Russian Academy of Sciences
Institute of Applied Physics

# ECRIS 2014

## 21st International Workshop on ECR Ion Sources

August, 24 – 28
Nizhny Novgorod, Russia

*PROGRAM AND ABSTRACTS*

Nizhny Novgorod
2014

**Workshop Chairman**

Dr. Vadim Skalyga

**Organized by**

Institute of Applied Physics, Russian Academy of Sciences

GYCOM Ltd.

**Sponsored by**

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Russian Foundation for Basic Research

Pantechnik

http://ecris14.iapras.ru

All abstracts printed as received

# WELCOME

Dear Colleagues!

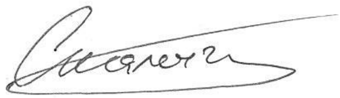
We are glad to welcome you in Nizhny Novgorod for the 21st International Workshop on ECR Ion Sources, hosted by Institute of Applied Physics and Gycom Ltd., on 24 - 28 August 2014.

The workshop is focused on the latest advances and breakthroughs in ECR ion sources performance, its modeling and applications, as well as plasma physics and related technologies. ECRIS Workshop is a well-known event being excellent for new result presentation, fruitful discussions and warm communication.

The 4th presentation of the Geller Prize – a biennial award for promising young scientists in the field of ECR ion sources – will be performed.

Nizhny Novgorod is one of the biggest Russian cities situated in the central-European part of Russia at the confluence of two great rivers, the Volga and the Oka. Nizhny Novgorod was founded in 1221, almost 800 years ago. We hope you would enjoy historical places and Russian cultural heritage during the Workshop.

Sincerely,



Vadim Skalyga, Chair

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## 2014 RICHARD GELLER PRIZE

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

This prize will be awarded for the fourth time during the 21st Workshop in Nizhny Novgorod (2014). An ad-hoc Geller Prize Award Committee will choose the winner of the Richard Geller Prize.

Nominations of candidates (who will be under 41 years of age on December 31, 2014) together with a one page description of the nominee's research work and up to three additional references who may be contacted by the committee, were submitted to the committee chair, Dr. Michael Hotchkis.

### *PRIZE PREZENTATION*

Presentation is on Thursday, August 28, 2014, 11:00 – 12:00, Workshop Main Hall.

### *SELECTION COMMITTEE*

- Michael Hotchkis, ANSTO, Australia (**Chair**)
- Santo Gammino, INFN/LNS, Italy
- Takahide Nakagawa, RIKEN, Japan
- Vadim Skalyga, IAP, Russia
- Daniel Xie, LBNL, USA
- Hongwei Zhao, IMP, China

PANTECHNIK

# GENERAL INFORMATION

### *WORKSHOP OFFICE*

The workshop office for administrative and proceeding assistance is located near the entrance of the Main Hall, where talks are given.

### *COMPUTERS AND PRINTERS*

Several computers are available in the lounge with an internet access. A printer is available on request at the secretary. Free wireless access is proposed during the workshop.

### *INFORMATION FOR SPEAKERS*

Presentations need to be in PPT or PDF format and have to be submitted through your JACoW repository account. If you are unable to upload it on the website, please install it on the presentation laptop at least 20 min before the session. Link to your account:
https://oraweb.cern.ch/pls/ecris2014/profile.html

### *ORAL SESSIONS*

All oral sessions will take place in the Main Hall. Please respect the time of your talk (15-17 min) and consider 5 min for discussion and questions.

### *POSTER SESSION*

Poster session will take place on Monday, August 25 (16:30-18:30) in the lounge near the Main Hall. You are invited to upload your poster in PPT or PDF format through the JACoW repository (find the link above).

### *DISPLAY*

You may put your poster up any time after 18:00 on Sunday, August 24rd. Your poster must be on display prior to the beginning of the session. We encourage you to leave your poster up till the end of the Workshop.

### *REMOVAL*

Please remove your poster before 12:30, Thursday, August 28.

### *VENDOR EXHIBITS*

Vendor exhibits are installed in the same lounge with posters.

List of exhibitors:

- Pantechnik
- VACOM Vakuum Komponenten & Messtechnik GmbH

***PROCEEDINGS***

All papers must be submitted to the JACoW repository before August, 28 (see Proceeding page of the website). Please come to the Workshop office desk if you encounter any difficulty.

***SECURITY***

Participants are responsible for their laptops and all the valuables that they bring to the workshop sessions.

***NO-SMOKING POLICY***

Russia has a no-smoking policy: smoking is restricted in all public and work places; smoking is only permitted outside, away from building entrance.

***WORKSHOP VENUE ADMITTANCE***

As IAP is a place of restricted access, you (and your companion) must have your ID together with your workshop badge all the time you are inside IAP and show it while entering/exiting if asked.

## WELCOME COCKTAIL
## SUNDAY, AUGUST 24, 18:00-22:00

You and your companion are invited to join us at a welcome cocktail on Sunday 24th, held from 18:00 to 22:00 at the lounge near the Main Hall of IAP. Checking-in and payment will be possible.

## LUNCH
## MONDAY, AUGUST 25, 13:00-14:30
## TUESDAY, AUGUST 26, 13:00-14:30
## WEDNESDAY, AUGUST 27, 12:30-14:00

Lunches for you and your companion are provided on Monday, Tuesday, and Wednesday in the Hurma restaurant, 50 meters away from the Workshop venue

## CONFERENCE RECEPTION: BOAT CRUISE
## TUESDAY, AUGUST 26, 16:30 – 22:00

On Tuesday 26th we would like to share with you and your companion the majesty and beauty of the Volga, cruising along the river on the modern side-wheeler. Snacks and drinks would be served.

## EXCURSION: CITY TOUR
## WEDNESDAY, AUGUST 27, 14:00-17:00

Excursion buses will leave from IAP at 14:00, riding you around the most interesting places in the Nizhny Novgorod, with several stops. Buses will come back to IAP before 17:00. Everybody is invited.

## BANQUET
## WEDNESDAY, AUGUST 27, 19:00-23:00

It is our pleasure to invite you to celebrate the 21st Workshop in the Hurma restaurant.

## GELLER PRIZE
## THURSDAY, AUGUST 28, 11:00-12:00

The Geller prize presentation will take place at the Main Hall. The nominee, selected by an ad-hoc committee chaired by Michael Hotchkis, will give a talk to present his awarded work.

## IAP TOUR
## THURSDAY, AUGUST 28, 14:00-16:30

The participants are welcome to visit the most interesting labs of IAP, 1.5 hour after Workshop closing remarks.

# CONTACTS

### *MAIN CONTACTS*

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### *PROCEEDING TEAM*

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Maxim Kuzin, co-Editor

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- T. Thuillier, LPSC, France
- R. Vondrasek, ANL, USA
- D. Xie, LBNL, USA
- H. Zhao, IMP, China

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- Vadim Skalyga,Chair
- Ivan Izotov
- Sergey Golubev
- Alexander Sidorov
- Alexander Vodopyanov
- Mikhail Viktorov
- Dmitry Mansfeld
- Sergey Razin

# SCHEDULE

| | Sunday, Aug 24 | Monday, Aug 25 | Tuesday, Aug 26 | Wednesday, Aug 27 | Thursday, Aug 28 | |
|---|---|---|---|---|---|---|
| 8:00 | | Check-in | | | | 8:00 |
| 8:30 | | | | | | 8:30 |
| 9:00 | | **Welcome** | **Status reports and new developments** (TUOMMH) | **Status reports and new developments (**WEOMMH) | **Applications** (THOMMH) | 9:00 |
| 9:30 | | **Status reports and new developments** (MOOMMH) | | | | 9:30 |
| 10:00 | | | | | | 10:00 |
| 10:30 | | | | Coffee Break | Coffee Break | 10:30 |
| 11:00 | | Coffee Break | Coffee Break | **Charge breeding, Theory and Simulations (**WEOBMH) | **Geller Prize** | 11:00 |
| 11:30 | | **Plasmas and beam diagnostic** (MOOBMH) | **Plasma heating and MW sources (**TUOBMH) | | | 11:30 |
| 12:00 | | | | | **Closing remarks** | 12:00 |
| 12:30 | | | **IOC meeting** | Lunch (provided) | | 12:30 |
| 13:00 | | Lunch (provided) | Lunch (provided) | | | 13:00 |
| 13:30 | | | | | | 13:30 |
| 14:00 | | | | Excursion | IAP RAS Tour | 14:00 |
| 14:30 | | **Ion beam extraction and optics, Miscellaneous** (MOOAMH) | | | | 14:30 |
| 15:00 | | | | | | 15:00 |
| 15:30 | | | | | | 15:30 |
| 16:00 | | | | | | 16:00 |
| 16:30 | | **Poster session & Industry exhibition** (MOPPH) | Boat cruise Workshop Reception | | | 16:30 |
| 17:00 | | | | | | 17:00 |
| 17:30 | | | | | | 17:30 |
| 18:00 | Welcome reception Check-in | | | | | 18:00 |
| 18:30 | | | | | | 18:30 |
| 19:00 | | | | Banquet | | 19:00 |
| 19:30 | | | | | | 19:30 |
| 20:00 | | | | | | 20:00 |
| 20:30 | | | | | | 20:30 |
| 21:00 | | | | | | 21:00 |
| 21:30 | | | | | | 21:30 |
| 22:00 | | | | | | 22:00 |
| 22:30 | | | | | | 22:30 |

# Program

# MONDAY, AUGUST 25

8:00 Check-in, payment

## 9:00 – 09:30
## WORKSHOP OPENING

9:00 Welcome
*Vadim Skalyga, chair*

## 9:30 – 11:00 MOOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:30 **MOOMMH01**
How can an ECRIS meet requirement of the next generation heavy ion accelerator facility
*Hongwei Zhao*

9:52 **MOOMMH02**
First ion beams extracted from a 60 GHz ECR ion source using polyhelices technique
*Thierry Lamy*

10:14 **MOOMMH03**
First results with the Superconducting Source for ions (SuSI) at 24 GHz
*Guillaume Machicoane*

10:36 **MOOMMH04**
Recent developments of RIKEN 28GHz SC-ECRIS
*Takahide Nakagawa*

***11:00 – 11:30***
***COFFEE BREAK***

## 11:30 – 13:00 MOOBMH
## PLASMAS AND BEAM DIAGNOSTIC

11:30 **MOOBMH01**
Periodic beam current oscillations driven by electron cyclotron instabilities in ECRIS plasmas
*Olli Tarvainen*

11:52 **MOOBMH02**
Emittance measurement for RIKEN 28 GHz SC-ECRIS
*Yoshihide Higurashi*

12:14 **MOOBMH03**
Frequency tuning effect on the bremsstrahlung spectra, beam intensity and shape in a 10 GHz, permanent magnet ECR ion source
*Gerard Oscar Rodrigues*

12:36 **MOOBMH04**
Emission Spectroscopy Diagnostic of Plasma inside 2.45 GHz ECR Ion Source at PKU
*Yuan Xu*

***13:00 – 14:30***
***LUNCH (PROVIDED)***

## 14:30 – 16:30 MOOAMH
## ION BEAM EXTRACTION AND OPTICS, MISCELLANEOUS

14:30 **MOOAMH01**
Simulation of the CERN GTS-LHC ECR ion source extraction system with Pb and Ar ion beams
*Ville Toivanen*

14:52 **MOOAMH02**
High Current Proton and Deuteron Beams for Accelerators and Neutron Generators
*Vadim Skalyga*

15:14 **MOOAMH03**
Optimization of Low-Energy Beam Transport
*Herman R. Kremers*

15:36 **MOOAMH04**
Axial Symmetric Open Magnetic Traps with Depressed Transversal Losses of Plasmas
*Alexander Sidorov*

15:58 **MOOAMH05**
Combination of two ECRIS calculations: plasma electrons and extracted ions
*Sandor Biri*

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## 16:30 – 18:30
## POSTER SESSION

# POSTER SESSION

**MOPPH001** Status on Current and Future ECRISs Developments at GANIL
*Pascal Jardin*

**MOPPH002** Production of metallic stable ion beams for GANIL and SPIRAL2
*Frederic Lemagnen*

**MOPPH003** Transfer of the IFMIF Injector from CEA/Saclay to Rokkasho site in Japan
*Raphael Gobin*

**MOPPH004** Status Report at the Heidelberg Ion-Beam Therapy (HIT) Ion Sources and the Testbench
*Tim Winkelmann*

**MOPPH005** Microwave Power Scaling to optimize Electron density and Temperature in ECR Produced Deuterium Plasma
*Sudhirsinh J Vala*

**MOPPH006** Direct injection of intense heavy ion beams from a high field ECR ion source into an RFQ
*Gerard Oscar Rodrigues*

**MOPPH007** Development of an in-situ emittance meter installed in LEBT following 18-GHz Superconducting ECR Ion Source
*Takashi Nagatomo*

**MOPPH008** Last results of LAPECR3 ion source at IMP
*Yun Cao*

**MOPPH009** Status of IMP permanent magnet Proton Source for CI-ADS Project
*Liangting Sun*

**MOPPH010** Development of a 14 GHz high intensity proton source
*Liangting Sun*

**MOPPH011** Development of Interface and Diagnostic System for ECR ion source At KBSI
*Byoung Seob Lee*

**MOPPH012** Beam slits and Faraday cup system for the measurement of ion beam profile in the 18 GHz ECRIS SMASHI
*Wonil Choo*

**MOPPH013** A new metal ion source using a waveguide directly-coupled and permanent magnet-embedded Lisitano antenna
*Soouk Jang*

**MOPPH014** Initial Performance of a Liquid Helium-free Superconducting ECR Ion Source SMASHI at NFRI
*Soouk Jang*

**MOPPH015** Production and Acceleration of Titanium-50 Ion Beam at the U-400 Cyclotron
*Sergei Bogomolov*

**MOPPH016** Modernization of the mVINIS Ion Source
*Andrey Efremov*

**MOPPH017** LEGIS facility for study of reactor steels radiation resistance
*Timur Kulevoy*

**MOPPH018** A microwave ion source for pulsed proton beam production at ESS-Bilbao
*Rosalba Miracoli*

**MOPPH019** Metallic beam Development with an ECR ion source at Michigan State University (MSU)
*Derek Elwin Neben*

# TUESDAY, AUGUST 26

## 9:00 – 11:00 TUOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:00 **TUOMMH01**
Improvement of Beam Intensities for ion beams with
Charge-to-Mass Ratio of 1/3 with Two-Frequency Heating Technique
*Atsushi Kitagawa*

9:22 **TUOMMH02**
ECR Ion Sources developments at INFN-LNS
*Luigi Celona*

9:44 **TUOMMH03**
Status Report of SECRAL II Ion Source Development
*Liangting Sun*

10:06 **TUOMMH04**
An ECR ion source with integrated sputter magnetron for large area metal ion beam generation and implantation
*Martin Kreller*

10:28 **TUOMMH05**
HIISI, New 18 GHz ECRIS for the JYFL Accelerator Laboratory
*Taneli Kalvas*

***11:00 – 11:30***
***COFFEE BREAK***

## 11:30 – 12:30 TUOBMH
## PLASMA HEATING AND MW SOURCES

11:30 **TUOBMH01**
The 60 GHz 300 kW Gyrotron System for
ECR Ion Source of New Generation
*Zakhar Gasajniev*

11:52 **TUOBMH02**
Millimeter Wave Microwave Sources for Electron Cyclotron Resonance Ion Sources
*Gregory Denisov*

## 12:30 – 13:00
## INTERNATIONAL ADVISORY COMMITTEE MEETING

***13:00 – 14:30***
***LUNCH (PROVIDED)***

***16:30 – 22:00***
***CONFERENCE RECEPTION: BOAT CRUISE***

# WEDNESDAY, AUGUST 27

## 9:00 – 10:30 WEOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

09:00 **WEOMMH01**
The Installation of the 28GHz Superconducting
ECR Ion Source At KBSI
*Mi-Sook Won*

09:22 **WEOMMH02**
First Commissioning Results of An Evaporative Cooling Magnet
ECRIS-LECR4
*Wang Lu*

09:44 **WEOMMH03**
Development of the magnetic system for new DECRIS-PM
ion source.
*Andrey Efremov*

10:06 **WEOMMH04**
Thermal Design of Refridgerated Hexapole 18 GHz ECRIS HIISI
*Taneli Kalvas*

***10:30 – 11:00***
***COFFEE BREAK***

## 11:00 – 12:30 WEOBMH
## CHARGE BREEDING, THEORY AND SIMULATIONS

11:00 **WEOBMH01**
Experimental activities with the LPSC charge breeder in the
European context
*Thierry Lamy*

11:22 **WEOBMH02**
Study of ECRIS scaling laws with the Particle-in-Cell code
*Vladimir Mironov*

11:44 **WEOBMH03**
Investigation on the origin of high energy x-rays observed in 3rd generation ECRIS
*Thomas Thuillier*

*12:06* **WEOBMH04**
Theory of cyclotron instability of hot electrons in ECRIS: origin, manifestation, and influence on plasma confinement
*Dmitriy Mansfeld*

***12:30 – 14:00***
***LUNCH (PROVIDED)***

***14:00 – 17:00***
***EXCURSION: CITY TOUR***

***19:00 – 23:00***
***BANQUET***

# THURSDAY, AUGUST 28

## 9:00 – 10:30 THOMMH APPLICATIONS

09:00 **THOMMH01**
Boron Ion Beam Production with the Supernanogan ECR Ion Source for the CERN BIO-LEIR Facility
*Joshua Tobias Stafford-Haworth*

09:22 **THOMMH02**
Application of an ECR Ion Source for Ionic Functionalization of Implant Materials on the Nanoscale
*Richard Racz*

09:44 **THOMMH03**
A Point-like Source of Extreme Ultraviolet Radiation Based on Non-equilibrium Discharge, Sustained by Powerful Radiation of Terahertz Gyrotron
*Alexander Sidorov*

***10:30 – 11:00***
***COFFEE BREAK***

## 11:00 – 12:00 GELLER PRIZE

## 12:00 – 12:30 CLOSING REMARKS

***14:00 – 16:30***
***IAP RAS TOUR***

# Abstracts

## 9:30 – 11:00 MOOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:30 MOOMMH01

### *How can an ECRIS meet requirement of the next generation heavy ion accelerator facility*

Hongwei Zhao, Liangting Sun (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, P.R.C.)

Driven by the requirement of nuclear physics research, a few next generation heavy ion accelerator facilities have been proposed such as GSI-FAIR, IMP-HIAF, JINR-NICA and JLAB-MEIC which require ion source to produce very intense pulsed-highly-charged heavy ion beams such as Au32+,U28+ and U35+ with beam current 10E11 particles per pulse. With more intense higher charge state heavy ion beam produced, the design and building of such a heavy ion accelerator complex will be more cost effective and more compact. This is a big challenge and also an opportunity for ECR ion source development. However, how can an ECR ion source compete with other ion sources such as EBIS,LIS and MEVVA ion sources to meet requirement of the next generation heavy ion accelerator complex? The potential performance of the next generation ECRISs working at the frequency 40~60 GHz and comparison with other possible ion sources will be presented. This paper will have a detailed discussion of the foreseen challenges of the next generation ECRISs and impact on the next generation heavy ion accelerator complex as well.

## 9:30 – 11:00 MOOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:52 MOOMMH02

### *First ion beams extracted from a 60 GHz ECR ion source using polyhelices technique*

Thierry Lamy[1], Julien Angot[1], Josua Jacob[1], Patrick Sole[1], Thomas Thuillier[1], Mikhail Bakulin[2], Anatoly Eremeev[3], Ivan Izotov[3], Boris Movshevich[3], Vadim Skalyga[3], François Debray[4], Cédric Grandclement[4], Philippe Sala[4], Christophe Trophime[4]

(1) LPSC, Grenoble, France
(2) GYCOM Ltd, Nizhny Novgorod, Russia
(3) IAP RAS, Nizhny Novgorod, Russia
(4) LNCMI, Grenoble, France

The first 18 GHz ECR plasma in an ion source prototype with a magnetic structure using high field magnets techniques was performed in 2012. The particularity of such a prototype is the establishing of a topologically closed ECR zone in a cusp configuration. During the current increase to get a closed 60 GHz zone, a failure appeared at 21000 A in one helix among the four. After the modification of the cooling circuit, the prototype was able to accept up to 26000 A allowing high frequency experiments. In the same time, a 60 GHz - 300 kW pulsed gyrotron has been successfully built and installed in Grenoble by IAP-RAS and Gycom company. The first 60 GHz ECR plasma has been produced in April 2014, the first pulsed beams have been extracted and analyzed. The experimental results obtained will be presented along with the perspectives of such developments.

*We acknowledge the support of the LNCMI-CNRS, member of the European Magnetic Field Laboratory (EMFL) and the International Science and Technology Center (project#3965).*

## 9:30 – 11:00 MOOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

10:14 MOOMMH03

### *First results with the Superconducting Source for Ions (SuSI) at 24 GHz*

Guillaume Machicoane[1], Dallas Gene Cole[1], Derek Elwin Neben[1], Larry Tobos[1], Daniela Leitner[2]

(1) NSCL, East Lansing, Michigan, USA
(2) FRIB, East Lansing, Michigan

The superconducting ECR ion source SuSI at Michigan State University was designed to operate primarily at 18 GHz and has demonstrated very good performance at this frequency especially when coupling two klystrons to the plasma [1]. Following a period of training, SuSI has been able to reach the magnetic field needed for operation in the high-B mode at 24 GHz. SuSI has several interesting features. First the axial magnetic profile is defined using 6 solenoids which provide some flexibility to adjust parameters such as field gradient at the resonance, Bminimum or plasma length. Second with a diameter of only 101mm, SuSI plasma chamber has a nominal volume of about 3.5 l. Therefore, power density in excess of 2 kW/l could be reach and lead potentially to new insight on the maximum performance achievable with an ECR. In January 2014, a 10 kW 24 GHz Gyrotron obtained from the Russian company GYCOM was commissioned at MSU on a dummy load and then connected to SuSI. We report here on the first measurements done with SuSI at 24 GHz.

*[1] L.T. Sun, J. Brandon, D.G. Cole, M. Doleans, G. Machicoane, D. Morris, T. Ropponen, L. Tobos., ECRIS 2010 (MOCOAK02)*

## 9:30 – 11:00 MOOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

10:36 MOOMMH04

### *Recent developments of RIKEN 28GHz SC-ECRIS*

Takahide Nakagawa, Yoshihide Higurashi, Masanori Kidera,
Jun-ichi Ohnishi, Kazutaka Ozeki (RIKEN Nishina Center, Wako, Japan)

Last year, we successfully produced intense beam of highly charged uranium ions (180 euA of U35+, 230euA of U33+) with sputtering method(28 GHz). For maximizing the beam intensity with the microwave frequency of 28 GHz, we investigated the effect of the magnetic field configuration on the beam intensity. To minimize the consumption rate of the uranium for long term operation, we measured the consumption rate and beam intensity under the various conditions to optimize the efficiency. Based on it, very recently, we achieved production of stable and intense uranium (2~3 puA of U35+) ion beam for long term (24 days without break) for RIKEN RIBF experiments. It is well-known that the large amount of X-ray heat load in the cryostat is serious problems for production of the intense beam with 28 GHz SC-ECRIS. To minimize this effect, we systematically measured the heat load and beam intensity under the various conditions (magnetic field configuration, RF power, gas pressure etc). In this contribution, we will present the results of these test experiments and operational experience of the RIKEN 28 GHz SC-ECRIS for RIKEN RIBF project.

## 11:30 – 13:00 MOOBMH
## PLASMAS AND BEAM DIAGNOSTIC

11:30 MOOBMH01

### *Periodic beam current oscillations driven by electron cyclotron instabilities in ECRIS plasmas*

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

(1) JYFL, Jyvaskyla, Finland
(2) CERN, Geneva, Switzerland
(3) IAP RAS, Nizhny Novgorod, Russia

Experimental observation of cyclotron instabilities in electron cyclotron resonance ion source plasma operated in cw-mode is reported. The instabilities are associated with strong microwave emission and a burst of energetic electrons escaping the plasma, and explain the periodic oscillations of the extracted beam currents. The instabilities are shown to restrict the parameter space available for the optimization of high charge state ion currents.

## 11:30 – 13:00 MOOBMH
## PLASMAS AND BEAM DIAGNOSTIC

11:52 MOOBMH02

### *Emittance measurement for RIKEN 28 GHz SC-ECRIS*

Yoshihide Higurashi, Takahide Nakagawa, Jun-ichi Ohnishi (RIKEN Nishina Center, Wako, Japan)

In 2013, the intense beams of highly charged uranium ion (180 euA of U35+, 230 euA of U33+) were extracted from RIKEN SC-ECRIS. Following the success, intense beam of U35+ ions was used for the RIBF experiment for 24 days without break. It is obvious that production of high-quality beam (smaller emittance and good stability etc.) is also important for RIKEN radio isotope beam factory (RIBF) project. For this reason, in 2014, we systematically measured the emittance and beam intensity of the highly charged uranium ions under various conditions (magnetic field configuration, extracted beam intensity, beam stability etc.) to search the optimum condition. In these experiments, we observed that the emittance size is strongly dependent on the magnetic field configuration, especially Bext. In this contribution, we present the effect of the various parameters (magnetic field configuration, extracted beam intensity, beam stability etc) of the SC-ECRIS on the beam intensity and emittance. We also discuss its mechanism in detail.

## 11:30 – 13:00 MOOBMH
## PLASMAS AND BEAM DIAGNOSTIC

12:14 MOOBMH03

### *Frequency tuning effect on the bremsstrahlung spectra, beam intensity and shape in a 10 GHz, permanent magnet ECR ion source*

Gerard Oscar Rodrigues[1], Dinakar Kanjilal[1], Narender Kumar[1], Kedar Mal[1], Yaduvansh Mathur[1], Amit Roy[2]

(1) IUAC, New Delhi, India
(2) VECC, Kolkata, India

The effect of the frequency tuning on bremsstrahlung spectra, beam intensity and shape in the 10 GHz, NANOGAN ECR ion source have been experimentally studied [1]. The aim was to study the effect on a lower frequency type of ECR source where the separation between various modes in the cavity is much larger. The warm and cold components of the electrons were observed to be directly correlated with the beam intensity enhancement in the case of Ar9+ but not so for O5+. However, the warm electron component was much smaller than the cold component. The beam shapes of O5+ measured as a function of frequency showed a strong variation without any hollow beam formation. Due to the use of an octupole magnetic structure in the NANOGAN ECR source, the quadrupolar structure of the ECR surface is modified with the frequency tuning. In general, we have observed a strong absorption of microwave power at various frequencies whenever the reflection co-efficient showed a minimum value and the effect was seen stronger for the higher charge states. Details of the measurements carried and its influence on the bremsstrahlung spectra, beam intensity and shape will be presented together with simulations.

[1] *Effect of frequency tuning on bremsstrahlung spectra, beam intensity, and shape in the 10 GHz NANOGAN electron cyclotron resonance ion source, Rev.Sci.Instrum. 85,02A944 (2014)*

## 11:30 – 13:00 MOOBMH
## PLASMAS AND BEAM DIAGNOSTIC

12:36 MOOBMH04

### *Emission spectroscopy diagnostic of plasma inside 2.45 GHz ECR ion source at PKU*

Yuan Xu[1], Jia Chen[1], Jia-er Chen[1], Zhiyu Guo[1], Shi Xiang Peng[1*], Haitao Ren[1], Jingfeng Zhang[1], Tao Zhang[1], Jie Zhao[1], Ailin Zhang[2]

(1) PKU, Beijing, P.R.C.
(2) Graduate University, Beijing, P.R.C.

The 2.45 GHz permanent magnet electron cyclotron resonance ion source (PMECR) at Peking University (PKU) can produce 100 mA H+, 40 mA H2+ and 20 mA H3+ under different conditions, but the physics processes and plasma characteristics within the discharge chamber are not very clear until now. Langmuir probe, laser detachment, absorption spectroscopy and optical emission spectroscopy are common approaches for diagnosing the plasma. Among those methods, optical emission spectroscopy is a simple in situ one without disturbing the plasma. To better understand the plasma producing processes, a new ion source with transparent quartz discharge chamber was designed at PKU so that plasma diagnostic can be performed through directly detecting the light generated within ECR zone by fiber optics. Collisional radiative (CR) model is utilized to calculate plasma parameters like electron density ne and electron temperature Te for non-equilibrium plasma in ECR ion source. The spectroscopy diagnosis platform has been constructed, and preliminary results will be presented in this paper.

*This work is supported by the National Science Foundation of China (Grant Nos. 11175009 and 91126004).*

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## 14:30 – 16:30 MOOBMH
## ION BEAM EXTRACTION AND OPTICS, MISCELLANEOUS

14:30 MOOAMH01

### *Simulation of the CERN GTS-LHC ECR ion source extraction system with Pb and Ar ion beams*

Ville Toivanen, Giulia Bellodi, Detlef Kuchler, Alessandra Maria Lombardi, Richard Scrivens, Joshua Tobias Stafford-Haworth (CERN, Geneva, Switzerland)

A comprehensive study of beam formation and beam transport has been initiated in order to improve the performance of the CERN heavy ion injector, Linac3. As part of this study, the ion beam extraction system of the CERN GTS-LHC 14.5 GHz Electron Cyclotron Resonance Ion Source (ECRIS) has been modelled with the ion optical code IBSimu. The simulations predict self-consistently the triangular and hollow beam structures which are often observed experimentally with ECRIS ion beams. The model is used to investigate the performance of the current extraction system and provides a basis for possible future improvements. In addition, the extraction simulation provides a more realistic representation of the initial beam properties for the beam transport simulations, which aim to identify the performance bottle necks along the Linac3 low energy beam transport. The results of beam extraction simulations with Pb and Ar ion beams from the GTS-LHC will be presented and compared with experimental observations.

## 14:30 – 16:30 MOOBMH
## ION BEAM EXTRACTION AND OPTICS, MISCELLANEOUS

14:52 MOOAMH02

### *High current proton and deuteron beams for accelerators and neutron generators*

Vadim Skalyga[1], Sergey Golubev, Ivan Izotov, Sergey Razin, Alexander Sidorov[1], Taneli Kalvas[2], Hannu Koivisto[2], Olli Tarvainen[2], Anna Maslennikova[3], Artur Volovecky[3]

(1) IAP RAS, Nizhny Novgorod, Russia
(2) JYFL, Jyvaskyla, Finland
(3) Nizhny Novgorod State Medical Academy, Nizhny Novgorod, Russia

This paper presents the latest results of high current proton and deuteron beam production at SMIS 37 at the Institute of Applied Physics. In this experimental setup the plasma is created by 37.5 GHz gyrotron radiation with power up to 100 kW in a simple mirror trap. High microwave power and frequency allow sustaining higher density hydrogen plasma in comparison to conventional ECRIS's or microwave sources. The low ion temperature, on the order of a few eV, is beneficial to produce proton beams with low emittance. Latest experiments with hydrogen and deuterium show possibility of beam formation with currents up to 550 mA at high voltages below 45 kV with normalized rms emittance lower than 0.2 π·mm·mrad. Such beams have a high potential for application in future accelerator research. Also in frames of the present paper it is suggested to use such an ion source in a scheme of D-D neutron generator. Such ion source can produce deuteron ion beams with current density up to 700-800 $mA/cm^2$. Generation of the neutron flux with density at the level of $(7\text{-}8)\bullet 10^{10}$ $s^{-1}cm^{-2}$ could be obtained in case of $TiD_2$ target bombardment with deuteron beam accelerated to 100 keV.

## 14:30 – 16:30 MOOBMH
## ION BEAM EXTRACTION AND OPTICS, MISCELLANEOUS

15:14 MOOAMH03

### *Optimization of low-energy beam transport*

Herman R. Kremers, Johannes P.M. Beijers, Sytze Brandenburg
(KVI, Groningen, Netherlands)

We have studied the extraction and transport of a low-energy ion beam between an Electron Cyclotron Resonance (ECR) Ion Source and the analyzing magnet. This first part of the transport line is particularly sensitive to emittance blowup caused by ion-optical aberrations and non-paraxiality of the beam. This can be prevented by an appropriate focussing element between ion source and analyzing magnet. We present the results of beam transport simulations for different focussing elements including an einzel lens, solenoid and quadrupole element. These calculations, verified by measurements, lead to a design of an optimal, low-energy beam transport line for ion beams with large beam divergences.

## 14:30 – 16:30 MOOBMH
## ION BEAM EXTRACTION AND OPTICS, MISCELLANEOUS

15:36 MOOAMH04

### *Axial symmetric open magnetic traps with depressed transversal losses of plasmas*

Alexander Sidorov, Sergey Golubev, Ivan Izotov, Sergey Razin, Vadim Skalyga, Alexander Vodopyanov (IAP RAS, Nizhny Novgorod, Russia)

Development trend of the modern ECR ion sources is connected with the continued increase of the heating radiation frequency and, as a consequence, increase of the magnetic field value. In this case the construction of the MHD stable non-axial symmetric magnetic systems becomes rather complicated. Thus, the search of axial symmetric magnetic systems with depressed transversal losses caused by MHD instabilities is in a great demand. In this report some of the possible versions of such magnetic systems are presented: cusp magnetic trap, system with magnetic divertor and the mirror trap with the differential rotation layer in plasmas. . Perspectives of using these systems in the ECR ion sources according to the results of experimental investigations on SMIS 37 setup in Nizhny Novgorod are discussed.

## 14:30 – 16:30 MOOBMH
## ION BEAM EXTRACTION AND OPTICS, MISCELLANEOUS

15:58 MOOAMH05

### *Combination of two ECRIS calculations: plasma electrons and extracted ions*

Sandor Biri[1], Richárd Rácz[1], Ralf Lang[2], Jan Maeder[2], Fabio Maimone[2], Peter Spaedtke[2], Klaus Tinschert[2]

(1) ATOMKI, Debrecen, Hungary
(2) GSI, Darmstadt, Germany

In strongly magnetized ECRIS plasmas collisions do not influence the path of the charged particle. Electrons and ions can move more freely only along the magnetic field line compared to the transverse direction. Extraction simulation requires that the trajectories of charged particles have to be traced through the plasma chamber. In previous simulations the particle density at the beginning of the trajectory deep inside the plasma has been unknown. Now the full 3D electron tracking within the plasma chamber has been combined with the generation of initial ion starting conditions including particle density for ion tracking. The TrapCAD code has been used to determine the electron spatial distribution in a certain energy window. The idea is that at the places where the electron reaches a specific energy, an ion trajectory can be started. The magnetic field has been modeled with OPERA. The computer code KOBRA3-INP has been used for ray tracing. First results will be discussed and compared with experimental experience. The number of affecting parameters on the operating conditions of the ion source may lead to a multi-dimensional optimization space for simulation.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH001

### *Status on current and future ECRISs developments at GANIL**

Pascal Jardin[1], Olivier Bajeat[1], C. Barue[1], Christophe Canet[1], Pierre Delahaye[1], Mickael Dubois[1], Michel Dupuis[1], Jean Luc Flambard[1], Romain Frigot[1], Christian Leboucher[1], Frederic Lemagnen[1], Laurent Maunoury[1], Benoit Osmond[1], Christophe Peaucelle[2], Hannu Koivisto[3], Patrick Sole[4], Thomas Thuillier[4]

(1) GANIL, Caen, France
(2) IN2P3 IPNL, Villeurbanne, France
(3) JYFL, Jyvaskyla, Finland
(4) LPSC, Grenoble, France

After almost ten years of design and construction, the first phase of the SPIRAL 2 project will be starting by end of 2014. The coming years will be devoted to test it up to reach the ambitious specifications of the project, and to upgrade the existing GANIL facility in order to enlarge the range of ions offered to the physics community. In the frame of SPIRAL 2, stable ion beams from gaseous and condensable elements have been developed and tested in collaboration with LPSC/Grenoble. While sufficient for the commissioning of the Linear accelerator, obtained intensities must be increased to fulfill the final expectations of the project. To reach this goal, development ways concerning new ECRIS's and methods for metallic element production are currently under consideration within collaborations in preparation. A SPIRAL 1 upgrade project has been launched in 2012 to produce heavier radioactive ions than today. To post-accelerate them, their charges will be bred by a Phoenix booster designed at LPSC, which is currently being transformed attempting to fit with the best breeding conditions. A review of current and future developments led and foreseen at GANIL will be presented.

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## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH002

### *Production of metallic stable ion beams for GANIL and SPIRAL2**

Frederic Lemagnen[1], C. Barue[1], Christophe Canet[1], Jean Luc Flambard[1], Romain Frigot[1], Pascal Jardin[1], Laurent Maunoury[1], Benoit Osmond[1], Julien Piot[1], Christophe Peaucelle[2], Benoit Gall[3], Thierry Lamy[4], Patrick Sole[4], Thomas Thuillier[4]

(1) GANIL, Caen, France
(2) IN2P3 IPNL, Villeurbanne, France
(3) IPHC, Strasbourg, France
(4) LPSC, Grenoble, France

GANIL has been producing many stable beams for nearly 30 years. Constant progress has been obtained in terms of intensity, stability and reliability. The presentation highlights recent results obtained for 50Ti beam production from an organo-metallic compound using the MIVOC (Metallic Ions from Volatile Compounds) method with the ECR4 ion source. The synthesis of this compound has been studied and realized by the IPHC-Strasbourg team from isotopically enriched titanium metal. Preliminary tests using natural titanocene were performed to validate the production method in terms of beam intensity, stability and reliability. Results obtained allowed us to program a physics experiment in September 2013. A $^{50}$Ti10+ beam was maintained stable for 300 h with a mean intensity of 20 µA. Q/A=1/3 ion source of SPIRAL 2 facility, whom commissioning will be led by end of 2014, is Phoenix V2 ion source which has been developed by LPSC-Grenoble. Results obtained for nickel ($^{58}$Ni19+) and calcium ($^{40}$Ca16+) in collaboration with LPSC Grenoble will be presented in this report.

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*CEA, Commissariat à L'Energie Atomique Bâtiment Le ponant D - 25 rue Leblanc 75015 PARIS*

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH003

### *Transfer of the IFMIF Injector from CEA/Saclay to Rokkasho site in Japan*

Raphael Gobin[1], Daniel Bogard[1], Nicolas Chauvin[1], Patrick Girardot[1], Patrice Guiho[1], Francis Harrault[1], Denis Loiseau[1], Franck Senee[1], Juan-Marcos Ayala[2], Yoshikazu Okumura[2], Atsushi Kasughai[3]

(1) CEA/DSM/IRFU, France
(2) IFMIF/EVEDA, Rokkasho, Japan
(3) JAEA, Rokkasho, Japan

The IFMIF Injector, dedicated to high intensity deuteron beams has been designed, built and tested at CEA/Saclay. After acceptance test completion, the Injector has been fully disassembled and prepared for the 2 month long ship trip between Europe and Japan. Beginning of 2014, the 35 large packages have been opened and the Injector re-installation has been performed in March, April and May. The check-out phase is expected in June followed by the production of the first hydrogen plasma and first proton beam. The deuteron beam commissioning is delayed after final tests of all the Injector elements including high power diagnostics. After a brief summary of the achieved results obtained at Saclay, this article reports the different phases from end of 2012 up to the first beam production at Rokkasho.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH004

### *Status report at the Heidelberg Ion-beam Therapy (HIT) ion sources and the testbench*

Tim Winkelmann[1], Rainer Cee[1], Thomas Haberer[1], Bernd Naas[1], Andreas Peters[1], Jochen Schreiner[1], Erik Ritter[2]

(1) HIT, Heidelberg, Germany
(2) DREEBIT GmbH, Dresden, Germany

Since October 2009 more than 2000 patients were treated at HIT. In a 24/7 operation scheme two 14.5 GHz electron cyclotron resonance ion sources are routinely used to produce protons and carbon ions. The integration of a third ion source into the production facility was done in summer 2013 to produce a helium beam. This paper will give a status report of the ion source operating experience and statistics and will summarize the enhancement activities, which were undertaken at an in-house ion source test bench.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH005

### *Microwave power scaling to optimize electron density and temperature in ECR produced deuterium plasma*

Abu Talat Tahir Mostako, Tejen Kumar Basu, Joydeep Ghosh, R Makwana, Ranjana Manchanda, Chandan Venkata Srinivasa Rao, Sudhirsinh J Vala, Niral Virani (Institute for Plasma Research, Bhat, Gandhinagar, India)

Efficiently produced deuterium plasma forms the starting point of all ECR ion sources for the production of high energy neutrons. Effective absorption of microwave power in the deuterium plasma ensures an intense ionization and hence optimum electron density and temperature. Optical emission spectroscopy is one of the diagnostic techniques used to measure parameters of produced ECR plasmas. In this paper, the effect of microwave power on electron temperature in deuterium plasma is investigated. The plasma was generated by 2.45 GHz ECR microwave source. The microwave power was varied from 100-400 W keeping the deuterium gas pressure in the range of ~ 5×10-4 mbar. The flow rate of gas was ~ 5×10-4sccm. Plasma was diagnosed by optical emission spectroscopic technique. Optical emission spectrum of the deuterium plasma was recorded in the wavelength region 350-900 nm. In the recorded spectrum, α, β, and γ Balmer atomic lines of deuterium were identified along with few neutral lines of chromium. The electron temperature of the deuterium plasma was measured by using Boltzmann plot. A detail analysis of recorded deuterium spectrum will be presented.

*[1] C E Bush et al Phy Plasm.2 2366 1995*
*[2] S J Zweben et al Phy Plasm. 1 1469 1994*
*[3] J. Zweiback et al Phy Rev Lett. 85, 3640 2000*
*[4] A Boileau et al J. Phy B At. Mol. Opt. Phys. 22, L145 1989*

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH006

### *Direct injection of intense heavy ion beams from a high field ECR ion source into an RFQ*

Gerard Oscar Rodrigues[1], Dinakar Kanjilal[1], Reinard Becker[2], Robert W. Hamm[3], Amit Roy[4]

(1) IUAC, New Delhi, India
(2) IAP, Frankfurt am Main, Germany
(3) R&M Technical Enterprises, Pleasanton, California, USA
(4) VECC, Kolkata, India

Beam intensities achievable from high performance ECR sources for highly charged ions are limited by the high space charge. For high performance ECR sources, the stray magnetic field of the source can provide focusing against the space charge blow-up of the beam in addition to the Direct Plasma Injection Scheme (DPIS) adapted from laser ion sources [1]. A combined extraction/matching system [2] has been designed for direct injection into a radio frequency quadrupole (RFQ) accelerator, allowing a total beam current of 10 mA for the production of highly charged 238U40+ (1.33 mA) to be injected at an ion source voltage of 60 kV. In this design, the features of IGUN have been used to take into account the rf-focusing of an RFQ channel (without modulation), the electrostatic field between ion source extraction and the RFQ vanes, the magnetic stray field of the ECR superconducting solenoid, and the defocusing space charge of an ion beam. The RFQ has been designed to suppress neighbouring charge states and to work as a filter for the desired 238U40+. This reduces the transport problem for the beam line as well as it reduces the emittance for the selected charge state.

*[1] R. Becker et al., PROC. EPAC-2004, TUPLT024*
*[2] G.Rodrigues et al., Rev.Sci.Instrum. 85,02A740 (2014)*

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH007

### *Development of an in-situ emittance meter installed in LEBT following 18-GHz Superconducting ECR Ion Source*

Takashi Nagatomo[1], Yukimitsu Ohshiro[2], Osamu Kamigaito[3], Masayuki Kase[3], Takahide Nakagawa[3], Yasuteru Kotaka[3,4], Vasilis Tzoganis[1,5]

(1) RIKEN, Saitama, Japan
(2) CNS, Saitama, Japan
(3) RIKEN Nishina Center, Wako, Japan
(4) SHI Accelerator Service Ltd., Tokyo, Japan
(5) The University of Liverpool, Liverpool, United Kingdom

Providing intense and highly charged heavy ion beams is one of the most essential and fundamental technologies to explore a trackless frontier so-called “Island of Stability” where relatively stable super heavy elements are considered to exist. Towards this goal, the development of an ion source that can provide a highly charged heavy ion beam with high intensity and low emittance is necessary. In order to provide the desired high intensity ion beam, the beam-radius expansion induced by space charge effects cannot be ignored, and it can cause considerable degradation of the beam emittance. To suppress such effects at the output of an ion source is one of the top priorities in the direction of improving both the quality and intensity of the beam. At first, we plan to examine the space charge effects with a high-intensity beam provided by the 18-GHz Superconducting ECR Ion Source at RIKEN Nishina Center. To measure the degradation of the beam emittance as function of the beam’s intensity, an in-situ emittance monitor system based on the pepperpot technique and applicable to a wide range of beam intensities is being developed. A report on the current status will be presented.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH008

### *Last results of LAPECR3 ion source at IMP*

Yun Cao (IMP, Lanzhou, P.R.C.)

A high charge state all permanent Electron Cyclotron Resonance Ion Source (ECRIS) LAPECR3 (Lanzhou All Permanent magnet ECR ion source No.3) has been successfully built at IMP in 2012. LAPECR3 was designed for the Heavy Ion Medical Machine (HIMM) project. More than 120 eμA of C5+ ion beam is extracted from the LAPECR3 ion source using CH4 gas and C2H2 gas. About 120 eμA of C5+ ion beam was extracted from the ion source, and the emittance was less than 75 π*mm*mrad when work gas was C2H2 gas. The experimental results will be presented in detail in this paper.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH009

### *Status of IMP permanent magnet proton source for CI-ADS project*

Qi Wu, Hongyi Ma, Liangting Sun, Yao Yang, Xuezhen Zhang, Zimin Zhang, Hongwei Zhao (IMP, Lanzhou, P.R.C.)

To produce the requested 10 mA proton beam for the China Initiative Accelerator Driven Sub-critical reactor Linac (CI-ADS), electron cyclotron resonance (ECR) ion sources operating at 2.45 GHz have been developed. The CI-ADS proton source developed at IMP can produced stable 35 keV/10 mA continuous wave (cw) beam at the RFQ entrance. The proton beam extracted by a 3-electrode extraction system passes through a low energy beam transport system (LEBT), which is composed of identical solenoids, into the 3.2 MeV radio-frequency quadrupole (RFQ). In order to ensure superconducting cavities commissioning and protection, an electrostatic-chopper has been designed and installed in the LEBT line that can chop the cw beam into a pulsed one. The achieved fall/rise time of the chopper is less than 20 ns. In this paper, the performance of the proton source and the LEBT, such as beam reliability, emittance and beam current tuning will be presented.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH010

### *Development of a 14 GHz high intensity proton source*

Wenhui Zhang, Yucheng Feng, Junwei Guo, Xixia Li, Hongyi Ma, Cheng Qian, Liangting Sun, Qi Wu, Hengjuan Zhang, Xuezhen Zhang, Zimin Zhang, Hongwei Zhao (IMP, Lanzhou, P.R.C.)

A high intensity ECR proton source with 14 GHz microwave heating was successfully developed at IMP. The idea of the working mechanism and the structure of the proton source, as well as using 14 GHz microwave heating, were first proposed in the world. The experimental platform was set up and preliminary commissioning was performed. The experimental results indicate that the source can produce a total of 4 mA CW hydrogen beams with microwave power of 200 W and extraction voltage of 40 kV, in which H2+ and H3+ are included. The successful commissioning of the proton source demonstrates that the proposed mechanism and the structure are feasible.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH011

### *Development of interface and diagnostic system for ECR ion source at KBSI*

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

(1) Korea Basic Science Institute, Busan, Republic of Korea
(2) Kyungpook National University, Daegu, Republic of Korea

The 28 GHz superconducting ECR ion source of KBSI (Korea Basic Science Institute) have been installed to produce high current, high charge state ions. Accelerated and focused ion beam should be diagnosed, so we developed the diagnostic system which composed of the slit, wire scanner, view screen and Faraday cup. The developed interface and diagnostic system for stable operation of ECR ion source were designed. These information will be used as references in a study of the optimum beam condition for extraction parameter on its performance. The details of diagnostic system and initial test results will be reported.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH012

### *Beam slits and Faraday cup system for the measurement of ion beam profile in the 18 GHz ECRIS SMASHI*

Wonil Choo, Soouk Jang, Hyun-Jong You (NFRI, Daejon, Republic of Korea)

A beam slits-Faraday cup (slits-cup) system is newly developed to evaluate the performance and the characteristics of the 18 GHz ECR SMASHI (Superconducting Multi-Application Source of Highly-charged Ions), which has been recently commissioned at national fusion research institute in Korea. The slits-cup system consists of a 2-way beam slits and a high power Faraday cup, so that they can collimate the ion beam and also measure the profile of the ion beam. The Faraday cup features a wide range of beam current (0 to 100 mA) and high beam-power capability (300 W). Also, the Faraday cup is designed to have strong features of low signal noise and free of arcing due to electrical wires not exposed to beam line. As for the 2-way beam slits, the slit positions and gaps are independently controllable. Each position of x- and y- slit could be moved by 60 mm, and the slit gap could be adjusted up to 50 mm. Beam profile was measured by adjusting the slit positions from 0 to 50 mm by maintaining the slit gap (e.g., 5 mm). Here, we describe a detailed design of the slit-cup system, beam profile measurements, and their comparisons with the wire scanner measurement.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH013

### *A new metal ion source using a waveguide directly-coupled and permanent magnet-embedded Lisitano antenna*

Soouk Jang, Wonil Choo, Hyun-Jong You
(NFRI, Daejon, Republic of Korea)

In order to generate high intensity metal ion beams, a new high density 2.45 GHz electron cyclotron resonance (ECR) ion source was designed. The ion plasma source is generated by a new type of Lisitano antenna, which is directly launched by a waveguide, where permanent magnets are embedded to have continuous toroidal configuration. Since the direct coupling by a waveguide enables the Lisitano antenna to achieve higher power capability (no power limitation), the source is able to generate higher plasma density. Also, the continuous toroidal configuration of the permanent magnets gives additional magnetic confinement to the fast electrons by ECR heating, thereby generating more uniform and higher density plasma. In this presentation, we describe a detailed design of the plasma source, microwave electromagnetic field simulations, and properties of the newly developed direct waveguide coupled Lisitano antenna.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH014

### *Initial performance of a liquid helium-free superconducting ECR ion source SMASHI at NFRI*

Hyun-Jong You, Wonil Choo, Soouk Jang
(NFRI, Daejon, Republic of Korea)

A new liquid helium-free superconducting electron cyclotron resonance ion source (ECRIS) has been successfully installed and initially evaluated at the National Fusion Research Institute (NFRI) in Korea. The source features a flexible high magnetic field (>2 T) [1], two-frequency heating, plasma diagnostic ports for extraction region, remotely positional three-electrode extraction system (puller-Einzel lens), and capability to generate a wide range of ion elements from gas to metal [2]. The source, named SMASHI (Superconducting Multi-Application Source of Highly-charged Ions), will be dedicated for development of advanced high-performance ECRIS and future application of highly charged ions in the area of matter interaction. In this presentation, we describe first operations of SMASHI and their initial results. Beam charge state spectra and their maximum intensities are provided for helium and argon beams.

*[1] H. J. You, et al., Rev. Sci. Instrum. 83, 02A326 (2012).*
*[2] H. J. You, et al., Rev. Sci. Instrum. 85, 02A916 (2014).*

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH015

### *Production and acceleration of titanium-50 ion beam at the U-400 Cyclotron*

Sergei Bogomolov[1], Andrey Evgenyevich Bondarchenko[1], Igor Kalagin[1], Konstantin Igorevich Kuzmenkov[1], Aleksander Lebedev[1], Vyacheslav Yakovlevich Lebedev[1], Vladimir Loginov[1], Roman Evegenievich Vaganov[1], Zouhair Asfari[2], Hugo Faure[2], Michel Filliger[2], Benoit Gall[2]

(1) JINR, Dubna, Russia
(2) IPHC, Strasbourg, France

The production of Ti-50 ion beam with ECR ion source using MIVOC method is described. The experiments were performed at the test bench with the natural and enriched compounds of titanium (CH3)5C5Ti(CH3)3. The compounds were synthesized in collaboration with IPHC (Strasbourg) group. In the experiments at the test bench the beam currents of Ti5+ - 80 mkA and Ti11+ - 70 mkA were achieved at different settings of the source. After successful tests two 3 weeks runs with Ti-50 beam were performed at the U-400 cyclotron for the experiments on spectroscopy of super heavy elements. The intensity of the injected beam of 50Ti5+ was about of 50-60 µA, during operation the source have shown stable operation. The compound consumption rate was determined to be about of 2.4 mg/h, corresponding to 50Ti consumption of 0.52 mg/h.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH016

### *Modernization of the mVINIS Ion Source*

Vladimir Bekhterev[1], Sergei Bogomolov[1], Andrey Efremov[1], Yurij Kostyukhov[1], Aleksander Lebedev[1], Aleksandar Slobodan Dobrosavljević[2], Nebojsa Neskovic[2], Ivan Milos Trajić[2], Velibor Vujović[2], Ljubisa T Vukosavljevic[2], Dragana Ćirić[2]

(1) JINR, Dubna, Russia
(2) VINCA, Belgrade, Serbia

The mVINIS ECR ion source was designed and constructed jointly by the team of specialists from FLNR JINR, Dubna and Laboratory of Physics, Vinča Institute, Belgrade. It was commissioned and put in operation in 1998. From that time it was widely used in the field of modification of materials by different kinds of multiply charged ions. Recently we decided to modernize mVINIS in order to improve its operation reliability. Our main goal was to refurbish its major components (vacuum pumps, microwave generator, control system etc.). Besides, we decided to enhance basic construction of the ECR ion source in order to improve the production of multiply charged ion beams from gaseous and solid elements. We changed the shape of the plasma chamber and consequently reconstructed the magnetic structure. Also we improved the construction of the injection chamber. All these improvements resulted in substantial increase of ion beam intensities, especially in the case of high charge state ions.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH017

### *LEGIS facility for study of reactor steels radiation resistance*

Timur Kulevoy[1], Andrey Aleev[1], Stanislav Leonidovich Andrianov[1], Boris Chalykh[1], Rostislav Kuibeda[1], Alexander Nikitin[1], Sergey Rogozhkin[1], Michele Comunian[2], Alessio Galatà[2]

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Considerable efforts have been drawn to adapt heavy ion beams imitation experiments for investigation of radiation stability of materials in nuclear industry, mainly structural materials - steels. Formation of defect structure in the steel using the neutron flow from the nuclear reactors is fraught with many difficulties such as a long-term session of exposure and induced radioactivity in the irradiated samples. Whereas, heavy ions could provide a versatile tool to induce a precise damage in material under controlled condition. The LEGnaro ECR Ion Source (LEGIS) installed at the high voltage (up to 300 kV) platform enables the unique possibility for wide range program of reactor steels investigation by heavy ion beams. The sample irradiation up to hundreds of dpa (displacement-per-atom) in less than an operation day can be provided by beams of different ions ranging from hydrogen to the iron with different energy. The investigation program and details of experimental facility are presented and discussed.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH018

### *A microwave ion source for pulsed proton beam production at ESS-Bilbao*

Rosalba Miracoli[1], Ibon Bustinduy[1], Pablo Echevarria[1], Mikel Eguiraun[1], Pedro J. Gonzalez[1], Leire Muguira[1], Igor Rueda[1], Iñigo Arredondo[2], Javier Corres[3], Daniel Belver[4], Nagore Garmendia[4], Zunbeltz Izaola[4]

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(4) ESS Bilbao, Leioa, Spain

Ion Source Hydrogen Positive (ISHP) is a 2.7 GHz microwave discharge installed at ESS Bilbao in Spain. This source will be employed in future application of high proton current in the field of research projects and for industrial processes. ISHP produces over 30 mA of pulsed proton beam by operating at 2.7 GHz. The magnetic field is produced by two independently movable coil pair and the extraction system is composed of a plasma electrode at high voltage platform potential, two ground electrodes, and a negatively biased screening electrode inserted between the ground electrodes. The last three electrodes are contained in the extraction column, and can be moved as a group by stepper motors, to change the distance between the plasma electrode and first ground electrode. Measurements with different extraction system setups will be described to show the improvement of the beam intensity and beam emittance.

## 16:30 – 18:30 MOPPH
## POSTER SESSION

MOPPH019

### *Metallic beam development with an ECR ion source at Michigan State University (MSU)*

Derek Elwin Neben, Dallas Gene Cole, Daniela Leitner, Guillaume Machicoane, Larry Tobos (NSCL, East Lansing, Michigan, USA)

ECR ion sources have been used at MSU to provide metal ion beams to the coupled cyclotron facility (CCF), and in the future, for The Facility for Rare Isotope Beams (FRIB). The challenges of metallic beam production with ECR are in production, efficiency, stability and contamination. Future facilities such as FRIB will add the challenge of intensity. At fragmentation facilities like MSU, primary beams from isotopes of elements such as cadmium, mercury, and several of the lanthanides family are of interest to the nuclear science community. Therefore, we have started a concerted effort to develop efficient methods to produce high intensity high charge beams from those challenging metals. Because of low natural abundances these metals can be very expensive and as in the case of 156Dy, 144Sm, and 174Yb are available in the sesquioxide form which is unsuitable for use in our standard ovens. We report here the development of mercury and cadmium metals. We also present results from the efficient offline chemical reduction of dysprosium, samarium, and ytterbium oxides into a metal sample. The samples were then run on our ECR ion sources to confirm the products of the reduction.

*[1] G. Machicoane, D. Cole, D. Leitner, et. Al., Rev. Sci. Instrum. 85, 02A957 (2014)*

*Supported by Michigan State University, National Science Foundation: NSF Award Number PHY-1102511*

## 9:00 – 11:00 TUOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:00 TUOMMH01

### *Improvement of beam intensities for ion beams with charge-to-mass ratio of 1/3 with two-frequency heating technique*

Atsushi Kitagawa[1], Keita Fukushima[2], Noriyuki Sasaki[2], Katsuyuki Takahashi[2], Wataru Takasugi[2], Takashi Fujita[1], Masayuki Muramatsu[1], Yushi Kato[3]

(1) NIRS, Chiba, Japan
(2) AEC, Chiba, Japan
(3) Osaka University, Osaka, Japan

Facilities of heavy ion radiotherapy use carbon ions due to its better biological dose distributions. The necessary energy is over 400MeV/u. A typical accelerator system consisits of a synchrotron and an injector. ECR ion sources have been developed and utilized to produce C4+ ions. On the other hand, in order to study basic biological researches with a such facility, there are occasionally requirements to produce other ion species like Ar or Fe. Since the injector design is fixed for the acceleration of ions with a charge-to-mass ratio of about 1/3, the ion source must produce Ar13+ and Fe19+. As a method to improve highly-charged ion production, the technique to feed multiple microwaves with different frequencies is well-known. Our group studied the improvements when the two frequencies are close together each with a power of more than 1kW using the 18GHz NIRS-HEC ECR ion source installed in the Heavy Ion Medical Accelerator in Chiba (HIMAC. Fe and Ni are interesting for a risk study in space environment. We combined the MIVOC method and the two-frequency heating technique for the production of Fe and Ni. The recent test results will be reported.

## 9:00 – 11:00 TUOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:22 TUOMMH02

### *ECR Ion Sources developments at INFN-LNS*

Luigi Celona[1], Giuseppe Castro[1], Santo Gammino[1], David Mascali[1], Lorenzo Neri[1], Giovanni Ciavola[2], Alessio Galatà[3], Giuseppe Torrisi[1,4]

(1) INFN/LNS, Catania, Italy
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(4) Universitá Mediterranea di Reggio Calabria, Reggio Calabria, Italy

At INFN-LNS, ECRIS development during the `90s boosted the K-800 Cyclotron performances: SERSE and CAESAR have then well supported Nuclear Physics research. For the new needs of the laboratory, further improvements are required and here described. Activities recently started aimed to the production of multicharged ion beams and to the production of intense light ion beams. Technological developments led the AISHa source design, now under construction, in order to adapt a high performance ECR ion source to hospital facilities needing multiply charged ion production with high reliability and brightness, easy operations and maintenance. The realization of the 75kV-70mA proton source, called PS-ESS, and of its LEBT for the forthcoming European Spallation Source in Sweden is one of the major engagements of the INFN-LNS. Other activities are ongoing on high charge state and high intensity beam production: a major update is going to be finalized on SERSE cryogenic system; at Vancouver, the VIS source is used for producing multi-mA beams of H2+ for a high-current cyclotron; a new flexible plasma trap is under test for fundamental research about innovative plasma heating methods.

## 9:00 – 11:00 TUOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:44 TUOMMH03

### *Status report of SECRAL II ion source development*

Liangting Sun (IMP, Lanzhou, P.R.C.)

For a new injector linac project launched at IMP, a superconducting ECR ion source SECRAL II is now under construction. This ion source is a duplicated one of SECRAL which is operated routinely for HIRFL facility at the frequency 18—24 GHz. SECRAL II is designed to be operated at the frequency of 28 GHz, which needs slightly higher radial field at the plasma chamber wall. The fabrication of the cold mass was started at early 2013, and it has been completed in May 2014. The engineering design of the whole superconducting magnet has also been finished and ready for fabrication. This paper will present the cold mass test results and the cryogenic system design. The beam extraction and analyzing design will be also discussed.

## 9:00 – 11:00 TUOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

10:06 TUOMMH04

### *An ECR ion source with integrated sputter magnetron for large area metal ion beam generation and implantation*

Martin Kreller[1], Alexandra Silze[2], Guenter Herbert Zschornack[2], Ullrich Hartung[3], Torsten Kopte[3], Tim Weichsel[3]

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High current metal ion sources are utilized for surface irradiation and implantation in semiconductor, medical or optical industry as well as in photovoltaics. Therefore, a new ECR ion source (ECRIS) combined with an inverted cylindrical sputter magnetron device for metal atom load of the plasma has been developed to produce high currents of metal ion beams. For the generation of mA currents of metallic ion beams the particle load of the plasma should be in the order of 1E18 particles per second. Double Langmuir probe and optical emission spectroscopy measurements are accomplished to determine the electron density in the plasma. The ion source is part of a new implantation platform which is suitable for the irradiation of a target width of 200 mm to produce homogeneous implantation profiles over the entire surface. This facility is including a dipole magnet to separate the produced metal ions from the process gas ions. Furthermore, an ion scan optic followed by an additional dipole magnet is developed to realize a pseudo broad beam scanning unit for large area implantation. In the presentation we describe the ion beam facility and report on first ion extraction experiments.

## 9:00 – 11:00 TUOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

10:28 TUOMMH05

### *HIISI, new 18 GHz ECRIS for the JYFL accelerator laboratory*

Hannu Koivisto[1], Pauli Heikkinen[1], Taneli Kalvas[1], Kimmo Ranttila[1],
Olli Tarvainen[1], Daniel Xie[2], Thomas Thuillier[3], Guillaume Machicoane[4]

(1) JYFL, Jyvaskyla, Finland
(2) LBNL, Berkeley, California, USA
(3) LPSC, Grenoble, France
(4) NSCL, East Lansing, Michigan, USA

At the end of 2013 the Academy of Finland granted an infrastructure funding for the JYFL Accelerator Laboratory in order to increase beam intensities for the international user community. The primary objective is to construct a new high performance ECR ion source, HIISI (Heavy Ion Ion Source Injector), for the K130 cyclotron. Using room temperature magnets the HIISI has been designed to produce about the same magnetic field configuration as the superconducting ECRIS SUSI at NSCL/MSU for 18 GHz operation. An innovative structure will be used to maximize the radial confinement and safety of the permanent magnets. The sextupole magnets are separated and insulated from the plasma chamber providing two advantages: 1) the permanent magnets can be cooled down to -20˚C, which increases especially their coercivity and 2) makes it possible to reach higher radial field at the inner surface of plasma chamber. Comprehensive simulations were performed with microwave power up to 6 kW to analyse and address all the heat loads and temperature distribution on the permanent magnet. In this article the magnetic field design and detailed innovative scheme for sextupole magnet will be presented.

## 11:30 – 12:30 TUOBMH
## PLASMA HEATING AND MW SOURCES

11:30 TUOBMH01

### *The 60 GHz 300 kW gyrotron system for ECR ion source of new generation*

Mikhail Bakulin[1], Zakhar Gasajniev[1], A. V. Chirkov[2], Gregory Denisov[2], Anatoly Georgievich Eremeev[2], Boris Movshevich[2], M. Y. Shmelyov[2], Thierry Lamy[3]

(1) GYCOM Ltd, Nizhny Novgorod, Russia
(2) IAP/RAS, Nizhny Novgorod, Russia
(3) LPSC, Grenoble, France

The 60 GHz Gyrotron system was specifically designed to meet the requirements of the ECR ion source prototype for production of radioactive multicharged ion beams at the Laboratoire de Physique Subatomique et de Cosmologie (LPSC). This system provides microwave power smoothly regulated from 20 kW to 300 kW in pulses from 0.05 to 1 ms with a repetition rate up to 3 Hz. The system includes a gyrotron, liquid-He cryomagnet, microwave quasioptical transmission line, whole set of power supplies, embedded controller, hard-wired interlocks, water-cooling subsystem. Architecture of the gyrotron system, control software, the user interface, the main system parameters, and performance in respect to output power stability will be described in the presentation.

## 11:30 – 12:30 TUOBMH
## PLASMA HEATING AND MW SOURCES

11:52 TUOBMH02

### *Millimeter wave microwave sources for electron cyclotron resonance ion sources*

Gregory Denisov, Yury Bykov, Anatoly Georgievich Eremeev, Igor Gennadyevich Gachev, Mikhail Glyavin, Vladislav Vitalyevich Holoptsev, Sergey Viktorovich Samsonov, Evgeny Maksovich Tai (IAP RAS, GYCOM Ltd, Nizhny Novgorod, Russia)

Two kinds of microwave sources (gyro-type devices) applicable for use in ECR ion sources are described: microwave oscillators and amplifiers. Gyrotron oscillators are capable to provide very high power (up to 1MW in CW regime) at any frequency in the millimeter wavelength range. Gyrotrons sources of moderate power are already used in several ion source setups where requested frequency and power are 24 GHz; 28 GHz and 10-15 kW/CW correspondingly. Usually gyrotron oscillator operates at one definite frequency. For special request a gyrotron can be designed for operation at two (three) frequencies or with some frequency tuning. Some pulse power gyrotrons (e.g.60 GHz/300kW) are also now under study to be applied in ion sources. Gyro-amplifiers have an instant frequency band of an amplified signal. Recent result on this activity at IAP includes realization of a CW Ka-band gyro-TWT. The best performance of this tube was obtained using an electron beam with voltage of (20+20 kV) and current of 1.4 A. In the regime of maximum instantaneous bandwidth it delivers output power within a frequency interval of 2 GHz in Ka-band with a maximum power of 7 kW. One more setup includes a Ka-band pulsed amplifier with a peak power of up to 150 kW and bandwidth of about 10% capable for operation with 10% duty factor. The gyro-TWTs are based on DC oil-cooled solenoids and single-stage depressed collectors.

## 9:00 – 10:30 WEOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:00 WEOMMH01

### *The installation of the 28GHz superconducting ECR ion source at KBSI*

Mi-Sook Won[1], Seyong Choi[1], Jonggi Hong[1], Seong Jun Kim[1], Byoung Seob Lee[1], Jung-Woo Ok[1], Jin Yong Park[1], Chang Seouk Shin[1], Jang-Hee Yoon[1], JungBae Bhang[2]

(1) Korea Basic Science Institute, Busan, Republic of Korea
(2) Kyungpook National University, Daegu, Republic of Korea

Since 2009, the 28 GHz superconducting ECR ion source has been developed to produce high current, diverse heavy ion charge state for the compact heavy ion linear accelerator at KBSI. Our goal is to generate high current fast neutron by using the heavy ion interaction with proton target. The superconducting magnet system with the liquid helium re-condensing cryostat, the 10 kW high power microwave system considering for optimum operation at the 28 GHz ECR Ion Source were completed in 2013. The microwave guide was connected with the plasma chamber including the gas supply system. The chamber part for plasma production and ion beam extraction were already assembled with the superconducting magnet structure. In this paper, we will present the current status about installation of ECR ion source and report the test results of ECR plasma ignition.

## 9:00 – 10:30 WEOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:22 WEOMMH02

### *First commissioning results of an evaporative cooling magnet ECRIS-LECR4*

Wang Lu[1], Yucheng Feng[1], Shuqing Guo[1], Baohua Ma[1], Hongyi Ma[1], Liangting Sun[1], Xuezhen Zhang[1], Hongwei Zhao[1], Lin Ruan[2], Bin Xiong[2]

(1) IMP, Lanzhou, P.R.C.
(2) IEE, Beijing, P.R.C.

LECR4 (Lanzhou ECR ion source No.4) is a room temperature ECR ion source, designed to produce high current, multiple charge state ions for SSC-linac project at IMP. The ion source has been optimized to be operated at 18 GHz. A unique feature of LECR4 is that all its solenoid coils are fully immersed in a special medium and cooled by evaporative cooling technology when excited. At design current, the coils can produce peak mirror fields on axis 2.3 Tesla at injection, 1.3 Tesla at extraction and 0.5 Tesla at minimum-B. The nominal radial magnetic field is 1.1 Tesla at plasma chamber wall, which is produced by a Halbach structure 36-segment hexapole. Recently, the project has made significant progress. In January 2014, the first plasma at 18 GHz was ignited. During the ongoing commissioning phase with a stainless steel chamber, tests with gaseous ion beams have been conducted. Some intense ion beams have been produced with microwave power less than 1.5 kW, such as 1.97 emA of O6+, 1.7 emA of Ar8+, 1.07 emA of Ar9+, 290 euA of Xe20+ and so on. In this paper, the design of LECR4 ion source will be presented, and the latest test results will also be given.

## 9:00 – 10:30 WEOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

9:44 WEOMMH03

### *Development of the magnetic system for new DECRIS-PM ion source*

Andrey Efremov[1], Vladimir Bekhterev[1], Sergei Bogomolov[1], Nikolay Nikolaevich Konev[2]

(1) JINR, Dubna, Russia
(2) ITT-Group, Moscow, Russia

Super-heavy-element factory is under development at the Flerov Laboratory for Nuclear Reactions, JINR, Dubna. The factory will include DC-280 cyclotron, which will be equipped with two 100 kV high voltage platforms. All-permanent magnet ECRIS will be installed on one of the platforms. The request for the source is a production of medium mass ions with A/q=4-7.5 such as 48Ca8+. Results of the detailed design of a magnetic structure for DECRIS-PM will be presented.

## 9:00 – 10:30 WEOMMH
## STATUS REPORTS AND NEW DEVELOPMENTS

10:06 WEOMMH04

### *Thermal design of refrigerated hexapole 18 GHz ECRIS HIISI*

Taneli Kalvas, Hannu Koivisto, Kimmo Ranttila, Olli Tarvainen
(JYFL, Jyvaskyla, Finland)

A project is underway for constructing a new 18 GHz ECR ion source HIISI at University of Jyväskylä. An innovative plasma chamber structure with grooves at magnetic poles is being studied. This allows large chamber radius at the poles, which is relevant for the performance of the ion source while smaller radius between the poles makes space for chamber water cooling. The hexapole will be refrigerated to sub-zero temperatures to boost the coercivity and the remanence of the permanent magnet material. The hexapole structure is insulated from high temperature solenoid coils and plasma chamber by vacuum. The thermal design of the structure has been made using a thermal diffusion code taking in account radiative, conductive and convective heat transfer processes. The heat flux from plasma has been estimated using electron trajectory simulations with sensitivity analysis on the electron energy distribution. The electron simulations are verified by comparing to experimental data from 14 GHz ECR. The electron and thermodynamic simulation efforts are presented together with an analysis of the H-field vs. coersivity in the permanent magnets.

## 11:00 – 12:30 WEOBMH
## CHARGE BREEDING, THEORY AND SIMULATIONS

11:00 WEOBMH01

### *Experimental activities with the LPSC charge breeder in the European context*

Thierry Lamy[1], Julien Angot[1], Thomas Thuillier[1], Pierre Delahaye[2], Laurent Maunoury[2], Jaroslaw Choinski[3], Lukasz Standylo[3], Alessio Galatà[4], Gabriele Patti[5], Hannu Koivisto[6], Olli Tarvainen[6]

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(2) GANIL, Caen, France
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(6) JYFL, Jyvaskyla, Finland

One of the Work Packages of the "Enhanced Multi-Ionization of short-Lived Isotopes at EURISOL" NuPNET project regards the ECR charge breeding. The LPSC charge breeder is used for experimental studies in order to better understand the fundamental processes involved in the 1+ beam capture by a 14 GHz ECR plasma. Some improvements, like higher symmetrization of the magnetic field at the injection side, higher pumping speed, have been carried out on the PHOENIX charge breeder. The impact of these modifications on the efficiencies and charge breeding times will be presented. In the same time, LPSC 1+ source developments have been performed in order to make easier the efficiency measurements with various elements and will be presented.

## 11:00 – 12:30 WEOBMH
## CHARGE BREEDING, THEORY AND SIMULATIONS

11:22 WEOBMH02

### *Study of ECRIS scaling laws with the Particle-in-Cell code*

Vladimir Mironov, Sergei Bogomolov, Andrey Efremov
(JINR, Dubna, Russia)

ECRIS scaling laws for the magnetic field configuration have been experimentally established elsewhere by systematically varying the magnetic fields at the injection, extraction, radial wall and at minimum. In an attempt to clarify the reasons for such the scaling, we had performed the detailed studies of the ion dynamics in ECRIS plasma with using the PIC code. With a minimal set of free parameters, we are able to reproduce the main features of ECRIS operation, including the dynamics with variations in the magnetic field. Details of the modeling will be given, as well as some recommendations for a source improvement.

## 11:00 – 12:30 WEOBMH
## CHARGE BREEDING, THEORY AND SIMULATIONS

11:44 WEOBMH03

### *Investigation on the origin of high energy x-rays observed in 3rd generation ECRIS*

Thomas Thuillier, Julien Angot, Josua Jacob, Thierry Lamy, Patrick Sole
(LPSC, Grenoble, France)

An unexpected parasitic high energy x-ray flux has been observed with the new generation ECR ion sources operated with frequencies>18 GHz. So far, the origin of the hot electrons generating such bremsstralhung x-rays is not yet understood. A review of the existing measurements and studies performed is proposed. In this paper, the ECR heating mechanism for the frequencies 18 GHz and 24-28 GHz is studied analytically and by simulation. The driving idea is to look for differences and investigate whether an intrinsic microscopic process could be responsible or not to this phenomenon.

## 11:00 – 12:30 WEOBMH
## CHARGE BREEDING, THEORY AND SIMULATIONS

12:06 WEOBMH04

### *Theory of cyclotron instability of hot electrons in ECRIS: origin, manifestation, and influence on plasma confinement*

Dmitriy Mansfeld[1], Ivan Izotov[1], Vadim Skalyga[1], Mikhail Viktorov[1], Olli Tarvainen[2]

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(2) JYFL, Jyvaskyla, Finland

Interaction between electromagnetic waves and particles in magnetoactive plasma under cyclotron resonance conditions can result in the growth of cyclotron instabilities of various kinds. Electron cyclotron instability (ECI) is a kinetic type instability, which is driven by the anisotropy of the energetic electrons distribution function traps with the transverse kinetic energy relative to the magnetic field dominating over the longitudinal one. One of the most interesting manifestations of ECI is the generation of bursts of electromagnetic radiation accompanied by hot electron precipitations from the trap. Such phenomena are observed in a wide range of plasma parameters: in the magnetospheres of the Earth and planets, in solar coronal loops, and in laboratory magnetic traps. Recently ECI were experimentally observed in ECR ion sources and it was shown that bursts of hot electrons escaping from the trap can destruct plasma confinement affecting highly charged ions beams current [1]. In this report we discuss basic mechanisms of cyclotron instability growth in non-equilibrium plasma of ECR discharge, main features of instability manifestation and its influence on ECRIS parameters.

*[1] Tarvainen et al 2014 Plasma Sources Sci. Technol. 23 025020*

## 9:00 – 10:30 THOMMH APPLICATIONS

9:00 THOMMH01

### *Boron ion beam production with the Supernanogan ECR ion source for the CERN BIO-LEIR facility*

Joshua Tobias Stafford-Haworth[1], Detlef Kuchler[1], Ville Toivanen[1], Joerg Roehrich[2]

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(2) HZB, Berlin, Germany

To deliver B3+ ions for medical research the compounds decaborane and m-carborane were tested using the metal ions from volatile compounds (MIVOC) method with the Supernanogan 14.5 GHz ECR ion source. Using decaborane the source delivered less than 10 uA intensity of B3+ and after operation large deposits of material were found inside the source. Using m-carborane 50 uA of B3+ were delivered without support gas. For both compounds Helium and Oxygen support gasses were also tested, and the effects of different source tuning parameters are discussed. The average consumption of m-Carborane was 0.1 mg/uAh over all operation.

## 9:00 – 10:30 THOMMH APPLICATIONS

9:22 THOMMH02

### *Application of an ECR ion source for ionic functionalization of implant materials on the nanoscale*

Richárd Rácz[1], Sandor Biri[1], Attila Csik[1], Peter Hajdu[1], Kálmán Vad[1], József Bakó[2], István Csarnovics[2], Csaba Hegedűs[2], Viktória Hegedűs[2], Sandor Kokenyesi[2], Jozsef Palinkas[2], Tünde Radics[2]

(1) ATOMKI, Debrecen, Hungary
(2) University Debrecen, Debrecen, Hungary

The 14.5 GHz ECRIS of Atomki is a classical room-temperature ion source designed for highly charged plasma and ion beam production. In the past two decades it was mainly used for low energy atomic physics research and for plasma diagnostics. Recently it partly operates as an ion implanter to deliver low energy particles from wide range of elements. Surface modification by variously charged heavy ions plays an increasingly important role since functionalization of surfaces and/or deeper layers at micro- and nanoscopic scale can be biologically useful for materials of medical implants. The functionalized surfaces have much potential in the field of nanotechnology, sensor devices as well. In collaboration with the University of Debrecen our group explores the physical and biological effect of such treatments. In the recent phase of the research work the implantation of titanium and zirconium-dioxide samples by calcium, gold and silicon ions is required. New vacuum chamber and sample holder for effective irradiation and the production of the beam itself were developed. The technical details of the irradiation and the first result of the physical investigations will be presented.

## 9:00 – 10:30 THOMMH
## APPLICATIONS

9:44 THOMMH03

### *A point source of extreme ultraviolet radiation based on non-equilibrium discharge, sustained by powerful radiation of terahertz gyrotron*

Alexander Sidorov, Mikhail Glyavin, Sergey Golubev, Ivan Izotov, Alexander G. Litvak, Grigory Luchinin, Dmitriy Mansfeld, Sergey Razin, Vadim Skalyga, Alexander Vodopyanov (IAP RAS, Nizhny Novgorod, Russia)

It is proposed in this paper to use discharge plasma supported by terahertz radiation as a source of EUV light for high-resolution lithography. In this report we discuss the experimental investigation of two types of EUV sources based on discharge, supported by powerful gyrotron radiation. Following investigation results are described: -a series of experiments that demonstrate the generation of EUV light from the vacuum-arc discharge plasma in tin vapor in the magnetic trap heated by gyrotron radiation with a frequency of 75 GHz under electron cyclotron resonance (ECR) conditions; -a numerical modeling of the plasma emissivity in the EUV range, depending on the parameters of the heating radiation is performed; -experimental studies of EUV emission from plasma discharge sustained by strong terahertz powerful radiation in inhomogeneous gas flows are started.

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