International Symposium on Electron Beam Ion Sources and Traps

EBIST 2018

23rd to 27th of October, 2018

Shanghai EBIT laboratory
Fudan University
Shanghai, China

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Topics:

- Progress and status of EBIS/T facilities
- Atomic spectroscopy of highly charged ions
- Charge-exchange and surface interaction with highly charged ions
- Charge breeding of stable and radioactive isotopes
- Nuclear physics with highly charged ions

Local Organizing Committee:

Ke Yao, Yang Yang, Liu Yang, Jun Xiao, Yang Shen, Baoren Wei, Zhimin Hu, Zhaowei Liu, Roger Hutton, Yaming Zou

Registration: Yanyuan Hotel, 270 Zhengtong Road
Venue: Guanghua Twin Tower, R103 (The East Podium Building)

13th International Symposium on Electron Beam Ion Sources and Traps

Program

October 23 - 27, 2018

Fudan University

Shanghai China

Tuesday 23 Oct.		
17:00 - 20:00	Registration	
Wednesday 24 Oct.		
Time	**Speaker**	**Title**
08:50 - 09:00	**Openning**	
	Chair:	
09:00 - 09:30	Alain Lapierre	The ReA EBIT Charge Breeder
09:30 - 10:00	Leigh Graham	The CANREB charge state breeder at TRIUMF
10:00 - 10:30	**Coffee Break**	
10:30 - 11:00	Endre Takacs	Isotopic Shift of Highly Charged Ion EUV Spectral Lines for Nuclear Charge Determination
11:00 - 11:30	Guiyun Liang	Charge-exchange spectroscopy in astrophysical plasmas
11:30 - 12:00	Hiroyoshi Sawa	Ion desorption from solid Ne surfaces induced by grazing incidence of slow multiply-charged Ar ions
12:00 - 14:00	**Lunch**	
	Chair:	
14:00 - 14:30	Joseph N. Tan	Experiments with a Unitary Penning Trap and its Application in Miniaturizing an EBIS/T
14:30 - 15:00	Zhimin Hu	Relativistic and QED Effects on Dielectronic Recombination of Highly Charged Heavy ions
15:00 - 15:30	Yang Yang	High-resolution tungsten spectroscopy relevant to the diagnostic of high-temperature tokamak plasmas and Researches on magnetic field induced transition
15:30 - 16:00	**Coffee Break**	
16:00 - 16:30	Peter Micke	The Heidelberg compact electron beam ion traps
16:30 - 17:00	Hannes Pahl	Progress of EBIS research and development at CERN
17:00 - 17:30	Ovsyannikov Vladimir	Main Magnetic Focus Ion Source: device with high electron current density
17:30 - 18:00	Alexey Boytsov	Applications of "Ef" Software for Electron Beam Ion Sources Design

Thursday 25 Oct.		
Time	**Speaker**	**Title**
08:50 - 09:00	**Openning**	
	Chair:	
09:00 - 09:30	Edward Beebe	The BNL EBIS Development Program: TestEBIS, RhicEBIS and ExtendedEBIS
09:30 - 10:00	Clayton Dickerson	Results of the CARIBU EBIS Reaccelerated Beam Program
10:00 - 10:30	**Coffee Break**	
10:30 - 11:00	Marek Pajek	Status of the Kielce EBIS facility
11:00- 11:30	Xiaolong Zhu	The progress report at the Lanzhou EBIS-A facility
11:30 - 12:00	SungNam Park	Status of the design and construction activities for the EBIT underway at UNIST for X-ray Spectroscopy of Highly-Charged Ions
12:00 - 14:00	**Lunch**	
14:00-18:00	Committee meeting.	
18:00	**Dinner**	

Friday 26 Oct.		
Time	**Speaker**	**Title**
	Chair:	
09:00 - 09:30	Oliver Kester	The TITAN EBIT charge breeder and spectrometry setup
09:30 - 10:00	Hyock-Jun Son	Current Development status of RAON EBIS Charge Breeder
10:00 - 10:30	**Coffee Break**	
10:30 - 11:00	Matthew Musgrave	Modeling of a Gas Injection System for Polarized 3He and Light Gases for the Extended EBIS Upgrade at BNL
11:00 - 11:30	Sergey Kondrashev	Development of high capacity distributed NEG pumping for the Extended EBIS Upgrade at BNL
11:30 - 12:00	Shunsuke Ikeda	Magnetic Alignment and Electron Beam Tests at the Extended EBIS test setup
12:00 - 14:00	**Lunch**	
	Chair:	
14:00 - 14:30	Evgeny Donets	Status report on recent developments in physics and technology of Electron String Ion Sources (ESIS)
14:30 - 15:00	Alexander Ramzdorf	Towards ISOL system for cancer therapy with positron-emissive ^{11}C ions
15:00 - 15:30	Masahiro Okamura	Laser driven initial ion beam provider for EBIS in BNL
15:30 - 16:00	**Coffee Break**	
16:00 - 16:30	Tomas Brage	Breit and QED in GRASP2k calculations, how can EBIT help
16:30 - 17:00	Naoki Kimura	Applications of buffer gas in a compact EBIT for reliable spectroscopic calibration
17:00 - 17:30	Daiji Kato	Modeling for emission line spectra of tungsten highly charged ions and its applications to tungsten measurements for fusion plasmas

Saturday 27 Oct.		
Time	**Speaker**	**Title**
	Chair:	
09:00 - 09:30	Thomas Stoelker	Storage and Trapping Facilities for Highly-Charged Ions at GSI/FAIR
09:30 - 10:00	Hanbing Wang	Towards precision laser spectroscopy of highly charged ions at heavy ion storage ring CSRe
10:00 - 10:30	**Coffee Break**	
10:30 - 11:00	Jun Xiao	Investigation of metastable levels in Highly Charged Tungsten ions at Shanghai EBITs
11:00 - 11:30	Hiroyuki SAKAUE	Observation of 4f-5s Electric Octupole (E3) Transition in the EUV Spectra of Ag-like Tungsten
	Closing Remarks	

The ReA EBIT Charge Breeder

Lapierre Alain [1]

[1]National Superconducting Cyclotron Laboratory, MSU - East Lansing,USA

The electron-beam ion trap (EBIT) charge breeder of the ReA post-accelerator, located at the National Superconducting Cyclotron Laboratory (Michigan State University), started on-line operation in September 2015. Since then, the EBIT has been delivering pilot beams of stable isotopes and several rare-isotope beams for the nuclear-physics program. This contribution will present results obtained over the years of charge-breeding efficiencies, pulse stretching, beam purity measurements, development of new stable-isotope beams, and control of an isomeric state (48-K), among others. This contribution will also discuss future plans regarding a second EBIS charge breeding for production of high-intensity ion beams.

The CANREB charge state breeder at TRIUMF

Leigh Graham[1]

[1]TRIUMF, lgraham@triumf.ca

The CANadian Rare-isotope facility with Electron-Beam ion source (CANREB) will couple with the worldleading isotope-production capabilities at TRIUMF to produce clean and controlled beams of selected exotic isotopes that have large number of neutrons. The EBIS will receive beam from the RFQ cooler and buncher prior to injection and the extracted beam will be separated by a NIER separator. The maximum electron beam parameter are 1 A beam current and 15 keV beam energy. An electron beam current density can be achieved to allow for charge states that result in an $A/q < 7$ for all ion species and a maximum repetition rate of 100 Hz. The CANREB EBIS will be operational in 2018 and is planned to be ready for beam delivery to experiments in 2019.

Isotopic Shift of Highly Charged Ion EUV Spectral Lines for Nuclear Charge Determination

R. Silwal[a;b], A. Lapierre[c], J.D. Gillaspy[b;d], A.C.C. Villari[c], G. Gwinner[e], S.A. Blundell[f] , J.M. Dreiling[b], A. Borovik Jr[g], Dipti[b], Yu. Ralchenko[b], and **E. Takacs**[a;b]

[a]Department of Physics and Astronomy, Clemson University, SC

[b]National Institute of Standards and Technology (NIST), Gaithersburg, MD

[c]National Superconducting Cyclotron Laboratory, Michigan State University, MI

[d]National Science Foundation, Arlington, VA

[e] Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada

[f]INAC/SYMMES, CEA-Grenoble/Universite Grenoble Alpes, France

[g]Physikalisches Institut Justus-Liebig Universitat Giessen, Giessen, Germany

Accurate measurements of mass and size of nuclei are primary importance for the study of fundamental symmetries, nucleon-nucleon interactions, nuclear astrophysics studies, and the structure of exotic nuclei [1]. The increased overlap of the electronic wave functions with the nucleus in highly charged high-Z systems makes them sensitive to nuclear effects making them a good probe of nuclear properties. In this work, we will discuss a technique for the determination of $\delta\langle r^2\rangle$ from the isotope shift measurement of the extreme-ultraviolet (EUV) transitions in highly charged ions.

The isotope shifts of the Na-like D1 (3s $^2S_{1/2}$ - 3p $^2P_{1/2}$), Mg-like 3s^2 $^1S_0$ - 3s3p $^1P_1$, Mg-like 3s^2 $^1S_0$ - 3s3p $^3P_1$, Al-like 3s^{2}3p $^2P_{1/2}$ -3s^{2}3p $^2P_{3/2}$, and Al-like 3s^{2}3p $^2P_{1/2}$ -3s^{2}3d $^2D_{3/2}$ transitions were measured between the isotopes of ^{124}Xe and ^{136}Xe. The electron beam ion trap at the National Institute of Standards and Technology (NIST) was employed to create these highly charged ions and measure the EUV transitions with a flat-field grazing incidence spectrometer [2].

The difference in the mean-square nuclear charge radius of xenon isotopes was determined by calculating the field shift and mass shift coefficients by two different methods: relativistic many body perturbation theory (RMBPT) and multi-configuration Dirac-Hartree-Fock (MCDHF) with the GRASP2K package [3].

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Charge-exchange spectroscopy in astrophysical plasmas

Guiyun Liang[1]

[1]National Astronomical Observatories, Chinese Academy of Science, China

X-ray emissions in comet (Comet C/Hyakutake) were observed firstly in 1996 by using the Röntgen X-ray Satellite[1]. Various explanations were proposed, wherever charge-exchange (CX) mechanism between the solar wind and cometary atmosphere was regarded as a plausible one after such X-ray detection in other comets[2] and planets (i.e. Earth, Venus, Saturn, Mar and Jupiter) in solar system[3]. Such X-ray emissions were detected in shock front of supernova remnants (SNR) [4] as well as some starburst galaxies. Recently, this kind of X-rays were also suggested to be a powerful tracer for both the locations where SNR hot gas interacts with neutral gas (notably in the thin post-shock layer) and the interfaces between the hot and cold gas in the ISM. This is key information to understand the feedback processes of supernovae, starburst galaxies and galactic winds. CX emission is made exclusively of lines, and being differs from that in case of coronal-like plasma[5,6]. In this report, we will present the research status of CX spectroscopy in astrophysics as well as our recent efforts on modeling and experiment in the framework of laboratory astrophysics[7].

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Ion desorption from solid Ne surfaces induced by grazing incidence of slow multiply-charged Ar ions

H. Sawa[1], S. Uchida[1], H. Ueta[1] and T. Hirayama[1]

[1] Department of Physics, Rikkyo University, Tokyo 171-8501, Japan.

We report here ion desorption from noble gas solids induced by the impact of slow multiply-charged ions (MCIs) in order to investigate potential sputtering processes. In our previous work [1, 2], we measured the mass distribution of ions desorbed from a surface of solid Ne under 1 keV Ar^{q+} ($q \leq 7$) impact, and reported that the potential sputtering of Ne_n^+ cluster ions was observed in the desorption yield of small size ($n \leq 3$) clusters. To acquire more detailed information about potential sputtering from noble gas solids, we constructed a new apparatus for coincidence measurements of scattered and desorbed ions induced by grazing incidence.

Figure 1 shows (a) the charge-state distribution of scattered ions from a surface of solid Ne (200 ML) by 6 keV Ar^{6+} impact and (b) the time-of-flight spectra of desorbed ions in coincidence with the scattered ions. Desorbed Ne^+ and Ne_2^+ are found in the spectra in coincidence with Ar^+ and Ar^{2+}, but not with Ar^0.

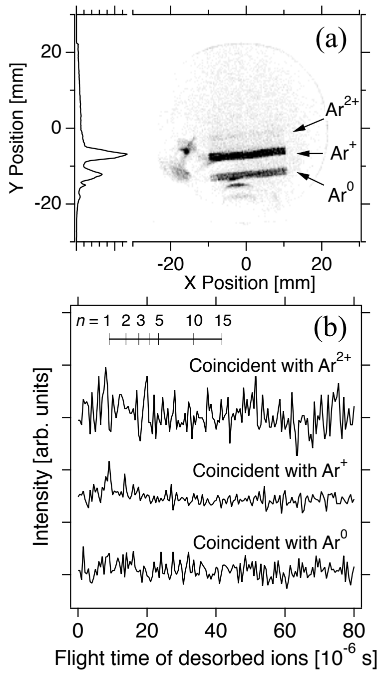

Figure 1. (a) Charge-state distribution of the scattered ions from a solid Ne surface (200 ML) by 6 keV Ar^{6+} impact. (b) TOF spectra of the desorbed ions in coincidence with the scattered ions shown above. The n denotes the size of desorbed Ne_n^+.

Neutralization of the incident MCIs starts at a relatively large distance (~ a few nm) from the surface by resonant capture of electrons from the target, which result in the formation of "hollow atoms" [3]. In the case of metal targets, neutralization of MCIs is finished after repetitive de-excitation of the hollow atoms and re-capturing of electrons, however, this is not the case for Ar^{q+} impact on Ne solid because the ionization energy of a Ne atom (target) is larger than the potential energy of Ar^+. Therefore, the assistance of the kinetic energy is required for the production of the neutral Ar^0, i.e. scattered Ar^0 can be a trigger of a collision cascade in solid Ne, which results in the desorption of Ne cluster ions [2]. Thus, we conclude that the desorption of Ne^+/Ne_2^+ in coincidence with $Ar^{1+/2+}$ is solely induced by the potential sputtering.

<u>References</u>

[1] K. Fukai, S. Fujita, T. Tachibana, T. Koizumi, T. Hirayama, J. Phys. Cond. Matt. **22**, 084007 (2010).

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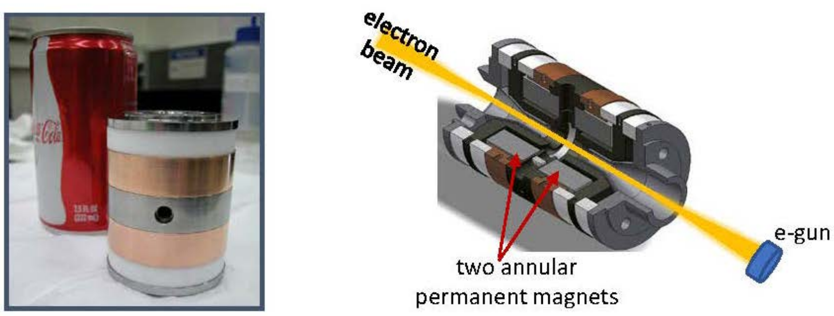
Experiments with a Unitary Penning Trap and its Application in Miniaturizing an EBIS/T

Joseph N. Tan[1]

[1]National Institute of Standards & Technology, Maryland 20899, U. S. A.

A compact Penning trap can be used to capture and isolate multiply ionized atoms, allowing measurements in a well-characterized environment. An extremely compact system is obtained if the Penning trap fields (E,B) are generated by a set electrodes with embedded permanent magnets [1], fully integrated into a hand-held unit as illustrated in Fig. 1(a). Some experiments in a unitary Penning trap are discussed briefly to illustrate its use for studying atomic processes and testing basic atomic theory [2,3].

Another application of a unitary Penning trap is its adaptation in constructing a small electron beam ion source/trap. Recent tests at NIST show that such a miniaturized EBIS/T, illustrated in Fig. 1(b), can produce a wide range of highly charged ions with low ionization thresholds [4]. This is an interesting regime for the production of multiply ionized atoms with forbidden transitions that have been proposed for the development of robust optical frequency standards and other precision measurements.



(a) (b)

Figure 1: (a) Photograph of a unitary Penning trap. (b) Schematic diagram of a small EBIS/T using a unitary Penning trap as the central drift tube.

<u>References</u>

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Relativistic and QED Effects on Dielectronic Recombination of Highly Charged Heavy ions

Zhimin Hu,[*,1] Gang Xiong,[*] Jiamin Yang,[*] Stanislav Tashenov,[†] Chintan Shah,[†] Holger Joerg,[†] Nobuyuki Nakamura,[‡] José R. Crespo López-Urrutia,[§] Jiyan Zhang,[*] and Baohan Zhang[*]

[*]Laser Fusion Research Center, China Academy of Engineering Physics, Mianyang 621900, China

[†]Physics Institute, Heidelberg University, 69120 Heidelberg, Germany

[‡]Institute for Laser Science, University of Electro-Communications, Tokyo 182-8585, Japan

[§]Max-Planck-Institut für Kernphysik, Heidelberg, 69117 Heidelberg, Germany

Synopsis The resonance strength and x-ray asymmetry measurements of DR show the significant Breit interaction contribution to electron-electron interaction, and the Compton polarimetry gives a higher sensitivity to this intrinsically relativistic effect. Those works allow one to access the QED corrections of the generalized Breit interaction.

The quantum electrodynamics (QED) effects are of importance for fundamental science, in particular, for atomic physics. QED effects have been tested by the precise measurement of transition energy of few-electron heavy ions. However, the QED effects on the atomic collisions have never been done in experiments. The lowest order QED effect in the electron collision can be described through so-called generalized Breit interaction, it can be derived rigorously within the framework of quantum electrodynamics (QED) as the retardation in the exchange of a virtual photon between the electrons. When the frequency of the virtual photon approaches zero, the simplified version of the Breit interaction can be obtained, which is also can be derived in the classical electrodynamics frame.

The importance of the Breit interaction has been confirmed in the electron-ion collisions, such as impact ionization, dielectronic recombination (DR), and impact excitation. Nevertheless, all of the experiments mentioned previously can be reproduced by the simplified Breit interaction theory. Aiming to test the QED effect, generalized Breit interaction effect, we have already done the anisotropy and polarization measurements of the DR x ray lines. The dominance of the Breit interaction has been demonstrated in the anisotropy measurements, and polarization measurements show the significant contribution of the Breit interaction. Most importantly, Compton polarimetry, which gives a higher sensitivity to the intrinsically relativistic Breit interaction effect, has been used in the electron ion beam trap (EBIT) experiments, and this technique is a promising approach to allow one to access the QED corrections of the generalized Breit interaction.

In this talk, we present the measurements of anisotropy[1,2], resonance strength[3,4,5] and linear polarization[6,7,8] of DR x-ray lines in EBIT.

References

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[1] E-mail: zhimin.hu@caep.cn

High-resolution tungsten spectroscopy relevant to the diagnostic of high-temperature tokamak plasmas and Researches on magnetic field induced transition

Y. Yang[1], J. Rzadkiewicz[2], K. Kozioł[2], W. Li[1], Tomas Brage[3], M. G. O'Mullane[4], A. Patel[5], J. Xiao[1], K. Yao[1], Y. Shen[1], D. Lu[1], R. Hutton[1], Y. Zou[1], and JET Contributors[5]

[1]Shanghai EBIT Laboratory, Key Laboratory of Nuclear Physics and Ion-Beam Application (MOE), Institute of Modern Physics, Fudan University, Shanghai 200433, China

[2]Narodowe Centrum Badań Jądrowych (NCBJ), Andrzeja Sołtana 7, 05-400 Otwock-Świerk, Poland

[3]Division of Mathematical Physics, Department of Physics, Lund University, Sweden

[4]Department of Physics, University of Strathclyde, Glasgow G4 0NG, United Kingdom

[5]Euratom/CCFE Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, United Kingdom

The x-ray transitions in Cu- and Ni-like tungsten ions in the 5.19–5.26Å wavelength range that are relevant as a high-temperature tokamak diagnostic, in particular for JET in the ITER-like wall configuration, have been studied. Tungsten spectra were measured at the upgraded Shanghai- Electron Beam Ion Trap operated with electron-beam energies from 3.16 to 4.55 keV. High-resolution measurements were performed by means of a flat Si 111 crystal spectrometer equipped by a CCD camera. The experimental wavelengths were determined with an accuracy of 0.3–0.4 mÅ. All measured wavelengths were compared with those measured from JET ITER-like wall plasmas and with other experiments and various theoretical predictions. It was found that such an extension brings the calculations closer to the experimental values in comparison with other calculations.

Magnetic field induced transition was studied systematically, especially with Ne-like and Cl-like isoelectronic ions. And an accidental degeneracy of quantum states in Fe9+ was found which induced a novel method to determine magnetic fields in low density plasma.

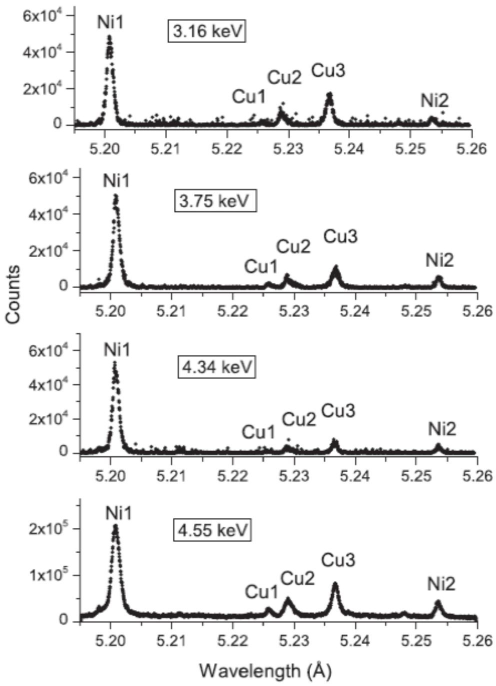

Figure 1. X-ray spectra of Cu- and Ni-like tungsten ions measured on the upgraded Shanghai EBIT for electron-beam energies of 3.16, 3.76, 4.34, and 4.55 keV.

The Heidelberg compact electron beam ion traps

P. Micke[1,2], S. Kühn[1], L. Buchauer[1], J. R. Harries[3], T. M. Bücking[1], K. Blaum[1], A. Cieluch[1], A. Egl[1],

D. Hollain[1], S. Kraemer[1], T. Pfeifer[1], P. O. Schmidt[2,4], R. X. Schüssler[1], Ch. Schweiger[1], T. Stöhlker[5,6,7], S. Sturm[1], R. N. Wolf[1], S. Bernitt[1], and J. R. Crespo López-Urrutia[1]

[1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

[2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

[3]National Institutes for Quantum and Radiological Science and Technology, SPring-8, Hyogo 679-5148, Japan

[4]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

[5]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany

[6]Helmholtz-Institut Jena, 07743 Jena, Germany

[7]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

In order to make highly charged ions (HCI) accessible for a wider physics community, we have developed a novel class of room-temperature electron beam ion traps (EBIT), the Heidelberg Compact EBITs (HC-EBIT). The magnetic structure is based on permanent magnets with a center field of 0.86 T for electron-beam compression, featuring stable, low-maintenance operation and an open structure to install detectors and spectrometers at a close distance of only a few cm from the trapped ions for large solid angles. The electron beam was operated up to 10 keV and 80 mA.

Four devices are in operation to provide HCIs for high-precision mass and g-factor measurements in Penning traps, high-resolution laser spectroscopy in cryogenic Paul traps aiming at HCI-based clock applications, to perform x-ray spectroscopy of dielectronic recombination with an exceptional electron-energy resolving power of more than 1500 at 5 keV of the iron KLL resonances, and x-ray laser spectroscopy at synchrotron or free-electron laser (FEL) facilities. For the latter application a novel off-axis electron gun was developed, offering a free axis along the electron beam for collinear overlap with the photon beam. Resonant photoexcitation of highly charged oxygen was demonstrated at the BESSY II synchrotron in Berlin. A second batch of three EBITs is currently under construction.

We report on the EBIT design and recent experiments.

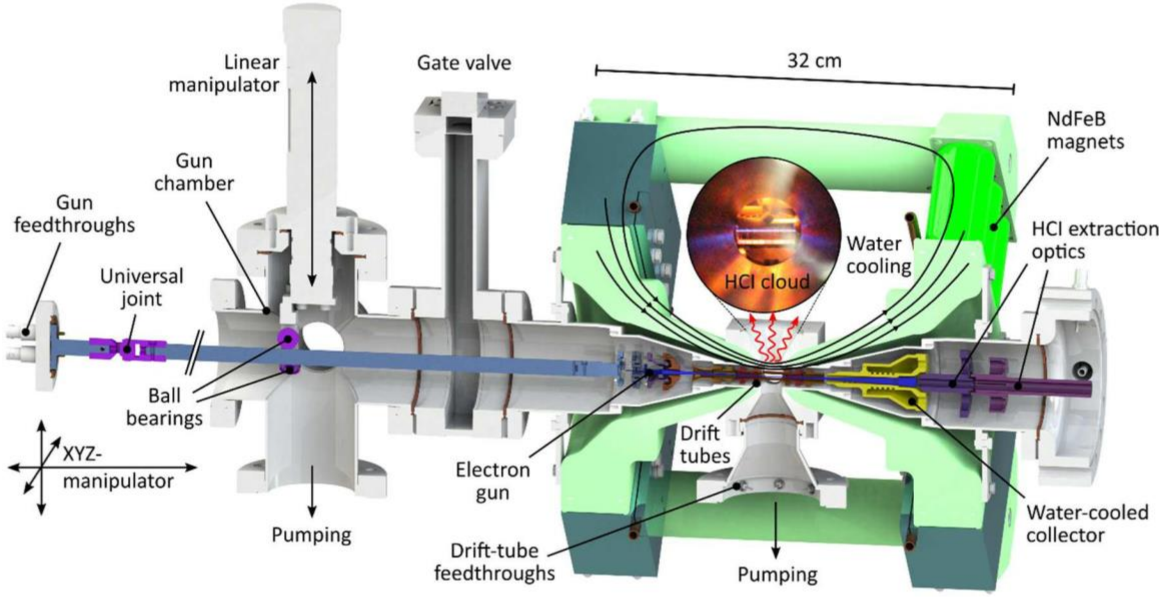

Figure 1: Simplified schematic of the HC-EBIT. The inset shows a photograph of a bluish fluorescing HCI cloud.

References
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(2018) peter.micke@mpi-hd.mpg.de

Abstract for EBIST 2018 Progress of EBIS research and development at CERN

Hannes Pahl[1, 2], Niels Bidault[1], Vittorio Bencini[1, 3], Martin Breitenfeldt[4], Angelo Granadeiro Costa[1, 5], Alexander Pikin[1, 6], Johanna Pitters[1], Fredrik Wenander[1]

[1] CERN, Route de Meyrin, 1211 Geneva 23, Switzerland

[2] Heidelberg Graduate School of Fundamental Physics, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

[6] INFN, Sapienza University of Rome, Piazzale Aldo Moro 2, 00185 Rome, Italy

[4] ADAM SA, Rue de Veyrot 11, 1217 Meyrin, Switzerland

[5] Centro de Ciências e Tecnologias Nucleares, Instituto Superior Técnico, University of Lisbon, E.N. 10 ao km 139, 2695-066 Bobadela LRS, Portugal

[6] School of Physics and Astronomy, The University of Manchester, Manchester, M13 9PL, United Kingdom

A high-compression Brillouin-type electron gun, the MEDeGUN, has been developed for medical and nuclear physics research applications. Recently, first tests of this gun were performed at the TwinEBIS test bench. We present the results and conclusions from the first commissioning run, during which a 10 keV electron beam of more than 1 A was successfully injected into a 2 T solenoid field. Ensuing modifications and additions to the setup are also discussed.

In order to prepare the TwinEBIS setup for future experiments, including comprehensive studies of the MEDeGUN performance, the test stand is going to be extended with a low-energy ion injection and extraction beamline. The installation of this beamline is foreseen in the upcoming year. Here, we report on the finalised design of the beamline, highlighting some of the key components including a three-way switchyard, gridded electrostatic lenses and the diagnostic equipment.

Furthermore, we are investigating the importance of dielectronic recombination for the charge state evolution inside an electron beam ion source and whether such resonances could be used to manipulate the resulting charge state distribution. Preliminary results from both simulations and measurements performed at REXEBIS (ISOLDE) for the KLL resonances of highly charged ^{39}K are discussed.

Main Magnetic Focus Ion Source: device with high electron current density

V. P. Ovsyannikov[1] and A. V. Nefiodov[2]

[1] Joint Institute for Nuclear Research, Dubna, Russia

[2] Petersburg Nuclear Physics Institute, St. Petersburg, Russia

The theoretical principles of the Main Magnetic Focus Ion Source (MaMFIS) with variable electron beam energy are presented. The MaMFIS technology is based on the use of a local ion trap, which appears in a crossover of rippled electron beam [1,2]. The concept of the ion source looks like the concept of electron microscope. The electron beam is focused into the region of the local ion trap, where the electron current density can reach extremely high values of the order of 10 kA/cm^2. Thus far a whole family of pilot models of ion source has been developed and tested. During recent experiments the x-ray spectra emitted due to the electron radiative recombination into the M- and L-shells of Ar, Ir, Ce and Bi ions are recorded.

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Applications of “Ef” Software for Electron Beam Ion Sources Design

Boytsov A.[1], Bulychev A.[2], Donets E.E[1]., Getmanov I.[3], Ovsyannikov V.[4],

[1]Joint Institute For Nuclear Research (Russian Federation, Dubna)

[2]Russian Quantum Center (Russian Federation, Moscow)

[3]Saint Petersburg State University (Russian Federation, Saint Petersburg)

[4]MaMFIS Group (Russian Federation, Dubna)

Design of modern electron beam ion sources (EBIS) requires numerical simulation of charged particle dynamics using different methods. Development of software for this task has been started at JINR[1]. Currently, it allows to model trajectories of particles in external fields using Boris time integration scheme. Particle-particle interaction can be taken into account using binary forces or Particle-In-Cell method[2]. Such components of electron beam ion sources as electron guns, drift structure, extraction system can be simulated. Main features of the software will be demonstrated. Simulation results of off-axial ion extraction from EBIS and electron beam in MAin Magnetic Focus Ion Source (MAMFIS)[3] will be presented as examples.

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The BNL EBIS Development Program: TestEBIS, RhicEBIS and ExtendedEBIS*

E. Beebe[1], G. Atoian[1], B. Coe[1], S. Ikeda[1], T. Kanesue[1], S. Kondrashev[1], D. McCafferty[1], M. Musgrave[2], M. Okamura[1], A. Pikin[3], D. Raparia[1], J. Ritter[1], B. Schoepfer[1], A. Zelenski[1]

[1]Brookhaven National Laboratory, Upton, NY 11973, USA

[2]MIT, Cambridge, MA, USA

[3]CERN, Geneva, Switzerland

The ExtendedEBIS will provide 2.1x10^9 Au^{32+}/pulse at the Booster ring entrance, a 40-50% intensity upgrade compared with the existing RhicEBIS at BNL. The increased intensity will be attained primarily through an increase in the ion trap length, while maintaining the electron beam power, as well as the launch and collection schemes. This concept was used in upgrading from the prototype TestEBIS, with electron beam 10A, to the RhicEBIS which doubled the trap length from 0.7m to 1.5m in the nominal design within a single longer solenoid. Since its installation in late 2009, the RhicEBIS has been very active and reliable, rapidly switching between highly charged ions of many species for both RHIC and NSRL operations. During the brief intervals between operations and accelerator maintenance periods, some electron gun development has been performed at the RhicEBIS facility. More demanding and time-consuming research has been done at the TestEBIS facility.

In the new ExtendedEBIS concept, the axial magnetic field for an extended ion trap region is achieved through the use of two closely coupled 5T superconducting solenoids, reinforced to withstand the axial forces between the modules. As part of the ExtendedEBIS upgrade, efficient gas injection capability using a pulsed valve (<1ms) will be installed to provide high intensities of light ions. Initial proof of principle using electron beams up to 6A has been demonstrated through a reduced diameter gas cell prototype geometry at the TestEBIS facility. Ion trapping and extraction manipulations using residual gas has also been demonstrated. The ExtendedEBIS is currently under construction in the former TestEBIS laboratory. A rapid sequence of tests will be made to achieve the necessary alignment, vacuum pumping, gas injection and external ion injection capabilities needed for the final operational machine. A gas injection cell will exist in the upstream solenoid with several stages of differential pumping between the adjacent trap region and the downstream solenoid trap region. Expected intensities, based on present performance and the scaled trap length are H^+~1x10^{12} ions/pulse and $^4He^{2+}$ ~5x10^{11} ions/pulse. The design includes provisions for providing beams of polarized $^3He^{2+}$ during a future upgrade, and could also accommodate the injection of isotopically enhanced gases such as ^{136}Xe.

*Work performed under contract No. DE-AC02-98CH1-886 under the auspices of the DOE of United States, and by the National Aeronautics and Space Administration.

Results of the CARIBU EBIS Reaccelerated Beam Program

Clayton Dickerson[1], Richard Vondrasek[1], Guy Savard[1], Daniel Santiago-Gonzalez[1]

[1]Physics Division, Argonne National Laboratory, Lemont, IL 60439, USA

The Electron Beam Ion Source (EBIS) charge breeder for the Californium Rare Isotope Breeder Upgrade (CARIBU) was recently commissioned for operation at the Argonne Tandem Linear Accelerator System (ATLAS). During the commissioning phase various EBIS performance characteristics were studied: charge breeding efficiencies and charge state distributions for a range of injected ion species, the trap electrode configuration, elongating the extracted pulse length, etc. Understanding these EBIS characteristics helped identify useful procedures to configure the accelerator and eventually deliver radioactive ion beams to target for experiments. The results of the EBIS development and ATLAS operations while delivering CARIBU reaccelerated beam will be presented.

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

Status of the Kielce EBIS facility

D. Banaś[1], Ł. Jabłoński[1], P. Jagodziński[2], A. Kubala-Kukuś[1], J. Semaniak[1], D. Sobota[1], I. Stabrawa[1], K. Szary[1], **M. Pajek[1]**

[1]Institute of Physics, Jan Kochanowski University, 25-406 Kielce, Poland
[2] Department of Mathematics and Physics, Kielce University of Technology, 25-314 Kielce, Poland

The electron beam ion source (EBIS) based laboratory for investigations of interactions of highly charged ions (HCI) with matter, which was established in the Jan Kochanowski University in Kielce, Poland, is discussed here. The HCI can be produced in the EBIS-A type ion trap (Dreebit, Germany) [1] and after ion extraction and charge state selection in the double-focusing bending magnet the ion beams are directed to the multipurpose experimental chamber. In this configuration of the EBIS the experiments can be conducted in three locations: the ion trap (X-ray emission from EBIT plasma), the Faraday cup after the bending magnet (electron impact fragmentation of molecules) and the multipurpose experimental chamber (ion-surface interactions) [2].

In order to study *in situ* the modifications of surfaces irradiated by HCI the EBIS facility is coupled to various surface diagnostic instruments [3] via the UHV sample manipulation and transfer devices. Presently the X-ray emission in EBIT/S can be measured by a silicon drift detector (SDD), but installation of high-resolution X-ray von Hamos and EUV grating spectrometers is planned. The installed surface diagnostic tools include photoelectron/Auger electron (PES/AES) and inverse photoelectron (IPES) spectroscopy, ion scattering spectroscopy (ISS) and μm-resolution scanning electron (SEM/SAM) and atomic-resolution scanning probe (AFM/STM) microscopy. The MBE system for deposition of nanolayers, equipped with electron diffraction instruments (LEED, RHEED), will be installed soon.

In this paper, three examples of recent experiments performed at the Kielce EBIS facility is discussed in more details: i) X-ray emission from "hollow" atoms formed in collisions of Xe^{q+} ions (q=26-35) with metallic Be, ii) formation of surface nanostructures on Au-nanolayers/Si bombarded by slow highly charged Xe ions, and (iii) fragmentation of deuterated propane (C_3D_8) molecules by keV-electrons. New findings will be emphasized and discussed here.

Acknowledgements

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The progress report at the Lanzhou EBIS-A facility

X. L. Zhu,[1,*] X. Ma,[1] J. Y. Li,[1] M. Schmidt,[2] W. T. Feng,[1] H. Peng,[3] J. W. Xu,[1,4] G. Zschornack,[2,5,6] H. P. Liu,[1] T. M. Zhang,[1] D. M. Zhao,[1] D. L. Guo,[1] Z. K. Huang,[1] X. M. Zhou,[1] Y. Gao,[1] R. Cheng,[1] H. B. Wang,[1,4] J. Yang,[1] and L. Kang[1]

[1]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
[2]DREEBIT GmbH, 01109 Dresden, Germany
[3]School of Nuclear Science and Technology, Lanzhou University, Lanzhou 730000, China
[4]University of Chinese Academy of Sciences, Beijing 100049, China
[5]Department of Physics, Dresden University of Technology, 01062 Dresden, Germany
[6]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany

A new, compact and flexible low energy experimental platform of highly charged ions (HCIs) based on an electron beam ion source of the Dresden EBIS-A type is presented. The so-called IMP EBIS-A Facility of the Institute of Modern Physics (IMP) in Lanzhou is designed as a user facility for the state-resolved charge exchange studies in HCIs with atoms and molecules collisions by cold target recoil ion momentum spectroscopy. The important feature of this facility is that it can provide higher charge state and lower energy heavy ions in room temperature and limited space. The IMP EBIS-A facility consists of the Dresden EBIS-A ion source, a Wien filter as well as beam focusing and beam diagnostics elements. All components are installed on a small high voltage platform connected with an ion beam deceleration and acceleration lens assembly. The testing results reached and exceeded the expectation of the design. The first experiment of state-resolved charge transfer based on the IMP EBIS-A facility was introduced based on the new cold target recoil ion momentum spectroscopy. Figure 1 shows a sketch of the IMP EBIS-A facility and COLTRIMS in Lanzhou.

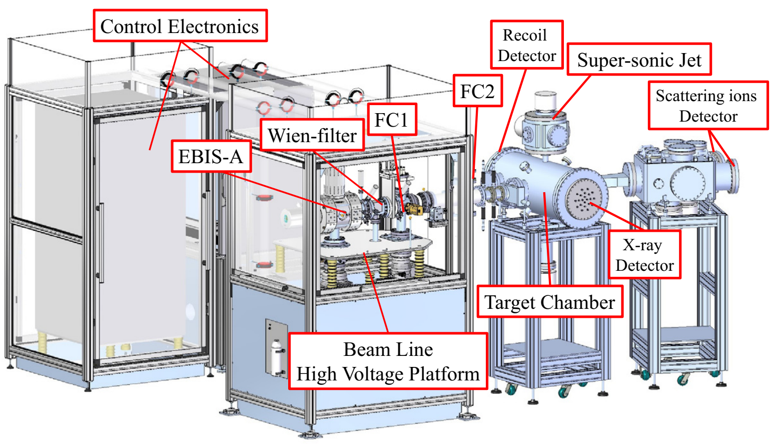

Figure 1: Sketch of the IMP EBIS-A facility and COLTRIMS at Institute of Modern Physics in Lanzhou.

* zhuxiaolong@impcas.ac.cn

Status of the design and construction activities for the EBIT underway at UNIST for X-ray Spectroscopy of Highly-Charged Ions.

SungNam Park[1] and Moses Chung[1]

[1]Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Korea

Intense Beam and Accelerator Laboratory(IBAL) at Ulsan National Institute of Science and Technology(UNIST) is building a miniaturized Electron Beam Ion Trap(mini-EBIT) for the spectroscopy of the highly charged Ions(HCIs). The compact, easily portable table-top mini-EBIT, with an on-axis electron gun which generates up to 8 keV energy-tunable electron beam, and a 0.86 T room-temp permanent magnet, allows us to do the X-ray spectroscopy of the HCIs in a cost-effective and low-maintenance way. Our primary goal is to do the astrophysics related X-ray spectroscopy at the newly built Korean PAL-XFEL(Pohang Accelerator Laboratory X-ray Free Electron Laser) facility. In this work, we present the status of the design and construction activities for the mini-EBIT underway at UNIST, in collaboration with Max-Planck Institute for Nuclear Physics in Germany.

The TITAN EBIT charge breeder and spectrometry setup

Oliver Kester[1]

[1]TRIUMF, okester@triumf.ca

The precision of mass measurements in a Penning trap is directly proportional to an ion's charge state and can be increased by using highly charged ions (HCI) from an Electron Beam Ion Trap (EBIT). To use this method for short-lived isotopes, very high electron beam current densities are required of the TITAN EBIT. This EBIT has produced charge states as high as Kr34+ and Ba54+ with electron beams of up to 500 mA and 27 keV. Aside the use as a charge state breeder the EBIT is used for in-trap decay spectroscopy. Therefore the EBIT is surrounded radially by seven low-energy planar Si(Li) detectors that allow for the detection of low-energy photons by providing backing-free storage of the radioactive ions, while guiding charged decay particles away from the trap centre via the strong (up to 6 T) magnetic field. In addition to excellent ion confinement and storage, the EBIT also provides a venue for performing decay spectroscopy on highly charged radioactive ions. Recent technical advancements have been able to provide capabilities on measuring weak electron-capture branching ratios of the intermediate nuclei in the two-neutrino double beta decay process.

Current Development status of RAON EBIS Charge Breeder

Hyock-Jun Son[1], Young-Ho Park[1], Sergey Kondrashev[2], Taeksu SHIN[1], Jongwon Kim[1], Jun Young Moon[1], Ramzi Boussaid[1], Seongjin Heo[3], Liu Haolin[3], Kyoung-Hun Yoo[4], and Moses Chung[4]

[1]Rare Isotope Science Project, Institute for Basic Science, Daejeon 34126, Republic of Korea

[2]Collider-Accelerator Department, Brookhaven National Laboratory, Upton, New York 11973, USA

[3]Department of Accelerator Science, Korea University, Sejong 30019, Republic of Korea

[4]Department of Physics, Ulsan National Institute of Science and Technology, Ulsan 44919, Republic of Korea

The RAON is a heavy ion accelerator facility, which is under construction in Korea for the Rare Isotope Science Project (RISP). This facility is designed to apply both In-flight Fragment (IF) and Isotope Separation On-Line (ISOL) techniques in order to produce various Rare Isotope (RI) beams for nuclear physics experiments. An Electron Beam Ion Source (EBIS) will be used for charge breeding of RI beams in the ISOL system [1]. The mass-to-charge ratio (A/Q) of the RI beams after the charge breeding is in between 2 and 6. The RAON EBIS charge breeder system can be divided into 4 sections such as electron gun (e-gun), collector, ion trap, and ion transport section. The RAON EBIS [2] will use a 3 A e-gun and a 6 T superconducting solenoid to increase electron beam current density for large trapping capacity, high breeding efficiency, and short breeding time. The ion trapping capacity of the RAON EBIS is expected to be 2.18 x 10^{11} charges under the expected conditions of the electron beam and magnetic field configuration. The electron beam will be dumped into the collector which has been designed with a maximum power consumption up to 20 kW.

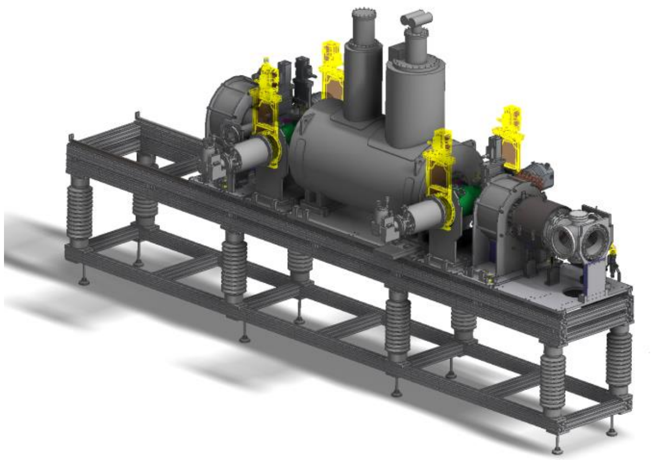

Figure 1: Design of RAON EBIS charge breeder

In our e-gun/collector test bench, an electron beam of 2.5 A has been extracted and collected. There are 10 drift tubes inside the trap chamber, and the ion trap length is about 800 mm. A strict vacuum level of 10^{-11} torr range is required in this region. The pumping system consists of two TMPs, two cryo-pumps, and NEG ZAO modules. A vacuum test of the ion trap section has been performed with baking, and the vacuum level reached 2.08 x 10^{-11} torr. For the ion transport line system, we have designed 5 sets of electrostatic ion beam optics to inject and extract the ion beams of different charge states. The manufacturing of the ion transport line system is nearly finished. Cs ions will be utilized for off-line commissioning of the RAON EBIS. Optimization of the extraction optics for the Cs^{1+} surface ionization ion source has been carried out using SIMION code, and the ion beam extraction test has been performed with a beam energy of 5 keV. In this paper, current development status and initial component test results of the RAON EBIS charge breeder will be presented in detail.

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Modeling of a Gas Injection System for Polarized ^{3}He and Light Gases for the Extended EBIS Upgrade at BNL

M. Musgrave[1], G. Atoian[2], E. Beebe[2], S. Ikeda[2], T. Kanesue[2], S. Kondrashev[2], J. Maxwell[3], D. McCafferty[2], R. Milner[1], M. Okamura[2], A. Pikin[4], D. Raparia[2], J. Ritter[2], B. Schoepfer[2], A. Zelenski[2]

[1]MIT, Cambridge, MA, USA

[2]Brookhaven National Laboratory, Upton, NY, USA

[3]Thomas Jefferson National Accelerator Facility, Newport News, VA, USA

[4]CERN, Geneva, Switzerland

The Extended EBIS Upgrade at BNL includes a system for efficient gas injection and ionization in the upstream section of the 5 T magnetic field. The design will feature the ability to polarize ^{3}He in the bore of the 5 T superconducting solenoid to enable the injection of polarized ^{3}He gas and the realization of a polarized $^3He^{++}$ ion source, which has been identified as an R&D priority for an electron-ion collider (EIC). The goal of the polarized $^3He^{++}$ ion source is to achieve 2.5×10^{11} $^3He^{++}$/pulse at 70% polarization. The gas injection system will also enable more efficient ionization of light gases and isotopically pure gases such as ^{136}Xe. Modeling is performed with MolFlow, which is a freely available Monte Carlo simulator for high vacuum developed by CERN. The model of the Extended EBIS gas injection system is used to optimize the high vacuum in the EBIS while enabling efficient ion production and to determine the ionization and charge breeding rates of the injected gas.

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Development of High Capacity Distributed NEG Pumping System for the Extended EBIS Upgrade at BNL

S. Kondrashev, E. Beebe, B. Coe, J. Ritter

Brookhaven National Laboratory, Upton, NY 11973, USA

Corresponding Author: Sergey Kondrashev, e-mail address: skondrashev@bnl.gov

Ultra-high vacuum is extremely important for stable and reliable operation of EBIS/T devices. We are developing linear pumping system based on ZAO NEG module recently introduced by SAES Getters. This pumping system will be used for Extended EBIS Upgrade which is presently under development at BNL. A new ZAO NEG material has higher pumping speed and, what is more importantly, significantly higher sorption capacity for all active gasses in comparison with previously available types of getters. ZAO NEG module has been modified to be heated up to 700 °C by passing up to 120 A DC current through stainless steel cage for required NEG activation and re-activation temperature cycles. A method of pumping speed measurements using pulsed gas injection into vacuum chamber has been developed and used for characterization of ZAO NEG-based linear pumping system. The results of tests and design of ZAO NEG-based linear pumping system will be presented and discussed.

Work supported by the US Department of Energy under contract number DE-SC0012704 and by the National Aeronautics and Space Administration.

Magnetic Alignment and Electron Beam Tests at the Extended EBIS test setup

S. Ikeda, E. Beebe, S. Kondrashev, M. Okamura, and J. Ritter

Collider-Accelerator Department, Brookhaven National Laboratory

The electron beam ion source (RhicEBIS) has been used to provide many types of highly charged ions with the Relativistic Heavy Ion Collider (RHIC) and the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory (BNL). At the lab, a new EBIS (Extended EBIS) is being developed to produce polarized helium-3 ions and larger number of ions within a single beam pulse. Extended EBIS has two separated 1.5-m superconducting magnets in series while RhicEBIS uses a 1.5-m magnet. In one of the magnets, a gas cell is placed to inject polarized helium or other types of gases. Meanwhile, the two magnets make at least 1.4 times longer trap region. Since two magnets are contained in cavities separately, the magnet system can have misalignment that would make it difficult to propagate electron beam or introduce larger beam emittance. We estimated possible magnet misalignment and displacement of the electron beam from an ideal center line. Then we are building a test setup to align magnet system and propagate the electron beam. In the conference, we will present the misalignment estimation and the results of the alignment and the electron beam propagation test.

Status report on recent developments in physics and technology of Electron String Ion Sources (ESIS)

A.Yu. Boytsov, D.E. Donets, E.D. Donets, **E.E. Donets**[1], D.O. Ponkin, D.N. Rassadov, A. Yu. Ramsdorf, V.V. Salnikov and V.B. Shutov

[1]Laboratory of High Energy Physics, Joint Institute for Nuclear Research, Dubna, 141980 Russia
e-mail: edonets@jinr.ru

Recent results on basic and applied studies on a production of highly charged ions with use of Electron String Ion Sources (ESIS) (EBIS working in a reflex mode of opereation) will be presented.

Krion-6T ESIS is a test stand version of an ion source for future JINR **NICA** collider. During recent years Krion-6T ESIS was successfully used twice on a Nuclotron - JINR superconducting synchrotron, and highly charged ion beams of $^{12}\mathbf{C}^{6+}$, $^{40}\mathbf{Ar}^{16+}$, $^{78}\mathbf{Kr}^{26+}$ and $^{124}\mathbf{Xe}^{41+}$ were produced and accelerated.

Stand results on production of HCI of heavy elements will be discussed. The observed efficient values of the ESIS trap capacity/ion yields and the efficient electron current density under various physics conditions will be emphasized.

Progress in a Tubular EBIS/ESIS development and recent results in applied researches with HCI will be briefly presented as well.

Towards ISOL system for cancer therapy with positron-emissive ^{11}C ions.

Yu. Boytsov,[1] E. D. Donets,[1] E. E. Donets,[1] **A.Yu. Ramzdorf**,[1]
K. Katagiri,[2] T. Wakui,[2] S. Hojo,[2]

[1]Joint Institute for Nuclear Research,Joliot-Curie 6, Dubna 141980, Russia

[2]National Institute of Radiological Sciences,4-9-1 Anagawa, Inage-ku, Chiba 263–8555, Japan

The facility for production of the radioactive ^{11}C ion beam is under development now at NIRS (Chiba, Japan). The system is based on the Isotope Separation On Line (ISOL) technique. The advantage of the radioactive ^{11}C beam in comparison with the ^{12}C beam in heavy ion cancer therapy is the possibility of precise real-time dose control using the positron emission tomography. The recent developments of the parts of ISOL system are presented. The ^{11}C Cryogenic Molecule Production/Separation (CMPS) system was designed and tested [1]. The EBIS type ion source was chosen as a Single Charged Ion Source (SCIS). The results of the SCIS test are presented. The optimal ^{11}C containing gaseous substance for use as working gas for the SCIS is discussed. The ESIS is proposed as a charge breeder for the ISOL system [2,3]. The required characteristics of further charge breeder are discussed. The multiply charged ^{11}C ion beam will be injected to the Heavy Ion Medical Accelerator Complex (HIMAC).

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Laser driven initial ion beam provider for EBIS in BNL

M. Okamura[1], S. Ikeda and T. Kanesue[1]

[1]Collider-Accelerator Department, Brookhaven National Laboratory

Since 2014, laser ion source (LIS) has been used to deliver solid based singly charged ions to the EBIS in BNL. The LIS can provide wide variety of intense ion beams with simple structure. More than ten solid materials can be mounted on a motorized linear stage and ion species are easily switched within several seconds. To have a reasonable ion pulse length induced laser plasma drifts in a three meter long solenoid magnet which is typically energized from 10 to 100 Gauss. Since a LIS does not use any gases, residual gas load to the EBIS can be minimized. In the symposium, detailed structure and features of the LIS will be explained.

Breit and QED in GRASP2k calculations, how can EBIT help

Tomas Brage[1]

[1]Division of Mathematical Physics, Department of Physics, Lund University,Sweden,
tomas.brage@fysik.lu.se

When aiming for high accuracy, there are two different and ”competing” challenges to Computational Atomic Physics. The inclusion of correlation requires large-scale calculations, especially the dynamic part, while the Relativistic and Breit corrections are of more fundamental importance. To test the latter it would therefore be essential to find systems where the former is small. In this talk we discuss systems that are Layzer-quenched[1], i.e. that due to the Pauli principle exhibit small correlation contributions. As examples we discuss the fine structure in in systems with $2p^5$ and $3d^9$ ground configurations[1,2]. We apply different models for QED and discuss the importance of the frequency dependent Breit-interaction, and finally we give recommendations on new experiments to probe the different calculations.

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Applications of buffer gas in a compact EBIT for reliable spectroscopic calibration

Naoki Kimura[1,2], Ryuunosuke Kodama[3], Kento Suzuki[3], Shimpei Oishi[3], Michiharu Wada[4], Kunihiro Okada[1], Noriaki Ohmae[5,6], Hidetoshi Katori[5,6,7], Nobuyuki Nakamura[3]

[1]Dept. of Physics, Sophia University, Tokyo 102-8554, Japan

[2]RIKEN Nishina Center, Saitama 351-0198, Japan

[3]Inst. for Laser Science, The University of Electro-Communications, Tokyo 182-8585, Japan

[4]Wako Nuclear Science Center, Inst. of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK), Saitama 351-0198, Japan

[5]Quantum Metrology Laboratory, RIKEN, Saitama 351-0198, Japan

[6]RIKEN Center for Advanced photonics, Saitama 351-0198, Japan

[7]Dept. of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan

Recently, visible transitions of highly charged ions (HCIs) have become attractive research topics for several applications such as analysis of the solar corona [1], plasma diagnosis in ITER [2] and the development of HCI atomic clocks [3,4]. Although some visible transitions in HCIs have been observed directly by a visible spectrometer connected with several electron beam ion traps (EBITs) [5-7], it is necessary to measure the wavelength as accurately as possible for the applications to HCI atomic clocks.

For reliable wavelength measurements of visible transitions in HCIs, we demonstrated a calibration method using noble gases introduced into a compact EBIT. The calibration lines derived from the neutral or singly ionized noble gas were observed at the same time as HCI line observation. By introducing this method, several systematic errors in spectroscopic calibration can be eliminated.

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Modeling for emission line spectra of tungsten highly charged ions and its applications to tungsten measurements for fusion plasmas

Daiji Kato[1,2], Shota Era[2], Hiroyuki A. Sakaue[1], Izumi Murakami[1,3], Motoshi Goto[1,3], Tetsutaro Oishi[1,3], Chihiro Suzuki[1], Nobuyuki Nakamura[4], and Shigeru Morita[1,3]

[1]National Institute for Fusion Science, Toki, Gifu 509-5292, Japan

[2]Department of Advanced Energy Engineering Science, Kyushu University, Fukuoka 816-8580, Japan

[3]Department of Fusion Science, SOKENDAI, Toki, Gifu 509-5292, Japan

[4]Institute for Laser Science, The University of Electro-Communications, Chofu, Tokyo 182-8585, Japan

Tungsten is selected as divertor materials for the next fusion device, ITER (international thermonuclear experimental reactor), because tungsten has a lower tritium retention, a lower sputtering rate by hydrogen isotopes, and a high thermal conductivity. However, extremely high heat flux (10-20 MW/m^2) and particle load (10^{24} DT/m^2) on the divertor surfaces will inevitably cause erosion of the tungsten wall. Tungsten contamination in core plasmas will strongly enhance radiation power loss of the core plasmas. Therefore, prediction and control of tungsten transport is a very important subject for sustainable applications of tungsten in ITER. Emission lines from tungsten ions can be used to measure tungsten ion distributions. However, applications of the tungsten emission lines to fusion plasma researches are rather limited due to a lack of knowledge on available spectral data especially for highly charged ions. Using a compact electron-beam-ion-trap (CoBIT) [1], 6g-4f, 5g-4f, 5f-4d, 5p-4d, and 4f-4d transitions of W^{19+} - W^{32+} in the extreme-ultra-violet (EUV) region [2] and magnetic-dipole transitions in the ground states of W^{7+} - W^{28+} in ultra-violet through visible regions [3-6] were studied, respectively. Some of these emission lines are observed from tungsten ions injected in core plasmas of Large Helical Device (LHD) using solid pellet injection techniques [7-10]. The LHD discharge sustained by neutral beam injection heating (> 10 MW) is entirely stable for a substantial amount of tungsten density.

The emission line spectra are analyzed using collisional-radiative (CR) models. In the present CR models, detailed kinetics of electron and proton collisions and radiative transitions of tungsten ions are solved using rate coefficients based on atomic data from HULLAC (Hebrew University Lawrence Livermore Atomic Code) [11]. Charge-state distributions of tungsten ions and local ion density distributions in LHD core plasmas are studied based on the emission line intensities. The charge-state distributions at the plasma center are obtained by spectral synthesis of EUV emission lines from W^{24+} - W^{34+} [12]. The radial ion density distributions of W^{26+} and W^{27+} in the LHD core plasmas are deduced from spatially resolved magnetic-dipole line intensities [13]. The deduced ion abundance ratio W^{27+}/W^{26+} agrees with the transport-free ionization equilibrium model using ionization-recombination rate coefficients of ADAS database [14].

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Storage and Trapping Facilities for Highly-Charged Ions at GSI/FAIR

Thomas Stöhlker[1,2,3] on behalf of the SPARC collaboration

[1]Helmholtz-Institut Jena, 07743Jena,Germany

[2]GSI Helmholtzzentrum für Schwerionenforschung, 64291Darmstadt,Germany

[3]IOQ, Friedrich-Schiller-Universität, 07737Jena,Germany

Interactions with matter involving heavy high-Z ions provide a unique testing ground for our understanding of quantum electrodynamics in the non-perturbative regime as well as of elementary atomic processes mediated by ultrafast electromagnetic interactions. For this realm of physics, the future international accelerator Facility for Antiproton and Ion Research (FAIR) has key features that offer a range of new and challenging research opportunities [1]. In this talk, I will in particular focus on the novel research opportunities provided by the ion storage rings of GSI/FAIR in combination with novel instrumentation. Most notably, the portfolio of trapping and storage ring facilities will cover a beam-energy regime of more than 10 orders of magnitude up to 5 GeV/u, for heavy ions at highest charge state. Examples for the high-energy domain include e.g. laser spectroscopy exploiting the large Doppler boost associated with relativistic ions. For medium and low beam energy regime, e.g. experiments at the border between atomic and nuclear physics will be addressed with emphasis on rare nuclear decay and reaction modes. As an example for such future experiments at CRYRING (currently getting commissioned at GSI/FAIR) [2], a recent precursor experiment for bare ions but low-beam energies will be discussed, relevant for nuclear reactions in stars. Here the focus is on the study of proton and alpha capture reactions [3].

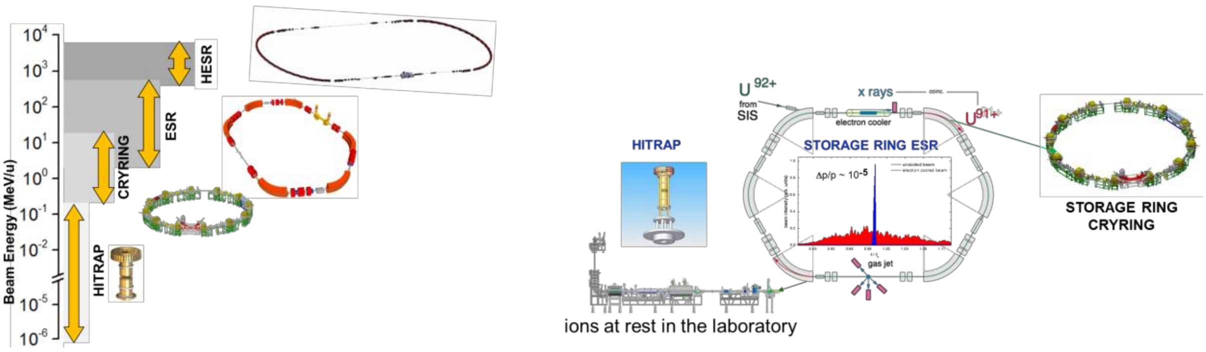

Figure 1: Left side; Portfolio of storage and trapping facilities at GSI/FAIR, comprising the trapping facility HITRAP and the storage rings CRYRING, ESR, and HESR. Right side; the ESR storage and trapping facility complex (HITRAP, ESR, CRYRING).

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Towards precision laser spectroscopy of highly charged ions at heavy ion storage ring CSRe

H. B. Wang[1], **W. Q. Wen**[1,i], Z. K. Huang[1], D. C. Zhang[2], D.Y. Chen[2], H.Y. Zhang[2], D. Winters[3], S. Klammes[3], D. Kiefer[4], Th. Walther[4], S. Litvinov[3], N. Khan[1,5], B. Hai[1,5], D. M. Zhao[1], X. L. Zhu[1], X. N. Li[1], J. Li[1], L. J. Mao[1], R. S. Mao[1], T.C. Zhao[1], J. X. Wu[1], D.Y. Yin[1], J. C. Yang[1], Y. J. Yuan[1], M. Bussmann[6] and **X. Ma**[1,ii]

[1] Institute of Modern Physics, Chinese Academy of Sciences, 730000 Lanzhou, China

[2] School of Physics and Optoelectronic Engineering, Xidian University, Xi'an, 710071, China

[3] GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

[4] Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany

[5] University of Chinese Academy of Sciences, 100049 Beijing, China

[6] Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Laser cooling of lithium-like $^{16}O^{5+}$ ion beams with an relativistic energy of 275.7 MeV/u was achieved for the first time at the heavy-ion storage ring CSRe in Lanzhou, China. In the experiment, a CW laser system with a wavelength of 220 nm was used to match the optical transition of $2s_{1/2}$-$2p_{1/2}$ of $^{16}O^{5+}$ ions at this beam energy. In order to cool the relativistic ion beams with only one counter-propagating CW laser, the ion beams were bunched by applying a sinusoidal voltage to the RF-buncher system. Fig. 1 (a) shows the Schottky spectrum of laser-cooled bunched $^{16}O^{5+}$ ion beams with a fixed laser. The relative longitudinal momentum spread of laser-cooled ion beams reached dp/p less than 1×10^{-6} as shown in Fig. 1 (b) which is extracted from slice (1) in Fig. 1 (a). The successful laser cooling of $^{16}O^{5+}$ ion beam demonstrates the highest charge state and highest energy of ions that have been ever cooled by lasers.

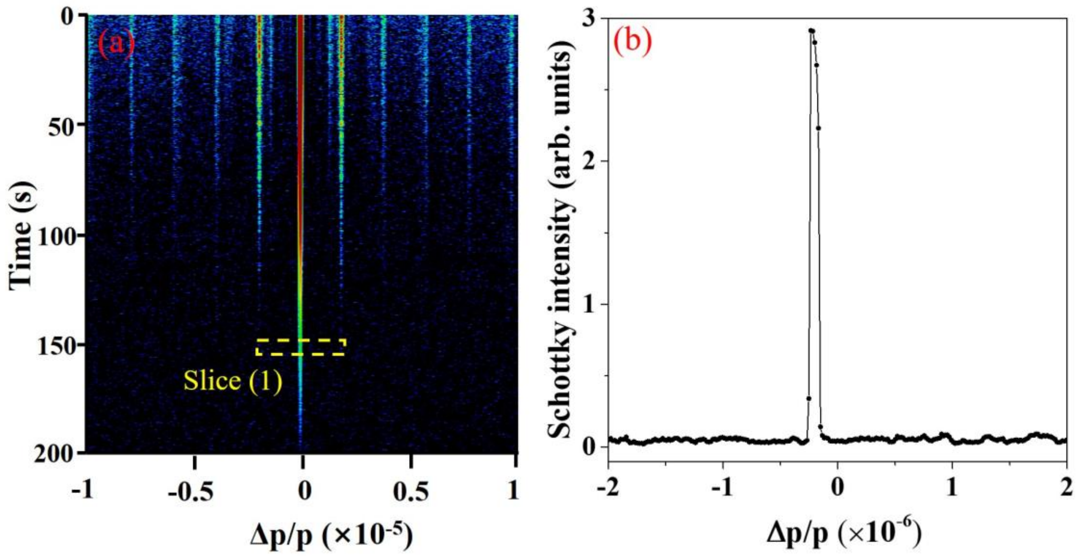

Figure 1: Figure 1. (a) Schottky spectrum of laser-cooled bunched $^{16}O^{5+}$ ion beams with a fixed laser. (b) The relative longitudinal momentum spread extracted from Slice (1) in figure (a)

Based on the successful laser cooling experiment of $^{16}O^{5+}$ ions, the precision laser spectroscopy experiment is in preparation at the CSRe. Two new optical detectors for forward emitted photons by the relativistic ions will be designed and installed at the CSRe [1, 2]. Besides, the high voltage of the electron cooler will be calibrated precisely to get the precise beam energy [3]. Precision laser spectroscopy of $^{16}O^{5+}$ ions for measuring the transition energy of $2s_{1/2}\rightarrow 2p_{1/2}$ and $2s_{1/2}\rightarrow 2p_{3/2}$ is foreseen, and the expected precision is about 10^{-5}.

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[i] wenweiqiang@impcas.ac.cn
[ii] x.ma@impcas.ac.cn

Tungsten Spectroscopy Studies at Shanghai EBITs

J. Xiao [1], B. Tu[1], K. Yao[1], Y. Yang[1], M. Li[1], Y. Shen[1], Y. Fu[1], B. Wei[1], C. Chen[1], T. Brage[1,2], R. Hutton[1] and Y. Zou[1]

[1]Shanghai EBIT Lab, Institute of Modern Physics, and Key Laboratory of Nuclear Physics and Ion-beam Application(MOE), Fudan University, Shanghai 200433, China

[2]Division of Mathematical Physics, Department of Physics, Lund University, Sweden

In this talk, recent fusion related tungsten spectroscopy studies at Shanghai EBITs[1-3] will be presented. During the past several years, tungsten spectra from visible to EUV region has been observed for the moderate and high charge state ions[4-11]. By analyzing the spectra with the help of theoretical calculations, using state-of-the-art techniques, we are able to identify term and fine structure splittings in the ground and the first excited configuration for several charge states. Meanwhile, some metastable levels which have extremely long lifetime and high population are also found, which may have large influences on the charge state distribution of tungsten ions in tokamaks. Figure 2 shows an extremely-long-lived metastable level in W^{52+} ions, which can be considered as a second ground for fusion plasma[11].

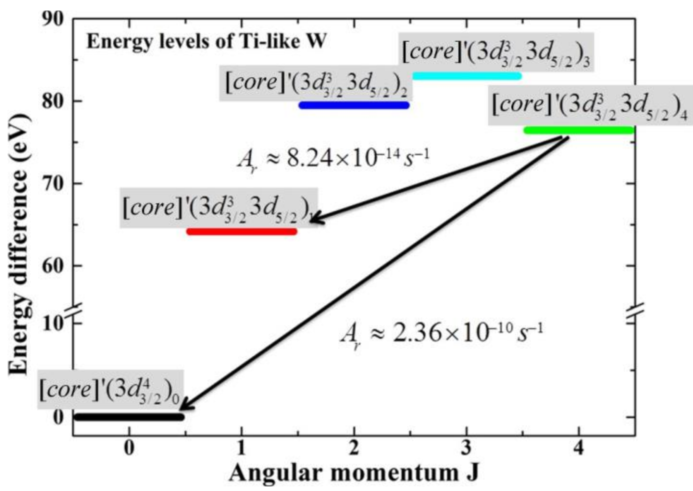

Figure 1: Levels diagram for the ground and first excited configuration of Ti-like W^{52+} ions.

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Observation of 4f-5s Electric Octupole (*E3*) Transition in the EUV Spectra of Ag-like Tungsten

H. A. Sakaue[1], D. Kato[1,2], I. Murakami[1,3], H. Ohashi[4] and N. Nakamura[5]

[1] National Institute for Fusion Science, Toki, Gifu 509-5292, Japan

[2] Department of Advanced Energy Engineering Science, Kyushu University, Fukuoka 816-8580, Japan

[3] Department of Fusion Science, The Graduate University for Advanced Studies (SOKENDAI), Toki, Gifu 509-5292, Japan

[4] Graduate School of Science and Engineering for Research, University of Toyama, Toyama, Toyama 930-8555, Japan

[5] Institute for Laser Science, The University of Electro-Communications, Chofu, Tokyo 182-8585, Japan

Atomic spectra are generally dominated by electric dipole (***E1***) transitions. However, radiative decay processes which are forbidden by the ***E1*** selection rules can take place through higher-order terms of the multipole expansion of the radiation field. The long-lived upper levels of such decays of low-probability often serve as diagnostics in nuclear fusion and astrophysical plasmas and other fields [1,2].

We focused on such forbidden transitions of long-lived upper levels in emission line spectra from highly charged tungsten ions. We have previously reported extreme ultra-violet (EUV) spectra of the highly charged tungsten ions with charge numbers from 19+ to 32+ in a compact electron beam ion trap (CoBIT) for the wavelength range of 15Å to 55Å. The dominant transitions in the EUV spectra are identified as 4f - 5g, 4f - 6g and 4d - 4f ***E1*** transitions [3]. In this talk, we report the measurements for an extended wavelength range of 60 Å to 140 Å. Figure 1 shows the EUV spectrum of CoBIT. In the measured spectra, strong emission lines near 90 Å are identified as the electric octupole (***E3***) transition of 4f - 5s in W^{27+}. In the spectra, the $4f_{7/2,5/2}$ - 5s transitions are identified as the first observation of spontaneous electric octupole decay. Although the Einstein A coefficient of these ***E3*** transitions are very small (~10^1 s^{-1} by Hullac-code) comparing with that of the ***E1*** transitions of 5p - 5d (~ 10^{11} s^{-1}) observed near 126Å, the ***E3*** emission line intensities are apparently as strong as the ***E1*** transition line. This is because the fractional population of the 5s-metastable state calculated using a collisional-radiative model is about ten orders of magnitude larger than that of the 5d excited state. Moreover, our theoretical investigation shows that the decays are observable only for a narrow atomic number (Z) region around 74 in spite that higher Z elements have much higher transition probability, which drastically increases with Z as Z^{40}.

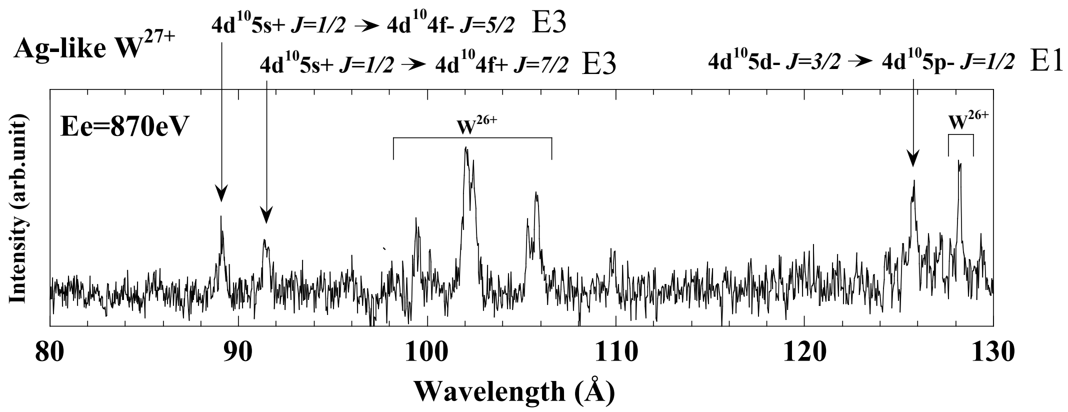

Figure 1: EUV spectrum of tungsten obtained with CoBIT at an electron energy of 870 eV.

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Design and Development of the GBAR Antiproton Trap

K. Yoo[1], S. H. Moon[1], M. Chung[1], D. H. Won[2], S. K. Kim[2], E. Lim[3], E. S. Kim[3]

[1]Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Korea

[2]Seoul National University, Seoul 08826, Korea

[3]Korea University, Sejong 30019, Korea

The GBAR experiment (Gravitational Behaviour of Antihydrogen at Rest) at CERN has been proposed to measure the gravitational acceleration of ultracold antihydrogen atoms [1]. In this experiment, antihydrogen ions are produced by antiprotons and positronium atoms at first. Then, antihydrogen atoms are produced for the free fall experiment after the photo-detachment of excess positrons from the cold antihydrogen ions. The energy of the antiproton beam before the positronium target chamber is about 1 keV (5.3 MeV from the CERN AD, 100 keV cooled by the ELENA, and 1 keV after the Decelerator). The cross section for the reaction between antiprotons and positroniums increases as their energy decrease [2]. That is, to make the productivity of the antihydrogen ions higher, the energy of the antiprotons should be decreased. In this regard, an antiproton trap is being designed and developed to slow down the antiproton beams after the Decelerator, and cool them by means of the electron cooling technique. This trap consists of a superconducting solenoid magnet, a series of ring electrodes including the trapping electrodes based on the Penning-Malmberg trap configuration, a set of extraction electrodes, optics for the beam transport, an electron gun (e-gun) for the electron cooling, and the vacuum and cryogenic systems for the UHV. Each electrode has been designed and optimized using the WARP PIC simulation, and the e-gun performance has been estimated using the CST simulation. Furthermore, the vacuum system has been developed for the preliminary test at the room temperature. In this work, the design and development status of each component of the trap will be presented.

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Venue

Guanghua Twin Tower

Registration & Welcome Reception

Yanyuan Hotel

Tuesday		Wednesday		Thursday		Friday		Saturday
23 Oct.	**Time**	**24 Oct.**	**Time**	**25 Oct.**	**Time**	**26 Oct.**	**Time**	**27 Oct.**
	08:50 - 09:00	**Openning: Yaming Zou**						
	Chair	**Ke Yao**	Chair	**Oliver Kester**	Chair	**Alain Lapierre**	Chair	**Edward Beebe**
	09:00 - 09:30	Alain Lapierre	09:00 - 09:30	Edward Beebe	09:00 - 09:30	Oliver Kester	09:00 - 09:30	Thomas Stoelker
	09:30 - 10:00	Leigh Graham	09:30 - 10:00	Clayton Dickerson	09:30 - 10:00	Hyock-Jun Son	09:30 - 10:00	Hanbing Wang
	10:00 - 10:30	Coffee Break+ Photo	10:00 - 10:30	Coffee Break	10:00 - 10:30	Coffee Break	10:00 - 10:30	Coffee Break
	10:30 - 11:00	Endre Takacs	10:30 - 11:00	Marek Pajek	10:30 - 11:00	Matthew Musgrave	10:30 - 11:00	Jun Xiao
	11:00 - 11:30	Guiyun Liang	11:00 - 11:30	Xiaolong Zhu	11:00 - 11:30	Sergey Kondrashev	11:00 - 11:30	Hiroyuki SAKAUE
	11:30 - 12:00	Hiroyoshi Sawa	11:30 - 12:00	SungNam Park	11:30 - 12:00	Shunsuke Ikeda		Closing Remarks
	12:00 - 14:00	**Lunch**						
	Chair	**Evgeny Donets**	14:00-18:00	Committee Meeting	Chair	**Thomas Stoelker**		
	14:00 - 14:30	Joseph Tan			14:00 - 14:30	Evgeny Donets		
	14:30 - 15:00	Zhimin Hu			14:30 - 15:00	Alexander Ramzdorf		
	15:00 - 15:30	Yang Yang			15:00 - 15:30	Masahiro Okamura		
17:00-20:00 Registration. Welcome Reception .	15:30 - 16:00	Coffee Break			15:30 - 16:00	Coffee Break		
	16:00 - 16:30	Peter Micke			16:00 - 16:30	Tomas Brage		
	16:30 - 17:00	Hannes Pahl			16:30 - 17:00	Naoki Kimura		
	17:00 - 17:30	Vladimir Ovsyannikov			17:00 - 17:30	Daiji Kato		
	17:30 - 18:00	Alexey Boytsov						
			18:00	Dinner				

Registration: Yanyuan Hotel, 270 Zhengtong Road

Venue: Guanghua Twin Tower, R103 (The East Podium Building)