface region. The initially strong diffraction patterns gradually faded in intensity until no diffraction spots were visible on the phosphor screen at the fluence of 6~8x1014 ions/cm2. To confirm the presence of the ion-induced amorphization in the near surface region, we used grazing incidence X-ray diffraction and electron diffraction in a transmission electron microscope. Both characterization techniques corroborated the RHEED in-situ measurement, showing the existence of an amorphous region produced by the 100 keV Ar ions.

Intermediate Commissioning Results of the ECR Injector of IFMIF/LIPAc Required to Deliver 70 mA/50 keV H+ and 140 mA/100 keV D+ Beams

[1]Benoit Bolzon, Nicolas Chauvin, Raphael Gobin, Franck Senee, [2]Francis Harrault, [3]Pierre-Yves Beauvais, Hervé Dzitko, [4]Philippe Cara, [5]Juan Knaster, Alvaro Marqueta, Koichi Nishiyama, Yoshikazu Okumura, Giuseppe Pruneri, Francesco Scantamburlo, [6]Michele Comunian, Enrico Fagotti, Andrea Pisent, [7]Luca Bellan, [8]Ryo Ichimiya, Akira Ihara, Atsushi Kasugai, Toshihiko Kitano, Masao Komata, Keitaro Kondo, Keishi Sakamoto, Takahiro Shinya, Masayoshi Sugimoto

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The LIPAc accelerator aims to operate in Rokkasho Fusion Institute a 125 mA/CW deuteron beam at 9 MeV to validate the concept of IFMIF's accelerators that will operate in CW 125 mA at 40 MeV. The 2.45 GHz ECR injector developed by CEA-Saclay is designed to deliver 140 mA/100 keV CW D+ beam with 99% D+ fraction ratio. Its LEBT relies on a dual solenoid focusing system to transport and match the beam into the RFQ. The normalized RMS emittance at the RFQ injection cone is required to be within 0.25π mm·mrad to allow 96% transmission through the 9.81 m long RFQ. An equal perveance H+ beam of half current and half energy as nominal with deuterons is used to avoid activation during commissioning. The injector commissioning at Rokkasho is divided into three phases to characterize the emittance between the solenoids of the LEBT (A1) and just downstream the RFQ injection cone (A2) and the extraction system of the source (A3). Phase A1 has been achieved and phase A2 continues in 2016 in order to reach the required beam parameters and to match the beam into the RFQ. This paper reports the commissioning results of phase A1 and the intermediate ones of phase A2 for H+ and D+ beams.

Development of a Compact High Intensity Ion Source for Light Ions at CEA-Saclay

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During the past 5 years, a R&D program has been launched to improve the beam quality of ECR 2.45 GHz high intensity light ion sources for high power accelerators. The main goal was to minimize the divergence and emittance growth of intense beams due to the space charge as early as possible on the low energy transfer line for a better injection in the second stage of acceleration (RFQ). This has been achieved by reducing the length of the extraction system, to be able to put the first solenoid as close as possible to the extraction aperture. This was performed with the ALISES concept (Advanced Light Ion Source Extraction System). Encouraging results have been obtained in 2012 but with limitations due to Penning discharges in the accelerating column. Taking advantages of ALISES geometry, intensive studies and simulations have been undertaken to eliminate the discharge phenomena. An Innovative and compact source geometry has been found and the source has been fabricated. This new prototype and its performances will be described, as well as magnetic field configuration studies and its influence on the extracted beam.

Footnote

This source developed at Saclay is under patent number FR 15 56871 and this patent is pending

Study of Ion Beam Extraction from an ECRIS: Beam Transverse Coupling and High Order Compensation

Yao Yang

IMP/CAS, Lanzhou

ECR ion source beam quality will deteriorate under the influence of beam transverse coupling and high-order magnetic field aberration. Ion beams from an ECR ion source will experience a descending axial magnetic field at the extraction region, leading to a strong transverse coupling to the extracted beam, with projection emittance growth both in horizontal and vertical and two eigen emittances separation. On the other hand, sextupole field in the ECR and the sextupole component in the analyzing dipole can also degrade the beam quality by resulting in beam distortion. Proper adjusting of the extraction field strength of the ion source and the pre-focusing solenoid field can help to weaken the correlation in the inter-plane phase spaces and reduce the projection emittances. Another approach to improve the beam quality is to compensate for the high-order magnetic fields. This paper presents the property of beam coupling in the transverse phase space by analytical theory and simulations. Some experimental results are also presented and discussed. In addition, a high-order compensation scheme is displayed, whose feasibility has been verified by preliminary tests with SECRAL at IMP.

Progress of an Intense Ion Source and Low Energy Beam Transport System for Jinping Underground Nuclear Astrophysics Experiments

Qi Wu

IMP/CAS, Lanzhou

Jinping Underground Laboratory for Nuclear Astrophysics (JUNA) will take the advantage of the ultra low background and high current accelerator facility to study directly a number of important reactions at stellar energies, such as 25Mg(p, γ)26Al, 19F(p,α)16O, 13C(α,n)16O, and 12C(α,γ)16O reactions. As a key component of high current accelerator facility, the performance of ion source has a very important effect on the beam quality. In order to produce the requested 10 emA H+, 10 emA He+ and 2.5 emA He2+ at the exit of low energy beam transport (LEBT) line, an intense 2.45GHz ECR ion source operated at the maximum energy of 50keV/q will be developed for JUNA project. The ion beam extracted by a 3-electrode extraction system passes through a low energy beam transport system, which is composed of identical solenoids and dipole magnet, into the entrance of acceleration tube (AT). In this paper, the main technique risks, physics design of the ion source and LEBT will be discussed. The progress of the ion source and LEBT, such as mechanical design, magnetic elements, beam diagnostic units of LEBT and development of ion source will be introduced.

Footnote

1. Q. Wu. Z.M. Zhang, L.T. Sun et al. Rev. Sci. Instrum. 85.02A703. (2014) 2. ZHANG Meng, PENG Shi-Xiang; SONG Zhi-Zhong etal. Chinese physics C, 2008 Vol. 32 (S1): 220-222

Agency

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Acceleration of the SILHI Source Beam at CEA/Saclay

Raphael Gobin

CEA/DSM/IRFU

CEA/Saclay is involved in high power proton accelerators for long years. This activity started in the 90's, with the development of the SILHI source which routinely produces tens mA of proton beam. Several industrial difficulties led to a very long IPHI RFQ construction process. The 352 MHz RFQ conditioning is presently in progress. Before the completion of the conditioning in CW mode, tests with pulsed proton beam have been decided. As a consequence, the SILHI source recently produced very short H+ beam pulses in order to allow the first IPHI beam acceleration. Such very short pulses, in the range of few hundred microseconds, allowed analyzing the beam loading of the RFQ cavity as well as conditioning the middle energy diagnostic. This article will focus on the source parameters and beam characteristics in the low energy beam line leading to the best RFQ transmission.

Commissioning of the High Intensity Proton Injector of the Facility for Anti Proton and Ion Research at CEA-Saclay

[1]Olivier Tuske, Nicolas Chauvin, Olivier Delferriere, Yannick Gauthier, Patrick Girardot, Nicolas Misiara, Yannick Sauce, Franck Senee, Claire Simon, [2]Thierry Vacher, [3]Frederic Ameil, Rustam Berezov, Ralph Hollinger

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The Facility for Antiproton and Ion Research (FAIR) located at GSI (Darmstadt) in Germany addresses several fields of physics research within a single installation. One of the contribution of Irfu/SACM at CEA-Saclay to the FAIR linear proton accelerator concerns the development and construction of the ion source and the low energy line. The 2.45 GHz microwave ion source will deliver a 100 mA H+ beam pulsed at 4 Hz with an energy of 95 keV. A low energy beam transport (LEBT) line based on a dual solenoids focusing scheme allows the injection of the proton beam into the radio frequency quadrupole (RFQ) within an acceptance of 0.3π mm.mrad (norm., rms). An electrostatic chopper system located between the second solenoid and the RFQ is used to cut the beam macro pulse from the source to inject 36 μs long beam pulses into the RFQ. This article reports the finalization of the installation of the injector with the detail of dedicated diagnostics, the first beam measurements and gives a planning of the different commissioning phases

Never Run Your ECR Ion Source with Argon in Afterglow for 6 Months!

Detlef Kuchler, Alice Ingrid Michet, Jose Antonio Ferreira Somoza, Ville Toivanen

CERN, Geneva

The fixed target experiment NA61 in the North Area of the SPS at CERN studies phase transitions in strongly interacting matter using the primary beams available from the CERN accelerator complex (protons and lead ions). In order to explore a wider range of energies and densities a primary argon beam was requested for the physics run in 2015. The GTS-LHC ECR ion source was running for many months during 2013 and 2014 to study the source behaviour and to setup the accelerator chain with argon ions. This paper reports the long term effects of the argon operation on the GTS-LHC ion source and the Low Energy Beam Transport (LEBT). Heavy sputtering inside the source caused a degradation of the plasma chamber and metal coating of insulators inside the beam extraction system. Iron ions could be found in the extracted beam. Also the pumping performance of ion getter pumps in the LEBT degraded significantly. Additional preventive maintenance was necessary to be able to run for long periods without risking serious damage to the ion source.

Development and Performance ECR Ion Source for Deuterium Ion Irradiation Facility

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The Fusion Neutronics laboratory at Institute for Plasma Research (IPR), has developed an indigenous compact 2.45 GHz, 2000 Watt, CW Electron Cyclotron Resonance (ECR) based low-energy deuterium ion irradiation facility. This 2.45 GHz ECR ion source is also being used in first phase of proposed 5 MeV radio frequency Quadrupoles Accelerator at IPR. The objective of the ECR ion source is to provide stable CW deuterium ion beam. In first experiment, we measured the deuterium ion beam currents as functions of discharge power and gas flow by using two electrode extraction system followed by Einzel lens,150 keV acceleration system, beam profile monitor and faraday cup. The latest results of measurement of Ion beam current, beam stability and beam profile of deuterium ion beam are presented in this paper. In next stage the existing two electrode extraction system is replaced by three electrodes extraction system. The design and simulation results of the three electrodes system is also presented in this paper.

Status Report on Metallic Beam Production at GANIL/SPIRAL 2

[1]Christophe Barue, Olivier Bajeat, Jean Luc Flambard, Romain Frigot, Pascal Jardin, Nicolas Lechartier, Frederic Lemagnen, Laurent Maunoury, Vincent Metayer, Benoit Osmond, [2]Christophe Peaucelle, [3]Patrick Sole, Thomas Thuillier

[1]GANIL, Caen, [2]IN2P3 IPNL, Villeurbanne, [3]LPSC, Grenoble Cedex

Primary ion beams from metallic elements are routinely produced at GANIL using ECR4 and ECR4M 'room temperature' ECR ion sources. Ionization efficiency measurements, partially presented in the past, are summarized in this report together with updated and new results obtained with Cd, Mo and Ta. Preliminary results for Ni and Ca obtained with the room temperature Phoenix-V2 ECR ion source, under commissioning for SPIRAL 2, are also included. These ionization efficiencies are compared according to the production methods: oven, sputtering, MIVOC, gaseous compounds. The presently SPIRAL 2 heavy ion injector designed for ions Q/A=1/3 shows clear limitations in terms of intensity for metallic ions with mass higher than 60 (intensity <1 pμA). In order to choose the best ion source for a future Q/A=1/6, 1/7 injector, best world results have been compiled for different existing 'room temperature' and superconducting ECR ion sources.

Footnote

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First Experiments on Applying the Gasdynamic ECR Ion Source for Negative Hydrogen Ion Production

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H- ion sources are of great demand for beam injection into cyclotrons and storage rings for example. It was recently demonstrated that gasdynamic ECR ion source based on ECR discharge in a simple mirror trap could be very efficient for proton beam production. It was suggested to use such kind of gasdynamic plasma source as the first stage in a scheme of H- source based on volumetric ion production through dissociative electron attachment. Experiments were performed with 37 GHz / up to 100 kW gyrotron radiation in a dual-trap magnetic system, which consists of two equal simple mirror traps. The first trap was used for plasma production under ECR conditions with parameters listed above. Dense hydrogen plasma flux from the first trap was allowed to flow into the second trap through a perforated plate. This grid was placed between two traps to prevent microwave leakage into the second part to avoid any kind of electron heating there. Plasma confined at the second trap had lower electron temperature enabling the production of H- ions and at the same time preventing their excessive stripping. Results demonstrating H- production using the described approach will be presented.

H+ and D+ High Current Ion Beams Formation from ECR Discharge Sustained by 75 GHz Gyrotron Radiation

[1]Vadim Skalyga, Sergey Golubev, Ivan Izotov, [2]Olli Tarvainen

[1]IAP/RAS, Nizhny Novgorod, [2]JYFL, Jyvaskyla

Operation of modern high power accelerators often requires production of intense beams of hydrogen ions. H+ and D+ beams are utilized or envisioned for use in linear accelerators. Requirements for the brightness of such beams grow together with the demand of accelerator development and arising experimental needs. Investigations at IAP RAS demonstrated a great benefit of gasdynamic ECR ion source in case of H+ and D+ ion beams formation from dense plasma of ECR discharge sustained by powerful gyrotron radiation with 37 GHz frequency and 100 kW power. High power and frequency allow sustaining higher density plasma (up to 2·10·13 cm) in comparison to conventional ECRISs or microwave sources. The low ion temperature, on the order of a few tens eV, is beneficial to produce light ion beams with low emittance. As the next research step at the Institute of Applied Physics (IAP RAS) it was decided to study light ion beam formation from plasma of ECR discharge sustained by 75 GHz / 200 kW gyrotron radiation in open magnetic trap of simple mirror configuration. The latest results of these experiments are discussed. Results on ion beam extraction and emittance measurements are presented.

Agency

Work was performed in frame of federal targeted program R&D in Priority Fields of the S&T Complex of Russia (2014-2020) contract #14.604.21.0065 (unique identification number RFMEFI60414X0065).

Development of Compact H+ ECR Ion Source with Pulse Gas Valve

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Compact H+ ECR Ion Source using permanent magnets is under development. A pulsed gas injection system achieved by a piezo gas valve can reduce the gas load to a vacuum evacuation system. This feature is suitable when the ion source is closely located to an RFQ. Results of a performance test will be presented.

Development of a New Compact 5.8 GHz ECR Ion Source at LPSC

[1]Julien Angot, Laurent Bonny, Josua Jacob, Thierry Lamy, Patrick Sole, Thomas Thuillier, Francesca Villa, [2]Pascal Sortais

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LPSC is developing a new 5.8 GHz compact ion source to produce low charge state ion beams and study their capture in the PHOENIX charge breeder. The source was designed to meet criteria like stability, compactness and low cost. It is mounted on a DN200 iso K flange and is fully under vaccum during operation. The technology brings modularity to ease the development. It can operate up to 60 kV. The plasma is heated by a 100W solid state amplifier. The ECRIS produces 1 mA of H+ beam with 20W of HF and low charge state Argon ions. It was tested under several microwave and magnetic configurations on a test bench equipped with a mass spectrometer and diagnostics. Given its excellent performances, this source is being installed to drive the accelerator based neutron source, GENEPI 2, at LPSC. The developments of the source together with the results of the experiments will be presented. Future plans for this ion source will also be discussed. This work was supported by the ERA-NET NuPNET in the frame of the EMILIE project.

Recent Work of High Intensity Beam Production With LECR4 Ion Source

Cheng Qian, Xing FANG, Junwei Guo, Yu Liu, W. Lu, Liangting Sun, Yao Yang, Youjin Yuan, Xiaohu Zhang, Xuezhen Zhang, Hongwei Zhao

IMP/CAS, Lanzhou

LECR4 (Lanzhou ECR ion source No.4) is a room temperature ion source at IMP with evaporative cooling system. This is a high charge state ECR ion source optimized for the operation at 18 GHz. To produce intense highly charged heavy ion beams, recently two interesting studies have been done. Firstly, the study of the influence of ion source injection pump to the production of highly charged heavy ion beams has made progress. Secondly, to improve the M/Q resolution of the ion beam analyzing system, a dual-solenoid design has been incorporated in the ion source beam line, which turns out to a very effective solution in term of M/Q separation under strong space charge effect. The research on these two issues will be discussed in the paper. The production of very intense highly charged ion beams such as 2.11 emA O6+, 0.62 emA Ar12+ and 0.4 emA Xe20+, 170 euA of Bi28+, and so on will also be presented.

All Permanent Magnet ECRISs for Heavy Ion Medical Machine at IMP

Yun Cao, Jiaqing Li, Baohua Ma, Liangting Sun, Hui Wang, Xuezhen Zhang, Hongwei Zhao

IMP/CAS, Lanzhou

For the Heavy Ion Medical Machine (HIMM) project at IMP, series of all permanent magnet ECR ion sources named as LAPECR3 have been designed, fabricated and tested. Two of them have already been connected to the accelerator injection beam line. These permanent magnet ECR ion sources can routinely produce 100 euA C5+ with the 4rms emittance of ~40 π.mm.mrad for operation. With the stable C5+ beam injection, the dedicated carbon beam accelerator which is composed of a compact cyclotron and a synchrotron ring has been successfully commissioned with C6+ being accelerated to the designed energy and slow extraction. This paper will give the typical performance of such a dedicated permanent magnet ECR ion source for hadron treatment machine. Study on long term stability and beam quality control will be presented.

ECR Ion Sources Operation for HIRFL

Xuezhen Zhang, Xing FANG, Yucheng Feng, Junwei Guo, Wang Lu, Hongyi Ma, Liangting Sun, Yao Yang, Youjin Yuan, Wenhui Zhang, Hongwei Zhao

IMP/CAS, Lanzhou

There are three high-intensity ECR ion sources serving as the pre-injectors for the HIRFL facility at the Institute of Modern Physics in Lanzhou, i.e. the Superconducting ECR ion source with Advanced design in Lanzhou- SECRAL, which started its service in 2007, a room temperature ECR ion source- LECR3 and a permanent ECR ion source. All species of ion beams from Hydrogen to Uranium can be delivered to the injector, a 1.7-meter Sector Focusing Cyclotron-SFC, with these three ion sources. The SECRAL ion source is mainly operated to provide the ion beams of high masses and medium to high charge states, especially metallic ones, such as Kr17+, Xe27+, Ni19+, Bi31+ and U33+ etc. The LECR3 in source is usually running for low and medium charge state ion beams, such as Ca12+, Ar11+, S11+, C4+ and so on. The total service time of these two ion sources are over 67,700 hours from January, 2007 to May, 2016, 26,600 hours of which are attributed to SECRAL and 41,100 to LECER3. The running time of the two ion sources for the production of metallic ion beams achieved to 15,500 hours. This paper will present the operation status of the on-line high charge state ECR ion sources.

Development of a 14GHz Intense Proton Source With Ultra-Low Consumption of Hydrogen Gas

Qi Wu

IMP/CAS, Lanzhou

In order to solve the problem of hydrogen pollution on the RFQ electrodes in the long-term operation, a new intense ECR proton source with a frequency of 14 GHz was designed and mounted at Institute of Modern Physics (IMP). The proton source is to lower the gas consumption and improve the long-term operation stability. This source could be a candidate for the C-ADS project to deal with the problems of high voltage sparking and hydrogen poisoning of RFQ in comparison with a 2.45 GHz proton source. The 14GHz proton source is now in the stage of commissioning. A total beam current of 10 emA has been measured with the extracted voltage of 35 kV and microwave power of 200 W, Which the gas consumption only about 0.5 sccm. It can be continuously stable operation for more than 31 hours in the case of the extraction about 6.5 mA mixed proton beam. In this paper, the structure, the experimental results and the preliminary analysis of the proton source are given.

Footnote

W.H. Zhang1[*], J.W. Guo, X.Fang, Q.Wu, C.Qian, Y.C.Feng, H.Y. Ma, X.Z.Zhang, L.T. Sun, Z.M.Zhang, Z.W.Liu,and H.W.Zhao

A New ECRIS Installation at the Argonne Tandem Linac Accelerator System

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ANL, Argonne, Illinois

For years ATLAS has operated with two ECR ion sources, ECR2 and the ECR charge breeder. In late 2015 the ECR charge breeder was decommissioned to make room for a new Electron Beam Ion Source exclusively for charge breeding low intensity radioactive ion beams. This has left the facility with a single ECR source for virtually all stable ion beam production. An existing all permanent magnet ECRIS, the BIE100[*], will be incorporated at ATLAS to recover operational flexibility. Design, installation plans and anticipated operational parameters are discussed.

Footnote

[*] Dan Z. Xie, Rev. Sci. Instrum. 73, 531 (2002); http://dx.doi.org/10.1063/1.1429320

Agency

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Design, Construction and Commissioning of the New Superconducting Source AISHa

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INFN/LNS, Catania

At INFN-LNS a new superconducting ECRIS named AISHa has been designed with the aim to provide highly charged ion beams with low ripple, high stability and high reproducibility, also fulfilling the needs of hospital installations (e.g. L-He free, easy to use, etc.). It is a hybrid ion source based on a permanent magnet hexapole providing 1.3 T on plasma chamber walls, and four superconducting coils for the axial trapping. The axial magnetic system is very flexible in order to minimize the hot electron component and to optimize the ECR heating by controlling the field gradients and the resonance length. The design of the hexapole aimed to minimize the demagnetization due to SC coils. The magnetic system measurement confirmed the effectiveness of the adopted solutions. Innovative solutions have been also implemented as it concerns the RF system design. It will permit to operate in single/double frequency mode, supported by variable frequency high power klystron generators, thus exploiting at the same time the FTE Frequency Tuning Effect and the Two Frequency Heating. The source has been assembled at the INFN-LNS site and the commissioning phase already started.

Beam Profile Measurements of 12C4+ Ion Beam From SMASHI

Wonil Choo, Soouk Jang, Hyun-Jong You

NFRI, Daejon

A new superconducting 18 GHz electron cyclotron resonance ion source (ECRIS), called SMASHI, has been successfully developed and constructed at the National Fusion Research Institute. A beam slits-Faraday cup (slits-cup) system and a wire scanner are newly developed to evaluate the performance and the characteristics of the 18 GHz ECR SMASHI. The slits-cup system consists of a 2-way beam slits and a high power Faraday cup, so that they can collimate the ion beam and also measure the profile of the ion beam. The wire scanner is a fork type scanner composed of three wires mounted in horizontal(x), vertical(y), and diagonal(s) directions. The wire scanner is inserted into the beam line by an angle of 45 degree, so that three directions of profiles can be simultaneously measured by one passage. In this presentation Upgraded beam charge spectra, their intensities, and beam profiles of 4He, 16O, 40Ar, and 132Xe ions are provided with the slit-Faraday cup system and the wire scanner. Also we present new results of recently produced 4C ion beam.

Plasma Characteristics of a New High Current Metal Ion Source at NFRI

Soouk Jang, Wonil Choo, Hyun-Jong You

NFRI, Daejon

To produce high current metal ion beam, a unique high density 2.45 GHz electron cyclotron resonance (ECR) plasma source has been fabricated and tested at the National Fusion Research Institute (NFRI). The ion source generates high current (~mA) metal ion beam by using a directly coupled waveguide and a permanent magnet embedded Lisitano antenna (PMELA) for sustaining high density plasmas. Previous to the ion beam extraction, we have measured the radial and axial plasma properties (electron density and temperature) by using the Langmuir probe. The probe tip (rp=0.025) was located in the top position (z=8 cm) of PMELA so that the plasma perturbations were minimized and the probe can be operated in weak magnetic field regime. In this presentation, we describe the overall design of the metal ion source and show characteristics of the plasma.

Innovative Mechanical Solutions in the Design of the High Intensity Proton Injector for the European Spallation Source

Giuseppe Gallo, Luciano Allegra, Luigi Celona, Santo Gammino, David Mascali, Lorenzo Neri, Giuseppe Torrisi

INFN/LNS, Catania

The design of the 2.45 GHz, 0.1 T microwave discharge Proton Source for the European Spallation Source (PS-ESS) has required on-purpose developed solutions in order to maximize the performances (proton current and emittance) keeping a very high reliability figure. The mitigation of maintenance issues has been the main guideline through the design phase to maximize the MTBF and minimize the MTTR. The mechanical design has particularly been based on advanced solutions in order to reduce as much as possible the venting time for the plasma chamber, to facilitate the replacement of extraction electrons and/or plasma chamber, and to simplify any after-maintenance alignment procedure. The paper will describe the strategy which has driven the design phase, the solutions adopted to fulfill the project goals and the results of the assembly phase recently concluded at INFN-LNS with successful vacuum tests.

A Study on the Superconducting Magnets for Raon 28 GHz ECR Ion Source

Jeong Il Heo, Sukjin Choi, Yonghwan Kim

IBS, Daejeon

A 28 GHz ECR Ion Source (ECRIS) has been developed through Rare Isotope Science Project(RISP) since 2011. It was made of Low Temperature Superconducting magnet to reach the magnetic field which required by 28 GHz ECR IS. A superconducting magnet was designed and manufactured for producing the ECR IS and a test was conducted. In this paper, the design and fabrication of the superconducting magnet for the ECR IS are presented. The results of experiments could not yet reach the designed current. The experiment is expected to reveal the ideal conditions required to reach the designed current.

Superconducting Magnets Design and Fabrication of 28 GHz Electron Cyclotron Resonance Ion Source for Heavy Ion Accelerator Facility at KBSI

Jonggi Hong, Jungbae Bahng, Seyong Choi, Seong Jun Kim, Byoung Seob Lee, Jung-Woo Ok, Jin Yong Park, Mi-Sook Won, Jang-Hee Yoon

Korea Basic Science Institute, Busan

The 28 GHz electron cyclotron resonance ion source (ECRIS) has been developed to produce a high current heavy ion for the linear accelerator at korea basic science institute (KBSI). Superconducting magnets of 28 GHz ECRIS are characterized by large fields and current densities. However, the design of superconducting magnets will be concerned about achieving a very good magnetic and protecting the magnet in case of mechanical degradation of the coil or the support structure, assembly, cool-down and magnet excitation. In this paper, the electromechanical design of the superconducting magnets for the 28 GHz ECRIS is proposed and verified by using the finite element method (FEM). Also, the design of the inner yokes surrounded by a hexapole is performed to enhance the characteristics of the radial magnetic field.

Analysis and Design of Impedance Matching Unit for Radio Frequency Ion Source

Yahong Xie, Shiyong Chen, Yuqian Chen, Yuming Gu, Chundong Hu, Caichao Jiang

ASIPP, Hefei

The ion source is the key parts of neutral beam injector. A radio frequency (RF) ion source has the merits of long pulse operation, much clean, economical and simple structure, which compare with the arc based ion source. The impedance matching unit is between the RF generator and the plasma load. It used to transmit the RF power to the antenna, and couple the power into the plasma. For the RF ion source for the fusion sciences research, a high voltage transformer need to be installed into the impedance matching unit, so, the RF generator can be works on the ground voltage when the ion source on the high voltage when the ion beam was extracted. The impedance matching unit compares the shunt capacitance (C1) and the series capacitance (C2). An impedance matching unit was analyzed and designed with and without the HV transformer (3:1). The plasma was generated with different type of matching unit. The details will be presented in this paper.

Agency

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Versatile High Power Microwave System for Frequency Tuning of the CAPRICE ECRIS

Fabio Maimone, Markus Endermann, Ralf Lang, Jan Maeder, Patrick Tedit Patchakui, Peter Spaedtke, Klaus Tinschert

GSI, Darmstadt

In the last years it was demonstrated that the variation of the microwave frequency generating the plasma inside ECR Ion Sources (ECRISs) allows to enhance the extracted current of highly charged ions both for gaseous and for metallic elements. In order to use this technique for the performance improvement of the CAPRICE-type ECRIS installed at the High Charge State Injector (HLI) of GSI, the microwave system has been modified. The new arrangement includes - besides the existing Klystron high power amplifier (HPA; max. 2 kW at 14.5 GHz) - two combined Traveling Wave Tube Amplifiers (TWTA) covering a bandwidth of 12.75-14.5 GHz, providing 650 W output power each, which are driven by one or two synthesizer tuners. The new system has been used during the routine operation of the ECRIS for production of different ion beams to be injected into the RFQ of the HLI. A detailed description of the main components of the new microwave system is presented, and the achieved characteristics of ion beam production using different microwave frequencies are described.

Improvement of the Microwave Ion Source at KOMAC

Hyeok-Jung Kwon, Yong-Sub Cho, Dae-Il Kim, Han-Sung Kim, Kye-Ryung Kim, Dong-Hyuk Seo

Korea Atomic Energy Research Institute (KAERI), Gyeongbuk

A test stand of the microwave ion source was developed at Korea Multi-purpose Accelerator Complex (KOMAC). The purpose of the test stand is to improve the microwave ion source which is currently used as the proton injector of the 100-MeV linac. In addition, the microwave ion source test stand will be used to check the possibility as an nitrogen beam ion source for the ion implanters which are under operation at KOMAC as well as to develop helium beam ion source of the 1 MeV/n radio frequency quadrupole (RFQ) for semiconductor irradiation. In this paper, the details of the microwave test stand are presented.

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This work was supported by the Ministry of Science, ICT &Future Planning of the Korean Government.

Precision Measurement of Lifetime of J + = 5/2 + Excited State of 133 Cs via γ − γ Coincidences using NaI(Tl) Scintillators

Innocent Jimmy Lugendo

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Metrological difficulties in measurement of lifetimes of nuclear states have posed controversies in the quest to answer the fundamental question of whether lifetimes of nuclear states are invariable or not. Despite the suggestions that lifetimes can slightly change depending on conditions of the nucleus, any claims of non-constancy of lifetimes as a consequence of deviation from the exponential decay curve must be experimentally verified and stability and precision of the employed instruments and uncertainty of the measurements must be presented. As a step towards studying the variation of lifetime of 5/2 + excited state of 133Cs under some resonance conditions, a system to precisely measure lifetime of this state via gamma-gamma coincidences using multiple scintillators is proposed. Preliminary tests using a pair of NaI(Tl) detectors have been conducted. Uncertainty budget is presented to show the accuracy and precision of the system and hence its legitimacy for measuring the variation of lifetime of the state. A measurement uncertainty of 0.661% was observed, indicating that the possibility of determining the variations of lifetime within 1% of the known value.

Development Progress of Large-Area High-Power Rf Ion Source for High-Energy Beam Applications

Doo-Hee Chang, Sung-Ryul Huh, Seung Ho Jeong, Bong-Ki Jung, Sun-Ho Kim, Tae-Seong Kim, Dong-Won Lee, Min Park

KAERI, Daejon

A large-area high-power radio-frequency (RF) ion source is being developed and tested for high-energy beam applications at the KAERI. The test RF ion source will be applied directly to the neutral beam injectors of experimental fusion devices and the beam accelerator of high-energy neutron sources. The test RF ion source consists of a rectangular quartz-discharge chamber, including an external helical-antenna and an antenna vacuum chamber. The antennal vacuum chamber is applied to suppress the high-voltage breakdown between the antenna coils. RF power can be transferred at up to 50 kW with a variable frequency of 2 MHz through an optimized RF matching system and an HF transformer, which is necessary for ion beam extraction through a high voltage application. An un-cooled slot-type Faraday shield is located inside the discharge chamber of the ion source for short-pulse operation of high-power RF discharge with a gas pressure of ~0.5 Pa. The uniformities of plasma parameter, such as a plasma density and an electron temperature, are measured at the lowest area of the discharge chamber using the water-cooled triple and RF-compensated electrostatic probes under the discharge chamber.

Current Status of the Control System Development for KBSI 28 GHz ECR Ion Source

Seongjun Kim, Seyong Choi, Jonggi Hong, Byoung Seob Lee, Jung-Woo Ok, Jin Yong Park, Jang-Hee Yoon

Korea Basic Science Institute, Busan

The heavy ion accelerator facility of KBSI successfully produced the various heavy ions beam. The real-time control system is required to control and monitor heavy ion accelerator system which composed of the gyrotron, superconducting magnet, LEBT. When the heavy ion particles are produced during ECR plasma ignition, the large amounts of X-rays are produced in the experimental area. We also need to control and maintain the accelerator systems to avoid the radiation damage. Now Control Systems are developed on the Microsoft C# development toolkit and the LABVIEW system together which controls all of information of accelerator operation including high voltage supplying system, vacuum data save/indication, remote adjustment of gas supplying system, superconducting magnet and LEBT magnet control, beam diagnostic system, alarm system, superconducting magnet's current status, temperature distribution in the cryostat chamber, helium re-condensing feedback system monitoring. Next we will convert our system into the EPICS(Experimental Physics and Industrial Control system) based on the Linux OS and report the current development status of EPICS control system for KBSI 28 GHz ECR ion source.

Fabrication Status of the Radio Frequency Quadrupole for the RISP

Bum-Sik Park, Bong Hyuk Choi, In-Seok Hong, Ji-Ho Jang

IBS, Daejeon

The facility for the Rare Isotope Science Project (RISP) will provide a proton to uranium for nuclear physics research. A 4-vane RFQ operating at 81.25MHz was designed and the development is under way to accelerate heavy ion beams from 10 keV/u to 500 keV/u, in CW mode. The RISP RFQ is consisted with 9-sections, 20-slug tuners, and 2-RF couplers. The octagonal shape RFQ is brazed to combine the 8 segment of vanes and quadrants. In this paper, it is described that the fabrication procedure and the RF tuning result.

Agency

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The Continuous Wave RF Test of an 81.25 MHz Normal Conducting Re-Buncher for MEBT in RISP

Hye-Jin Kim, Bong Hyuk Choi, O. Choi, JaeEun Han, Do Yoon Lee, Bum-Sik Park, Ki Taek Son

IBS, Daejeon

The Medium Energy Beam Transport(MEBT) line in RAON heavy-ion accelerator consists of quadrupole magnets and normal-conducting(NC) bunchers. The quarter wave resonator type re-buncher and loop type power coupler were designed and fabricated in last year. The fabricated NC QWR buncher has an resonant frequency of 81.25 MHz, a geometric beta of 0.032, and an effective length of 24 cm. The RF conditioning of the re-buncher and coupler is performed with a low power. The power of RF conditioning is slowly increased while we are paying attention not to exceed a limit of vacuum pressure in the buncher cavity. In this presentation, we show results of the RF testing of the 10 kW normal conducting QWR type re-buncher in MEBT line of RAON.

Recently Test Results for RISP Prototype RFQ

Bong Hyuk Choi, JaeEun Han, In-Seok Hong, Hye-Jin Kim, Do Yoon Lee, Bum-Sik Park

IBS, Daejeon

The RISP main RFQ is designed to accelerate from proton to uranium at 81.25 MHz. The designed RFQ is 4 vane type for CW operation and total length is about 5 m. Required design total RF power is about 100 kW with margin. Prototype RFQ is built the last 600 mm segment to verify the mechanical assembly concept and to define procedures of test for RF power and cooling mechanism. Measured tuning capacity of a tuner and temperature coolant are about 9 kHz/mm and -2.3 kHz/℃, respectively. The presentation shows the results of the test.

Magnet Power Supply at PAL-XFEL

[1]Ki-Hyeon Park, Seong-Hun Jeong, Young-Gyu Jung, Dong Eon Kim, Hong-Gi Lee, Sangbong Lee, Bong-Gi Oh, Hyung Suck Suh, [2]Won-Shik Choi, In Soo Ko

[1]PAL, Pohang, Kyungbuk, [2]POSTECH, Pohang, Kyungbuk

All magnets and magnet power supplies (MPS) for PAL-XFEL had been installed at the XFEL site. The total number of installed MPSs was amounted to 624. Their performance tests were carried out to every MPSs before installation. Now they were under operation mode by the control group. Here MPS design schemes are described in terms of getting high stability, accuracy, repeatability, etc. The embedded functions to make the easy operation or maintenance are also explained. And various test results and some issues generated while operation were mentioned.

Development of S-band Accelerating Components for PAL-XFEL

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Vitzrotech Co., Ltd., Ansan City, Kyunggi-Do

Vitzrotech had participated in design, analysis and fabrication of prototype and development of the accelerator components for the 4th Generation X-Ray Free Electron Laser of Pohang Accelerator Laboratory from 2011 to 2013 and completed fabrication and installation of the components through series production from 2013 to 2015 as well. The accelerator components that Vitzrotech supplied and completed installation are Accelerating columns, Energy doubler, Directional coupler-Single/Dual Type, 3dB Power divider, Power splitter, Power combiner, SiC Dummy load and other Waveguide parts. We, Vitzrotech designed accelerator components through CAD and CST for Electromagnetic. We used Network analyzer for evaluation of the waveguides performance and verified through high power testing system of PAL for Accelerating column, Energy doubler, Directional coupler, 3dB Power divider, SiC Dummy load. Vitzrotech has investigated for the performance of the components which Vitzrotech has fabricated in the meantime and compared with globally required standards. Especially, it showed superior performance of 32dB (Directivity) than the highest levelled one of world best in case of directional coupler.

Magnetic Field Design for 2.45 GHz Negative Hydrogen PMECRIS Chamber using FEM Simulation

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Institute for Plasma Research, Bhat, Gandhinagar

Negative hydrogen ECRIS plasma is confined by NdFeB permanent magnet antenna around cylindrical cavity wall. Measured axial and radial magnetic field is benchmarked with the simulated data. Four axially magnetized ring magnets of remanance flux density of 1.17T is simulated using bounded current ampere's law technique. Gradient of radial and axial magnetic flux density is calculated to estimate lighter ions leaking out of the plasma wall sheath region. The peak values of radial magnetic field gradient between plasma sheath region and cavity outer wall surface increases from 0.1x10·(7) A/m2 to -0.2x10·(7) A/m2 respectively. Axial magnetic field gradient along inner ECR chamber wall increases from -2.1x10·(7) A/m2 to 2.5x10·(7) A/m2 .ECR contour dimensions of 875 Gauss which corresponds to microwave plasma resonating frequency of 2.45GHz is of thickness ~1mm and having major and minor radius of 30mm and 28mm respectively.

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Investigation of Electron Trajectories in an Ion Channel Magnetized Free Electron Laser With a Rectangular Hybrid Wiggler

Masoud Alimohamadi

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A theory of electron trajectories in a rectangular hybrid wiggler magnetized free electron laser with ion channel guiding using particle dynamics is considered. The rectangular hybrid wiggler is planned in a configuration composed of rectangular rings with alternating ferrite and dielectric spacers immersed in a solenoidal magnetic field. The steady-state orbits for a single electron in this configuration are obtained. The rate of change of axial velocity with energy, the characteristic function Φ, is derived and studied numerically.

Recent Beam Dynamics Studies for the SCL Demo of RISP

Hyunchang Jin, In-Seok Hong, Ji-Ho Jang

IBS, Daejeon

The Rare Isotope Science Project (RISP) has been developed the RAON accelerator to accelerate heavy ion and rare isotope beams for the various kinds of science programs. In the RAON accelerator, the beams created by a superconducting electron cyclotron resonance ion source (ECR-IS) will be accelerated by the Radio Frequency Quadrupole (RFQ) after passing through the Low Energy Beam Transport (LEBT) section. These accelerated beams will pass the Medium Energy Beam Transport (MEBT) section for the beam matching and be re-accelerated by the superconducting linac (SCL) for the higher beam energy. Prior to the construction of the RAON accelerator, the performance of each component of LEBT, RFQ, MEBT and SCL should be examined for the efficient mass production. Accordingly, we have been constructing the test facility, which is named SCL demo, since 2015. First beam test with an oxygen beam will be carried out at the end of 2016 and the next test with a bismuth beam will be performed in 2017. In this paper, we will present the beam dynamics studies with the recent lattice design of the SCL demo and describe the simulations results with the oxygen and bismuth beams.

Transverse Four-Dimension Phase-Space Distribution Measured by the Pepper-Pot Type Emittance Meter

[1]Takashi Nagatomo, Osamu Kamigaito, Masayuki Kase, Takahide Nakagawa, [2]Vasilis Tzoganis

[1]RIKEN Nishina Center, Wako, [2]Cockcroft Institute, Warrington, Cheshire

Emittance of the highly charged heavy ion beam extracted from ECR ion source should be matched with the acceptance of the following LEBT and accelerator to improve transport efficiency. Observation of the transverse four-dimension phase-space distribution provides quantitative and essential information to improve the matching. We have developed an on-line pepper-pot-type emittance meter, which is a suitable device to obtain the 4-D phase-space distribution from an image of beamlets passing through the well-aligned pinholes. The emittance meter consists of a copper plate with a pinhole array, which is movable along the beam axis, and an imaging screen (P46) with a MCP. We optimized the analysis procedure to obtain the distribution so that the elapsed time of the analysis was shortened as 0.5 seconds, and which was enough short for on-line measurements. We will discuss the quality of the obtained 4-D distribution by comparing it with the one obtained from a simulation. Further, we will also discuss how the fringing field of the mirror field Eext of ECRIS and gas pressure in the extraction chamber affect the 4-D distribution to establish a method of the emittance matching.

Effect of Repair for Plasma Chamber System in KBSI ECR Ion Source

Jin Yong Park, Jungbae Bahng, Seyong Choi, Jonggi Hong, Seong Jun Kim, Byoung Seob Lee, Jung-Woo Ok, Mi-Sook Won, Jang-Hee Yoon

Korea Basic Science Institute, Busan

The 28 GHz superconducting electron cyclotron resonance (ECR) ion source has been developed to produce a high current heavy ion for the linear accelerator at KBSI (Korea Basic Science Institute). The aim of this study was to generate fast neutrons with the proton target by p(Li,n)Be reaction. In last year, we presented the first results of ion beam extraction in ICIS2015. In this year, ECR ion source was overhaul for improve performance. We changed the extraction system and bias disk on plasma chamber. The paper describes the effect of repair for plasma chamber system. And we will announce results of ion beam extraction.

LEBT System for RISP

In-Seok Hong

IBS, Daejeon

RISP proposed a low energy beam transport for matching heavy ion beams between a 28GHz electron cyclotron resonance ion source (ECRIS) and radiofrequency quadrupole (RFQ). We considered triplets and doublets of the electrostatic quadrupoles for beam focusing and dipole magnets for acromatic beam transport. Multi harmonic buncher and velocity equalizer for spontaneously acceleration uranium 33+ and 34+ ion beam was considered and slow chopper will be used for pulse ion beam commissioning of the RFQ.

Footnote

This work was supported by RISP which is funded by the Ministry of Science, ICT and future Planning (MSIP) and National Research Foundation (NRF) of Korea.

Emittance Measurement for a Low Energy Heavy Ion Beam

[1]Deok-Min Kim, [2]In-Seok Hong

[1]Korea University, Seoul, [2]IBS, Daejeon

Allison scanner was proposed to measure the ion beam emittance at the low energy beam transport (LEBT). Beam emittance measurement of the LEBT is needed to satisfy the acceptance of the radio frequency quadrupole for rare isotope science project (RISP). To establish a process to minimize a noise is necessary for accurate emittance measurement. To do this, we considered reducing noise data using Self-Consistent Un-Biased Elliptical-Exclusion (SCUBEE). Allison scanner and the data gain system for the measurement was implemented with LabVIEW program and installed in the LEBT section. Preliminary emittance results from the Electron Cyclotron Resonance Ion Source will be presented.

Footnote

[*] emittance, [*] scubee

The Design of Computer Data Processing System for RF Ion Source on NbI

[1]Xiaodan Zhang, [2]Chundong Hu, Caichao Jiang, Yahong Xie, Yuanzhe Zhao

[1]Qinghai University, Qinghai Province, [2]ASIPP, Hefei

The Neutral Beam Injection (NBI) heating as one of the most efficient and significant auxiliary heating way is widely used on the international fusion devices. As the key source components of NBI, the Radio Frequency Ion Source (RF ion source) is gradually applied for offering the source plasma with the advantages of relatively easy to control and maintain. In this paper, the design of computer data processing system including data acquisition, processing and control for RF ion source is presented. The RF signals to be measured are acquired by the data acquisition device and processed by the lossless LZO algorithm, then they are transferred to the data server. The corresponding interfaces are offered by the computer data processing system for data resolution, inquire and analysis. The key technology including the multithreading technology, TCP protocol with C/S mode and LZO algorithm are used on the implementation of software programming. This design is very practical application significance for the RF experiments.

Fast Sputtering Measurements of Uranium with an 18 GHz ECRIS and Ion Density Simulations with a Kinetic Global Model (KGM)

[1]Derek Elwin Neben, Jesse Fogleman, Alfonse N. Pham, Shane Renteria, Larry Tobos, [2]Guillaume Machicoane, [3]Daniela Leitner, [4]Guy Parsey, [5]John Verboncoeur

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Existing heavy ion facilities such as the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University rely on Electron Cyclotron Resonance (ECR) ion sources as injectors of highly charged ion beams. Long ion confinement times are necessary to produce dense populations of highly charged ions because of steadily decreasing ionization cross sections with increasing charge state. To further understand ion extraction and confinement we are using a fast sputtering technique first developed at Argonne National Laboratory [1] to introduce a small amount of uranium metal into the plasma at a well-defined time. In addition we utilize an axial x-ray apparatus [2] to characterize the hot electron plasma population via its bremsstrahlung emission. We plan to compare electron energy and uranium intensity decay curves on the Superconducting Source for Ions (SuSI) with the goal of probing the relation between ion confinement times and high energy electrons. To understand the role of ionization and recombination reactions on intensity we employ a Kinetic Global Model (KGM) [3]. Simulations of SuSI using KGM are presented in combination with x-ray and sputtering measurements.

Footnote

* R. Vondrasek, et. Al., Rev. Sci. Instrum. 73, 548 (2002)

** T. Ropponen, et. Al., Proceedings of ECRIS2010, Grenoble France (2010)

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Measurement of Microwave Frequencies Emitted by Instabilities of ECRIS Plasma with Waveguide Filters and Microwave Sensitive Diodes

[1]Joose Orpana, Taneli Kalvas, Hannu Koivisto, Risto Juhani Kronholm, Janne Laulainen, Olli Tarvainen, [2]Ivan Izotov, Dmitriy Mansfeld, Vadim Skalyga

[1]JYFL, Jyvaskyla, [2]IAP/RAS, Nizhny Novgorod

Periodic emission of strong microwave bursts at certain frequencies is a characteristic feature of kinetic instabilities in ECRIS plasmas. Precise measurement of the temporally evolving microwave frequency spectra requires a high bandwidth oscilloscope, which can make the experiments prohibitively expensive to conduct. An alternative low-cost method to study the microwave emission in narrow frequency bands is to apply high-pass waveguide filters and microwave sensitive diodes. The microwave emission from the plasma of the JYFL 14 GHz ECRIS has been studied with both methods. The results of the experiments are compared and their interpretation is discussed. It is demonstrated that the method based on filters and diodes can provide useful information about the microwave emission spectra induced by electron cyclotron instabilities.

Investigation of 2.45 GHz Microwave Radiated Argon Plasma under Magnetized Condition

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Institute for Plasma Research, Bhat, Gandhinagar

Compact microwave discharged ECRIS is one of the most popular devices for space propulsion and material processing .This work models microwave plasma coupling in 2D axis symmetric and investigates plasma parameters and modified electric field in plasma environment. A microwave field of the order of 1.3 x10・(5) V/m is obtained at the center of plasma chamber cavity for an input microwave power of 500W.Microwave radiated plasma has a maximum density of 9.04 x10・(16) / m3 after some microwave periods (0.01s).The steady state peak electron temperature is around 3eV under 1 mbar pressure of argon gas. Most of power deposition takes place on the ECR surface which is the 875G contour resonating with the electron frequency. Steady state argon plasma results show that beyond critical plasma density of 7.4x1016 / m3 most of the microwave power is deposited at the plasma edge.

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Kinetic Instabilities in ECR Plasmas Under Conditions of Two-Frequency Heating

[1]Vadim Skalyga, Ivan Izotov, [2]Dmitriy Mansfeld, [3]Taneli Kalvas, Hannu Koivisto, Jani Komppula, Risto Juhani Kronholm, Janne Laulainen, Olli Tarvainen

[1]IAP/RAS, Nizhny Novgorod; UNN, Nizhny Novgorod, [2]IAP/RAS, Nizhny Novgorod, [3]JYFL, Jyvaskyla

Multiple frequency heating is one of effective techniques to improve the performance of ECR ion sources. It was demonstrated that periodic ion beam current oscillations in ECRIS at high heating power and low magnetic field gradient are associated with kinetic plasma instabilities. Recently it was proven that one of the main features of multiple frequency heating is a stabilizing effect, namely the suppression of electron cyclotron instability in ECRIS plasmas. Due to this it is possible to run the ion source in stable mode using higher microwave power, thus obtaining better ion beam parameters. Unfortunately, even with use of such technique the plasma becomes unstable at some threshold level. The work is devoted to experimental investigations of the peculiarities of cyclotron instability in the case of two-frequency heating. It was found out that the microwave emission spectrum of the plasma related to the instability is affected by the ratio of injected power shared between the frequencies. The frequency with higher power was found to determine the microwave emission spectrum, being correlated with the one obtained in single frequency operation with the given injected frequency.

Design of a Langmuir Probe for Low-Pressure High-Density Plasma Diagnostics

Sung-Ryul Huh, Dae-Sik Chang, Chul-Kew Hwang, Jeong-Tae Jin, Seok-Kwan Lee, Byung-Hoon Oh

KAERI, Daejon

The Langmuir probe is one of the most common and simplest plasma diagnostics to measure plasma parameters. However, unlike its simple structure, the delicate design and difficult interpretation are required for obtaining reliable current voltage characteristics and then acceptable parameters. Furthermore, such low-pressure high-density plasmas with magnetic fields as magnetized microwave plasmas and electron cyclotron resonance (ECR) plasmas can cause probe tip melting and make it even harder for the analysis. In this work, a Langmuir probe and an instrument system have been designed for characterization of KAERI ECR ion source during long pulse operation. Validity conditions associated with probe size and magnetized plasma are taken into account and also thermal analysis of probe for predicting probe melting is carried out. The estimated probe temperature has been calculated considering a balance between radiative cooling and probe heating by ions and electrons. In the presentation, the analysis results and design of the probe for ECR plasmas are presented and discussed in detail.

Heating of Microwave Plasmas to Further Increase Their Densities

Dr. Gerard Oscar Rodrigues, Rajeev Ahuja, Dinakar Kanjilal, Narender Kumar, Yadhuvansh Mathur, Unnam Koteshwar Rao

IUAC, New Delhi

In our earlier work with 2.45 GHz microwave ion sources, we have measured x-ray bremstraahlung as a function of the RF power, gas pressure and magnetic field and it was observed that relatively higher energy x-rays were evolved due to launching of the EM wave in the under-resonance region, which is generally not explainable by normal ECR heating mechanism. The extra-ordinary wave, X, whose wave vector k and electric field vector, E, which are perpendicular to B when launched in under-resonance region facilitates the X-B mode conversion, where the B wave is called as the Bernstein wave. Signatures of Bernstein wave generation are the conversion from an underdense to an overdense plasma and observation of high energy electrons. In the newly installed 2.45 GHz microwave ion source based facility, experiments have been undertaken to study these kind of plasmas through x-ray measurements.

Thursday

September 01, 2016

Recent production of intense high charge ion beams with VENUS

[1]Daniel Xie, Janilee Yvette Benitez, Claude M Lyneis, Damon Todd, [2]Wang Lu

[1]LBNL, Berkeley, California, [2]IMP/CAS, Lanzhou

Several modifications have been made to the VENUS to enhance its performance at high microwave power and bring its performance closer to the levels predicted by scaling laws for 28 GHz operation. Two of these modifications improved its tolerance for operation at microwave power up to 10 kW. The cooling scheme on the plasma wall was improved to eliminate damage caused by localized electron heating. Similarly the extraction electrode was redesigned to transport away the electron heating more effectively. The third modification reduced the waveguide diameter, which launches the 28 GHz power into the plasma chamber. The source now runs efficiently at 10 kW of injected power with a more favorable magnetic field configuration. The production of intense highly charged ion beams with VENUS has been substantially enhanced. It has produced a number of record CW beams: 4.5 emA of O6+, 0.40 emA of Ar16+ and 0.06 emA of Ar17+ and for the first time the VENUS has produced more than 1 emA of Ar12+ and O7+. Source tuning is currently underway to explore the potential of VENUS and the overall improved source performance will be presented.

Development Status of 28 GHz Superconducting ECR Ion Source for the KBSI Accelerator

Seyong Choi, Jungbae Bahng, Jonggi Hong, Seong Jun Kim, Byoung Seob Lee, Jung-Woo Ok, Jin Yong Park, Mi-Sook Won, Jang-Hee Yoon

Korea Basic Science Institute, Busan

A 28 GHz superconducting ECR ion source has been developed as an injector apparatus for heavy ion accelerator of KBSI. The final goal of accelerated ion beam was aimed to generate fast neutrons with the proton target by p(Li,n)Be reaction under inverse kinematics scheme. In 2014, most of parts for ECR ion source was developed and assembled. We have made the first ECR plasma generation and ion beam extraction, which was reported in 2014. For optimizing the operational issues of ECR ion source, we carried out various experiments with respect to several species of ion beam. Recently, we have encountered to maintain the cryogenics for superconudcting magnet due to the operating time of cryocooler and compressor. We modified three parts during maintanance: (1) installation of iron pole in the hexapole magnet to enhance the radial magnetic field, (2)new recondensation device to increase the efficiency of the liquid helium liquification, (3)bias disk modification for better beam extraction. We will present the current status and further modificaion effect on the 28 GHz superconducting ECR ion source of KBSI.