## Concluding Remarks (ICIS2019)

### -Statistics-

<table>
<thead>
<tr>
<th>Topic</th>
<th>Oral presentation</th>
<th>Poster presentation</th>
<th>Total</th>
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<tbody>
<tr>
<td>Fundamental processes in ion sources, plasma</td>
<td>9 (2+7)</td>
<td>&gt;20</td>
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<td>Polarized ion sources (Brightness award)</td>
<td>1 (1+0)</td>
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<td>Applications of ion sources</td>
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<td>Production of high intensity ion beams</td>
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<td>Production of highly charged ion beams</td>
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<td>Negative ion sources</td>
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<td>Radioactive ion beam sources and charge breeders</td>
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<td>Ion sources for fusion</td>
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<td>Beam formation, extraction, transport, and diagnostics</td>
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<td>Key technologies for ion sources</td>
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High Power Accelerator for Basic & Appl. Researches and Relative Ion Sources

W. Zhan

Review of High Intensity Ion Source Development and Operation

R. Pardo

Types of Ion Source for Consideration

• Light Ions
  • Protons and isotopes of hydrogen
  • Helium (mass: 3 or 4)
  • Lithium

• Positive Ions
  • Penning Ion Gauge (PIG)
  • Vacuum Arc Sources (MEVVA, etc.)
  • Multicusp Ion Sources
  • Electron Cyclotron Resonance (ECR) ion sources
Topics
• Fundamental processes in ion sources, plasma

7 in 9 presentation  ECR plasma

“……..The poor ECRIS people do not even understand why their source performed so well.” (R. Geller, ECRIS and ECR plasma )

Temperature saturation (high energetic X-ray)

J. Li (IMP)
Effects of magnetic configuration on hot electrons in SECRAL-II plasma

the ratio of $B_{\text{min}} / B_{\text{ecr}} > 0.75 - 0.8$, $T_s$ saturates and electron cyclotron instability appears simultaneously

$n_e :$ electron density
$\tau_i :$ ion confinement time
$T_{\text{opt}} :$ electron temperature

$I_q = \frac{n_q V}{\tau_i}$

$B_{\text{min}}/B_{\text{ecr}}$ vs $T_s (\text{keV})$

$18\text{GHz}$
$24\text{GHz}$
**Topics**

- Fundamental processes in ion sources, plasma

**Electron energy distributions and X-ray from hot electrons($T_e$)**

**Lost electron energy distributions**

I. Izotov (IAP)
Measurements and simulations of the energy distribution of electrons lost from the minimum B field
little studied, though being crucial for the confinement of the plasma and performance of the ion source, is the electron energy distribution (EED)
observed changes in EED of the escaping electrons introduced by the secondary frequency in different regimes, including the one with the secondary frequency being below the cold ECR in the magnetic trap.

II. Isherwood (MSU)
Measurement of the energy distribution of electrons escaping confinement from an Electron Cyclotron Resonance ion source

Results showed a large peak of electrons in the 600-1000 keV energy range.
Topics
• Fundamental processes in ion sources, plasma

Ion confinement time

M. Marttinen (JYU)
Estimating ion confinement times from beam current transients in conventional and charge breeder ECRIS

Ions in an ECRIS plasma may obtain much higher temperatures than is conventionally believed, i.e. on the order of 10 eV. The temperature is also observed to be charge state dependent.

The confinement time is estimated to be on the order of tens of milliseconds for Cu and K ions at charge to mass ratios between 0.15 and 0.27, with higher charge states corresponding to longer confinement times.
A. Galatà (INFN-LNL)

**Self-consistent modeling of beam-plasma interaction in the charge breeding optimization process**

Progress made in the development of the numerical code, focusing the attention on the latest simulations of charge breeding of Rb1+ ions employing a self-consistent plasma target model. The effect of the real plasmoid/halo structure on the capture process will be underlined, as well as the influence of different plasma excitation frequencies.

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Y. Kato (Osaka Univ.)

**Plasma heating (Upper hybrid resonance heating )**

It has been concluded that the **UHR must have occurred by applying multiplex microwaves with their frequencies away from those for ECR in ECRIS.** In this paper we will describe brief theoretical background and these new experimental results.
Multi-diagnostics setup as a tool to overcome the limits of compact ion sources
development of time resolved diagnostics gives precious information about the strategy for decreasing the beam ripple and increasing the operability domain of ion sources.
Topics
Production of high intensity ion beams

Light ion beam (H+, D+) (2.45 GHz ECRIS)

S. Peng (PKU)
Selectable high intensity ion species of H+/H2 +/-H3 + beam with a 2.45 GHz ECR ion source

With these improvements, more than 42 mA H2 + ion beam with species fraction of 54% and 20 mA H3 + ion beam with species fraction of 55% a miniaturized ECR ion source was developed and a 52 mA hydrogen beam was extracted. Measurement results with the miniaturized ECR ion source show that under different working parameters H+, H2 + and H3 + fraction can reach up to 88%, 80% and 82%, respectively.

### PMECRIS (Peking Univ.)

![Diagram of PMECRIS](image)

<table>
<thead>
<tr>
<th>Ion type</th>
<th></th>
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<th></th>
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<tbody>
<tr>
<td><strong>Current[mA]</strong></td>
<td>H+</td>
<td>D+</td>
<td>He+</td>
<td>O+</td>
<td>Ar+</td>
</tr>
<tr>
<td>130</td>
<td>83</td>
<td>65</td>
<td>70</td>
<td>70</td>
<td>84</td>
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<tr>
<td><strong>Density[mA/cm²]</strong></td>
<td>460</td>
<td>294</td>
<td>230</td>
<td>247</td>
<td>247</td>
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<tr>
<td><strong>Application</strong></td>
<td>DWA/Proton Therapy*</td>
<td>PKUNIFTY</td>
<td>Coupled RFQ</td>
<td>SFRFQ</td>
<td>Ion Implantation</td>
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</table>
Light ion beam (H+, D+) (2.45 GHz ECRIS)

T. Akagi (QST)
Commissioning of high current H+/D+ ion beams for the Linear IFMIF Prototype Accelerator (LIPAc)

Latest results obtained through the efforts to characterize the pulsed D+ beam as well as H+ beam extracted from injector.

D+ beam with 140 mA.

Heavy ion beam (MEVVA, PIG) (B+)

E. Oks (HCEI)
Generation of boron ion beam by different methods

To obtain boron ions, pulsed discharge systems of a vacuum arc discharge and a high-current magnetron discharge in self-sputtering mode were used.
Overview of high intensity ion source development in past 20 years at IMP

We still foresee the facilities to be built in the near future, for instance HIAF (High Intensity heavy ion Accelerator Facility) and CiADS (China initiative ADS), and so on, which have strong demands of high intensity ion beams of H~U.

14.5~45 GHz for highly charged heavy ions
2.45 GHz for light ions

Y. Higurashi (RIKEN)
Status and perspectives for high intensity uranium beams from the RIKEN 28 GHz ECRIS

Using these results, we produced ~200μA of U^{35+}, 225μA of U^{33+}, 300μA of U^{29+} at the microwave power of ~2.5 kW (28 GHz + 18 GHz). For long term operation (longer than one month), intense beam of U^{35+} ions (120~140μA) was produced.

W. Lu (IMP)
Production of intense uranium beams with inductive heating oven at IMP

As the main injector of HIAF project, the high-charge state ECR ion source needs to provide intense uranium beams, such as 700 euA of U^{35+} oven can reach up to 2000 degree C with ~1.2 kW of heating power.
Junwei Guo (IMP)
A new microwave coupling scheme for high intensity highly charged ion beam production by high power 24-28 GHz SECRAL ion source

Based on the study of 24 GHz SECRAL ion source performances working at different launching systems, a new microwave coupling scheme is proposed in this paper, which can not only realize efficient power matching and feeding, but also effectively adjust the rf power distribution on the ECR surface.

New solution: Vlasov-type launcher

### Improvement of High-Charged Ion Intensity

<table>
<thead>
<tr>
<th></th>
<th>SECRAL 24 GHz $\text{TE}_{01}$-32 mm (eμA)</th>
<th>SECRAL 24 GHz $\text{TE}_{01}$-20 mm (eμA)</th>
<th>SECRAL-II 28 GHz $\text{TE}_{01}$-20 mm (eμA)</th>
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<tr>
<td>$\text{Ar}^{11+}$</td>
<td>1620</td>
<td></td>
<td></td>
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<tr>
<td>$\text{Ar}^{12+}$</td>
<td>1030</td>
<td>1420</td>
<td>1.38</td>
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<td>$\text{Ar}^{14+}$</td>
<td>506</td>
<td>846</td>
<td>1.67</td>
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<tr>
<td>$\text{Ar}^{16+}$</td>
<td>182</td>
<td>350</td>
<td>1.91</td>
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<tr>
<td>$\text{Ar}^{17+}$</td>
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<td>130</td>
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<tr>
<td>$\text{Xe}^{26+}$</td>
<td></td>
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<tr>
<td>$\text{Xe}^{27+}$</td>
<td>700</td>
<td>920</td>
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<td>235</td>
<td>322</td>
<td>1.37</td>
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<td>$\text{Xe}^{34+}$</td>
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<td>$\text{Xe}^{35+}$</td>
<td>45</td>
<td>90</td>
<td>2</td>
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E. Beebe (BNL)
New developments on the RHIC-EBIS for the BNL heavy ion program

The Extended EBIS will provide \( 2.1 \times 10^9 \text{ Au}^{32+} / \text{pulse} \) at the Booster ring entrance, a 40-50\% intensity upgrade compared with the existing RhicEBIS at BNL.

The axial magnetic field for an extended ion trap is achieved through the use of two closely coupled 5T superconducting solenoids, reinforced to withstand the axial forces between the modules.

Beams of \( 3\text{He}^{2+} \) with intensity up to \( 2.5 \times 10^{11} \) ions per pulse and 70\% polarization will be produced for RHIC and the future Electron Ion collider.
The RHIC Optically-pumped Polarized H- Ion Source (OPPIS) upgrade with the atomic beam hydrogen injector and the He-ionizer cell was commissioned for operation in the Run-2013. The use of the high brightness primary proton source resulted in higher polarized beam intensity and polarization delivered for injection to Linac-Booster-AGS-RHIC accelerator complex. The proposed polarized 3He++ acceleration in RHIC and future electron- ion collider (eRHIC) will require about 2\cdot10^{11} ions in the source pulse. A new technique had been proposed for production of high intensity polarized 3He++ ion beam. It is based on ionization and accumulation of the 3He gas (polarized by optical-pumping and metastability-exchange technique in the high magnetic field of a 5.0 T) in the Electron Beam Ion Source (EBIS).
M. Stockli (ORNL)
Upgrading the LANSCE accelerator complex with a SNS RF-driven H- ion source

LANSCE and SNS are considering the use of a SNS H- ion source on the LANSCE accelerator because it should a) decrease the source replacement time by a factor of ~8, b) increase source lifetime by a factor of 2-3, and c) increase the accelerator power by up to ~40%. However, this is a significant challenge as characteristics and normal operating regimes are drastically different.

R. Welton (ORNL)
Installation and commissioning of the ion source systems for the new SNS 2.5 MeV injector

The new injector was developed at ORNL in an offline beam test facility and consists of an ion source, Low Energy Beam Transport (LEBT) and Radio Frequency Quadrupole (RFQ). This report first describes the installed configuration of the new injector detailing the ion source system. The first beam current, RFQ transmission, emittance and energy measurements from the injector installed on the SNS are reported which not only show a significant performance improvement for our existing facility but will now make accessible the higher beam current requirements for future SNS upgrade projects.
A. Ueno (J-PARC)

**J-PARC H- source** for 100 mA high energy and high duty factor H- LINACs

**8 hours 100 mA beam** operation was demonstrated in a test stand by increasing the terminal voltage from 50 kV to 62 kV.

All Transverse Emittances of H$^-$ Ion Beams with (WH-, IH-) of (50 keV, 66 mA), (56 keV, 80 mA) and (62 keV, 100 mA) in Test-Stand were Improved by about 8% by Shortest Beam Extractor.
J. Hiratsuka (QST)
Achievement of high power and long pulse negative ion beam acceleration for JT-60SA NBI

negative ion beam (70 MW/m², 500kV) accelerations over 100 s with high power density has never been achieved before in the world. This result fulfills the requirement of the negative ion source for the neutral beam injector (NBI) of JT-60SA (500 keV, 130A/m² for 100 s) and also contributes to the 1 MeV negative ion accelerator for the ITER NBI. Acceleration of 500 keV, 154 A/m² beams for 118 s has been achieved.

S. Lawrie (UKRI)
A pre-injector upgrade for the ISIS pulsed spallation neutron facility, including a medium energy beam transport line and an RF-Driven, non-caesiated, external-antenna H– ion source

A long-lifetime, non-caesiated, RF-driven, external antenna H– ion source based on the successful CERN Linac4 and SNS designs is being constructed which will improve facility up-time and reliability.

latest developments on the MEBT before focusing on the RF ion source.
M. Sasao (Doshisha Univ.)
Prospect of Cs-free hydrogen negative ion sources using C12A7 plasma electrodes

A new inorganic material, C12A7 electride [1,2] has been experimentally studied as a candidate material for Cs-free hydrogen negative ion (H-) sources. It was found that the H- current extracted from the source with an electride Plasma Electrode (PE) is higher than with a clean molybdenum, by a factor of 80-100.

In the present study, key issues to realize a compact H-source for the actual use in accelerator injectors are investigated. Firstly, the ECR ion source was modified so that a dense plasma from the ECR region could be injected directly towards the PE. Preliminary results showed a clear dependence on the microwave power and the H- current increased by more than a factor 10.

Operation of RF ion source in CSNS
W. Chen

RF coupled H- source is under development. The commissioning of the source started in the January of 2019. When un-cesiated, it produced more than 30 mA beam at an RF power of 32 kW and pulse width of 450 μs.

- Silicon nitride plasma chamber
- Indirect water cooling
- 1500 Watt power allowed
- Thread teeth separated, epoxy sealed antenna
- Spark-gap ignitor
• Topics
• Ion sources for fusion

SPIDER, MITICA and ELISE (ITER project)

SPADER: full-scale negative ion source

MITICA: full-scale prototype of ITER HNB

ELISE

SPIDER
• Topics
• Ion sources for fusion

SPIDER, MITICA and ELISE (ITER project)

G. Serianni (Consorzio RFX)

First operation in SPIDER and the path to complete MITCA

- MITICA progressing
  - High voltage insulation tests on-going; breakdown tests due soon
- SPIDER operation without caesium:
  - Negative ion current density up to 25А/m²
  - Ratio of electron to negative ion current down to 40
  - Beamlet divergence in 20-30mrad range

C. Poggi (Consorzio RFX)

Design and development of an Allison type emittance scanner for the SPIDER ion source

Allison type emittance scanner for the SPIDER negative ion beam was developed and proposed for the installation on the STRIKE supporting structure.
D. Wünderlich (MIP)
Formation of large negative deuterium ion beams at ELISE

Aim of ELISE is to demonstrate the ITER requirements in terms of extracted negative hydrogen ion densities (329A/m² for hydrogen, 286A/m² for deuterium) for an pulse length of up to one hour in deuterium (1000s in hydrogen). Determined by IR calorimetry is an almost perfect global beam uniformity, which is degrading slightly (from 100% to 90%) over the length of the pulse. These pulses represent a milestone towards operation of the ITER NBI system during the initial operational phase in hydrogen (up to 2035).

A. Mimo (MIP)
ELISE test facility has been equipped with a **Cavity Ring-Down Spectroscopy system**, in collaboration with the National Institute of Fusion Science (NIFS) in Toki, Japan.

• CRDS system reliably and routinely in operation at ELISE since end 2018:
  • Successful measurement of negative ion density along 1 m plasma
  • Long pulse operation (thousands seconds), reliable and good performance of the cavity mirrors
  • **Negative ion density between $4 \cdot 10^{16}$ and $10^{17}$ m$^{-3}$ measured** 20 mm far from PG ($\approx$ vertically symmetric) and stable during long pulses
  • Negative ion density strongly affected by beam extraction
  • Isotope effect: higher density needed in D2 to reach same extracted current as in H$_2$?
K. Ikeda (NIFS)
Extension of high power deuterium operation of negative ion based neutral beam injector in LHD

D⁻ current is improved : 46A => 55.4A (j = 233 A/m²).
Iₑ/Iₑ⁻ current ratio is improved : 0.38 => 0.28 in the same arc power condition, which is maintained 0.31 at maximum D⁻ current.

Injection beam power is improved : 2.3 MW => 2.9 MW in BL3.
Total injection power also increased 6.3 MW => 7.0 MW by 3 beam lines.

K. Nagaoka (NIFS)
Optical Characteristics of Negative Ion Beam with Multi-Beam-Axes Produced by LHD-type Negative Ion Source

The beam divergence angle of ITER-like RF negative ion source has not achieved the ITER requirement. In this study, the experimental investigation of the phase space structure (emittance diagram) of negative ion beam produced with a Research & development Negative Ion Source at National Institute for Fusion Science (NIFS-RNIS) which is scaled a half volume to LHD sources was carried out,

Precisely measured the beam optics with Pepper-pot phase space analyzer
Observed **three component in the beam**
Using the focusing elements, the beam is well focused under some conditions
• Topics
• Ion sources for fusion

CHINA

Y. Xie (IPP, CAS)
R&D progress of RF ion source for neutral beam injector at ASIPP

Double drivers RF source was developed and achieved long pulse of 1000s with RF power of 82 kW. The negative ion extractor/accelerator was designed and developed. The negative ion was extracted and 10 A/m² negative hydrogen ion was extracted with RF power of 20 kW (without cesium).

M. Cavenago (INFN-LNL)
Improvements of the NIO1 installation for negative ion sources

Several bias and magnetic configurations were tested; in particular the Bx filter (setup f3 for NIO1) now seem to operate fairly well.
L. Maunoury (GANIL)
Charge breeding at Ganil: improvements, results and comparison with the other facilities
prior to its installation in the middle of the low energy beam line of the SPIRAL1 facility, the 1+/n+ system charge breeder has been modified based on the experiments performed on the CARIBU Facility at Argone National Laboratory. Thus, this year, 38mK / 38K radioactive ion beam has been successfully delivered to a physics experiment over a period of 1 week. The yields on the physics target were in the range of ~24.

A. Annaluru (GANIL)
The study of 1+ ion beam interaction in an ECR charge breeder ion source plasmas using Monte-Carlo Charge Breeding Code (MCBC)
The simulations results showed good agreement with the experiments and revealed the role of Coulomb collisions in the charge breeding process leading to a necessary detailed analysis using a full six-dimensional (6D) phase space Monte-Carlo Charge Breeding code (MCBC).
A. Lapierre (FRIB)

EBIS/T charge breeders for RIB facilities

Several postaccelerators at RIB facilities currently in operation and under construction employ electron-beam ion sources and traps (EBIS/T's) as charge breeders. **Compared with other charge breeding techniques, EBIS/T's have many advantages:** high efficiency, fast and variable breeding times, small beam emittances, and high beam purity.
R. Kronholm (JYU)
ECRIS Plasma Spectroscopy with a High Resolution Spectrometer
This enables studying multiple plasma parameters non-invasively through optical emission spectroscopy (OES) of weak emission lines characteristic to ECRIS plasmas. The measured ion temperatures in the JYFL 14 GHz ECRIS are between 5–28 eV, depending on the plasma species and charge state. It was found that 1+ ions reach temperatures on the order of 10 eV.

O. Tarvanien (UKRI-STFC/ RAL/ ISIS)
Plasma diagnostic tools for ECR ion sources - what can we learn from these experiments for the next generation sources

To do list (Olli Tarvanien)
- Reliable method to measure $n_e$ of (conventional) minimum-B ECRIS
- Connection between bremsstrahlung spectrum and EED
- Connection between escaping EED and confined EED
- Data explaining what defines the instability threshold
- Data explaining why two-frequency heating suppresses instabilities
- Ion temperature in charge breeder ECRIS (gas mixing)
- Experiments on different generation sources
**Transport**

T. Nagatomo (RIKEN)
Well-controlled emittance of the metallic ion beam extracted from the 28-GHz Superconducting ECR ion source adapting the superconducting acceleration cavity for new super heavy elements research

We installed a slit triplet around a double focal point of the low energy beam transport (LEBT) to limit the transverse emittance of the ion beam with monitoring the emittance using several pepperpot emittance meters.

**Diagnostics (heavy ion)**

K. Nakamura (Univ. Tokyo)
Feasibility study of a compact heavy ion source for investigation of laboratory magnetospheric plasma

We are developing a laser ion source to deliver a probe beam to investigate a plasma trapped by a dipole magnetic field. The Ring Trap 1 (RT-1) device at the University of Tokyo in which magnetically levitated superconducting coil produces dipole magnetic fields imitates magnetospheric plasmas in planets.
S. Kondrashev (BNL)

**Development of a highly efficient NEG pumping system for EBIS**

Ultra-high vacuum inside the ion trap volume is crucial for stable and reliable operation of an Electron Beam Ion Source (EBIS). We have developed and tested a **compact linear pumping system based on ZAO NEG module with high pumping speed and enhanced sorption capacity for all active gases.**
ICIS2019 Lanzhou China

• Topics
• Applications of ion sources

A. Efremov (JINR)
The role of ion sources in synthesis of the super-heavy Elements

P. Klar (Univ. Giessen)
Ion thrusters and electrical propulsion Developments

Effective production of $^{48}\text{Ca}$ beam

$^{48}\text{Ca}^{+} + ^{238}\text{U} \rightarrow ^{249}\text{Cf}$

Period 7 element (Z-118)

150th anniversary on the discovery of the periodicity of chemical elements

$^{48}\text{Ca}^{+} \rightarrow ^{238}\text{U} \rightarrow ^{249}\text{Cf}$

Hall thruster

Gridded ion thruster

Pulsed thruster

Plasma-dynamic thruster

Neutron generator

S. Ikeda (BNL)
Neutron generator based on intense lithium beam Driver

We are proposing a compact neutron generator based on Li beam driver. Nowadays, many proposals of small size neutron generator using Li (p, n) Be or Be (p, n) B reactions are seen, since availability of research nuclear reactor is getting difficult. These reactions are endothermic and undesired radiations could be reduced, because no nuclear reactions are expected below the threshold energies.

Inverse kinematics \( p(Li, Be)n \)

Medical application

A. Kitagawa (NIRS)
Present status of ion sources at QST-NIRS and carbon-ion radiotherapy facilities

A compact ECR ion source, named Kei2, has been developed for carbon-ion radiotherapy at QST-NIRS. After the successful performance test, Kei-series, a commercial version of Kei2, are used at four Japanese facilities at present and another will be installed in the 7th facility in Japan. Additionally, two sources are under construction at Seoul and Taipei.
C-PIMS based on a 2.45 GHz microwave ion source and a floating potential charge exchange cell

W. Wu

Carbon positive-ion mass spectrometry (C-PIMS)

They propose a new conceptual design based on a 2.45 GHz microwave ion source and a floating potential charge exchange cell (CXC).

• Topics
• Applications of ion sources

Capabilities of radio-frequency ion-sources in surface modification of materials

M. Becker,

Materials processing by ion beams is a very powerful technique for obtaining and shaping new materials.

The fundamental knowledge about of the interaction between ions and solids in conjunction with well characterized ion sources is the basis of a successful application of these techniques.
Where no one has gone before
-History of universe-

- The birth of mass
  - $10^{-11}$ s
  - $10^4$ s
  - 3 min
- The birth of proton and neutrons
  - 380 thousand yr
- The birth of heavy elements
  - 4 billion yr
- The birth of life
  - 13.8 billion yr

Big Bang

BNL

ECR ion source

EBIS(T)

Intense heavy ion beam

Charge breeder for RI beam

EBIS

Laser ion source

Where no one has gone before

- History of universe

ICIS2019 Lanzhou China
Where no one has gone before
-Go to period 8 element (New Elements Z=119, 120..)-

V+Cm  Z=119,  cross section ~10pb

DECRIS-PM
9+  10+ 11+ 12+

50Ti   90  72  60  23  10pμA on target

RIKEN 28GHz SC-ECRIS
13+

51V    615 (300 for long term)

Key point  not the energy, but the intensity
Ion source development

L. Zhu et al, PRC 89, 024615 (2014)
Where no one has gone before
-Sevier requirements (good field for developments)-

HIAF project 45 GHz 20kW

238U^{35+} 46+ 14 keV/u 0.05-0.1 pmA
(>0.7 mA of^{35+} U ion)
Where no one has gone before

-What is the limitation of the ion source performance? -

Model calculation based on the Fokker-Planck eq. predicted the limit od power absorption.
Additionally, the beam intensity of highly charged heavy ions are limited by the ion source structure.

Stable plasma

+ Plasma instability?
Where no one has gone before

-new idea( negative ion)-

New material for H- formation


Negative-hydrogen-ion production from a nanoporous 12CaO·7Al₂O₃ electrone surface

A high production rate of negative hydrogen ions (H-) was observed from a nanoporous 12CaO·7Al₂O₃ (C12A7) electrone surface immersed in hydrogen/deuterium low-pressure plasmas.
What’s Next

-TRIUMF (ICIS2021)-

TRIUMF is Canada’s particle accelerator center. From the hunt for the smallest particles in the universe to the development of new technologies, including next-generation batteries and medical isotopes, TRIUMF is pushing the frontiers in research to advance science, medicine, and business (Triumf home page: www.triumf.ca/home/about-triumph)

EBIS and EBIT


H- ion source


M.Marchetto, IPAC2015, WEYC3