ICIS2023 - 20th International Conference on Ion Sources September 17-22, 2023

Sunday, 17 September 2023 - Friday, 22 September 2023

Victoria Conference Centre

Book of Abstracts

Contents

Monday / 87

The Development of Pepper-Pot Emittance Monitor in Gunma University

Authors: Hiroki Kanda[1]; Keijiro Takeda[1]; Kohei Hattori[2]; Masao Nakao[3]; Masatoshi Itoh[2]; Mitsuhiro Fukuda[1]; Nobumasa Miyawaki[4]; Satoshi Adachi[2]; Satoshi Kurashima[4]; Takafumi Hara[1]; Takashi Wakui[4]; Tetsuhiko Yorita[1]; Tsun Him Chong[1]; Tsutomu Shinozuka[2]; Yasuyuki Morita[1]; Yohei Matsuda[5]; Yuusuke Yasuda[1]

[1] *Osaka University*

[2] *Tohoku University*

[3] *Gunma University*

[4] *National Institutes for Quantum Science and Technology*

[5] *Konan University*

Corresponding Author: nakaom@gunma-u.ac.jp

In Gunma University Heavy Ion Medical Center, carbon ion therapy has been performed since 2010. The carbon ion (C⁴⁺) for the injector is made with KeiGM ion source. There is another KeiGM ion source in Gunma University for the both the purpose of a reserve machine and for research and development. A wire-slit type emittance monitor has already been installed as a beam diagnostic device, and a pepper-pot emittance monitor (PPEM) was newly installed. PPEM has the advantage of shortening the measurement time. The emittance of He, C, Ne, and other ions was measured using PPEM, changing RF frequency, power, and gas flow rate to find the optimum parameters. Emittance variation with charge number of the ions were also measured.

Funding Agency:

Gunma University

Email Address:

nakaom@gunma-u.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 56

Generation of Plasmas from Multiple Targets by Laser Ion Source for TIARA Ion Implanter

Author: Keisuke Yamada[1]

Co-authors: Hirotsugu Kashiwagi [2]; Seiji Hosoya [1]

[1] *National Institutes for Quantum Science and Technology*

[2] *QST*

Corresponding Author: kashiwagi.hirotsugu@qst.go.jp

The 400 kV ion implanter in Takasaki Ion Accelerators for Advanced Radiation Application (TIARA) is mainly used for research and developments in the field of material science, and it is necessary to produce beams of various ion species. Therefore, we are developing a laser ion source for an ion implanter on an offline test bench to produce beams of various ion species and to switch quickly between the ion species to be produced. The laser ion source is possible to generate plasma directly

from any solid sample by irradiating a focused pulsed laser beam onto a solid target sample, and by attaching multiple target samples of different materials to a target stage, it is possible to switch the ion species produced by simply moving the stage. In this presentation, we report the results of plasma generation experiments using multiple targets with different mass numbers.

Funding Agency:

Email Address:

yamada.keisuke@qst.go.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Hirotsugu Kashiwagi

Monday / **2**

In Situ Effective Pumping Speed Measurements as a Tool for Non-Evaporable Getter Activation and Saturation Monitoring

Author: Sergey Kondrashev[1]

Co-authors: Edward Beebe ; Benjamin Coe

[1] *Brookhaven National Laboratory*

Corresponding Author: skondrashev@bnl.gov

We have developed method of in situ effective pumping speed measurements based on injecting of small amount of gas into a volume of a vacuum chamber and subsequent recording of pressure burst decay time dynamics using Residual Gas Analyzer (RGA). Within the certain range, the pressure burst caused by injected gas will drop exponentially in time and exponential coefficient of such pressure decay is proportional to total effective pumping speed of all vacuum pumps acting on vacuum chamber volume. Thus, effective pumping speed can be extracted from the dependence of injected gas specie pressure vs time recorded by RGA. Non-Evaporable Getters (NEGs) are widely used for multiple ultra and extremely high vacuum devices and applications over the last several decades. Moreover, possible NEG applications were recently expanded into vacuum devices with relatively high-pressure levels, up to 10E-7 Torr, by invention of, so called, high capacity ZAO NEG which can be operated at elevated temperatures. The intrinsic property of all NEG-based vacuum pumps is the reduction of their pumping speed, called NEG saturation, after certain period of operation. Typical time interval for such process can span from about a month and up to a few years depending on NEG type, vacuum level of NEG pump operation, and residual gas content. After that, NEG pump will require to undergo re-activation cycle to restore pumping speed back close to initial value. For many applications it is almost impossible to realize what is the current pumping speed of NEG pump is and when the pump should be re-activated. Developed method of in situ effective pumping speed measurements can be used as a tool for NEG-based pumps activation and saturation monitoring. Application of such approach to monitor pumping status of NEG pumps was utilized at Extended EBIS which is recently developed for Relativistic Heavy Ion Collider (RHIC) and future Electron Ion Collider (EIC). The results obtained are presented and discussed.

Funding Agency:

Brookhaven Science Associates, LLC

Email Address:

skondrashev@bnl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 12

The Variation of the Beam According to the RF Power Frequency, Vacuum, Gas Mixing Ratio of the 14.5 GHz ECRIS

Author: Jeongil Heo[1]

Co-authors: Hyungjin Kim [1]; Inseok Hong [1]

[1] *Institute for Basic Science*

Corresponding Author: jiheo@ibs.re.kr

RAON(Rare isotope Accelerator complex for ON-line experiments) is a heavy ion accelerator that is being built in Daejeon, South Korea. RAON plans to operate a 28 GHz ECRIS(Electron Cyclotron Resonance Ion Source) with fully superconducting magnet and a 14.5 GHz ECR ion source with fully permanent magnet. The 14.5 GHz ECRIS was manufactured by PANTECHNIK and installed in our beam line in September 2020. Initial beam conditioning of the RAON accelerator will be performed using 14.5 GHz ECRIS. Conditioning using Argon, Oxygen, and Neon beams is planned to be performed for initial conditioning of the LEBT, RFQ, MEBT, SCL3, and KoBRA sections. Before conditioning each section, an experiment was performed on each beam at a 14.5 GHz ECR ion source through changes in RF power, frequency, vacuum, and gas mixing ratio. Beam current and emittance according to each parameter were measured and compared.

Funding Agency:

Email Address:

jiheo@ibs.re.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 134

Progress of the Laser Ion Source Upgrade for RHIC and NSRL Program at BNL

Authors: Benjamin Coe[None]; Chong-Jer Liaw[1]; Edward Beebe[None]; Masahiro Okamura[1]; Sergey Kondrashev[1]; Shunsuke Ikeda[2]; Takeshi Kanesue[1]

[1] *Brookhaven National Laboratory*

[2] *BROOKHAVEN NATIONAL LABORATORY*

Corresponding Author: tkanesue@bnl.gov

The LION2 is being constructed to replace the existing LION, which is a laser ablation ion source to provide various species of heavy ions for Relativistic Heavy Ion Collider (RHIC) and NASA Space

Radiation Laboratory (NSRL) at BNL. LION and LION2 provide singly charged heavy ions, which are transported and then trapped by an electron beam ion source, so called Extended-EBIS, for further ionization. LION2 is designed for better beam performance and reliability. This paper will present the design and construction status of the LION2.

Funding Agency:

Email Address:

tkanesue@bnl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 35

Multi-Filament Ion Source for Uniform Ion Beam Generation

Authors: Jungbae Bahng[1]; Yuncheol Kim[2]

Co-authors: Bong-Hyuk Choi [3]; Jinsung Yu [3]; Seung-Hee Nam [3]

[1] *Kangwon National University Hospital*

[2] *Korea University*

[3] *Pohang accelerator laboratory*

Corresponding Author: bahngjb@gmail.com

Ion beams are employed in various fields such as semiconductor manufacturing, surface modification, and material science. The uniformity of ion beams is crucial in many applications, but conventional ion sources that use a single filament often limit the uniformity and intensity of the ion beam. This paper presents a study that aims to optimize a multi-filament ion source to enhance the uniformity of ion beams. The study includes a detailed explanation of the ion source components and design, methods for measuring ion beam uniformity, experimental design, results, and analysis, discussions and conclusions, and suggestions for future research directions. The experimental results demonstrate that the use of a multi-filament ion source improves ion beam uniformity compared to a single-filament ion source. An optimal design for the ion source components and new approaches for improving ion beam uniformity are described. The study's results provide important information for improving ion beam uniformity and offer a technical basis for providing high-quality products and services in various industries.

Funding Agency:

Grant from South Korea

Email Address:

bahngjb@gmail.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Jungbae Bahng

Monday / 26

Development of Cold Cathode PIG with Floating Reflector

Authors: Nagaaki Kamiguchi[1]; Nobuaki Takahashi[1]

[1] *Sumitomo Heavy Industries, Ltd.*

Corresponding Author: nagaaki.kamiguchi@shi-g.com

The cold cathode type PIG ion sources were often employed for compact cyclotrons with high magnetic field as internal source. The ion sources are preferable to conduct maintenance easily without vacuum break of cyclotrons to avoid long downtime. In this study, cold cathode PIG H+ ion source was developed with extraction mechanism along to main magnetic field direction for the spiral sector AVF cyclotrons which were difficult to be accessed on median plane.
Ordinary cold cathode type PIG ion sources consist of a pair of cathodes and a cylinder shape anode. The bias voltage to generate discharge is loaded to both cathodes. But in this study the bias voltage was loaded to only single side of cathodes and another side of cathode was floating from the ground so that the ion source was made small as the bias line to another side cathode was omitted. The potential level of floating cathode was equipotential through plasma. The discharge characteristic and extraction beam current were measured with this developed ion source for performance evaluation. The extraction current with DC beam was 3 μA maximum and it is relatively low output when compared among other cold cathode PIG ion sources. The reason of low current was that insulation break-down occurred before the discharge transferred to arc mode so that enough ionized current could not be obtained. The bias voltage could not be loaded over 2.2 kV stably. Besides, the cooling pathway performs too much to heat up the cathode by ionized current of glow discharge and the temperature did not raise so hot that thermal electron emission starts. Some modifications are needed to achieve H+ 300μA output.

Funding Agency:

Email Address:

nagaaki.kamiguchi@shi-g.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 40

Recent Progress of the Movable Vlasov Launcher at Institute of Modern Physics

Author: Xinyu Wang[1]

Co-authors: Jibo Li [1]; Jindou Ma [1]; Liangting Sun [1]; Xuezhen Zhang [1]; Yucheng Feng [2]; Zonghu Zhang [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Corresponding Author: wangxinyu2020@impcas.ac.cn

To investigate the coupling efficiency between microwave with frequency above 20 GHz and plasma in an electron cyclotron resonance (ECR) ion source, a movable Vlasov launcher has been developed at Institute of Modern Physics (IMP). The beam intensity and axial bremsstrahlung were simultaneously measured with SECRAL-II (Superconducting ECR ion source with Advanced design in Lanzhou No. II) ion source at different positions of the Vlasov launcher. The experimental results clearly demonstrate that the position of the Vlasov launcher has significant impact on the beam intensity as well as charge state distribution (CSD), which indicates a variation of the produced beam intensity by a factor of 5 when the launcher is moved along the off-axis position. Meanwhile, it is shown that the bremsstrahlung spectrum counts within an energy range of 1-20 keV are particularly sensitive to the position of the Vlasov launcher, which implies that changing the position of the Vlasov launcher will modulate the electron energy distribution function (EEDF) and promising microwave coupling efficiency with regards to highly charged ion beam production could be achieved at the optimum position where more warm electrons are produced. This study will have a fundamental impact to the microwave coupling scheme of the third generation ECR ion sources and thus give a new insight into the design of microwave coupling scheme for the fourth generation ECR ion sources.

Funding Agency:

Email Address:

wangxinyu2020@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 47

Towards Tests of a Combined RFQ Cooler with Axial Magnetic Field

Author: Alessio Galatà[1]

Co-authors: Alberto Ruzzon [2]; Francesco Cavaliere [3]; Giancarlo Maero [3]; Marco Cavenago [2]; Mario Maggiore [2]; Massimiliano Romé [3]; Michele Comunian [2]

[1] *INFN-Legnaro National Laboratories*

[2] *INFN-LNL*

[3] *Dip. Fisica Univ. Studi MI*

Corresponding Author: alessio.galata@lnl.infn.it

In mass spectrometry of exotic ion beams a cold ion beam is required, to achieve a mass resolution goal of 1:20000, which is a typical requirement for nuclear physics studies of isobaric ions. In the radiofrequency (rf) quadrupole cooler (RFQC), which is a kind of linear ion trap, rf fields and ion-gas collisions may give considerable increase or decrease of the beam transverse emittance and its energy spread, depending on a delicate tuning of heating and cooling effects; an equivalent pseudo equilibrium temperature may introduced, dominated by ion beam energy and balance of collisions and confinement forces (not by equipment temperature as discussed, also with comparison to cryogenic traps). An extra confinement may be added by a solenoidal magnetic field, as in the RFQC prototype installed in the Eltrap machine, which are briefly described. This provides a versatile test bench (separated from a closed accelerator installation) for detailed studies of cooling dynamics in several regimes (ballistic or diffusive), and of several RFQC technical optimizations, including differential gas pumping and rf voltage distribution to RFQC electrodes. First commissioning of the gas pumping system is reported. Also characterization of the rf matching box and electrode multiplexer systems are described.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 49

The Resonance Ionization Laser Ion Source for Radioactive Ion Beams at CERN-ISOLDE: Expanding Limits of Selectivity, Intensity, and Nuclear Structure Laser Spectroscopy

Author: Reinhard Heinke[1]

Co-authors: Asar AH Jaradat [1]; Bruce Marsh [1]; Cyril Bernerd [1]; Daniele Scarpa [2]; Dominik Studer [3]; Emilio Mariotti [4]; Felix Weber [5]; Isabel Hendriks [1]; Katerina Chrysalidis [1]; Kim Rijpstra [6]; Klaus Wendt [5]; Lisa Centofante ; Magdalena Kaja [5]; Mattia Manzolaro [2]; Mia Au [1]; Omorjit Singh Khwairakpam [7]; Ralitsa Mancheva [8]; Sebastian Raeder [3]; Sebastian Rothe [1]; Sophie Hurier [9]; Thomas Cocolios [10]; Tom Kieck [3]; Valentin Fedosseev [1]

[1] *CERN*

[2] *INFN*

[3] *GSI Darmstadt*

[4] *Università degli Studi di Siena*

[5] *JGU Mainz*

[6] *SCK CEN*

[7] *INFN-LNL*

[8] *CERN, KU Leuven*

[9] *SCK CEN & KULeuven*

[10] *KU Leuven*

Corresponding Author: reinhard.heinke@cern.ch

The Resonance Ionization Laser Ion Source RILIS, employing laser radiation in a hot cavity ion source diretly coupled to an isotope production target, has become a principal method for provision of radioactive ion beams at facilities world-wide, such as at CERN-ISOLDE or -MEDICIS. Stepwise resonant excitation and subsequent detachment of an electron via element-unique atomic shell transitions allows for highly efficient and chemically selective provision of the desired nuclide in the mass-separated ion beam.

Alongside a summary of its use in standard operation, we report on developments regarding key aspects for specific applications:
The specialized high selectivity RILIS variant LIST, employing spatial separation of the hot cavity from a dedicated laser ionization volume in a directly adjacent RF quadrupole unit, has been augmented with perpendicular laser beam access. It allows for reduction of the effective Doppler broadening in interaction with the hot atom vapor, thus enhancing spectral resolution from linedwidths in the GHz regime down to a few 100 MHz. This novel unit was employed to perform nuclear structure investigations on neutron-rich actinium isotopes. The results outline its potential for further high-resolution applications, and greatly enhanced capabilities for isomer-selective ionization of nuclides for experiments demanding highest ion beam purity.
On a parallel development route, various facilities undertake joint efforts to maintain the high efficiency of RILIS sources also under exceptionally high ion load circumstances. These occur, e.g., during the time-critical extraction of radioisotopes from pre-irradiated targets in off-line operation mode, as part of the European medical radionuclide provision program PRISMAP. Systematic investigations of the required plasma ion confinement are carried out by combination of simulation models and dedicated analysis experiments on different laser ion source models employed by the network participants.

Funding Agency:

Email Address:

reinhard.heinke@cern.ch

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 50

Production of Neative Ion Beams through Charge Tranfer between Negative Hydrogen Ion Beams and Non-metallic Gases

Author: Andrew Paul[1]

Co-authors: Stephane Melanson [2]; Tobias Junginger [3]; Morgan Dehnel [2]

[1] *D-Pace Inc.*

[2] *D-Pace*

[3] *TRIUMF*

Corresponding Author: andrew.paul@d-pace.com

Negative ion beams are used for a wide range of applications when tandem accelerators are leveraged. Research areas which utilize tandems include nuclear structure, environmental studies, and materials characterization. Tandem accelerators are also used for industrial applications such as ion implantation in semiconductor devices, as well as for medical applications such as Boron Neutron Capture Therapy. A common method for producing certain negative ions is a double-charge exchange ion source which employs an upstream ion source to produce a beam of positive (+1) ions in the keV energy range which are incident on a vacuum region with alkali metal or alkaline-earth metal vapour. The incident positive beam experiences a double electron capture from the metallic vapour such that an energetic negative (1−) ion beam emerges. The use of metallic vapours causes contamination of vacuum surfaces which can result in electrical shorts and arcing, and difficult maintenance with such combustible materials. Doupé and Litherland have demonstrated that negative ion beams can be created by electron transfer from a negative beam (Cu^-) incident on a neutral, non-metallic vapour (ICl). The goal of this paper is to follow the example of Doupé and Litherland and create negative ion beams by impinging an H^- beam from D-Pace's TRIUMF licenced ion source (10-30 keV, 0-15 mA) onto non-metallic vapours (He, H2, O2, CO2) in order to avoid contamination and to explore new methods of negative ion production through charge exchange. The charge exchange will take place in an in-vacuo electrostatic accelerator which will be used to extract any newly created negative ions that could be formed (He^-, H^-, $H2^-$, O^-, $O2^-$, C^-, CO^-, CO¬2^- etc). The newly created negative ions will be separate from the incident H^- beam using a 1:500 resolution mass spectrometer system. Ultimately, the conversion rates from the incident H^- beams will be reported as measured.

Funding Agency:

MITACS

Email Address:

andrew.paul@d-pace.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 63

Design and commissioning of a versatile surface ion source

Author: Suresh Saminathan[1]

Co-authors: David Wager [1]; Brian Minato [1]; Marco Lovera [1]; Tomislav Hruskovec [1]; Julie Cho [1]; Paul Dirksen [1]; Friedhelm Ames [1]; Marco Marchetto [1]; Rick Baartman [1]; Keerthi Jayamanna [1]; Tiffany Angus [1]; Brad Schultz [1]; Christopher Charles [1]

[1] *TRIUMF*

Corresponding Author: suresh@triumf.ca

A compact surface ion source was designed and commissioned for commissioning the low energy beam facilities of ARIEL facility at TRIUMF. The ion source was based on the principle of surface ionization, in which ions are generated from a neutral atom by impact with a solid surface. The design of the ion source considered several factors, including the type of ion beams, beam intensity, the beam energy, and the beam emittance of the extracted ion beams from the source. Commercially available alkali material with an ionizer are used in the source and it is integrated with the in house design of extraction and transport system. Its performance was characterized using diagnostics techniques, and its key parameters, such as beam current, emittance, and beam species, were measured. The results showed that the compact surface ion source was able to achieve high ionization efficiency and stable operation, and was suitable for use in commissioning and operation of various ion beam facilities in particle accelerator laboratories.

Funding Agency:

Email Address:

suresh@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 53

Various Parameter Measurements in Dual-ECR Heating on Electron Cyclotron Resonance Ion Source

Author: Kouki Iwahara[1]

Co-authors: Takumu Maenaka [1]; Yushi Fujimura [1]; Yushi Kato [1]

[1] *Osaka Univ.*

Corresponding Author: iwahara@nf.eie.eng.osaka-u.ac.jp

We have been researching about efficient generation of multiply-charged Ar ion on electron cyclotron resonance ion source (ECRIS). Confining the plasma magnetically, ECRIS is one of the major ion sources on accelerators because it is possible to generate plasma efficiently by introducing microwaves. On conventional ECRIS, microwaves are introduced from upstream side of the mirror field at the opposite side of ion beam extraction. On the other hand, our ECRIS has some ports for measurements, so microwaves are introduced from downstream side of the mirror field at the side of ion beam extraction and we succeeded in generating multiply-charged Ar ion. In addition, we succeeded in generating multiply-charged Ar ion by Dual-ECR heating, which means we introduced microwaves both the rod antenna at the downstream side and the coaxial antenna at the upstream side. We measured the distribution of ion saturation current perpendicular to the magnetic field at several positions. Our previous parameters obtained about Dual-ECR heating had been only two parameters, i.e., the beam current and the ion saturation current. We obtained the relationship between a net microwave power and the beam current of multiply-charged Ar ion and confirmed increase of the ion saturation current related. After that, we measured the beam current and plasma parameters such as electron density and electron temperature, and we obtained their spatial distributions. As a result, it was revealed for the first time that the beam current of multiply-charged Ar ion and the plasma parameters were corelating for each antenna and Dual-ECR heating. This paper will describe the measurement results of the beam current and plasma parameters for cases of each antenna and Dual-ECR heating.

Funding Agency:

Email Address:

iwahara@nf.eie.eng.osaka-u.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 55

Production and Characterization of Highly Charged Alkali Ions from the TITAN Electron Beam Ion Trap

Author: Fernando Alejandro Maldonado Millan[1]

Co-authors: Anna Kwiatkowski [2]; Jaime Cardona [2]; John Ash [2]; Rane Simpson [2]; Yilin Wang [3]; Zachary Hockenbery [4]

[1] *UVIC/TRIUMF*

[2] *TRIUMF*

[3] *Graduate student*

[4] *McGill*

Corresponding Author: maldonado@triumf.ca

Highly Charged Ions (HCIs) enable increased precision when measuring the masses of short-lived radioactive ions. The TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) facility receives radioactive, singly charged ions (SCIs) from the ISAC facility before charge-breeding them to HCIs. Specifically, the TITAN Electron Beam Ion Trap (EBIT) generates the higher charge states, while the Measurement PEnning Trap (MPET) measures the mass of the ion of interest. Despite previous successful experimental campaigns, the EBIT has presented operational challenges preventing new experiments using HCIs. Several aspects of the EBIT including the electron gun and ion transport optics were recharacterized to assess the status and limitations of the EBIT. Consequently, the EBIT has now been able to charge-breed residual gas, argon, and alkalis. Time-of-flight spectra measurements have shown charges up to 10+ for 85Rb. This paper presents a general description of the TITAN layout, the experimental setup, and the results demonstrating the production of HCIs from alkali SCIs. The promising results will enable the delivery of radioactive HCIs to MPET in late 2023 or early 2024.

Funding Agency:

Email Address:

maldonado@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 68

Development of a Penning Gauge Ion Source with a Filament for a Compact Ion Microbeam System

Author: Yasuyuki Ishii[1]

Co-authors: Takeru Ohkubo [1]; Hirotsugu Kashiwagi [1]; Yuichi Yamazaki [1]; Shinobu Onoda [1]

[1] *National Institutes for Quantum Science and Technology*

Corresponding Author: ishii.yasuyuki@qst.go.jp

A penning ion source with a filament has been developed for a compact ion microbeam system to form submicron ion beam. A duoplasmatron-type ion source has, so far, been used for the system. However, the duoplasmatorn-type ion source is large power consumption as well as a large size. It is an obstacle to reduce the size of the system. As an ion source to overcome the demerits, a penning gauge ion source, as referred to "PIG ion source", is a candidate of a suitable ion source for the system. If a typical PIG ion is used, the usage of its source is difficult to form a microbeam. Therefore, a PIG ion source has been developed the system. The key feature of the ion source is beam energy spread to form a submicron beam width. The spread is caused by discharge voltage to generate plasma in the ion source. One of the methods to generated the plasma is the usage of a filament. Thus, a PIG ion source with a filament has mainly developed in this study. In the presentation, the features of the developed PIG ion source will be reported.
Acknowledgement
This study is supported by JSPS KAKENHI Grant Numbers JP20H00145, JP20H02673, and Moonshot R&D Grant Number JPMJMS2062.

Funding Agency:

JST, JSPS

Email Address:

ishii.yasuyuki@qst.go..jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 69

Ti Beam Extraction from Laser Plasma Transported by Solenoidal Magnetic Field

Author: Hirotsugu Kashiwagi[1]

Co-authors: Keisuke Yamada [2]; Seiji Hosoya [2]

[1] *QST*

[2] *National Institutes for Quantum Science and Technology*

Corresponding Author: kashiwagi.hirotsugu@qst.go.jp

In a laser ion source (LIS), a target material in a vacuum chamber absorbs focused laser energy to produce a dense plasma, from which the beam is extracted. The LIS can generate plasma from a variety of solid targets, and the ion species can be easily changed by replacing or mounting multiple target samples. Based on this feature, we are developing a LIS for ion implanters requiring a wide variety of ion species.

The LIS plasma spreads three-dimensionally with a wide angular distribution, and only the ions in the plasma that reach the extraction electrode aperture are extracted. Therefore, only a small fraction of the generated ions is used as a beam. In order to obtain higher beam intensity by increasing the number of ions reaching the beam extraction region, we have developed a plasma transport and beam extraction system with a solenoid magnet that suppresses the plasma spreading by an axial magnetic field. At the conference we will present experimental results of extracting an ion beam from a Ti plasma transported in a solenoidal magnetic field.
This work was supported by JSPS KAKENHI Grant Number 18K11937, 21H03749

Funding Agency:

Email Address:

kashiwagi.hirotsugu@qst.go.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 102

Status of the CANREB EBIS at TRIUMF

Author: Brad Schultz[1]

Co-authors: Mathieu Cavenaile [1]; Christopher Charles [1]; Friedhelm Ames [1]; Oliver Kester [1]

[1] *TRIUMF*

Corresponding Author: bschultz@triumf.ca

The CANadian Rare isotope facility with Electron Beam ion source (CANREB) is part of the new Advanced Rare IsotopE Laboratory (ARIEL) at TRIUMF. CANREB can accept stable or rare isotope beams from a variety of ion sources. The injected beams are pulsed using a radiofrequency quadrupole cooler/buncher, and energy adjusted using a pulsed drift tube for injection into an electron beam ion source (EBIS) charge state breeder. The EBIS was designed for a maximum electron beam current of 500 mA at a maximum magnetic field of 6 Tesla. Ions are charge bred to $A/q < 7$ within 10 ms and extracted at energies up to 14 keVxq. The highly charged ions are A/q-separated using a Nier-type spectrometer before being transported to the linac for post-acceleration. Recent efforts have focused on improving the performance of CANREB systems, including progress in dealing with EBIS technical limitations, and will be presented here.

Funding Agency:

Email Address:

bschultz@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 75

Gas Mixing and Double Frequency Operation of the Permanent Magnet Quadrupole Minimum-B Electron Cyclotron Resonance Ion Source CUBE-ECRIS

Author: Ville Toivanen[1]

Co-authors: Taneli Kalvas [1]; Hannu Koivisto [1]; Sami Kosonen [1]; Olli Tarvainen [2]

[1] *Accelerator Laboratory, Department of Physics, University of Jyväskylä*

[2] *UK Science and Technology Facilities Council*

Corresponding Author: ville.a.toivanen@jyu.fi

The CUBE-ECRIS is a recently commissioned permanent magnet electron cyclotron resonance (ECR) ion source developed at the university of Jyväskylä accelerator laboratory. The special features of the new ion source design include an unconventional quadrupole minimum-B magnetic field structure and a slit beam extraction system necessitated by the line-shaped plasma loss fluxes. The 10 GHz CUBE-ECRIS is based on the ARC-ECRIS magnetic field topology, which is theoretically scalable for up to 100 GHz, and represents an intermediate step to develope this concept towards higher frequency operation. Gas mixing and double frequency operation are two widely used methods with conventional ECR ion sources to optimize high charge state ion production. The work presented here demonstrates the applicability of these methods for boosting the CUBE-ECRIS performance. We present the results of an experimental study where these techniques were employed for the production of argon, krypton and xenon ion beams. Oxygen and helium were used as mixing gases and microwave frequencies between 10 and 11 GHz were used for single and double frequency operation. Gas mixing has a strong impact on the high charge state performance of the CUBE-ECRIS. For example, the highest observed charge state increased from 14+ to 19+ for krypton and from 16+ to 23+ for xenon with oxygen gas mixing. Double frequency operation provides an additional performance improvement, for example the currents of argon 9+ and 11+ beams, produced with gas mixing, increased 30% and 100% when the plasma heating was switched from single to double frequency operation at the same total power. The results show that these well-established methods provide improved high charge state performance also with ECR ion sources that are based on quadrupole minimum-B plasma confinement and slit beam extraction.

Funding Agency:

Academy of Finland Project funding (N:o 315855)

Email Address:

ville.a.toivanen@jyu.fi

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 83

Beam Emittance Growth of Highly Charged Ion Beams from the RIKEN SC-ECRIS

Author: Glynnis Mae Saquilayan[1]

Co-authors: Jun-ichi Ohnishi ; Takahide Nakagawa [1]; Takashi Nagatomo [1]; Yoshihide Higurashi [1]

[1] *RIKEN*

Corresponding Author: glynnismae.saquilayan@riken.jp

The beam emittance of extracted ions from ion sources is an important parameter relating to the beam quality of high energy accelerators such as the Radioactive Isotope beam Factory (RIBF) in RIKEN. In order to improve the output beam intensity and transmission efficiency to be well within the acceptance range of low-energy beam transport systems, it is important to maintain a low beam emittance and understand the different factors that can affect its growth. From ion production, extraction, beam focusing, and mass separation, the analysis of the beam emittance is complex as it is affected by the ion source operation and various beam optical components. Therefore, the first step is to consider the ion source parameters such as extraction voltage, extraction beam current, microwave power, and other parameters to systematically study the effect on the beam emittance size.

The RIKEN 28-GHz superconducting electron cyclotron resonance ion source (SC-ECRIS) was operated to produce multiply charged ions and then separated through a magnetic ion analyzer. Using a slit-type emittance monitor, the beam emittance sizes of the produced highly charged ion beams of Ar, Xe, V and U were measured. To minimize the influence of space charge effects for downstream of the analyzing magnet, the measured beam intensities of highly charged heavy ions (Ar and Xe ions) were kept constant and the observed emittance sizes showed a difference in growth with the increasing extraction current for both x and y beam emittances.

In this contribution, the experimental results of the beam emittance measurements and the influence of the ion source parameters including the effects of space charge are presented in detail.

Funding Agency:

Email Address:

glynnismae.saquilayan@riken.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 107

The Extraction of Both Positive and Negative Ions from a Modified Volume Cusp H- Ion Source

Author: Stephane Melanson[1]

Co-authors: Anand Mathai George [2]; Morgan Dehnel [3]

[1] *D-Pace*

[2] *TRIUMF/D-Pace*

[3] *D-Pace, Inc.*

Corresponding Author: stephane@d-pace.com

The TRIUMF licensed H^- ion source is known to produce 15 mA of H^- ions, but some applications, such as those using higher energy research cyclotrons, require the injection of both positive and negative ions. Furthermore, when using a tandem accelerator, there would be a benefit in using an ion source that can directly extract H^- and He^+. In this case, a charge exchange chamber would only have to be used with the He beam to create He^-. In this paper we present the conversion of the H^- ion source to allow for the extraction of both positive (He^+, H^+, H_2^+ and H_3^+) and negative (H^- and D^-) ions by the addition of a suppression electrode and other modifications to be described. Up to 3 mA of protons and 2 mA of He^+ can be extracted when using positive extraction power supplies and up to 5 mA of H^- can be extracted when the polarity of the power supplies switched to negative extraction. We study how the ion source parameters affect the proton fraction and we look at the influence of the magnetic filter field in the plasma chamber. Finally, we present the results of the extraction with the RF powered version of the ion source.

Funding Agency:

Email Address:

stephane@d-pace.com

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Monday / 91

Production of High Intensity Ruthenium Ion Beams with High Isotope Purity Using Metal Ions from Volatile Compound (MIVOC) Method at iThemba LABS

Author: Joele Mira[1]

Co-authors: Muneer Sakildien [2]; N Kheswa [2]; Sizwe Buwa [2]; Skye Segal [2]

[1] *iThemba LABS - NRF*

[2] *iThemba LABS*

Corresponding Author: jp.mira@ilabs.nrf.ac.za

The paper presents measurements on the production of ruthenium ion beams from high isotope purity using MIVOC method. The measurement was carried out at iThemba LABS using one of the two ECR ion source which is the copy of the Grenoble Test Source (GTS). Due to many existing isotopes with similar abundances of Ruthenium (96Ru abundance 5.5%, 98Ru abundance 1.9%, 99Ru abundance 12.7%, 100Ru abundance 12.6%, 101Ru abundance 17%, 102Ru abundance 31.6%, 104Ru abundance 18.7%) the mass separation and identification is difficult. The synthesis of the enriched ruthenocene is performed in the target laboratory at iThemba LABS. The in-house synthesis of ruthenocene from enriched materials allows for new ion beams with intensities not possible so far to be developed.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 99

Status of the High-Current Electron-Beam Ion Source Charge Breeder for the Facility for Rare-Isotope Beams

Author: Hyock-Jun Son[1]

Co-authors: Alain Lapierre [1]; Antonio Villari [1]; Stefan Schwarz [1]

[1] *FRIB/MSU*

Corresponding Author: son@frib.msu.edu

The Reaccelerator (ReA) of the Facility for Rare-Isotope Beams (FRIB) employs an Electron-Beam Ion Trap (EBIT) as a charge breeder to reaccelerate rare-isotope beams to several MeV/u. The ReA EBIT uses a Pierce-type electron gun with its cathode partially immersed in the fringe field of a 4-T superconducting solenoid. A barium-impregnated tungsten dispenser cathode is used to produce an electron current of 300 −600 mA, corresponding to an electron current density of 170 −340 A/cm^2 in the ion trap region. The maximum trap capacity of the ReA EBIT is 10^{10} elementary charges. However, this is insufficient to handle high RIB rates, which are expected to exceed to 10^{10} particles/s in some case. In order to accept such rates, a High Current Electron-Beam Ion Source (HCEBIS) has been built and is now being commissioned. The HCEBIS is based on main components of the former Test-EBIS at Brookhaven National Laboratory. The HCEBIS electron beam is launched from a 9.2-mm lanthanum hexaboride convex cathode immersed in a 0.1-T axial magnetic field from a room-temperature coil and adiabatically compressed into the 4-T field of a superconducting solenoid. An electron-beam current of 1 A with a 50% duty cycle has been produced. More than 2 A was obtained for short duty cycles. An upgrade to increase the electron-beam current of up to 4 A in the future will allow for a maximum trap capacity of 2.4×10^{11} elementary charges. This paper presents the status of the HCEBIS, including the results of the electron-beam commissioning and systematic studies.
This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics and used resources of the Facility for Rare Isotope Beams (FRIB), which is a DOE Office of Science User Facility, operated by Michigan State University, under Award Number DE-SC0000661.

Funding Agency:

U.S. Department of Energy, Office of Science

Email Address:

son@frib.msu.edu

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 101

Discharge in the Trumpet Regions of the CANREB EBIS

Author: Christopher Charles[1]

Co-authors: Brad Schultz [1]; Friedhelm Ames [1]; Mathieu Cavenaile [1]; Oliver Kester [1]

[1] *TRIUMF*

Corresponding Author: ccharles@triumf.ca

Under operational conditions, high-voltage breakdown continues to occur inside the electron beam ion source (EBIS) at CANREB (the CANadian Rare isotope laboratory with Electron Beam ion source). Discharge tracks along components inside the high-vacuum together with data acquired during use of the system have isolated the most serious discharges to the collector trumpet (CT) region for a relatively narrow combination of high magnetic field (ca. 3 Tesla), high-voltage (ca. 10 kV applied to the drift tubes), and variable vacuum conditions. Recent tests indicate similar discharges are occurring around the gun-trumpet (GT) region. Penning or magnetron discharge were proposed to be involved, however, a clear understanding of the active processes and their interdependences remains obscure. Here we use OmniTrak (3D) to simulate the electric and magnetic field environment inside the EBIS, to better quantify the nature of the chronic discharges and their underlying mechanisms. E and B fields and electron motions are simulated around surfaces where the most serious damage occurred in the CT region. Effects of the 40K stainless-steel heat shield (at ground potential) surrounding the CT electrode (at high voltage) are simulated, because recent removal of this shield was found to reduce the severity of discharge. Different geometries of this 40K heat shield are simulated

to determine the impact on the fields and electron motion in the CT region. This work aims to provide insight to the discharge mechanisms, so that the EBIS may be restored to full specs for creation and delivery of highly charged ions for nuclear astrophysics experiments at TRIUMF.

Funding Agency:

NSERC

Email Address:

ccharles@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 114

Simple 3D PIC Analysis for Beam Phase Space Oscillation in RF Driven Negative Hydrogen Ion Source

Author: Takanori Shibata[1]

Co-authors: Katsuhiro Shinto [2]; Haruhisa Nakano [3]; Kazuo Hoshino [4]; Kenji Miyamoto [5]; Kiyonori Ohkoshi [2]; Kesao Nanmo [1]; Kiyoshi Ikegami [1]; Isao Kawai [6]; Hidetomo Oguri [2]; Motoi Wada [7]

[1] *J-PARC center / High Energy Accelerator Research Organization (KEK)*

[2] *J-PARC center / Japan Atomic Energy Agency*

[3] *National institute for Fusion Science*

[4] *Keio University*

[5] *Naruto University of Education*

[6] *Nihon Axis Co., Ltd*

[7] *Doshisha University*

Corresponding Author: takanori.shibata@kek.jp

Temporal oscillation of the negative hydrogen ion (H^-) beam phase space in Radio Frequency (RF) ion source is a serious problem which causes increase in the beam divergence angle in the fusion application or unexpected beam loss due to Twiss mismatch in the accelerator application. Physical mechanism of the oscillation is investigated by a simple 3D Particle-In-Cell (PIC) model. The model takes into account the transport processes of electron, proton and H^- in the extraction region. The calculation domain is in vicinity of the single beam aperture in J-PARC ion source configuration. In order to understand relation between the plasma density oscillation and the extracted H^- beam characteristics, the input electron and proton fluxes from the driver region are varied parametrically with the fundamental and the second harmonics of the J-PARC RF frequency (2 and 4 MHz). The numerical results give an idea to the main physical processes between the oscillations of the plasma parameters and the extracted H^- ion trajectories in the different RF phases.

Funding Agency:

Email Address:

takanori.shibata@kek.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 127

Effect of the Oscillation of Upstream Plasma Density on Plasma Meniscus in RF Negative Ion Sources

Author: Katsuya Hayashi[1]

Co-authors: Kazuo Hoshino [1]; Akiyoshi Hatayama [1]; Kenji Miyamoto [2]

[1] *Keio University*

[2] *Naruto University of Education*

Corresponding Author: hayashi@ppl.appi.keio.ac.jp

Recently, it has been observed in RF H- sources that the beam optics, for example, the beam divergence angle oscillates periodically[1]. Therefore, it is important to understand the effect of time-oscillation on the plasma meniscus in the downstream extraction region close to the extraction hole under the existence of a large amount of negative ions.

As a first step for understanding meniscus oscillation, dependence of the meniscus shape on the upstream plasma-density has been investigated by using a 3D-PIC code, KEIO-BFX code. Taking the upstream plasma-density as a parameter, a series of simulations has been carried out for the range of 5×1017~1.5×1018 m-3. In each case, the simulation has been continued until the steady state has been obtained for a given value of the constant upstream plasma-density. The effect of both volume and surface produced H- ions are taken into account.

The comparison of the results among a series of simulations shows that the effective distance between the plasma meniscus and the extraction grid depends on the upstream density. Also, it has been shown that the meniscus depends on the amount of the surface negative ion production and the ratio of the negative ion and electron density even in the same upstream plasma-density [2.3].

In this study, as a next step, we investigate the time evolution of the plasma meniscus in the oscillating upstream plasma density assuming the RF discharge. For this purpose, KEIO-BFX is extended to time-dependent simulation model, the upstream plasma density oscillating by the time variation of the RF input power deposition. In the presentation, the time-evolution of the meniscus shape, the potential profile, the extracted beam quality, etc. will be discussed.

[1] T. Shibata, et al, AIP Conference Proceedings 2373, 050002 (2021)
[2] K. Hayashi, et al., Plasma Fus. Res. 18, 1401008 (2023).
[3] K. Hayashi, et al, in proc. Negative Ions, Beam and Sources, online, October 2022.

Funding Agency:

Japan Science and Technology Agency

Email Address:

phy-kh@keio.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Katsuya Hayashi

Monday / 130

The SPES Laser Ion Source: Time Structure and Laser Enhancement Measurements at ISOLDE-CERN

Author: Omorjit Singh Khwairakpam[1]

Co-authors: Bruce Marsh [2]; Cyril Bernard [3]; Daniele Scarpa [4]; Emilio Mariotti [5]; Katerina Chrysalidis [2]; Lisa Centofante [4]; Mattia Manzolaro [6]; Piergiorgio Nicolosi [7]; Ralitsa Mancheva [8]; Reinhard Heinke [2]; Sebastian Rothe [2]; Thierry Stora [2]; Valentin Fedosseev [2]

[1] *INFN-LNL; University of Siena*

[2] *CERN*

[3] *CERN; KU Leuven*

[4] *INFN-LNL*

[5] *Università degli Studi di Siena*

[6] *INFN*

[7] *CNR-IFN, Padova*

[8] *CERN, KU Leuven*

Corresponding Author: khwairakpam@lnl.infn.it

SPES is a 2°-generation ISOL facility in the last stage of construction in INFN-LNL, Italy. One of the many developmental activities carried out inside SPES project is a *thermally optimized ion source (IS)*. The SPES surface ion source (made of Ta) was successfully tested in 2017 [1].
In the beginning of 2023, the same SPES-IS has been used to test its performance as a resonance ionization laser ion source (RILIS) at CERN-ISOLDE Offline 2 [2]. Time structure measurements (TSMs), laser resonant enhancement ratios (LERs) and efficiency test were performed to characterize the RILIS using the elements Sm and Ga.
The TSMs were made for various total ion currents (TICs), regulated by surface ionized K (to simulate ion load by contaminants). Laser ion confinement inside the IS is observed along the whole length of the IS assembly i.e., the hot cavity and the transfer line. A good proportion of the ions is produced in the transfer line which can be attributed to the "alignment system"introduced in the SPES-IS. The IS can maintain a good laser ion confinement with ease till a TIC of 1.2μA at temperatures of 2000℃ and above. Also, TSMs were performed for reverse polarized IS at 2000℃.
LER measurements were performed in a similar approach. No significant changes in the ratio values are observed for Sm while varying the TIC for IS temperatures at 2000℃ (LER= 8.0-9.6) and 2200℃ (LER= 4.9-5.3). However, at 1800℃, the LER shows an initial high value of 33 at a very low TIC and drops rapidly to a value of 8.3 at TIC of about 230 nA.
The study showed a clear dependency of the laser ion confinement on the factors: IS temperature (which directly links to thermionic electron emission), positive ion density and possibly also the neutrals. Moreover, the IS clearly exhibited high thermal stability and endurance during the whole campaign over two weeks with multiple heating and cooling cycles.
[1] http://dx.doi.org/10.1063/1.4998246
[2] https://doi.org/10.1016/j.nimb.2019.07.016

Funding Agency:

SPES, INFN Italy; CERN; FWO-Vlaanderen, Begium

Email Address:

Khwairakpam@lnl.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Omorjit Singh Khwairakpam

Monday / 139

Design and Evaluation of a Variable-Field Thomson Parabola for a keV Ion Beam

Author: Shadrach Hepner[1]

Co-authors: Robin Langtry [2]; Scott Schipmann [2]; Vladlen Podolsky [2]

[1] *Avalanche Energy Designs*

[2] *Avalanche Energy*

Corresponding Author: shepner@avalanche.energy

Avalanche Energy is developing deuterium ion beams for the Orbitron fusion concept. To understand the fusion output of the reactor, knowledge of the ion beam species and energy composition is paramount. We have successfully implemented a Thomson Parabola to determine the relative composition and energy spread of multiple species in the beam. To distinguish species within a wide range of masses and energies, we allowed for highly variable electric and magnetic field strengths. To this end, we used electromagnets with an iron core to vary the magnetic field. The iron core focuses and magnifies the field from the coils and doubles as electrodes for a potential difference up to 10 kV.
In this work, we discuss the design and implementation of this diagnostic. We illustrate a magnetic field calibration procedure and discuss requirements for the field strength and shape. We then mount it in the beam line with a downstream phosphor screen, multichannel plate and camera set up to determine beam deflection distance. We finally illustrate the analysis procedures and present results with simultaneous differentiation of D+, D2+, D3+ and Ar+ at energies from 8-12 keV.

Funding Agency:

Email Address:

shepner@avalanche.energy

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Monday / 140

A Steerable, Compact 20 kV Einzel Lens with Low Aberrations

Author: Scott Schipmann[1]

Co-authors: Robin Langtry [1]; Shadrach Hepner [2]; Vladlen Podolsky [1]

[1] *Avalanche Energy*

[2] *Avalanche Energy Designs*

Corresponding Author: sschipmann@avalanche.energy

Avalanche Energy is developing deuterium ion beams for the Orbitron fusion concept. To successfully deliver high currents to the reactor, both focusing and steering are necessary. Many concepts proposed to solve this problem rely on separated focusing and steering sections. However, doing so inherently extends the beamline and may enhance beam losses. Combining the two into a single piece, while decreasing beamline length, may induce aberrations when steering is applied. Based on simulation work by Mandal et al. (Mandal et al., 2011) for low energy beams, we utilized an "x-cut" pattern to separate the central electrode into four pieces, resulting in four unequally shaped lens segments. Biasing these segments relative to the others can steer the beam in any direction.
This improves on a simpler design of cutting the lens into four equal segments by smoothing out the electric field pattern within the lens and thus reducing aberrations in the beam. In this work, we present the design, analysis, diagnosis, and successful implementation of this steerable Einzel lens operable up to a 20 kV bias. In IBSIMU, we compared this design to the simpler concept of cutting

the central lens into four equal segments, each of which can be individually biased. We tested both lenses with an 8 kV deuterium ion beam and analyzed the light patterns produced on a phosphor screen with a multichannel plate amplification. We found in both simulations and experiments that the steerable Einzel lens with the novel design can better focus the beam without losing current to aberrations due to a more uniform electric field pattern within the lens.

Mandal, P., Sikler, G., & Mukherjee, M. (2011). Simulation study and analysis of a compact einzel lens-deflector for low energy ion beam. Journal of Instrumentation, 6(02), P02004–P02004. https://doi.org/10.1088/1748-0221/6/02/P02004

Funding Agency:

Email Address:

sschipmann@avalanche.energy

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Monday / 156

Effort Towards a High Intensity Titanium Beam with the VENUS ECR Ion Source

Author: Janilee Benitez[1]

Co-authors: Damon Todd [1]; Daniel Xie [1]; Jaime Cruz-Duran [1]

[1] *Lawrence Berkeley National Lab*

Corresponding Author: jybenitez@lbl.gov

Recent superheavy element production research has involved the bombardment of heavy-element foils by high currents of neutron-rich ion beams having atomic numbers near 20 and energies near 5 MeV/nucleon. Production rates scale with incident current, and the 88-Inch Cyclotron at LBNL has demonstrated the ability to deliver over 2 pμA for some of these beams largely because of its injector: the superconducting ECR ion source VENUS. The search for the next elements on the periodic table, elements 119 and 120, will likely involve 50Ti as the incident beam. Titanium is a difficult beam to produce as it requires relatively high temperatures to sublimate material into the source (~1700 C). In addition, the material itself acts as a getter metal on chamber surfaces making stable source operation difficult during and after a high intensity run. As a result, the reported titanium currents on target worldwide were limited in the hundreds of pnA. By using a "boat"oven design capable of withstanding the strong Lorentz forces in VENUS, we have been able to demonstrate 48Ti currents on target in excess of 1.4 pμA. We will present the oven improvements that made this possible and will discuss our next steps as we aim for 2 pμA.

Funding Agency:

Email Address:

jybenitez@lbl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 166

Experimental Characterization of a Multi-Cusp Electron Source as Charge Neutralizer for Ion Implanter

Author: Minkeun Lee[1]

Co-authors: Junbeom Park [1]; Jiseong Nam [1]; Kyung-Jae Chung* [1]

[1] *Seoul National University*

Corresponding Author: lmk0486@snu.ac.kr

In this study, we conducted experimental study on a hot-cathode, multi-cusp electron source as charge neutralizer device for ion implanters. This device is divided into a plasma source area using a hot-cathode and magnetic multi-cusp, and a transport area that transports extracted electrons through an axial magnetic field by the electromagnet. We utilized a biased mesh to measure the quantity of low-energy electrons, which significantly contribute to the neutralization of the ion beam charge, among the transported electrons. Also, we analyzed the effects of various variables through experiments, and the discharge voltage, gas pressure, and magnetic field strength were found to be variables that monotonically increase with the low-energy electrons measured at downstream. In contrast, the extraction energy of the electron beam and the voltage of the accelerating electrode showed a complex relation with them. In particular, we found the plasma potential which can be adjusted by controlling the voltage of the accelerating electrode plays a significant role for the transport of low-energy electron beam. We also observed that the change in plasma potential triggered instability propagating in the azimuthal direction, affecting the quantity and temperature of electrons at downstream.

Funding Agency:

Ministry of Commerce, Industry and Energy

Email Address:

jkjlsh1@snu.ac.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 165

New Technique of Injecting Radioactive Ions into Charge Breeding ECR Ion Source

Author: Gabriel Tabacaru[1]

Co-authors: Juha Arje [1]; Veli Kolhinen [1]; Brian Roeder [1]; George Kim [1]; Don May [1]; Henry Clark [1]

[1] *Cyclotron Institute, Texas A&M University*

Corresponding Author: tabacaru@comp.tamu.edu

Cyclotron Institute at Texas A&M University started a project to develop the reacceleration of radioactive ions using the two operational cyclotrons and a Charge Breeding ECR ion source. The radioactive ions are produced primarily via (p,n) reactions using the well-known IGISOL technique. The reaction products are transported into a Charge Breeder ECR ion source where their charge state is boosted from 1+ to higher, depending on the product of interest and the operational state of the Charge Breeder ECR ion source. The transport of the products and the injection into the ion source are very important for the efficiency of charge breeding. Two techniques have been used:

acceleration–deceleration method (classic) and low - energy RF-only sextupole ion guide transport and injection method (innovative technique). The last method appears to be very efficient and great charge breeding efficiency was observed. The presentation of the entire project, the new injection technique, experimental results, and future plans will be discussed.

Funding Agency:

Email Address:

tabacaru@tamu.edu

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Gabriel Tabacaru

Monday / 179

Dual Frequency Enhancement of the SuperNanogan Multi-Charged Ion Source at TRIUMF ISAC Facility

Authors: Brad Schultz[1]; Brian Minato[1]; Christopher Charles[1]; Friedhelm Ames[1]; Joseph Adegun[1]; KEERTHI JAYAMANNA[1]; Marco Lovera[1]; Spencer Kiy[1]; Suresh Saminathan[1]; Tiffany Angus[1]

[1] *TRIUMF*

Corresponding Author: keerthi@triumf.ca

In 2008, a SuperNanogan ECR ion source from PANTECHNIK was introduced in addition to an in-house developed microwave ion source and a surface ion source to complement the TRIUMF offline ion source facility to provide highly charged ions to ISAC experiments. Originally, it employed a 400 W Travelling Wave Tube Amplifier (TWTA) for RF heating, but less than 50 W was enough to produce all the multi-charged beams required by the experiments. Later, a 50W solid-state amplifier was added for redundancy purposes but we found a significant improvement when both were switched on at the same time. With the dual frequency, less than ten times of the total power is needed to produce the same charges with more currents than with the single frequency. The beam stability and the ability to extract higher charged ions also improved with the dual frequency enhancement. The operational experience and the results are discussed in this paper.

Funding Agency:

Email Address:

keerthi@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Monday / 187

Design, Characterization and Applications of Low-Energy Ion Source for Modifying Polymer Surface Properties

Author: Haifa Alyousef[1]

Co-authors: A. Atta [2]; H M Abdel-Hamid [3]

[1] *Department of Physics, College of Science, Princess Nourah bint Abdulrahman University - P.O. Box 84428, Riyadh 11671, Saudi Arabia)*

[2] *Physics Department, College of Science, Jouf University, Saudi Arabia*

[3] *Radiation Physics Department, National Center for Radiation Research and Technology (NCRRT), Atomic Energy Authority (AEA), Cairo, Egypt*

Corresponding Author: haalyousef@pnu.edu.sa

For this work, a cold cathode ion source with a Langmuir electric probe was constructed to produce an ion beam that could be successfully applied to a variety of applications. A steady discharge plasma media was produced by adjusting its operation conditions, such as the discharge voltages, electrode gap, as well as gas pressure. Additionally, the I-V plasma graph is recorded by inserting an electrical probe into the discharge plasma to identify plasma characteristics. The probe can be directed to any location inside the plasma region. To record the plasma parameters, including electron temperature and density, the gas pressure as well as probe-cathode spacing are changed. Moreover, the discharge characteristics will be fine-tuned and discussed by assessing the current discharges under the influence of gas pressure and cathode-probe distances. By subjecting the polymeric films to the extracted beams, the surface properties are altered. By increasing the irradiation period, the surface free energy is raised. This ion source is extremely effective and specifically designed to meet the demands of applications like polymeric surface modification.

Funding Agency:

Email Address:

haalyousef@pnu.edu.sa

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 190

Recent Progress of the UNIST-EBIT for Highly Charged Ion Studies

Author: Je Hwan Han[1]

Co-authors: Sung Nam Park [1]; Emre Cosgun [1]; Bok Kyun Shin [2]; Kyounghun Yoo [3]; Moses Chung [1]

[1] *Ulsan National Institute of Science and Technology*

[2] *Pohang Accelerator Laboratory*

[3] *Instituite for Basic Science*

Corresponding Author: ykh8287@ibs.re.kr

Highly charged ions (HCIs) are currently utilized in numerous fundamental and applied sciences, including astrophysics, dark matter search, optical clocks, semiconductor lithography, and quantum dot fabrication, to name just a few examples. At UNIST, a tabletop electron beam ion trap (EBIT) has been developed for creating and studying HCIs. The UNIST-EBIT compresses the electron beam by 72 permanent magnets (up to 0.84T) and produces up to He-like Ar ions. The primary objective of the UNIST-EBIT is to obtain X-ray spectrum data essential in astrophysics. We use highly charged Fe ions to understand the visible matter in stars, supernovas, near-stellar clouds, and jets from black holes. Following the first X-ray spectroscopy experiments at the Pohang Accelerator Laboratory Free

Electron Laser (PAL-XFEL) facility, a systematic upgrade is underway to address the alignment issues encountered during the initial beam time. Meanwhile, optical clocks based on HCIs are receiving significant attention from the scientific community. The UNIST-EBIT can also provide various HCIs for optical clock applications. For this purpose, designing an extraction beamline along with an initial extraction experiment of Ar ions from the EBIT is underway. To extract Ar ions, we consider constructing an automatic control system with EPICS. In this work, we present the recent progress of the UNIST-EBIT for such future experiments.

Funding Agency:

Email Address:

ykh8287@ibs.re.kr, mchung@unist.ac.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 188

Structural and Optical Properties of Flexible Polymer Nanocomposites Films for Optoelectronics Applications

Author: Nuha Al-Harbi[1]

Co-authors: A. Atta [2]; Haifa Alyousef [3]

[1] *Department of Physics, Faculty of Applied Sciences, Umm Al-Qura University, Makkah, Saudi Arabia*

[2] *Physics Department, College of Science, Jouf University, Saudi Arabia*

[3] *Department of Physics, College of Science, Princess Nourah bint Abdulrahman University - P.O. Box 84428, Riyadh 11671, Saudi Arabia)*

Corresponding Author: haalyousef@pnu.edu.sa

In this study, we address the the effects of low energy hydrogen ion beam irradiation on the optical characteristics of polymeric nanocomposite films for used in optoelectronics devices. The composite films are irradiated using broad beam cold cathode ion source with hydrogen ion energy ranging from 1 to 6 keV. The techniques of X-ray diffraction, Fourier transform infrared spectrum, as well as scanning electron microscopy are all used to investigate the untreated and irradiated films and determine their properties. Both the optical energy band tails and the optical energy bandgap of untreated as well as modified films were determined. The FTIR peaks are indicative of inorganic nanoparticles bound to the polymer chains, and XRD validated the successful synthesis of the polymeric composite films. Scanning electron microscopy (SEM) pictures have shown that the nanofiller is loaded and distributed uniformly throughout the polymeric layer. Moreover, the refractive index, extinction coefficients, and dispersion properties were also established for the pure and treated films. On the other hand, the ion penetration depths, the electronic stooping, nuclear energy loss and distributions of scattered atoms are recorded using SRIM Monte Carlo simulation programs. In light of these findings, the irradiated flexible composite films with low energy hydrogen ion beam can be used in a variety of fields, including those dealing with batteries, super-capacitors, detectors, as well as optoelectronics.

Keywords: Polymer nanocomposite, Ion irradiation, surface characterization, Optical properties, Optoelectronics Applications.

Funding Agency:

Email Address:

nfhariby@uqu.edu.sa

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 51

Design for an 18 GHz Open Hexapole ECR Source

Author: Richard Vondrasek[1]

Co-authors: Jake McLain [1]; Robert Scott [1]

[1] *Argonne National Laboratory*

Corresponding Author: vondrasek@anl.gov

Responding to a request by the user community for higher beam intensities, an upgrade of the Argonne National Laboratory ECR2 ion source is in progress. The upgrade has three main constraints: 1) The overall source architecture as defined by the solenoid coils cannot change, 2) radial access to the plasma chamber has to be maintained, and 3) the amount of time the source can be shut down for hardware installation is < 2 months.

A new NdFeB open hexapole is projected to produce a 1.1 T wall field with six radial slots (6.35 mm x 91.2 mm) allowing solid material access and ~120 l/s of pumping to the plasma chamber. The axial magnetic fields will be enhanced with a vanadium permendur plug and optimization of the iron resulting in a Binj of 2.4 T, Bmin of 0.4 T, and Bext of 1.0 T and magnetic gradients of 5.9 T/m for 14.5 GHz and 7.4 T/m for 18 GHz.

The plasma is currently heated with multiple-frequency RF provided by two traveling wave tube amplifiers (TWTA) operating between 11 and 14.5 GHz and capable of providing 1100 W total power. The new magnetic structure will support 18 GHz operation with RF provided by a new TWTA.

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

Funding Agency:

U.S. Department of Energy

Email Address:

vondrasek@anl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 90

Design and Preliminary Tests of an Active Plasma Chamber for ECR Ion Sources

Authors: Fabrizio Odorici[1]; Giuseppe Castro[2]; Filippo Russo[3]; Ornella Leonardi[2]; Luigi Celona[2]; Grazia D'Agostino[3]; Marco Guerzoni[4]; Luciana Malferrari[4]; Anselmo Margotti[4]; Santo Gammino[2]; Francesco Chines[3]; Giacomo Costanzo[3]; Michele Furini[4]; Cristiano Gessi[4]; Roberto Michinelli[4]; Davide Siliato[3]

[1] *Istituto Nazionale di Fisica Nucleare –Sezione di Bologna,*

[2] *INFN-LNS*

[3] *INFN-Laboratori Nazionali del Sud*

[4] *Istituto Nazionale di Fisica Nucleare –Sezione di Bologna*

Corresponding Author: celona@lns.infn.it

An innovative plasma chamber for Electron Cyclotron Resonance Ion Sources has been developed at INFN and will soon be installed and tested with the AISHa (Advanced Ion Source for Hadrontherapy) ion source. It consists in inserting a particular liner into the existing chamber, which allows an electrical segmentation of the internal walls of the chamber. The purpose of this system is to reduce the ion losses induced by the anisotropic diffusion mechanism, improve the plasma confinement and thus increase the overall performance of the ion source. In fact, in ECRIS plasmas, electrons mostly diffuse along magnetic field lines while ions mostly leak across magnetic field lines. In particular, the inner walls of the plasma chamber are covered with 30 tiles, each polarized with a given positive voltage. The tiles are made of Al-6082 and anodized except for the surface directly facing the plasma. The anodizing process makes each tile electrically insulated from the others and from the plasma chamber while preserving the correct operation of the cooling system. The tiles are wrapped by 2 half-cylinders made of Al-6082 acting as shells. Some tiles are equipped with a temperature sensor and machined to allow the wiring of the entire system. In this work the results of the preliminary tests of the thermal and electrical behaviour of the active chamber and the future perspectives are presented.

Funding Agency:

5th National Committee of INFN - Grant IONS

Email Address:

fabrizio.odorici@bo.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Fabrizio Odorici

Monday / 143

Numerical Analysis of Isotope Effects of Vibrationally Excited Molecule in Negative Ion Source

Authors: Kengo Iwanaka[1]; Kazuo Hoshino[1]; Haruhisa Nakano[2]; Takanori Shibata[3]; Kenji Miyamoto[4]

[1] *Keio University*

[2] *National institute for Fusion Science*

[3] *KEK*

[4] *Naruto University of Education*

Corresponding Author: kengo.iwanaka@keio.jp

Recently, the Research and development Negative Ion Source (RNIS) at National Institute for Fusion Science (NIFS) changed operation gas from hydrogen to deuterium. It is reported that the electron

density differs by around three times with the operation gas [1]. The physical mechanism of the significant increase of the electron density is still not clear.
In the previous studies [2], a three-dimensional kinetic electron transport code KEIO-MARC has been applied to the analysis of hydrogen isotope effects on the increase of an electron density. Isotope effects on the Coulomb collision process, confinement by the sheath, and atomic/molecular processes have been analyzed under the condition of fixed background particle density (ion, atom, molecular). However, the increase of the electron density has not yet been fully explained.
On the other hand, the analysis using a zero-dimensional model was also done [3]. The model focuses on the isotope effect for vibrationally excited levels of electronically grounded hydrogen molecules. The results showed an increase of the electron density due to the difference in the ionization channel numbers via the molecular vibrationally excited state. However, this model assumes a Maxwellian electron energy distribution function (EEDF), which is different from that calculated by KEIO-MARC.
In this study, the zero-dimensional model is coupled with the KEIO-MARC code. The preliminary result for the hydrogen case shows that the number of low energy electrons (below 10 eV) increases from the previous result [2] due to the change of background hydrogen atoms, molecules, H_2^+ and H_3^+ density. In the presentation, the isotope effects of the vibrationally molecular excited state with the self-consistent EEDF will be discussed.
[1] H. Nakano, et al., J. J. Appl. Phys. **59**, SHHC09 (2020).
[2] R. Kato, et al., J. Phys.: Conf. Ser. **2244**, 012035 (2022).
[3] T. Shibata, et al., J. Phys.: Conf. Ser. **2244**, 012002 (2022).

Funding Agency:

Email Address:

kengo.iwanaka@keio.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 162

H- Ion Source RF Plasma Testing with 13.56 MHz and 27.12 MHz at the Spallation Neutron Source (SNS)

Author: Amith Hulikal Narayan[1]

Co-authors: Baoxi Han [1]; Robert Welton [1]; Chris Stinson [1]; Greg Terszakowec [1]; Chip Piller [1]; Vic Andzulis [1]; Vestal Carter ; Yoon Kang

[1] *Oak Ridge National Laboratory*

Corresponding Authors: narayana@ornl.gov, hanb@ornl.gov

The baseline RF-driven H- ion source configuration at the Spallation Neutron Source (SNS) facility uses a continuous wave (CW) 600 W 13.56 MHz RF system to ignite and maintain a low-intensity plasma inside the ion source vacuum chamber. After the continuous low-intensity 13.56 MHz plasma has been established, a pulsed (typical 1 ms pulse width and 60 Hz pulse repetition rate) 80 kW 2 MHz RF system is used to increase the plasma intensity for the production of the pulsed H- ion beam. Incremental upgrades and improvements to the SNS ion source systems have resulted in the ability to reliably operate an H- ion source for SNS neutron production run cycles that can last up to four months. Conditions inside the SNS H- ion source change throughout a four-month run cycle due to changes in impurity levels, sputtering, and erosion. As the internal ion source conditions change during the run cycle, there can also be changes in plasma stability and the 13.56 MHz RF power level required to ignite the plasma. This paper presents the results of testing performed on the SNS Ion Source Test Stand (ISTS) system, where we looked at plasma ignition and plasma stability for H- ion sources of different ages using 13.56 MHz RF and 27.12 MHz RF.

Funding Agency:

ORNL

Email Address:

narayana@ornl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Amith Hulikal Narayan

Monday / 14

The High Power-Beam Efficiency Investigation of Miniaturized ECR Ion Source

Authors: Tenghao Ma[1]; Bujian Cui[1]; Wenbin Wu[2]; Yaoxiang Jiang[1]; Zhiyu Guo[1]; Jiaer Chen[1]; Shixiang Peng[1]

[1] *Peking University*

[2] *Institute of Applied Physics and Computational Mathematics*

Corresponding Author: sxpeng@pku.edu.cn

A miniaturized 2.45GHz microwave ion source (MIS) with plasma chamber of 30 mm x 40 mm and has the ability to produce more than 20 mA CW hydrogen ion beam with 180 W microwave power has been built at Peking University(PKU)[1]. To understand the plasma evolution mechanism of MIS, a hybrid discharge heating (HDH) mode that contains a surface wave plasma (SWP) ignition discharge process and an electron cyclotron resonance(ECR) ionization was proposed, and the power-beam efficiency is increased to 25 mA/100 W[2]. The power-beam efficiency is a key parameter to evaluate an ECR ion source, and many factors can affect it. Under the structure of this MIS, factors such as input power, pressure, magnetic field configuration, and the wall material and the size of plasma chamber has been investigated. Based on this research, a more compact 2.45GHz microwave ion source with inner diameter of 24mm has been developed. A 32.5 mA hydrogen ion beam was obtained with only 100 W microwave power. RF power efficiency of this one is increased from 25 mA/100 W to 32.5 mA/100 W.

[1] J.M. Wen, S. X. Peng, H. T. Ren, et al., Chin Phys B. 27, 055204 (2018).
[2] W. B. Wu, S. X. Peng, A. L. Zhang, et al., J. Appl. Phys. 132, 083305 (2022).

Funding Agency:

NSFC 11975036

Email Address:

sxpeng@pku.edu.cn

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Shixiang Peng

Monday / 28

Experiment of Highly Charged Ion Production by Changing the Microwave Injection Position at Compact ECR Ion Source

Author: Mana Miyagawa[1]

Co-authors: Kazuki Sakamoto [2]; Toyohisa Asaji [2]; Masayuki Muramatsu [3]

[1] *Sumitomo Heavy Ibdustries,Ltd*

[2] *National Institute of Technology, Niihama College*

[3] *National Institutes for Quantum Radiological Science and Technology, National Institute of Radiological Sciences*

Corresponding Author: mana.miyagawa@shi-g.com

Kei3 is a prototype of compact ECR ion source developed for various ion production at QST-NIRS. It has confirmed that Kei3 has an ability to produce highly charged heavy ion, for example, carbon, neon and argon, but the beam current was not high enough. To improve this situation, we optimized microwave frequency and injection position in the plasma chamber.
Microwave has a large effect to production of ion, the injection efficiency to ECR plasma is a key to obtain high current beam.
In this study, we measured Ar4+ beam current by moving the injection position 2mm step along beam axis from peak of axial magnetic field. We also measured it when microwave frequency was varied from 9.75 GHz to 10.00 GHz in 0.01 GHz step. Microwave was transmitted by coaxial cable, and it was injected through antenna. The dependence of microwave frequency and antenna position on beam current was measured in this experiment. Coaxial cable was set at r=18 mm to prevent damage due to heat input by the plasma.
The beam current was not observed at the start position, but it increased periodically along the injection position. The maximum beam current was 26.8 uA observed at microwave frequency of 9.84 GHz and 45 mm inner position of the peak of magnetic field. It was 1.8 times larger than 5 mm inner position of the peak. As a result, the injection position of microwave should at the inner position of peak of magnetic field for more efficient highly charged ion production.

Funding Agency:

Email Address:

mana.miyagawa@shi-g.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 97

Design Improvements to the SNS Ion Source and Diagnostics

Authors: Baoxi Han[1]; Chris Stinson[1]; Dave Willis[2]; Greg Terszakowec[1]; Robert Welton[3]; Vic Andzulis[1]

[1] *Oak Ridge National Laboratory*

[2] *SNS ORNL*

[3] *ORNL-SNS*

Corresponding Author: welton@ornl.gov

The U.S. Spallation Neutron Source (SNS) is a state-of-the-art neutron scattering facility delivering the world's most intense pulsed neutron beams to a wide array of instruments which are used to conduct investigations in many fields of science and engineering. Neutrons are produced by spallation reactions within a liquid Hg target bombarded by protons from a storage ring that is supplied by a high-intensity, 1 GeV H- LINAC. The LINAC is, in turn, fed by an RF-driven, multicusp, H- ion

source which provides 50-60 mA of ions with a pulse width of 1ms and repetition rate of 60Hz (6% duty-factor) for maintenance-free runs of several months with near 100% availability. The ion source research and development program at ORNL has played a key role in enabling and supporting this success and continues to provide sufficient beam current margin for future facility upgrades. This report provides a discussion of ongoing design work which has been undertaken since the previous ICIS conference in 2021. These include (i) mechanical modifications to the source outlet aperture size which resulted in dramatically increased beam current from the source, (ii) refinement of the SNS Allison emittance scanner that has enabled LEBT beam measurements at full beam power, (iii) modelling-driven improvements to the LEBT chopper target which should enable full beam-blanking during routine operations, (iv) the design and initial data from a thermal imaging system for the electrostatic Low Energy Beam Transport (LEBT) that tracks lens temperatures during routine operations allowing early intervention before thermal runaway and finally, (v) the design of an advanced elemental Cs system capable of more precise control of source cesiations compared with the Cs2CrO4 system.

Funding Agency:

DOE

Email Address:

welton@ornl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 113

Factors Influencing the Fluctuation Amplitude of the H- Ion Beam Extracted from an RF Wave Excited Ion Source Plasma

Author: Motoi Wada[1]

Co-authors: Katsuhiro Shinto [2]; Takanori Shibata [3]

[1] *Doshisha University*

[2] *J-PARC center / Japan Atomic Energy Agency*

[3] *KEK*

Corresponding Author: takanori.shibata@kek.jp

An internal antenna type RF driven negative hydrogen (H^-) ion source supplies beams to the J-PARC accelerator facility. The H^- ion beam current exhibits high stability, while it fluctuates with less than 5% amplitude of the DC current when a Faraday cup measures the current extracted from the source mounted on a test stand. Two frequencies are identified as the main oscillation components, 2 MHz and 4 MHz which are the driving RF frequency and the second harmonic, respectively. The amplitude levels of these components appear larger as parts of the beam directing specific angles passing through a slit are detected. A possible reason for observing a small amplitude oscillation in the total beam intensity is the averaged phase-shift of the local beam depending upon the position of the H^- ion production and the succeeding trajectory reaching the Faraday cup. To confirm if the phase-shift is the main reason for diminishing the oscillation amplitude for the total beam, the phase-shift between the 2 MHz and 4 MHz components were measured for beams passing through a 0.1 mm slit detected by a Faraday cup having a 0.1 mm entrance slit. The result indicated the phase-shift changed substantially depending upon the position, but no simple model can explain the measured spatial distribution of the phase-shift. Further attempts will be made to clarify the beam dynamics relevant to the H^- ion beam transport including the measurements of the beam current phase-shift with respect to the RF antenna current, and the time evolution of Balmer-α light emission from the source plasma.

Funding Agency:

Japan Society of Promotion of Science

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Takanori Shibata

Monday / 118

Extraction of Conversing Ion Beam from Laser Ion Source for Direct Plasma Injection Scheme

Author: Kazumasa Takahashi[1]

Co-authors: Masahiro Okamura [2]; Shunsuke Ikeda [3]; Takashi Kikuchi [1]; Takeshi Kanesue [2]; Toru Sasaki [1]

[1] *Nagaoka University of Technology*

[2] *Brookhaven National Laboratory*

[3] *BROOKHAVEN NATIONAL LABORATORY*

Corresponding Author: kazumasa@vos.nagaokaut.ac.jp

Laser ion sources are expected to be used in various applications of heavy ion beam technology. The plasma direct injection scheme (DPIS) is a method used to accelerate high-current ion beams extracted from a laser ion source, which are then injected into a radio frequency quadrupole (RFQ) linear accelerator. In this study, a new injection method was demonstrated that avoids the RF field of the RFQ linear accelerator affecting the ions in the beam extraction gap. In this method, an ion beam is extracted from a plasma using an electric field generated at a gap between an electrode that can extract a converging ion beam and a grounded aperture. The ion beam passes through the aperture and is then injected into the RFQ linear accelerator. This approach allows the use of a large-diameter extraction electrode, which is not limited by the spacing of the RFQ electrode rods. The proposed electrode was found to allow a larger ion beam current to be extracted than the conventional electrode. It was also shown that the current can be further increased by applying a solenoidal magnetic field to the laser-produced plasma. However, it was observed that the beam current depends on the inner diameter of the transport pipe leading to the gap for ion beam extraction.

Funding Agency:

Email Address:

kazumasa@vos.nagaokaut.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 151

Implantation Chamber for Molecular Beam Development and Diffusion Studies

Author: Wiktoria Wojtaczka[1]

Co-authors: Edgar Reis [2]; Edgars Mamis [2]; Mathieu Bovigny [2]; Mia Au [2]; Sebastian Rothe [2]; Simon Stegemann [2]; Thomas Cocolios [1]

[1] *KU Leuven*

[2] *CERN*

Corresponding Author: wiktoria.wojtaczka@kuleuven.be

The ISOL (Isotope Separation On-Line) method has been widely used for the production of radioactive ion beams for nuclear physics research. The development of isotope extraction via molecular sidebands has gained significant interest in recent years [1,2,3] because of their potential to provide access to less volatile elements that are otherwise not possible to extract out of the target. In this context, we present the commissioning of an implantation chamber designed for molecular beam development and diffusion studies. The set up consists of a heatable sample holder located in a vacuum chamber and connected to a residual gas analyser (RGA). Ion beams, provided for example by an off-line separator, are implanted into the sample, after which an oven heats up the sample to release implanted species which are subsequently studied in the RGA. The system was commissioned at the off-line separator at ISOLDE using various molecular species with the FEBIAD ion source [4]. The same principle may be employed to study diffusion characteristics by implanting isotopes into materials of interest and study the release profile in the RGA upon sample heating. The implantation chamber is currently coupled to the Offline 1 separator at ISOLDE [5] where it is being characterized; it can also be completely isolated from the separator.
[1] J. Ballof "Radioactive molecular beams at CERN-ISOLDE." CERN PhD Thesis (2021)
[2] G. Arrowsmith-Kron et al. arXiv preprint, arXiv:2302.02165 (2023)
[3] M. Kronberger et al. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 317 (2013): 438-441
[4] L. Penescu et al. Review of Scientific Instruments 81.2 (2010): 02A906
[5] J. Lettry, Off-Line Isotope Separator, 1994. URL https://cds.cern.ch/record/2691985

Funding Agency:

Research Foundation –Flanders

Email Address:

wiktoria.wojtaczka@kuleuven.be

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 161

Pulse Stretching Out of the CANREB EBIS

Author: Mathieu Cavenaile[1]

Co-authors: Brad Schultz [1]; Christopher Charles [1]; Friedhelm Ames [1]; Oliver Kester [1]; Rituparna Kanungo [2]

[1] *TRIUMF*

[2] *Saint Mary's University*

Corresponding Author: mcavenaile@triumf.ca

The CANadian Rare isotope facility with Electron-Beam ion source (CANREB) at TRIUMF is set to deliver rare isotope beams in high charge states. In the Electron Beam Ion Source (EBIS) ions are charge-bred by collisions with an electron beam of up to 500 mA. A strong magnetic field (up to 6T) maximizes the overlap between ions and electron beam and increases the breeding efficiency. Ion confinement is maintained by a combination of an electrostatic field and the electron beam space-charge potential. Ions are released by lowering the trapping potential with a step function. The system is operated at a pulse repetition frequency up to 100 Hz.
Due to the short trap length, this fast extraction scheme produces pulses shorter than 10 μs with high instantaneous rates that can saturate detectors in experiments. Stretching the pulse can be done using a slowly varying voltage function to modify trap electrode potentials instead of a step function. The ideal function produces a pulse with a flat top distribution and can be calculated by knowing the ion energy distribution inside the trap. The latest pulse stretching results will be discussed including the latest pulse durations up to 1.4 ms that have been produced. The slow extraction scheme has also been used for a measurement of the effective energy distribution of the ions inside the trap.

Funding Agency:

Email Address:

mcavenaile@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Monday / 183

Dynamic Change of the Negative Ion Yield and Work Function of Plasma Electrode Materials due to Hydrogen Plasma Exposure

Author: Mamiko Sasao[1]

Co-authors: Gilles Cartry [2]; Haruhisa Nakano [3]; Jean-Marc Layet [2]; Juan-Pablo Broude [4]; Mayuko Nishiwaki [5]; Motoi Wada [5]

[1] *Organization for Research Initiatives and Development, Doshisha University*

[2] *Aix-Marseille Université*

[3] *National Institute of Fusion ScienceNIFS*

[4] *Aix-Marseille University*

[5] *Doshisha University*

Corresponding Author: mnsasao@yahoo.co.jp

The work function of plasma electrodes (PE) in negative hydrogen ion sources plays an important role to increase the H-/D- yields, and cesium (Cs) are currently used to control the work function. It has been known that a half monolayer (or less) Cs coverage shows the minimum work function, but it can be decreased more when the surface is immersed in a hydrogen plasma (Wada et al., 1990, and Cristofaro et al., 2017).
Recently, a new material, C12A7 electride has been studied as one of the promising candidate PE materials for Cs-free negative hydrogen ion sources (Sasao et al., 2018), and the work function of this material was affected by positive or negative electrical bias applied with respect to surrounding plasma (Heiler et al., 2021).
In order to clarify the mechanism that changes electride work function due to plasma exposure, series of experiments were carried out using a surface produced negative ion measurement system and a photoelectron yield spectroscopy system installed on the diffusion plasma reactor at PIIM Aix-Marseille University (Cartry, 2017, Cartry, 2023). In the present paper, we report unique phenomena

of rapid and dynamic change of the work-function of C12A7 electride, of the time constant of several ten-seconds observed after the plasma turn-off. This phenomenon was investigated for various plasma and surface conditions. By measuring the energy spectra of negative ions emitted perpendicularly from the surface, roles of hydrogen absorbate on work function reduction and hence on the H- production by the backscattering and desorption processes are investigated. The knowledge obtained in the present work are discussed from viewpoints of design and operation of ion sources with plasma electrodes or plasma grids of C12A7 electride.

Funding Agency:

Doshisha University

Email Address:

msasao@mail.doshisha.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

MAMIKO SASAO

Tuesday / 64

Experimental and Numerical Characterization of the TRIUMF-FEBIAD Cathode Used to Produce Radioactive Ions

Author: Fernando Alejandro Maldonado Millan[1]

Co-authors: Alexander Gottberg [2]; Carla Babcock [2]; Tom Day Goodacre [2]

[1] *UVIC/TRIUMF*

[2] *TRIUMF*

Corresponding Author: maldonado@triumf.ca

The FEBIAD ion source is routinely used to produce radioactive ions of halogens, molecules, and noble gases in several ISOL facilities worldwide. At TRIUMF, an extensive numerical and experimental campaign has been performed to fundamentally understand the source while improving its reliability and overall performance. Particularly, the cathode temperature has been studied by pyrometric measurements and numerical simulations. The temperature found in and around the cathode face explains the electron emission profile, and why not all the emitted electrons are available for the ionization process. The main findings have been used on a numerical ionization model for more realistic electron emission.

Funding Agency:

Email Address:

maldonado@trimf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 189

Development of a Novel Internal Radiofrequency Ion Source for Cyclotrons

Author: Miguel LEON LOPEZ[1]

Co-authors: Antonio ESTEVEZ FORNARI [1]; Concepción OLIVER AMOROS [1]; Daniel GAVELA PEREZ [1]; Diego OBRADORS CAMPOS [1]; Fernando TORAL FERNANDEZ [1]; José Manuel PEREZ MORALES [1]; Luis GARCIA-TABARES RODRIGUEZ [1]; Pedro CALVO PORTELA [1]; Tomas ERIKSSON [2]

[1] *CIEMAT*

[2] *GE HealthCare*

Corresponding Author: miguel.leon@ciemat.es

Abstract:

IRISC (Internal Radiofrequency Ion Source for Cyclotrons) is an innovative design of an internal ion source, primarily for producing H- ions, in which radiofrequency (RF) power is supplied to its electrodes for achieving electron emission. Theoretical work shows that both lower electrode sputtering and higher ion production efficiency may be achieved as compared to its standard direct current (DC) counterparts. Thus, IRISC arises as a ground-breaking Penning ion source with significant importance for compact cyclotrons. IRISC dimensions have been matched to CIEMAT's AMIT DC cold-cathode ion source so that side-by-side testing might be carried out and, eventually, both types can be used within the AMIT cyclotron. This contribution presents IRISC RF simulations, key design aspects, feedback from manufacturing process of the first prototype and early-stage test results.

Funding Agency:

EU Horizon 2020 Grant Agreement 101004730

Email Address:

miguel.leon@ciemat.es

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Miguel LEON LOPEZ

Tuesday / 112

Formation of Self-Focused Ion Beam

Author: Vadim Dudnikov[1]

[1] *retired*

Corresponding Author: taneli.kalvas@jyu.fi

The formation of self-focused ion beam with a small diameter is proposed. The device for the formation of self-focused ion beam consists of a hollow anode and enveloped anode, separated from the anode by an insulator, gas delivery system. A discharge is supported by the voltage applied between the cathode and anode. The ion beam is self-focused by the spherical emission surface of emitting plasma.
The result of computer simulation of self-focused ion beam production is presented. The device for self-focused ion beam production is described.

Funding Agency:

doe

Email Address:

dvg43@yahoo.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Vadim Dudnikov

Tuesday / 105

Modelling of Plasma Discharge in a Filament Negative Ion Source

Author: Valeria Candeloro[1]

Co-authors: Emanuele Sartori [2]; Masashi Kisaki [3]; Mieko Kashiwagi [3]; Hiroyuki Tobari [3]; Gianluigi Serianni [4]

[1] *Centro Ricerche Fusione (CRF) - UNIPD*

[2] *Università degli Studi di Padova*

[3] *National Institutes for Quantum and Radiological Science and Technology (QST)*

[4] *Consorzio RFX*

Corresponding Author: emanuele.sartori@igi.cnr.it

Most of the currently operating Negative ion Neutral Beam Injectors (N-NBIs) exploit filament-powered sources for the generation of beam ions. Being widely used in fusion experiments, the arc technology has been thoroughly investigated and optimized over the years, allowing to achieve excellent performances in terms of extracted beam optics.

The source geometry, the magnetic field topology and the arc power strongly influence both the plasma discharge and the background gas properties and, consequently, the beam features. In this framework, this contribution describes a numerical investigation of the plasma properties in a filament-powered negative ion source, performed by means of a 2D3V PIC-MCC code. Specifically, we discuss plasma formation by the thermionic electrons emitted by the filaments, investigating their interaction with the background gas. We also study the plasma diffusion through the magnetic filter field and how the latter modifies plasma density, electron temperature and plasma potential along the axial direction when approaching the plasma facing electrode. The positive ion and neutral properties in the proximity of the extraction region are characterised, as the former are the base of the surface production mechanism of negative ions. Finally, we also examine the influence of multi-cusp confinement on the behaviour of filament sources.

The results of this numerical investigation will be helpful to define what are the key physical phenomena underlying the efficiency of filament sources, and will contribute to the development of Radio-Frequency (RF) driven negative ion sources for ITER, in the perspective of reducing the performance gap for the production of cold negative ion beams.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 125

Charge State Dependence in Increase of Ion Beam Current from Laser Ion Source by Applying Solenoidal Magnetic Field

Author: Kaoru Ishikuro[1]

Co-authors: Kazumasa Takahashi [1]; Toru Sasaki [1]; Takashi Kikuchi [1]; Jun Hasegawa [2]; Jun Tamura [3]; Kazuhiko Horioka [2]; Ken Takayama [4]

[1] *Nagaoka University of Technology*

[2] *Tokyo Institute of Technology*

[3] *JAEA*

[4] *KEK*

Corresponding Author: s203119@stn.nagaokaut.ac.jp

Applying a solenoidal magnetic field to a laser produced plasma is a method to increase the ion beam current supplied from a laser ion source. The purpose of this study is to investigate the ion charge state dependence of the beam current increase in the laser ion source by applying a solenoidal magnetic field. The plasma generated by a Nd:YAG laser was injected into a magnetic field generated by a solenoid coil with length of 30 mm. The current waveforms of the ion beam extracted from plasmas were measured as a function of the magnetic flux density for the solenoidal field. In addition, the beam current waveforms at each charge state were analyzed by magnetic deflection. Based on the beam current for total ions and one for each charge states, we will discuss the ion charge state dependence in multiplication factor of ion beam current by applying the solenoidal magnetic field.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 135

Study on Ion Current Density of Different Species in Laser Produced Plasma in a Solenoid Magnet

Authors: Masahiro Okamura[1]; Sergey Kondrashev[1]; Shunsuke Ikeda[2]; Takeshi Kanesue[1]

[1] *Brookhaven National Laboratory*

[2] *BROOKHAVEN NATIONAL LABORATORY*

Corresponding Author: tkanesue@bnl.gov

A solenoid magnetic field along the expanding laser-produced plasma is an essential technique of a laser ablation ion source, which can increase ion beam current at beam extraction by a factor of 2. Solenoid field is also practically important for beam operation to control beam current without changing the condition of laser ablation. However, the motion of laser-produced plasma influenced by the solenoid field is not fully understood. To better understand the effect of the solenoid field, ion current density along the solenoid including fringe field region is experimentally investigated from different species of different mass. The result of the experiment will be discussed.

Funding Agency:

Email Address:

tkanesue@bnl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 20

A High-Intensity, Low-Energy Heavy Ion Source for a Neutron Target Proof-of-Principle Experiment at LANSCE

Author: Andrew Cooper[1]

Co-authors: Aaron Couture [1]; Rene Reifarth [2]; Shea Mosby [1]

[1] *Los Alamos National Laboratory*

[2] *Goethe University Frankfurt*

Corresponding Author: alcooper@lanl.gov

The capability to directly study neutron capture reactions on radionuclides with half-lives on the order of minutes would allow key cross section measurements in nuclear astrophysics and energy applications. However, such experiments with stationary targets are currently impossible because of signal detection and target sample fielding issues. To overcome these challenges, a neutron target facility is being developed to permit neutron capture experiments on unstable isotopes in inverse kinematics at the Los Alamos Neutron Science Center (LANSCE). This next-generation facility will consist of a heavily moderated, high-intensity spallation neutron target coupled with a radioactive ion beam storage ring. A proof-of-principle experiment is underway to demonstrate this neutron target concept at LANSCE in the near term with stable ions and without a storage ring. Here, mA-level beams of 10-50 keV heavy ions exhibiting large resonant neutron capture cross sections will be generated by a new ion source, transported through a large-volume neutron moderator surrounding an adjacent spallation target driven by the LANSCE accelerator, and collected downstream of the moderator for subsequent decay-counting measurements. The neutron density within the moderator will be obtained from these decay yields and compared with Monte Carlo N-Particle (MCNP) simulation results. The science application, operational requirements, and performance objectives for this heavy ion source will be presented.

Funding Agency:

U.S. DOE and NNSA

Email Address:

alcooper@lanl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 29

A Long-life Laser Ion Source Using a Reproducible Solidified Gas Target

Authors: Jun Hasegawa[1]; Yuji Inoue[2]; Naoki Matsubara[2]; Jun Tamura[3]; Kazumasa Takahashi[4]; Kazuhiko Horioka[2]; Ken Takayama[5]

[1] *Laboratory for Zero Carbon Energy, Institute of Innovative Research, Tokyo Institute of Technology*

[2] *Tokyo Institute of Technology*

[3] *Japan Atomic Energy Agency*

[4] *Nagaoka University of Technology*

[5] *High Energy Accelerator Research Organization (KEK)*

Corresponding Author: hasegawa.j.aa@m.titech.ac.jp

A laser ion source employing a cryogenically solidified gas target has been developed and demonstrated to supply highly charged carbon ions for a long period of time without being limited by the lifetime of the laser target. This new laser ion source is expected to be applied to the next-generation heavy ion cancer treatment accelerator based on inductive synchrotron technology. A solid carbon dioxide (CO2) layer with a thickness of about 10-500 μm was formed on the cylindrical cold head cooled by liquid nitrogen by sublimation of CO2 gas. By irradiating the layer with a frequency-doubled Nd:YAG laser, an ablation plasma containing highly charged carbon ions was generated and analyzed. Although the solid CO2 layer is locally removed by a single laser irradiation, we could stably and repeatedly supply carbon ions by precisely controlling the laser irradiation position on the target with stage controllers. We found that the thickness of the CO2 layer strongly affected not only the size of the removed layer, but also the damage on the cold head surface. These results are likely due to the laser peening effect associated with laser ablation. In the presentation, we discuss several important issues essential for the practical application of laser ion sources using the reproducible cryogenic target, i.e., optimization of conditions for cryogenic target formation, reproducibility of laser ablation from regenerated solid CO2 layers, and damage to the substrate accompanying laser irradiation and their mitigation measures.

Funding Agency:

Email Address:

hasegawa.j.aa@m.titech.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Tuesday / 71

The Evolution of ALISES III

Author: Augustin Dubois[None]

Co-authors: Francis Harrault [1]; Olivier Delferriere [2]; Olivier Tuske [3]; Yannick Gauthier [1]; Yannick Sauce [1]

[1] *Université Paris-Saclay, CEA, Département des Accélérateurs, de la Cryogénie et du Magnétisme, 91191, Gif-sur-Yvette, France.*

[2] *CEA-Saclay*

[3] *CEA SAclay, France*

Corresponding Authors: augustin.dubois@cea.fr, olivier.delferriere@cea.fr, otuske@cea.fr

Since 1995, the Laboratory for Accelerator Studies and Development at CEA Saclay specializes in producing ECR intense light Ion Sources, for high intensity proton or deuteron. The initial source SILHI designed for IPHI accelerator was the root of the sources provided to laboratories around the world, such as IFMIF, FAIR or SPIRAL2. In parallel, the Ion Source team started a new R&D program on high intensity ECR compact ion sources with the ALISES source family.
The years spent on testing and improving ALISES I & II lead us to design a new source, named ALISES 3. The development of this source gathers the advantages of each improvement tested on ALISES I & II, to achieve an even smaller and pragmatic configuration.
The manufacturing of ALISES 3 took place during the improvement of the BETSI test bench, from 50kV to 100kV. The goal of this source is to obtain the same characteristics as the original SILHI, with fewer parts and easier maintenance.
This paper describes the evolution of ALISES 3 and the beam characteristics at each step. BETSI test bench is equipped with an Allison Scanner and Faraday cup to analyze the emittance and the beam current.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / **72**

Production of Intense Uranium Ion Beam for RIKEN RI Beam Factory

Author: Yoshihide Higurashi[1]

Co-authors: Takahide Nakagawa [1]; Jun-ichi Ohnishi ; Hiromitsu Haba [1]; Glynnis Mae Saquilayan [1]

[1] *RIKEN*

Corresponding Author: glynnismae.saquilayan@riken.jp

Production of intense highly charged uranium (U) ion beam is strongly demanded to produce intense radioactive isotope (RI) beam at several accelerator facilities, because of its high efficiency of RI production with the in-flight fission of U ion. At RIKEN, intense highly charged U ion beam from ion source has been required for this purpose. To meet the requirement, in the beginning, we used the sputtering method and successfully produced intense U ion beam. However, in the experience of U ion beam production for long term, we recognized that we need to produce more stable and intense beam from the ion source using another method. Because a metallic U rod always interacts with plasma and this method sometimes destabilizes plasma. Therefore, we developed the high temperature oven (HTO) to produce U vapor and tried to produce intense and stable beam of highly charged U ion. Additionally, to supply enough vapor, we developed the double oven system and studied the effect of the consumption rate on the beam intensity of highly charged U ion systematically. Based on the results, we optimized the consumption rate to maximize the beam intensity. Consequently, intense U ion beams of, 350 electric micro A of U33+ (consumption rate of about 12 mg/h) 250 electric micro A of U35+ (about 10 mg/h), 36 electric micro A of U46+ (about 3 mg/h) and 10 electric micro A of U54+ (less than 1 mg/h), were successfully produced at the injected microwave power of about 3 kW. In these experiments, we also measured the emittance of the U35+ ion beam under the various conditions. We observed that the emittance is strongly dependent on the extraction beam intensity.
In this contribution, a brief review of the recent developments, especially optimization of the material consumption rate to maximize the beam intensity, leading to these intensities and systematical study of the emittance, are presented.

Funding Agency:

Email Address:

higurasi@riken.jp

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Tuesday / 74

Simulation of Laser-Plasma Focusing with a Tapered Solenoid Magnet

Author: Seiji Hosoya[1]

Co-authors: Hirotsugu Kashiwagi [2]; Keisuke Yamada [1]

[1] *National Institutes for Quantum Science and Technology*

[2] *QST*

Corresponding Author: kashiwagi.hirotsugu@qst.go.jp

The Laser Ion Source (LIS) can generate ion beams of various elements, including metals with high melting points. Since rapid beam switching is possible by loading multiple solid targets, we are developing LIS with the goal of mounting it in the 400 kV ion implanter, which requires a wide variety of ion species.
LIS can generate a high current ion beam by increasing laser energy. Also, by increasing the laser repetition rate, a large average current can be obtained. However, this method has the problem of consuming a significant amount of the target during long operation periods. In addition, since LIS plasma has a wide angular distribution, only a fraction of the plasma is used to produce an ion beam, and most is lost in the chamber. In order to obtain large current with relatively small laser energy and low target consumption, we are studying the use of a taper solenoid magnet near the plasma generation point to suppress plasma diffusion and increase the fraction of plasma converted into a beam. In the conference, we will report the results of simulation of plasma trajectory in a tapered solenoid magnetic field using the Particle-In-Cell (PIC) method.
This work was supported by JSPS KAKENHI Grant Number 21H03749.

Funding Agency:

Email Address:

hosoya.seiji@qst.go.jp

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Hirotsugu Kashiwagi

Tuesday / 81

Research and Development Activities to Increase the Performance of the CAPRICE ECRIS at GSI

Author: Fabio Maimone[1]

Co-authors: Aleksandr Andreev [1]; Michael Galonska [1]; Ralph Hollinger [1]; Ralf Lang [1]; Jan Mäder [1]; Patrick Tedit Patchakui [1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung*

Corresponding Author: f.maimone@gsi.de

At GSI the CAPRICE ECRIS is in operation to deliver high-charge state ion beams from gaseous and metallic elements to the accelerator facility. In order to fulfill the demand for higher intensity and stability of high-charge state ions, a test campaign has been carried out at the ECR test bench. The objective of the measurements was the enhancement of ion source performance in terms of extracted current and charge states of gaseous and metallic ion beams in CW mode and in pulsed mode by tuning the ion source parameters.
The ion beam stability has been monitored by an optical emission spectrometer (OES) which has been used to check the plasma and the temperature of the resistively heated oven. The OES has been already used as a diagnostic tool for ion source monitoring during metal ion beam operation in particular for Ca ion beams. During the test campaign, it has been investigated that the OES can be used for monitoring the stability of ion beams from gaseous elements, as well.
The main achieved results during the measurement campaign are reported.
The ion beams extracted from the CAPRICE ECRIS have been simulated with a particle tracking code in order to study and improve the beam matching into the RFQ. The preliminary results of this study together with the possible modification of the extraction column are presented.

Funding Agency:

Email Address:

f.maimone@gsi.de

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / **92**

Application of Optical Emission Spectroscopy to Electron Cyclotron Resonance Ion Sources

Authors: Giuseppe Castro[1]; Ornella Leonardi[1]; Filippo Russo[2]; Davide Siliato[2]; Grazia D'Agostino[2]; Giacomo Costanzo[2]; Luigi Celona[1]; Santo Gammino[1]; Riccardo Reitano[3]

[1] *INFN-LNS*

[2] *INFN-Laboratori Nazionali del Sud*

[3] *Università degli studi di Catania - Physics department*

Corresponding Author: castrog@lns.infn.it

Electron Cyclotron Resonance Ion Sources (ECRIS) are widely used to produce highly charged high intensity ion beams for research, medical and industrial applications.
ECRIS performances, namely the charge state distribution and beam intensity, depend critically on the electron energy distribution function. Further improvements of ECRIS performances require a deeper and deeper understanding of the plasma heating mechanisms and ion generation by means of opportune plasma diagnostics. Amongst others, Optical Emission Spectroscopy (OES) is the most remarkable for application in ECRIS: it is a non-invasive diagnostic able to operate also in high-voltage conditions and it requires only small room for operation. OES has been already tested for plasma diagnostics in proton sources.
This work presents the experimental set-up developed for the plasma diagnostic of the Advanced Ion

Source for Hadrontherapy (AISHa), an ECRIS for medical applications, together with the strategy used to relate plasma emission lines in the visible and near-infrared domain to plasma parameters for some ions of interest. Preliminary experimental results on a plasma reactor and perspectives will be also discussed.

Funding Agency:

5th National Committee of INFN - Grant IONS

Email Address:

castrog@lns.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 103

Multi-Charged Phosphorus and Cesium Beams at the OLIS Facility at TRIUMF

Author: Christopher Charles[1]

Co-authors: Bianca Currie [2]; Brian Minato [1]; Claire Hamilton [1]; Friedhelm Ames [1]; Keerthi Jayamanna [1]; Maia Pysklywec [3]; Marco Lovera [1]; Olivier Shelbaya [1]; Spencer Kiy [1]; Tiffany Angus [1]

[1] *TRIUMF*

[2] *UWO*

[3] *University of Victoria*

Corresponding Author: ccharles@triumf.ca

We describe the development of novel $^{31}P^{+n}$ and $^{133}Cs^{+n}$ beams for fundamental nuclear astrophysics research at TRIUMF's ISAC (Isotope Separator and ACcelerator) complex. Both beams were individually created for different experiments, and for the first time at TRIUMF's Off-Line Ion Sources (OLIS) facility by dual-frequency electron cyclotron resonance (ECR) using a Supernanogan ion source. Vapour pressures produced from pure samples of both elements were created and directed into the ECR plasma without support gas following heating of either (a) red phosphorus in an oven facing the plasma, or (b) cesium metal in a custom boiler/heater and transfer-line assembly. Charge-state spectra of $^{31}P^{+n}$ and $^{133}Cs^{+n}$ obtained before and after the ISAC linear accelerator confirmed the isotopic identity and purity of each beam. P and Cs expands the portfolio of available stable beams at ISAC to quantify the reaction rates of explosive nucleosynthetic processes, i.e. ^{133}Cs to constrain neutron capture rates of r-process nucleosynthesis, while ^{31}P to constrain thermonuclear reaction rates in the convective-reactive regions of AGB stars, novae, and phosphorus-rich stars with unexpected overabundances of elements.

Funding Agency:

NSERC

Email Address:

ccharles@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 106

Positive to Negative Helium Ion Production Ratios when Using Nano-Foils as a Charge Exchange Medium

Author: Philip Jackle[1]

Co-authors: Aleksei Bunevich [1]; Karen Kavanagh [1]; Morgan Dehnel [2]

[1] *Simon Fraser University*

[2] *D-Pace, Inc.*

Corresponding Author: pjackle@sfu.ca

Negative helium ions are typically created from positive helium ions which undergo double charge exchange with a neutral, atomic vapour, in a metallic vapour charge exchange apparatus. For high production rates of He^- (1 to 5%) alkali metals are used as the charge exchange material. However, alkali vapours are deleterious in vacuum systems, particularly ones with nearby electrodes for beam optics or acceleration. Additionally, He^- is used in power semiconductor wafer manufacture, where alkali metals are contaminants.
Here we describe ongoing efforts to measure the creation of negative helium using nanometer-range foils of carbon as the charge exchange medium, thus avoiding problematic metallic vapours. A helium ion microscope (HIM) is used as a source of He^+ (15 keV to 30 keV, 50 fA to 10 pA), modified to include a radiation camera (Advacam MiniPIX) for ion detection. The use of carbon foils up to 50 nm thick are investigated, with conversion rates of He^+ to He^- reported and observations made on effects to the foil due to He^+ bombardment. Future work will investigate the use of other foil materials.

Funding Agency:

NSERC Alliance

Email Address:

pjackle@sfu.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 108

Status Update of the ATLAS ECR Ion Sources at Argonne National Laboratory

Author: Robert Scott[1]

Co-authors: Jake McLain [1]; Richard Vondrasek [1]

[1] *Argonne National Laboratory*

Corresponding Author: rscott@anl.gov

The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory typically operates 24 /7 with weekly ion beam changes and an annual 1 month maintenance period. Due to recent installations and upgrades at ATLAS, user demands for new beams and higher intensities have expanded an already diverse operational envelope of both electron cyclotron resonance ion sources (ECRIS), ECR2 and ECR3. A variety of material introduction techniques including sputter, oven, reduction and gas feed were used to meet the challenge of an intense run schedule. With two ECRIS

available to feed the accelerator, beam development and preparation were able to occur concurrently with ATLAS programmatic activities. Highlights of operational experiences and improvements with ECR2 and ECR3 over the last 2 years are presented.

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

Funding Agency:

U.S. D.O.E, Office of Nuclear Physics

Email Address:

rscott@anl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 110

Design and Evaluation of Laser Ablation Source for Isotope Analysis on TITAN

Author: Behnam Ashrafkhani[1]

Co-authors: Ania Kwiatkowski [2]; Chris Chambers [2]; Michael Wieser [1]; Robert Ian Thompson [1]

[1] *University of Calgary*

[2] *TRIUMF*

Corresponding Author: behnam.ashrafkhan1@ucalgary.ca

Laser ablation source (LAS) is an adaptable and efficient ion production technique for mass spectrometry, allowing for flexible analysis of various sample types. By depositing laser energy into the target, atoms or molecules in the sample are ionized. The development of a LAS for supplying stable isotopes to TRIUMF's TITAN platform enables novel studies, such as isotope abundance measurement and precision mass measurement calibration. To ensure reproducibility and accuracy with this technique, efficient ion transport and consistent initial conditions must be maintained, including ionization efficiency, narrow energy distribution, and controlled beam divergence. Achieving efficient ion capture across the entire surface of a sample and reliable ion delivery from target to mass spectrometer through ion optics is also crucial for accurate results. To overcome these challenges, the study used SIMION software to optimize the ion optical design and improve performance.
The low number of ions of interest relative to the total number produced (e.g., 10 ions of interest out of 10^14 ions) is a key factor investigated in LAS performance. Thus, specific attention was paid to the design to realize efficient production and capture of the ions with a "built-in"low-resolution mass filter. To identify the effective operational range, energy distribution, beam divergence, and ablation spot position were examined. In addition, the study explored the innovative use of high voltage switching on bender electrodes to enable high pass mass filtering, the integration of Pierce electrodes to shape the beam, and the use of Einzel lenses to collimate the ion beam.
The combination of the nanosecond pulsed laser ablation ion source with a multi-reflection time-of-flight mass spectrometer MR-TOF-MS should result in an analytical tool designed to achieve high spatial resolution (50 µm) and high transport efficiency within energy distributions of 0-50 eV for beam divergence angle under 30⊠.

Funding Agency:

NSERC

Email Address:

behnam.ashrafkhan1@ucalgary.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Behnam Ashrafkhani

Tuesday / 111

High Current Positive Ion Source for Copernicus NBI Based on a Cold-Cathode Arc Plasma Generator

Author: Yuji Shimabukuro[1]

Co-authors: Christopher Campbell [2]; Anton Bondarenko [2]; Kurt Knapp [2]; Tadafumi Matsumoto [2]; Sergey Korepanov [2]

[1] *University of California, Irvine*

[2] *TAE Technologies*

Corresponding Author: yshimabukuro@tae.com

At TAE Technologies, a next-generation Field-Reversed Configuration (FRC), known as Copernicus, is being built. The current device, C-2W, has achieved steady-state beam-driven FRCs up to 30 ms using four 15 kV and four 40 kV NBIs(neutral beam injector)[1]. In order to increase FRC performance in the next generation device, both beam energy and beam power will be increased beyond these values.
The positive ion source in development is composed of 8 arc drivers [2] and a 720x360x300 mm expansion chamber. The arc plasma initiated by the spark at the cold cathode needle tip grows up to 600 A of arc current and is emitted to the expansion chamber. The duoplasmatron type arc driver emitted highly ionized plasma jet is collisionless and travels toward the plasma grid (PG) within the expansion chamber. The arc driver can produce high proton ratio, low transverse ion temperature, and high ion current density plasma regardless of the chamber dimensions. Plasma uniformity is one of the big challenges in this type of ion source since the produced plasma naturally has a peak at the center of the driver axis [3,4]. To improve spatial uniformity especially in the peripheral region, the expansion chamber is surrounded by NdFeB magnets along the beam axis to reflect positive ions [2, 5]. For the uniformity estimation, a three-dimensional proton trajectory calculation considering the initial ion velocity was adopted and could reproduce the previous configuration. The new arc driver's layout for Copernicus has been optimized using the developed method, and the calculated uniformity is 85% over the extraction area.
In this paper, improvement of the source uniformity for the large high current ion source of Copernicus NBI and relevant diagnostics development will be discussed.
[1] H.Gota et al., Nucl. Fusion 61,106039(2021).
[2] P.Deichuli et al., RSI 75,1816(2004).
[3] W.Stirling et al., RSI 48,533(1977).
[4] C.Tsai et al., RSI 48,651(1977).
[5] P.Deichuli et al., RSI 86,113509(2015).

Funding Agency:

Email Address:

yshimabukuro@tae.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 116

Development of a New J-PARC-Made Internal Antenna for the J-PARC RF-Driven H^- Ion Source

Author: Katsuhiro Shinto[1]

Co-authors: Takanori Shibata [2]; Kiyonori Ohkoshi [1]; Kesao Nanmo [3]; Isao Kawai [4]; Kiyoshi Ikegami [3]

[1] *J-PARC center / Japan Atomic Energy Agency*

[2] *KEK*

[3] *J-PARC center / High Energy Accelerator Research Organization (KEK)*

[4] *Nihon Axis Co., Ltd*

Corresponding Author: takanori.shibata@kek.jp

We have been conducting the test of a new home-made internal antenna for the J-PARC RF-driven cesiated H^- ion source. After the development of the first J-PARC-made antenna, the composition of the porcelain enamel coating of the antenna was changed to reduce possible outgassing of the impurities from the previous antenna coating. During the test of high-density plasma production by the new antenna, we monitored the outgassing characteristics of the new antenna by measuring the mass spectrum of the source gas and optical emission spectrum of the plasma. It is confirmed that no remarkable impurities were detected from the new antenna. We also carried out the H^- beam extraction and measured the H^- beam characteristics by using the new antenna. The observed emittances of the H^- beam extracted from the J-PARC RF-driven cesiated H^- ion source by using the new antenna were similar to those by using the SNS-made antenna. To accelerate the endurance test of the new antenna, we applied the antenna for the high-density plasma production to the 5% duty factor (1 ms pulse width with 50 Hz repetition rate) with the 2 MHz RF input power of approximately 60 kW. These values are much higher than those in the J-PARC nominal operation; 0.8 ms pulse width with 25 Hz repetition rate (the duty factor of 2%) with the RF input power of approximately 30 kW. This presentation shows the results of the characteristics of the new J-PARC-made antenna and discusses the feasibility of the new antenna for use in the J-PARC accelerator operation.

Funding Agency:

Email Address:

kshinto@post.j-parc.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Takanori Shibata

Tuesday / 117

Status of the RFQ Cooler Buncher for Rare Isotope Experiments at RAON

Author: Seongjin Heo[1]

Co-authors: Kyounghun Yoo [2]; Takashi Hashimoto [2]; Hee Joong Yim [2]; Yeong Heum Yeon [2]; JaeWon Jeong [2]; Wonjoo Hwang [2]; Dong-Joon Park [2]; Jin Ho Lee [2]

[1] *Institute for Basic Science (IBS)*

[2] *IBS*

Corresponding Author: sjheo@ibs.re.kr

The beamline of Isotope Separation On-Line (ISOL) system at RAON was constructed. The produced ions from the Target Ion Source (TIS) are cooled and bunched using the Radio Frequency Quadrupole Cooler Buncher (RFQ CB) to improve the charge breeding efficiency of the Electron Beam Ion Source (EBIS) charge breeder and the performance of the Multiple-Reflection Time-of-Flight Mass Spectrometer (MMS) and the Collinear Laser Spectroscopy (CLS). The RFQ CB can deliver up to 1E+8 ions per bunch to the EBIS by cooling and bunching DC beam from the TIS. The beamline has been optimized using a stable ion beam such as Cs, Na, and Sn. As a result, 1e+8 ions could be sent in a bunch with a length of several ten of microseconds. In the first half of this year, rare isotopes (RI) were produced using 70 MeV protons extracted from the cyclotron and a SiC target. Commissioning is currently in progress to send a small amount of RI to the MMS, CLS, and EBIS. This report will discuss the current status of the RFQ CB for the RI experiment.

Funding Agency:

IBS

Email Address:

sjheo@ibs.re.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 158

Status of the nuCARIBU Project at ATLAS

Author: Clayton Dickerson[1]

[1] *Argonne National Laboratory*

Corresponding Author: cdickerson@anl.gov

CARIBU (Californium Rare Isotope Breeder Upgrade) is a source of neutron-rich fission fragments from a plating of 252Cf. Operating for over a decade, CARIBU has provided unique beams for stopped and reaccelerated experiments. Unfortunately, consistently generating a thin plating of Cf has proved very difficult. To eliminate this risk and increase the overall intensity of n-rich ions, ATLAS started the nuCARIBU project to convert the fission fragment creation to a mechanism of neutron induced fission of actinide foils. The system will be driven by a 6 MeV, 0.5 mA proton cyclotron, and use a 7Li target for neutron production. This paper will present the details of the reconfiguration of the CARIBU area, the cyclotron installation and commissioning, the process to incorporate this fundamentally new source into operation, and the subsystems needed to make the transition successful.
This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357 and used resources of ANL's ATLAS facility, an Office of Science User Facility.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 167

Measurement of Instability in the Hot-Cathode Penning Ion Gauge Ion Source

Author: Minkeun Lee[1]

Co-authors: Junbeom Park [1]; Jiseong Nam [1]; Kyung-Jae Chung*

[1] *Seoul National University*

Corresponding Author: lmk0486@snu.ac.kr

In this study, plasma parameters and instability were measured using a single Langmuir probe in a hot cathode Penning ion gauge ion source. Experiments were performed with argon gas at an operating pressure of 1 mTorr. We observed an increase in electron temperature corresponding to an increase in discharge current. At the same time, we noted an increase in plasma instability with increasing discharge current, and this instability caused nonlinearity in the relationship between discharge voltage and electron density. The electron density was highest around 80 V at low discharge currents, and the highest electron density was observed at higher discharge voltages with low instability amplitudes at high discharge currents. These phenomena demonstrate that the instability affecting the diffusion of electrons perpendicular to the magnetic field is strongly correlated with electron density and temperature, which in turn can affect the ion species and the ion beam current.

Funding Agency:

Ministry of Commerce, Industry and Energy

Email Address:

jkjlsh1@snu.ac.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 138

Characterization of a Broad Beam Ion Source Converted into a High Intensity Deuterium Beam

Author: Vladlen Podolsky[1]

Co-authors: Robin Langtry [1]; Scott Schipmann [1]; Shadrach Hepner [2]

[1] *Avalanche Energy*

[2] *Avalanche Energy Designs*

Corresponding Author: vpodolsky@avalanche.energy

Avalanche Energy is developing deuterium ion beams for the Orbitron fusion concept. For these and similar projects, modification of off-the-shelf high current ion sources enables affordable and rapidly accessible alternatives to custom-built systems. We have successfully operated the Veeco Mark 1 broad beam source on deuterium to create multi-keV energy ions. By applying custom optics and

steering downstream of the source, we focused and collimated the beam into the Orbitron through a ¼ inch downstream orifice.
To characterize the beam's spread and losses, we implemented a series of faraday cup, wire probe and Bergoz induction coil diagnostics throughout the beam path. These measurements provided feedback to our optics design choices and allowed for a rapid design and iteration loop to maximize current delivered to the Orbitron. Moreover, the species and energy content of the ion beam was characterized using a Thomson Parabola developed in house. These tools showed a predominantly D2+ beam with over 1 mA of beam current delivered to the system.

Funding Agency:

Email Address:

vpodolsky@avalanche.energy

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Vladlen Podolsky

Tuesday / 141

Ion Source Emittance Parameter Identification and Beam Optics Design Using Surrogate Optimization

Authors: Robert Thompson[1]; Shadrach Hepner[2]; Vladlen Podolsky[1]

Co-authors: Robin Langtry [1]; Scott Schipmann [1]

[1] *Avalanche Energy*

[2] *Avalanche Energy Designs*

Corresponding Author: vpodolsky@avalanche.energy

Avalanche Energy is developing deuterium ion beams for the Orbitron fusion concept. To deliver a maximized, focused beam to the reactor, some of our experiment configurations utilize a Veeco Mark 1 broad beam ion source. To focus this beam into a small aperture, carefully designed optics are vital, the design of which is a nontrivial process.
The performance of the beam optics is a function of the ion source emittance and current characteristics upstream of the extraction region. We first measured the current density distribution downstream of the ion source without beam optics using electrostatic probe measurements. We then developed an iterative ion optics optimization procedure that evaluated the impact of electrode spacing and sizing on simulated and experimentally measured beam performance, using the previously identified ion source emittance parameters as an input.
The system identification procedure and the ion optics optimization utilize a surrogate optimization approach, which is uniquely suited for our simulation-based, computationally expensive objective function evaluations which have significant variability in time required to perform the evaluations. By implementing and testing the optics produced by this scheme, we show through a suite of diagnostics that the optimization significantly decreases the emittance of the beam and functions well for delivery of current to the Orbitron.

Funding Agency:

Email Address:

athompson@avalanche.energy

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Vladlen Podolsky

Tuesday / 142

Demonstration of MeV-Class Beam Acceleration with ITER Relevant Perveance for Long Duration

Author: Masashi Kisaki[1]

Co-authors: Hiroyuki Tobari [2]; Junichi Hiratsuka [3]; Kazune Suzuki [3]; Masahiro Ichikawa [3]; Masamichi Murayama [3]; Mieko Kashiwagi [2]; Yasuyuki Tanaka [4]

[1] *National Institutes for Quantum sience and Technology*

[2] *National Institutes for Quantum and Radiological Science and Technology (QST)*

[3] *National Institutes for Quantum Science and Technology*

[4] *National Institutes for Quantum Science and Technology (QST)*

Corresponding Author: kisaki.masashi@qst.go.jp

Neutral beam system for heating & current drive (HNB) of ITER requires high power beams of 0.87 MeV and 46 A (230 Am-2) hydrogen negative ion (H-) for 1000 s, and of 1 MeV and 40 A (200 Am-2) deuterium negative ion (D-) for 3600 s. The H- ion beam demonstration toward 0.87 MeV and 230 A/m2 for 300 s, where the beam duration exceeds 50 s required in the initial HNB operation, is under progress in a Megavolt Test Facility (MTF: 1 MV, 0.5 A). The beam source consists of cesium seeded and filamented arc driven ion source and five-stage accelerator. To obtain suitable cesium distribution in the ion source for the stable negative ion production for 300 s, the wall temperature was kept < 60 ℃ by adding heat sink around the wall. A compressed air-cooled plasma grid (PG) was newly developed to control the PG temperature within 200-300 ℃ since it was limited around 200 ℃ in the conventional refrigerant of hot water or oil. To protect the filament from the damage due to serge energy at arcing, fast cut-off system of an arc power supply was developed. As for the accelerator, the interval of apertures and the gap distance were adjusted to be the same as the ITER accelerator even the number of the aperture is only nine due to the MTF's capability. The amount of the aperture displacement of a steering grid and the shape of so-called kerb were tuned with a three-dimensional beam trajectory calculations in order to compensate the beamlet deflections by the magnetic field produced by electron deflection magnets and the beamlet-beamlet interaction, respectively. As the results of these modifications, the negative ion beams with the ITER relevant perveance have been successfully achieved for 300 s at 300 keV, 100 s at 500 keV and 10 s at 750 keV. The grid heat load was suppressed below the target value for long pulse operations. The beam energy and the pulse are now increased by increasing the negative ion current to maintain the perveance matched condition.

Funding Agency:

Email Address:

kisaki.masashi@qst.go.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 144

Evaluation of H-/D- Density Using Langmuir Probe Measurement in a Cs Seeded Negative Ion Source

Author: Engrhyt Rattanawongnara[1]

Co-authors: Haruhisa Nakano [2]; Kenichi Nagaoka [2]; Masaki Osakabe [1]; Takeiri Yasuhiko [2]; Tsumori Katsuyoshi [2]

[1] *SOKENDAI university*

[2] *National Institute of Fusion ScienceNIFS*

Corresponding Author: engrhyt.rattanawongnara@nifs.ac.jp

Negative-ion density measurement in negative-ion sources is still in demand for improving the design and efficiency of the sources [1,2].
A new analysis method called the 'electron reduction Langmuir probe model' is developed for an area that cannot use a laser-related measurement [3], such as inside the extraction hole.
A validity check of the new analysis is performed in hydrogen and deuterium plasma for utilizing and improving the technique.
Langmuir probe-assisted photodetachment [4,5,6] calibrated with cavity ring down line integral [7] is a standard for negative ion density.
A linear correlation between negative ion density from the electron reduction method and the standard shows that the new analysis method can be a replacement with careful calibration.
[1] M. Bacal, Plasma Sources Sci. Technol. 2, 190 (1993)
[2] K. Tsumori and M. Wada, New J. Phys. 19 045002 (2017).
[3] E. Rattanawongnara et al., Plasma and Fusion Research 18, 1401020 (2023).
[4] M. Bacal, Rev. Sci. Instrum. 71, 3981 (2000).
[5] N. Oudini et al., Plasma Sources Sci. Technol. 28, 065016 (2019).
[6] N. Sirse et al., Plasma Sources Sci. Technol. 20, 055003 (2011).
[7] S. Masaki et al., Rev. Sci. Instrum. 91, 013512 (2020).

Funding Agency:

Email Address:

engrhyt.rattanawongnara@nifs.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 147

EBIS Charge Breeder Performance Using Rare Isotope Beam in RAON

Author: Kyounghun Yoo[1]

Co-authors: Jinho Lee [1]; Hee-Joong Yim [1]; Wonjoo Hwang [1]; Takashi Hashimoto [1]; Jae-Won Jeong [1]; Yeong-Heum Yeon [1]; Dong-Joon Park [1]; Seongjin Heo [2]; Taeksu Shin [1]

[1] *Instiitute for Basic Science*

[2] *Institute for Basic Science (IBS)*

Corresponding Author: ykh8287@ibs.re.kr

The Rare Isotope Accelerator complex for ON-line experiments (RAON) was constructed to produce more exotic rare isotopes (RI) by combining the ISOL and IF methods. In the ISOL facility, RIs are generated in the Target/Ion Source (TIS) module with the proton beam and extracted to the ISOL beamline. The properties of the RI ion beam transported through the ISOL beamline should be matched to the injection conditions of the post-accelerator, which require A/q<6 and 10 keV/u. To satisfy these conditions, an Electron Beam Ion Source (EBIS) charge breeder was installed, producing highly charged ions of RI in the ISOL system. The singly charged ions are injected into the EBIS charge breeder, and their charge states increase by using the electron beam up to 2 A in the high magnetic field of 6 T. These highly charged ions with A/q<6 in the EBIS are extracted and transported to the post-accelerator. Before using the RI ions, the commissioning of the RAON EBIS using stable ions, including the Cs ion beam in 2021 and the Sn and Na ion beams in 2022, confirms matching the required conditions. The first RI generation in the ISOL system has been started with the SiC target. Upon extracting RI beams from the ISOL system, the RAON EBIS will report the charge breeding results with RI beams to match the conditions of the post-accelerator in RAON.

Funding Agency:

Email Address:

ykh8287@ibs.re.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 148

First Numerical Evidence of the Two-Close Frequency Heating Effect on Electron Cyclotron Resonance Ion Sources

Author: Alessio Galatà[1]

Co-authors: Angelo Pidatella [2]; Bharat Mishra [3]; Carmelo S. Gallo [1]; David Mascali [2]; Eugenia Naselli [4]; G. Torrisi [2]; Giorgio Finocchiaro [5]; Richard Rácz [6]; Sandor Biri [7]

[1] *INFN-Legnaro National Laboratories*

[2] *INFN, Laboratori Nazionali del Sud*

[3] *INFN-LNS and University of Catania*

[4] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN, LNS)*

[5] *INFN, Laboratori Nazionali del Sud & University of Catania*

[6] *Institute for Nuclear Research (Atomki)*

[7] *Institute for Nuclear Research (Atomki),*

Corresponding Author: alessio.galata@lnl.infn.it

The two-close frequency heating (TCFH) is a new implementation of the well-known two frequency heating. In TCFH, the two frequencies differ less than 200-300 MHz each other in order to establish two contiguous ECR resonance zones. TCFH has been proved to be a powerful technique to suppress plasma instabilities in Electron Cyclotron Resonance Ion Sources (ECRIS), as well as to improve their performances. Its beneficial effect, compared to the application of a single frequency, is always deduced from the extracted charge states distributions and from the detection of the plasma self-emission in the X-ray and microwave ranges. This paper presents the first approach to a numerical description of the two-close frequency effect, based on the relevant plasma parameters of the ECRIS setup operating at ATOMKI-Debrecen. Simulations have been performed by our PIC-Full Wave code, joining electron kinetics and FEM solution of Maxwell equations in a cold plasma model. Results on plasma electron density and energy distribution will be shown, together with a direct comparison with the already published data on X ray emission and extracted charge states distributions.

Funding Agency:

Email Address:

alessio.galata@lnl.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Tuesday / 150

TRIUMF's H− Ion Source Development to Date

Author: KEERTHI JAYAMANNA[1]

Co-authors: Brian Minato [1]; Daniel Portilla [1]; Friedhelm Ames [1]; Iouri Bylinskii [1]; Marco Lovera [1]; Richard Baartman [1]; Suresh Saminathan [1]

[1] *TRIUMF*

Corresponding Author: keerthi@triumf.ca

TRIUMF's 500 MeV cyclotron has been powered by an arc discharge H− ion source developed in-house 30 years ago. Since then, new additions to TRIUMF, like ISAC, have required increasing amounts of beam current from the cyclotron. The ARIEL facility will also require an additional 100 µA, in addition to the existing 300 µA required by the current beam lines. To meet the growing intensity demands of experiments, improvements in the source beam current and brightness are necessary. Due to historical reasons, the initial beam energy has been limited to 12 keV and the power to the source filament is limited to 2.5 kW. Therefore, the need for a state-of-the-art new ion source has become an increasingly prominent concern. This new source will be designed to produce a high-brightness 25 keV H− beam with a long filament lifetime. A historical overview of source development at TRIUMF will be presented, specifically regarding the new filament design, optimization multi-cusps, filter fields, and recent results from the ion source test bench.

Funding Agency:

Email Address:

keerthi@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Tuesday / 169

Characterization of a Cs-free Negative Hydrogen Ion Source System Using Multi-Pulsed Plasma Sources

Author: Sung-Ryul Huh[1]

Co-authors: Kihyun Lee [1]; Bong-Ki Jung [1]; Jonggab Jo [1]; Seung Ho Jeong [1]; Tae-Seong Kim [1]; Dae-Sik Chang [1]

[1] *Korea Atomic Energy Research Institute*

Corresponding Author: srhuh7@kaeri.re.kr

A cesium-free negative hydrogen/deuterium ion source system using two pulsed plasma sources has recently developed at Korea Atomic Energy Research Institute. The system operates with two alternate pulsing sequences related to the respective plasma sources, thereby switching the plasmas in the after-glow state in an alternating manner. As a result, the ion source system can offer a continuous supply of negative ions at high densities. This is not possible with conventional single pulsing. In order to understand the physics of the ion source system, in this study, the negative ion behavior in the system is experimentally investigated and then compared with that in a single pulsing mode. For experiments, time-resolved Langmuir probe and laser photodetachment diagnostic techniques are employed. In this presentation, experimental results and analysis will be presented and discussed in detail.

Funding Agency:

Email Address:

srhuh7@kaeri.re.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / **180**

Resonant Ionization Laser Ion Source at TRIUMF –Quo Vadis? Future Directions with an Ambitious View into the Future

Author: Jens Lassen[1]

Co-author: Ruohong Li [1]

[1] *TRIUMF*

Corresponding Author: lassen@triumf.ca

The current status of the TRIUMF resonant ionization laser ion source (T RILIS) is that isotopes from 42 different elements have been delivered successfully and are part of the RILIS portfolio with ionization schemes for another 7 elements ready to be deployed on-line. As such the resonant ionization laser ion source is an indispensable ion source at TRIUMF's isotope separator and accelerator facility –as it is at other radioactive ion beam facilities. The current systems are using high repetition rate, pulsed, tuneable laser systems and installations that require expert control and operation.
I will describe the current T RILIS laser ion source system and operation model and project / cost and lay out the development path for a future system that may allow hot-cavity RILIS systems to become less dependent on expert control, but allow for substantially less personnel critical operation. Such developments could, in a decade or two, turn RILIS not only into a standard ion source for RIB facilities, but also for dedicated ion-sources and analytical instruments.

Funding Agency:

TRIUMF / NSERC

Email Address:

lassen@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Jens Lassen

Tuesday / 173

Radioactive Ion-Beam Development at SPIRAL1-GANIL

Author: Pierre Chauveau[1]

Co-authors: Clément Michel [1]; Jean-Charles Thomas [1]; Mickaël Dubois [2]; Pascal Jardin [1]; Pierre Delahaye [1]; Romain Frigot [1]; Samuel Damoy [1]; Stéphane Hormigos [1]; Vincent Bosquet [1]; Laurent Maunoury [3]

[1] *GANIL*

[2] *GANIL - CNRS*

[3] *Normandy Hadrontherapy*

Corresponding Author: pierre.chauveau@ganil.fr

The SPIRAL1 facility provides post-accelerated radioactive ion beams (RIBs) since 2001. Initially limited to isotopes of gaseous elements, SPIRAL1 has been upgraded over the last decade to produce radioactive ions of condensable elements. It does so by using both a hot 1+ ion source and an ECR Charge Breeder where the latter is used to increase the ion charge state for post-acceleration. The SPIRAL1 team at GANIL is pursuing R&D on both fronts in order to expand the offer of RIBs.
The SPIRAL1 facility is compatible with several target ion-source systems (TISS) which are being tested and developed:
• A FEBIAD-type electron-impact ion source has been tested online several times over the last few years with promising results. The latest online experiment allowed to produce radioactive isotopes of Chromium (^{48,49}Cr), which is the most refractory element ionized at SPIRAL1 to date.
• A surface ion source, MonoNaKe, is being modified to produce beams of short-lived lithium isotopes.
• The TULIP project aims at producing short-lived neutron-deficient ions through fusion-evaporation reactions. Two TISS are being developed and are dedicated to alkali and metallic elements.
The SPIRAL1 Charge Breeder (SP1CB) is now fitted with a fixed frequency amplifier (Klystron) and a variable frequency amplifier (travelling wave tube). Using one amplifier, the other, or both, enables several heating modes, which gives a certain amount of control on the charge state distribution at the output of SP1CB. We are currently investigating the effect that several parameters of SP1CB (magnetic field, support gas, etc) have on its performance, while using it either as a charge breeder (by injecting 1+ ions) or as a "standard"ECR ion source (by injecting neutral gas).
In this conference, we aim to present recent developments and results on the production of radioactive ion beam at SPIRAL1 facility in France.

Funding Agency:

Email Address:

pierre.chauveau@ganil.fr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 185

Development of an Image Analysis Method for Pepperpot Emittance Monitors

Authors: Yasuyuki Morita[1]; Takashi Nagatomo[2]; Yuta Nakashima[3]

[1] *RIKEN*

[2] *RIKEN Nishina Center*

[3] *IDS, Osaka University*

Corresponding Author: yasuyuki.morita@riken.jp

The Nishina Center for Accelerator Science uses a pepperpot emittance monitor to measure the emittance of low-energy beams from ion sources. PPEM does not require moving slits, etc. Therefore, four-dimensional information of (x,x',y,y') can be measured in a short time. On the other hand, it is difficult to identify the origin of the spot. We are therefore attempting to identify the origin of the spots by moving the pepperpot mask. Although this method has been effective to a certain extent, the position of the spot also shifts as the mask is moved. When the position of the spot moves, the problem arises that spots with large angles can be confused with other origins. If the analysis is performed as is, the shape will be different from the original phase space distribution. In this study, we introduced a method to track the movement of the spot when the pepperpot mask is moved. The introduction of this method is expected to accurately identify the origin of previously confused spots. In this presentation, we will report on the proposal of the spot tracking method and its development status.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 178

A Novel Plasma Source Concept for Negative Ion Generation in Neutral Beam Injectors for Fusion Applications

Author: Giuseppe Chitarin[1]

Co-authors: Domenico Abate [2]; Filippo Elio [3]; Emanuele Sartori [4]; Gianluca Spizzo [5]

[1] *Univ. of Padova and Consorzio RFX*

[2] *Consorzio RFX*

[3] *deutelio*

[4] *Consorzio RFX - Università degli Studi di Padova*

[5] *CNR-ISTP and Consorzio RFX*

Corresponding Author: giuseppe.chitarin@unipd.it

The negative ion sources currently used for Fusion applications produce tens of Amperes of Hydrogen or Deuterium ion current from a low-temperature (few eV) plasma. Being the negative ion current typically limited below 200 - 300 A/m2 at the extraction apertures, these sources can be quite large and their input power ranges from some tens to hundreds of kW. Two source types are currently used: the Japanese "kamaboko" sources, and the radio-frequency (RF) plasma-driver sources, mainly developed in EU. The former exploits an arc discharge produced by hot filaments biased w.r.t. the containing chamber, whereas the latter uses cylindrical coils operating at about 1-2 MHz. The generated plasma expands towards a cesiated Plasma Grid (PG), where some of the impinging particles are converted into negative ions and then accelerated through the grid apertures. In both types a power of about 2-4 MW/m2 is necessary for achieving the required negative ion current.
The main reasons for this are: (1) the low-temperature plasma is confined just by the cusp-shaped magnetic field produced by permanent magnets located outside the plasma chamber; (2) a large fraction of the electric power of the RF coils is dissipated by eddy currents induced on the surrounding metallic structures.
In principle, a current-free plasma (such as the one considered in these sources) could be confined

using a purely poloidal magnetic field configuration. In fact, a dipole configuration allows to achieve an efficient plasma confinement, without requiring a net plasma current. This concept has already been applied in the LDX device [Garnier et al., Nucl. Fusion 49 (2009) 055023] and a similar configuration has been proposed for the Polomac device [F. Elio, Fusion Engineering and Design 89 (2014)]. In the paper we propose a novel Ion source, based on the Polomac configuration, estimate the particle trajectories so as to assess the equilibrium and low-temperature plasma confinement capabilities of such device.

Funding Agency:

Email Address:

giuseppe.chitarin@igi.cnr.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / **79**

Installation and First Results of a 1.1 kW TWT System for the AECR-U Based Ion Source at UMCG-PARTREC

Authors: Alexander Gerbershagen[1]; Herman Kremers[1]

Co-authors: Brian Jones [1]; Sytze Brandenburg [1]

[1] *University Medical Center Groningen*

Corresponding Author: h.r.kremers@umcg.nl

Due to the demand for intense high-charged stable ion beams for medical and nuclear physics a traveling-wave-tube (TWT) based RF generator has been installed and commissioned at the Advanced Electron Cyclotron Resonance Upgrade (AECR-U) ion source at the UMCG-PARTREC facility. The generator comprises 2 x 750W in-phase combining TWT RF generators with an output frequency range of 12.75-14.5 GHz. Beside its capability to provide the plasma heating needed, it is a very convenient scanning device to identify intense and stable ion-beam regimes within the plasma-heating frequency domain. The new rf generator replaces a 14.1 GHz fixed frequency klystron. Scanning of the plasma-heating frequency allows for an increase of the beam current, for example a factor of 2 for 129Xe17+ and 67% for 4He1+ beams, this with respect to former 14.1 GHz fixed frequency. Additionally, stable regimes in the frequency spectrum are identified as the ion-beam stability is monitored at every frequency. In this paper we present the setup, the measurements, and discuss the increase in intensity, fluctuations in stability as well as the overall reproducibility of helium, carbon, and xenon ion beams. These results improve the stability and increase the beam intensity at the UMCG-PARTREC facility.
Author Keywords: [ECR Ion Source] [TWT] [Plasma Heating] [AGOR]

Funding Agency:

UMCG-PARTREC

Email Address:

h.r.kremers@umcg.nl

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

H.R. Kremers

Tuesday / 23

2.45 GHz Surface Wave Plasma Source Development for Plasma Flood Gun

Authors: Bujian Cui[1]; Shixiang Peng[1]; Tenghao Ma[1]; Wenbin Wu[2]; Yaoxiang Jiang[1]

[1] *Peking University*

[2] *Institute of Applied Physics and Computational Mathematics, Beijing 100094, China*

Corresponding Author: sxpeng@pku.edu.cn

In a modern ion implanter, plasma flood gun (PFG) is used to neutralize wafer charge during doping process, preventing the breakdown of floating wafers caused by the space charge accumulation. Surface wave plasma (SWP) source that has a simple structure and no hot filament requirement, which can avoid metal pollution, is a potential competitive prospect as a PFG for ion implanter. At Peking University (PKU), SWP source research based on 2.45 GHz microwave is launched recently. Our aim is to establish a high intensity plasma with gas pressure in 10-3 Pa order that are critical required by ion implanter. To achieve this goal, we established a two-dimensional axisymmetric discharge model to optimize the structural parameters of the SWP source. Counting in various physical parameters in a 2.45GHz SWP source, such as electron temperature, electron density, electric field mode, energy deposition and electron generation rate, a prototype SWP source with RF coupling through a cylindrical dielectric antenna was designed and tested. In subsequent continuous wave (CW) experiments, the extracted electron beam can be more than 90 mA at input RF power of 500 W and argon gas pressure of 5.5×10-3 Pa. Detail will be presented in this article.

Funding Agency:

NSFC 11975036

Email Address:

sxpeng@pku.edu.cn

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Shixiang Peng

Tuesday / 54

Enhanced Production of Multicharged Ions by Mixing Low Z Gas and Emittance Measurement on Electron Cyclotron Resonance Ion Source

Author: Yushi Fujimura[1]

Co-authors: Kouki Iwahara [1]; Yushi Kato [1]

[1] *Osaka Univ.*

Corresponding Author: fujimura@nf.eie.eng.osaka-u.ac.jp

We have been studying efficient production of multicharged ions in an electron cyclotron resonance ion source (ECRIS). The gas mixing method, in which low Z gas is mixed into produced plasma, is known as a relatively simple method for highly efficient production of multicharged ions. In addition, it is expected that heating low Z ions selectively by ion cyclotron resonance (ICR) will further improve the efficient production of multicharged ions. Although the principle of the gas mixing method is not yet fully understood, it is considered to be due to the cooling effect by collisions between ions. It is necessary to obtain parameters related to the ion temperature in order to experimentally confirm the ion cooling effect. Therefore, we obtained parameters by emittance measurements using the wire probe and multi slit for ion beams. In this experiment, He was mixed as a low Z gas into the Ar plasma as an operating gas, and the charged state distribution of the ion beams was measured to confirm the increase in the multicharged ions due to the gas mixing effect. We have also conducted emittance measurements on the multicharged Ar ion beams and compared the value of root mean square emittance with and without He mixing. In the future, we plan to conduct heating low Z ions selectively by ICR by introducing low frequency electromagnetic waves, and to investigate the characteristics of ion beams by emittance measurements.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Tuesday / 66

Multidimensional Characterization of a FEBIAD Ion Source and its Web-Interface Implementation for Offline and Online Operations

Author: Fernando Alejandro Maldonado Millan[1]

Co-authors: Alexander Gottberg [2]; Carla Babcock [2]; Spencer Kiy [2]; Tom Day Goodacre [2]

[1] *UVIC/TRIUMF*

[2] *TRIUMF*

Corresponding Author: maldonado@triumf.ca

The ISAC-FEBIAD ion source is an electron impact ion source typically used to ionize radioactive molecules or isotopes of elements with ionization potentials higher than 10 eV. The source key tuning parameters are the anode voltage that defines the electron energy, and the magnetic field that controls the electron density inside the anode volume. Both values are only varied in a small and limited range. However, recent investigations have shown the need to explore the entire range of operational values accessible by the power supplies, due to the intrinsic variation from source to source arising from slight differences in manufacturing and assembling. Offline investigations led to a systematic and automatic measurement paradigm that shows how each target ion source unit can exhibit maximum efficiency in different operational settings. The online implementation has shown equivalent results on stable species. The algorithm has been implemented as a web interface thanks to the high-level application infrastructure available at TRIUMF. This work becomes relevant as the offline investigation will become crucial before operating the ion source online. By automatically scanning the operational space, it is possible to tune and optimize a stable ion beam, from which an optimal operation is expected for radioactive species of the same element.

Funding Agency:

Email Address:

maldonado@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 159

Study of Accelerating Channels for Copernicus Beams

Author: Anthony Cooper[1]

Co-authors: George Strashnoy ; Ken Franzen ; Sergey Korepanov

[1] *TAE Technology*

Corresponding Author: acooper@tae.com

TAE Technologies pursues an alternative approach to magnetically confined fusion with the advanced, beam-driven field-reversed configuration (FRC) [1]. Heating, current drive, and partial fueling from neutral beam injection are essential to sustainment of the FRC plasma [2]. The next generation device, Copernicus, aims to achieve the D-T reactor relevant plasma performance with a hydrogen plasma. This will require an increase in neutral beam power input from the NBI system on the present device. The beams will be based on positive ion sources with three-electrode ion optic systems (IOS) and operate at 60-80 keV. We will present an ongoing study of the ion optic system for these hydrogen neutral beams, highlighting simulations and experiments on several different extraction electrode geometries and accelerating voltages. First, with the use of IBSimu, simulations of the ion-optics, plasma extraction, and space charge dominated ion beam transport with a single aperture in the electrode are studied. These simulations are then experimentally verified on a test stand, complete with an ion source with a small number of apertures in the ion optic system, and a suite of diagnostics. These diagnostics examine the beam divergence, perveance, and the gas composition of the vacuum. The measured divergence is then compared to the simulated divergence from IBSimu.

[1] H. Gota et al., Nucl. Fusion 59, 112009 (2019)
[2] J. Titus et al., Review of Scientific Instruments 89, 10I123 (2018)

Funding Agency:

Email Address:

acmc4398@gmail.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 176

Novel Modelling of Metal Atoms Diffusion and Ion Transport in ECR Plasma Relevant to Ion Sources and In-Plasma Nuclear Physics Studies

Author: Angelo Pidatella[1]

Co-authors: Alessio Galatà [2]; Bharat Mishra [3]; Eugenia Naselli [4]; Luigi Celona [5]; Ralf Lang [6]; FABIO MAIMONE [7]; Giorgio Mauro [8]; Domenico Santonocito [8]; G. Torrisi [8]; David Mascali [8]

[1] *INFN - Laboratori Nazionali del Sud*

[2] *INFN-Legnaro National Laboratories*

[3] *INFN-LNS and University of Catania*

[4] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN, LNS)*

[5] *INFN-LNS*

[6] *GSI Helmholtzzentrum für Schwerionenforschung*

[7] *GSI HELMHOLTZZENTRUM FÜR SCHWERIONENFORSCHUNG*

[8] *INFN, Laboratori Nazionali del Sud*

Corresponding Author: eugenia.naselli@lns.infn.it

Metals can be injected into electron cyclotron resonance ion sources (ECRIS) via many techniques, among which resistive ovens are used to vaporise neutral metals, later captured by the energetic plasma environment that will stepwise ionise them, hence giving multiply charged ion beams for accelerators. Recently, PANDORA, a novel ECR plasma trap, has been conceived to perform interdisciplinary research spanning from nuclear physics to astrophysics [1], where in-plasma high charge states of metallic species are demanded. However, a full knowledge on the vaporisation method and on the coupling of neutral atoms with plasma and its overall dynamics is still not available. Simulations, hence, are of fundamental relevance to improve the overall efficiency, reduce consumption of rare expensive isotopes, and to improve the ion source performance. In this context, we present a numerical study about metallic species suitable for oven injection in ECRIS, focusing on metals diffusion, transport, and wall deposition under molecular flow regime. These aspects depend on the geometry of the evaporation inlet, its thermodynamics properties, and plasma parameters, which impact on ionisation and charge-exchange rates, thus on the fraction of reacting neutrals. We studied the metal dynamics with and without plasma. Results underline the plasma role on space-dependent conversion yield, as given by the strongly anisotropic and inhomogeneous ECR plasma. The plasma and its parameters have been modelled using an established self-consistent particle-in-cell model [2,3]. The numerical tool is conceived for the PANDORA plasma trap, but can be extended to other ECR plasmas and traps. As test cases we studied the 134-Cs and 48-Ca radioisotopes, as metals of interest for the modern nuclear physics. A focus is given on the β-decaying 134-Cs, as a physics case for PANDORA, stressing on the poisoning effect by neutral metals deposition at the chamber wall and how the study can support for solutions.

Funding Agency:

Email Address:

pidatella@lns.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Angelo Pidatella

Tuesday / 181

Creation and Characterisation of Multi-Charged Cerium Beams at the TRIUMF OLIS Facility

Author: Philipp Justus[1]

Co-authors: Christopher Charles [2]; Friedhelm Ames [2]; KEERTHI JAYAMANNA [2]; Stephan Malbrunot-Ettenauer [3]

[1] *Max Planck Institute for Nuclear Physics*

[2] *TRIUMF*

[3] *CERN*

Corresponding Author: ccharles@triumf.ca

We discuss the development of novel lanthanide beams at TRIUMF's Off-Line Ion Sources (OLIS) Facility, focusing here on $^{140}Ce^{+n}$ for astrophysical research and molecule formation studies between halogens and lanthanides for electron dipole moment measurements. Cerium is the first lanthanide beam created at the OLIS facility by dual frequency electron cyclotron resonance (ECR) using a Supernanogan ion source. Pure cerium was sputtered from a solid metal sample under different gas, bias, and geometric conditions. We discuss the response of the ECR plasma environment on the charge state distribution and current yields. Charge-states up to +21 were observed, and we readily obtained 3e9 pps of $^{140}Ce^{+1}$ that was subsequently delivered to TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) for molecular formation experiments. Charge state spectra measured by the OLIS mass analyzer and the TITAN MRToF confirmed the purity of the delivered Ce beam in the desired charge states. Cerium expands the portfolio of beams at TRIUMF for basic molecular, nuclear, and astrophysical research. Topics include problems on (1) interstellar medium Ce enrichments from s-process yields of AGB stars, and (2) at TITAN for using Ce as a Th chemical analog for rare radioactive molecule formation and studies on electron electric dipole moments.

Funding Agency:

NSERC

Email Address:

ccharles@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Christopher Charles

Tuesday / 21

Initial Experimental Results on Ion Cyclotron Resonance Heating Selectively Mixed Low Z Ions to Enhance Production Efficiency of Multicharged Ions on Electron Cyclotron Resonance Ion Source

Author: Yushi Kato[1]

Co-authors: Shuhei Harisaki [1]; Wataru Kubo [1]; Yushi Fujimura [1]; Kouki Iwahara [1]

[1] *Osaka Univ.*

Corresponding Author: kato@eei.eng.osaka-u.ac.jp

We have been experimentally measuring the charge state distribution of the multiply-charged ion current generated and extracted from an electron cyclotron resonance (ECR) ion source (ECRIS), and plasma parameters such as electron density, electron temperature, and space potential of the plasma in the ECRIS, and then investigating the correspondence between them. According to the accessibility conditions of wave propagation in the magnetized ECRIS plasma, it is speculated that the essential factor that determines the limitations in the multiply charged ion current in the current ECRIS is not simply the ordinary wave cutoff (O-cutoff) density, nor the right-hand polarization wave cutoff (R-cutoff) density, but rather the higher density limit one, i.e., the left-hand polarization wave cutoff (L-cutoff) density where electromagnetic waves no longer can exist. Therefore, it is necessary to overcome this limitation in the ECRIS, other than the conventional method of simply increasing the frequency and the magnetic field strength. One direction is developing conventional dual-frequency heating, i.e. high frequency resonance, which is a conversion from electromagnetic waves to electrostatic waves with no cutoff. The other direction is the introduction of ion cyclotron resonance (ICR) or lower hybrid resonance (LHR) by introducing electromagnetic waves at very lower frequencies than ECR's one, which has no density limit in a more intrinsic sense. In the case of ion heating, we conduct heating low-mass ions selectively in enhanced producing multiply charged ion by mixing low-mass element gas, which has been conventionally performed in ECRIS, or relaxation of the potential well based on the existence of resonant electron particles by ECR. We aim to improve the efficiency of multiply-charged ion generation based on this method. This paper will describe the initial experimental results of ICR application by introducing low-frequency RF electromagnetic waves in the ECRIS.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 61

RF Frequency Combining for the ATLAS ECR Ion Sources

Author: Jake McLain[1]

Co-authors: Richard Vondrasek [1]; Robert Scott [1]

[1] *Argonne National Laboratory*

Corresponding Author: jmclain@anl.gov

The ECR2 and ECR3 ion sources at the Argonne Tandem Linac Accelerator System (ATLAS) operate with two microwave frequencies, improving their performance over single frequency operation. A typical method for transmitting both microwave frequencies is by having two separate frequency generators with their own corresponding amplifiers. These amplifiers transmit their microwaves into the ion source using separate waveguides. Another method that is investigated is to combine the low power microwave frequencies with a splitter/combiner and input the combined signals into the high-power amplifier, where the combined signal is amplified and transmitted down a single waveguide into the ion source. These different methods for delivering microwave power with multiple frequencies are compared, focusing on the average charge state and the intensities of each of the charge states for an oxygen plasma produced by the ECR2 ion source.

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

Funding Agency:

U.S. Department of Energy

Email Address:

jmclain@anl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 85

Performance Increase for a Medical Proton Beam ECRIS Through Dual Frequency Heating at MedAustron Ion Therapy Centre

Author: Rainer Rockenbauer[None]

Co-authors: Nadia Gambino ; Claus Schmitzer

Corresponding Author: rainer.rockenbauer@medaustron.at

MedAustron is a synchrotron based ion beam therapy centre located in Lower Austria. Proton and carbon ion energies in the three treatment rooms range from 62-252 MeV and 120-400 MeV/u, respectively. A fourth non-clinical research room is used to commission helium ion beams, among other research activities.
The injector features three identical electron cyclotron resonance ion sources from Pantechnik, called Supernanogan, operating at 14.5 GHz. Two ion sources are used for proton and carbon ion beam production. The third source is dedicated for helium beam production as well as for accelerator performance and improvement studies.
In this work we propose an alternative heating mechanism for proton beam production by using the dual frequency heating (DFH) mode. DFH was tested on the third source as well as on the clinical proton source. Different frequency pairs were measured in the range from 13.75-14.50 GHz in 50 MHz steps. The goal was to increase the overall beam stability, a key factor for medical ion sources and to reduce the emittance of the extracted beam in order to increase the overall beam transmission through the different sections of the accelerator with respect to single frequency heating (SFH).
At equal power input, the H3+ beam current could be increased by 36% compared to SFH. Maintaining the SFH beam current, at reduced input power in DFH, the emittance could be reduced by 20%. The overall transmission through the accelerator stages was also improved: Transmission increased by 10% from the LEBT to the LINAC section resulting in an increased synchrotron beam current of 25%. This results in a higher particle count in the ring and a larger number of particles per applied spill leading to an overall increase in accelerator performances.

Funding Agency:

Email Address:

rainer.rockenbauer@medaustron.at

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 126

Advances in Particle-In-Cell Modeling of Low-Temperature Plasma Ion Sources

Author: Seth Veitzer[1]

Co-authors: Daniel Main [2]; Daniel Murray [2]; Eve Lanham [2]; Ilya Zilberter [2]; Jarrod Leddy [2]; John R Cary [3]; Scott Kruger [2]; Thomas G. Jenkins [2]

[1] *TECH-X CORPORATION*

[2] *Tech-X Corp.*

[3] *Tech-X Corp*

Corresponding Author: veitzer@txcorp.com

Ion sources that use low-temperature plasma (LTP) discharges are used in a variety of applications, including ion implantation, mass spectrometry, and plasma processing. In recent years, there has been a growing interest in using particle-in-cell (PIC) modeling to improve the performance and optimization of LTP-based ion sources. PIC modeling is a powerful tool for simulating the dynamics of plasmas because it accurately models the effects of self-consistent fields, charge deposition, plasma chemistry, magnetic confinement, and accurate sheath physics. However, PIC simulations can be computationally demanding, especially for 3D systems.
We present new advances in PIC modeling of LTP ion sources. We focus on two key challenges: 1. Efficient and accurate modeling of plasma chemistry: Plasma chemistry is a complex process that can have a significant impact on the performance of LTP ion sources. We demonstrate using global models to reduce the computational cost of plasma chemistry simulations, and diagnostics for understanding the physics of those reactions. 2. Energy-conserving PIC models: PIC simulations typically require a fine spatial grid in order to resolve the Debye length. This can be computationally expensive, especially for 3D systems. We present a new energy-conserving PIC model implementation that allows us to perform simulations without resolving the Debye length. We validate these methods on two different types of LTP ion sources: a Bernas source and a Penning source. Our results show that these methods can significantly improve the efficiency and accuracy of PIC simulations of LTP-based ion sources.

Funding Agency:

Email Address:

veitzer@txcorp.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 175

The NIST-Boulder Electron Beam Ion Trap/Source

Authors: Albert Henins[1]; Aung Sis Naing[1]; David S. La Mantia[1]; Joseph Tan[1]

Co-authors: Alessandro Banducci [2]; Samuel Brewer [2]

[1] *National Institute of Standards & Technology*

[2] *Colorado State University*

Corresponding Author: joseph.tan@nist.gov

A room-temperature electron beam ion source/trap has been designed and constructed at the National Institute of Standards & Technology (NIST). Its peak magnetic field of 0.67 T is generated in an extremely compact architecture by embedding strong rare-earth (NdFeB) magnets within the drift tubes, which are partly constructed of electrical iron. Six ports in the midplane are available to facilitate the production of highly charged ions (HCIs) and to perform spectroscopic experiments using the intense electron beam to excite the trapped ions. For instance, precise spectroscopy and tests of atomic theory can be made utilizing a Transition-Edge-Sensor (TES) x-ray microcalorimeter, as have been done with the 192-pixel TES spectrometer recently installed at the NIST EBIT (a superconductive 3-T device) in Gaithersburg, Maryland. The new portable system will be installed at another NIST campus in Boulder, Colorado, where the Quantum Sensor Group is developing a new generation of TES sensors. This NIST-Boulder EBIT (B-EBIT) is also an ion source that can extract a wide range of charge states for various applications, such as investigations of HCIs with forbidden atomic transitions that are potential candidates for very stable optical frequency standards. A convenient feature is the minimal space required by integrating the permanent magnets and the electrodes into

a single stack that can fit entirely in off-the-shelf vacuum chambers. In this presentation, we discuss the main characteristics, as well as some tests of its operation using a time-of-flight microchannel plate on axis and a silicon drift detector in the midplane.

Funding Agency:

U.S. Dept. of Commerce/ NIST

Email Address:

joseph.tan@nist.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Joseph Tan

Tuesday / **48**

Design of the Beam Transport Optics of TRIUMF's New 300 keV H^{-} Ion Source

Author: Suresh Saminathan[1]

Co-authors: Keerthi Jayamanna [1]; Yuri Bylinskii [1]; Rick Baartman [1]; Brian Minato [1]; Marco Lovera [1]; Oliver Law [1]; Nemanja Jovicic [1]; Mark Ilagan [1]; Daniel Portilla [1]; Marco Marchetto [1]; Thomas Planche [1]

[1] *TRIUMF*

Corresponding Author: suresh@triumf.ca

The ion source and injection system beamline is used to transport the 300 keV H^{-} beam from the ion source to the injection point of the 500 MeV cyclotron at TRIUMF. A new ion beam transport system has been designed to transport a highly intense and bright beam extracted from the H^{-} ion source. This new system will be installed at the new injection terminal for TRIUMF's 500 MeV cyclotron. The low energy part of the transport section (25 keV) in the injection terminal has been designed with magnetic optical elements in order to maintain space-charge neutralization. The injection terminal includes a permanent magnet solenoid lens, magnetic steerers, a pulser, a beam dump, and a 300 kV accelerator column with electron and positive ion suppressor rings. Beam optics calculations have been performed, including space-charge effects up to 1 mA. The simulation results of the beam optics design and the initial beam emittance measurements for the prototype beam transport system will be presented.

Funding Agency:

Email Address:

suresh@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / **59**

Permanent Magnet ECR Ion Source and LEBT Dipole for Single-Ended Heavy Ion ToF-ERDA Facility

Author: Olli Tarvainen[1]

Co-authors: Dan Faircloth [1]; Hannu Koivisto [2]; Sami Kosonen [2]; Taneli Kalvas [3]; Ville Toivanen [4]

[1] *UK Science and Technology Facilities Council*

[2] *University of Jyvaskyla, Department of Physics*

[3] *University of Jyväskylä, Department of Physics*

[4] *Accelerator Laboratory, Department of Physics, University of Jyväskylä, FI-40014 Jyväskylä, Finland*

Corresponding Author: olli.tarvainen@stfc.ac.uk

We present the status of the ion source and low energy beam transport prototyping activities for a single-ended heavy ion time-of-flight elastic recoil detection analysis (ToF-ERDA) equipment for depth profiling of light elements. The environmentally friendly concept is based on a permanent magnet ECR ion source and dipole magnet on a 500 kV platform without SF_6 insulation, producing high charge state noble gas ion beams, e.g. 3-6 MeV argon. We report experimentally measured argon beam currents achieved with the CUBE-ECRIS permanent magnet minimum-B quadrupole ion source [1, 2], demonstrating ion fluxes of Ar^{6+}-Ar^{12+} in excess of 1-10 particle nA required for the low energy ToF-ERDA application. It is shown that the CUBE-ECRIS can produce over 1 particle nA krypton and xenon beams up to charge states Kr^{19+} and Xe^{24+}, which opens the door to extending the ToF-ERDA application to depth profiling of thin films containing heavier elements. Methods, such as increased microwave power and improved low energy beam transport, to reach higher charge states and final beam energies of these noble gas ions are outlined. Furthermore, we present the design, construction and validating field measurements of an adjustable-field permanent magnet 90 degree dipole prototype [3], completing the front-end of the envisioned ToF-ERDA facility. Finally, the status of the dipole magnet's integration into the CUBE-ECRIS test stand at the JYFL accelerator laboratory is described.

[1] T. Kalvas, O. Tarvainen, V. Toivanen, H. Koivisto, J. Instrum. 15, P06016 (2020).
[2] T. Kalvas et al, Plasma Sources Sci. Technol. 31 12LT02, (2022).
[3] O. Tarvainen et al, Nucl Instrum Methods Phys Res B 538, (2023), pp. 110-114.

Funding Agency:

Email Address:

olli.tarvainen@stfc.ac.uk

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Tuesday / 137

Beam Optics Study during Long-Pulse MeV-Class Beam Operation for the ITER HNB

Author: Yasuyuki Tanaka[1]

Co-authors: Hiroyuki Tobari [1]; Junichi Hiratsuka [1]; Kazune Suzuki [1]; Masahiro Ichikawa [1]; Masamichi Murayama [1]; Masashi Kisaki [1]; Mieko Kashiwagi [1]

[1] *National Institutes for Quantum Science and Technology (QST)*

Corresponding Author: tanaka.yasuyuki@qst.go.jp

The neutral beam injector for heating & current drive (HNB) for ITER requires the deuterium negative ion beam (D⁻) with 1 MeV, 40 A (200 A/m²) for 3600 s and hydrogen negative ion beam (H⁻) with 870 keV, 46 A (230 A/m²) for 1000 s. The required beam divergence angle is less than 7 mrad. Ensuring this beam divergence angle is essential to suppress excess power loads on the beamline, and consequently to realize high power and long pulse beam injection. To assure the design integrity of the ITER HNB accelerator, the beam emission spectroscopy (BES) was newly installed as contactless measurement of the beam during long pulse at MeV test facility (MTF: 1 MV, 0.5 A), which is a test facility to demonstrate the same intense hydrogen negative ion beams required for the ITER HNB. The accelerator in MTF is five stages MAMuG (Multi-aperture multi-grid) accelerator with the same acceleration gap of the ITER's one with nine apertures to extract the beam. In the first test of the BES, change of the beam current measured electrically can be represented in this BES system even in the complicated beam profiles of the multi beamlets. The divergence angles were measured at the beam energy from 300 keV to 750 keV with the same perveance. The divergence dependence on the beam energy was successfully confirmed. It was also observed that there were some fluctuations of the beam emission light during the long pulse. The cause of it was examined with the ion source condition and the beam footprint measurement. Such effective beam monitoring system for the ITER HNB by using ITER-relevant intense and long pulse beams is reported.

Funding Agency:

Email Address:

tanaka.yasuyuki@qst.go.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

191

Opening Remarks

77

For Intense Proton Beam Production with Compact Ion Sources: The ALISES Ion Source Family Developed at CEA Saclay

Author: Olivier Tuske[1]

Co-authors: Augustin Dubois [1]; Olivier DELFERRIERE [1]; Yannick GAUTHIER [1]; Yannick SAUCE [1]

[1] *Université Paris-Saclay, CEA, Département des Accélérateurs, de la Cryogénie et du Magnétisme, 91191, Gif-sur-Yvette, France.*

Corresponding Author: otuske@cea.fr

The production of intense proton beams in CEA Saclay started in the 90's with the development of the SILHI source to inject the IPHI accelerator. This ECR ion source is still in operation nowadays. ECR plasma is well-known heating process and plasma chamber internal dimensions were investigated in order to reduce size and maintenance time. In 2012 R&D investigations on those simple plasma chamber parameters were started with the design of the first ALISES ion source that will give birth to a new source family that still in progress today. This paper will summarize the different steps of this development.

Funding Agency:

Email Address:

otuske@cea.fr

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Tuske Olivier

120

Performance of Laser Ion Source LION Operated at Brookhaven National Laboratory

Author: Kazumasa Takahashi[1]

Co-authors: Kotaro Kondo ; Masahiro Okamura [2]; Megumi Sekine ; Shunsuke Ikeda [3]; Takashiro Karino ; Takeshi Kanesue [2]

[1] *Nagaoka University of Technology*

[2] *Brookhaven National Laboratory*

[3] *BROOKHAVEN NATIONAL LABORATORY*

Corresponding Author: kazumasa@vos.nagaokaut.ac.jp

LION is a laser ion source that has been in operation at Brookhaven National Laboratory (BNL). It is the first laser ion source to supply ion beams stably for users at a large accelerator facility in the world. LION is located at the upstream end of the heavy ion accelerator complex at BNL and supplies singly charged ion beams of various ion species. LION has been in operation from 2014 to 2023 and is planned to be upgraded. This presentation summarizes the operational performance achieved by LION.

Funding Agency:

Email Address:

kazumasa@vos.nagaokaut.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

33

Visible Camera-Based Diagnostic to Study Negative Ion Beam Profiles in ROBIN Ion Source

Author: Sidharth Kumar Dash[1]

Co-authors: Mainak Bandyopadhyay [2]; Kaushal Pandya [3]; Manas Bhuyan [4]; Ratnakar Yadav [4]; Hiren Mistri [5]; Mahendrajit Singh [2]

[1] *1.Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India 2. Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra 400094, India.*

[2] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India. 2. ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India. 3. Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra 400094, India.*

[3] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India.*

[4] *ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India.*

[5] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India*

Corresponding Author: sidharth.dash@ipr.res.in

The ion beam divergence & uniformity/homogeneity apart from beam energy are two crucial parameters of a large-size ion source-based NBI (Neutral Beam Injector) for the physical interpretations of beam dynamics & control of its extraction system. Characterization of H^- ion beam in ROBIN (Rf Operated Beam source in India for Negative ion) source using two orthogonally placed cameras installed at the top & a side port of the beamline, at an axial distance ~ 1.42m & ~ 1.90m from the grounded grid (GG) respectively are presented in this report. As the beam particles travel through the background gas, it emits photons in the visible range due to the production of excited species. The cameras characterize the beam profile based on the photon intensity level that is proportional to the beam current density. The ROBIN ion source with masked large area grid (LAG) extraction system, having only 146 open beamlet apertures dispersed equally on two grid segments for beam extraction. The grid segments are inclined by $0.873°$ from the vertical plane towards the forward direction. The exposed area of the grid segments focuses the beam vertically at a distance of $\sim$ 3m. The initial observations through lateral camera at 1.9m shows: individual beamlet identities are lost & each segment forms a Gaussian-type beam profile which eventually merges into a super-beam with a nearly flat-top profile with Gaussian wings at the edges. The shape of the super-beam depends on the mechanical beam focussing & the space-charge blowing-up effect. The estimation of beam uniformity/homogeneity & divergence is complex & so a beam modeling activity is initiated. The total beam profile is obtained by integrating all the beamlet profiles over the whole extraction area. The correlation between the measurements & simulation of the beam is highlighted in the report. Tomographic analysis using camera data & analytical models is the future scope of action.

Funding Agency:

Homi Bhabha National Institute

Email Address:

sidharth.dash@ipr.res.in

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

78

Production and Pre-Acceleration of Intense Light Ion Beams Based on Laser Ion Sources

Author: Huanyu Zhao[1]

Co-authors: Junjie Zhang [1]; Bo Zhang [1]; Yuting Lu [1]; Longfei An [2]; Liangting Sun [2]; Hongwei Zhao [2]

[1] *Institute of Modern Physics, Chinese Academ of Sciences*

[2] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: zhaohy@impcas.ac.cn

The capability of laser ion sources to produce high intensity short pulse ion beams, especially from solid element, makes them promising pre-injectors for some application facilities, such as cancer therapy facilities and accelerator-based neutron sources. Aiming at these applications, some specific ions, like carbon, lithium ions, have been produced and optimized in terms of the high charge state yields and the repeatability of the ion pulses with the laser ion source at the Institute of Modern physics in the past years. Specially, the capability of 50-hour operation of the carbon ion beams have been demonstrate by the laser ion source, with the pulse-to-pulse repeatability within 15% for the main pulse parameters, the total charge, peak current and pulse duration. Furthermore, the intense C6+ ions produced by the laser ion source was accelerated by a radio frequency quadrupole (RFQ) linac based on the Direct Plasma Injection Scheme (DPIS) to the energy 586 keV/u. The peak current at the exit of the RFQ and after the dipole magnet achieved 27 and 13 emA, respectively.

Funding Agency:

Email Address:

zhaohy@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

104

Feasibility Study of High Intensity Lithium Beam Production for Directional Pulsed Neutron Flux Generation

Authors: Anastasia Cassisa[1]; Antonino Cannavó[1]; Giovanni Ceccio[1]; Kazumasa Takahashi[2]; Masahiro Okamura[3]; Shunsuke Ikeda[4]; Takeshi Kanesue[3]

[1] *Nuclear Physics Institute of the Czech Academy of Science*

[2] *Nagaoka University of Technology*

[3] *Brookhaven National Laboratory*

[4] *BROOKHAVEN NATIONAL LABORATORY*

Corresponding Author: okamura@bnl.gov

A compact accelerator-driven neutron generator with a lithium beam driver can generate neutrons in a forward direction, even using incident beam energy at a near-threshold energy. Especially for medical and industrial applications, the ability to suppress unwanted radiation to patients is a major advantage. However, it is difficult to supply a high-intensity lithium-ion beam, and its practical application has been considered impossible. Therefore, to solve the most important issue, the lack of ion flux, a direct plasma injection method was adopted. In this method, pulsed high-density plasma from a metallic lithium foil generated by laser ablation is efficiently injected and accelerated by a radio-frequency quadrupole linear accelerator (RFQ linac). As a result, a peak beam current of 35 mA, which is higher than that of conventional ion sources, can be obtained. This demonstrated the feasibility of constructing a neutron generator using inverse kinematics scenario.

Funding Agency:

Email Address:

okamura@bnl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

133

Evolution of Transverse Phase-Space Distribution of Highly Charged Heavy Ion Beams through LEBT

Author: Takashi Nagatomo[1]

Co-authors: Glynnis Mae Saquilayan [2]; Jun-ichi Ohnishi ; Keita Kamakura [3]; Takahide Nakagawa [2]; Yoshihide HIGURASHI [2]

[1] *RIKEN Nishina Center*

[2] *RIKEN*

[3] *Center for Nuclear Study, The University of Tokyo*

Corresponding Author: nagatomo@riken.jp

We studied how the transverse phase-space distribution (PSD) of heavy-ion beams extracted from an ECR ion source (ECRIS) changes as a function of the extraction current $I_{\rm ext}$ through the LEBT. Heavy ion beams produced by ECRIS are distributed over a certain range of charge, so that the total current extracted from the ion source $I_{\rm ext}$ is an order of magnitude larger than that of the target ion beam. Therefore, when aiming for higher intensity ion beams than the now, the $I_{\rm ext}$ will also increase, and the emittance increase due to the space-charge effect (SCE) of $I_{\rm ext}$ is expected to become a serious problem. From the view point, it is necessary to clarify how the transverse PSD changes with changes in the extraction current $I_{\rm ext}$.
The emittance of Ar beams with several charges extracted from the 28-GHz superconducting ECRIS at the RIKEN was measured with a pepper-pot type emittance meter installed after the magnetic analyzer. The Ar beam was tuned to a few 10 μA to avoid significant SCE of its own. The $I_{\rm ext}$ was varied from 1.4 mA to 7.0 mA, mainly by adjusting the amount of N_2-support gas and microwave power for ECR heating.
It is found that the x and y emittances of $\mathrm{Ar}^{10+,11+,13+}$ increase with increasing values of $I_{\rm ext}$. Furthermore, it is found that the x-y distribution at the analyzing slit does not spread in a similar shape. These Ar beams, which are annularly distributed (hollow beam) up to $I_{\rm ext}$ ~ 2 mA, but from $I_{\rm ext}$ ~ 3mA, are gradually concentrated in a few localized spots. Finally, at 7 mA, the beams no longer have annular structure. These changes in the beam distribution are not distributions that can be simply predicted from the beam spread due to SCE only. We will discuss whether the combination of the SCE and aberrations during LEBT transport can explain these changes in the transverse PSD, or whether we need to include phenomena inside the ECRIS.

Funding Agency:

Email Address:

nagatomo@riken.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

70

Roadmap for the Increase of Beam Brilliance from ECRIS and Microwave Discharge Ion Sources

Authors: Andrea Miraglia[1]; Armando Coco[2]; Francesco Grespan[3]; Gino Sorbello[4]; Giovanni Russo[2]; Giuseppe Bilotta[2]; Giuseppe Castro[1]; Lorenzo Neri[5]; Luigi Celona[1]; Michele Comunian[3]; Ornella Leonardi[1]; Santo Gammino[1]; Sebastiano Boscarino[2]

[1] *INFN-LNS*

[2] *UNICT-DMI*

[3] *INFN-LNL*

[4] *UNICT-DIEEI*

[5] *INFN*

Corresponding Author: neri@lns.infn.it

The requirements for future accelerator chains need to increase the injected beam brilliance significantly, still keeping high the beam quality in terms of reliability, reproducibility and stability. A roadmap for ion source development may consist of several steps: plasma simulation, multiphysics simulation of each system component, high-level control system, plasma characterisation, beam characterisation, data analysis and, again, plasma simulation. The cycle starts and ends with plasma simulation because it is the instrument that shows how different phenomena take part in the plasma and beam formation and because, in such a way, the accuracy grows with each cycle. Commercial multiphysics simulation tools are essential for adequately designing all ion source equipment: magnets, intense electrostatic field regions, microwave propagation and coupling, thermal dissipation and vacuum. The dependence of source performances from source parameters (magnetic field profile, gas pressure, microwave power) has been widely investigated using a high-level control system able to test tens of thousands of source configurations without human interaction. This kind of characterisation allowed us to identify a new magnetic configuration, High Stability Microwave Discharge Ion Sources, that produces a beam with high stability, intensity and brilliance. The plasma simulation tool we developed discloses the role of two types of electrostatic waves in plasma formation and their correlation to stability. The simulation provides a complete view of ions and electrons energy and density distributions, the formation of the plasma meniscus and the beam extraction. The paper will present the results obtained with this development procedure on Microwave Discharge Ion Sources and how we started to apply it to the Electron Cyclotron Resonance Ion Sources development.

Funding Agency:

Email Address:

neri@lns.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

109

The Child Langmuir Illusion

Author: Dan Faircloth[1]

Co-authors: Olli Tarvainen [2]; Sami Kosonen [3]; Taneli Kalvas [4]; Ville Toivanen [5]

[1] *ISIS-RAL-STFC-UKRI*

[2] *UK Science and Technology Facilities Council*

[3] *University of Jyvaskyla, Department of Physics*

[4] *University of Jyväskylä, Department of Physics*

[5] *Accelerator Laboratory, Department of Physics, University of Jyväskylä, FI-40014 Jyväskylä, Finland*

Corresponding Author: dan.faircloth@stfc.ac.uk

It is a commonly held belief that the beam current extracted from an ion source varies with the applied extraction voltage with a V^(3/2) power law as defined by the space charge limited Child Langmuir equation.
However, recent experiments and modelling work have shown that the reason for the apparent

V^(3/2) relationship is not caused by space charge limited extraction, but instead the experimentally observed power law is caused by changes in the shape of the plasma meniscus and collimation on the extraction electrode. At lower extraction voltages the measured beam current is divergence limited. Due to computational limitations previous attempts to model this effect either rely on analytical equations to represent the plasma (e.g IBSimu), or they rely on combining a Particle in Cell (PIC) model of the plasma with a beam tracing model to track the beam through the extraction gap. Combining models or relying on analytical equations always leave questions about the reliability of the overall results. Here we present a single PIC model that is capable of modelling both the plasma meniscus and beam transport in the extraction gap in a single model using a variable density mesh in VSim. A single PIC model for extraction and beam transport provides strong proof that the origin of the V^(3/2) relationship for plasma ion sources is caused by meniscus focussing and collimation, not by space charge limited extraction. Excellent correlation between the PIC model, IBSimu and experiment is shown for low current Ar+ beams.
The maximum beam current and plasma densities that are currently computationally feasible to simulate are investigated for 2D3V Axisymmetric and full 3D variable density mesh PIC models in VSim.

Funding Agency:

Email Address:

dan.faircloth@stfc.ac.uk

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

115

Photo-Assisted Negative Ion Production in Caesium Sputter Ion Source

Author: Akbar Hossain[1]

Co-authors: Jaakko Julin [1]; Mikael Reponen [1]; Mikko Kivekäs [1]; Mikko Laitinen [1]; Olli Tarvainen [2]; Risto Kronholm [1]; Taneli Kalvas [1]; Ville Toivanen [1]

[1] *University of Jyväskylä*

[2] *STFC ISIS Pulsed Spallation Neutron and Muon Facility, Rutherford Appleton Laboratory, Harwell, OX11 0QX, UK*

Corresponding Author: akbar.a.hossain@jyu.fi

The production of negative ions in caesium sputter ion sources occurs on the surface of a cathode, which contains the ionized material and is covered by a thin layer of caesium that enhances the negative ion yield by lowering the work function. We have recently demonstrated that the negative ion beam currents can be enhanced by exposing the ion source cathode to a laser beam [1-3]. In this paper, we present new results on the laser-assisted enhancement of Br^- beam current. These results have been obtained by systematically varying the ion source parameters, most importantly the ionizer and Cs oven temperatures, and measuring the effect of a 15 W, 445 nm laser on the beam current with different cathode holder materials (Al, Ti, Ni, C or Cu). We discuss two findings that are relevant for the ion source operation. First, it is shown that the laser allows reaching higher beam currents at low ionizer temperatures compared to running the source without the laser but at higher ionizer temperature. Second, we sometimes observe a "priming effect", i.e. applying a number of laser pulses at certain ion source settings causes the beam current measured without the laser to increase significantly and remain high after ceasing the laser pulsing. These observations suggest that the photo-assisted effect is related to changes of the cathode caesium coverage. Finally, we report the results of our first attempts to sustain a stable beam current at the elevated level, achieved through active control of the laser power. This last experiment is relevant for applications of the caesium sputter source, e.g. in accelerator mass spectrometry.
REFERENCES:

1. Tarvainen O et al 2020 J. Appl. Phys. 128 094903
2. Tarvainen O et al 2021 AIP Conf. Proc. 2373 020001
3. A Hossain et al 2022 J. Phys. D: Appl. Phys. 55 445202

Funding Agency:

Email Address:

akbar.a.hossain@jyu.fi

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

149

3D Self-Consistent Full Wave –PIC Models for Investigating Space-Resolved ECR Plasma Properties

Author: Bharat Mishra[1]

Co-authors: Alessio Galatà [2]; Angelo Pidatella [3]; G. Torrisi [3]; Claudia Salvia [4]; Giorgio Mauro [3]; Eugenia Naselli [5]; Richard Rácz [6]; Sandor Biri [7]; David Mascali [3]

[1] *INFN-LNS and University of Catania*

[2] *INFN-Legnaro National Laboratories*

[3] *INFN, Laboratori Nazionali del Sud*

[4] *Università degli studi di Catania , INFN-LNS, Centro Siciliano di Fisica Nucleare e Struttura della Materia*

[5] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN, LNS)*

[6] *Institute for Nuclear Research (Atomki)*

[7] *Institute for Nuclear Research (Atomki),*

Corresponding Author: mishra@lns.infn.it

Simulations are a powerful method to study the correlation between output beams and internal dynamics of ECR plasmas, which involve a complex interplay between injected power, RF frequency, gas type and pressure. Modelling the microscopic properties of such plasmas is essential not only for fundamental research into the operation of ECR ion sources but also for applications like the PANDORA facility which aims to utilise the stellar-like laboratory plasma to measure in-plasma β-decay rates.

We present here some details on a 3D full wave-PIC code suite originally developed to model electron dynamics self-consistently with EM field propagation in the plasma under the cold electron approximation, but now extended to include ion dynamics as well. The coupled PIC codes have been updated to include stepwise ionisation, self-generated potential dip, and atomic excitation and can now furnish space-resolved information on charge density, energy and charge state distribution (CSD).

The models are currently being upgraded to include thermal plasma effects through evaluation of the hot plasma dielectric tensor to first order in temperature, thus including collisionless wave damping mechanisms. Furthermore, efforts are also underway to include collisional excitation and spontaneous emission in ions to obtain atomic level distributions along with CSD. Preliminary runs of the simulation show an encouraging match on comparison with experimental data and offer several perspectives for future improvements.

Funding Agency:

Email Address:

mishra@lns.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Eugenia Naselli

94

Plasma Homogeneity over One Extraction Beamlet Group at the Half Size ITER Negative Ion Source at ELISE Test Facility

Author: Dimitar Yordanov[1]

Co-authors: Araceli Navarro [2]; Christian Wimmer [3]; Dirk Wünderlich [2]; Rudi Riedl [2]; Ursel Fantz [4]

[1] *Max Planck Institute for Plasma Physics*

[2] *Max-Planck-Institut für Plasmaphysik*

[3] *Max-Planck-Institut f. Plasmaphysik*

[4] *Max-Planck-Institut für Plasmaphysik (IPP)*

Corresponding Author: dimitar.yordanov@ipp.mpg.de

The ion source for neutral beam injection at ITER has to provide high intensity and low divergence negative hydrogen and deuterium ion beam. Extracting the negative ions from the plasma is inevitably accompanied by co-extraction of electrons, which can limit the source performance, especially in deuterium. Reducing the co-extracted electrons is done by applying a magnetic filter field and a positive bias on the first grid of the extraction system (plasma grid) and on a window-frame plate in front of the plasma grid (bias plate) with respect to the source walls. On the one hand, the filter field reduces the electron temperature and the amount of co-extracted electrons, on the other hand, it introduces **E** x **B** drift. This drift creates a vertical plasma inhomogeneity in front of the extraction area and consequently a strong inhomogeneity of the co-extracted electrons.
Vertical plasma inhomogeneity close to the extraction area may have an impact on the extracted negative ion beam uniformity. This motivated detailed studies on the plasma inhomogeneity of a beamlet group in the half-ITER-sized ELISE ion source using a movable Langmuir probe. The investigations are done in deuterium at different filter field configurations and with different biases on the plasma grid and on the bias plate. It is demonstrated that the vertical distribution of the plasma potential changes together with the plasma grid sheath –from repelling to attracting sheath. A repelling sheath reduces the flux of electrons from the plasma towards the PG surface and consequently increases the co-extracted electron current, while the surface-produced negative ions are accelerated towards the plasma volume. The attracting sheath collects the electrons on the grid and reduces the flux of negative ions leaving the grid surface and moving towards the plasma volume.

Funding Agency:

EUROfusion

Email Address:

dimitar.yordanov@ipp.mpg.de

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

73

Production of Intense Vanadium Ion Beam for Super-Heavy Element Research Experiments

Author: Yoshihide Higurashi[1]

Co-authors: Takahide Nakagawa [1]; Jun-ichi Ohnishi [1]; Takashi Nagatomo [1]; Glynnis Mae Saquilayan [1]

[1] *RIKEN*

Corresponding Author: higurasi@riken.jp

Recently, production of highly charged medium mass heavy ion beams, such as Titanium (Ti), Vanadium (V), and Chromium (Cr) ions, are strongly demanded for the synthesis of new elements. At RIKEN, especially, production of intense 51V13+ ion beam for long term was strongly required for synthesis of the new element (Z=119). For this purpose, we constructed new superconducting electron cyclotron resonance (ECR) ion source and produced intense 51V13+ ion beam. For production of intense beam effectively, optimization of both consumption rate of the material and microwave power are very important. Therefore, we carefully studied the effect of not only microwave power, but also material consumption rate on the beam intensity systematically. Consequently, we produced about 1 emA of V13+ ion beam at the injected microwave power of about 3.5 kW at the extraction voltage of 12.6 kV. Additionally, to optimize the transmission efficiency of the beam in the accelerator, we studied the emittance size under the various conditions. In these test experiments, we observed that the emittance of V13+ ion beam was strongly dependent on the extraction current. It may be due to the space charge effect. In this paper, we report the experimental results of V13+ ion beam production under the various conditions (support gas pressure, consumption rate, microwave power) and the emittance measurements.

Funding Agency:

Email Address:

higurasi@riken.jp

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

192

Announcements

34

Innovative Cesiation Deriving Incredible 145 mA Beam from J-PARC Cesiated RF-Driven H⁻ Ion Source

Author: Akira Ueno[1]

[1] *Japan Atomic Energy Agency (JAEA)*

Corresponding Author: akira.ueno@j-parc.jp

In NIBS2022, the stable 8-hour operation of the J-PARC cesiated RF-driven H^- ion source in a test-stand with a 69.9 keV 120 mA beam and a beam duty factor of 4 % (1 ms x 40 Hz) was reported. However, the Cesiation condition was produced after many times and rather large amount of Cesium and H2Os injections. The necessary plasma electrode temperature (TPE) of 254 °C was also much

higher than those not only for the J-PARC source (about 70 °C) but also for the standard cesiated H^- ion sources (180 ~ 200 °C).

In this paper, the novel Cesiation procedure (how to inject H2Os and Cesium), which reproduces the Cesium effects lasting not only for the high TPE but also for the high-density plasma bombardments, is presented. The innovative Cesiation derived a 76.5 keV 145 mA beam from the J-PARC source in the test-stand. The measured results of the 145 mA beam, extraction electrode current and RF waveforms, parameter trends of an 8-hour 145 mA operation and the transverse emittances are also presented. The available H^- ion intensity for the J-PARC source operation energy of 52.5 keV was increased from 72 mA to 83 mA, which was consistent with the 1.5 power law on the beam energy compared with 145 mA for 76.5 keV.

Funding Agency:

Email Address:

akira.ueno@j-parc.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Akira UENO

37

Physics and Engineering Design of the 500 keV Beam Source for the BEST Neutral Beam Injector

Authors: Jianglong Wei[1]; Yahong Xie[1]; Yuming Gu[1]; Yuwen Yang[1]; Junwei Xie[1]; Lixin Yang[1]; Xufeng Peng[1]; Chundong Hu[1]; Yuanlai Xie[1]

[1] *Institute of Plasma Physics, Chinese Academy of Sciences*

Corresponding Author: jlwei@ipp.ac.cn

Burning plasma Experimental Superconducting Tokamak (BEST) will be a new magnetic confinement fusion device (major radius ~3.6 m, minor radius ~1.1 m, plasma current <7 MA, toroidal field <6.1 T) located at Hefei, China. BEST aims to research and develop the physics and technology of the fusion power to generate electricity. Neutral beam injection is one of the auxiliary heating and current drive systems for the BEST to ignite and sustain the D-T burning plasma. The BEST NBI system is now under final design, which has one injector with one beam source. The BEST beam source is required to generate a 500 keV and 20 A beam of deuterium negative ions for the first phase (800 keV and 31.25 A for the second phase). This paper presents the important details of the physics and engineering design of the 500 keV BEST beam source, which mainly consists of a four-driver RF plasma source and a three-stage electrostatic accelerator. The concepts, structures and parameters of the design are determined and supported via a series of numerical analyses, experimental activities, and also the R&D experience of the negative ion beam source worldwide.

Funding Agency:

Email Address:

jlwei@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

24

Work Function of the Caesiated Converter Surface at the BATMAN Upgrade H- Ion Source at Different Source Parameters

Author: Adrian Heiler[1]

Co-authors: Christian Wimmer [1]; Jacob Berner [1]; Ursel Fantz [1]

[1] *Max-Planck-Institut für Plasmaphysik (IPP)*

Corresponding Author: adrian.heiler@ipp.mpg.de

Negative hydrogen ion sources for neutral beam injection (NBI) systems for nuclear fusion experiments rely on the surface production of negative hydrogen ions on a low work function converter surface. The state-of-the-art technique for the generation of low work function surfaces is steady evaporation of the alkali metal Cs into the ion source. As the Cs layers are affected by residual gases from the background pressure (typically 10^{-7}–10^{-6} mbar) during vacuum phases as well as by reactive hydrogen particles and energetic photons during plasma phases, non-pure Cs layers are present and are subject to temporal dynamics. In consequence, the achievement of a stable and reliably good ion source performance (i.e., high extracted ion current and technically manageable co-extracted electron current) is challenging and in particular an issue for long pulse operation (1 h required in the case of ITER).
To control the work function and get insight into temporal dynamics in different operational scenarios, a work function diagnostic has been developed that is suitable for harsh ion source environments. High power fiber-coupled LEDs are used to irradiate the surface with different photon energies in vacuum phases between plasma pulses, and the resulting photocurrents are measured to evaluate the absolute work function according to the Fowler method. The diagnostic is successfully benchmarked at a dedicated laboratory experiment and is applied at the BATMAN Upgrade test bed at IPP, which is equipped with an ion source 1/8 of the size of the ITER NBI source and has recently been upgraded for long pulse operation. It is shown that the work function is subject to pronounced temporal dynamics and is far below the one of bulk Cs in a well-conditioned source. Investigations are performed both in H_2 and D_2 for operational scenarios with different pulse lengths to identify correlations between the work function, parameters such as the Cs density and ion source performance.

Funding Agency:

Email Address:

adrian.heiler@ipp.mpg.de

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

89

Optimizing the ITER NBI ion source by dedicated RF driver test stand

Author: Isabella Mario[1]

Co-authors: Emanuele Sartori [1]; Antonio Pimazzoni [1]; Gianluigi Serianni [1]

[1] *Consorzio RFX (CNR, ENEA, INFN, UNIPD, Acciaierie Venete SpA), Corso Stati Uniti 4, 35127 Padova, Italy*

Corresponding Author: isabella.mario@igi.cnr.it

The experimental fusion reactor ITER will feature two heating neutral beam injectors (NBI) capable of delivering 33(50) MW of power into the plasma. NBI consists of a plasma source for production of negative ions (extracted negative ion current up to $329\ \mathrm{A/m^2}$ in H and $285\ \mathrm{A/m^2}$ in D) then accelerated up to 1 MeV for one hour. The negative ion beam is neutralized, and the residual ions are electrostatically removed before injection. The beam divergence has to be 3 to 7 mrad.
The ion source in ITER NBIs relies on RF-driven, Inductively-Coupled Plasmas (ICP), based on the prototypes developed at IPP Garching; RF-driven negative-ion beam sources have never been employed in fusion devices up to now. Compared to filament sources, beams extracted from RF sources exhibit larger divergence, which might result in unexpected heat loads over the accelerator grids. Previous studies verified that such beam features are not due to the electrostatic grids shape, so it is believed plasma differences between the two source types play a role. Recent results of SPIDER, the full size ITER NBI ion source operating at NBTF in Consorzio RFX, Padova, highlighted non-uniformities, which are then projected into the properties of beam.
One RF driver, identical to the ones used in SPIDER, installed in a relatively small-scale experimental set-up, more flexible than large devices, is starting operations to carry out experiments on the properties of RF-generated plasmas, to contribute to the assessment of negative ion precursors, and their relationship with the plasma parameters, particularly when enhancing plasma confinement.
The scientific questions that have arisen from SPIDER operation guided the design of the test stand, which is described in this contribution together with the diagnostic systems and related simulation tools. The test stand will also allow testing technological developments and optimised engineering solutions related to the ICP design at the NBTF.

Funding Agency:

Eurofusion

Email Address:

isabella.mario@igi.cnr.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

129

Plasma Properties in Giant Negative Ion Sources for Fusion

Author: Emanuele Sartori[1]

Co-authors: Gianluigi Serianni [2]; Pierluigi Veltri [3]; Matteo Brombin [2]; Michele Fadone [2]; Nicolò Marconato [2]; Isabella Mario [2]; Diego Marcuzzi [2]; Palak Jain [4]; Riccardo Agnello [2]; Riccardo Casagrande [2]; Samuele Dal Bello [2]; Alberto Maistrello ; Roberto Pasqualotto [2]; Antonio Pimazzoni [4]; Carlo Poggi [2]; Basile Pouradier-Duteil [2]; Beatrice Segalini [5]; Alastair Shepherd [6]; Monica Spolaore [2]; Vanni Toigo [2]; Margherita Ugoletti [2]; Roman Zagorski [7]; Barbara Zaniol [2]; and NBTF team as listed in E. Sartori et al 2022 Nucl. Fusion 62 086022 [2]; Domenico Bruno [8]; Francesco Taccogna [8]; Bernd Heinemann [9]; Christian Wimmer [10]; Dirk Wünderlich [9]; Ursel Fantz [11]; Haruhisa Nakano [12]; Katsuyoshi Tsumori [12]; Hiroyuki Tobari [13]; Masashi Kisaki [13]; Mieko Kashiwagi [13]

[1] *Consorzio RFX - Università degli Studi di Padova*

[2] *Consorzio RFX*

[3] *ITER Organization*

[4] *Consorzio RFX (CNR, ENEA, INFN, UNIPD, Acciaierie Venete SpA), Corso Stati Uniti 4, 35127 Padova, Italy*

[5] *University of Padua - Consorzio RFX*

[6] *CCFE, Culham Science Centre, Abingdon OX14 3DB, Oxon, UK*

[7] *National Centre for Nuclear Research Pl-05-400 Otwock, Poland*

[8] *Istituto per la Scienza e Tecnologia dei Plasmi (ISTP)-CNR, Sedi di Bari e Padova, Italy*

[9] *Max-Planck-Institut für Plasmaphysik*

[10] *Max-Planck-Institut f. Plasmaphysik*

[11] *Max-Planck-Institut für Plasmaphysik (IPP)*

[12] *National institute for Fusion Science*

[13] *National Institutes for Quantum and Radiological Science and Technology (QST)*

Corresponding Author: emanuele.sartori@igi.cnr.it

Giant negative ion sources are used for neutral beam injectors in fusion devices. A high density of cold negative hydrogen ions is required over the large extraction area of the caesium-seeded plasma source, to provide the required negative ion current, distributed uniformly over thousands of extraction apertures. In this regard, it is expected that the expansion of plasma and neutrals from the driver region provides as uniform as possible plasma properties at the extraction region, for adequate compensation of the space charge of such large negative ion density, and relatively slow precursors for the negative ion conversion at caesiated surfaces. These conditions are difficult to achieve in the presence of the transverse magnetic field necessary to filter the diffusion of electrons to the extraction region. The driver region can be either a large volume multi-cusp filament-arc plasma, or an inductively-coupled plasma discharge realised in multiple drivers with external radiofrequency antennas: neutral beams based on filament sources for negative ions reached impressive performances in the recent decades, and an intense development program is in progress for the rf-driven source plasma to bridge the gap in view of the ITER neutral beam injector. The optimization of the ITER beam source plasma, aiming at extracting 350/290 A/m^2 of H^-/D^- with low-divergence at the low filling pressure of 0.3 Pa, is challenging.
A review of the ITER beam source physics is provided, based on experimental measurements obtained until now also on the one-to-one prototype SPIDER, and on results of numerical models. This is in the line of the massive work done until now towards the development of negative ion sources, based on both filament arc and rf sources. An overview of the ongoing R&D physics program for SPIDER is also proposed and results of experiments performed at other test facilities are presented.

Funding Agency:

Email Address:

emanuele.sartori@igi.cnr.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

155

First Results from the Hybrid RF-FA Ion Source at NIFS

Author: Katsuyoshi Tsumori[1]

Co-authors: Werner Kraus [2]; Haruhisa Nakano [1]; Yasuhiko Takeiri [1]; Katsunori Ikeda [1]; Kenji Saito [3]; Ning Tang [4]; Na Wang [4]; Engryht Rattanawongnara [1]; Kenichi Nagaoka [1]; Pierluige Velrti [3]; Stefan Briefi [2]; Bernd Heinemann [2]; Ursel Fantz [2]; Masaki Osakabe [1]

[1] *National Institute for Fusion Science*

[2] *IPP Garching*

[3] *ITER Organization*

[4] *ASIPP*

Corresponding Author: tsumori@nifs.ac.jp

Reduction of beamlet divergence angle is one of the most challenging issues in negative ion sources driven with Radio-Frequency (RF). Minimum divergence of the beamlet accelerated from Filament-Arc (FA) driven source is ~5 mrad, while that from RF driven source is ~12 mrad, which is larger than the beamlet divergences of 7 mrad required for ITER HNB and DNB. The reason why the beamlet

divergences are different in FA and RF discharges is not clear so far. To investigate the reason, a RF system was added to the present FA system at the NIFS NBI Test Stand (NIFS NBTS) and a FA-RF hybrid system, which is available to compare the beamlet characteristics using the same geometric, magnetic configuration and accelerator, was composed; (oscillator) and several components needed for the RF plasma generation (RF-driver, Faraday Shield, coil, etc) have been provided by IPP Garching. The ion source installed at the NBTS is modified to a FA-RF hybrid source by replacing the backplate to attach the RF driver on it. The NIFS NBTS equips several diagnostic devices to measure the source plasmas and accelerated beamlets and has a possibility to reveal the reason why the beamlet divergence is so different in the FA and RF driven modes.
In the presentation we are going to discuss the characteristics of the RF generator, matching box, distribution of the plasma parameters such as electron density, temperature and plasma potential, comparison of beamlet profiles in FA and RF modes and COMSOL simulation results.
•The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

Funding Agency:

National Institute for Fusion Science

Email Address:

tsumori@nifs.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Katsuyoshi Tsumori

67

Towards ITER-Relevant CW Extraction at Negative Ion Sources for Fusion

Author: Dirk Wünderlich[1]

Co-authors: Christian Wimmer [2]; Niek den Harder [1]; Michael Barnes [1]; Adrian Heiler [3]; Araceli Navarro [1]; Rudi Riedl [1]; Dimitar Yordanov [4]; Ursel Fantz [3]; Bernd Heinemann [1]

[1] *Max-Planck-Institut für Plasmaphysik*

[2] *Max-Planck-Institut f. Plasmaphysik*

[3] *Max-Planck-Institut für Plasmaphysik (IPP)*

[4] *Max Planck Institute for Plasma Physics*

Corresponding Author: dirk.wuenderlich@ipp.mpg.de

Negative hydrogen or deuterium ion sources for neutral beam injection (NBI) systems used at fusion devices are based on the surface production process at a caesiated low work function converter surface. The ITER NBI system will deliver a large beam (≈2 m × 1 m, extraction area ≈0.2 m^2) with an accelerated current of 40 A negative deuterium ions (46 A in hydrogen) with a high homogeneity, low divergence and being stable over one hour. While producing a stable and homogeneous negative ion beam is not an issue, during long pulses typically a significant increase in the co-extracted electrons is observed, limiting the pulse length or the achievable performance. This effect is particularly pronounced in deuterium and it is attributed to an increasing work function of the converter surface. A major and still open challenge is to develop conditioning techniques providing a homogeneous and stable low work function of the converter surface.

In the last years the negative ion source test facilities at IPP Garching, BATMAN Upgrade (using the small prototype source) and ELISE (using a source of the same width but only half the height of the

ITER NBI source) have been converted into CW machines. While BATMAN Upgrade focusses on basic physics investigations, aim of ELISE is to demonstrate that the ITER targets can be achieved by ion sources with an ITER-relevant size.

The contribution presents the status of both test facilities as well as latest results achieved during long pulse operation in hydrogen and deuterium. Investigations are performed on homogenizing and stabilizing the co-extracted electrons by either actively modifying plasma properties close to the converter surface or by modifying the flux of Cs onto the converter. For example, vertical plasma asymmetries, caused by plasma drifts, can be affected by biasing surfaces or introducing additional surfaces into the plasma and Cs can be evaporated in direct vicinity to the converter for a more controllable caesiation.

Funding Agency:

EUROfusion

Email Address:

dirk.wuenderlich@ipp.mpg.de

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

98

Beam Divergence of RF Negative Ion Sources for Fusion

Author: Christian Wimmer[1]

Co-authors: Michael Barnes [1]; Niek den Harder [1]; Frederik Merk [1]; Araceli Navarro [1]; Guillermo Orozco [1]; Gianluigi Serianni [2]; Pierluigi Veltri [3]; Dirk Wünderlich [1]; Dominikus Zielke [1]; Ursel Fantz [1]

[1] *Max-Planck-Institut f. Plasmaphysik*

[2] *Consorzio RFX*

[3] *ITER Organization*

Corresponding Author: christian.wimmer@ipp.mpg.de

Neutral beam injectors (NBI) for fusion facilities have strict requirements on the beam divergence (7 mrad for the ITER NBI at 1 MeV). Measurements of the single beamlet divergence of RF negative ion sources (at lower beam energy < 100 keV) show significantly higher values (12-15 mrad), also larger than filament arc sources at similar beam energies. This opened up questions whether the higher divergence is a problem at all after full acceleration, whether it is caused by different measurement or evaluation techniques, or whether it is a direct cause of the RF source, e.g. due to a higher temperature of negative ions. In a joint effort modeling and diagnostic capabilities at NNBI test facilities have been massively extended and evaluation methods benchmarked. Particularly challenging is the strong increase in beamlet divergence at a lower filling pressure, seen both in filament arc and RF sources. More energetic negative ions in the source at lower filling pressure might be the reason, hints given by beam simulations [1].

Beside the source and beam investigations carried out in SPIDER (with selected, isolated apertures rather than the total of 1280 apertures) at Consorzio RFX [2], the IPP test facilities ELISE (640 apertures) and BATMAN Upgrade (70 apertures) contribute to the physics understanding of the beam optics in RF sources. ELISE is capable to determine beam properties and uniformity on a global scale. BATMAN Upgrade offers an extended set of diagnostics for measuring and correlating the single beamlet divergence to fluxes and energy distributions of the parent particles atomic hydrogen and positive ions in the source plasma.

This contribution summarizes the present beam divergence understanding gained from experimental measurements and beam optics simulations. The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

[1] N. den Harder et al., contribution to the IAEA FEC 2023
[2] E. Sartori et al., this conference

Funding Agency:

Email Address:

christian.wimmer@ipp.mpg.de

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

177

Recent Research and Development of RF-Driven H- Sources at CSNS

Author: Weidong Chen[1]

[1] *Institute of high energy physics, Chinese academy of sciences (CAS)*

Corresponding Author: chenwd@ihep.ac.cn

The RF-driven ion source has been put into commissioning on China spallation neutron source (CSNS) accelerator since September of 2021. It has a service life time of more than 310 days and availability of almost 100%. To fully meet the requirements of CSNS project phase-II (CSNS-II), the beam intensity should be enhanced and the transverse emittance should be minimized. This report covers the recent research and development of the RF-driven H^- source, including the impurities elimination from the hydrogen plasma, the transverse emittance optimization, and space charge compensation study. A new test bench consisting of an ion source and an LEBT is constructed to carry out these measurements and research. A featured function of the LEBT is the electrostatic beam chopping. The influence of chopping electric field to the space charge compensation is also experimentally studied.

Funding Agency:

Email Address:

chenwd@ihep.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

62

Recent Advancements in the H- Injector Performance for the Spallation Neutron Source Operation and Upgrade

Author: Baoxi Han[1]

Co-authors: Chip Piller [1]; Chris Stinson [1]; Greg Terszakowec [1]; Martin Stockli [1]; Robert Welton [1]; Sang-Ho Kim [1]; Syd Murray Jr. [1]; Terry Pennisi [1]; Vic Andzulis [1]; Vladimir Peplov [1]

[1] *Oak Ridge National Laboratory*

Corresponding Author: hanb@ornl.gov

The Spallation Neutron Source (SNS) located at the Oak Ridge National Laboratory is an accelerator-based, pulsed neutron scattering facility utilized for a broad range of scientific research applications. For the past decade, the facility has operated at its original design beam power of 1.4 MW, and it is currently undergoing an upgrade to double its power to 2.8 MW within the next several years. A 65-keV H- injector, which comprises an rf-driven H- ion source and an electrostatic low energy beam transport system, delivers the required high-current, time-structured H- beam to the accelerator. At present, the H- injector can reliably provide 50-60 mA beam current at 6% duty-factor (1 ms, 60 Hz) for a 3-4 month service cycle on the accelerator front-end. To ensure sufficient operational margins for the SNS routine production runs and ongoing upgrade requirements, the injector system has been continuously improved on the R&D test facility. This paper presents the recent advancements in the injector system performance including enhancing the ion source beam output capability to 80 mA, improving the low energy beam transport and diagnostics, and upgrading the beam chopper system.

Funding Agency:

Email Address:

hanb@ornl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

57

The CUBE-ECRIS Prototype - Towards a 100 GHz ECRIS

Author: Taneli Kalvas[1]

Co-authors: Ville Toivanen [1]; Sami Kosonen [1]; Hannu Koivisto [1]; Olli Tarvainen [2]

[1] *University of Jyvaskyla, Department of Physics*

[2] *UK Research and Innovation, STFC Rutherford Appleton Laboratory*

Corresponding Author: taneli.kalvas@jyu.fi

The vast majority of the ECRIS are based on magnetic confinement with solenoid and sextupole field components. The development of such structure using present superconducting wire technology is limited to 56 GHz, whereas the minimum-B quadrupole ARC-ECRIS topology has been theoretically shown to enable up to 100 GHz operation. The CUBE-ECRIS is a recently commissioned permanent magnet implementation of the quadrupole topology and it has been used to demonstrate the applicability of the concept as a high charge state ion source. This work introduces technological challenges specific to the concept, especially the slit beam extraction system necessary due to beam formation at a line-shaped plasma loss. We present the most recent performance measurements of the ion source with measured charge state distributions for helium, argon, krypton and xenon. We show emittance measurements and analyze them together with transmission efficiency measurements with the aid of beam formation and transport simulations. Optional beam transport solutions for the slit beam are also presented. An outlook is presented with the next steps of the CUBE project being beam transport studies with a permanent magnet dipole and a possible upgrade to a 14 GHz permanent magnet CUBE.

Funding Agency:

Academy of Finland Project funding (N:o 315855)

Email Address:

taneli.kalvas@jyu.fi

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

10

Positive Ion Sources for Supplying with Mono/multi Charged Ions the C400 Cyclotron Devoted to the CYCLHAD Hadrontherapy Center at Caen

Author: Laurent Maunoury[1]

Co-authors: Dominique Bérard [2]; Guillaume Collignon [3]; Julien Perrussel [2]; Pascal Sortais [2]; Philippe Paliard [2]; Philippe Velten [1]; Vincent Engelen [3]; Xavier Donzel [3]

[1] *Normandy Hadrontherapy*

[2] *Polygon Physics*

[3] *Ion Beam Application*

Corresponding Author: laurent.maunoury@normandy-hadrontherapy.com

Normandy Hadrontherapy (NHa) and Ion Beam Application (IBA) are collaborating to develop a full hadrontherapy treatment solution based on a new multiparticle cyclotron. C6+ and He2+ ions will be accelerated up to 400 MeV/u and (H2)+ up to 260 MeV/u. Three different ion sources will be carried out for each accelerated particle: the mono-charged ion sources (H2)+ and low charged ion source He2+ are provided by the Polygon Physics (PP) company. The carbon ion source is under development at NHA in collaboration with IBA and PP.
The (H2)+ ion source is an industrial Tubular Ecr Source (TES) type one fitted for the needs of the NHa C400 cyclotron (60µA of (H2)+). The He2+ ion source is a classic 10GHz ECR type one with a new concept because the complete source is set inside a vacuum chamber and it runs under 10-6 mbar of gas residual pressure. The 12C6+ ion source is also an ECR type ion source operating at 14.5GHz frequency. Its design is under progress to produce a beam of naked carbon with a high stability and reproducibility.
The article will present the External Injection System of the NHa C400 cyclotron, hence it will focus on the experimental results obtained with the (H2)+ ion source and preliminary outputs from the He2+ ECRIS. A presentation of the multicharged ECRIS design dedicated to the 12C6+ production will be done.

Funding Agency:

Email Address:

laurent.maunoury@normandy-hadrontherapy.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

95

ASTERICS, a New 28 GHz Electron Cyclotron Resonance Ion Source for the SPIRAL2 Accelerator

Author: Thomas Thuillier[1]

Co-authors: Andrea Cernuschi [1]; Armand SInnana [2]; Arnaud Trudel [3]; Benoit Osmond [3]; Bertrand Hervieu [2]; Christophe Berriaud [2]; Christophe Peaucelle [1]; Cyrille Berthe [3]; Damien Goupillière [4]; Damien Simon [2]; Elena Fernandez-Mora [2]; Eric Lagorio [1]; Eric Perbet [1]; Florian Kiener ; Frederic Lemagnen [3]; Gilles Minier [2]; Hélène Felice [2]; Julien Angot [1]; Mickael Dubois [3]; Patrick Sole [1]; Pierrick Giroud-Garampon ; Robert Touzery [2]; Sony Trieste [2]; Sophia Schick [1]; Thierry Cadoux [2]

[1] *LPSC*

[2] *CEA*

[3] *GANIL*

[4] *LPC*

Corresponding Author: thomas.thuillier@lpsc.in2p3.fr

A new A/Q=7 injector is under development for the SPIRAL2 accelerator at Caen, France (NEWGAIN*project). A new 28 GHz superconducting electron cyclotron resonance ion source (ECRIS) named ASTERICS**, located on a high voltage platform, is under design for this project. The source features a modern cryostat allowing for the saving of helium during a quench and a large plasma chamber (90 mm radius and 600 mm length). The physical and technical motivations for a larger plasma volume are detailed and estimates of expected beam intensities enhancement discussed. The source will mainly produce metallic ion beams: the concept of a temperature-controlled liner (up to ~1000℃) will be presented. The design of the ion source and the high voltage platform, with a focus on the ECRIS superconducting magnet [1] will be detailed.

- NEWGAIN is the acronym for NEW GAnil Injector. Project funded by Agence Nationale de la Recherche.

** ASTERICS is the acronym for Advanced Spiral Two Electron cyclotron Resonance Ion source at Caen with Superconducting magnets

[1] D. Simon et al., "Design of ASTERICS: A Superconducting 28 GHz ECR Ion Source Magnet for GANIL," in IEEE Transactions on Applied Superconductivity, vol. 33, no. 5, pp. 1-5, Aug. 2023, Art no. 4002905, doi: 10.1109/TASC.2023.3260779.

Funding Agency:

Email Address:

thomas.thuillier@lpsc.in2p3.fr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

22

Initial Experimental Results of Producing Multicharged Ions Efficiently by Lower Hybrid Resonance Heating with Exciting Helicon Waves on Electron Cyclotron Resonance Ion Source

Author: Yushi Kato[1]

Co-authors: Shuhei Harisaki [1]; Wataru Kubo [1]; Kouki Iwahara [1]; Yushi Fujimura [1]

[1] *Osaka Univ.*

Corresponding Author: kato@eei.eng.osaka-u.ac.jp

For many years, we have been promoting basic and applied research on multiply-charged ion generation in an electron cyclotron resonance (ECR) ion source (ECRIS). Based on these experimental results, we considered the accessibility conditions for wave propagation in the magnetized plasma in ECRIS, and proposed various microwave feeding methods to improve the efficiency of multiply-charged ion generation by ECR, and tried them experimentally. As a typical original application case, the lowest-order Bernstein wave (BW) mode of conversion from electromagnetic (EM) to electrostatic wave (ES) mode in extra-ordinary mode (X-mode) introduction of higher frequency microwaves than ECR ones had been tried to induce upper hybrid resonance (UHR) heating. Next, we firstly excite helicon waves by introducing electromagnetic waves with frequencies lower than those of ECR and UHR into the ECRIS. Then, we generate the lower hybrid resonance (LHR) in the ECRIS by the electric field of the X-mode of the helicon wave which additionally heat the electrons, and then it was conducted to improve the efficiency of multiply-charged ion generation experimentally. As a result, due to the introduction of the X-mode electric field by the helicon wave introduction, under the critical condition where the LHR condition is satisfied, the LHR efficiently contributes to the electron heating, and the efficient generation of multiply charged ions is achieved, and then multicharged ion current were increased successfully. Under this condition, the electron energy distribution function obtained by the electrostatic probe measurement shows an increase in the high-energy region in the corresponding region, supporting occurrence of the resonance heating. In this paper, for the first time we will describe the initial experimental results on enhanced production of multiply-charged ions by the LHR resonance phenomenon of the low-frequency RF electromagnetic waves introduced to the ECRIS.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

80

European Effort to Improve Highly Charged Heavy Ion Beam Capabilities with ECR Ion Sources

Author: Hannu Koivisto[1]

Co-authors: Aleksandr Andreev [2]; Z. Asfari [3]; Sandor Biri [4]; Luigi Celona [5]; L. Charbonnière [3]; C. Charpentier [3]; Mickaël Dubois [6]; M. Filliger [3]; Alessio Galatà [7]; Benoit Gall [3]; Carmelo S. Gallo [7]; Michael Galonska [2]; Santo Gammino [5]; A. Gerbershagen [8]; B.N. Jones [8]; Herman Kremers [8]; Risto Kronholm [1]; Ralf Lang [2]; Frédéric Lemagnen [6]; Ornella Leonardi [5]; Fabio Maimone [9]; David Mascali [10]; Jan Mäder [2]; Eugenia Naselli [11]; Richard Rácz [12]; Thomas Thuillier [13]; Oskari Timonen [1]; Ville Toivanen [1]; G. Torrisi [10]

[1] *Accelerator Laboratory, Department of Physics, University of Jyväskylä*

[2] *GSI Helmholtzzentrum für Schwerionenforschung*

[3] *Université de Strasbourg, CNRS, IPHC*

[4] *Institute for Nuclear Research (Atomki),*

[5] *INFN-LNS*

[6] *GANIL, Grand Accélérateur National d'Ions Lourds*

[7] *INFN-Legnaro National Laboratories*

[8] *University Medical Center Groningen*

[9] *GSI HELMHOLTZZENTRUM FÜR SCHWERIONENFORSCHUNG*

[10] *INFN, Laboratori Nazionali del Sud*

[11] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN, LNS)*

[12] *Institute for Nuclear Research (Atomki)*

[13] *CNRS-LPSC*

Corresponding Author: hannu.koivisto@phys.jyu.fi

The European Electron Cyclotron Resonance (ECR) ion source community has more than 20 years of experience working together in various EU-funded projects. In the recent project, called ERIBS (European Research Infrastructure –Beam Services), we will focus on improving ion beam services for the EURO-LABS (European-Laboratories for Accelerator Based Sciences) research infrastructures. The EURO-LABS is a four-year project funded by the Horizon Europe program of the European commission for years 2022 - 2026. In ERIBS collaboration the best expertise, know-how and practices of our community will be exploited and transferred between the partners to take full advantage of the European ion source infrastructure. The aim is to extend the beam variety available for the European user community by developing beam production methods and techniques. This development includes further improvement of technologies related to high temperature ovens, axial sputtering and MIVOC method for all the participating laboratories. We will also aim to improve both short- and long-term plasma and beam stability, as well as methods for online monitoring of these conditions. This can be realized by optical emission spectroscopy, identifying kinetic plasma instabilities by means of hard x-ray detection and using online beam current monitoring systems. An example of the recent developments is the new service provided by the CNRS-IPHC team to synthesize enriched MIVOC compounds for the other ERIBS partners. For example, the team successfully prepared an enriched Chromocene compound, which was needed to produce ^{54}Cr and ^{50}Cr beams for the JYFL and GANIL nuclear physics programs, respectively. During the project the efforts will also continue to further advance the European ion beam database for beam preparation practices.

Funding Agency:

EU Horizon research and innovation programme

Email Address:

hannu.koivisto@phys.jyu.fi

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

88

Technical Approach towards the 4th ECR Ion Source FECR and the Latest Progress

Author: Liangting Sun[1]

Co-authors: Beimin Wu [1]; Canjie Xin [1]; Enmin Mei [1]; Hongwei Zhao [2]; Jibo Li [1]; Li Zhu [1]; Libin Li [1]; Lixuan Li [1]; Mingzhi Guan [1]; Shijun Zheng [1]; Wang Lu [3]; Wei Wu [1]; Xianjin Ou [1]; Xinyu Wang [1]; Xudong Wang [1]; Xuezhen Zhang [4]; Yuquan Chen [1]

[1] *Institute of Modern Physics, CAS*

[2] *Institute of Modern physics,CAS*

[3] *Institute of Modern Physics*

[4] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: sunlt@impcas.ac.cn

Aiming to the production of 1 emA U3x+ intense highly charged ion beam, the 4th generation ECR ion source 45 GHz FECR (First 4th generation ECR ion source) is under development at IMP. Fundamental progresses have been made towards this challenging machine. The first superconducting

ECR ion source magnet based on Nb3Sn technology is going to be in place to provide sufficient magnetic confinement to the 45 GHz microwave heated plasma. A new microwave coupling method called the Vlasov launcher has been proposed and successfully tested that can enhance the peak performance by 20% or higher. High power plasma chamber incorporated with the micro-channel cooling concept has been successfully developed and put in operation to handle the very challenging localized over-heating with the power dump density of ~10 MW/m2 or beyond, which enables the long-term stable operation of an ECR ion source at 10 kW power level. Careful tuning of a 24 GHz ECR ion source operating at afterglow mode has made very intense pulsed highly charged ion beams. Typical ion beams such as 503 eμA Xe30+, 266 eμA Xe34+, 169 eμA Xe38+ and 50 eμA Xe42+ at the FWHM pulse length of ~10 ms have been produced. Intense ion beams have been already used for routine operation at IMP, such as the continuous operation of Kr26+ or Xe32+ at the intensities of 200~300 eμA. This paper will present the status of the FECR and the key technologies to make it work at high microwave power and high intensity ion beam production.

Funding Agency:

NSFC with contract No. 11427904, 12025506

Email Address:

sunlt@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

84

Time-Resolved Measurement of Optical Emission Line Profiles from Electron Cyclotron Resonance Ion Source Plasma

Author: Oskari Timonen[1]

Co-authors: Hannu Koivisto [1]; Risto Kronholm [1]; Ville Toivanen [1]

[1] *Accelerator Laboratory, Department of Physics, University of Jyväskylä*

Corresponding Author: oskari.p.i.timonen@jyu.fi

Optical emission spectroscopy provides a noninvasive method to probe the properties of hot and highly charged magnetically confined plasmas. The optical emission line profiles enable, for example, identifying the different species and characterizing the relative population densities and temperatures of the ions and neutrals forming the plasma. The feasibility of this approach has been demonstrated at University of Jyväskylä accelerator laboratory by measuring the light emitted by Electron Cyclotron Resonance Ion Source (ECRIS) plasma with a high-resolution spectrometer setup POSSU (Plasma Optical SpectroScopy Unit). In these previous studies the emission line profiles were measured by scanning the desired wavelength range by rotating the diffraction grating of the spectrometer. This process is slow compared to many interesting plasma phenomena, thus limiting the applicability of the setup. Recently, POSSU has been upgraded by changing the light sensor from a photomultiplier tube to a position sensitive imaging sensor. As a result, it is possible to measure simultaneously a 1 - 2 nm wavelength range, with a spectral resolution in the order of picometers, without moving the grating. This enables time-resolved study of the optical emission line profiles. The measured wavelength region can be chosen between 370 nm and 870 nm, which covers the visible light spectrum, by turning the grating. The time evolution of optical emission line profiles emitted from the JYFL 14 GHz ECRIS plasma, during shifting plasma conditions induced by changing the gas balance, has been measured to demonstrate this new capability. The temporal evolution of temperatures and emission intensities of selected ion and neutral species, correlated with extracted ion beam currents, are presented.

Funding Agency:

Academy of Finland Project funding (N:o 315855)

Email Address:

oskari.p.i.timonen@jyu.fi

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

193

Excursion

4

Upgrade and Improvement of the TRIUMF Charge State Booster ECRIS

Author: Joseph Adegun[1]

Co-authors: Friedhelm Ames [1]; Oliver Kester [1]

[1] *TRIUMF*

Corresponding Author: jadegun@triumf.ca

The RF system of the TRIUMF electron cyclotron resonance ion source charge state booster (CSB) was recently upgraded for the implementation of two-frequency heating using a single waveguide. The injection and extraction optics as well as the injection and extraction systems of the CSB were systematically modelled and optimized. The quadrupole scan technique was developed for beam emittance measurement. The implementation of the two-frequency heating and systematic optimization were conducted to improve the efficiency and beam quality of the charge state booster. Under the single-frequency heating regime with well-optimized plasma and beam optics, the maximum charge state of 133Cs isotope that could be produced was 27+ with an efficiency of 1.5 % and the peak of the efficiency distribution was on Cs23+ with an efficiency of 8.8 % but with the two-frequency heating, the maximum charge state of cesium that could be produced shifted to 32+ with an efficiency of 0.02 % and the peak of the efficiency distribution shifted to Cs26+ with an efficiency of 9.1 %. For the tests with 238U isotope and under the single-frequency heating regime, the maximum charge state that could be produced was 36+ with an efficiency of 0.03 %. This could be improved to a 39+ charge state under the two-frequency heating with an efficiency of 0.02%. Although the peaks of the efficiency remain the same for both heating regimes at 28+, the efficiency of U28+ under the two-frequency heating regime was more than a factor of 2 higher. Another significant effect of the two-frequency heating on the CSB was that the total beam emittance was about a factor of 2 smaller than the total emittance measured under the single-frequency heating counterpart due to the increase in the electron energy most especially in the plasma core.

Funding Agency:

NSERC

Email Address:

jadegun@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

132

Design of a Novel ECR Ion Trap Facility for Fundamental Plasma Processes and Nuclear Physics Studies

Author: Eugenia Naselli[1]

Co-authors: Alessio Galatà [2]; Angelo Pidatella [3]; Bharat Mishra [4]; David Mascali [3]; Domenico Santonocito [3]; G. Torrisi [3]; Giorgio Finocchiaro [5]; Giorgio Mauro [3]; Luigi Celona [6]; Richard Rácz [7]; Sandor Biri [8]

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN, LNS)*

[2] *INFN-Legnaro National Laboratories*

[3] *INFN, Laboratori Nazionali del Sud*

[4] *INFN-LNS and University of Catania*

[5] *INFN, Laboratori Nazionali del Sud & University of Catania*

[6] *INFN-LNS*

[7] *Institute for Nuclear Research (Atomki)*

[8] *Institute for Nuclear Research (Atomki),*

Corresponding Author: eugenia.naselli@lns.infn.it

An innovative ECR ion trap facility, called PANDORA (Plasma for Astrophysics, Nuclear Decay Observation and Radiation for Archaeometry), was designed for fundamental plasma processes and nuclear physics investigations. The overall structure consists of three main pillars: a) a large (70 cm in length, 30 cm in diameter) ECR plasma trap with a fully superconducting B-minimum magnetic system (Bmax = 3.0 T) and an innovative design to host detectors and diagnostic tools; b) an advanced non-invasive plasma multidiagnostic system to locally characterize the plasma thermodynamic properties; c) an array of 14 HPGe detectors.
The PANDORA facility is conceived to measure, for the first time, in-plasma β-decaying isotope rates under stellar-like conditions. The experimental approach consists in a direct correlation of plasma parameters and nuclear activity by disentangling - through the multidiagnostic system that will work in synergy with the γ-ray detector array - the photons emitted by the plasma (from microwave to hard X-ray) from γ-rays emitted after the isotope β-decay.
In addition to nuclear physics research, fundamental plasma physics studies can be conducted in this unconventional ion source equipped with tens of detection and diagnostic devices (RF polarimeter, OES, X-ray imaging, space and time-resolved spectroscopy, RF probes), with relevant implications for R&D of ion sources for accelerator physics and technology.
Several studies have already been performed in downsized nowadays operating ECRIS. Stable and turbulent plasma regimes have been described quantitatively, studying the change of plasma morphology, confinement, and dynamics of losses using space resolved X-ray spectroscopy, also measuring locally the plasma density and temperature. A fully virtual experiment joining PIC plasma simulations, dynamics of metallic isotopes injection in plasma and GEANT4 simulations modeling the response of the HPGe array and diagnostics tools is ongoing.

Funding Agency:

Email Address:

eugenia.naselli@lns.infn.it

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Eugenia Naselli

131

FRIB ECR Ion Sources Operation and Future Development

Author: Junwei Guo[1]

Co-authors: Dan Morris [1]; Guillaume Machicoane [1]; Jie Wei [1]; Larry Tobos [1]; Nathan Bultman [1]; Philip Morrison [1]; Randy Rencsok [1]; Terrell Gee [1]; Ting Xu [1]; Tomofumi Marurta [1]; Xing Rao [1]; Xiaoji Du [1]; Yoonhyuck Choi [1]; Tengming Shen [2]; Diego Arbelaez [2]; Paolo Ferracin [3]; Soren Prestemon [2]

[1] *Facility for Rare Isotope Beams*

[2] *Lawrence Berkeley National Laboratory*

[3] *LBNL*

Corresponding Author: guoju@frib.msu.edu

The Facility for Rare Isotope Beams (FRIB) has become operational as a user facility in April 2022. The primary beam power available on target routinely now reaches 5 kW and preparations for operation at 10 kW are underway with an ultimate design goal to deliver 400 kW within the next 6 years. FRIB front end currently operates two ECR ion sources: a room temperature ECR ion source operating at 14 GHz, ARTEMIS, in operation since 2016, and a High-power superconducting Nb-Ti ECR ion source (HP-ECR) in operation at 18 GHz since January 2023. The HP-ECR has demonstrated the magnetic field necessary for operation at 28 GHz and preparations are underway for high power operation, including the installation of a 28 GHz gyrotron microwave system, upgraded radiation shielding, improved new plasma chamber, high temperature oven and so on. In addition, to mitigate single point failure for intense highly charged ion beam and maintain high availability, a second 28 GHz ECR ion sources based on a Nb3Sn sextupole is being developed in collaboration with the superconducting magnet group at Lawrence Berkeley National Laboratory (LBNL) that developed the original cold mass for the 28 GHz HP-ECR. This paper presents progress made in some of these areas as well as summarize the current state of the FRIB ion sources and future development.

This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under the Cooperative Agreement DE-SC0000661

Funding Agency:

U.S. Department of Energy Office of Science

Email Address:

guoju@frib.msu.edu

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

96

First Ion Source at ISOL@MYRRHA with an Improved Thermal Profile - From Prototype to the First Experimental Validation

Author: Sophie Hurier[1]

Co-authors: Alexandros Koliatos [2]; João Pedro Ramos [3]; Jürgen Verlinden [3]; Katerina Chrysalidis [2]; Kim Rijpstra [3]; Lucia Popescu [3]; Mia Au [2]; Philip Creemers [3]; Ralitsa Mancheva [4]; Thomas Cocolios [5]

[1] *SCK CEN & KULeuven*

[2] *CERN*

[3] *SCK CEN*

[4] *CERN, KU Leuven*

[5] *KU Leuven*

Corresponding Author: sophie.hurier@sckcen.be

MYRRHA will be the world's first large-scale Accelerator Driven System at power levels scalable to industry. In ISOL@MYRRHA, Radioactive Ion Beams (RIBs) will be produced using the Isotope Separation On-Line (ISOL) technique, with increased isotope production through high-intensity primary beam and long irradiation times. High-quality RIBs are to be maintained over that period, up to 4 weeks. As an initial source, a surface ion source, or hot cavity, was chosen for its reliability and simple design.
This ion source type was studied theoretically and experimentally by Kirchner [1990, Nucl. Instrum. Methods Phys. Res. A 292] and the temperature was clearly identified as a key element to the ion source operation, but it was assumed to be constant along the cavity. However, a set of finite element thermal-electric simulations performed with ANSYS as well as measurements conducted by researchers at SPES [Manzolaro 2017, Rev. Sci. Instrum. 88] have shown a temperature inhomogeneity along the cavity, where the temperature is the highest in the middle of the cavity and decreases towards both edges.
A new ion source design was studied to reduce this inhomogeneity: a modified heating system was proposed with an Active Thermal Screen (ATS). The formerly passive thermal screen from SPES and ISOLDE is now an actively heated part which will heat up the cavity end. As a first validation of this design, simulations were performed in an earlier work [Hurier 2020, J. Phys. Conf. Ser. 2244] and the calculated thermal profile showed a significantly reduced temperature drop at the cavity's end compared to SPES results. A first prototype was constructed and tested at CERN to validate the ANSYS thermal-electric simulations. Secondly, the surface (and laser) ionisation properties of this prototype were tested at the ISOLDE Offline II at CERN. These experimental results will be presented in this contribution.

Funding Agency:

SCK CEN Academy

Email Address:

sophie.hurier@sckcen.be

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Kim Rijpstra

154

Radioactive Molecular Ion Beams at CERN-ISOLDE

Author: Mia Au[1]

Co-authors: Bruce Marsh [1]; Christoph E. Düllmann [2]; Christoph Schweiger [1]; Edgar Reis [1]; Frank Wienholtz [3]; Jake Johnson [4]; Jochen Ballof [5]; Jordan Reilly [6]; Julius Wessolek [1]; Katerina Chrysalidis [1]; Lukas Nies [7]; Lutz Schweikhard [7]; Maxime Mougeot ; Michail Athanasakis-Kaklamanakis [4]; Moritz Schlaich [3]; Paul Fischer [7]; Reinhard Heinke [1]; Robert Berger [8]; Sebastian Rothe [1]; Shane Wilkins [9]; Simon Stegemann [1]; Ulli Koester [10]; Wiktoria Wojtaczka [4]

[1] *CERN*

[2] *Johannes Gutenberg-University Mainz*

[3] *TU Darmstadt*

[4] *KU Leuven*

[5] *FRIB/MSU*

[6] *University of Manchester*

[7] *University of Greifswald*

[8] *Philipps-Universität Marburg*

[9] *MIT*

[10] *ILL*

Corresponding Author: mia.au@cern.ch

The ISOLDE facility at CERN provides ion beams of nuclides produced in reactions between 1.4-GeV protons and thick targets. Molecules have been studied as a method to deliver beams of release-limited refractory elements by forming volatile molecules [1-5]. Molecular sideband extraction is also used as a technique to improve beam purity. Molecular beams additionally provide opportunities for fundamental physics studies [6-11].
We present our work on molecular ion beam development at ISOLDE and beam composition studies using: the ISOLTRAP Multi-Reflection Time-of-Flight Mass Spectrometer (MR-ToF MS) [12] for identification by ToF mass measurements, online gamma-ray spectroscopy at the ISOLDE tape station [13,14], and off-line alpha- and gamma-ray spectrometry of ion-implanted samples.
This project has received funding from the European's Union Horizon 2020 Research and Innovation Program (grant number 861198 project 'LISA'MSC ITN) and support by the German Federal Ministry of Education and Research (BMBF) (grant numbers 05P18HGCIA, 05P21RDFNB, and 13E18CHA, Wolfgang Gentner Program)
[1] R. Eder et al., Nucl. Inst. and Meth. B 62, 535 (1992)
[2] R. Kirchner, Nucl. Inst. and Meth. B 126, 135 (1997)
[3] H. Frånberg et al., Rev. Sci. Inst. 77, 03A708 (2006)
[4] J. Ballof et al., Eur. Phys. J. A 55, 65 (2019)
[5] U. Köster et al., Eur. Phys. J. Special Topics 150, 293 (2007)
[6] G. Arrowsmith-Kron et al., arXiv, DOI 10.48550/arXiv.2302.02165 (2023)
[7] T. A. Isaev et al, Phys. Rev. A, 82, 052521 (2010)
[8] T. A. Isaev et al., arXiv, DOI 10.48550/arXiv.1310.1511 (2013)
[9] M. Safronova et al., Rev. Mod. Phys. 90, 025008 (2018)
[10] N. Hutzler et al., arXiv, DOI 10.48550/ARXIV.2010.08709 (2020)
[11] R. Garcia-Ruiz et al., Nature 581, 396 (2020)
[12] R. N. Wolf et al., Int. J. Mass Spec. 123, 349 (2013)
[13] S. Stegemann et al., Nucl. Inst. and Meth. B. Conf. Proc. EMIS XIX (2022)
[14] R. Catherall et al., J. Phys. G : Nucl. Part. Phys., 44, 094002 (2017)

Funding Agency:

Email Address:

mia.au@cern.ch

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

186

Ion Sources for Radioactive Ion Beam Delivery at CERN-ISOLDE

Author: Sebastian Rothe[1]

[1] *CERN*

Corresponding Author: sebastian.rothe@cern.ch

The ISOLDE radioactive ion beam facility is located at CERN's Proton Synchrotron Booster, where thick targets are irradiated with 1.4-GeV protons. Over 1000 different radioisotopes with half-lives down to milliseconds can be delivered to low-energy experimental setups at up to 60 keV, or post accelerated using the REX and HIE ISOLDE linear accelerators.
One important factor for planning experiments at ISOLDE and other RIB facilities alike is the yield or production rate of the desired isotope. When deciding on the target and ion source combination different aspects must be considered: the reaction cross-section for the isotope production in the target matrix, the diffusion and effusion properties of the element, and the optimal ionization mechanism. In addition to the absolute rate of a certain isotope of interest, the unwanted isobaric contaminants often must be addressed by choosing additional purification techniques. Examples are use of a neutron converter, quartz transfer lines, creation of radioactive molecules, or the use of the Laser Ion Source and Trap (LIST).
Here we will introduce the ISOL process and illustrate the aspects to be considered when selecting target and ion source combinations to optimize the yield and purity of the radioactive ion beam for the user. The ongoing and future ion source developments will be discussed and development facilities will be introduced.

Funding Agency:

Email Address:

sebastian.rothe@cern.ch

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Sebastian Rothe

60

Review of the High-Current Capabilities and Upgrades of the EBIS/T Charge-Breeding System of the Reaccelerator at the Facility for Rare-Isotope Beams

Author: Alain Lapierre[1]

Co-authors: Antonio Villari [1]; Hyock-Jun Son [1]; Stefan Schwarz [1]

[1] *FRIB/MSU*

Corresponding Author: lapierre@frib.msu.edu

The Reaccelerator (ReA) of the Facility for Rare-Isotope Beams (FRIB) at Michigan State University (MSU) uses a helium gas-filled Radio-Frequency Quadrupole (RFQ) ion trap and an Electron-Beam Ion Trap (EBIT) as a charge-breeding system. Rare isotopes produced via projectile fragmentation or in-flight fission are selected by the Advanced Rare Isotope Separator of FRIB and stopped in a helium gas cell before transport at low energy to ReA. Continuous ion beams are injected into the RFQ trap, which cools and bunches the ions, that are then ejected as ion pulses. The ion pulses are injected into the EBIT, captured, charge bred, ejected, and accelerated by the superconducting linear accelerator of ReA to several MeV/u.

The electron current of the EBIT (300 - 600 mA) limits its capacity to ~2E10 charges, yielding maximum rates of less than ~2E10 pps for light ions. An upcoming upgrade to the EBIT electron gun is expected to provide 2 A in current. In parallel, a high-current electron-beam ion source (HCEBIS) is being commissioned. In its present configuration, the HCEBIS can provide an electron current of 2 A. An upgrade will increase the current to 4 A. The implementation of these two upgrades is

expected to allow for maximum rates of ~2E11 pps (light ions), compatible with FRIB projected rates. This will also provide redundancy of the breeders.

We present the status of the upgraded EBIT and HCEBIS. We also review the expected high-intensity capabilities of the future ReA frontend considering the maximum capacity of the RFQ trap.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics and used resources of the Facility for Rare Isotope Beams (FRIB), which is a DOE Office of Science User Facility, operated by Michigan State University, under Award Number DE-SC0000661.

Funding Agency:

U.S. Department of Energy, Office of Science

Email Address:

lapierre@frib.msu.edu

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

194

Brightness Award Talk

Corresponding Author: valentin.fedosseev@cern.ch

174

Novel ECR Magnets in Development and Under Construction at LBNL

Author: Mariusz Juchno[1]

Co-authors: Aurelio Hafalia [1]; Damon Todd [1]; Daniel Xie [2]; Janilee Benitez [2]; Jie Wei [3]; Junwei Guo [3]; Lianrong Xu [1]; Paolo Ferracin [4]; Soren Prestemon [1]; Tengming Shen [1]

[1] *Lawrence Berkeley National Laboratory*

[2] *Lawrence Berkeley National Lab*

[3] *Facility for Rare Isotope Beams*

[4] *LBNL*

Corresponding Author: mjuchno@lbl.gov

Future heavy-ion driver accelerators will require high charge state ECR sources operating beyond the currently achievable heating radio frequency of 28 GHz. Lawrence Berkeley National Laboratory is exploring two technological paths that can enable reaching this goal. The first approach is by using Mixed Axial and Radial field System (MARS). This novel coil system allows the use of the Nb-Ti superconducting coil system to reach the 45 GHz resonant heating while operating within the field limit of 9 T at 4.2 K. This project aims at building a new ion source at the 88 inch cyclotron facility at LBNL. The second approach is by using a traditional sextupole-in-solenoid coil configuration, similar to VENUS magnet, but with sextupole coils that are wound using the Nb3Sn superconductor that has a much higher field limit of 22 T at 4.2 K. This project, in collaboration with FRIB facility at Michigan State University, aims at building a 28 GHz ion source but it allows to develop coil fabrication techniques that will be critical for the next generation ion sources as well. This article describes the design of both magnet systems and summarizes coil fabrication challenges, the development and

prototyping efforts so far.
This work was supported in part by the U.S. DOE, Office of Science, Office of Nuclear Physics under contract number DE-AC02-05CH11231 (MARS) and DE-SC0000661 (FRIB).

Funding Agency:

DOE, Office of Science, Office of Nuclear Physics

Email Address:

mjuchno@lbl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

16

The PI-LIST: High-Resolution Crossed-Beams Laser Spectroscopy inside the ISOLDE Laser Ion Source

Authors: Asar AH Jaradat[1]; RILIS team[None]

[1] *CERN*

Corresponding Author: asar.a.h.jaradat@cern.ch

Laser resonance ionization spectroscopy is a sensitive tool for investigating nuclear structures [1], but its spectral resolution is limited by Doppler broadening, which becomes significant at ion source temperatures of approximately 2000℃. This can limit resolution to 1-10 GHz, making it difficult to measure nuclear magnetic and quadrupole moments.
A new laser ion source design has been implemented at ISOLDE to provide in-source spectroscopy capabilities with higher resolution than previously achievable. It is based on the high beam purity Laser Ion Source and Trap (LIST) [2, 3], featuring spatial separation of the hot cavity where potential ion beam contamination can arise from non-laser related ionization mechanisms such as surface ionization. This design features the Perpendicularly Illuminated LIST (PI-LIST) [4], which uses a crossed laser/atom beam geometry for spectroscopy, resulting in only the transverse velocity spread of the atom ensemble contributing to the experimentally observed Doppler broadening. This allows for spectral resolutions down to 100-200 MHz, an order of magnitude below usual limitations. This technique was used to study neutron-rich actinium isotopes with the highest spectral resolution ever achieved for in-source resonance ionization spectroscopy at ISOLDE, CERN.[5] Technical implementation challenges and limits, such as efficiency loss, will also be discussed.
[1] V. Fedosseev et al., J. Phys. G: Nucl. Part. Phys. 44 084006 (2017)
[2] D. Fink et al., Nucl. Instr. Meth. B, 317 B, 417-421 (2013)
[3] D. Fink et al., Phys. Rev. X 5, 011018 (2015)
[4] R. Heinke et al., Hyperfine Interact 238, 6 (2017)
[5] E. Verstraelen et al., Phys. Rev. C 100, 044321 (2019)

Funding Agency:

CERN, Marie Skłodowska-Curie Actions grant 861198

Email Address:

asar.a.h.jaradat@cern.ch

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

7

Commissioning and First Operation of East Japan Heavy Ion Center at Yamagata University

Author: Hikaru Souda[1]

Co-authors: Azusa Sato [2]; Fumihisa Ouchi [1]; Hiraku Sato [1]; Hongbo Chai [1]; Kenji Nemoto [1]; Kyohei Nagai [2]; Masashi Katsumata [2]; Michitaro Sei [2]; Miyu Ishizawa [1]; Shinya Sato [1]; Shun Sawamura [2]; Sung Hyun Lee [1]; Takayuki Kanai [3]; Takayuki Taguchi [2]; Takeo Iwai [1]; Yohei Kanto [1]; Yoshiyuki Ueno [1]; Yuya Miyasaka [1]

[1] *Yamagata University*

[2] *Accelerator Engineering Corporation*

[3] *Tokyo Women's Medical University*

Corresponding Author: souda@med.id.yamagata-u.ac.jp

A world smallest carbon ion radiotherapy facility, East Japan Heavy Ion Center, Faculty of Medicine, Yamagata University, started treatment operations in February 2021. The treatment system consists of an ECR ion source, an RFQ and IH-type drift tube linac, a 430 MeV/u synchrotron and a spot-scanning irradiation system. It has two treatment rooms, one is a fixed horizontal beam port and the other is a rotating gantry beam port with superconducting magnets.
The ECR ion source is the 6th Kei2-type permanent magnet 10 GHz ECR ion source with a maximum field of 0.8 T. All the improvements of the previous facilities are applied to the ion source, such as helium gas-assisted operation and changes in the shape of an anode electrode and a cathode electrode to reduce the discharge. Owing to these improvements, the ion source has been operated stably during the commissioning and clinical operation.
The irradiation system of Yamagata University eliminated the plastic block range shifter to realize a compact gantry, and has 600 energy levels to control the beam range in step of 0.5 mm. In order to optimize the beam transport parameters quickly, automation tools for orbit correction were developed.
Machine commissioning and clinical commissioning were carried out in parallel to allow treatment to begin earlier. First, the horizontal fixed beam port was commissioned by verifying the dose distribution of the treatment planning system. Then, the gantry beam port was commissioned by full beam distribution measurement for representing beam angle of 90 degree, and other angles were sequentially released after the compatibility measurement of beam position, beam size, and two-dimensional uniformity. In September 2022, we were able to accept all treatment sites in the gantry port with angle step of 30 degrees. By March 2023, 890 cancer patients had been treated and 24 angles with a 15 degree step were available. Further improvements to increase beam efficiency are ongoing.

Funding Agency:

Email Address:

souda@med.id.yamagata-u.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

45

HVE Ion Sources for Medium and High-Energy Accelerator Systems

Author: Arun Tejaswee Annaluru[1]

Co-author: Dirk Jozef Willem Mous [1]

[1] *High Voltage Engineering Europa B.V.*

Corresponding Author: aannaluru@highvolteng.com

Since decades, High Voltage Engineering (HVE) manufactures particle accelerator systems for research and industry. HVE's product line includes Singletron and Tandetron accelerator systems with terminal voltages of up to 6 MV. They are dedicated to a wide range of applications, including ion implantation and irradiation, Ion Beam Analysis (IBA), Accelerator Mass Spectrometry (AMS), and neutron calibration. In this paper, we give an overview of the different positive and negative ion sources that are applied in these systems.

We focus especially on the recent development and the performance of a compact 2.45GHz permanent magnet ECR bipolar ion source (HVE Model SO-160), used for negative light-ion injection into tandem accelerators. It generates high-current, low-emittance light-ion beams at 30 keV energy. The novelty in the design of this ion source is that it combines direct negative extraction for H- with positive extraction for He+ that is followed by charge exchange to He- in a Na-based electron donor canal. The switch-over between H and He operation is fully automated and computer controlled, including the change-over of the required power supplies, and does not require any mechanical changes on the source head. The source produces in excess of 300 euA of H- and more than 25 eμA of He-. It is expected the design allows for substantially higher currents, especially for H-.

Funding Agency:

Email Address:

aannaluru@highvolteng.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Arun Annaluru

86

Compact Monoenergetic Proton Generator in MeV Region Using NANOGAN

Author: Tetsuhiko Yorita[1]

Co-authors: Yasuyuki Morita [2]; Keiji Takahisa [3]; Tatsushi Shima [1]; Hiroki Kanda [1]; Mitsuhiro Fukuda [1]

[1] *RCNP, Osaka Univ.*

[2] *RIKEN*

[3] *Kobe Tokiwa Univ.*

Corresponding Author: yorita@rcnp.osaka-u.ac.jp

For simple applications, such as the calibration of a charged particle detector, a multi-MeV proton generator may be preferable to cyclotrons or electrostatic accelerators such as Van de Graaff generator. Thus, a compact proton generating system, consisting of 10Ghz ECR ion source NANOGAN and a deuteron target, was developed at the Research Center for Nuclear Physics at Osaka University. A $^3He^{2+}$ beam was generated by the NANOGAN with the acceleration voltage of 20~40 kV in an experiment that utilized the fusion reaction ^3He + deuteron (D) ⟶ proton(P) + ^4He. The monochromatic protons with energies of 14.67 MeV were successfully obtained at the atmosphere side of the target in the experimental setup, when a novel target base with a thin metal foil and Polyimide film window are used.

Funding Agency:

Email Address:

yorita@rcnp.osaka-u.ac.jp

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

15

A New Proton Injector Based on PKU-type 2.45GHz PMECR for BNCT Facility

Authors: Bujian Cui[1]; Jiaer Chen[1]; Shixiang Peng[1]; Tenghao Ma[1]; Yaoxiang Jiang[1]; Zhiyu Guo[1]

[1] *Peking University*

Corresponding Author: sxpeng@pku.edu.cn

The first fully domestically boron neutron capture therapy demonstration device located in Yangtze River Delta region based on an accelerator neutron source will be build recently. It is held by "Xi'an Jiaotong University-Huzhou Neutron Science Laboratory" joint lab established by Xi'an Jiaotong University and Huzhou Industrial Group. The BNCT facility requires a proton beam of 30 mA@40 keV at RFQ entrance, with its beam duty cycle between 0.5%-100%, and its normalized root mean square emittance less than 0.2 π.mm.mrad. The device development cycle is 10 months. Ion source group of Peking University (PKU) is in charge of the proton ion source and its low energy beam transportation section (LEBT). A PKU type compact permanent magnet 2.45 GHz ECR ion source(PKU-Type PMECR) and a two solenoid LEBT is under development for this purpose. Further, this LEBT integrates beam chopper, absorption area for the chopped beam, ACCT, electron trap in a vacuum tube with the length of 210 mm after the second solenoid. So far, the project has completed work such as scheme demonstration, system mechanical design, ion source conditioning, and peripheral component procurement. Detail will be presented in this article.

Funding Agency:

NSFC 11975036

Email Address:

sxpeng@pku.edu.cn

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Shixiang Peng

58

A Review of State-of-the-Art Ion Source Plasma Diagnostics

Author: Olli Tarvainen[1]

Co-author: Ursel Fantz [2]

[1] *UK Science and Technology Facilities Council*

[2] *Max-Planck-Institut für Plasmaphysik (IPP)*

Corresponding Author: olli.tarvainen@stfc.ac.uk

There are a huge variety of ion source types employed to produce charged particle beams for discovery physics and accelerator applications such as neutral beam heating of thermonuclear fusion plasmas and spallation neutron sources. In most ion sources the ion beams are extracted directly from a plasma sustained by a DC or RF energy source. What is common to all ion sources is the need for diagnostics to quantify their performance and develop them further. The purpose of this review paper is to describe the state-of-the-art plasma diagnostic methods used for ion source development, operations, and monitoring. We present examples of diagnostics techniques, such as optical emission spectroscopy and x-ray diagnostics, applied to negative and positive ion sources highlighting similarities of the diagnostic needs and individual diagnostic challenges pertaining to specific types of ion sources, e.g. microwave sources (including ECR ion sources), RF-driven sources, and arc discharges. The overarching message is that further advances in ion source performance, deeper understanding of the underlying physics, and validation of novel ion source concepts require complimentary plasma diagnostics.

Funding Agency:

Email Address:

olli.tarvainen@stfc.ac.uk

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

17

Implicit PIC Development for Bounded Plasmas

Author: Nicolas Savard[1]

Co-authors: Gwenael Fubiani [2]; Morgan Dehnel [3]; Rick Baartman

[1] *TRIUMF, D-Pace*

[2] *LAPLACE*

[3] *D-Pace*

Corresponding Author: nicolas@d-pace.com

Particle-in-Cell (PIC) codes used to study plasma dynamics within ion sources typically use an explicit scheme. These methods can be slow when simulating regions of high electron density in ion sources, which require resolving the Debye length in space and the plasma frequency in time. Recent developments on fully-implicit PIC models in curvilinear geometries have shown that these spatial/time scales can be significantly decreased/increased respectively, allowing for notable speed-ups in simulation time, and thus making it a potential tool for studying the physics of ion sources. For this purpose, a charge and energy conserving implicit PIC code has been developed in 1D to show its potential for simulating bounded plasmas. In this paper, we use this model to simulate a 1D analytical benchmark of a bounded plasma with fixed power input and Maxwellian electron distributions. The results are shown to compare well to analytical theory and to the results using an explicit PIC code. We demonstrate the ability of the implicit PIC code to speed-up simulation time by nearly a factor of 10x compared to explicit PIC, which would correspond to a speed-up of up to 1000x in 3D.

Funding Agency:

Email Address:

nsavard@triumf.ca

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

27

Investigation of Plasma Chamber Erosion in an RF Ion Source

Authors: Anand Mathai George[1]; Cornelia Hoehr[2]; Morgan Dehnel[3]; Stephane Melanson[3]

[1] *TRIUMF/D-Pace*

[2] *TRIUMF*

[3] *D-Pace*

Corresponding Author: ageorge@triumf.ca

D-Pace is developing a 13.56 MHz RF ion source capable of producing negative ions (H^-, D^-). The ion source is a hybrid design between the TRIUMF-licensed filament ion source and the RADIS ion source licensed from the University of Jyväskylä. An Inductively Coupled Plasma (ICP) is generated inside the plasma chamber using a planar spiral external antenna, powered by an RF power supply. The RF power is coupled between the antenna and the plasma through an Aluminum Nitride (AlN) dielectric window.

The RF ion source is expected to offer a 'maintenance-free' operation compared to a filament ion source due to the absence of any filaments that erode in the plasma. However, the RF ion source is challenged by the erosion of the copper plasma chamber during the operation. This leads to the deposition of copper layers on the plasma-exposed surface of the AlN window. These metal deposits decrease the power coupling from the spiral antenna to the plasma and deteriorate the beam current from the ion source. Different experiments were performed to control the deposition of copper on the dielectric window in an H_2 plasma.

The copper deposition can be reduced by maintaining the surface of the dielectric window at high temperatures. Operation of the ion source at high H_2 gas pressures ($\geq$ 20 mtorr) can also reduce the formation of copper layers considerably. Moreover, it was found that the erosion is directly related to the value of the electric potential applied to the plasma electrode during the beam extraction. A reduction in the ratio of the plasma exposed area of the plasma electrode to the grounded surface area of the plasma chamber to $\approx$ 0.03, reduces or nearly completely eliminates the formation of copper layers on the dielectric window. A combination of these solutions is incorporated into the operation of the RF ion source and the latest results are presented in the paper.

Funding Agency:

MITACS

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

93

Determining Absolute VUV Fluxes for Assessing the Relevance of Photon-Surface Interaction in Ion Sources

Author: Roland Friedl[1]

Co-authors: Caecilia Fröhler-Bachus [1]; Ursel Fantz [2]

[1] *AG Experimentelle Plasmaphysik (EPP), University of Augsburg*

[2] *Max-Planck-Institut für Plasmaphysik (IPP)*

Corresponding Author: roland.friedl@uni-a.de

The ion source discharge influences the plasma-facing surfaces by impinging fluxes of ions, radicals and photons. This plasma surface interaction is particularly important for, but not limited to, caesiated ion sources for negative hydrogen ions due to its influence on the surface work function and possible photo-emission of electrons into the plasma sheath. While the role of ions and radicals is widely accepted in the course of plasma surface interaction and quantitative measurements have been performed throughout the literature, VUV photons (< 200 nm) are often disregarded. The reason is mostly the complicated setup to measure such fluxes absolutely and energy-resolved. However, they impact the surface with at least 6.2 eV and several studies have already confirmed that comparable fluxes to the ion fluxes can easily occur [Barton2000, Fantz2016].
To overcome the drawback of complex VUV-spectroscopic systems including their calibration, several alternative solutions have been applied in the past, where a VUV-sensitive photo diode with optical filters was already employed in the ion source community [Komppula2015]. This contribution takes up the basic concept and enhances it by direct in-house absolute calibration of the system down to 46 nm against a VUV spectrometer [Fröhler-Bachus2021]. The system is calibrated for energy-resolved absolute VUV flux measurements up to photon energies of 27 eV in a variety of gases and gas mixtures, including Ar, H2, O2 and N2 [Friedl2023].
Demonstration of the system is presented at the ion source of the BATMAN Upgrade facility. The system was used to measure the VUV fluxes of the hydrogen plasma in the driver region as well as in the region close to the extraction surface. Using solid angle calculations and a ray tracing code, the total energy-resolved flux onto the plasma grid was determined. Comparable fluxes to the impinging ion flux could be shown, and the major contribution to this flux originates from the driver plasma.

Funding Agency:

German Research Foundation (DFG): FR 3881/1-1.

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

160

Using Machine Learning Algorithms for ECR Tuning and Physics Studies

Authors: Alex Kireef[1]; Damon Todd[1]; Heather Crawford[1]; Janilee Benitez[2]; Larry Phair[1]; Marco Salathe[1]; Victor Watson[1]; Wenhan Sun[None]; Yubin Hu[1]

[1] *Lawrence Berkeley National Laboratory*

[2] *Lawrence Berkeley National Lab*

Corresponding Author: dstodd@lbl.gov

The superconducting ECR ion source VENUS remains one of the world's highest-performing ECRs for producing high-current, highly-charged ion beams. However, VENUS has up-to-twenty control parameters defining an operation space that is largely unexplored and inside which record beams are still produced via dedicated tuning time. This size of operation space has proven manageable for computer algorithms such as Bayesian Optimization. Therefore, we are endeavoring to apply this and related machine learning techniques to the problems of maximizing VENUS performance, improving stability control, and understanding the underlying physics dictating source performance. We have implemented algorithms that vary all control parameters and maximize beam currents for gas-fed plasma beams. We have added a cost function to find optimized solutions more efficiently and we are working to develop a neural network based on collected source data. We will report on our progress, present our results, and discuss both the challenges we have overcome and those that still remain.

Funding Agency:

United States Department of Energy

Email Address:

dstodd@lbl.gov

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

171

X-Ray Diagnostics of ECR Ion Sources

Author: Richard Racz[1]

[1] *Institute for Nuclear Research (Atomki)*

Corresponding Author: rracz@atomki.hu

ECR (Electron Cyclotron Resonance) Ion Sources (ECRIS) are widely used to provide highly charged heavy ions for high energy accelerators. In their plasmas, ECRISs are able to generate electron population having enough high energy to effectively ionize the atoms up to their inner shells. The quality (intensity, emittance, stability) of the ion beam used by the end-stations of the accelerators is strongly determined by the general plasma conditions, therefore plasma diagnostics techniques were implemented and developed during the more than 50 years colorful history of ECRISs. One of the most commonly used non-destructive diagnostic methods is based on the investigation of spectral and/or spatial distribution of the X-ray photons emitted by the plasma and plasma chamber complex. The interaction of warm and hot electrons with the plasma atoms, ions and plasma chamber walls results intense X-ray emission and by applying X-ray plasma diagnostic technics meaningful, quantitative plasma parameters (density, temperature) can be revealed. During my talk I will go through the main features of the ECRIS related X-ray measurement techniques in the context of their contribution to the understanding of ECR Ion Sources.

Funding Agency:

Email Address:

rracz@atomki.hu

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

136

Fifteen Years of Developments of Isotopic MIVOC Metallic Beams

Author: Benoît Gall[1]

[1] *IPHC / Université de Strasbourg*

Corresponding Author: benoit.gall@iphc.cnrs.fr

Some metallic ion beams such as titanium are quite difficult to produce at the intensity level required in order to deliver several particle micro-amperes on target for nuclear physics experiments. At the University of Jyväskylä (JYFL), Matti Nurmia proposed to use organometallic compounds giving birth to the so-called MIVOC method [1]. Ferrocene is the archetype of metallic beams procced via this Method. J Arje, H. Koivisto and their colleagues identified several organometallic compounds that were successfully accelerated at JYFL [1].
In order to make the first prompt spectroscopy of 256Rf (Z=104), an intense metallic 50Ti beam was necessary. This implied chemistry with isotopically enriched compounds. We started to develop MIVOC compounds of titanium-50 (92+%) at the University of Strasbourg. We could successfully prepare pentamethylcyclopentadienyl trimethyl titanium that was accelerated at JYFL cyclotron [2]. This beam was then used in many laboratories such as (GANIL, RIKEN, DUBNA), leading to significant improvement of our process. This was the start of 15 years of isotopically enriched MIVOC compound preparations leading to rather intense and versatile isotopic beams of titanium vanadium and chromium.
It is proposed in a first part of this presentation to detail the MIVOC developments done and ongoing in Strasbourg. A special focus will then be given to the limitations observed for very high intensity metallic beams. The last part of the talk will be devoted to the development of an inductive oven performed in order to feed the ECR plasma directly with metallic vapors.
[1] H. Koivisto et al., NIM B 187 (2002)111,
[2] J. Rubert et al., Nucl. Instr. & Meth. Phys. Res. B 276 (2012) 33–37.

Funding Agency:

Université de Strasbourg, USIAS, IPHC UMR 7178,

Email Address:

benoit.gall@iphc.cnrs.fr

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

52

Research Progress on Beam Diagnostic Calorimeter Based on Unidirectional Carbon Fiber-Carbon Matrix Composite at ASIPP

Author: Yongjian Xu[1]

Co-authors: Yue Hu [1]; Ling Yu [1]

[1] *Institute of plasma physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences*

Corresponding Author: yjxu@ipp.ac.cn

Unidirectional carbon fiber-carbon matrix (CFC) composite can be used to diagnose the main features of a particle beam such as its power, divergence and uniformity. Diagnostic calorimeter based on CFC has been developed by the research team of neutral beam injection (NBI) around the world because of its high space resolution. At ASIPP, a negative ion source based neutral beam injector is under construction with H0 beam power of 2 MW at the beam energy of 200-400 keV for the beam duration of 100s. In order to assess the beam characters, a diagnostic calorimeter based on CFC has been developed in the negative ion source test facility. The calorimeter is made of 8 CFC tiles with the size of 200 mm × 400 mm, and it can be moved in/out beam channel by the driving of the step motor. Two IR cameras with 640 × 480 resolution are used to capture the infrared image. This contribution describes test results of CFC and the structure design of diagnostic calorimeter.

Funding Agency:

Email Address:

yjxu@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

38

Development of a Low Emittance Proton Injector for a Transportable Compact Neutron Source

Authors: Qi Wu[1]; Yuguo Liu[2]; Jianli Liu[1]; Xing Fang[1]; liangting sun[1]; Hongwei Zhao[1]

[1] *Institute of Modern physics,CAS*

[2] *IMP*

Corresponding Author: wuq@impcas.ac.cn

A transportable compact neutron source is under development for nondestructive testing of concrete structures such as bridges. It consists of a compact proton injector, a 2.5 MeV Radio-Frequency Quadrupole (RFQ) linac and lithium target. To meet the requirements of a 2.5 MeV RFQ linac, a new compact ion Source-LEBT integrated proton injector was developed at IMP. It includes a permanent magnet compact 2.45 GHz ECR ion source, two sets of deceleration-acceleration type Einzel lenses, a beam kicker, an ACCT and a set of beam steers. For an electrostatic LEBT, thermal deformation, optics mismatching and sparks between the LEBT sections were the main technology difficulties. Therefore, this paper was mainly studied how to achieve good beam matching and low emittance beam. Test results of this ion source prove that it is the ability of delivering a proton beam with current of 20 mA operated in 30 kV. The range of duty factor was form1% to 4% (50 Hz/0.3 ms, 200 Hz/0.2 ms). After series of experimeatal investigation, the beam current and emittance at the entrance of RFQ can meet the requirements of a 2.5 MeV RFQ. The rms emittance at the LEBT exit is less than 0.15 πmm.mad.

Funding Agency:

Email Address:

sunlt@impcas.ac.cn,wuq@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

123

The Development Technology of UCx Targets at BRISOL

Authors: Baoqun Cui[1]; Bing Tang[None]; Lihua CHEN[2]; Ruigang Ma[3]; Xie Ma[3]; Yingjun Ma[3]

[1] *CIAE*

[2] 中国原子能科学研究院

[3] *China Institute of Atomic Energy*

Corresponding Author: maxie1412@163.com

On-line Isotope separator of Beijing radioactive ion-beam facility(BRISOL) produces medium and short-lived radio-isotope beams by irradiating a target with a 200-A 100-MeV proton beam provided by a cyclotron. Recently, UCx targets have been developed at BRISOL. At fisrt, lanthanum carbide has been chosen as an analogy for uranium carbide, so that air sensitive target material processing can be developed without the risk of radioactive contamination. Cold-pressed method was developed at BRISOL by the preparation of lanthanum targets and then the UCx targets was fabricated. The development of UCx targets will be presented in this paper.

Funding Agency:

Email Address:

maxie1412@163.com

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

31

Effect of a Biased Disk on the Afterglow Characteristic of HECRAL Ion Source

Author: Jibo Li[1]

Co-authors: Cheng Qian [1]; Liangting Sun [1]; Lixuan Li [1]; Xinyu Wang [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: jiboli@impcas.ac.cn

Previous studies indicate that the biased disk enhances the charge state distribution (CSD) in the plasma in continuous wave (CW) mode and it also improves the ion flux towards the extraction in pulsed mode. However, in these studies the biased disk voltage is always shifted from 0 V to a certain value (or vice versa) with different timing, for an electron cyclotron resonance (ECR) ion source operated in afterglow mode, this means that the RF-heating stage and RF-off stage could not be simultaneously affected in this condition. Therefore, in this study, to further investigate the effect of the biased disk on both the RF-heating stage and RF-off stage in afterglow mode, the waveform characteristic was systematically measured between two non-zero voltages with different timing on HECRAL (Hybrid superconducting Electron Cyclotron Resonance ion source with Advance in Lanzhou) ion source. The experimental results are presented and the physical mechanism behind experimental observation is discussed.

Funding Agency:

Email Address:

jiboli@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

32

Design of a Medium Temperature Resistance Oven for ECR Ion Sources at Institute of Modern Physics

Author: Wang Lu[1]

Co-authors: Cheng Qian [2]; Hongyi Ma [3]; Jindou Ma [2]; Liangting Sun [2]; Lixuan Li [2]; Wenhui Zhang [1]; Xinyu Wang [2]; Xuezhen Zhang [2]; Yucheng Feng [1]

[1] *Institute of Modern Physics*

[2] *Institute of Modern Physics, Chinese Academy of Sciences*

[3] *Institute of Modern Physcis*

Corresponding Author: luwang@impcas.ac.cn

With the successful development of inductive oven in 2019, there are three kinds of metal ovens at Institute of Modern Physics (IMP) now: low temperature oven, inductive high temperature oven and traditional mini-oven. To expand the range of temperature coverage, a new resistive medium temperature oven has been proposed in 2022 and fabricated in 2023. It is designed for the optimal working range of 700- 1600℃, the main purpose is to produce refractory metal vapor with medium service temperature, such as Fe, Ni, Cr, Mn, etc. A special feature of this oven is the added gap between the ceramic crucible and the heating coil to avoid compatibility problems at high temperature. The off-line test result shows that this oven can reach up to about 1600 ℃ at 0.5 kW of DC power. In this contribution, we will present the structure of this medium temperature oven and discuss the testing results as well.

Funding Agency:

Email Address:

luwang@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

8

Design of Magnetic Filter Field in the High Power Negative Ion Beam Source with Large Area for CRAFT NNBI

Authors: Junwei Xie[1]; Yahong Xie[1]; Jianglong Wei[1]; Lizhen Liang[1]; Na Wang[1]; Yuwen Yang[1]; Chundong Hu[1]; Yuanlai Xie[1]

[1] *Institute Of Plasma Physics Chinese Academy Of Sciences*

Corresponding Author: junwei.xie@ipp.ac.cn

Neutral beam injection (NBI) is an indispensable auxiliary heating method used in thermonuclear magnetic confinement fusion devices. The Comprehensive Research Facility for Fusion Technology (CRAFT) needs a well-matched neutral beam injection system for experimental research. The condition that a high current beam with high beam energy is needed in the process of fusion can be satisfied by a giant Negative ion based Neutral Beam Injection (NNBI) system. However, negative ions can be destroyed by electrons with high energy in the plasma generator and expansion chamber of beam source easily, so the electron energy should be decreased to reduce the losses of negative ions by collision. A magnetic filter field (MFF) in front of the plasma grid (PG) can be introduced to cool down the electron temperature. A MFF generated by a current flowing through the PG and 6 conductors was designed based on the simulation results that the electron temperature can be decreased from 7eV to 1eV. Furthermore, this system can make the field flexible and comprehensive in value and space distribution than the permanent magnets. The design can provide a reference for the development of MFF applied on the negative beam source for CRAFT NNBI.

Funding Agency:

Email Address:

junwei.xie@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

19

A Compact DD Neutron Generator with High Neutron Yield

Author: Lihua Chen[1]

[1] 中国原子能科学研究院

Corresponding Author: wdf_221@163.com

Neutron generator has the characteristics of high neutron energy generation, high inherent safety and flexible use scenarios, and is widely used in many fields, such as scientific research, activation analysis and contraband monitoring. This paper introduces the development of a small Neutron generator based on ECR source, which is being developed by China Institute of Atomic Energy. The generator uses a 2.45GHz high current ECR ion source to generate a high current D beam of several mA magnitude. After acceleration, it bombards a water-cooled self generated pure copper target to generate 2.5MeV neutrons through (D, D) nuclear reaction. This paper introduces the design of a small Neutron generator based on ECR source and the preliminary measurement results of neutron yield. The neutron yield of the device can reach over 1 * 109n/s using a 3He neutron detector. During the nearly 300 hours of experimental testing, the generator operated stably without any component damage. The generator has the characteristics of small size, high yield, long expected working life, etc., which can meet the needs of scientific research and some industrial applications for 2.5 MeV neutron source.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

13

The Development of the Ion Source and Target for BRISOL

Authors: Baoqun Cui[1]; Bing Tang[None]

[1] *CIAE*

Corresponding Author: tangb364@126.com

The Beijing Radioactive ion beam facility Isotope Separator On-Line（BRISOL）is a radioactive ion beam facility based on a 100MeV cyclotron providing 200μA proton beam bombarding the thick target to produce radioactive nuclei, which are transferred into an ion source to produce singly charged ion beams. A surface ion source had been developed for BRISOL, and the first radioactive beams (37K+, 38K+, 42K+, etc.) were produced by bombarding a CaO target with a 100MeV proton beam from the cyclotron in 2014. A FEBIAD ion source with MgO target are successful used to the first physics experiments, including the decay study of 20Na with the energy of 110keV and the elastic scattering study of 21Na and 22Na beams, post-accelerated by a 13MV tandem. The refractory carbide targets such as SiC, LaC2 and UC2 are also developing for more radioactive beams. The first online test of SiC target has been completed recently, and radioactivity beams of 25Al, 26Al, and 28Al were produced. The details of the development of BRISOL facility and the online experimental results will be presented in this paper.

Funding Agency:

Email Address:

tangb364@126.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

36

A Study of Temperature and Electric Potential Distribution in a Novel Pyroelectric Neutron Generator

Authors: Xiang CAO[1]; Zhen Yang[1]; Liang Lu[1]; Liping Zou[1]; Wei Ma[1]; Zhiping Zou[1]; Yubo Xin[1]; Shengda Tang[1]

[1] *Sun Yat-sen University*

Corresponding Author: caox53@mail2.sysu.edu.cn

Pyroelectric neutron generator is an ideal neutron calibration source for free of radioactive contamination and high-frequency noise interference. The basic principle involves using pyroelectric crystals to generate high-voltage electric fields, which in turn accelerate deuterons produced by ionization to bombard deuterium-rich targets, initiating deuterium-deuterium (D-D) nuclear reactions to generate neutrons. Existing pyroelectric neutron generators utilize field emission ionization to produce deuterons, which limits the beam current and acceleration voltage, thereby limiting the neutron yield.

A novel pyroelectric neutron generator that uses a pulsed 1064 nm laser to irradiate the LiTaO3-Mo-TiDx substrate simultaneously for heating and ionization was introduced. This paper discusses the temperature change range and rate of the LiTaO3 single crystal pyroelectric material under laser irradiation, as well as the pulse energy, repetition frequency, loading time, and spot size. In parallel, numerical simulations of the surface charge, potential, and acceleration gap electric field distribution of the LiTaO3-Mo-TiDx substrate have been conducted based on the single-crystal system theory model and the finite element method. The relationship between temperature change and maximum potential and acceleration gap electric field distributions has been established. The main factors affecting the maximum potential and electric field distribution are also analyzed.

Funding Agency:

Email Address:

caox53@mail2.sysu.edu.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Xiang CAO

43

Studies on the Electron Energy Distributions in the 18 GHz High Temperature Superconducting (HTS) ECR Ion Source

Author: Lakshmy PS[1]

Co-authors: Mukesh Kumar [1]; Gurjar R.K [1]; Ruby Santhi [1]; G.O Rodrigues [1]

[1] *Inter University Accelerator Centre*

Corresponding Author: plankudy@gmail.com

P. S. Lakshmy*, Mukesh Kumar, R.K.Gurjar, Ruby Santhi and G.Rodrigues
Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi, India.

The 18 GHz High Temperature Superconducting (HTS) Electron Cyclotron Resonance Ion Source [1] is the main positive ion injector for the upcoming, High Current Injector (HCI) Programme which is presently being commissioned at IUAC, New Delhi. In general, X-ray bremsstrahlung from an ECR ion source gives an idea of the energy distributions of cold, warm and hot electrons. In our earlier studies [2], wall bremsstrahlung components were studied to understand the hot electron confinement conditions. Also, bremsstrahlung measurements were carried out to study the effect of dc bias voltage [3] on the high temperature component of the electrons. In our present work, we report on the recent measurements of bremsstrahlung ; since the production of highly charged ions is dependent on the electron energy distributions inside the plasma, the effect of the axial magnetic fields on electron energy distributions and simultaneous effect on charge state distributions will be presented.
*Corresponding Author: P. S. Lakshmy, E-mail Address: plankudy@gmail.com
[1] D.Kanjilal et al., Review of Scientific Instruments, Vol.77, 03A317 (2006).
[2] R.Baskaran et al., Review of Scientific Instruments, Vol. 79, 02A324 (2008).
[3] G.Rodrigues et al., Review of Scientific Instruments, Vol. 81, 02A323 (2010).

Funding Agency:

IUAC, New Delhi, India

Email Address:

plankudy@gmail.com

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

P.S.Lakshmy

44

Numerical Simulation and Experimental Study on the Ejecting Electrons from the Prototype Negative Ion Source at ASIPP

Authors: Yuwen Yang[1]; Jianglong Wei[2]; Yahong XIE[1]; Chundong Hu[1]

[1] *Institute of Plasma Physics,Chinese Academy of Sciences*

[2] *Institute of Plasma Physics, Chinese Academy of Sciences*

Corresponding Author: yuwen.yang@ipp.ac.cn

A negative ion based neutral beam injection (NNBI) test facility is one of the significant components of Comprehensive Research Facility for Fusion Technology (CRAFT) in China. A quarter-size beam source for the CRAFT NNBI test facility has been developed firstly. It consists of a single driver RF plasma source and a negative ion accelerator. The typical extraction voltage is 4~8 kV and the acceleration voltage is 40~50 kV. In the accelerator, the grid electrodes contain plasma grid (PG), extraction grid (EG) and ground grid (GG). The PG and the EG are adopted the circular apertures while the GG is adopted the slot-type apertures. During a long-pulse beam extraction, it is found that the gas pressure in the beamline vacuum vessel has gradually increased and the temperature of the cryopump rises from ~8 K to ~20 K. Moreover, the vessel wall appears a high temperature after several long-pulse shots. The numerical simulation shows that the heat loads on the vessel wall are caused by the stray electrons ejecting from the accelerator. The stray electrons can be generated by the stripping loss of negative ions, the ionization of background gas, and the secondary emission from the grids. The slot-type apertures increase the number of stray electrons ejecting from accelerator. The location of hot spots measured by infrared thermography is consistent with the simulation result. In order to solve this problem, the electron dumps are designed to avoid the direct impinging of the ejecting electrons on the cryopump and the vessel wall. The experimental results indicate that the gas pressure is stable during the long-pulse beam extraction and the hot spots on the vessel disappear.

Funding Agency:

Email Address:

yuwen.yang@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

65

Transmission of Highly Charge Heavy Ion Beams from an ECR Source with High Efficiency and High Quality

Author: Zehua Jia[1]

Co-authors: Bo Zhang [1]; Jibo Li [1]; Liangting Sun [2]; Peng Zhang [1]; QI WU [3]; Yao Yang [1]; Yu Tang [1]; Yuhan Zhai [1]

[1] *imp*

[2] *Institute of Modern Physics, Chinese Academy of Sciences*

[3] *Institute of Modern physics,CAS*

Corresponding Author: jiazehua@impcas.ac.cn

Due to the unique magnetic field structure of the Electron Cyclotron Resonance (ECR) ion source, conventional idealized beam models cannot adequately reproduce the state of high charge state ion beams extracted from it. Consequently, beam transport designs based on idealized models exhibit suboptimal performance in efficiently generating high-quality beams during practical transport. Advanced techniques involving phase space reconstruction and back-simulations considering space charge effects are capable of more realistically depicting the phase space evolution of high charge state ion beams during transmission. The resulting end-to-end simulations obtained using this methodology provide a reliable guarantee for the production of high-quality beams. This approach has been partially validated at the Low Energy Accelerator Facility (LEAF), where it has yielded highly favorable outcomes. The corresponding knowledge and experience have subsequently been applied to the design of the Low Energy Beam Transport (LEBT) segment of the High Intensity Accelerator Facility (HIAF) project. This poster aims to provide a brief overview of the progress made in this work.

Funding Agency:

The National Natural Science Foundation of China

Email Address:

jiazehua@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

76

Production of Intense Uranium Ion Beams with SECRAL-II Ion Source

Authors: lixuan Li[None]; jibo Li[1]; jindou Ma[None]; wang Lu[None]; yucheng Feng[None]; liangting Sun[None]

[1] 中科院近代物理研究所

Corresponding Author: lilixuan@impcas.ac.cn

Intense highly charged uranium ion beam production is essential for heavy ion accelerators in operation and those under construction. Although metallic beam production is tricky, based on our earlier study, intense uranium beams can be expected when operating a third generation electron cyclotron resonance (ECR) ion source especially in afterglow mode with double frequency heating. In this study, we aim to produce intense uranium beams with SECRAL-II (Superconducting ECR ion source with Advanced design in Lanzhou No. II) ion source at high frequency (24+18 GHz) and high power (~8 kW) in both continuous wave (CW) and afterglow modes. The experimental results will be reported in this presentation.

Funding Agency:

Email Address:

lilixuan@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

119

The Effect of Different Bias Application Methods on the Plasma Parameters of the Extraction Area

Authors: Xufeng Peng[1]; Jianglong Wei[2]; Yongjian Xu[1]; Yahong XIE[3]; Yuming Gu[3]; Ling Yu[1]; Yuwen Yang[1]; Chundong Hu[1]; Yuanlai Xie[1]

[1] *Institute of plasma physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences*

[2] *Institute of Plasma Physics, Chinese Academy of Sciences*

[3] *Institute of Plasma Physics,Chinese Academy of Sciences*

Corresponding Authors: xufeng.peng@ipp.ac.cn, jlwei@ipp.ac.cn

The suppression of co-extracted electrons has always been one of the key problems in the operation of negative ion sources, as the co-extracted electrons not only cause energy waste, but also create a great heat load on the extraction grid (EG). A positive bias is usually applied to the plasma grid (PG) to reduce the co-extracted electron current. There are several ways to connect the bias voltage, as the BP, PG, and expansion chamber are insulated from each other, such as between the bias plate (BP) and expansion chamber, between the PG and expansion chamber, between the PG and BP + expansion chamber (the BP and expansion chamber have the same potential), and between the BP and PG. In this paper, the effects of different ways to connect the bias voltage on the plasma parameters in the extraction area are studied by using an electrostatic probe. Finally, the optimal way to connect the bias voltage is obtained, and the reason for the optimal bias voltage connection is analyzed.

Funding Agency:

Email Address:

xufeng.peng@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

121

A Core Snubber for CRAFT NNBI Based on Amorphous

Authors: Bo Liu[1]; Zhimin Liu[2]; Caichao Jiang[2]; Sheng Liu[2]; Shiyong Chen[2]; Junjun Pan[2]; Chundong Hu[2]; Yuanlai Xie[2]

[1] *University of Science and Technology of China*

[2] *Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230031, China*

Corresponding Author: bobliu@mail.ustc.edu.cn

The negative ion based neutral beam injector (NNBI) of 400 keV beam energy is a subproject of Comprehensive Research Facility for Fusion Technology (CRAFT) in China. A core snubber will be used to absorb the energy released by the stray capacitance during the occurrence of accelerator ignition faults, avoiding greater losses. The equivalent model of the CRAFT NNBI high potential circuit was established during the core snubber design process, including the ignition point. The circuit resistance and inductance required to limit the ignition current to below 3 kA are determined by solving the equivalent circuit equation. The circuit inductance which is determined by the core of the snubber can be solved by the equation of inductance-core parameters. Therefore, the required core parameters can be calculated. Amorphous was selected as core materials by comparing the frequency response, saturated magnetic flux, and cost-effectiveness of each material horizontally. The magnetic flux distribution of the completed winding core under the excitation current is completed

through finite element analysis. In addition, fully utilizing the hysteresis curve of the material by applying a bias current of approximately 200 A to the core snubber, resulting in a magnetic flux change of approximately 3 T when a ignition occurs.

Funding Agency:

National Natural Science Foundation of China

Email Address:

jcch@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

122

Additive Manufacturing of High-Temperature Ion Sources for the Production of Radioactive Ion Beams

Authors: Michele Ballan[1]; Pietro Rebesan[2]

Co-authors: Adriano Pepato [2]; Alberto Andrighetto [1]; Alberto Campagnolo [3]; Alberto Girotto [4]; Alberto Monetti [1]; Aldo Zenoni [4]; Antonietta Donzella [4]; Daniele Scarpa [1]; Diego Paderno [4]; Giorgia Franchin [3]; Giovanni Meneghetti [3]; Ileana Bodini [4]; Mattia Manzolaro [1]; Paolo Colombo [3]; Stefano Corradetti [1]; Valerio Villa [4]

[1] *INFN-LNL*

[2] *INFN-PD*

[3] *UNIPD-DII*

[4] *UNIBS-DIMI*

Corresponding Author: michele.ballan@lnl.infn.it

In the facilities for the production of Radioactive Ion Beams (RIBs) according to the Isotope Separation On Line (ISOL) technique, a production target is typically impinged by a high energy and high intensity primary beam, generating radioactive isotopes. The target is coupled to an ion source, where the produced species are ionized, allowing their electrostatic extraction and acceleration as a RIB, useful for several multidisciplinary experimental activities. With the aim of an efficient RIB production, both target and ion source work in the 1600-2200℃ temperature range at high vacuum. Until now the most important requirements for such devices have been satisfied by means of traditional manufacturing techniques. However, new generation ISOL facilities demand for higher performance and reliability standards, difficult to achieve with traditional manufacturing techniques. With this aim, the Selective Production of Exotic Species (SPES) group at Legnaro National Laboratories (LNL) has started a structured program of research activities on targets, ion sources and molecular beams, in the context of HISOL (High performance ISOL systems for the production of RIBs), experiment financed by the Italian National Institute for Nuclear Physics (INFN). Moreover, the INFN Padova Division and the Department of Industrial Engineering of Padova University have developed the technology required for the Additive Manufacturing (AM) of refractory metals such as Tantalum, Tungsten and Molybdenum, typically used for the production of ISOL ion source components. With AM technologies more degrees of freedom are available for the design process, and a high geometrical complexity is achievable. Recently, the first AM ion source components were successfully tested. In particular, AM Ta cathodes were produced with high geometrical accuracy and exhibited high stability at high temperature for more than 100 hours, whereas Mo anodes were successfully employed for the production of ion beams.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

146

Studying Instabilities in a PIG Ion Source

Author: Moenir Sakieldien[1]

[1] *iThemba LABS*

Corresponding Author: m.sakieldien@ilabs.nrf.ac.za

At iThemba Laboratory for Accelerator Based Sciences (LABS), a Penning Ionization Gauge (PIG) Ion Source is used for proton production. The accelerated proton beam impinges on a target, and after chemical extraction and purification, is used to manufacture a range of radioisotopes. The accelerated proton beam is also used to study various low-cross section nuclear physics processes. Over the years the PIG source have become prone to various instabilities. These instabilities have a profoundly negative impact on the extracted proton beam and therefore on the applications mentioned above. While the root cause of these instabilities remain largely unknown, a concerted effort has been made to gain a better understanding of the source of the aforementioned instabilities. With this presentation we will report on two approaches that will be used to shed more light on the observed instabilities. The first involve implementing novel optical diagnostics to learn more on the plasma processes leading to the observed instabilities. The second approach is to leverage the power of Machine Learning algorithms to characterize the impact of the various ion source parameters on the instabilities. The progress and preliminary results of these investigations will be reported on.

Funding Agency:

Email Address:

m.sakieldien@ilabs.nrf.ac.za

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

152

Overcoming Plasma Shifting by Designing a Langmuir Probe for Precise Microwave Plasma Characterization

Authors: Ram Swaroop[1]; G.O Rodrigues[2]

[1] *Central University of Punjab Bathinda Ghudda*

[2] *Inter University Accelerator Centre*

Corresponding Authors: rscuhp11pas18@gmail.com, gerry@iuac.res.in

Microwave plasmas fascinate researchers and scientists, yet it is a challenging field of research. The Central University of Punjab (CUPB) in Bathinda, established a 2450MHZ microwave flash design facility [1,2] to examine the properties of this peculiar kind of plasma. During ignition of the plasma, plasma shifting in the waveguide caused several problems. Even though microwave coupling and

cavity design models worked out well, plasma shifting persisted. . By re-examining the design, the problem was identified at the plasma electrode's form. To fix the plasma shifting inside the waveguide, ta shifting mechanism was adapted and it opened up new opportunities for microwave plasma research. The experiment used a lab made Langmuir probe using of ceramic pipes of various sizes with tungsten wire as the probe. After the Langmuir probe's structural design and construction was completed, a breadboard electronic circuit was tested and the Langmuir probe could detect the microwave plasma. The Langmuir probe which was used to measure microwave plasma properties is also discussed in detail.

Funding Agency:

NA

Email Address:

gerry@iuac.res.in

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Dr. G.O Rodrigues and Ram Swaroop

168

Development of an RF-Driven Ion Source for the KSTAR Neutral Beam Injection System

Author: Min Park[1]

Co-authors: Byoungseung Kim [2]; Byungkeun Na [3]; Jinhyun Jeong [3]; Jong-Gu Kwak [3]

[1] *Korea institute of Fusion Energy*

[2] *UST-KFE School*

[3] *Korea Institute of Fusion Energy*

Corresponding Author: mpark@kfe.re.kr

The current ion sources employed in the KSTAR (Korea Superconducting Tokamak Advanced Research) neutral beam injection system utilize conventional filament-driven multicusp ion sources. However, the primary limitations of this source arise from the usage of 12 tungsten filaments, leading to complexities and maintenance issues. To overcome these drawbacks, the development of an RF-driven ion source has been initiated. In this study, a preliminary performance evaluation was conducted for an inductively coupled plasma source, employing a 5.5 kW RF power supply operating at 13.56 MHz.
To comprehensively characterize the plasmas, plasma diagnostics were conducted using an RF-compensated single Langmuir probe. Moreover, a 2-D plasma modeling utilizing COMSOL was performed, enabling a thorough analysis by comparing the modeling results with experimental data. The integration of experimental measurements and computational simulations offers crucial guidance for the development of the RF ion source, ensuring its compliance with the specific requirements for implementation in the KSTAR neutral beam injection system.

Funding Agency:

Email Address:

mpark@kfe.re.kr

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

182

Study on Discharge Characteristics of High Power RF Ion Source with Dual-Drive for Neutral Beam Injector

Authors: Caichao JIANG[1]; Bo Liu[2]; Jianglong Wei[1]; Zhimin Liu[3]; Shiyong Chen[3]; Junjun Pan[3]; Sheng Liu[3]; Yahong Xie[1]; Chundong Hu[1]; Yuanlai Xie[1]

[1] *Institute of Plasma Physics, Chinese Academy of Sciences*

[2] *University of Science and Technology of China*

[3] *Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230031, China*

Corresponding Author: jcch@ipp.ac.cn

In order to meet the requirement of the neutral beam long pulse operation for CFETR and fusion reactor, it is urgent to carry out the research of high power RF ion source. As the extracted area of ion source is bigger, multi-driver is an inevitable choice. According to the structure of multi-driver, some problem such as, disturb between adjacent drivers and plasma uniformity, will occur. These problems are key issue which restrict the stable-state operation of ion source. In this proposal, firstly, the electromagnetic field's distribution of multi-driver for high power RF ion source is analyzed and the mutual electromagnetic interference among multi-driver is researched and the optimized design is obtained; Secondly, the plasma discharge model of multi-driver RF ion source is established based on the first step, the influence on the plasma stability and uniform discharge is investigated and a corresponding discharge control method is proposed to compensate for the mutual interference during multi-driver discharge. Finally, combined with the simulation results, the discharge experiment of dual-drive RF ion source was carried out based on the RF ion source test platform. By optimizing the discharge control method, the goal was to obtain stable and uniform plasma discharge of dual-drive RF ion source.

Funding Agency:

NNSFC(Contract No. 11975263)

Email Address:

jcch@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

Caichao JIANG

184

The HITRAP Cooling Penning Trap Instrumentation and Status of Operation

Author: Sergiy Trotsenko[1]

Co-authors: Nils Simon Stallkamp [1]; Simon Rausch [2]; Max Henrik Horst [2]; Dennis Neidherr [1]; Svetlana Fedotova [1]; Gleb Vorobyev [1]; Wolfgang Geithner [1]; Zoran Andelkovic [1]; Frank Herfurth [1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung GmbH*

[2] *GSI Helmholtzzentrum für Schwerionenforschung GmbH/TU Darmstadt*

Corresponding Author: s.trotsenko@gsi.de

The HITRAP facility, located at the GSI Helmholtzzentrum für Schwerionenforschung GmbH in Darmstadt, Germany, is designed to decelerate, cool and transport heavy, highly charged ions (HCI) created by the GSI accelerator complex to various attached experiments. The system consists of a two-stage deceleration structure, an interdigital H-type linac (IH) and a radio-frequency quadrupole (RFQ), followed by a cryogenic Penning-Malmberg trap for subsequent ion stopping and cooling. The deceleration stages reduce the ion energy from initially 4 MeV/u to 500 keV/u and to 6 keV/u respectively, before forwarding a slow, but hot ion bunch towards the cooling trap.
The trap is operated such that electrons, created by an external photoelectron source, are stored simultaneously with ions and serve as cold thermal bath. After cooling, a low-energy transfer beamline allows the transport and delivery of cold ions towards user experiments.
To support the challenging commissioning and setup especially of the low energy part of HITRAP, dedicated and innovative beam instrumentation had to be purpose built. Commissioning is supported by a small, room temperature, permanent magnets EBIT of the Dreebit type.
Recently, Ar^{16+} ions from the small EBIT were used to establish the first signs of electron cooling of highly charged ions. The newly installed diagnostics, measurement results for charge exchange investigation, online alignment and electron cooling will be presented.

Funding Agency:

Email Address:

S.Trotsenko@gsi.de

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

6

X-Ray Spectroscopy of Laser-Produced Al Plasma near the Target Surface in a Laser Ion Source

Author: Yuting Lu[1]

Co-authors: Caojie Shao [1]; Junjie Zhang [1]; Longfei An [1]; Liangting Sun [1]; Huanyu Zhao [1]; Hongwei Zhao [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: luyt@impcas.ac.cn

The spatially-resolved X-ray spectrum of laser-produced Al plasma near the target surface has been obtained in the energy range of 1.5-2.2 keV using a compact flat crystal spectrometer. The widely-used temperature and density diagnostics, the line ratios of Lyα/Heβ and IC/Heα, were measured and compared with the calculation results of a steady-state collisional-radiative model, so that the temperature and density profiles with a spatial resolution of 55 μm were obtained within 200 μm from the target plane. The plasma parameters derived from the spatially-integrated spectrum were used to calculate the ionization state distribution near the target surface with the steady-state model and the result was compared with the ion charge state distribution measured with an Electrostatic Ion Analyzer (EIA) at the distance of 4.2 m from the target surface. The validity of the steady-state model is discussed, as well as the difference between the calculated ion charge state distribution and that measured with the EIA.

Funding Agency:

National Natural Science Foundation of China

Email Address:

luyt@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

9

Production of intense carbon beams for long-term stable operation with an all-permanent magnet electron cyclotron resonance ion source

Author: Jiaqing Li[1]

Co-authors: Liangting Sun [1]; Yun Cao [1]; Jindou Ma [1]; Gang Jin [1]; Zhidong Chang [1]; Xuezhen Zhang [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: lijiaqing@impcas.ac.cn

An all-permanent magnet electron cyclotron resonance ion source-LAPECR3 (Lanzhou All Permanent magnet Electron Cyclotron Resonance ion source No.3) had been developed as the dedicated C5+ ion injector of Heavy Ion Medical Machine (HIMM) accelerator facility since 2009 in China. The first HIMM demo facility was built in Wuwei city in 2015, and the facility had been officially licensed to treat patients in early 2020. The facility has been proven to be very effective, and more than 700 patients have been treated so far. There are still some details that should be improved to make the facility more reliable and stable. For instance, LAPECR3 ion source could produce more than 100 eμA of C5+ ion in the early stage of ion source operation. However, after several months'operation, there would be serious carbon contamination on the chamber wall, which reduces the performance of the ion source and leads to unscheduled maintenance. In order to improve the performance of the ion source for long term operation, some approaches, for instance plasma cleaning technique, had been taken to reduce carbon contaminations. This paper will introduce the attempts to reduce the carbon contaminations and present the latest results of the ion source.

Funding Agency:

Email Address:

lijiaqing@impcas.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

11

Direct Injection of Intense Heavy Ion Beams from an Electron Cyclotron Resonance (ECR) Ion Source into a Radio Frequency Quadrupole (RFQ) Accelerator

Author: Robert W Hamm[1]

Co-authors: Gerard Rodrigues [2]; Lakshmy PS [2]

[1] *R&M Technical Enterprises*

[2] *Inter University Accelerator Centre*

Corresponding Author: plankudy@gmail.com

The use of high intensity, heavy ions from an ECR ion source for heavy ion accelerators usually entails the employment of a low energy beam transport (LEBT) section and magnetic charge state analysis, but space charge can severely limit the transmission. It has been proposed [1] instead to use a Radio Frequency Quadrupole (RFQ) to efficiently address this problem. The stray magnetic field of the ECR ion source can be used to provide focusing against the space charge blow-up at extraction by using the Direct Plasma Injection Scheme (DPIS) developed for laser ion sources. The RFQ will then focus and transport the injected beam and will also eliminate most of the charge states extracted from the ECR ion source. This narrowing of the charge state distribution is a filter, reducing the low energy beam transport problem as well as the emittance growth for the desired beam. A combined extraction/matching system has been designed for direct injection into a 48.5 MHz RFQ to produce 238U40+ (0.52 emA) and 209Bi30+ (1.047 emA) beams. The computer simulation code IGUN has been used to design the injection directly into the RFQ from the ECR. The RFQ design has been modified with a pre-buncher built into the vanes to narrow the transmitted charge state distribution as much as possible. The design details of this system and predicted performance will be presented.
[1] G. Rodrigues, R. Becker,R. W. Hamm, R. Baskaran,D. Kanjilal and A. Roy, Rev.Sci.Instrum.,85,02A740 (2014)
[2] G. Rodrigues, R. Becker,R. W. Hamm and D. Kanjilal, Proceedings of ECRIS 2014, Nizhny Novgorod, Russia
[3] R.W.Hamm and G.Rodrigues, 12th Int.Part.Acc.Conf, IPAC 2021, Brazil, doi:10.18429/JACoW-IPAC2021-MOPAB351

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract:

Dr.G.Rodrigues

39

Development of Negative Ion Source with Double Drivers for the CRAFT Neutral Beam Injector

Authors: Yahong XIE[1]; Jianglong Wei[2]; Yuming Gu[1]; Yuwen YANG[1]; Junwei XIE[1]; Na Wang[1]; Xufeng Peng[1]; Yuanzhe Zhao[1]; Lizhen Liang[1]; Yongjian Xu[1]; Caichao Jiang[1]; yuanlai xie[1]; Chundong Hu[1]

[1] *Institute of Plasma Physics,Chinese Academy of Sciences*

[2] *Institute of Plasma Physics, Chinese Academy of Sciences*

Corresponding Author: xieyh@ipp.ac.cn

The Comprehensive Research Facility for Fusion Technology (CRAFT) is a large scientific device that is preferentially deployed for the construction of major national science and technology infrastructures. A radio frequency (RF) negative ion based neutral beam injection (NNBI) system with beam energy of 400 keV, beam power of 2 MW and beam duration of 100 s was designed to deliver energetic neutral beam for fusion research. To understand the physics and pre-study the engineering problems for RF negative ion source, several negative sources with different sizes and structures were developed and tested, including the prototype negative ion source with single driver, double drivers and four drivers. So far, the prototype negative ion source has been tested on a small test facility. The negative ion beam with beam energy of 54kV, negative ion current of 3.5A and beam pulse of 105 s was achieved. The extracted negative ion current density is around 160 A/m2. Last year, the negative ion source with double drivers was designed and developed (a new test facility was also developed for the ion source conditioning too). Now, the negative ion source with double driver was finished assemble and under testing. The details of design and experimental results of ion source will be reported in this paper.

Funding Agency:

Email Address:

xieyh@ipp.ac.cn

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

82

High Throughput Ion Source Developments for Medical Radioisotope Production

Author: Ralitsa Mancheva[1]

Co-authors: Bruce Marsh [2]; Daniele Scarpa [3]; Emilio Mariotti [4]; Katerina Chrysalidis [2]; Kim Rijpstra [5]; Lisa Centofante ; Mattia Manzolaro [3]; Omorjit Khwairakpam [3]; Reinhard Heinke [2]; Sebastian Rothe [2]; Sophie Hurier [6]; Thomas Cocolios [7]

[1] *CERN, KU Leuven*

[2] *CERN*

[3] *INFN*

[4] *Università degli Studi di Siena*

[5] *SCK CEN*

[6] *SCK CEN & KULeuven*

[7] *KU Leuven*

Corresponding Author: ramanche@cern.ch

Resonance laser ionization is an efficient and highly selective method for producing ions of a wide variety of elements. In the laser ion source of ISOLDE –RILIS (Resonance Ionization Laser Ion Source), the laser interaction with the atoms takes place inside a metal tube which is heated to temperatures of up to 2200 degrees Celsius. This heating induces electron emission from the metal walls, which in turn leads to the creation of so-called "surface ions"inside this hot cavity. If the overall ion load of laser and surface ionized species reaches a certain threshold, the confining potential created by the electron emission is compromised and efficient extraction of the laser ions is no longer guaranteed. This effect is especially prevalent in facilities like MEDICIS which demand a high ion throughput and fast extraction for collection of medically relevant radioisotopes in high quantities but also with high purity for patient treatment.

This work will present the limits of the current laser ion source at MEDICIS and introduce recent developments towards a new high throughput ion source. Four different ion source designs, including those of new facilities specifically aiming to produce medical radionuclides will be compared. The performance evaluation is done by looking at the time structure of the extracted laser ions which is imprinted on them by the pulsed laser system. The experimental data is compared to simulations of the ion extraction to investigate how factors such as heat distribution and resulting electron emission impact the confinement of the ions inside the source.

Funding Agency:

Email Address:

I have read the Code of Conduct to attend ICIS2023.:

Yes

Presenter if not the submitter of this abstract:

3

Pattern Transitions on Argon Ion Sculpted Silicon Surfaces

Author: Rakhi[1]

Co-author: Subhendu Sarkar [2]

[1] *Indian Institute of Technology Ropar, 140001, India*

[2] *IIT Ropar Punjab 140001*

Corresponding Author: 2018phz0013@iitrpr.ac.in

The dynamic of self-organized nanopatterns on solid surfaces has been studied using low energy ion beam but it remains a central theme within ion beam sputtering still. The previous work for dynamical characterization has been focused on ion sputtering of Silicon surfaces using unconventional methods. To invoke new phenomena is not achievable using single fixed beam configuration.
In this report, we show that unconventional methods with swinging of Si substrate for formation of new nanopatterns. This is significant because it is given nanopatterns transitions rather ripple orientation which theoretically point out till now.
In this work, we experimentally investigated morphology evolution using low energy Ar+ ion beam sputtered Si surfaces at off normal incidence using an unconventional method of substrate swinging by different azimuthal angles and speeds from 1 to 16 rotations per minute (RPM). The azimuthally swinging Si substate exhibit four regimes which included ripples along with triangular structures, ripple devoid of triangles, smooth surfaces and disordered rippled topographies. Specifically, we find that the extrema of lateral correlation length, nanostructure aspect ratio and the local surface slope bear a direct relation to the sharp and intense spectral features observed in our study. Our observations were found to be highly reproducible. Our results were explained in the light of linear and non-linear regimes of sputtering. The crucial role played by dispersive linear terms explained the formation of the hierarchical structures at small swing angles. Once the dispersive effects die down, the ripples change their orientation. The asymmetry in surface structures was explained by the near-surface mass transport phenomenon at oblique azimuthal angles. This study demonstrates for the role of this unconventional technique to drive a system towards abrupt morphological transitions not observed otherwise.

Funding Agency:

Email Address:

2018phz0013@iitrpr.ac.in

I have read the Code of Conduct to attend ICIS2023.:

Presenter if not the submitter of this abstract: