V4.0

XIXth International Workshop on ECR Ion Sources

ECRIS 2010

LPSC Grenoble, France, August 23 – 26, 2010

Book of abstracts

V4.0

09:00-10:30 *Status of ECRIS Operation* **Malaku Room**
MOCOAK **Chair: Santo Gammino**

09:00 **MOCOAK01**

SECRAL Status and Test Operation at 24GHz

Zhao Hongwei, Lu Wang, Sun Liangting, Guo Xiaohong, Zhang Xuezhen, Cao Yun, Zhao Huanyu, Xie Dan Zuqi

Institute of Modern Physics, CAS, Lanzhou, China

SECRAL has been in routine operation at 18GHz for HIRFL (Heavy Ion Research Facility in Lanzhou) accelerator complex since May 2007. It has delivered many highly charged heavy ion beams for the HIRFL accelerator and the total beam time so far has exceeded 3000 hours. To further enhance the SECRAL performance, a 24GHz/7kW gyrotron microwave amplifier has been installed and tested. Very exciting results were produced with quite a few new record highly-charged ion beam intensities. Bremstrahlung measurements at 24GHz have shown that X-ray is much stronger at higher RF frequency, higher RF power and higher minimum B field. Beam emittance study has been conducted in order to improve the beam brightness. An additional cryostat with five GM cryocoolers was installed atop the SECRAL to liquefy the boil-off helium gas to minimize the liquid helium consumption. The latest results and reliable long-term operation for the accelerator have once again demonstrated that SECRAL is one of the best performance ECR ion source for the production of highly-charged heavy ion beams. Detailed and future developments of SECRAL will be presented.

09:00-10:30 *Status of ECRIS Operation* **Malaku Room**
MOCOAK **Chair: Santo Gammino**

09:22 **MOCOAK02**

Intense Ion Beam Production with SuSI

Sun Liangting, Brandon John, Cole Dallas, Doleans Marc, Morris Dan, Machicoane Guillaume, Pozdeyev Eduard, Ropponen Tommi, Tobos Larry

National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, USA

SuSI ion source, a 3rd generation fully superconducting ECR ion source is now used for injection into the Coupled Cyclotron Facility since September 2009. Initial performances during the commissioning of SuSI were mainly limited by the microwave power available from a single 18 GHz microwave amplifier, especially for the production of heavier ion beams. The Injection of SuSI was modified to add a second 18 GHz amplifier, to reach a maximum of 3.0 kW of RF power inside the plasma chamber. Production of heavy ion beams, such as Kr14+, Bi30+ and U33+ is reported, to demonstrate the performance of SuSI. Additional studies were made with various ion source parameters to optimize the beam intensity within a normalized emittance of 0.9pi.mm.mrad as needed for the FRIB project and will be reported in this paper.

09:00-10:30 *Status of ECRIS Operation* **Malaku Room**
MOCOAK **Chair: Santo Gammino**

09:44 **MOCOAK03**

Status of new RIKEN SC-ECRIS

Nakagawa Takahide[(1)], Higurashi Yoshihide[(1)], Ohnishi Jun-Ichi[(1)], Aihara Toshimitsu[(2)], Tamura Masashi[(2)], Uchiyama Akito[(2)]

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(2) SHI Accelerator Service, Japan

To increase the beam intensity of highly charged heavy ions for RIKEN RIBF project, we constructed and tested RIKEN new SC-ECRIS. After obtaining the first beam in the spring of 2009, we tried to optimize the ion source condition for maximizing the beam intensity with 18GHz microwave. In this experiment, we intensively studied the effect of the magnetic field gradient and ECR zone size on the beam intensity. In this experiment, it was clearly seen that the gentler field gradient and lager ECR zone size give higher beam intensity. Based on these studies, we produced 550microA of Ar11+ and 350microA of Ar12+ at the RF power of 1.8kW. In this summer, we will try use the 28GHz microwaves to increase the beam intensity. In this contribution, we present the structure of the SC-ECRIS and the results of test experiments with 18 GHz microwave in detail. We also present the future plan to increase the beam intensity.

09:00-10:30 *Status of ECRIS Operation* **Malaku Room**
MOCOAK **Chair: Santo Gammino**

10:06 **MOCOAK04**

Status of the VENUS ECR Ion Source

Leitner Daniela[(1)], Lyneis Claude[(1)], Leitner Matthaeus[(1)], Hodgkinson Adrian[(1)], Loew Timothy[(1)], Ferracin Paolo[(1)], Sabbi Gianluca[(1)], Machicoane Guillaume[(2)], Pozdeyev Eduard[(2)]

(1) Lawrence Berkeley National Laboratory, Berkeley, USA
(2) Michigan State University, East Lansing, USA

The fully superconducting 28-GHz VENUS ECR ion source serves as prototype injector for the Facility for Rare Isotope Beams (FRIB) project at Michigan State University (MSU) as well as injector ion source for the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL). As such the source has produced many record beams of high charge state as well as high-intensity, medium charge state ions. As the FRIB project has now entered the preliminary design phase, Lawrence Berkeley National Laboratory is involved in the design of two new VENUS-like ECR injector ion sources for the FRIB facility. This paper will review the requirements for the FRIB injector, and present VENUS cryostat design changes which will allow installation on a 100 kV platform. In addition, a possible future upgrade path for the FRIB injector using an advanced Nb3Sn magnet structure is described. In 2008, at LBNL the VENUS ECR ion source experienced a major setback when one of the sextupole leads evaporated during a quench caused by a low liquid helium level in the cryostat. The repair process and the long reconstruction effort as well as the status of the reinstallation will be
described.

11:00-12:30 *Status & New Developments* **Malaku Room**
MOCOBK **Chair: Claude Lyneis**

11:00 **MOCOBK01**

*ECR ion sources for the Facility for Rare Isotope Beams (FRIB) project at Michigan State University**

Machicoane Guillaume[(1)], Doleans Marc[(1)], Kester Oliver[(1)], Pozdeyev Eduard[(1)], Ropponen Tommi[(1)], Sun Liangting[(1)], Tanke Eugene[(1)], Wu Xiao[(1)], Leitner Daniela[(2)]

(1) Michigan State University, East Lansing, USA
(2) Lawrence Berkeley National Laboratory, Berkeley, USA

Once operational, the Facility for Rare Isotope Beams (FRIB) will open the possibility to gain key understanding in nuclear science and in particular regarding the properties of nuclei far from the valley of stability or the nuclear processes in the universe. In addition it will also allow experimentersto test fundamental symmetries. The production of rare isotopes with FRIB will be achieved, using a heavy ion driver linac that will accelerate a stable isotope beam to 200 Mev/u and deliver it on a fragmentation target. FRIB aims to reach a primary beam power of 400 kW for light to heavy elements up to Uranium. To meet the intensity requirement two high performance ECR ion sources operating at 28 GHz will be used to produce high intensity of medium to high charge state ion beams. Plans regarding initial beam production with the ECR ion sources and beam transport through the front end will be discussed *Work supported by US DOE Cooperative Agreement DE-SC0000661

11:00-12:30 *Status & New Developments* **Malaku Room**
MOCOBK **Chair: Claude Lyneis**

11:22 **MOCOBK02**

Present Status of FLNR (JINR) ECR Ion Sources

Bogomolov Sergey, Efremov Andrey, Loginov Vladimir, Lebedev Alexander, Yazvitsky Nikolay, Bekhterev Vladimir, Kostukhov, Yury, Gulbekian Georgy, Gikal Boris, Drobin Valery, Seleznev Vasily

JINR , Dubna, Russian Federation

Six ECR ion sources have been operated in the Flerov Laboratory of Nuclear Reactions (JINR). Two 14 GHz ECR ion sources (ECR4M and DECRIS-2) supply various ion species for the U400 and U400M cyclotrons correspondingly for experiments on the synthesis of heavy and exotic nuclei using ion beams of stable and radioactive isotopes. The 18 GHz DECRIS-SC ion source with superconducting magnet system produce ions from Ar up to W for solid state physics experiments and polymer membrane fabrication at the CI-100 cyclotron. The third 14 GHz ion source DECRIS-4 with “flat” minimum of the axial magnetic field is used as a stand alone machine for test experiments and also for experiments on ion modification of materials. The other two compact ECR ion sources with all permanent magnet configuration have been developed for the production of single charged ions and are used at the DRIBs installation and at the MASHA mass- spectrometer. In this paper, present status of the ion sources, recent developments and plans for modernization are reported. Also the results of the preliminary test of the DECRIS-SC2 ECR source will be presented.

11:00-12:30 *Status & New Developments* **Malaku Room**
MOCOBK **Chair: Claude Lyneis**

11:44 MOCOBK03

Status of ion sources at HIMAC

Kitagawa Atsushi[(1)], Fujita Takashi[(1)], Muramatsu Masayuki[(1)], Sakamoto Yukio[(1)], Hojo Satoru[(1)], Sasaki Noriyuki[(2)], Takasugi Wataru[(2)], Biri Sandor[(3)], Drentje Arne[(4)]

1) National Institute of Radiological Sciences, Chiba, japan
(2) Accelerator Engineering Corporation, Japan
(3) ATOMKI, Debrecen, Hungary
(4) KVI, Gröningen, Netherlands

Since 1994, heavy-ion radiotherapy using carbon ions is successfully carried out with the Heavy Ion Medical Accelerator in Chiba (HIMAC) at the National Institute of Radiological Sciences (NIRS). Over 5000 cancer patients have already been treated with 140-400 MeV/u carbon beams. These clinical results have clearly verified the advantages of carbon ion. The ion source needs to realize a stable beam with the same conditions for daily operation. Maintenance is restricted to once per year. However, the deposition of carbon on the wall of the plasma chamber is normally unavoidable. This causes an ‘anti-wall-coating effect’, i.e. a decreasing of the beam (typically 50 % after a few months of operation), especially for the higher charge-state ions due to the surface material of the wall. The ion source has - even in this bad condition – still to produce a sufficiently intense and stable beam. We summarize our experience during 16 years of operation and show the scope for further developments. HIMAC is dedicated to radiotherapy, but it has as a second essential task to operate as a facility for physicist users. In that scope it accelerates many ion species for basic experiments. In order to serve all HIMAC users at best, the extension of the range of ion species is an important subject in ion source development. For example, in order to increase the ECRIS-beam intensity for heavier ions, microwave is applied at different frequencies by a traveling wave tube amplifier and....

11:00-12:30 *Status & New Developments* **Malaku Room**
MOCOBK **Chair: Claude Lyneis**

12:06 **MOCOBK04**

*The ORNL MIRF HV Platform and Floating Beamline Upgrade Project**

Meyer Fred W

Oak Ridge National Laboratory, Oak Ridge, USA

We report on recent upgrades of the ORNL Multicharged Ion Research Facility, and our activities in the area of ECR ion source diagnostic measurements. The upgrades include installation of a new all permanent magnet ECR ion source [1] on a high voltage platform that increases our high energy beam production capability to 250keV/q, and installation of a floating beamline fed by a 10 GHz CAPRICE ECR ion source for producing decelerated ion beams to energies as low as a few eV/q range. The primary application of all the produced ion beams is to study fundamental collisional interactions [2] of multicharged ions with electrons, atoms, and surfaces. We also summarize recent diagnostic measurements of the ECR plasma potential and other plasma parameters using an in-situ Langmuir probe installed in the ECR edge plasma and complementary measurements [3] using an external beam deceleration method.

[1] D. Hitz et al. , "An All-Permanent Magnet ECR Ion Source for the ORNL MIRF Upgrade Project," AIP Conference Proceedings 749, 123 (2005), Woodbury, NY.
[2] F.W. Meyer, "ECR-Based Atomic Collision Physics Research at ORNL MIRF," in Trapping Highly Charged Ions: Fundamentals and Applications, J. Gillaspy, ed., Nova Science Pub., New York, 2000, pp. 117-164.
[3] P.R. Harris and F.W. Meyer, Rev. Sci. Inst. 81, 02A310 (2010).

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14:00-15:50 *Status & New Developments* | **Malaku Room**
MOCOCK | **Chair: Takahide Nakagawa**

14:00 **MOCOCK01**

PK-ISIS: a new superconducting ECR ion source at Pantechnik

Villari Antonio[(1)], Bieth Claude[(1)], Tasset-Mayé Olivier [(1)], Gaubert Gabriel[(1)], Bougy Wilfried [(1)], Sineau Anthony[(1)], Brionne Nicolas [(1)], Vallerand Cynthia [(1)], Donzel Xavier [(1)], Leroy Renan[(1)(2)], Thuillier Thomas[(3)]

(1) Pantechnik 13 rue de la Résistance 14400 Bayeux, France
(2) GANIL, Caen, France
(3) LPSC, UJF, CNRS/IN2P3, INP Grenoble, Grenoble, France

The new ECR ion source PK-ISIS was recently commissioned at Pantechnik. Three superconducting coils generate the axial magnetic field configuration while the radial magnetic field is done with multi-layer permanent magnets. Special care was devoted in the design of the hexapolar structure, allowing a maximum magnetic field of 1.32 T at the wall of the 82 mm diameter plasma chamber. The three superconducting coils using Low Temperature Superconducting wires are cooled by a single double stage cryo-cooler (4.2 K). Cryogen-free technology is used, providing reliability, easy maintenance at low cost. The maximum installed RF power (18.0 GHz) is of 2 kW. Metallic beams can be produced with an oven (Tmax = 1400 °C) installed with an angle of 5° with respect to the source axis or a sputtering system, mounted in the axis of the source. The beam extraction system is constituted of three electrodes in accel- decel configuration. Description of the source and results of the magnetic measurements will be given. Performances of the source in terms of beam intensities and charge states distribution will be presented.

14:22 **MOCOCK02**

3D simulation studies and optimization of magnetic holes of HTS-ECRIS for improving the extraction efficiency and intensities of highly charged ions

Rodrigues Gerard, Lakshmy P.S, Mathur Y., Dutt R.N., Rao U.K., Baskaran R., Kanjilal D., Roy A.

Inter University Accelerator Centre, New Delhi, India

3D simulation studies using RADIA code have been performed to optimise the magnetic holes in high temperature superconducting electron cyclotron resonance (HTS-ECRIS) ion source for improving the extraction efficiency and intensities of highly charged ions. The magnetic field improvements using simple techniques like optimisation of iron regions is found to be economical. The extraction efficiency can be increased three-fold in the case of a hexapole magnet depending on the level of the uniformity of the fields in the high and low regions. This technique further minimises localized heating of the plasma chamber walls which can improve the vacuum conditions in an ECR ion source. For superconducting sources where the x-ray heat load poses severe problems during operation, such a reduction of heating load is of great significance. The typical triangular pattern of the plasma impact observed on the plasma electrode of HTS ECRIS at various tuning conditions are reproduced by the simulations. Details of the simulations and experimental results will be presented.

[1] D.Kanjilal, G.Rodrigues, P.Kumar, A.Mandal, A.Roy, C.Bieth, S.Kantas, P.Sortais,Rev.Sci.Instrum.,77 (2006) 03A317
[2] G.Rodrigues, P.S.Lakshmy, R.Baskaran, D.Kanjilal, A.Roy, Rev.Sci.Instrum. Vol 81,02A323 (2010)

14:00-15:50 *Status & New Developments* **Malaku Room**
MOCOCK **Chair: Takahide Nakagawa**

14:44 **MOCOCK03**

Design study of a higher magnetic field SC ECRIS at IMP

Xie Daniel, Lu Wang, Zhang Xuezhen, Zhao Hongwei

IMP, Lanzhou, China

Development of ECR ion source has demonstrated that, as the empirical scaling laws summarized, higher magnetic field with higher operation frequencies will greatly improve the source performance. Based on the great success of SECRAL, a higher magnetic field SC ECRIS is planned to meet the new accelerator demands at IMP. However, there are many practical issues in the design and construction of a higher field SC ECRIS that need to be addressed. In this paper we will present and discuss the design features of the higher field SC ECR with a maximum axial field of 7.0 T and a radial field of 3.5 T at the plasma chamber inner surface, and operating frequency up to 50 GHz.

14:00-15:50 *Status & New Developments* **Malaku Room**
MOCOCK **Chair: Takahide Nakagawa**

15:06 **MOCOCK04**

Measurement of the Sixty GHz ECR Ion Source using Megawatt Magnets - SEISM magnetic field map

Marie-Jeanne Mélanie[(1)], Angot Julien[(1)], Debray François[(2)], Fourel Christian[(1)], Giraud Julien[(1)], Jacob Josua[(1)], Kamke Michael[(2)], Lamy Thierry[(1)], Latrasse Louis[(1)], Matera Jacques[(2)], Morfin Jérôme[(1)], Pfister Rolf[(2)], Sole Patrick[(1)], Thuillier Thomas[(1)], Trophime Christophe[(2)], Verney Eric[(2)], Vieux-Rochaz Jean-Louis[(1)]

(1) LPSC, UJF-CNRS/IN2P3-INP Grenoble, Grenoble, France
(2) LNCMI, Grenoble

LPSC has developed a prototype of 60GHz Electron Cyclotron Resonance (ECR) Ion Source called SEISM. The first 60GHz magnetic structure is based on a cusp geometry, using resistive polyhelix coils designed in collaboration with the Intense Magnetic Fields National Laboratory (LNCMI). A dedicated test bench helices coils in their tanks, electrical, and water cooling environment was built to study the mechanics, thermal behaviour and magnetic field characteristics obtained at various current levels. During the last months, measurements were performed for several magnetic configurations, with up to 7000A applied on the injection/extraction coils set. The magnetic field achieved at13000A is expected to allow 28GHz ECR condition. However, cavitation issues that appeared around 7000A are to be solved before carrying on with the tests. This contribution will recall some of the crucial steps in the prototype fabrication, and show preliminary results from the measurements at 7000A. Possible explanations for the discrepancies observed between the results and the simulation will be given.

14:00-15:50 *Status & New Developments* | **Malaku Room**
MOCOCK | **Chair: Takahide Nakagawa**

15:28 **MOCOCK05**

Multigan®: a new multicharged ions source based on axisymetric magnetic structure

Maunoury Laurent(1), Pacquet Jean-Yves(1), Dubois Mickael(1), Pierret Christophe(2), Delahaye Pierre(1), Jardin Pascal(1), Leherissier Patrick(1), Michel Matthieu(1), Gaubert Gabriel(3), Villari Antonio(3), Biri Sandor(4)

(1) GANIL, Cae, France
(2) CIMAP, Caen, France
(3) Pantechnik, Bayeux, France
(4) ATOMKI, Debrecen, Hungary

Standard ECR ion sources have radial magnetic field created by a multi-pole, e.g. hexapole or higher order, which fills all space in the center of the source structure. Based on the Monogan® ECRIS [1] concept, a new multicharged ECR ions source has been designed with a large opening space in the center of the source structure. This particular design allows, in a first approach, direct radial contact with the ECR plasma, allowing positioning of probes and targets for radioactive beam production very close to the plasma region. Secondly, the absence of a multi-pole allows considering extremely high magnetic fields with significantly smaller structural constraints. This source is combining the advantages of the axisymetric magnetic feature of MonoganR with higher frequencies. This paper will describe the magnetic structure calculation as well as the mechanical design and stresses of a full permanent magnet ion source using this concept. This source will be the first prototype of such an ECR ion source. Finally, using TrapCad code [2], an estimation of the electronic energy distribution has been calculated and thus, the performance of the source has been deduced. The beam formation and extraction were also roughly calculated taking into account magnetic and electric fields.

[1] P. Jardin et al., Review of Scientific Instruments, 73, 789 (2002)
[2] L. Maunoury et al., Plasma Sources Science and Technology , 18, 015019 (2009)

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT01

Operation of KeiGM for the carbon ion therapy facility at Gunma University

Muramatsu Masay[(1)], Kitagawa Atsushi[(1)], Hojo Satoru[(1)], Miyazaki Hirohumi[(2)], Ueno Takeshi[(2)], Sawada Kenji[(2)], Tsuchiyama Masaru[(3)], Ueda Satoshi[(3)], Kijima Yuko[(3)], Torikai Kota[(4)], Yamada Satoru[(4)]

(1) National Institute of Radiological Sciences, Chiba, Japan
(2) Sumitomo Heavy Industries, Ltd., Japan
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(4) Gunma University, Maebashi City, Japan

Carbon-ion radiotherapy has been carried out at Gunma University Heavy Ion Medical Centre (GHMC) since March 2010. A compact ECR ion source for GHMC, so-called KeiGM, supplies C4+ ions for treatment. A microwave source with the traveling-wave-tube was adopted for KeiGM, with a frequency range and maximum power of 9.75 - 10.25 GHz and 750 W, respectively. KeiGM was operated from March to May 2010 for the clinical trial without any trouble and maintenance. KeiGM supplied the carbon ions from 7:30 in the morning to 0:00 midnight on weekdays. Sometimes it was operated for the beam tuning of accelerator on Saturday and Sunday too. The operation time of KeiGM for two months was about 780 hours.
Although the beam intensity decreased by 20% at first, it has been constant for the last two months. The beam intensity of C4+ was 200 euA at 30 kV extraction in May 2010. The fluctuation of beam intensity was less than 10%. The operation parameters were as follows; the microwave frequency and power were 10.042 GHz and 300 W, respectively. CH4 gas was fed, and the gas flowrate was 0.054 cc/min. The extraction voltage was 30 kV. The repetition frequency and pulse width were 0.36 Hz and 50 msec, respectively. Gunma University has successfully treated the first 12 patients for the clinical trial, thus the Japanese Ministry of Health and Labor Welfare approved GHMC as “advanced medicine”. We will report the operation of KeiGM and the status of their daily treatment.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT02

Two-chamber configuration of the Bio-Nano ECRIS

Uchida takashi[1], Minezaki Hidekazu[1], Tanaka Kiyokatsu[2], Muramatsu Masayuki[3], Asaji Toyohisa[2], Kitagawa Atsushi[3], Kato Yushi[4], Yoshida Yoshikazu[1], Racz Richard[5], Biri Sandor[5]

(1) Toyo University, Japan
(2) Tateyama Machine Co., Ltd., Japan
(3) National Institute of Radiological Sciences, Japan
(4) Osaka University, Osaka, Japan
(5) Institute of Nuclear Research (ATOMKI), Debrecen, Hungary

The Bio-Nano ECRIS was designed for new materials production on nano-scale [1]. Our main target is the endohedral fullerene, which have potential in medical care, biotechnology and nanotechnology. In particular, iron-encapsulated fullerene can be applied as a contrast material for magnetic resonance imaging or microwave heat therapy. There are several promising approaches to produce the endohedral fullerenes using an ECRIS. One of them is the ion-ion collision reaction of fullerenes and aliens ions to be encapsulated in the mixture plasma of them. Another way is the shooting of ion beam into a pre-prepared fullerene layer. In this study, the new device configuration of the Bio-Nano ECRIS is reported which allows the application of both methods. The plasma chamber is divided into two chambers by installing mesh electrodes. In the gas injection-side 1st chamber at 2.45 GHz plasmas (N2, Ar, He, Fe,…) are produced on the usual way. These ions then are extracted to the 2nd chamber where an evaporation boat for fullerene is installed. The fullerene neutrals can be
ionized (using 10 GHz in the 2nd chamber) and are deposited on a large plasma electrode where they are continuously irradiated by the ions from the 1st chamber. The ions produced either in the 1st or 2nd chamber can be in-situ extracted and analyzed. The basic concept and the preliminary results using Ar gas and N2 gas plasmas will be presented.

[1] T. Uchida et al., Proc. ECRIS08, Chicago, USA, pp. 27-31 (2008)

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT03

Prospect for compact size ECRIS in application to analytical system

Kidera Masanori[(1)], Takahashi Kazuya[(1)], Nagamatsu Tsuyoshi[(2)], Seto Yasuo[(3)], Toda Masayoshi[(4)], Enomoto Shuichi[(5)], Tanaka Tatsuhiko[(2)]

(1) RIKEN, Wako, Japan
(2) Tokyo University of Science, Tokyo , Japan
(3) National Research Institute of Police Science, Kashiwa, Japan
(4) Tokyo University of Marine Science and Technology, Tokyo, Japan
(5) Okayama University, Okayama, Japan

A place of an activity of ECR ion sources is not only ion source on a heavy ion accelerator facility. A highly ionization efficiency, flexibility of ionized sample, low consumption rate in sample, and non-equilibrium ECR plasma, etc. that a ECR ion source have, may be needed in other fields at time. We have developed several kinds of small ECRISs that have customized for the analysis. The purposes of the analysis are, precise measurement of isotope ratio of a metal element, detection of chemical warfare agents, and detection of produced molecular (or fragment) ions by the ECR plasma. In this workshop, we will report the compact ECRISs by a permanent magnet type for the analytical system.

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT04

Neutralisation of accelerated ions and detection of resulting neutrals

Peleikis Thies, Lauri Panitzsch, Michael Stalder

Institut für Experimentelle und Angewandte Physik, University of Kiel, Kiel, Germany

At the University of Kiel, the Department of Experimental and Applied Physics is running an ECR ion source in order to, amongst others, calibrate space instruments designed to measure solar wind properties and suprathermal particles. The ion source is able to produce medium to highly charged ions which are then accelerated by an electrostatic field up to 400 keV per charge. In order to extend the particle spectrum from ions to neutral atoms we are planning to install a device for the beam particle neutralisation. It will be used to calibrate instruments which measure neutral particles. This device will be located downstream from the sector magnet and the acceleration-stage. The sector magnet separates the ions by their m/q ratio. This way the type and the energy of the ions can be determined before the neutralisation. Neutralisation can be achieved either by passing the ions through a thin carbon foil (thickness ~88nm) or through a gastarget (thickness ~6mm, pressure ~0.1mbar) where charge-exchange occur. The remaining ions behind the neutraliser will be suppressed by an electrostatic separator. Both methods will alter the beam properties and lead to a divergence in energy and an angular spread of the beam. Simulations regarding these effects will be discussed. The overall progress on this project will be presented.

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT05

High current production with 2.45 GHz ECR Ion source

Coly Arona[(1)], Lamy Thierry[(1)], Thuillier Thomas[(1)], Gaubert Gabriel[(2)], Villari Antonio[(2)],
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(2) Pantechnik 13 rue de la Résistance 14400 Bayeux, France

A new test bench has been installed at LPSC dedicated to 2.45 GHz ECR Ion Sources characterization. Several magnetic structures have been tested around the same plasma cavity. For example, a current density of 70 mA/cm2 has been measured with the MONO1000 source lent by GANIL. An original ECRIS, named SPEED (for 'Source d'ions à aimants PErmanents et Extraction Dipôlaire'), presenting a dipolar magnetic field at the extraction will also be presented.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT06

Ionization efficiency of a COMIC ion source equipped with a quartz plasma chamber

Suominen Pekka[(1)], Stora Thierry[(1)], Sortais Pascal[(2)], Médard Jerome[(2)]

(1) CERN, Swiss
(2) LPSC, UJF, CNRS/IN2P3, INP Grenoble, Grenoble, France

The ISOLDE facility at CERN produces a wide range of radioactive ion beams due to a long history on target and ion source development. Because the radioactive isotope production is very limited, the most important ion source parameters are high ionization efficiency, selectivity and reliable operation under intense radiation. Currently used ion sources (mainly laser (RILIS [1]) and arc discharge -type ion sources (VADIS [2])) do not efficiently ionize light noble gases, such as helium, and molecules, such as CO, N2 and NO. These beams were previously planned to be produced with 1+ ECR ion sources operating at 2.45 GHz (for example MINIMONO [3]) but due to new and more efficient RF coupling of COMIC-type ion sources [4], we expect to advance in 2.45 GHz ECRIS utilization for radioactive beam production. The new COMIC source designed by LPSC, Grenoble incorporates special features such as a plasma chamber fully made of quartz (Q-COMIC). This should provide chemically good conditions for molecular ion beam production, especially for carbon. This paper presents the first ionization efficiency measurements of the Q-COMIC.

[1] V.N. Fedosseev, et al, Nucl. Instrum. Methods Phys. Res. B 266/19-20 (2008) 4378.
[2] PhD thesis, univ. polyt. Bucarest, L. Penescu (2009)
[3] F. Wenander, W. Farabolini, G. Gaubert, P. Jardin, J. Lettry, Nucl. Phys. A, 746 (2004) 659
[4] P. Sortais, T. Lamy, J. Médard, J. Angot, L. Latrasse, and T. Thuillier, Rev. Sci. Instrum. 81 (2010) 02B314

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT07

Preliminary steps for high intensity beam tomography reconstruction

Mateo Cherry May, Adroit Guillaume, Farabolini Wilfrid, Gauthier Yannick, Gobin Raphael, Harrault Francis, Nyckees Sebastien, Pottin Bruno, Sauce Yanick, Senee Franck, Tuske Olivier, Vacher Thierry

CEA Saclay, France

Particle accelerators with high intensity beams require non-interceptive diagnostics because any interceptive tools can be damaged during measurements. At CEA Saclay, the use of tomography to develop a non-interceptive transverse profile monitor is foreseen. This profile monitor will be tested on the BETSI ion source test bench and on the SILHI source platform. Tomography, which is basically an image reconstruction based on the several projections of the object, is widely used in medical community. And for the purposes of particle accelerators, tomography will be used to understand beam profiles. When using this technique to reconstruct beam profile, it is imperative to have foreknowledge on the number of projections needed and the sensitivity of the reconstruction to the uncertainties in the input parameters. Previous results have shown that six projections are sufficient to reconstruct an image with closer approximation. To verify this, an experiment using an expanded laser beam is done prior to the design of the monitor. Reconstructed beam profiles of the laser using six projections are reported.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT08

He^{2+} source based on penning discharge with additional 75 GHz ECR heating

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It is well known that one can reach high average charge of ions in the ECR plasma by increasing plasma density and decreasing neutral gas pressure. ECR discharge could be realized at very low gas pressure, but discharge startup takes longer time when gas pressure is low. So, it is impossible to realize ECR discharge with limited microwave heating pulse duration at gas pressure lower certain threshold value. This problem could be solved with help of trigger plasma, which should be ignited at low gas pressure in the trap with high magnetic field. This fore plasma could help to decrease ECR plasma startup time significantly and make it possible to realize ECR plasma at very low pressure in pulse operation regime. We suggest penning type discharge as a trigger discharge for fast startup of pulsed ECR plasma. Penning type discharge glows at as low pressure as needed. Discharge was realized in the simple mirror magnetic trap at pressure about 1E-5 mbar. Helium was used as an operating gas. Significant plasma density (about 1e11 cm-3) was obtained at the moment just before microwave heating pulse started. Gyrotron radiation with frequency of 75 GHz, microwave power up to 200 kW and pulse duration up to 1 ms, was used for plasma heating. In the present work the fully striped helium ions were demonstrated, average charge of ions in the plasma was equal 2. Temporal evolution of charge state distribution was investigated. Charge state distribution over helium pressure was also studied.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT09

Beam Simulations in the Extraction Line of the RIKEN 28 GHz ECR Ion Source

Ohnishi Jun-Ichi, Higurashi Yoshihide, Nakagawa Takahide

RIKEN Nishina Center, Wako, Japan

The superconducting ECR ion source enabled to use a 28 GHz microwave source was constructed. It aims at providing intense beams of highly charged heavy ions like U35+ to the RIKEN RI-beam factory (RIBF). Its operation began using two 18 GHz microwave sources from summer of 2009. We performed the beam simulations in its extraction line using the 3d code SCALA. It was found that the calculation reproduces the measured phase space distributions of the extracted and analyzed beams. So we investigated by these beam simulations how the beam emittance is changed due to the space charge effect and the effect when a correction sextupole magnet will be placed just after the ion source. Moreover, the difference between 18 GHz and 28GHz operations is described.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT10

The Light Ion Guide CB-ECRIS project at the Texas A University Cyclotron Institute

Tabacaru Gabriel[(1)], May Don[(1)], Arje Juha[(2)]

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(2) University of Jyvaskyla, Jyvaskyla , Finland

Texas A is currently configuring a scheme for the production of radioactive-ion beams that incorporates a light-ion guide (LIG) coupled with an ECRIS constructed for charge-boosting (CB-ECRIS). This scheme is part of an upgrade to the Cyclotron Institute and is intended to produce radioactive beams suitable for injection into the K500 superconducting cyclotron. The principle of operation is the following: a primary beam from the K150 cyclotron interacts with a production target placed in the gas cell. A continuous flow of helium gas maintains a constant pressure of 500 mbar maximum in the cell. Recoils are thermalized in the helium buffer gas and ejected from the cell within the gas flow through a small exit hole. The positively charged recoil ions (1+) are guided into a 2.5 m long, rf-only hexapole and will be transported in this manner on-axis into the CB-ECRIS. The CB-ECRIS operates at 14.5 GHz and has been specially constructed by Scientific Solutions of San Diego, California for charge-boosting. An overview of the entire project will be presented with details on different construction phases. Specific measurements and results will be presented as well as future development plans.

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT11

DRAGON a new 18 GHz RT ECR ion source with a large plasma chamber

Lu Wang, Xie Dan Zuqi, Zhang Xuezhen, Zhao Hongwei

Institute of Modern Physics, CAS, Lanzhou, China

Building a strong radial magnetic field with a permanent hexapole magnet for an ECRIS is extremely challenging so that the conventional wisdom requires a small but not optimal plasma chamber that is typically of ID less or equal to 80 mm. A new 18 GHz RT ECR ion source, DRAGON, has been designed with a large bore permanent hexapole and source construction has begun at IMP. Its plasma chamber is of ID of 126 mm, the same as that of the superconducting ion source SECRAL, with maximum radial field strength reaching 1.5 Tesla at the plasma chamber wall. The overall magnetic strengths of DRAGON, with maximum axial fields of 2.7 Tesla at the injection and 1.3 Tesla at the extraction, are very similar to those of SECRAL operating at 18 GHz and hopefully the SECRAL performance. The source solenoid magnet coils are cooled by an evaporative coolant at about 50 degree C. In addition, the source is thickly insulated for beam extraction at 50 kV and higher voltage up to 100 kV can be explored. This article will present the design details and discussions of this new ion source.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT12

Tests of the Versatile Ion Source (VIS) for high power proton beam production

Gammino santo[(1)], celona luigi[(1)], maimone fabio[(1)], miracoli Rosalba[(1)], mascali david[(1)], adroit guillaume[(2)], senee frank[(2)], ciavola giovanni[(1)]

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(2) Commissariat à l'Energie Atomique (CEA)-Saclay, France

The sources adapted to beam production for high power proton accelerators must obey to the request of high brightness, stability and reliability. The Versatile Ion Source (VIS) is based on permanent magnets (maximum value around 0.1 T on the chamber axis) producing an off-resonance microwave discharge. It operates up to 75 kV without a bulky high voltage platform, producing several tens of mA of proton beams and monocharged ions. The microwave injection system and the extraction electrodes geometry have been designed in order to optimize the beam brightness. Moreover, the VIS source ensures long time operations without maintenance and high reliability in order to fulfil the requirements of the future accelerators. A description of the main components and of the source performances will be given. A brief summary of the possible options for next developments of the project will be also presented, particularly for pulsed mode operations that are relevant for some future projcts (e.g. the European Spallation Source of Lund).

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT13

MONOBOB II : Latest results of monocharged ion source for SPIRAL2 RIB

Dubois Mickael, Bajeat Olivier, Barue Christophe, Canet Christophe, Dupuis Michel, Flambard Jean Luc, Frigot Romain, Jardin Pascal, Leboucher Christian, Lecesne Nathalie, Lecomte Patrice, Leherissier Patrick, Lemagnen Frederic, Osmont Benoit, Pichard Alexandre, Pacquet Jean Yves, Maunoury Laurent

GANIL, Caen, France

MONOBOB II is an electron cyclotron resonance ion source (ECRIS) based on a cylindrical symmetry magnetic structure [1]. It has been designed for the SPIRAL2 project in order to ionize radioactive gases coming from the production targets of the Target Ion Source System (TISS). The goal is to build a long-lived ECRIS with the aim of running three months in the hostile environment of the production target while keeping high ionization efficiencies. The Target Ion Source System has been tested using noble gases (He, Ne, Ar, Kr and Xe), with and without target in order to observe the behavior of the source coupled to the target. Currently, the target is made of ~1000 carbon slices, having the same geometry as the final UCx target. So far, its temperature has been limited to 1500°C. Ionization efficiencies and response times of the TISS have been measured versus gases and target temperature [2]. Results should lead to determine the maximum radioactive ion production which can be reasonably expected with the final TISS. The status of this development will be presented.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT14

The Design of 28 GHz ECR Ion Source for the Compact Linear Accelerator in Korea

Won Misook[(1)], Lee Byoungseob[(1)], Park Jinyong[(1)], Kim Dongjun[(1)], Kim Jonhpil[(1)], Yoon Janghee[(1)], Bae Jongseong[(1)], Ahn Jungkeun[(2)] , Wang Sonjong[(3)], Nakagawa Takahide[(4)]

(1) Korea Basic Science Institute, Busan, Republic of Korea
(2) Pusan National University, Busan, Republic of Korea
(3) Korea Atomic Energy Research Institute, Daejon, Republic of Korea
(4) RIKEN, Wako, Japan

The construction of a compact linear accelerator is in progress by Korea Basic Science Institute. The main capability of this facility is the production of multiply ionized metal clusters and the generation more intense beams of highly charged ions for material, medical and nuclear physical research. To produce the intense beam of highly charged ions, we will construct an Electron Cyclotron Resonance Ion Source (ECRIS) using 28GHgz micrewaves. For this ECRIS, The design of a superconducting magnet, microwave inlet, beam extraction and plasma chamber was completed. Also we are constructing a superconducing magnet system. In this presentation, we will report the current status of development of our 28GHz ECRIS.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT15

The Design Study of Superconducting Magnet System for a Advanced ER Ion Source

Lee Byoungseob[1], Won Misook [1], Park Jinyong[1], Kim Dongjun[1], Kim Jonhpil[1], Yoon Janghee[1], Bae Jongseong[1], Ahn Jungkeun[2]

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

The Korea Basic Science Institute is developing a superconducting magnet system for 28 GHz Electron Cyclotron Resonance Ion Souce (ECRIS). We are invetigating in order to realize compact size, economic operation and generation of high current beam. Although companies and researchers have valuable experience, skill and ability in designing of superconducting magnet for ECRIS, they did not exactly proposed a excellent superconducting magnet system for ECRIS because many superconducting magnets were not required. Of course they do if we requried many magnets for the various appliation of ECRIS. In this presentation, we have filed reports of former reseacher and we have discussed the realization of ECRIS over 35 GHz.

16:10-17:30 *Poster Session 1* Atrium
MOPOT

MOPOT16

Early uranium ion production in SUSI and a low power survey of offset axial sputtering

Cole dallas, Machicoane Guilluame, Sun Liangting, Ropponen Tommi, Tobos Larry

NSCL/MSU, East Lansing, USA

Prototype sputtering hardware has been tested in the SUSI ion source and early uranium ion production is discussed. Also, results of a low power survey of axialsputtering, to test sputtering efficiency at incremental radial offsets from on axis position, is reported.

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT17

Tests of a New Axial Sputtering Technique in an ECRIS

Scott Robert, Vondrasek Richard, Pardo Richard

Argonne National Laboratory, Argonne, USA

Axial and radial sputtering techniques have been used over the years to create beams from an ECRIS at multiple accelerator facilities. Operational experience has shown greater beam production when using the radial sputtering method versus axial sputtering. At Argonne National Laboratory, previous work with radial sputtering has demonstrated that the position of the sputter sample relative to the plasma chamber wall influences sample drain current, beam production and charge state distribution. The possibility of the chamber wall acting as a ground plane which influences the sputtering of material has been considered, and an attempt has been made to mimic this possible ground plane effect with a coaxial sample introduced from the injection end. Results of these tests will be shown as well as comparisons of outputs using the two methods. This work is supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357.

16:10-17:30 ***Poster Session 1*** Atrium
MOPOT

MOPOT18

Atmospheric pressure deposition of ZnO films by an DC Arc Plasmatron

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Nuclear and Energy Engineering Dep., Jeju National University, Jeju, Republic of Korea

The effect of the deposition parameters on the structure and properties of ZnO films deposited by DC arc plasmatron at the atmospheric pressure was studied. The varied parameters were gas flow rates, precursor composition, substrate temperature and post-deposition annealing temperature. Vapor of Zinc acetylacetone was used as source materials, oxygen was used as working gas and argon was used as the cathode protective gas and a transport gas for the vapor. The plasmatron power was varied in the range of 700-1500 watts. Flow rate of the gases and substrate temperature rate were varied in the wide range to optimize the properties of the deposited coatings. After deposition films were annealed in the hydrogen atmosphere in the wide range of temperatures. Structure of coatings was investigated using XRD and SEM. Chemical composition was analyzed using x-ray photoelectron spectroscopy. Sheet conductivity was measured by 4-point probe method. Optical properties of the transparent ZnO-based coatings were studied by the spectroscopy. It was shown that deposition by a DC Arc plasmatron can be used for low-cost production of zinc oxide films with good optical and electrical properties. Sheet resistance of 4 Ohms•cm was achieved after the deposition and 30 min annealing in the hydrogen at 350°C. Elevation of the substrate temperature during the deposition process up to 350°C leads to decreasing of the film's resistance due to rearrangement of the crystalline structure.

08:40-10:30 *Ion Beams & LEBTs* **Malaku Room**
TUCOAK **Chair: Richard Vondrasek**

08:40 **TUCOAK01**

First A/Q=3 beams of Phoenix V2 on the Spiral2 LEBT

Peaucelle Christophe[(1)], Thuillier Thomas[(2)], Lamy Thierry[(2)], Angot Julien[(2)], Uriot Didier[(3)], Biarrotte Jean-Luc[(4)], Grandemange Pierre[(2)]

(1) Institut de Physique Nucléaire Lyon, France
(2) LPSC, UJF, CNRS/IN2P3, INP Grenoble, Grenoble, France
(3) CEA, Gif-sur-Yvette, France
(4) Institut de Physique Nucléaire Orsay, France

The heavy ions low energy beam transport line (LEBT) of Spiral2 built at LPSC Grenoble is fully operational since the beginning of 2010. This LEBT has been calculated and designed to hold permanently 15 mA of multicharged ions extracted from the source at 60 kV. PHOENIX V2 ECRIS is presently installed on the LEBT and first tests started few months ago: A reliable beam of 1 mAe of O6+ beam at 45 kV has already been obtained for a long period with a very good transmission, and good reproducibility. Tests continue with an optimization of Ar12+ beam performance. The promising results of these first runs, particularly emittance measurements, profiles and optimization of charge optics will be presented along. The ECRIS Phoenix V2 and different equipments installed on this line (vacuum system, optic elements, diagnostics…) will be described. The future program and planned improvements on the LEBT will be also discussed in this paper.

08:40-10:30 *Ion Beams & LEBTs* **Malaku Room**
TUCOAK **Chair: Richard Vondrasek**

09:02 **TUCOAK02**

Ion Beam Brightness Study on SECRAL

Yun Cao

Institute of Modern Physics, CAS, Lanzhou, China

The Superconducting Electron Cyclotron Resonance ion source with Advanced design in Lanzhou (SECRAL) had been commissioned in 2005 and has been in routine operation for the Heavy Ion Research Facility in Lanzhou (HIRFL) accelerators since 2007. Even operated at 18 GHz, SECRAL has produced many outstanding intense ion beams, such as 0.81 emA of O7+, 0.81 emA of Ar11+, 0.5 emA of Xe20+ and 0.3 emA of Xe27+. To further understand the physics process involved in ECR plasma, especially to have a better understanding of the quality of the ion beam extracted from SECRAL, a new ion beam diagnosis system has been developed for thebeam transport line of SECRAL in 2008. Besides two viewing targets, two Allison type emittance scanners with updated structure have also been installed on the new diagnosis system. To understand the extracted beam qualities in relation to the ECR hot plasma, not only the emittance of the analyzed beam has been measuredbut Bremsstrahlung radiation has also been measured at the same time. Also the measurement results indicate the space charge effect of the ion beams and the coupling of solenoid lens may not be ignored for the intense ion beams. The measurement setup and results, and discussions will be presented in this report.

08:40-10:30 *Ion Beams & LEBTs* **Malaku Room**
TUCOAK **Chair: Richard Vondrasek**

09:24 **TUCOAK03**

Plasma-to-Target WARP simulations of Uranium beams extracted from VENUS compared to emittance

Winklehner Daniel[(1)], Todd Damon S.[(1)], Grote David P.[(1) (2)], Leitner daniela[(1)]

(1) Lawrence Berkeley National Laboratory, Berkeley USA
(2) Lawrence Livermore National Laboratory, Livermore, USA

The superconducting ECR ion source VENUS was built as injector for the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL) and as prototype injector for the Facility for Rare Isotope Beams (FRIB) in Michigan. This work presents the latest results of an ongoing effort to simulate both, the extraction from ECR ion sources, and the Low Energy Beam Transport (LEBT). Its aim is to help understand the influence of parameters like initial ion distributions at the extraction aperture, ion temperatures and beam neutralization on the quality of the beam and to provide a design-tool for increasing the efficiency of the extraction- and transport-system. The initial conditions (i.e. spatial- and velocity-distribution of the ions prior to extraction from the ion source) are obtained semi-empirically by tracking the ions of different species from sputter marks on the biased disk on the far end of the source to the extraction region by following the magnetic field lines and scaling the Larmor radii of the ions appropriately. Extraction from the plasma and consequently the source is then simulated with the versatile WARP simulation code. The same code is also used for the actual simulation of ion transport through the beam line. Simulations of multi-species Uranium beams with different drain currents, initial ion temperatures and levels of neutralization in the beam line are compared to each other and to emittance measurements and beam profiles of VENUS beams.

08:40-10:30 *Ion Beams & LEBTs* **Malaku Room**
TUCOAK **Chair: Richard Vondrasek**

09:46 **TUCOAK04**

Production of U ion beam from RIKEN SC-ECRIS with sputtering method

Higurashi Yoshihide[1], Nakagawa Takahide[1], Ohnishi Junnichi[1], Haba Hiromitsu[1], Ikezawa Eiji[2], Fujimaki Masaki[1], Watanabe Yutaka[1], Komiyama Misaki[1], Kase Masayuki[1], Goto Akira[1], Kamigaito Osamu[1], Aihara Toshimitsu[2], Tamura Masashi[2], Uchiyama Akito[2]

(1) RIKEN, Wako, Japan
(2) SHI Accelarator Service Ltd, Japan

In 2008, we successfully produced 345MeV/u U beam (~0.4 pnA on target) for RIKEN RIBF project. However, to meet the requirement of the RIBF (primary beam intensity of 1pμA on target), we still need to increase the beam intensity. To increase the beam intensity of U ion, we started to make a test experiments forproduction of U ion beam from the new SC-ECRIS. In this experiment, we produced 2~1.5pμA of medium charge state U ion (ex., 55eμA of U31+, 57 eμA of U27+) at the RF power of 1.2kW with sputtering method. For testing the effect of the ionized gas on the U ion beam, we chose Ar, Ar+O2 and O2 gas for producing U ion beam. In this experiment, we observed that the beam intensity of lower charge state of U ion beam (<33+) was increased and the emittance of the U ion beam was decreased from ~0.1pi.mm mrad (1rms) to 0.05 pi.mm mrad with adding Ar gas to O2 gas. Using this method, we supplied U35+ beam for ~1 month without break for the RIBF experiment. In this contribution, we present the experimental results for production of U ion beam from SC-ECRIS in detail and future plan to increase the U ion beam intensity.

08:40-10:30 *Ion Beams & LEBTs* **Malaku Room**
TUCOAK **Chair: Richard Vondrasek**

10:08 **TUCOAK05**

An interpretation of the data measured with the KVI4D emittance meter

Kremers h.R., Beijers J.P.M., Brandenburg S., Mulder J., Saminathan S., Mironov V.

Kernfysisch Versneller Institute, Gröningen, Netherlands

We use a pepperpot emittance meter to determine the full transverse trace-space distribution of low-energy ion beams. One of the problems encountered with our emittance meter is that the correlation between the measured ion images and the holes in the pepperplate is somewhat ambiguous caused by the convoluted character of the trace-space distribution. In this paper we describe a method to solve this problem and illustrate it with measurements of the 4d transverse trace-space distribution behind the analyzing magnet of a 21 keV He1+ beam extracted from the KVI-AECR ion source. From these measurements together with ion-transport simulations we conclude that second-order aberrations in the analyzing magnet cause a significant increase in the effective beam emittance.

11:00-12:30 *Pulsed Operation* **Malaku Room**
TUCOBK **Chair: Peter Spaëdtke**

11:00 **TUCOBK01**

Preglow phenomenon origins and its scaling for ECRIS

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Preglow effect investigation is one of topical directions of ECR ion sources development at present. Preglow is of interest for efficient short-pulsed multicharged ion source creation. Particularly, such source of intense beams of shortliving radioactive isotopes multi-charged ions is one of key elements in “Beta- Beam” European project [1]. Use of Preglow-generating regime of an ECRIS operation is a promising way of pulsed high-intense multi-charged ion beams production with much shorter edges in comparison with usual operation regime. The first theoretical investigations of Preglow phenomenon were performed in references [2,3]. Present work describes modified model of ECR discharge development in a magnetic trap of the ECRIS as a continuation of [2,3]. Numerical simulations made with the updated model allow authors to propose more physical and intuitive explanation of Preglow phenomenon origins. Obtained dependences of Preglow characteristics on experimental conditions offer a scaling for a wide range of ECRISes.

[1] (ONLINE) http://beta-beam.web.cern.ch/beta-beam/task/diverse/mandate.htm
[2] T. Thuillier et all. R.S.I., 79, 02A314, 2008.
[3] I. Izotov et all. IEEE Trans. Plasma Sci. 36, 1494, 2008.

11:00-12:30 *Pulsed Operation* — **Malaku Room**
TUCOBK — **Chair: Peter Spaëdtke**

11:22 TUCOBK02

"Preglow" investigation in ECR discharge @ 37 GHz, 100 kW

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(2) LPSC, UJF, CNRS/IN2P3, INP Grenoble, Grenoble, France

Multicharged ion beams generation in "Preglow" regime is now considered as the main way of short pulsed ion source creation for "Beta Beam" project. The "Preglow" effect has been investigated at a several laboratories (LPSC, JYFL, IAP RAS). The effect was discovered at LPSC on PHOENIX ion source using 18 GHz radiation for plasma heating. Investigations at 14 GHz frequency were made at JYFL. Theoretical analysis demonstrated the advantage of MW frequency increase. Theoretical calculations predict possibility of "Preglow" peaks generation with duration about tens microseconds and rather high average ion charge. At present time at LPSC a joint construction of a new generation ECR ion source with 60 GHz gyrotron plasma heating is running. As a continuation of previous research at 14, 18 and 28 GHz at present work results of experimental and theoretical "Preglow" effect investigations at SMIS 37 setup with 37,5 GHz MW plasma heating are reported. Received data are important as fundamental result in physics of ECRISs and at the same time it is the next step on the way of 60 GHz SEISM facility creation. "Preglow" effect was observed and investigated in experiments with ECR discharge stimulated with gyrotron radiation @ 37.5 GHz, 100 kW. Received dependencies of the "Preglow" parameters are in good correspondence with results of numerical simulations. It was shown in experiments that generation of "Preglow" peak with duration about 30 μs is possible.

11:00-12:30 *Pulsed Operation* **Malaku Room**
TUCOBK **Chair: Peter Spaëdtke**

11:44 **TUCOBK03**

Time Evolution of Plasma Potential in Pulsed Operation of ECRIS

Tarvainen Olli[(1)], Higurashi Yoshihide[(2)], Koivisto Hannu[(1)], Nakagawa Takahide[(2)], Ropponen Tommi[(3)], Toivanen Ville[(1)]

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(2) Institute of Physical and Chemical Research RIKEN, Japan
(3) National Superconducting Cyclotron Laboratory, Michigan State University (NSCL-MSU), East Lansing, USA

The time evolution of plasma potential has been measured in pulsed operation mode with electron cyclotron resonance ion sources at JYFL and RIKEN. Three different ion sources with microwave frequencies ranging from 6.4 to 18 GHz were employed for the experiments. The plasma potential during the preglow and afterglow transients was compared with steady state conditions. The plasma potential was observed to increase 25-75 % during the preglow and 10-30 % during the afterglow. We describe the experimental procedure and present the results of the study in detail.

11:00-12:30 *Pulsed Operation* **Malaku Room**
TUCOBK **Chair: Peter Spaëdtke**

12:06 **TUCOBK04**

Micropulses generation in ECR breakdown stimulated by gyrotron radiation @ 37,5 GHz

Skalyga Vadim, Zorin Vladimir, Izotov Ivan, Golubev Sergey, Sidorov Alexander, Razin Sergey, Vodopyanov Alexander

Institute of Applied Physics of the Russian Academy of Sciences (IAP-RAS), Nizhny Novgorod, Russian Federation

Present work is devoted to experimental and theoretical investigation of possibility of short pulsed (< 100 μs) multicharged ion beams creation. The possibility of quasi-stationary generation of short pulsed beams under conditions of quasi-gasdynamic plasma confinement was shown in recent experiments. Later another way of such beams creation based on “Preglow” effect was proposed. In present work it was demonstrated that in the case when duration of MW pulse is less then formation time of “Preglow” peak, realization of a regime when ion current is equal to zero during MW pulse and intense multicharged ions flux appears only when MW ends could be possible. Such pulses after the end of MW were called "micropulses". In present work generation of micropulses was observed in experiments with ECR discharge stimulated by gyrotron radiation @ 37,5GHz, 100 kW. In this case pulses with duration less than 30 μs. Probably the same effect was observed in GANIL where 14 GHz radiation was used and pulses with duration about 2 ms were registered. In present work it was shown that intensity of such micropulse could be higher than intensity of “Preglow” peak at the same conditions but with longer MW pulse. The generation of micropulses of nitrogen and argon multicharged ions with current of a few mA and length about 30 μs after MW pulse with duration of 30-100 μs was demonstrated. The low level of impurities, high current density and rather high average charge make possible to consider such micropulse regime as perspective way for creation of a short pulsed ion source.

14:00-15:50 *Applications* **Malaku Room**
TUCOCK **Chair: Laurent Maunoury**

14:00 **TUCOCK01**

Beam, Multi-Beam and Broad Beamproduction with COMIC devices

Sortais Pascal[(1)], Lamy Thierry[(1)], Medard Jerome[(1)], Angot Julien[(1)], Peaucelle Christophe[(2)]

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(2) Institut de Physique Nucléaire de Lyon, Villeurbanne France

The COMIC discharge cavity is a very versatile technology. We will present new results and devices that match new applications like: molecular beams, ultra compact beam line for detectors calibrations, quartz source for on-line application, high voltage platform source, sputtering /assistance broad beams and finally, a quite new use, high energy multi¬-beam production for surface material modifications. In more details, we will show that the tiny discharge of COMIC can mainly produce molecular ions (H3+). We will present the preliminary operation of the fully quartz ISOLDE COMIC version, in collaboration with IPN-Lyon, we will present a first approach for a slit extraction version of a three cavity device,
and after discussing about various extraction systems on the multi discharge device (41 cavities) we will show the low energy broad beam (2 KV) and high energy multi-beams (10 beams up to 30 KV) productions. We will specially present the different extraction systems adapted to each application and the beams characteristics which are strongly dependent on the voltage distribution of an accel-accel two electrodes extraction system.

14:00-15:50 *Applications* **Malaku Room**
TUCOCK **Chair: Laurent Maunoury**

14:22 TUCOCK02

Status of the Electron Cyclotron Resonance Ion Source Development at Peking University

Peng Shixiang, Song Zhizhong, Yu Jinxiang, Yuan Zhongxi, Zhang Meng, Ren Haitao, Zhao Jie, Lu Pengnan, Zhou Quanfeng, Guo Zhiyu, Chen Jia'er, Lu Yaunrong

Peking University, Beijing, China

Several compact 2.45 GHz Electron Cyclotron Resonance Ion Sources (ECRIS) have been developed at Peking University for ion implantation [1], separated function Radio Frequency quadruple (SFRFQ) [2] and for the Peking University Neutron Imaging Facility (PKUNIFTY) [3]. Studies are focused on methods of magnetic field generation, magnetic fields configuration, microwave window design, microwave coupling, and structure selection of extraction electrodes. Up to now, our sources have produced 25 mA O+/ He+ ion, 10mA N+ ion, 100 mA H+ and 83 mA D+ ions, respectively. Details will be reported in the paper.

[1] Zhizhong Song, Dong Jiang, and Jinxiang Yu, Small microwave ion source for an ion implanter. Review of Scientific Instruments 67,1003(1996)
[2] S. X. Peng, M. Zhang, Z. Z. Song, R. Xu, J. Zhao, Z. X. Yuan, J. X. Yu, J. Chen, Z. Y. Guo, Experimental Results of an Electron Cyclotron Resonance Oxygen Source and a LEBT System for 1 MeV Integral Split Ring Radio Frequency Quadrule Accelerator Upgrade Project. Review of Scientific Instruments, 2008, 79: 02B706.
[3] M. Zhang, S. X. Peng, H. T. Ren, Z. Z. Song, Z. X. Yuan, Q. F. Zhou, P. N. Lu, R. Xu, J. Zhao, J. X. Yu, J. E. Chen, Z. Y. Guo, and Y. R. Lu, Upgrade of the extraction system of permanent magnet electron cyclotron resonance ion source. REVIEW OF SCIENTIFIC INSTRUMENTS 2010, 81:02B715. *Correspondence author. Email: sxpeng@pku.edu.cn

14:00-15:50 *Applications* Malaku Room
TUCOCK Chair: Laurent Maunoury

14:44 **TUCOCK03**

Development of 14 GHz electron cyclotron resonance ion source at KAERI

Oh Byung-Hoon, In Sang-Ryul, Lee Kwang-Won, Seo Chang Seog, D. Jin, jung-tae, Chang Dae-Sik, Jeong Seong-Ho, Hwang Chul-Kew

Korea Atomic Energy Research Institute, Daejon, Republic of Korea

A 14 GHz ECRIS has been designed and fabricated in KAERI (Korea Atomic Energy Research Institute) to produce multi-charged ion beam (especially for C6+ ion beam) for medical applications. The magnet system has solenoid coils made with copper conductor and a hexapole made with permanent magnet. The solenoid coils are composed of two axial coils to make mirror fields in both sides of the chamber and one trim coil at the center to control the layer of the resonance region. The hexapole is made with 24-sector NdFeB permanent magnet. Radial field higher than 1.2 T at the chamber wall position has been measured, and axial field higher than 1.7 T at the entrance center of RF power and 1.1 T at the exit center of ion beam have been measured. A welded tube with aluminum and stainless steel is used for a ECR plasma chamber to improve the production of secondary electron. Cooling channel is made on the wall of the Al tube. A 2 kW Krystron is used as a microwave energy source. A DC break made with PEEK(Polyether Ether Ketone) for high voltage insulation and field shielding, and a RF window made with ceramic for vacuum insulation are inserted in the RF circuit. A movable beam extractor with 8 mm aperture covers different species and different charge numbers of the beam. Experimental results on ECR plasma and initial beam extraction with KAERI ECR ion source will be discussed.

14:00-15:50 *Applications* **Malaku Room**
TUCOCK **Chair: Laurent Maunoury**

15:06 **TUCOCK04**

Mass Spectrometry with an ECR IonSource

Hotchkis Michael, Button David

ANSTO, Kirrawee DC, Australia

Several groups [1-3] have demonstrated the usefulness of ECR ion sources in forms of mass spectrometry, for the detection of rare long-lived radioisotopes, trace elements and stable isotope ratios. Mass spectrometry imposes strict constraints on the ion source. First, the ion source must be free of backgrounds at the same m/q ratio as isotope of interest. Backgrounds take several forms, including beams generated from residual gas or other materials in the source, either of the element of interest, or other elements which cause isobaric or other m/q ambiguities. Second, the ion source must exhibit a minimum 'memory' effect from sample to sample. We are interested in isotopic ratios of carbon, nitrogen and oxygen. These elements are ubiquitous in vacuum systems and so this work has its own particular challenges, especially in relation to the design and operational characteristics of the ion source. Initial work has revealed retention effects which reduce the sample clear out rates, and cause persistent backgrounds [4]. We will present results of our most recent efforts to control these problems.

[1] P. Collon et al., Nucl. Instrum. Methods B 2004 223/224: 428
[2] M. Kidera et al., Eur. J. Mass Spectrom. 2007; 13: 239
[3] M. Hotchkis et al., Rapid Comm. Mass Spec. 2008; 22: 1408-1414
[4] D. Button and M.A.C. Hotchkis, Proc. 18th ECRIS Workshop, Sept 15-18, 2008, Chicago, USA, http://www.JACoW.org/

14:00-15:50 *Applications/Special Talk* **Malaku Room**
TUCOCK **Chair: Laurent Maunoury**

15:28 **TUCOCK05**

Working of the 10 GHz CAPRICE source

Jacquot Bernard

Former member of CEA Grenoble, France

Coherent synthesis of irrefutable experimental facts is presented. The presence of TEM mode in CAPRICE sources is rationally explained. Experimental results in accordance with TEM mode are revealed. Control of anisotropic magnetized cold plasma enables CAPRICE sources to be rationally optimized up to two orders of magnitude without increasing RF power. High B mode and biased disc effect would then be clearly understood. Getting on in best understanding of ECR sources working can then be expected.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT01

Plans for Laser Ablation of Actinides into an ECRIS for Accelerator Mass Spectroscopy

**Pardo Richard[(1)], Vondrasek Richard[(1)], Scott Robert[(1)], Kondev Filip[(1)], Palchan Tala[(1)], Kondrashev Sergey[(1)], Paul Michael[(2)], Collon Philippe[(3)], Youinou Gilles[(4)], Salvatores Massimo[(5)], Palmotti Giuseppe[(4)], Mcgrath Chris[(4)],
Imel George[(4)]**

(1) Argonne National Laboratory, Argonne, USA
(2) Hebrew University, Jerusalem, Israel
(3) University of Notre Dame, Notre Dame, USA
(4) Idaho National Laboratory, Idaho Falls, USA
(5) CEA-Cadarache, France

A project using accelerator mass spectrometry (AMS) at the ATLAS facility to measure neutron capture rates on a wide range of actinides in a reactor environment is underway. This project will require the measurement of many samples with high precision and accuracy. The AMS technique at ATLAS is based on production of highly- charged positive ions in an ECRIS followed by linear acceleration. We have chosen to use laser ablation as the best means of feeding the actinide material into the ion source because we believe this technique will have more efficiency and lower chamber contamination thus reducing ‘cross talk’ between samples. In addition a multi- sample holder/changer is part of the project to allow quick change between multiple samples. The status of the project, design, and goals for initial off-line ablation tests will be discussed as well as the overall project schedule. This work is supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT02

Enhancement of ECR performances by means of carbon nanotubes based electron guns

Odorici Fabrizio[1], Cuffiani M[2], Malferrari L[3], Rizzoli R[3], Veronese G.P.[3], Celona Luigi[4], Gammino Santo[4], Mascali David[4], Gambino Nadia[4], Miracoli Rosalba[4], Serafino Tiziana[5], Castro Giuseppe[4], Ciavola Giovanni[4]

(1) INFN, Sezione di Bologna, Bologna, Italy
(2) Dipartimento di Fisica, Università di Bologna, Bologna, Italy
(3) Istituto per la Microelettronica ed Microsistemi del CNR, Catania, Italy
(4) INFN-LNS, Catania, Italy
(5) Università di Messina, Messina, Italy

One of the main goals of the scientific community which deals with ECR Ion Sources is the optimization of the Eelectron Energy Distribution Function (EEDF) inside the plasma. The EEDF consists of three different populations (cold, warm and hot electrons): the cold and the warm populations are responsible of the stabilization and of the efficient ionization of the plasma respectively. The presence of the hot population is doubly detrimental: in high frequency sources they lead to the heating of LHe in the superconducting coils' cryostat and are also useless for the generation of high intensity ion beams, because of their small cross section. Therefore the injection of additional electrons inside the plasma may increase the density of cold and warm electrons, enabling at the same time to reduce the number of the high energy ones. The CANTES experiment tested the use of carbon nanotubes (CNTs) to emit electrons in presence of strong applied electric fields, in order to provide additional electrons to the plasma core. This technique was used with the Caesar ECR ion source, at INFN-LNS, demonstrating that the total extracted ion current is increased and that a relevant reduction of the number of "high energy" electrons (above 100 keV) can be obtained. This last result is even more important, because CNTs may be an effective and reliable tool to permit the operation of ECRIS at large power and high frequencies without any detrimental effect on the source stability and reliability coming from hot electrons. Details of the construction of CNTs based electron gun and their behaviour in plasma environments are presented. Preliminary results in terms of performances of the Caesar ECR ion source and possible future applications will be also discussed.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT03

A new BETSI test bench at CEA/Saclay

Nyckees Sebastien, Adroit Guillaume, Delferrière Olivier, Duperrier Romuald, Gauthier Yves, Gobin Raphael, Harrault Francis, Mateo Cherry May, Pottin Bruno, Sauce Yannick, SenéeFranck, Tuske Olivier, Vacher Thierry

CEA Saclay, France

By the 90s, CEA has undertaken to develop the production of high intensity light ion beams from plasma generated by electron cyclotron resonance (ECR). Important results were obtained with the SILHI source in pulsed or continuous mode. Presently, CEA/Saclay is now involved in the construction of different injectors dedicated to large infrastructures like IFMIF or Spiral 2. Other installations are also interested by high intensity ion sources like ESS or FAIR. To improve and test new sources, a new test bench named BETSI (Banc d'Etudes et de Tests des Sources d'Ions) is now operating for several months. Low energy beam line diagnostics consist of a Faraday cup, cameras and a species analyzer. The SILHI emittance scanner can also be installed on the beam line. On this test bench, different permanent magnet source configurations are tested. In order to modify plasma chamber size and shape, a new ECR source design is developed. An experimental study of the plasma visible light emitted through electrodes was implemented on BETSI using a monochromator. Extracted beam intensity of a permanent magnet source is compared to plasma light emission. Results obtained with monochromator will be compared with SOLMAXP code in order to explore radio frequency wave and plasma interaction.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT04

MICROGAN ECR Ion Source in a Van De Graaff accelerator terminal

Gaubert Gabriel[(1)], Tasset-Mayé Olivier[(1)], Villari Antonio[(1)], Bieth Claude[(1)], Chavez De Jesus Carlos[(2)], Bougy Wilfried[(1)], Brionne Nicolas[(1)], Donzel Xavier[(1)], Gamboni Thierry[(2)], Geerts Wouter[(2)], Jaime Tornin Riccardo[(2)], Lövestam Goran[(2)], Mondelaers Willy[(2)], Sineau Anthony[(1)], Vallerand Cynthia[(1)]

(1) PANTECHNIK, Bayeux, France
(2) IRMM, Retieseweg, Belgium

The Van de Graaff accelerator at IRMM works since many years providing proton, deuteron and helium beams for nuclear data measurements. The original ion source was of RF type with quartz bottle. This kind of source, as well known, needs regular maintenance for which the accelerator tank must be completely opened. The heavy usage at high currents of the IRMM accelerator necessitated an opening about once every month. Recently, the full permanent magnet Microgan ECR ion source from PANTECHNIK was installed into a new terminal platform together with a solid state amplifier of 50W, a dedicated dosing system for 4 gases (with respective gas bottles H2, D2, He and Ar), and a set of dedicated power supplies and electronic devices for the remote tuning of the source. The new system shows a very stable behavior of the produced beam allowing running the Van de Graff without maintenance for several months. This contribution will describe the full installed system in details (working at high pressure in the terminal, spark effects and optic of the extraction).

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT05

An ECR table plasma generator

Rácz Richárd[(1)], Biri Sándor[(1)], Pálinkás, József[(2)]

(1) Institute of Nuclear Research ATOMKI, Debrecen, Hungary
(2) University of Debrecen, Hungary

A simple ECR plasma device was built in our lab using the “spare parts” of the ATOMKI ECR ion source. We call it “ECR table plasma generator”. It consists of a relatively big plasma chamber (ID=10 cm, L=40 cm) in a thin NdFeB hexapole magnet with independent vacuum and gas dosing systems. For microwave coupling two low power TWTAs can be applied individually or simultaneously, operating in the 6-18 GHz range. There is no axial magnetic field and there is no extraction. The intended fields of usage of the plasma generator are: 1. A simple, cheap and safeeducational working place for students. 2. To prepare, to test or to simulate measurements with electrostatic movable Langmuir probes. The exchange time of the (damaged) probes is very short. 3. To prepare, to test or to simulate plasma diagnostic measurements in the visible light and X-ray ranges using cameras and spectrometers. 4. To cover and/or to modify solid surfaces with plasma particles, including fullerenes. In the paper the technical details of the plasma generator and some preliminary plasma photo results are shown.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT06

Using Mass-flow controllers for obtaining extremely stable ECR ion source beams

Donzel Xavier[1], Bougy Wilfried[1], Brionne Nicolas[1], Gaubert Gabriel[1], Leroy Renan[1][2], Sineau Anthony[1], Tasset-Mayé Olivier[1], Vallerand Cynthia[1], Villari A.C.C.[1]

(1) PANTECHNIK, Bayeux, France
(2) GANIL, Caen, France

Beam stability and reproducibility is of paramount importance in applications requiring precise control of implanted radiation dose, like in the case of Hadrontherapy. The beam intensity over several weeks or months should be kept constant. Moreover, the timing for changing the nature of the beam and, as a consequence, the tuning of the source should be minimized. Standard valves usually used in conjunction of ECR ion sources have the disadvantage of controlling the conductance, which can vary significantly with external conditions, like ambient temperature and inlet pressure of the gas. The use of flow controllers is the natural way for avoiding these external constraints. In this contribution we present the results obtained using a new model of Mass-flow controller in the source Supernanogan, for production of C (4+) and H3 (+) beams. Extremely stable beams (+/- 2.5%) without retuning of the source over several weeks could be obtained. The reproducibility of the source tuning parameters could also be demonstrated.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT07

Preliminary design of BLISI, an off resonance microwave proton source

Djekic Slobodan[(1)], Cortazar Daniel[(1)], De Cos David[(1)], Canoto David Fernandez[(1)], Hassanzadegan Hooman[(1)], Galipienzo Julio[(2)], Bustinduy Ibon[(1)], Feuchtwanger Jorge[(1)], Lucas Julio[(3)], Jugo Josu[(4)], Munoz Juan Luis[(1)], Rueda Igor[(1)], Portilla Joaquin[(4)], Etxebarria Victor(4), Bermejo Javier[(4)]

(1) ESS Bilbao, Spain
(2) AVS, Eibar, Spain
(3) Elytt, Madrid,Spain
(4) UPV, Bilbao, Spain

A new high current off resonance microwave H+ source is currently in the last stages of design at ESS-Bilbao, in collaboration with two external companies Elytt and AVS. The design is intended to be a high-stability, high-current ion source capable of delivering a 70 mA proton beam with a 70 keV energy at the end of the extraction. The plasma system designed by Elytt consists of a water-cooled plasma chamber that sits between two independently powered magnetic coils that generate the ECR magnetic field; in addition they can be moved independently to further shape the magnetic field in the chamber. A CPI 2.7 GHz klystron provides the microwave energy and a fully controlled microwave system to minimize reflected power and improve the source overall performance is also under construction. The extraction column designed by AVS will consist of a movable tetrode system designed for a maximum acceleration potential of 70 kV, the shape of the electrodes is at an earlier design stage at ESS- Bilbao. We will present the current layout of the source, simulations and schematics of the source.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT08

Performance of the LBNL AECR-U with a TWTA

Benitez Janilee, Leitner Daniela, Kireeff-Covo Michel, Lyneis Claude

Lawrence Berkeley National Laboratory, Berkeley, USA

The Advanced Electron Cyclotron Resonance - Upgrade ion source (AECR-U) at the Lawrence Berkeley National Laboratory has successfully utilized double frequency microwave heating (14.3 GHz and 10.4 GHz) for several years [1]. Recently a traveling wave tube amplifier (TWTA), providing frequencies in the range of 10.75GHz-12.75GHz, was added as a secondary heating frequency, replacing the previous 10.4 GHz Klystron. The TWTA opens the possibility to explore a wide range of secondary frequencies and a study has been conducted to understand and optimize its coupling into the AECR-U. In particular, the reflected power dependence on heating frequency has been mapped out with and without the presence of plasma. A comparison is made to determine how the presence of plasma, confinement fields, and other source parameters affect the reflected power and if and how the amount of reflected power can be correlated to the source ion beam performance.

[1] Z. Q. Xie and C. M. Lyneis, RSI 66 (1995).

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT09

New Measurements Of Bremsstrahlung Radiation From SECRAL

Zhao Huanyu, Zhang Wenhui, Cao Yun, Zhao Hongwei, Lu Wang, Zhang Xuezhen, Zhu Yuhua, Li Xixia, Xie Dan Zuqi

Institute of Modern Physics, CAS, Lanzhou, China

Measurement of Bremsstrahlung radiation from ECR plasma can yield certain information of the ECR heating process and a plausible estimate of the X-ray heat load to the cryostat of a superconducting ECR source which needs seriously addressed. With a newly-developed collimation system, which defines a narrower spatial range of the measurement and provides an effective shielding from the background, a systematic measurement of the Bremmstrahlung emitted axially from the SECRAL (Superconducting ECR Ion Source with Advanced design in Lanzhou) plasma were carried out recently. The spectral temperature Tspe, a relative index of mean energy of the plasma hot electrons, was derived through linear fitting of the spectra in semi-logarithm coordinates. This article will present and discuss the evolutions of the X-ray flux and the hot electron energy with various source parameters, such as heating frequency, RF power and magnetic field configuration. And possible solutions to reduce the X-ray heat load induced by Bremsstrahlung radiation are proposed and discussed.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT10

Effects of microwave frequency fine tuning on the performance of JYFL 14 GHz ECRIS

Toivanen Ville(1), Aho Vesa(2), Celona Luigi(2), Ciavola Giovanni(2), Galatà Alessio(3), Gammino Santo(2), Jones Peter(1), Kauppinen Janne(1), Koivisto Hannu(1), Mascali David(1)(4), Peura Pauli(1), Ropponen Tommi(5), Tarvainen Olli(1), Ärje Juha(1)

(1) University of Jyväskylä, JYFL, Jyväskylä, Finland
(2) INFN-LNS, Catania, Italy
(3) INFN-LNL, Legnaro; Italy
(4) Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania, Italy
(5) NSCL-MSU, East Lansing, USA

Measurements have been carried out at Department of Physics, University of Jyväskylä (JYFL) to study the effects of microwave frequency fine tuning on the performance of JYFL 14 GHz electron cyclotron resonance ion source. The frequency was varied within an 85 MHz band around the normal operation frequency of 14.085 GHz. The radial bremsstrahlung emission was measured for plasma diagnostics purposes and mass separated ion beam currents extracted from the ion source were recorded at the same time. Also, beam quality studies were conducted by measuring the ion beam emittance and shape with and without enhanced space charge compensation. The obtained results are presented and possible origins of seen phenomena in measured quantities are discussed.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT11

Measurements of low energy x-ray spectrum, plasma formation and decay at the 6.4 GHz LBNL ECR

Noland Jonathan[(1)], Tarvainen Olli[(2)], Benitez Janilee[(1)], Leitner Daniela[(1)], Lyneis Claude[(1)], Verboncoeur John[(3)]

(1) Lawrence Berkeley National Laboratory, Berkeley, USA
(2) University of Jyväskylä, JYFL, Jyväskylä, Finland
(3) University of California at Berkeley, USA

Two standard plasma diagnostics (x-ray spectroscopy and measurement of the diamagnetic current) have been employed at the LBNL 6.4 GHz ECR. These diagnostics are combined with time resolved current measurements to study the plasma breakdown, build up and decay times, as well as electron heating. Individual charged particles in a magnetized plasma orbit in such a way that the magnetic field produced by their motion opposes any externally applied magnetic field. When a charged particle density gradient exists in a plasma, a net current arises. This “diamagnetic” current is proportional to the time-rate-of-change of the perpendicular component of the plasma pressure, and can be measured with a loop of wire as the plasma ignites or decays. Another common plasma diagnostic that is used to characterize an ECR plasma is measurement of the x-ray spectra created when energetic electrons scatter off of plasma ions. The x-ray spectra provide insight on the relative abundance of electrons of different energies, and thus the electron energy distribution function. The x-ray spectra can also be used to estimate the total x-ray power produced by the plasma. In this paper diamagnetic loop diagnostics and set-up is described in detail. In addition, diamagnetic loop and low energy x-ray measurements (few keV to 100 keV) taken on the LBNL 6.4 GHz ECR ion source are presented and discussed.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT12

Microwave frequency dependence of the properties of the ion beam extracted from a CAPRICE type ECRIS

Maimone Fabio[(1)(2)], Tinschert Klaus[(1)], Celona Luigi[(3)], Spaedtke Peter[(1)], Maeder Jan[(1)], Rossbach Jon[(1)], Lang Ralf[(1)]

(1) GSI, Darmstadt, Germany
(2) Università degli Studi di Catania, Catania, Italy
(3) INFN-LNS, Catania, Italy

In order to improve the quality of ion beams extracted from ECR ion sources it is mandatory to better understand the relations between the plasma conditions and the beam properties. The present investigations concentrate on the analysis of different beam properties under the influence of various applications of frequency tuning and of multiple frequencies heating. The microwave frequency feeding the plasma affects the electromagnetic field distribution and the dimension and position of the ECR surface inside the plasma chamber. This in turn has an influence on the generation of the extracted ion beam in terms of its intensity, of its shape and of its emittance. In order to analyze the corresponding effects measurements have been performed with the Caprice type ECRIS installed at the ECR Injector Setup (EIS) of GSI. The experimental setup uses a new arrangement of one or more microwave sweep generators which feed a Traveling Wave Tube amplifier covering a wide frequency range from 12.5 to 18 GHz. This arrangement provides a precise determination of the frequencies and of the reflection coefficient along with the beam properties. A sequence of viewing targets positioned inside the beam line monitors the beam shape.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT13

Influence of initial plasma density and mean electron energy on the Preglow effect

Izotov Ivan(1), Tarvainen Olli(2), Toivanen Ville(2), Koivisto Hannu(2), Zorin Vladimir(1), Skalyga Vadim(1), Sidorov Alexander(1)

(1) IAP-RAS, Nizhny Novgorod, Russian Federation
(2) University of Jyväskylä, JYFL, Finland

The investigation of the Preglow effect is driven with the aim of creating a short- pulsed multicharged ion source. Recent experimental investigations have revealed strong influence of seed electrons, i.e. initial plasma density, on the amplitude and duration of the Preglow peak [1]. Present work, consisting of experiments and simulations, is dedicated to further investigation of the Preglow dependence on initial plasma density and electrons energy. Experimental investigation was performed at University of Jyvaskyla (JYFL) with the A-ECR type ECRIS operated with 14 GHz frequency. Helium was used for the study. An initial ionization degree of the gas was varied by changing the pulse duration and duty factor. Time-resolved ion currents of He+ and He2+ were recorded. Calculations were made by using 0-dimensional model described in references [2], [3] and based on the balance equations for the particles confined in the magnetic trap. Results of simulation are compared with experimental Preglow peaks and discussed. Good agreement between experimental data and simulation encourages us to conduct a further study, aimed at optimizing the Preglow by tuning source parameters and initial plasma conditions.

[1] O. Tarvainen et all. Rev.Sci.Instrum., 81, 02A303, 2010
[2] T. Thuillier et all. Rev.Sci.Instrum., 79, 02A314, 2008
[3] I. Izotov et all. IEEE Trans. Plasma Sci. 36, 1494, 2008

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT14

Optimized extraction conditions from high power-ECRIS by dedicated dielectric structures

Schachter Leon[(1)] , Stiebing Kurt[(2)], Dobrescu Serban[(1)]

(1) National Institute for Physics and Nuclear Enginnering, Bucharest, Romania
(2) Institut für Kernphysik der Johann Wolfgang Goethe- Universität (IKF), Frankfurt, Germany

The MD-method of enhancing the ion output from ECR ion sources is well established and basically works via two mechanisms, the regenerative injection of cold electrons from an emissive dielectric layer on the plasma chamber walls and via the cutting of compensating wall currents, which results in an improved ion extraction from the plasma. As this extraction from the plasma becomes a more and more challenging issue for modern ECRIS installations with high microwave power input, a series of experiments was carried out at the 14 GHz ECRIS of the Institut für Kernphysik in Frankfurt/Main, Germany (IKF). In contrast to our earlier work, in these experiments emphasis was put on the second of the above mechanisms namely to influence the sheath potential at the extraction by structures with special dielectric properties. Two different types of dielectric structures, Tantalum-oxide and Aluminum oxide (the latter also being used for the MD-method) with contrastingly different electrical properties were mounted on the extraction electrode of the IKF-ECRIS, facing the plasma. For both structures an increase of the extracted ion beam currents for middle and high charge states by 60-80 % was observed. The method is able to be applied also to other ECR ion sources for increasing the extracted ion beam performances.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT15

Permanent Magnet ECRIS for the KEK Digital Accelerator

Leo Kwee Wah(1), Takayama Ken(2), Arai Teruo(2), Okazaki Koji(3), Takagi Akira(2, Adachi Toshikazu(2), Koyama Kazuyoshi(2), Wake Masayoshi(2), Arakida Yoshio(2)

(1) Graduate University for Advanced Studies, Japan
(2) High Energy Accelerator Research Organization, Japan
(3) Nippon Advanced Technology Co. Ltd., japan

The existing KEK 500 MeV booster synchrotron is renovated into a digital accelerator (DA) capable of accelerating all species of ion [1]. The KEK-DA is an induction synchrotron employing no large injector. Its concept was demonstrated in 2006 using the 12 GeV proton synchrotron [2,3], where a proton bunch was accelerated with pulse voltages generated by a transformer instead of RF. In the KEK-DA, O, Ne, and Ar ions from the ECRIS embedded in the 200 kV high-voltage terminal (HVT) are directly injected into the ring though the low energy beam transport line. The permanent magnet ECRIS, in which a plasma is fired by x-band microwave pulses of 3 msec at 10 Hz, has been assembled at KEK. Its operational performance such as charge-state spectrum, emittance, and current is tested since the last year. In addition, the HVT with a voltage stabilizing circuit is being assembled now. Beam dynamical analysis from the cathode hall to the separation magnet, where possible charge-state ions are contaminated in the space-charge limit and beam focusing is realized through the Einzel lens and tandem acceleration gaps, is discussed as well as operational characteristics of the ECRIS.

[1] K. Takayama et al., “All-ion Accelerator: an Injector-free Synchrotron”, J. of Appl. Phys. 101, 063304(2007).
[2] K.Takayama et al., “Experimental Demonstration of the Induction Synchrotron”, Phys. Rev. Lett. 98, 054801 (2007)
[3] K.Takayama and R.Briggs (Eds.), Induction Accelerators (Springer-Verlarg, 2010).

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT16

Long-term operation experience with two ECR ion sources and planned extensions at HIT

Winkelmann Tim, Cee Rainer, Haberer Thomas, Naas Bernd, Peters Andreas

HIT-Heidelberger Ionenstrahl Therapie, Heidelberg, Germany

The HIT (Heidelberg Ion Beam Therapy Center) is the first hospital-based treatment facility at a hospital in Europe where patients can be treated with protons and carbon ions. Since the commissioning starting in 2006 two 14.5 GHz electron cyclotron resonance ion sources are routinely used to produce a variety of ion beams from protons up to oxygen. The operating time is 330 days per year, our experience after three years of continuous operation will be presented. In the future a helium beam for patient treatment is requested, therefore a third ion source will be integrated. This third ECR source with a newly designedextraction system and a spectrometer line will be installed at a testbench to commission and validate this section. Different test settings are foreseen to study helium operation as well as enhanced parameter sets for proton and carbon beams in combination with a modified beam transport line for higher transmission efficiency. An outlook to the possible integration scheme of the new ion source into the production facility will be discussed.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT17

CEA/Saclay light ion sources status and developments

Gobin Raphaël[(1)], Adroit Guillaume[(1)], Bourdelle Gilles[(1)], Chauvin Nicolas[(1)], Delferriere Olivier[(1)], Authier Yannick[(1)], Girardot Patrick[(1)], Harrault Francis[(1)], Mateo Cherry May[(1)], Nyckees Sebastien[(1)], Sauce Yannick[(1)], Senee Franck[(1)],Tuske Olivier[(1)], Van Hille Carine[(2)], Marolles Cedric[(1)], Pottin Bruno[(1)]

(1) CEA/Saclay, DSM/IRFU/SACM, France
(2) CEA/Saclay, DSM/IRFU/SIS, France

After several years of high intensity light ion beam production with the SILHI source, CEA Saclay is now involved in the construction of different injectors dedicated to large infrastructures like IFMIF or Spiral 2. Other installations are also interested by high intensity ion sources like ESS or FAIR. Such machines plan to produce and accelerate proton or deuteron beams in pulsed or continuous mode. The SILHI source, based on ECR plasma generation, already demonstrated its performance in both modes. As a consequence, at present time the construction of 2 new injectors for Spiral 2 and IFMIF (source and low energy beam lines) is in progress at CEA/Saclay. This article will report on the status of both installations. It will also point out on additional developments presently under progress for high intensity beam characterization or plasma production understanding. Such developments are mainly done with the new BETSI test bench operating for several months.

16:10-18:00 *Poster Session 2* Atrium
TUPOT

TUPOT18

Sheath Formation of a Plasma Containing Multiply Charged Ions, Cold and Hot Electrons, and Emitted Electons

You Hyun Jong

National Fusion Research Institute (NFRI), Daejon, Republic of Korea

A model of sheath formation was extended to a plasma containing multiply charged ions (MCIs), cold and hot electrons, and secondary electrons emitted either by MCIs or hot electrons. The present study was motivated by the fact that the secondary electron yields are strongly dependent on the charge state of the ions and on the incident energy of electrons. Therefore, the contributions of the secondary electron emissions on the sheath formation would be severe in ECRIS plasmas where the charge state of ions is high and highly energetic electrons exist. In the model, modification of the “Bohm criterion” was given; thereby the sheath potential drop and the critical emission condition were analyzed. The model calculations were made mainly on the effects of the emitted electrons on the variations of the sheath potential drop, the particle and heat flux to the wall, by which some explanations for the effect of secondary electrons in ECR ion sources are given.

16:10-18:00 ***Poster Session 2*** Atrium
TUPOT

TUPOT19

Stimulated Nonlinear RFS in Magnetized Plasma

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This is Raman Forward Scattering (RFS) of a high intensity short laser pulse in an underdense magnetized plasma; taking into account the relativistic effect is demonstrated. A model is developed on the basis of simple assumptions about the mechanism of stimulated Raman forward scattering. Differential equations which model the instability for large pump strengths are coupled and derived analytically. Growth rate of RFS is obtained and efficacy of magnetic field in rating of instability is investigated. It is shown that constant external magnetic field alters the growth rate effectively.

08:40-10:30 ***Plasma & Beam Investigations*** **Malaku Room**
WECOAK **Chair: Hongwei Zhao**

08:40 WECOAK01

Characterization of the microwave coupling to the plasma chamber of the LBL ECR ion source

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The characteristics of the microwave coupling of the 6.4 GHz ECR ion source were measured as a function of frequency, input power and time dependence. In addition the plasma diamagnetism and bremsstrahlung could be measured to help quantify the time dependence of the plasma build up and energy content. The LBL ECR plasma chamber, which has a diameter to wavelength ratio of 1.9 is not as over-moded as the 14 GHz AECR-U, which has a ratio greater than 3. This makes it possible to locate frequencies, where a single RF mode is predominately excited. For one of these modes we were able to demonstrate that with no plasma in the cavity, it is over-coupled and as the power is increased, the plasma density rises and the plasma loading increases it becomes under-coupled. By measuring the ratio of the incident to reflected power it is possible to show the microwave electric field levels saturate with increasing power. In the paper, the time dependence of the plasma loading and plasma diamagnetism as a function of input power and time are analyzed. The measurements of the plasma loading also provide insight into the dynamics of microwave heating in a multimode cavity.

08:40-10:30 ***Plasma & Beam Investigations*** **Malaku Room**
WECOAK **Chair: Hongwei Zhao**

09:02 **WECOAK02**

Some considerations about frequency tuning effect in ECRIS plasmas

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During the last years many experiments have demonstrated that slight variations in microwave frequency used to heat and sustain the plasma of ECRIS may strongly influence their performances (frequency tuning effect) both in terms of extracted current and mean charge state. Theoretical investigations revealed that this phenomenon can be correctly explained assuming that the plasma chamber works as a resonant cavity: standing waves are excited inside of it, and their spatial structure considerably changes even with slight variations of the pumping frequency. Therefore some particular modes present a higher electric field on the resonance surface that is the only region in which the energy transfer from waves to electrons occurs. Experimental measurements carried out on microwave discharge plasmas at high density (up to 1011 cm-3) featured that even if the absorption of electromagnetic energy at the ECR surface is evident, the stochastic nature of the wave-electron interaction allows the wave to be reflected at the extraction flange, thus forming a standing wave. The model here proposed, and based on PIC and MonteCarlo collisional simulations, puts in evidence that the frequency tuning effect in ECRIS has a global influence on plasma properties: it strongly affects both ion and electron dynamics. Electron heating, electron density distribution, ion formation and acceleration at resonance surface, beam formation are determined by the particular mode excited inside the cavity. This means that the frequency tuning will be an important tool for future ECRIS for the optimization of the beam quality (emittance, etc.).

08:40-10:30 ***Plasma & Beam Investigations*** **Malaku Room**
WECOAK **Chair: Hongwei Zhao**

09:24 **WECOAK03**

Studies of the ECR plasma in the visible light range

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In order to investigate experimentally ECR plasmas one way is to record their optical spectra or photos in the infra-red, visible light (VL), ultra-violet or X-ray regions. The measurements and analysis of photos and spectra taken in any of these regions are usually affordable tasks. The non-destroying nature of this method is certainly an advantage, but the drawback is that the recorded information in most cases means integration over a specific line-of-sight in the plasma volume. Recently high resolution VL plasma photographs were taken at the ATOMKI-ECRIS using an 8 megapixel digital camera. Plasmas were generated from eight gases (He, methane, N, O, Ne, Ar, Kr, Xe) and from their mixtures. The analysis of the photo series gave us many qualitative and numerous valuable physical information on the nature of ECR plasmas [1, 2]. It is a further challenging task to understand the colors of this special type of plasmas. The colors can be determined by the VL electron transitions of the plasma atoms and ions. Through the examples of He and Xe we analyze the physical processes which effects the characteristic colors of these plasmas.

[1] Racz R., Biri S., Palinkas J.: Electron cyclotron resonance plasma photos. Review of Scientific Instruments 81 (2010) 02B708
[2] Racz R., Biri S., Palinkas J.: ECR Plasma Photographs as Plasma Diagnostic. Submitted to Plasma Sources Science and Technology.

08:40-10:30 ***Plasma & Beam Investigations*** **Malaku Room**
WECOAK **Chair: Hongwei Zhao**

09:46 **WECOAK04**

Bremsstrahlung and ion beam current measurements with SuSI ECR ion source

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The Superconducting Source for Ions (SuSI) at the National Superconducting Cyclotron Laboratory at Michigan State University is a fully superconducting 3rd generation ECR ion source. The axial magnetic field is generated by six solenoid magnets which allow controlling the magnetic field characteristics, such as resonance locations, mirror ratios and magnetic field gradients, almost independently. In addition, a collimation scheme in the SuSI beam line after the analyzing magnet has been developed to optimize the ion beam production from the ion source within a given acceptance. These aspects make SuSI an excellent tool for ECRIS research and development. In this paper we will focus on the bremsstrahlung and ion beam current measurements where the gradient on the magnetic field is changed while keeping the Bmin and axial plasma length as constants. We will also show how the shift of the extraction side resonance location affects the extracted ion beam currents and radiation spectra and, finally, we will discuss about the effect of flatB mode with a modern superconducting ECR ion source on the ion beam production and radiation levels.

08:40-10:30 *Plasma & Beam Investigations* **Malaku Room**
WECOAK **Chair: Hongwei Zhao**

10:08 **WECOAK05**

Maximum bremsstrahlung energy versus different heating limits

Koivisto Hannu, Aho Vesa, Toivanen Ville, Tarvainen Olli, Jones Peter, Saren Jan, Peura Pauli

Department of Physics,University of Jyväskylä, Finland

A comprehensive set of bremsstrahlung measurements have been performed at JYFL (University of Jyvaskyla, Department of Physics) in order to understand the parameters affecting the time evolution of electron energy. In order to extend the understanding of electron heating, a new set of measurements with the JYFL 6.4 GHz ECRIS have been initiated to further study the parameters affecting the maximum bremsstrahlung energy. In the measurements the effect of magnetic field gradient, microwave power, plasma size and gas pressure were studied. In the analysis, main focus will be given to compare the results with different theoretical electron heating limits.

11:00-12:30 *Charge Breeding, Optics*
WECOBK

Malaku Room
Chair: Oliver Kester

11:00 **WECOBK01**

Commissioning of the ECRIS Charge State Breeder at TRIUMF

Ames Friedhelm[(1)], Baartman Rick[(1)], Bricault Pierre[(1)], Jayamanna Keerthi[(1)], Lamy Thierry[(2)]

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Radioactive isotopes produced at the ISOL facility ISAC at TRIUMF are usually extracted from the target ion source system as singly charged ions. If the mass of those ions exceeds A=30 their acceleration requires the breeding to highly charged ions. A modified version of an ECRIS charge breeder (14.5 GHz PHOENIX from Pantechnik) has been installed and a first on-line test resulting in the successful acceleration of 80Rb14+ has been performed already in 2008. During the radioactive beam time periods of 2009 and 2010 further measurements with stable and radioactive ions from different target ion source combinations have been performed to fully commission the system. Breeding efficiencies of several percent in the maximum of the charge state distribution have been achieved. Detailed results will be presented.

11:00-12:30 ***Charge Breeding, Optics*** **Malaku Room**
WECOBK **Chair: Oliver Kester**

11:22 **WECOBK02**

Recent Performance of the ANL ECR Charge Breeder

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The construction of the Californium Rare Ion Breeder Upgrade (CARIBU), a new radioactive beam facility for the Argonne Tandem Linac Accelerator System (ATLAS), is nearing completion. The facility will use fission fragments, with charge 1+ or 2+, from a 1 Ci 252Cf source; thermalized and collected into a low-energy particle beam by a helium gas catcher. An existing ATLAS ECR ion source was modified to function as a charge breeder in order to raise the ion charge sufficiently for acceleration in the ATLAS linac. A surface ionization source or an RF discharge source provide beams for charge breeding studies. An achieved efficiency of 11.9% for 85Rb19+, with a breeding time of 200 msec, and 15.6% for 84Kr17+ has been realized. Both results are with the source operating with two RF frequencies (10.44 + 11.90 GHz). After modification to the injection side iron plug, the charge breeder has been operated at 50 kV, a necessary condition for the resolution of the isobar separator.
This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

11:00-12:30 *Charge Breeding, Optics* **Malaku Room**
WECOBK **Chair: Oliver Kester**

11:44 **WECOBK03**

Fine frequency tuning of the PHOENIX charge breeder used as a probe for ECRIS plasmas

Lamy Thierry[(1)], Angot Julien[(1)], Galata Alessio[(2)]
Koivisto Hannu[(3)], Marie-Jeanne Melanie[(1)], Medard Jerome[(1)], Sortais Pascal[(1)], Tarvainen Olli[(3)], Thuillier Thomas[(1)], Toivanen Ville[(3)]

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Fine frequency tuning of ECR ion sources is a main issue to optimize the production of Multiply charged ion beams. The PHOENIX charge breeder operation has been tested in the range 13.75 – 14.5 GHz with an HF power of about 400 W. The effect of this tuning is analyzed by measuring the multi-ionization efficiency obtained for various characterized injected 1+ ion beams (produced by the 2.45 GHz COMIC source). The 1+/n+ method includes the capture and the multi ionization processes of the 1+ beam and may be considered as a plasma probe. The n+ spectra obtained could be considered, in first approach, as an image of the plasma of the charge breeder. However, in certain conditions it has been observed that the injection of a few hundreds of nA of 1+ ions (i.e.: Xe1+) in the plasma of the charge breeder, is able to destroy the charge state distribution of the support gas (i.e.: up to 40 % of O6+ and O7+ disappears). The study of this phenomenon will be presented along with plasma potential measurements for various charge states. This study may help to understand the ECRIS creation (or destruction) of highly charged ions.

11:00-12:30 ***Charge Breeding, Optics*** **Malaku Room**
WECOBK **Chair: Oliver Kester**

12:06 **WECOBK04**

Ion beam focussing and steering using a 3D-movable extraction

Panitzsch Lauri, Stalder Michael, Wimmer-Schweingruber Robert

CAU Kiel, Germany

The Department of Experimental and Applied Physics (IEAP) at the University of Kiel (CAU Kiel) is establishing a solar wind laboratory for the calibration of space instrumentation. The main item of this facility is a 11GHz (Plateau) ECR ion source. It can be operated at two different radial magnetic confinements, using a set of permanent magnets in either hexapole or dodekapole arrangement. While beam focussing by moving the extraction along the beam line to match the ion beam into the analysing magnet is well known, little is known about beam steering by moving the extraction in the plane perpendicular to the beam line. For the hexapole-configuration we will present our results about the feasibility of ion beam focussing and steering using a 3D-movable extraction. The beam profiles of these measurements will be recorded in comparatively high resolution with a Faraday cup array (see paper doi: 10.1063/1.3246787). This method will be shortly introduced within this talk, as well.

09:00-10:30 ***Ions Production & Beam Study*** **Malaku Room**
THCOAK **Chair: Renan Leroy**

09:00 **THCOAK01**

A correction scheme for the hexapolar error of an ion beam extracted from an ECRIS

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The extraction of any ion beam from ECRIS is determined by the good confinement of such ion sources. It has been shown earlier, that the ions are coming from these places, where the confinement is weakest. The assumption that the low energy ions are strongly bound to the magnetic field lines require furthermore, that only these ions which start on a magnetic field line which go through the extraction aperture can be extracted. Depending on the setting of the magnetic field, these field lines may come from the loss lines at plasma chamber radius. Because the longitudinal position of these field lines depends on the azimuthal position at the extraction electrode, the ions are extracted from different magnetic flux densities. Whereas the solenoidal component is not curable, the hexapolar component can be compensated by an additional hexapole after the first beam line focusing solenoid. The hexapole has to be rotatable in azimuthal direction and moveable in longitudinal direction. For a good correction the beam needs to have such a radial phase space distribution, that the force given by this hexapole act on the aberrated beam exactly in such a way to create a linear distribution after that corrector.

09:00-10:30 ***Ions Production & Beam Study*** **Malaku Room**
THCOAK **Chair: Renan Leroy**

09:22 **THCOAK02**

Kinetic Plasma Simulation of Ion Beam Extraction from a Hexapole ECR Ion Source

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Designing optimized ECR ion beam sources can be augmented by the accurate simulation of beam optical properties in order to predict ion extraction behavior. However, the complexity of these models can make PIC-based simulations time- consuming. In this paper, we describe a self-consistent finite element simulation of a permanent magnet hexapole ECR ion source with a multi-electrode extraction system. This simulation includes the interactions of electrons and ions in the ion source plasma chamber, the extraction of the beam from the plasma instead of from a free plasma surface, and the influence of secondary charged particles generated by ion collisions in the residual gas on the space charge in the beam. The model incorporates mixed linear and quadratic finite elements and non-linear magnetic materials. It uses a kinetic plasma emission model and generates secondary charged particles by sampling the primary beam trajectories. This method offers a fast and accurate modeling environment, including space charge interactions, suppressed electron flow, and magnetic field influences, and allows analysis of ion beam behavior under conditions of varying current density, electrode potential, and background gas pressure. The simulation predicts a triangular ion beam cross- section, which rotates in the magnetic field near the extraction electrodes.

09:00-10:30 *Ions Production & Beam Study* **Malaku Room**
THCOAK **Chair: Renan Leroy**

09:44 **THCOAK03**

Dipole magnet optimization for high efficiency low energy beam transport

Saminathan Suresh, **Beijers J. P. M, Mulder Jan, Mironov Vladimir, Brandenburg Sytze**

Kernfysisch Versneller Instituut, Gröningen, Netherlands

Losses in the low-energy beam transport line from KVI-AECRIS to AGOR cyclotron are estimated to be around 50%. Numerical simulations of the beam transport were performed using the tracing code LORENTZ-3D. It was found that most of the losses are due to second order optical aberrations in the 110-degree analyzing magnet. These aberrations result in an increase of the effective emittance in both horizontal and vertical directions. We will show that by suitably modifying the magnet pole surfaces the second-order aberrations can be compensated to a large extent resulting in a substantially lower effective emittance of the transported beam.

09:00-10:30 ***Ions Production & Beam Study*** **Malaku Room**
THCOAK **Chair: Renan Leroy**

10:06 **THCOAK04**

Modeling ECRIS using a 1D multifluid code

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We developed a one-dimensional (1D) multifluid code to simulate the production and the transport of multiple ion species in an electron cyclotron ion source (ECRIS). The ion species are assumed to be highly collisionally coupled. Each ion species is treated as a independent fluid. This allows us to study the influence of the ion temperature. The temperature is assumed to be equal for all charge states and in the whole ECRIS. As starting parameters we choose a hot magnetically trapped electron distribution, a cold electron distribution trapped by the plasma potential an the neutral density. Modeling the interaction of the different fluids led to a new understanding of the influence of the electrostatic potential that balances the pressure gradient of the ions species in the ECRIS. The highest charge states are not confined strongest as in the over barrier model but expelled in comparison to lower charge states. It can be shown that the relative velocity v of the treated fluids scales as v ~ T^(5/3) with the ion temperature. First results of the simulations are presented together with a discussion of the modeling approach for the multifluid case and its theoretical predictions. As a baseline for our simulations we mainly used the results of the 1D GEM ECRIS fluid simulations.