The 23rd International
Conference on Accelerators and
Beam Utilization

ICABU 2019

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ICABU
2019

November 13-15, 2019
Hotel ICC, Daejeon, Korea

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The 23rd **I**nternational **C**onference on **A**ccelerators and **B**eam **U**tilization

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The 23rd International Conference on Accelerators and Beam Utilization

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- In Soo Ko (PAL)
- Jae In Shin(KAFAT)
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- Sun Soon Park (DAWONSYS)
- Se Byeong Lee (NCC)
- Seung Jeong Noh (Dankook Univ.)
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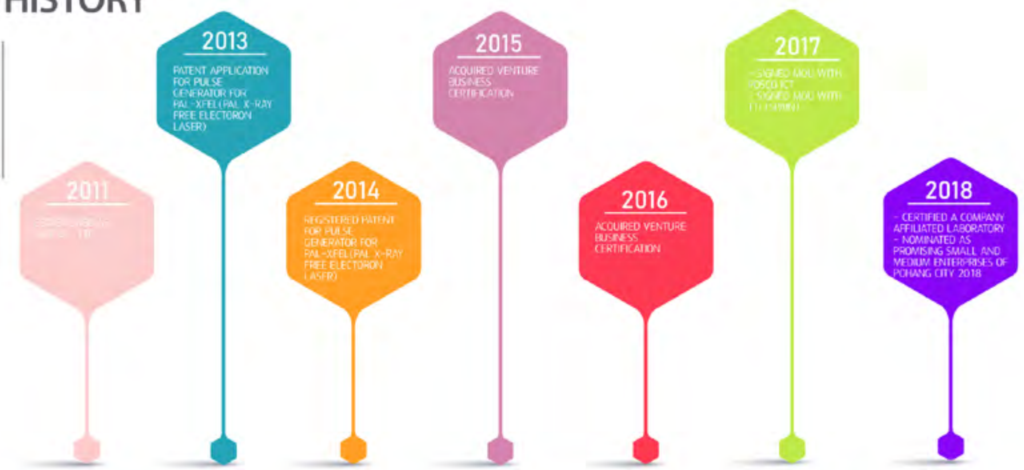
BUSINESS

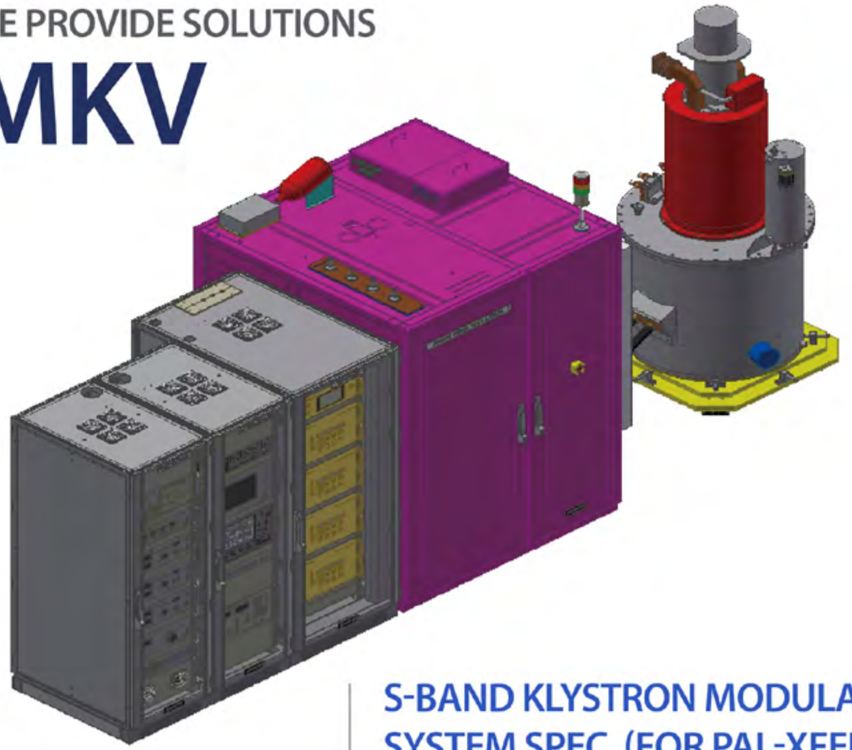
- TECHNICAL SUPPORT AND MAINTENANCE FOR ACCELERATOR
- MAIN PRODUCT FOR ACCELERATOR DEVELOPMENT AND HANDLING (RF, HIGH VOLTAGE PULSE, VACCUM, ELECTRON GUN, CRYOGENIC)
- RESEARCH AND DEVELOPMENT FOR 200MW HIGH VOLTAGE PULSE POWER SYSTEM
- AGILENT VACUUM DISTRIBUTOR
- SOLID STATE POWER AMPLIFIER (SSPA), LOW LEVEL RF SYSTEM (LLRF)
- DESIGN AND MANUFACTURE OF CUSTOM PRODUCTS FOR ACCELERATOR

HISTORY



WE PROVIDE SOLUTIONS

MKV



S-BAND KLYSTRON MODULATOR SYSTEM SPEC. (FOR PAL-XFEL)

Peak Power	200 MW
Peak Output Voltage	400 kV
Peak Output Current	500 A
Pulse Width	7.5 ㎲
Flat-Top	4.0 ㎲
Pulse Repetition Rate	60 Hz
Output Pulse Voltage Stability(RMS)	<35 ppm

Scientific Program of ICABU 2019

❶ November 13 (Wednesday)

08:00~09:00	Registration		
09:00~09:10	Opening Address	Myeun Kwon (RISP/IBS)	
09:10~09:40	Commissioning Status of the Linac for the Facility for Rare Isotope Beams	Steven Lidia(FRIB/MSU)	[Chair] Myeun Kwon (RISP/IBS)
09:40~10:10	CEPC Status and Plan	Jie Gao(IHEP)	
10:10~10:30	Coffee Break		
10:30~11:00	Status of SHINE Accelerator and FEL	Haixiao Deng(SARI)	[Chair] In-Soo Ko(POSTECH)
11:00~11:30	Operation of the European XFEL	Winfried Decking(DESY)	
11:30~12:00	Capabilities of Current and Future X-ray Sources	Kwang-Je Kim(Univ. of Chicago)	
12:00~12:10	Photo Taking		
12:10~13:30	Lunch		
13:30~14:00	Developments of SCUs for the Light Sources	Efim Gluskin(ANL)	[Chair] Do-Young Noh(GIST)
14:00~14:30	Experience with Radioactive Ion Beam Diagnostics at ATLAS	Clay Dickerson(ANL)	
14:30~15:00	**Facility Talk 1** Progress of the Rare Isotope Science Project (RISP)	Myeun Kwon(RISP/IBS)	
15:00~15:20	Coffee Break		
15:20~15:50	**Facility Talk 2** Introduction to Beam Facility of KOMAC and Utilization	Jun Kue Park(KAERI)	[Chair] Kwang-Je Kim (Univ. of Chicago)
15:50~16:20	**Facility Talk 3** Operation Status of PAL	Heung-Soo Lee(PAL/POSTECH)	
16:20~18:20	RAON Facility Tour		

❷ November 14 (Thursday)

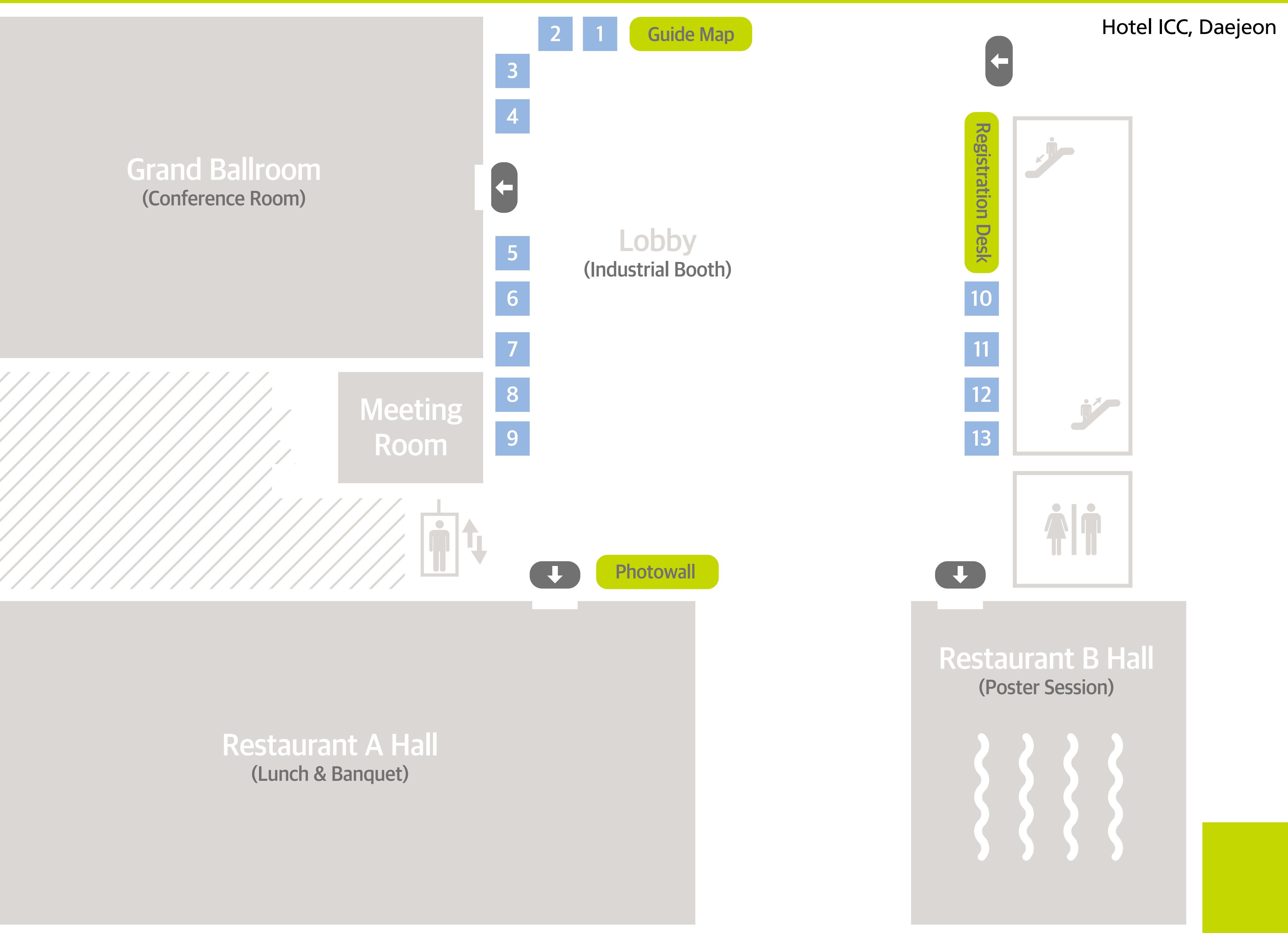
09:00~09:30	Required Technologies for the Fabrication of Solid State Based Quantum Devices	Jan Meijer (U. Leipzig)	[Chair] Jae-Sang Lee (KAERI)
09:30~10:00	Use of MeV Energy Electrostatic Accelerators in Materials Modification and Analysis	Stjepko Fazinic (Rudjer Boskovic Institute)	
10:00~10:20	Fine Controlling for Luminescence Color of Carbon based anomaterials through Charged-Beam Irradiation	Dong-Hyuk Park (Inha U.)	
10:20~10:40	Coffee Break		
10:40 ~ 11:10	Recent Progress in High Temperature Superconductor Magnet Technology for High Field Magnet Applications	Seungyong Hahn (Seoul Nat'l U.)	[Chair] Heung-Soo Lee (POSTECH)
11:10 ~ 11:30	Current Status of Two New 4th Generation Synchrotron Light Source Proposals in Korea - Chungbuk and Jeonnam	Yujong Kim (KAERI)	
11:30 ~ 11:50	Lattice Design and Beam Dynamics Studies for Fourth-Generation Storage Ring	Seunghwan Shin (PAL/POSTECH)	
11:50 ~ 12:10	Radiation Generation with an Existing Demonstrator of Energy-Recovery CW SRF Accelerator	Ji-Gwang Hwang (HZB, Germany)	
12:10 ~ 12:20	Photo Taking		
12:20 ~ 13:00	Lunch		
Special Session : Medical Device Utilizing Accelerator and Beam			
13:00 ~ 13:40	Proton Stimulation Therapy on Alzheimer's Disease Mouse Model	Jong-Ki Kim (Daegu Catholic U.)	[Chair] Se-Byeong Lee (NCC), Woo-Yoon Park (Chungbuk Nat'l Univ.)
13:40 ~ 14:20	The Italian National Centre for Oncological Hadrontherapy : Status and Perspectives	Sandro Rossi (CNAO, Italy)	
14:20 ~ 14:40	Coffee Break		
14:40 ~ 15:10	Laser Wakefield Accelerator for Very High Energy Electron Beam Therapy	Jaehoon Kim (KERI)	[Chair] Dong-O Jeon (IBS), Do-Hoon Lim (Sungkyunkwan Univ.)
15:10 ~ 15:40	Research & Development Using Ion Beams at HIMAC	Shigekazu Fukuda (NIRS/QRST, Japan)	
15:40 ~ 16:10	Clinical Applications of A-BNCT	Hyo Jung Seo (Dawon Medax)	
16:10 ~ 16:40	Flash RT : From Photon to Particle	Woo-Yoon Park (Chungbuk Nat'l U.)	
16:40 ~ 17:00	Coffee Break		
17:00~17:15	Medical X-band Linear Accelerator for the High-precision Radiotherapy	Yongseok Lee (KERI)	[Chair] Ui-Jung Hwang (Chungnam Nat'l Univ.)
17:15~17:30	Preliminary dosimetric study of proton minibeam radiation therapy for choroidal melanoma	Myeongsoo Kim (NCC)	
17:30~17:45	Falloff Detection Algorithm for Multi-slit Prompt-gamma Camera to Measure Beam Range in Proton Therapy	Youngmo Ku (Hanyang U.)	
17:45~18:00	Gamma Electron Vertex Imaging System to Detect Interfractional Range Shift in Spot Scanning Proton Therapy : A Monte Carlo Simulation Study	Sung-Hun Kim (Hanyang U.)	
18:30 ~ 20:30	Banquet		

❸ KOPUA2019 Session (Thursday, November 14, 2019 (the 2nd day of ICABU2019)

10:40~10:50	Opening Address		[Chair] Jun Sik Lee Seung Jeong Noh
10:50~11:15	Cell type-dependent effects of proton beam irradiation in hepatocellular carcinomas	LEE, Kyu-shik (Dongguk Universty)	[Chair] Kyung-Soo Nam (Dongguk Univ.)
11:15~11:40	Mutation breeding research using ion beam with high-LET	Si-Yong Kang (KAERI)	
11:40~12:10	KOPUA General Assembly and Group Photo		
12:10~12:20	ICABU 2019 Group Photo		
12:20~13:30	Lunch		
13:30~13:55	Current status of the beam facility and utilization at KOMAC	Jun Kue Park (KOMAC/KAERI)	[Chair] Seung Jeong Noh (DanKook Univ.)
13:55~14:20	International Fusion Materials Irradiation Facility (IFMIF): An example of neutron generation based on very intense proton/deuteron accelerators	CHUNG, Moses (UNIST)	
14:20~14:40	Coffee break		
14:40~15:05	Proton Irradiation Effect on AlGaN/GaN HEMTs fabricated by Ion Implantation	KIM, Dong-seok (KOMAC/KAERI)	[Chair] CHUNG, Moses (UNIST)
15:05~15:30	Nanoscale pattern formation at surfaces by ion beam sputtering	KIM, Jae-sung (Sookmyung Univ.)	
15:30~17:00	Poster Session with Coffee		[Chair] Jun Kue Park (KOMAC/KAERI)

❹ November 15 (Friday)

09:00~09:30	Status of Experimental systems of RAON	Young-Jin Kim (RISP/IBS)	[Chair] Young-Kwan Kwon (RISP/IBS)
09:30~10:00	Pushing the Frontier of Accelerator Applications at TRIUMF	Alexander Gottberg (TRIUMF)	
10:00~10:30	Post-acceleration of Radioactive Ion Beams at the ISOLDE/CERN facility	Alberto Rodriguez (ISOLDE/CERN)	
10:30~10:50	Coffee Break		
10:50~11:10	Instrumentation for the Facility for Rare Isotope Beams	Steven Lidia (FRIB/MSU)	[Chair] Jongwon Kim (RISP/IBS)
11:10~11:30	The Continuous Beam Muon Source in Japan, RCNP-MuSIC	Akira Sato (RCNP/Osaka U.)	
11:30~12:30	Poster Session		
12:30~18:00	Historic Site Tour		



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[2]*Department of Accelerator Science, Korea University*
[3]*Department of Physics, Ulsan National Institute of Science and Technology*

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PK-2	Proton Beam-Induced p53-Mediated Cell Cycle Arrest in HepG2 Hepatocellular Carcinoma Cells Kyu-shik LEE *School of Medicine, Dongguk University* Kyung-soo NAM *Department of Pharmacology, School of Medicine, Dongguk University*
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PK-12	Temperature-dependent Structural and Electrical Properties of Ion-implanted VO2 films In-Hui HWANG, Hee-Cheol YOON, Sang-Wook HAN* *Department of Physics Education, Jeonbuk National University*
PK-13	Study on the Ion Beam Analysis for the Metal Ion Beam Irradiated Samples Kye-Ryung KIM, Yong-Sub CHO, Seung-Ho LEE, Nam-Woo KANG *Korea Atomic Energy Research Institute*
PK-14	Photostable and Biocompatible Polymer Sunscreen Ingredients Fabricated by Electron Irradiation Sang Yoon LEE, Hyung San LIM, Na Eun LEE, Sung Oh CHO *Korea Advanced Institute of Science and Technology*
PK-15	Permeation of hydrogen and deuterium in Er2O3 thin film on a type 316L stainless steel substrate Halim CHOI, W. J. BYEON, Yongmin KIM *Department of Physics, Dankook University*

Wednesday

ICABU 2019

W-1

Commissioning Status of the Linac for the Facility for Rare Isotope Beams

Steven Lidia

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Abstract

The Facility for Rare Isotope Beams will be completed in late 2021. We report here on the current efforts to commission the first stages of the 200 MeV/u superconducting, CW heavy ion linac. The status of the cryogenic plant and distribution system, accelerator cryomodule commissioning and operations, ion source and Front End transport development, RFQ commissioning, and beam dynamics development to support high power operation are reviewed. Progress in the design and testing of the liquid lithium beam stripper and high power target systems are discussed. Plans for commissioning the remainder of the linac systems are presented.

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CEPC Status and Plan

Jie Gao

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Abstract

In Sept. 2012 Circular Electron Positron Collider (CEPC) was proposed by Chinese scientists just after Higgs Boson was found at CERN on July 4, 2012. Since then CEPC has progressed by completing Pre-CDR in 2015, CEPC Accelerator Progress Report in 2017, and CDR in 2018. CEPC Accelerator entered TDR phase in 2019. In this paper CEPC TDR progress in optimization design and key hardware R&D, civil enegineering design and site selections, industrialization preparation, international collaboration, etc. are reported. Aiming to finish CEPC TDR at the end of 2022 and complete the CEPC construction in 2030, CEPC development plan is also presented.

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Multi-energy operation for the continuous-wave X-ray free electron laser facility

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Abstract

The parallel operation of multiple undulator lines with a wide spectral range is an important way to increase the e[U+FB03]ciency of x-ray free electron laser (XFEL) facilities, especially for machines with high-repetition-rate. In this talk, a double bend achromats based delay system is proposed to delay electron beams, thereby changing the arrival timing of those delayed electron beams in the accelerating structure behind the system. Combining with kicker-septum technique, the delay system can be used to generate bunch-to-bunch energy changed electron beams in the continuous wave XFEL facility. Start-to-end simulations based on the Shanghai high repetition rate XFEL and extreme light facility parameters are performed to demonstrate that the delay system can [U+FB02]exibly control electron beam energy from 1.48 GeV to 8.74 GeV at the end of the linac.

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Operation of the European XFEL

Winfried Decking for the European XFEL operation

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Abstract

The European XFEL is a Hard X-Ray Free Electron Laser based on a 17.5 GeV superconducting accelerator. It serves three undulator beam-lines simultaneously and has been opened for user operation in September 2017.

The actual layout wand highlights form the commissioning and first two years of operation will be presented.

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Capabilities of Current and Future X-ray Sources

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Abstract

The so-called 4GSR—X-ray production facilities based on the spontaneous undulaor radiation from “ultimate storage rings” will in near future produce an average brightness B_av greater than 10ˆ22 photons/(mmˆ2 mrˆ2 sec 0.1 % BW). The first generation X-ray free-electron lasers (XFELs) using Cu-linacs, including LCLS, SACLA, Pohang XFEL, etc, produce about the same B_av , even though the pulse repetition rate of an XFEL is much lower than in 4GSR. High rep-rate XFELs employing superconducting RF accelerators, such as the European XFEL that began operation in 2018 and LCLS-II which will begin in 2022 will reach B_av ¯ 10ˆ25. In the future, an X-ray FEL oscillator (XFELO) can potentially deliver three orders of magnitude higher brightness, B_av > 10ˆ28. An R&D program has begun to test the basic concepts of an XFELO. In particular, an R&D program for two-pass amplification in an X-ray cavity installed in the undulator hall of the LCLS using double electron bunches from the SLAC Cu-linac was launched recently.

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Developments of Superconducting Undulators at the Advanced Photon Source

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Abstract

Advanced Photon Source More than 60 undulators currently operate at the Advanced Photon Source (APS), delivering bright x-ray beams to APS users. The majority of these devices are hybrid permanent undulators. However, there are also five electromagnetic undulators; three of them are superconducting undulators (SCUs), two are planar SCUs, and one is a helical SCU. Since 2013 there has been at least one SCU in operation at the APS, and through all six years, the APS SCUs have operated with predicted or better than predicted radiation performance and with 99% availability. Over the next three years the APS SCU team is facing several challenging tasks. The present planar SCUs are comprised of ˜1.1-m-long magnets, each operated within a 2-m-long cryostat, while the planar SCUs for the upgraded APS facility (APSU) will have ˜1.8-m-long magnets that will operate within a 5-m-long cryostat. The long cryostat will support the operation of two SCUs in either an in-line configuration or a canted arrangement. Another great challenge is the development and construction of an arbitrary polarizing SCU, called SCAPE. The prototype of such device is currently under development. Progress is also being made in the development of a planar SCU wound with Nb3Sn superconductor. A Nb3Sn SCU is being designed with two 1.3-m-long magnets within a 5-m-long cryostat, and installation on the APS storage ring is planned for 2021. During the APS upgrade shutdown this device will be reconfigured as the free electron laser (FEL) SCU module prototype, and tested at the APS SCU magnet measurement facility. Along with the cryogenic and magnet systems, the supporting systems, which are required to verify the alignment of the undulators and the magnetic field under cryogenic operating conditions, are being developed to meet the APSU and X-ray FEL requirements.

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Diagnostics for ATLAS Reaccelerated RIB Operations

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Abstract

The Argonne Tandem Linear Accelerator System (ATLAS) has over two decades of experience evaluating and optimizing low intensity radioactive ion beams (RIB) generated from 252Cf fission fragments or via the in-flight production method. RIBs from these two sources present a wide range of properties, thus a range of detector technologies are used for the diagnostics. Fission fragment beams are generally high mass, 90 < A < 160, with energies from 50 keV to greater than 1 GeV, while in-flight beams are generally lower mass, A < 30, with energies from 10 to 15 MeV/u. Solid state detectors, MCPs, and gas ionization chambers are all used depending on the beam properties. Each detector type provides unique advantages that enable ATLAS to improve the transmission, quality, and operational efficiency of RIB delivery.

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.

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Progress of the Rare Isotope Science Project

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Abstract

The Rare Isotope Science Project (RISP) is being gone through the most critical period, when the superconducting cavities and cryo-modules begin to be installed at the tunnel and all the core components are under fabrication and assembly. First beam is expected within one and half year from the low energy accelerator section and the day-one experiment using the low energy stable ion beam is just beneath the horizon. Total 56 cryo-module for the low energy section will be tested at the cryo temperature, installed at the tunnel, connected to the valve-boxes and activated to

accelerate various ion beams. Integration and Installation of the low energy accelerator consists of many multi-faceted activities, include the survey and alignment, assembly of warm and cold section, vacuum tightening, rf conditioning, etc. In this presentation, recent progress of RISP will be presented, focussing on the integration activities.

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Introduction to the beam facility of KOMAC and utilization

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Abstract

In this talk, we will address the ion beam facilities installed at Korea multi-purpose accelerator complex (KOMAC). At KOMAC, there are two main buildings for the beam facilities, where one is being used for the 100 MeV proton accelerator, the other one being used for the ion beam facilities. Since the second half of 2013, the 100 MeV proton accelerator has been supporting scientific beam-users such as radioisotopes production, material science, and radiation hardness study. Recently, we have been developing the neutron beam and secondary particles of Li-8. For the ion beam facilities, we have been providing various gaseous and metal ion beams with the energy less than 200 keV. Besides, we have been developing an analysis instrument, the so-called tandem accelerator for the particle-induced X-ray emission and Rutherford backscattering spectroscopy.

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Operation Status of PAL

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Pohang Accelerator Laboratory

Abstract

The Pohang Accelerator Laboratory includes PLS-II, the third generation radiation accelerator, and PAL-XFEL, the FE accelerator. IThe third generation radiation accelerator, which started supporting users in September 1995, has 35 beamlines in operation and one beamline under construction. The PAL-XFEL accelerator has begun supporting users in June 2017 and currently has seven experimental units on three beamlines. I will present the operation status of the PLS-II and the PAL-XFEL accelerators.

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Thursday

Required technologies for the fabrication of solid state based quantum devices

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Abstract

The second quantum mechanical revolution is based on the manipulation and control of single or coupled quantum systems called qubits. Qubits based on artificial atoms and using the spin state of an electron or of nuclei are one of the most promising candidates for the production of quantum information technology or quantum sensors. The negatively charged NV centers based on the nitrogen atom and a vacancy in diamond is one of these solid state qubits at room temperature. The main advantages of NVs are that they are easy to control, have long coherence times even under normal environmental conditions, are scalable and their fabrication can be in-tegrated into a standard CMOS process line. However, to create a quantum register, the individ-ual NV centers must be placed with 5 nm accuracy in an almost perfect diamond crystal. Ion implantation is the only way to generate and address NV centers in diamond with high lat-eral resolution. But compared to a standard implantation process, here the number of implanted nitrogen atoms has been controlled and almost every implanted N atom has to be converted into a negatively charged NV center. While technologies for the implantation of countable single ions have already been tested, the NV creation yield and their charge stability have been long time an obstacle to the development of coupled NV centers. Recently, we have found that addi-tional sulfur implantation in diamond solves this problem and increase the creation yield of shal-low implanted NVs from 7% to 80%, all NV centers are negatively charged and furthermore the method increases the coherence time of the NVs by a factor of 20. The talk will discuss the state of the art of single-ion nano-implantation techniques and new developments in materials science to overcome the limitations encountered in the construction of NV centers so far.

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ICABU 2019

Use of MeV energy electrostatic accelerators in materials modification and analysis

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Abstract

Through the Laboratory for Ion Beam Interactions the Division of Experimental Physics of the Ruđer Bošković Institute (RBI) operates and maintains the Tandem Accelerators Facility, that physically consists of the 6 MV Tandem Van de Graaff and 1 MV Tandetron accelerators, associated beam lines and eight end-stations. The accelerators can deliver various ions with energies from 0.1 to tens MeVs. The accelerators are mainly used for ion beam modification and analysis studies and occasionally for experimental nuclear physics, i.e. measurements of nuclear reaction cross sections and other fundamental parameters relevant for astrophysics, ion beam modification and analysis (IBA) of materials and other applications.

The facility is equipped with general IBA end station for RBS (Rutherford Backscattering Spectrometry), PIXE (Particle Induced X-Ray Spectrometry) and PIGE (Particle Induced Gamma-Ray Spectrometry), and with stations for Time-of-Flight Elastic Recoil Detection Analysis (TOF-ERDA), ion channeling, MeV SIMS (Secondary Ion Mass Spectrometry), and High-Resolution PIXE. In addition, two ion microprobes and dual beam end station are available to users.

In this work the overview of the RBI Tandem Accelerator Facility will be presented, with the focus on its recent use for materials modification and analysis. A huge potential of the experimental setups will be demonstrated by presenting selected applications performed recently on a wide range of materials using broad and focused ion beams. Recently the facility has been increasingly used to study fusion energy related materials, including analysis of plasma facing components[1] and loose materials[2] (dust) collected after experimental campaigns with fusion devices. In addition, large irradiation chamber has been constructed to apply dual ion beams for materials irradiation in order to simulate potential damage of fast neutrons that could be expected in fusion reactors after long runs[3,4]. Another well developed application includes the use of ion beams to study radiation hardness and charge collection efficiency of solid state radiation detectors and related materials by Ion Beam Induced Current (IBIC) and Time Resolved IBIC techniques[6-8]. The range of recent applications also include the use of swift heavy ions for material modification studies[9-13] (including ion track formation in crystalline materials and damage of 2D materials like graphene), elemental depth profiling in thin films[14], analysis of aerosols, cultural heritage objects[15] and biomedical applications[16]. Potential for further developments will also be discussed, including the need and availability of fundamental data[17].

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Fine Controlling for Luminescence Color of Carbon based nanomaterials through Charged-Beam Irradiation

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Abstract

We report a precise approach to take controlling of luminescence color in carbon based nanomaterials including carbon dots (CDs), organic semiconductors (OSs) through charged-beam irradiation. The charged-beam with various dosages (1.0 □1016 ~ 1.0 □1019 electrons/cm2) and energy (20 ~ 140 keV) were irradiated on the materials. The structural properties of the ion-beam irradiated CD and OS were investigated by ultraviolet-visible (UV/Vis) absorption spectra and Raman scattering experiments. The conformational changes and dedoping effects of CD and OS due to the charged-bema treatments were visualized through nanoscale confocal Raman mapping experiments. From the laser confocal microscope (LCM) photoluminescence (PL) images and spectra of the CDs and OSs, we observed significant controlling of the LCM PL characteristics depending on the charged-beam dosage and energy in the beam irradiated CDs and OSs. We observed the red-shift and bright emission of the LCM PL peak of the systems when increasing the dosage of the charged-beam irradiation, implying tune of the luminescent color of the CDs and OSs. The results might have originated from the dedoping effect and conformational modification through interaction between the irradiated charged-beam and the carbon main chains. Based on these results, we found that the optical properties of CDs and Oss had been successfully controlled by the charged-beam irradiating conditions.

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Recent Progress in High Temperature Superconductor Magnet Technology for High Field Magnet Applications

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Abstract

Firstly introduced in 2010 at the MIT Francis Bitter Magnet Laboratory, the "No-Insulation" winding technique has been regarded as a "game changer" in high temperature superconductor (HTS) magnet technology, as it enables an NI HTS magnet to be highly compact and affordable, yet reliable to a level that has never been achieved with conventional systems. Significant progress in the NI-HTS technology has transformed future dream of HTS machines into reality, i.e., meet rigorous HTS system specifications that were infeasible mainly due to old technical challenges and high cost of HTS machines. We are now at the threshold of a new era in which HTS will play an increasingly indispensable role in a number of energy applications that include electric power system, high energy physics, non-invasive diagnostics such as MRI and NMR, environmental industry, and more. This seminar presents an overview of the recent progress in NI HTS magnet technology with focus on medical applications, especially the next-generation compact high field accelerator dedicated to cancer treatment.

Acknowledgement

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Current Status of New Advanced Synchrotron Light Source in Korea

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Abstract

Recently, the demand of a new advanced synchrotron light source is rapidly growing in Korea. Among many Korean local governments, Chungbuk-do and Jeonnam-do have been actively preparing to host the new light source in their own province. At the moment, the new advanced synchrotron light source will have a 4 GeV superconducting linac for the CW mode injection and a 4 GeV synchrotron where the Multi-Bend Achromat (MBA) based Diffraction Limited Storage Ring (DLSR) concept is used. In this paper, we report Korean accelerator community's efforts, status of local government proposals, and accelerator design works for the 4 GeV advanced synchrotron light source.

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Lattice Design and Beam Dynamics Studies for Fourth-Generation Storage Ring

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Abstract

As the fourth generation storage rings (4GSR) based on the multi-bend achromat (MBA) lattice concept are emerging as part of a world-wide push beyond the brightness and coherence reached by present third generation storage rings, 4GSR is being studied at Pohang Accelerator Laboratory. The lattice of lower emittance and larger dynamic aperture is designed and various beam dynaics studies including the damping wiggler effect on reducing emittance further are investigated. In this presentation, we describe the studies on various beam dynamics for 4GSR in addition to the description on 4GSR lattice design.

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Radiation generation with an existing demonstrator of energy-recovery CW SRF accelerator

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Abstract

In the past decades, many accelerator laboratories have put a great effort into developing a compact energy-recovery linac (ERL) demonstrator in order to verify technical aspects of the generation, acceleration, transport, and recovery of high brightness and high average current electron beams in a superconducting radio-frequency (SRF) linear accelerator. Beyond these goals, the ERL demonstrator also offers unique opportunities to study novel schemes for THz and X-ray radiation generation. In this presentation, we discuss feasible options for such schemes serving THz and X-ray radiation at the low-energy energy-recovery CW SRF accelerator.

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Thursday Medical

ICABU 2019

Proton stimulation therapy on Alzheimer's disease mouse model

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Abstract

Iron oxide magnetite was identified as redox-toxic mineralization in hallmarks of AD from patient or transgenic AD mice brain (1-3). We have discovered therapeutic effect of proton stimulation in AD plaque targeting magnetite. Our prior works (4-5) as proof-of-concept stud-ies of proton stimulation on iron oxide minerals in Ab fibril or in a plaque-forming transgenic AD mice model demonstrated disruption of Ab-magnetite complex and removal of Ab-plaque burden (60-90% in single treatment) and detoxi-fication of ferrous magnetite into soluble ferric magnetite in dose-dependent manner. Proton stimulation was performed in traversing pristine mode without deposition Bragg peak inside tis-sue with entrance dose of 1-4 Gy. Therefore, this innovative treatment on AD brain did not damage on normal tissue including microvessel, demonstrating no ischemic damage or inflam-mation, haemorrhage after treatment. We sug-gest further study with heavy ion beam to take an advantage of higher peak-to-plateau ratio at higher energy and enhanced electron emission from magnetite via nanoradiator effect in 1-5 Gy compared with proton stimulation. Since iron-oxide mineral is not only in AD dementia but also Parkinson's disease, we want to investigate this technique in any iron-oxide mineral forming protein aggregates of neuro-degenerative diseases under organized international collaborative research group.

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The Italian National Centre for Oncological Hadrontherapy: status and perspectives

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Abstract

Some elementary particles used for experiments of fundamental physics have properties useful to the treatments of patients affected by oncological pathologies. They are protons and carbon ions, collectively named hadrons hence the term hadrontherapy. Hadrons, in particular carbon ions, are more precise on the target than conventional X-rays and possess radiobiological characteristics suited to treat radioresistant or inoperable tumours. Italy is at the forefront of these techniques and in Pavia a clinical facility called CNAO (Italian acronym that stands for National Centre for Oncological Hadrontherapy) has treated so far more than 2500 patients with very good results. The CNAO has been created by the Health Ministry and has been realised by CNAO Foundation in collaboration with the Italian Institute of Nuclear Physics (INFN), CERN, GSI and other institutions in Italy and abroad. The facility in Pavia delivers beams of hadrons in three treatment rooms with four fixed beam ports: three horizontal and one vertical. Recently a new room, with an horizontal beamline and multiple isocentres, has been completed and will be fully devoted to research applications. The CNAO has also launched a development programme to add a new single room for protontherapy with a gantry and a dedicated accelerator.

The talk will deal with the rationale of hadrontherapy and will give an overview of the status of hadrontherapy in the world. The clinical cases and results obtained at CNAO will be used as example of hadrontherapy outcome on tumour treatments. The characteristics of the accelerators and systems involved in the clinical applications will be introduced. Attention will be devoted to the most interesting aspects of research and development in the hadrontherapy domain.

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Laser wakefield accelerator for very high energy electron beam therapy

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KERI

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KIRAMS

Abstract

The very high energy electron beam has been studied as a new cancer treatment technology because its dose distribution can penetrate deep into the human body without being affected by the internal structure, especially air bubbles, bones, and can be easily adjusted using an electric field. Such a new therapy scheme requires a small electron accelerator with more than 250 MeV energy. A laser wakefield accelerator (LWA) can be a feasible candidate for VHEE therapy, which uses the interaction between a high power fs laser and a plasma. Due to the very high acceleration gradient in LWA, a compact table top high energy electron accelerator can be made. The LWA was studied for therapy system. The electron energy and the dose distribution were main topics of this study. By controlling the plasma density profile, very high energy electron beam with 250 MeV was obtained. The dose distribution, measured by using tough phantom and EBT3 film, indicates the quasi-monoenergetic distribution of the electron.

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Research & Development Using Ion Beams at HIMAC

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NIRS / QST

Abstract

The Heavy Ion Medical Accelerator in Chiba (HIMAC) was completed in 1993 as the world's first facility using a heavy-ion accelerator dedicated to medical applications and its clinical trials have been started since June 1994. By March 2019, more than 11,000 cancer patients have been treated.

HIMAC has been used not only for medical applications but also for basic science experiments such as nuclear physics, atomic physics, and radiobiology, since October 1994, which was almost same with the beginning of clinical research. Over 100 basic science research with HIMAC are conducted every year.

For high-energy physics experiment, typical available beams range from He to Fe. The highest energy is 800 MeV/n for Si and its intensity is round 4x10^8 pps(particles/second). The secondary beams are also available, which are produced by above-mentioned primary beams. For atomic physics, medium-energy beams ranging from He to Fe are available with maximum energy of 6 MeV/n and its intensity of 2x10^12 pps. For radiobiology experiment, a large and uniform irradiation fields are provided. The user can select a mono-energetic beam with a narrow Bragg Peak or a beam with a Spread-Out Bragg Peak (SOBP).

Cancer clinical trials using HIMAC are conducted from 7 am to 7 pm on weekdays. During other time periods (night and weekends), research centered on irradiation experiments using heavy particle beams from HIMAC is being conducted. Research themes are widely carried out as joint research between the proposed researchers and NIRS/QST researchers, based on proposals from researchers inside and outside the institution.

In my presentation, the details of beam lines for experiments, operation of HIMAC and some research results will be introduced.

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Clinical Applications of A-BNCT

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Abstract

Boron Neutron Capture Therapy (BNCT) is a binary therapy using thermal neutrons and boron compounds. Selectively localized boron nucleus (B-10) in tumor cells capture thermal neutrons easily and become alpha particles and recoiling Lithium-7 nucleus with high linear-energy-transfer (150 ~ 200 keV/mm) within 5-9 mm. Therefore, BNCT is a cell based target therapy and also alpha particle and lithium particle therapy. The interest of BNCT has been increased gradually since clinical researches using nuclear reactor represented the promising results. To improve the clinical outcome of BNCT and compensate for the other conventional therapies, the translational studies of BNCT and many clinical trials are prerequisite. Up to date, clinical trials of BNCT include malignant glioma, melanoma and head and neck cancer mostly. And some clinical cases in variable refractory diseases such as malignant mesothelioma, extra-mammary Paget's disease, hepatoma and osteosarcoma have been studied. Likewise, non-clinical trials of multiple animal tumor models have been introduced to prepare further extended clinical applications. To satisfy the clinician's demand for the hospital based neutron generators, an accelerator based BNCT (A-BCNT) have been being developed. In Korea, BNCT national project by Dawonsys began since 2016 and linear accelerator based BNCT facilities have been installed successfully at Songdo. Now we expect to treat cancer patients in hospital based A-BNCT in Korea near future.

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FLASH-RT: From Photon to Particles

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Abstract

adiation therapy (RT) is one of the main modalities for cancer treatment. Over half of cancer patients receive RT during their lives with cancer. Although RT methods have been developed through over one hundred years a lot, more than one fourth of the patients suffer from progressive or recurrent diseases after treatment. The goal of RT is to treat the disease with minimal adverse effect. Normal tissue damage is the most important factor which limits irradiating enough dose for tumor control.

FLASH-RT is a ultra-fast delivery of radiation with a dose rate of several orders (≥40 Gy/sec) higher than those currently used in routine clinical practice (~0.05 Gy/sec). In various animal (mouse, cat, pig and zebrafish) and tissue (intestine, skin, lung and brain) models FLASH-RT showed less damage to normal tissue (Dose modifying factor: 1.13~1.8) and equal antitumor effect upon same RT dose. Accordingly, FLASH-RT would make it possible to deliver higher doses and lead to tumor control without increasing normal tissue toxicity.

In my presentation I will discuss experimental data, biological mechanism and the points to be solved for a clinical application of FLASH-RT.

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Medical X-band Linear Accelerator for the High-precision Radiotherapy

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Abstract

Radiation oncology uses high-energy linear accelerator (LINAC) to treat cancer effectively. The using high-energy x-ray or electron beam generated by linear accelerator makes it possible to treat cancer cells while reducing damage to normal tissues. Modern medical linear accelerators are being integrated with imaging diagnostic devices such as CT or MRI to perform high-precision radiation treatments, which also include advanced treatment planning systems (TPS). The compact LINAC system using X-band RF technology has advantages in terms of converging with other imaging diagnostic devices, radiation shielding, and mechanical operation stability of radiation treatment systems. The developed X-band LINAC linear accelerator system applied 9.3 GHz RF frequency band technology and have been developed for use in CT-LINAC cancer treatment devices. The developed LINAC has a side-coupled structure, which reduces the size of the accelerator tube and improves the beam acceleration efficiency. With an electric field strength of 16.8 MeV/m, the LINAC can accelerate the electron beam up to 6 MeV and generate the electronic beam output more than 80 mA. So far, when the source skin distance (SSD) is 80cm, The X-ray dose output is stably more than 800 cGy. The performance optimization process related to X-ray dose rate, beam profile such as symmetry and penumbra is in progress.

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Preliminary dosimetric study of proton minibeam radiation therapy for choroidal melanoma

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Abstract

The choroidal melanoma is the most common primary malignant intraocular tumor. This study aimed to evaluate dosimetrically the feasibility of saving both lens and ciliary body in the choroidal melanoma treatment by spatially fractionated proton minibeams. A multi-slit brass collimator was designed by the Monte Carlo simulation data, and fabricated with 0.4 mm beam opening and 1.1 mm center to center distance. The collimator could be installed at the end of proton beam nozzle, which generated proton minibeams. A phantom was also fabricated for proton beam dosimetry, involving five polymethylmethacrylate (PMMA) plates of 2 mm and 8 mm thickness, respectively. A peak to valley dose ratio (PVDR) of proton minibeams was used to validate the feasibility of lens and ciliary body sparing. The PVDR values were measured at various air gaps and PMMA depths by using a Gafchromic EBT3 film. The typical single-scattered proton beam used to treat choroidal melanoma was delivered to the EBT3 films in the phantom: the energy of proton beam was 60 MeV, and its depth dose profile was a full spread out Bragg peak (SOBP). The average dose at mid-depth of the SOBP was approximately 300 cGy with ±3 % of ripple. Dosimetric evaluation showed the PVDR depended on the air gap significantly. It varied from 3.4 to 1.1 in the air gap range from 2 mm to 62 mm. The PVDR values at 2, 12, 22, and 32 mm PMMA depths were 2.0, 1.5, 1.1, and 1.06, respectively. This result shows that the spatially fractionated proton minibeams might save the lens and ciliary body seated in the shallow depth during the proton minibeam radiotherapy of choroidal melanoma.

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Falloff Detection Algorithm for Multi-slit Prompt-gamma Camera to Measure Beam Range in Proton Therapy

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Abstract

In the field of proton therapy, many research groups are working on in vivo range verification for reduction of the range uncertainty, which may lessen safety margin and increase conformality of delivered dose. In this regard, we developed a multi-slit prompt-gamma camera, which measures the distribution of prompt gamma-rays (PG) emitted from the proton trajectory, to verify beam ranges based on the correlation between the range and the falloff position on the PG distribution [1]. To determine the estimation value of the range on the PG distribution, an algorithm based on sigmoidal curve-fitting has been used, with which, however, the precision in range determination was not enough to reduce the range uncertainty in a low count circumstance as spot scanning proton therapy. In the present study, as an alternative to the existing, a new algorithm called 'falloff detection' was developed and evaluated. The principle of the falloff detection algorithm is as follows. First, the PG distribution is converted into a falloff intensity distribution. The conversion is performed by setting two windows of a fixed width on both sides of each data point and subtracting the total counts in the distal from the proximal window. Next, a cut-off level is set on the acquired distribution to remove noise. The level is determined as a constant ratio to the maximum peak height. Third, the centroid above the cut-off level is calculated to find the maximum falloff position considering falloff intensities as weights. Finally, the estimation value of the range is determined by adding an offset value to the centroid to compensate for the constant difference between the range and the maximum falloff. To evaluate the developed algorithm, a simulation study using Geant4 (ver. 10.04) was conducted. Proton beams were irradiated on a cylindrical water phantom (d = 15 cm, h = 25 cm), and the PG distributions were acquired with the camera positioned at 5 cm away from the beams. Varying the beam energy and the number of protons, simulations were repeated 10 times for each condition. After that, the conventional and new algorithms were applied to the measured distribution and determined the ranges. Table 1 shows the ranges determined by each algorithm. The result shows that the falloff detection algorithm had better precision in all conditions compared to not only the existing algorithm but the typical safety margin (3% + 3 mm). Considering 3×107 is approximately the average number of protons per spot at the National Cancer Center in Korea, the camera with the developed algorithm has high possibility to reduce the range uncertainty in spot scanning proton therapy. In the future, the algorithm will be further evaluated experimentally.

Table 1. Ranges determined with sigmoidal curve fitting and falloff detection algorithm.

Algorithm	Sigmoidal curve Fitting			Falloff detection		
Beam energy (MeV)	100	130	160	100	130	160
True range ± margin (mm)	77.6±5.3	123.4±6.7	177.4±8.3	77.6±5.3	123.4±6.7	177.4±8.3
Number of protons	Mean ± precision (1.5σ) of measured ranges					
3×10^8	77.5±0.7	123.5±0.9	177.5±1.2	77.5±0.3	123.5±0.4	177.5±0.6
1×10^8	77.5±1.9	123.5±3.4	177.7±4.8	77.5±0.6	123.5±0.7	177.5±1.0
3×10^7	77.6±3.9	123.7±10.3	177.1±13.8	77.5±0.9	123.6±1.6	177.6±2.2

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Gamma Electron Vertex Imaging System to Detect Interfractional Range Shift in Spot Scanning Proton Therapy: A Monte Carlo Simulation Study

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Abstract

aaIn proton therapy, the range of the proton beam is highly sensitive to uncertainties, while an accurate and precise beam range control is crucial for treatment quality and patient safety. To improve the clinical benefit of proton therapy, therefore, the reduction of beam range uncertainty is necessary, which may translate into reduction of normal tissue toxicity and enhancement of tumor control. To reduce the range uncertainties, prompt gamma (PG) imaging has been studied by several groups, and we have developed the gamma electron vertex imaging (GEVI) system aiming for application to spot scanning proton therapy. In this study, the detection of interfractional range shifts in spot scanning proton therapy were simulated for the GEVI system by Geant4 Monte Carlo simulations. The interfractional range shifts were introduced by retrieving relative change of beam range in different shift scenarios. For treatment planning, we used a cubic dose distribution with single field, 2 Gy fractional dose, 50 mm × 50 mm × 50 mm target volume, and 12 energy layers. The most six distal energy layers were irradiated into a homogeneous PMMA phantom, and the range shifts were detected using the GEVI system. The beam range was shifted by covering the beam path with additional PMMA phantoms of 5, 7 and 10 mm in two ways. In global shift, firstly, all spots were affected, and in local shift, secondly, a portion of spots were affected. The retrieved range shifts were evaluated by spot-wise analysis to compare two spots with and without shift, and statistical hypothesis test to investigate significant differences between each range shift and zero (one-sample t-test) and between each range shift and others (ANOVA). In hypothesis tests, SPSS 25 (IBM, NY) with 5% significance level was utilized. To improve PG statistics, each spot was replaced by a spot aggregated with neighboring spots including itself. Aggregating adjacent spots, two-dimensional Gaussian model (s = 7.8 mm) was used, weighted with respective distance and delivered dose. As results of spot-wise analyses, the interfractional range shifts were measured with -0.53±0.11 (1.5s) mm and 1.86±0.17 (1.5s) mm for global and local shift, respectively. The estimated precisions were much smaller than the typical safety margin (3% + 3 mm) in proton therapy. For the hypothesis tests, all shift scenarios showed significant difference with zero as results of one-sample t-tests and difference with others as results of ANOVAs. This simulation study will be extended to experimental study using a therapeutic proton beam.

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The 23rd International Conference on Accelerators and Beam Utilization

ICABU 2019

Friday

ICABU 2019

Status of Experimental Systems of RAON

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Abstract

The construction of the heavy ion accelerate complex, RAON (Rare isotope Accelerator complex for ON-line experiments), has been carried out under RISP of IBS since 2011. RAON will provide various stable and rare isotope beams with wide range of energy and high intensity to experiment halls. RAON will use Inflight Fragment (IF) and Isotope Separation On-Line (ISOL) systems for production and separation of rare isotope beams. Both ISOL and IF system can be operated in combination as the second stage production manner, which is the unique feature of RAON, allowing to reach more than 80% of the unexplored region in the chart of nuclide. Currently, the fabrication of major components for accelerator systems is under process. In this talk, the overview of RAON project, its scientific programs, progress on accelerator and experimental systems will be presented.

Keywords : RAON, Rare Isotope Accelerator, Inflight Fragment(IF), Isotope Separation On-Line (ISOL)

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Pushing the Frontier of Accelerator Applications at TRIUMF

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Abstract

For 50 years, TRIUMF has stood at the frontier of scientific understanding as Canada's particle accelerator centre. Driven by two made-in-Canada cutting edge accelerators - the world's largest cyclotron, and our new high-power superconducting linear accelerator - we continue to ask the big questions about the origins of the universe and everything in it.

With over five decades of experience in the production of accelerator-based isotopes for science, TRIUMF also ensures that Canada remains on the leading edge of research and development of accelerators applied to nuclear medicine. TRIUMF's medical isotope program is primed to develop alternative tools and methods to meet the growing demand for life-saving isotopes. The new Institute for Advanced Medical Isotopes (IAMI) - a multi-institutional research hub and facility focusing on advanced isotope development and radiopharmaceutical development – will serve as a conduit for isotopes produced using all TRIUMF's accelerators spanning the energies from 13 MeV all the way up to 520 MeV. New applications of accelerators for the treatment of diseases are being developed and will also be presented.

ISAC-TRIUMF is the only ISOL facility worldwide that is routinely operating targets under particle irradiation in the high-power regime in excess of 10 kW. TRIUMF's current flagship project ARIEL, Advanced Rare IsotopE Laboratory, will add two new target stations providing isotopes to the existing experimental stations in ISAC I and ISAC II at keV and MeV energies, respectively. In addition to the operating 500 MeV, 50 kW proton driver from TRIUMF's cyclotron, ARIEL will make use of a 35 MeV, 100 kW electron beam from a newly installed superconducting linear accelerator. Together with additional 200 m of RIB beamlines within the radioisotope distribution complex, this will put TRIUMF in the unprecedented capability of delivering three RIB beams to different experiments, while producing radioisotopes for medical applications simultaneously – enhancing the scientific output of the laboratory significantly.

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Post-Acceleration of Radioactive Ion Beams at the ISOLDE/CERN Facility

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Abstract

Located at CERN, ISOLDE is one of the world's leading research facilities in the field of nuclear science. Radioactive Ion Beams (RIBs) are produced when high energy protons are transferred to the facility from the Proton Synchrotron Booster (PSB) and impinge one of the two available targets. The RIB of interest is extracted and transported to the experimental stations, either directly, or after being accelerated in the REX/HIE-ISOLDE post-accelerator. In addition to a Penning trap to accumulate and transversely cool the beam and a charge breeder to boost the charge state of the ions, the post-accelerator includes a linac with both normal and superconducting sections and three HEBT lines. Specifications and technical details of the post-accelerator as well as information on the beams recently delivered to the experimental stations will be provided. The most relevant results of the beam commissioning campaigns that followed the installation of each of the four cryomodules and the experience gained over the last four years of operations will also be discussed.

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Instrumentation for the Facility for Rare Isotope Beams

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Abstract

A large suite of beam diagnostics and instrumentation have been developed and commissioned for the FRIB linac and target systems. This talk will present the status of diagnostic system measurements to support current beam commissioning activities in the Front End and linac segments. The status of the target imaging system and testing are reviewed. Aspects of the machine protection system and global timing system to support flexible, high power operation are presented.

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The Continuous Beam Muon Source in Japan, RCNP-MuSIC

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Abstract

RCNP-MuSIC is the continuous muon beam facility in Japan. It was built in Research Center of Nuclear Physics (RCNP) of Osaka University, and started to provide muon beams to the world wide users in 2015. Muons are generated using 392 MeV protons hitting a Graphite target. Then, all charged secondary particles are immediately captured by a 3.5 Tesla magnetic field. This particle capture system is the most unique feature of the MuSIC system. A radiation tolerant superconducting solenoid magnet was developed for the system. The captured pions and muons are transported by a 2 Tesla large-bore solenoid channel. The muon intensity at the end of the transport solenoid was measured as about 108/s for 0.4 kW proton beam in 2012. This successful demonstration is a great milestone toward the COMET experiment, which plans to use 1010/s with a 56 kW proton beam at J-PARC. The second pion capture system designed for the COMET experiment is now under construction at J-PARC.

On the other hand, in 2013, the MuSIC transport solenoid was expended by a 18 m-long normal-conducting beam line to start muon programs at RCNP. After the beam line commissioning, finally official operations for users were started from November 2015. Sixteen user experiments have been already performed by 2019. The continuous muon beam from the MuSIC beamline offers new opportunities to various users not only particle and nuclear physicists, but also material scientists, archaeologists and so on. Design and current status of the RCNP-MuSIC are presented in this paper

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Cell type-dependent effects of proton beam irradiation in hepatocellular carcinomas

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Abstract

Hepatocellular carcinoma (HCC) is the most common type of liver cancer which the 5-year survival rate is below 12%. Almost patients diagnosed HCC are died within 6-24 months and fewer than 5% patients can be treated by surgical resection. Therefore, we assessed the effect of proton beam irradiation on three different kinds of HCC cells, HepG2, Hep3B and SK-Hep1. We found that proton beam induced DNA damage in the three kinds of HCC cells. However, cytotoxicity of a proton beam in the cells was cell-specific. Although proton beam irradiation induced cell cycle arrest in HepG2 cells mediated by p53-mediated p21 induction below 72 h, the lowest cytotoxicity was shown the cells. In contrast, cell deaths of Hep3B and SK-Hep1 cells were induced by proton beam irradiation below 72 h. In case of SK-Hep1, the cell death was mediated with the increase of BAD expression and caspase-3 cleavage and the decrease of Bcl-xL expression. However, the change of apoptotic factors expression and activation was not detected in Hep3B cell. Furthermore, signaling pathways regulating cellular responses by proton beam irradiation were also different. Taken together, this investigation demonstrates that therapeutic efficacy of a proton beam is determined by the type of HCC cells and suggests that patient-specific therapeutic strategy is needed to improve HCC treatment using a proton beam.

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Mutation breeding research using ion beam with high-LET

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Abstract

Ion beam with high liner energy transfer (LET) show high relative biological effectiveness (RBE) and it gives more effective for a broad variation of plant mutation induction than low LET radiations, i.e., X- and gamma-rays and electrons. It has been suggested that ion beams induce higher single and double strand DNA breaks as well as large DNA deletion than low LET radiations. The KOMAC (Korea Multi-Purpose Accelerator Complex) under the KAERI was constructed in Gyeongju and then has been provide 45 MeV and 100 MeV proton beam irradiation service since 2013. We investigated the radiation damages and mutation induction in the Cymbidium and other plants caused by two types of proton beams. From the research result, proton beam especially with 100 MeV caused extremely oxidative stress in Cymbidium compared with gamma-ray and it is also expected to be a useful tool for mutation induction in plants. In 2017, our research group started wide researches for setting the irradiation condition of 100 MeV proton beam of the KOMAC for mutation breeding to 15 main crop plants as well as for development of useful new genetic resources. The LAON heavy ion beam accelerator (200 MeV) has been constructed at the Institute of Basic Science in Korea. In near future, many applications in the plant mutation breeding will be done using the proton and heavy ion beam with high LET. In this presentation, I would like to introduce the basic characteristics, some successful research achievements and current status of research of the plant mutation breeding using ion beam in Korea and Japan.

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Current status of the beam facility and utilization at KOMAC

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Abstract

In this talk, we will address the ion beam facilities installed at Korea multi-purpose accelerator complex (KOMAC). Since the second half of 2013, the 100 MeV proton accelerator has been supporting scientific beam-users such as radioisotopes production, material science, and radiation hardness study. Recently, we have been developing the neutron beam and secondary particles of Li-8. For the ion beam facilities, we have been providing various gaseous and metal ion beams with the energy less than 200 keV. Besides, we have been developing an analysis instrument, the so-called tandem accelerator for the particle-induced X-ray emission and Rutherford backscattering spectroscopy.

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International Fusion Materials Irradiation Facility (IFMIF): An example of neutron generation based on very intense proton/deuteron accelerators

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Abstract

Accelerator-based high-flux neutron sources have a wide range of applications ranging from basic scientific research in nuclear physics and nuclear data measurements, to applications such as spallation neutron sources for material and biological sciences, nuclear waste treatment, accelerator-driven systems, and fusion material testing. Recent trend in the community is to push the operating limits of the proton/deuteron accelerators beyond 100 mA CW, even toward 1 A CW. In this talk, we review world-wide activities for neutron generations based on very intense proton/deuteron accelerators. In particular, we take the International Fusion Materials Irradiation Facility (IFMIF) as an example which deals with many challenges in accelerator technologies and high-intensity beam dynamics.

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Proton Irradiation Effect on AlGaN/GaN HEMTs fabricated by Ion Implantation

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Abstract

AlGaN/GaN high electron mobility transistors(HEMTs) are have been demonstrated as promising candidates for high power and high frequency electronics used in a space environment because GaN-based material has a higher radiation hardness compared to Si and other III-V materials [1]. Protons are abundant in a space environment, and especially trapped in the inner-belt of Van Allen Belts where satellites and spacecraft operate. The trapped protons have various energies from hundreds of keV to several hundred MeV [2]. In this work, the proton Irradiation effect on AlGaN/GaN HEMTs fabricated by different isolation method were compared [3] and the dependence of proton irradiation fluence and energy on electrical properties of fabricated devices were investigated.

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[3] D.-S. Kim, et al., IEEE Trans. Nucl. Sci., V.65, P.579, 2018.

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Nanoscale pattern formation at surfaces by ion beam sputtering

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Abstract

Ion beam sputtering (IBS) induces the self assembly of the patterns on the surfaces of wide range of materials ranging from inorganic to organic materials. Thus IBS modifies the surface properties, and the patterned surface is also used as an ordered template for the growth of the nanostructure.

Moreover, the pattern formation raises interesting issues on the mechanism of the self assembly. In the present talk, I will review the recent progress on the IBS-induced pattern formation and the remaining issues.

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Accelerator

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PA-1

Fabrication Process of Single Spoke Resonator Type-1 (SSR1) Superconducting (SC) Cavity for RAON

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Abstract

Accelerator System Division (ASD) of Rare Isotope Science Project (RISP) in the Institute of Basic Science (IBS) conducted the design and fabrication of single spoke resonator type-1 (SSR1) and type-2 (SSR2) superconducting cavity. In this paper, we will show the detail fabrication procedures of SSR1 SC cavity including pressing, machining, electron beam welding (EBW), buffered chemical polishing (BCP), high pressure rinsing (HPR), and clean assembly. Also, we will show the bare cavity cold test results during vertical test (VT).

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Vertical Test for QWR Cavities in RAON Accelerator

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IBS

Abstract

Vertical test for QWR cavities are performed to make RAON accelerator. The performance of QWR cavities are tested in RAON SRF facility. The experimental procedure of the vertical test is introduced. Lorentz force detuning coefficient is measured and frequency change as a function of pressure is also measured. Quality factors for the QWR cavities are measured as a function of accelerating electric field.

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HLS and WPS systems for monitoring ground behavior and device alignment

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Abstract

Several parts that comprise the large scientific equipment should be installed and operated at precise three-dimensional location coordinates X, Y, and Z through survey and alignment to ensure their optimal performance. As time goes by, however, the ground goes through uplift and subsidence, which consequently changes the coordinates of installed components and leads to alignment errors DX, DY, and DZ. As a result, the system parameters change, and the performance of the large scientific equipment deteriorates accordingly.

Measuring the change in locations of systems comprising the large scientific equipment in real time would make it possible to predict alignment errors, locate any region with greater changes, realign components in the region fast, and shorten the time of survey and alignment. For this purpose, HLS (hydrostatic levelling sensor) and WPS (wire position sensor) system are installed in PAL-XFEL.

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The Simulation Study on Multiturn ERL-Based EUV FEL for Photolithography

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Abstract

포토리소그래피 공정은 EUV를 이용해 실리콘에 반도체 회로 패턴을 새기는 과정으로 반도체 생산의 핵심 공정이다. ERL 기반 EUV FEL은 차세대 EUV소스이다. 본 연구에서는 지난 연구 결과인single turn 디자인에 비해 크기가 더 작으면서도 10 KW 이상의 출력을 낼 수 있도록 전자 빔을여러번 회전시키는 multi-turn 디자인을 기반으로 전산 모사를 수행하였다. 본 연구에서 제시하는 디자인에서는 에너지 15 MeV, 전하량 40 pC의 전자 빔이 1개 의 rf cavity를 통과한 후 180도isochrnous arc를 통과한다. 이 과정을 600 MeV가 될 때 까지 반복한 후 compression을 거쳐undulator를 통과한다. 그 후 가속되는 과정과 반대로 감속 되며 전자 빔의 에너지를 회수한다.시뮬레이션 결과 EUV-FEL은 15.5 KW의 출력을 보였고 loss 없이 전자 빔의 에너지가 15 MeV까지 감속되 빔의 손실 없이 에너지가 회수된 것을 확인하였다. 이러한 디자인을 통해 10 KW 이상의 높은출력의 빛을 더 실용적인 크기의 시설을 통해 제공함으로서 반도체 산업에 기여할 수 있것으로 기대된다.

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Study on Performance Upgrade of the PLS-II Storage Ring

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Abstract

The PLS-II is a third generation light source operating since 2011. It has double bend structure with non-zero dispersion at the straight section. We propose and study the several performance upgrade of the PLS-II. At first, we introduce the canted insertion device beamline to increase the number of beamline. Currently, all the straight section is filled. Secondly, we study the upgrade of the bending magnet to the superbend magnet. Bending field is doubled and the critical energy is increase to 17 keV. Finally, a short bunch mode is studied. 5 ps rms bunch length is aimed for the time resolved experiment using the low alpha mode and the increase of RF gap voltage.

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Parameter Study for the 4GSR Magnet System

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Abstract

Korea is trying to develop next generation low emittance storage ring synchrotron light source which has a beam emittance lower than the existing 3rd generation synchrotron light source. This new type of synchrotron light source is call 4GSR and it features very small emittance less than 100 pm, and very small dynamic aperture. Also it requires very unique magnet system which is very different from the previous generation. New type of magnet includes, longitudinal gradient magnets, combined function magnet with very strong quadrupole components, very small magnet aperture with very high quadrupole strength. In this report, concepts and parameters are studied meeting all these demanding requirements of Korean 4GSR.

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EPICS Integration of RAON Beam Diagnostics Electronics

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Abstract

RAON(Rare Isotope Accelerator complex for ON-line experiments) aims at the beam energy of 200MeV/u(238U) and maximum beam power of 400kW. The role of beam diagnostics system of RAON for the setting of accelerator parameters is to monitor and control the acceleration transport of the beam for improvement of accelerator system. The beam diagnostics systems have to monitor current, position, phase, size, transverse and longitudinal emittances of the beam. The electronics of the beam diagnostics system must be operated in conjunction with the main control system of the central control center. As a large-scaled experiment facility, RAON applied EPICS(Experimental Physics and Industrial Control System) middleware to develop the distributed real-time control system. For this reason, beam diagnostics electronics had to be developed using EPICS middleware. Electronics for monitoring beam current and beam loss use CAEN's PICO board in a uTCA form factor chassis and NI's Compact-RIO hardware. The control for interfacing with uTCA's DAQ module uses Durutronix's ZQ900 board.

In addition, the motion control of Faraday-cup and Wire-scanner for beam diagnosis control the servo motor drive using PLC controller. The I/O signals and acquisition data of these beam diagnostics electronics are integrated into the EPICS middleware.

As a result, this paper describes the results of the design and development for EPICS integration of RAON beam diagnostics electronics.

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Analysis and solution for the beam dump which arises during cryogenic adsorber regeneration process in the PLS-II

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Abstract

Pohang Light Source-II (PLS-II) is a user service facility which provides 19 times of 10-day-long continuous beam time in a year. One of the most important tasks to achieve the beam time availability is the reliable operation of superconducting radio frequency (SRF) system. Through the diagnosis system of RF system by using a postmortem and a data acquisition system, most of beam dump events due to SRF system were analyzed to prevent recurrence. However, from year 2016 to 2018, there have been 25 times of beam dump events showing a similar RF signal patterns, but their cause was unknown. Recently, we found out that 22 out of 25 beam dump events arose during cryogenic adsorber regeneration process. The cause of beam dump events was analyzed with a relation of adsorber regeneration process to get the solution. After applying the solution no more beam dump event happens during the adsorber regeneration process. In this report, more details will be presented.

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Simulation Study of the Beam Extraction with an Electrostatic Einzel Lens for Low Energy Accelerator Mass Spectrometry

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Abstract

The radiocarbon dating using the compact or low energy accelerator mass spectrometer (AMS) is rapidly developing. A gaseous ion source was simulated and designed to remove the sample preparation saving with the time consumption. A simulation study of the low energy accelerator mass spectrometry with ion source and low energy beam transport was conducted to optimize the beam separation. The use of the electrostatic einzel lens revealed the enhancement of the beam focusing and separation. The ion beam trajectories were calculated using the IGUN and SIMION program. The simulation results of the ion beam extraction are presented in this paper.

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Development of a multi-purpose low energy beam transport system for a light heavy ion beam accelerator

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Abstract

The Low Energy Beam Transport (LEBT) system of the Korea Basic Science Institute (KBSI) had been designed to transport ion beam to the following RFQ accelerator as well as to diagnose beam properties and to select required ion beam from undesired various ion beam at the same time. In order to utilize the generated ion beam in the low energy region such as few tens and hundreds keV, an ion beam implantation system has been developed as a key utility for material science study. Moreover a pepper-pot emittance meter is going to be installed in the LEBT for quickly transverse emittance measurement to verify previous slit scanned emittance measurement. The LEBT system has been re-designed to satisfy the requirements, considering fringe field effect of developed magnets. In this paper, we described the magnetic field distributions and their shielding in terms of beam dynamics study, and detail results of the beam dynamics on the two kinds of the operation modes.

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Beam loss studies at the high energy beamlines of the RAON accelerator

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Abstract

The RAON accelerator is currently under construction to generate and accelerate stable ions and rare isotopes for various kinds of scientific programs, and it will be completed by the end of 2021.

In the RAON accelerator, the beams generated by ion sources such as ECR-IS and ISOL can be used in high energy experiments such as a beam irradiation system (BIS) and a muon spin rotation/relaxation/resonance (muSR) system after being accelerated by low energy and high energy superconducting linacs. After the high energy superconducting linac, the beam passes through the high energy beamline and then coincides with the target. The lattices of the high energy beamlines were designed achromatically to minimize the emittance growth in 2015. However, as the specification of magnets in the beamline was changed after first lattice design, a beam dynamics simulation has been performed newly, and beam loss studies have been also conducted. Here we will present the simulation results of the beam dynamics and describe the beam loss studies performed on the high energy beamlines of the RAON accelerator.

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Determination of electron beam parameters for 4 MV biological X-ray irradiator

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DIRAMS

Abstract

Typically, the gamma-ray irradiators using high-activity radioisotopes have been used in preclinical studies with experimental cells and animals to improve the survival rate of the cancer treatment.

However, in the use of gamma-ray irradiators, there are disadvantages in periodic source exchange and high-risk radiation management. To overcome these disadvantages, the low-energy electron linear accelerator (LINAC) can be proposed in applications of the preclinical studies. Since the precise dose delivery to the sample is one of the important parameters in the biological researches, the LINAC beam should be designed with the predetermined reference dose. In this research, the parameters of the pulsed electron beams were studied as a function of doses to the biological samples for the optimal LINAC design. The calculations were performed with the Monte Carlo N-Particle transport code (MCNP) to evaluate the X-ray doses to the samples in unit of Gy per incident electron at a reference distance. The electron beam parameters of the LINAC were derived from the calculation results. The optimal operation ranges for pulse width, pulse frequency, and pulse beam current were evaluated to deliver dose rate of more than 2 Gy/min at the distance of 40 cm from the target. (This work was supported by the Dongnam Institute of Radiological & Medical Sciences

(DIRAMS) grant funded by the Korea government (MSIT) (50498-2019).)

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80 MW Klystron and 200 MW Modulator for PAL-XFEL

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Pohang Accelerator Laboratory

Abstract

The construction of Pohang Accelerator Laboratory X-ray Free Electron Laser(PAL-XFEL) was completed by the end of 2015. Acceleration modules used in the 4th generation electronic acceleration are 51 modules including Hard X-ray and Soft X-ray. Among the high power pulse power devices used as energy source for accelerating electrons in the 4th generation linear accelerator, the beam is being supplied to the user in 60 Hz, 4uS, SLED tune mode of the 49sets module installed in the hard X-ray. The PAL-XFEL needs a highly stable electron beam. The very stable beam voltage of a klystron-modulator is essential to provide the stable acceleration field for an electron beam. Thus, the modulator system for the XFEL requires less than 50 ppm beam voltage stability. To get this high stability on the modulator system, the inverter type HVPS is a pivot component. And the modulator needs lower noise and more smart system. The commissioning began in April 2016, and the lasing of the hard X-ray FEL was achieved on end of 2016. Beginning to provide users with beams from 2017, we will present the Klystron-modulator system when providing beams to users in 2018.

This work is supported by Ministry of Science and ICT(Information/Communication Technology).

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Inspecting the Polarity of Drift Tube Quadrant Magnet at KOMAC

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KOMAC, KAERI

Abstract

The proton beams from 3-MeV to 100 MeV have been provided at Korea multi-purpose accelerator complex (KOMAC). KOMAC has the 11 sets of Drift Tube Linac tank in order to accelerate the proton beam. During the maintenance period, the inspection of the polarity of the drift tube quadrant magnet was scheduled which is equipped in DTL 21, DTL22, DTL23, DTL24. We introduce the measurement method by using the hole effect sensor with the 25 meters chain. For the effective inspection this special tool was designed and fabricated. This paper will provide the description of the test system and the summary of the test results.

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FEL simulation of new hard X-ray undulator line at PAL-XFEL

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Abstract

PAL-XFEL has been successfully operated and the most-stable XFEL facility in the world. For hard X-ray beamline, there is only one undulator line of which the maximum undulator parameter K is 1.87 and the minimum photon energy with 10.5 GeV electron beam is about 14.5 keV. When the lower photon energy is required from the beamline users, the electron beam energy has to be decreased from 10.5 GeV and it results in the decreased accessible FEL pulse energy. To make full use of PAL-XFEL performance in the lower photon energies, therefore, new hard X-ray undulator line with higher undulator parameter K has to be installed in the vacant space beside the existing undulator line. In this presentation, FEL-related fundamental parameters are determined for new

hard X-ray undulator line and compared with existing undulator line. FEL simulation results using

GENESIS are also presented.

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Collective ion accelerator on the base of a cold-cathode magnetron gun in plasma mode

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Abstract

Acceleration of ions in high-power pulsed electric discharges of low pressure up to energies much higher than the corresponding applied voltage is known. However, this phenomenon has not yet received practical use because of its low efficiency and poor reproducibility. It has now been experimentally established that the ion energy increases in direct proportion to the rate of current increase and the length of the accelerating gap. Recently similar effect is observed in connection with investigation of a high current non-sputtering magnetron discharge. During the transition of a magnetron gun to a high-current plasma mode, the author observed a rapid growth of the beam current with a speed corresponding to and greater than the speed at which anomalous ion acceleration was experimentally observed. This process has excellent repeatability. The length of the accelerating gap significantly exceeded than known. In addition, a positive current surge was observed at the collector before the beginning of the rapid growth of the electron beam current. The corresponding charge of this pulse exceeds the observed charge of accelerated electrons by more than two orders of magnitude. All this indicates that in this case there can be effective ion acceleration by a high-current electron beam from a magnetron gun. For verification of effective acceleration, it is required to perform experiments on the direct detection of accelerated ions. The discovered effect can become the basis of simple portable and cheap ion accelerators. Such accelerators can find a variety of applications. They may be of the greatest interest for neutron generation. Of the applications, neutron capture cancer therapy may be the most promising. With further development, the accelerators can be used in control neutron sources for safe nuclear power reactors.

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Fabrication of the Interlock System for the DIRMAS Linac

Dong Eun LEE, Hee Chang KIM, Dong Hyeok JEONG, Manwoo LEE, Seungheon KIM, Sang Koo KANG, Heuijin LIM, Kyo Hyun LEE, Sangjin LEE, Kyoung Won Jang JANG

DIRAMS

Abstract

We designed and fabricated an interlock system to prevent personnel and the DIRAMS linac devices from dangerous situations and to perform the safe operation. The interlock system consists of a main part to control interlock signals of the linac and a display part that indicates where problems occurred. The circuit diagram of the interlock system was based using relays for interlock signal switching, inverters, diodes to improve the relay stability and LEDs. We arranged a series of relays that the switch is closed when a current flows through the coil of the relay. It was designed that the interlock signal changed from ground (0) to high state (1) when the problem occurred during operation. Then, the current did not flow through the coil and the relay switch was opened. Finally, the red LED turned on. We included the system ready button (hardware button) to reconfirm the system state. We tested the interlock system for beam operation and also for unexpected events such as sudden door opening, out of the vacuum range, etc. (This work was supported by the Dongnam Institute of Radiological & Medical Sciences (DIRAMS) grant funded by the Korea government (MSIT) (No. 50495-2019)).

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Non-contact Coordinate Measurement Machine for measuring 3D profile of cavities

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DIRAMS

Abstract

A non-contact coordinate measurement machine (CMM) has been implemented for measuring 3D profile of cavities in the Dongnam Institute of Radiological and Medical Sciences (DIRAMS). This machine consists of motors in three dimensions, a height sensor and a jig to ensure alignment. To inspect status of each cavity before assembling and brazing, scanning and analysis are sequentially performed. In scanning part, the machine obtains the data with the several methods to reduce the measured time, such as the operation with different resolution depending on the path and with reduced communication with the motors and the sensor. Analysis with the data comprises the three parts to find the heights, the radiuses and the diameters of the cavities which can affect the RF characteristics. The analysis algorithm uses mainly the curve fitting, the histogram to improve the accuracy of analysis. In this paper, we describe the purpose of system, the design of system, the algorithm of scanning and analysis and the results of measurement. (This work was supported by the Dongnam Institute of Radiological & Medical Sciences (DIRAMS) grant funded by the Korea government (MSIT) (No. 50598-2019).

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Improvement of Multi Harmonic Buncher's Quality Factor for RAON

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RISP

Abstract

The linear accelerator RAON of the Rare Isotope Science Project (RISP) is developed to accelerate heavy ions from helium to uranium. The injector line consists of ECR, LEBT, RFQ and MEBT, and multi-harmonic buncher (MHB) was proposed to improve beam quality. The MHB is located before the RFQ and the fundamental frequency is half the frequency of the RFQ. The MHB produces waveform similar to saw-tooth wave by synthesizing first, second, and third harmonics. Through the synthesized waveform, two beams with different A/q are accelerated more efficiently. An electromagnetic field simulations of the designed MHB have been done by the CST micro wave studio (MWS). In order to obtain the MHB design with a higher quality factor, an optimization process is carried out.

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1.6 MW, 350 MHz Pulse Klystron Installation and Output Test for KOMAC RF System

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Abstract

KOMAC provides proton beam service to users by using 100MeV proton accelerator. A total of nine Klystrons are used to drive the accelerator. Two klystrons were replaced due to aging of the klystrons. The Klystron specifications are 350 MHz, repetition rate 60 Hz, pulse width 1.5 ms and 1.6 MW output under electron beam voltage 106 kV and electron beam current 26 A. Klystrons are currently operating 24 hours at 1.5 ms electron beam pulse width, 500 us RF pulse width and 10Hz repetition rate. In this paper, we will discuss newly installed Klystron output test results and device fault events.

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Beam Dynamics for Different A/Q in RAON SCL3

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Abstract

SCL3 in RAON (Rare-isotope Accelerator complex for ON-line experiment) facility is a superconducting linac which can accelerate ions with different A/Q from proton (A/Q = 1) to uranium (A/Q = 7.2). The input energy of the linac is fixed to be about 0.506 MeV/u for all combination of a mass number (A) and a charge state (Q). In order to get large enough longitudinal acceptance for the whole range of A/Q, we need to carefully select operation parameters like amplitudes and phases of RF system, and the strength of quadrupole. This work summarized how to obtain reasonable values of operation parameters, and how the resulting output energies of SCL3 depends on A/Q.

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Design of 2.5kW DC power supply with low voltage ripple for industrial magnetron

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UST

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PAL

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Abstract

This paper presents a design of 2.5kW (5kV, 0.5A) DC power supply for 2.45GHz industrial magnetron. The designed DC power supply is based on LCC resonant converter. With its capability of soft switching, LCC resonant converter can achieve high switching frequency, which results in increase of power density and decrease of switching noise and output voltage ripple. In designing the LCC resonant converter, the leakage inductance of power transformer is utilized as resonant inductor without additional inductance and the parallel resonant capacitor consists of parasitic capacitance of power transformer and capacitors used for balancing voltages of diodes in output rectifier to minimize filter components of the resonant converter. Furthermore, output voltage ripple less than 1% is achieved with 400kHz switching frequency. In an aspect of efficiency, trapezoidal shape of resonant current waveform is applied to decrease overall conduction losses and efficiency of up to 96% is achieved. In addition, power supplies for 60kW industrial magnetron and 30kW gyrotron developed in Korea Electrotechnology Research Institute(KERI) are introduced.

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A study on the performance of cryostat for 28 GHz Electron Cyclotron Resonance Ion Source at KBSI

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Abstract

VIBA (Versatile Ion Beam Accelerator) is a compact linear accelerator facility using the 28 GHz ECRIS (Electron Cyclotron Resonance Ion Source) at KBSI (Korea Basic Science Institute). The superconducting magnets of 28 GHz ECRIS produce high magnetic fields for strong confinement of plasma in ion source chamber. For stable operating the superconducting magnets, performance of cryostat is also essential. However, the 28 GHz ECRIS produces significant quantities of the distribution of heating and bremsstrahlung. In addition, a part of the bremsstrahlung produced by the collision of the electrons within the plasma chamber is absorbed by the cold mass of the superconducting magnet leading to an additional heat load in the cryostat. In this paper, a study on the performance of cryostat for 28 GHz ECRIS is performed to improve the cooling efficiency of cryostat. Moreover, a new plasma chamber has been installed that tantalum shielding bore to reduce the effect of bremsstrahlung.

Keywords : 28 GHz ECRIS, Cryostat, Superconducting magnet.

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Compact Design of Solid-state Marx Modulator for Nanosecond Pulse

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Abstract

This paper presents the design of the solid-state Marx modulator for nanosecond rising time and pulse width for various applications such as accelerator kicker system and plasma application.

For minimizing pulse width and falling time, the active pull-down switch that discharge the stored energy on the parasitic capacitance is suggested instead of diode. In order to accomplish the fast rising of output pulse, the exact synchronization of all gate signal as well as the minimized stray inductance of gate current path are essential. Therefore, the main considerations in terms of PCB artwork are that the distance of all component on PCB should be close to the all the ON/OFF switches as much as possible.

In order to satisfy the required specifications, two types of the solid-state Marx modulator are developed according to the power capacity of 1 kW and 100 W.

The designed specifications of 1 kW modulator are satisfied as 10 kV, under 50 ns of pulse width, under 20 ns of rising and falling time. The developed 1 kW marx modulator is tested to PAW (plasma activated water) application. These results indicate that the developed marx modulator might be useful for wide applications and have a high commercial value.

Furthermore, the developed specifications of 100 W modulator are achieved as 10 kV, under 45 ns of pulse width, under 15 ns of rising and falling time. The developed 100 W modulator can be implemented for pseudo-single camshaft bunch operation in accelerator kicker system.

The detailed experimental results of plasma and accelerator application will be discussed in conference. Moreover, in addition to the nanosecond solid-state Marx modulator, a variety of solid-state pulse power modulator developed by KERI will be introduced.

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The RAON Integrated Control System

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Abstract

The RAON accelerator facility which is under construction in South Korea consists of many subsystems. These subsystems have many control devices such as Programmable Logic Controller, Power Supply, Motor, and FPGA. In order to integrate these devices into main control system, the RAON integrated control system consist of three parts which are the main control room, server & storage system, and control network. All accelerator control signals are integrated into EPICS and transmitted over a 200Gbps redundant backbone control network. In addition, the control signals sent from the device are controlled and monitored with video wall based system which composed of 36 monitors in the main control room. In this paper, we will describe a design of the RAON integrated control system and the result of a performance test.

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Method of Finding the Optimized Condition of High Power S-band klystron Operation by Adjusting Input Driving Power

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Abstract

A klystron is one of the effective RF amplifiers and mainly consists of four parts, a gun, a cavity, a collector, and a output section. Its normal life time is about 100,000 hours and main reasons of klystron failure are come from gun, cavity arcing, or cathode exhausts. Except klystron failure related to electron gun, cavity arcing is main reason of broken. Fortunately, the cavity arcing problem could be solved by changing operation condition if there is no mechanical defects. Magnetic field strength, cathode heater current, and driving power are decide movement of electron beam. Changing those parameters affect the movement of electron beam and the change prevent occurrence cavity arcing. To expand life time of klystron, our group focused on the adjusting input driving power method. The klystron beam bunching simulation was conducted by FCI code of EMSYS program to finding optimized operating condition. After the simulation, manufactured klystron is operated according to result of simulation. As a result, the klystron is worked better than non fitting klystron after changing input driving power. In this article, we report on the both comparison of simulation result and experiment. Also, introduce a method of finding the optimized condition of high power S-band klystron operation by adjusting klystron input driving power.

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Fabrication of 4 MeV C-band Accelerating column for Biological X-ray Irradiators

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DIRAMS

Abstract

X-ray irradiators are necessary to replace gamma-ray irradiators for biological researches due to the reduction of nuclear reactors producing radioisotopes worldwide. A plan for the development of mega-voltage X-ray irradiator was established based on the C-band compact linear accelerator (LINAC) technology at the Dongnam Institute of Radiological & Medical Sciences (DIRAMS). In the preliminary studies, we determined that the optimal electron beam energy as a biological irradiator was 4 MeV. The on-axis coupled accelerating column consisting of normal cells, bunching cells, and coupler cells was designed and made by CNC machines. The resonance frequencies were measured for each processed cell and the assembled accelerating column. After frequency measurements, the brazing process was carried out in a vacuum furnace at the DIRAMS. The Electric field of the brazed accelerating column was measured using a bead-full measurement system. And the flatness of the column was evaluated with the measured electric field. In the future, RF conditioning and beam generation of the 4 MeV accelerating column will be tested.

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Technology of High Voltage and RF Commissioning for High Power Pulse Klystron

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Abstract

The final step during the development of klystron is the high voltage and RF processing for stable operation. The purpose of the processing is to remove microscopic surface by high voltage and RF pulses in the electron gun, cavity, and etc. During the manufacturing process to get a stable performance of high power about 80 MW, at a pulse repetition rate of 60 Hz, the final phase of high voltage and RF processing is an important task. Usually, to processing the klystron, a common method is gradually step up the high voltage from modulator. However, we proposed a new method for bellow. (I) Processing in the multipacting section. (II) Method of high voltage step up, according to pulse width and pulse repetition rate. (III) Increase the pulse width in high voltage conditions. (IV) Aging process at specific voltage. In this paper, we describe a method that obtains high power through the above processing.

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Study on the Twiss Parameters in the Injector Beam Line of AMS with NS-FFAG Magnets

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Abstract

The Accelerator Mass Sepctrometer (AMS) is a general technique to measure isotopic ratios which are cosmogenic isotopes. In the AMS, atoms extracted from a sample are ionized, accelerated, separated according to momentum and charge, and then individually detected after identification with atomic number and mass. The injection system includes the ion source, beam transport, and mass analysis equipment before the accelerator. The beam transport in the injection system should transfer multi isotopes such as 12C, 13C and 14C, which isotopes having a different twiss parameters. The difference of twiss parameters decreases the beam transmission for simultaneously transmitting multi isotopes. The new injection system is recommended in this paper to eliminate difference with Non-Scaling Fixed Field Alternating Gradient magnets.

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The improvement of connection stability with a device in RF field

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Abstract

6 MeV C-Band linear accelerator (LINAC) is developed at the Dongnam Institute of Radiological & Medical Sciences (DIRAMS). While the machine is beamed on, an automatic frequency control (AFC) system is required due to a variation of the resonant frequency of cavities. But a connection error occurred when RF power was high during operation. This paper presents a way to do a stable communication in RF field. We have used three protocols to test a connection performance. The RS-232 protocol or TCP/IP is commonly used but is easily disconnected in a high RF power. The RS-485 is known as a protocol which is more noise resistant than RS-232 because RS-485 transmits differential signals. We tested the AFC system using a RS-485 device in operating the LINAC and it showed that the system controlled a frequency for matching the resonant frequency of the accelerator.

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RF Design of New Waveguide Hybrid

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Abstract

We have proposed a new rectangular waveguide hybrid capable of handling hundreds of mega-watts. The new hybrid is based on the short-slot hybrid with two steps structure for matching the hybrid mode. We have designed the available hybrids at 2.856 GHz S-band and 11.424 GHz X-band using Computer Simulation Technology (CST) Micro Wave Studio (MWS) Time-Domain Solver and Optimizer. In the newly designed S- and X-band hybrids, the return loss and the isolation are better than 70 dB. The output power for the two output ports is -3.01±0.01 dB, where the phase difference of two output ports is 90±0.01. The maximum values of the electric field and the magnetic field are 670 V/m, 2.07 A/m and 2360 V/m, 5.83 A/m for the 1 W input power at S- and X-band, respectively. This paper will propose new hybrids, which optimized at S- and X-band, and describe their performance.

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Upgrade Plan of the KOMAC Proton Linac for Atmospheric Radiation Test

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KOMAC/KAERI

Yong-Sub Cho

KAERI

Abstract

At Korea Multi-purpose Accelerator Complex (KOMAC), a 100-MeV high power proton linac has been used for proton beam irradiation services for various applications and research programs including material science, bio-medical science, semiconductor applications as well as nuclear physics and basic science since commissioning of the machine in 2013. Recently, demands for the fast neutron from users in semiconductor industries are increasing to test the semiconductor device SER (soft error rate) or SEE (single event effect). At present, we provide pilot services to users with pulsed white-spectrum neutron (max. neutron energy ~ 100 MeV) generated at beam dump, which is made of copper. However, the neutron energy should be increased at least up to 200 MeV to meet the international standards such as ISO26262 or JEDEC89A. For the upgrade of the linac energy up to 200 MeV, we conducted a preliminary design study, including SRF based linac structure, a neutron generation target and a neutron utilization facility. Upgrade plan of the KOMAC linac along with the preliminary results of the design study will be given in this presentation.

Acknowledgement

This work has been supported through KOMAC (Korea Multi-purpose Accelerator Complex) operation fund of KAERI by MSIP (Ministry of Science and ICT and Future Planning).

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LLRF Control System Development for RISP SRF Cavities

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Abstract

Rare Isotope Science Project (RISP) is constructing equipment and facilities for the Rare isotope Accelerator complex for ON-line experiments (RAON). RAON is a large basic science research facility built around a heavy-ion accelerator. Superconducting RF cavities of 81.25 MHz quarter wave resonators (QWRs), 162.5 MHz half wave resonators (HWRs), and 325 MHz single spoke Resonators (SSRs) have been fabricated and tested. The requirements of RF stability are ±1 % in amplitude and ±1° in phase. Low-level RF (LLRF) control system for SRF cavities has been developed and tested. Digital self-excited loop and RF direct detection was implemented and feedback control algorithm has been tested. This paper describes LLRF control system development for the SRF cavities.

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Pump-down of an in-vacuum undulator vacuum chamber

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Abstract

Initial pump-down curves were measured for an in-vacuum undulator vacuum chamber made of stainless steel tubes and plates (type 316L). Hydrocarbon contaminants dominated the outgassing during the first pump-down and were partially removed by a mild chemical cleaning. The outgassing rate after the mild cleaning was 10-100 times higher than that after an ordinary chemical cleaning procedure for the use of ultra-high vacuum. A heat treatment at 860C for 2 h in vacuum was carried out to reduce further the outgassing. Then the initial pump-down curve was measured again and the outgassing rate was found to be close to a normal one. Finally, a hydrogen outgassing rate as low as 7x10−13 mbar L s−1 cm−2 was achieved by this heat treatment which seems to be much weaker than the normally expected treatment intensity. The result shows that the diffusion process effectively governs degassing at the predetermined heat processing time and temperature.

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Comparison of system pressures for a vacuum system made of steels

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Abstract

Ultimate pressures of two ultra-high vacuum systems were measured and compared after a bakeout at 150 [U+2103] for 48 h. The first system is made of untreated stainless steel (type 304) and the pressure reached a value corresponds to a hydrogen outgassing rate of 3x10−12 mbar L s−1 cm−2. A lower base pressure was obtained by the second system of which vacuum chamber was made of thick mild steel: the corresponding rate was 6x10−13 mbar L s−1 cm−2. The measured pressures will be compared with each other by numerical calculations and will be discussed in terms of hydrogen degassing process during manufacturing.

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FEL Optimization by Commissioning of Hard X-ray Undulator Line at PAL-XFEL

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Abstract

PAL-XFEL has been successfully operating with more than 98% availability for the user service since March 2017. A Hard X-ray (HX) line consists of an e-gun, S-band accelerators, an X-band linearizer, three bunch compressors (BC), dog-leg, and an undulator line. It generates 2.5 – 15-keV FEL with over than 1-mJ pulse energy. This performance is acquired from optimizing the FEL pulse energy by undulator commissioning. The undulator K-tuning and vertical offset scanning are conducted for maintaining K-values of undulators. The Beam Based Alignment (BBA) in the undulator line and e-beam size matching are conducted for the transverse matching between FEL and e-beam. The phase between FEL and e-beam is matched by the phase shifter scanning and the FEL pulse energy are optimized by undulators tapering. In this paper, we present details of the commissioning sequence and the performance of the PAL-FEL operation.

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A Study on Ion Beam Extraction Optimization of ICP type Ion Source in High Current Ion Implanter

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Abstract

In high current ion implant equipment used in the ion implantation for semiconductor process, thermionic discharged ion sources are commonly used for plasma generation. Thermionic discharged ion sources are based on electron emission from a hot cathode to produce the desired plasma density by ionization of the background gas. The use of filaments is essential for cathode heating, but corrosion of the filaments due to heating leads to reduce their lifetime and performance. So the development of new ion sources with long PM cycles and relatively low maintenance costs is required. In this study, we developed an ICP(Inductively Coupled Plasma) type plasma ion source that can be applied to the same pressure conditions and spaces as before. We also conducted the research on the optimization of ion extraction according to the change of plasma parameters such as plasma potential, electron density and electron temperature using Ion Beam Simulation(IBSimu).

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RF Performance Tests with FPGA-Based Digital LLRF and Superconducting Cavities for RISP

Hyojae Jang, Kyungtae Seol, Oh Ryong Choi, Kitaek Son, Doyoon Lee, Youngkwon Kim

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Abstract

An ion accelerator, RAON is under construction in Daejeon, Korea by Rare Isotope Science Project (RISP) in Institute of Basic Science (IBS). In this accelerator various ions such as uranium, proton, carbon, calcium, etc. are planned to be accelerated by four kinds of superconducting cavities. The four kinds of cavities are QWR (Quarter Wave Resonator), HWR (Half Wave Resonator), and two kinds of SSR (Single Spoke Resonator) with different betas. Recently the RF performance tests with newly developed FPGA-based digital LLRF and superconducting cavites are being conducted at SRF (Superconducting Radio Frequency) facility. In this presentation the status and test result of RAON LLRF performance test will be described.

* This work supported by the Rare Isotope Science Project of Institute for Basic Science funded by Ministry of Science and ICT and NRF of Korea (2013M7A1A1075764)

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Current status of the medium energy beam transport system of RAON

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Abstract

The Medium Energy Beam Transport (MEBT) system for RAON will match the optical parameters in transverse and phase space between the RFQ and superconducting linac (SCL). It is composed of 4 normal conducting quarter wave resonators and 11 quadrupole magnets. The normal conducting QWRs are re-bunching machines and the quadrupole magnets have transverse beam focusing and steering elements. Detailed status of the system will be present this workshop.

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Development Status of 1-MV Single-ended Electrostatic Accelerator for Industrial Applications

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Abstract

At Korea Atomic Energy Research Institute, 1-MV single-ended accelerator is being developed to obtain various gaseous ion beams such as hydrogen, oxygen, etc. with energy below 1 MeV for various industrial ion beam irradiation such as semiconductor device manufacturing process. A compact gaseous ion source that can fit inside a 1-MV high-voltage terminal has been developed in the form of an rf ion source using 20-MHz high-frequency, capable of delivering hundreds of uA of ions for hydrogen. A 60-cm-long acceleration tube made of ceramic-metal joint technology was developed to accelerate ions from the ion source to 1 MeV. The 1-MV high voltage power supply is

the ELV type, which was developed at Budker Institute of Nuclera Physics in 1971, commonly used in industrial electron accelerators. ELV type high voltage power supply using AC power supply of 400 Hz has the advantage of easy maintenance and repair, high current and high efficiency suitable for industrial applications. The ion source power supply is designed and manufactured to supply 200-W DC power over 1-MV high voltage by installing a separate coil in the ELV type high voltage power supply. The beam-line for beam transport after the accelerator tube is a quadrupole triplet for beam focusing, a switch magnet for filtering ions with different mass-to-charge ratios, an electrostatic scanner for magnifying the beam up to 200-mm diameter, and a sample irradiation system which consists of a sample irradiation vacuum chamber and a beam measurement system.

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Introduction of 14.5 GHz ECR ion source for initial beam conditioning of RAON accelerator

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Abstract

RAON is a heavy ion accelerator that is being built in Daejeon, South Korea, with the goal of 2021. RAON plans to operate a 28 GHz ECR ion source with fully superconducting magnet and a 14.5 GHz ECR ion source with fully permanent magnet. Currently, the 28 GHz ECR ion source is manufactured and under test operation, and the 14.5 GHz ECR ion source is currently being manufactured by PANTECHNIK Co. of France and will be installed in the injector zone in ISOL experiment space in January 2020. Starting in September 2020, initial beam conditioning of the accelerators will be performed through Ar8+ and O6+ with beam energy of 10 keV/u using 14.5 GHz ECR ion source. To satisfy the beam energy of 10 keV/u, the ion source will operate on a 2stage high voltage platform and operate under high voltage conditions of up to 70 kV. After the initial conditioning, we will conduct experiments to extract various types of beams and optimize for stable beam supply.

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Development of quad scan analysis GUI at KOMAC beamlines

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KOMAC/KAERI

Abstract

At Korea Multipurpose Accelerator Complex (KOMAC), several beamlines are built to transport proton beams to a designated target room. In the beamlines, 8 wire scanners are installed and operational to measure a beam profile in X and Y axes. Using a wire scanner and a quadrupole magnet, quad scan method can be performed. During a quad scan, beam profiles are measured over a range of quadrupole strengths, and RMS beam size is calculated for each beam profile. We have developed a graphical user interface (GUI) using PyQt which enables the online-measurement of RMS beam size and gives out the X, Y Twiss parameters and emittance of the proton beam entering the scanning quadrupole magnet. We have implemented this GUI in the accelerator control room and in this paper, some of the beam experiment result using this GUI is present.

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A stripline-based non-destructive beam profile monitor for J-PARC muon g-2/EDM experiment.

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UNIST

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CAPP/IBS

Abstract

The muon g-2/EDM experiment at J-PARC aims to measure the muon magnetic moment anomaly, a_μ and electric dipole moment, d_μ with high precision of 450 parts-per-billion (ppb) and 70 ppb for statistical and systematic uncertainties of a_μ and a sensitivity of 1.5E-21 e · cm for d_μ. Such a precision can be acieved by XY coupling of beam phase space with help of several skew quadrupole magnets. The XY coupling can help to prevent the muon particles from being lost by vertical divergence within the storage magnet. Otherwise, the beam would be vertically defocused while the particles travels to the storage region. Since it's important to monitor the XY coupling quality in the beam operation, a non-destructive beam profile monitoring system will be crucial and is under developing. The device is a stripline-based with 8 feedthrough. It will reconstruct the coupling parameters such as skew angle and beam size by using multipole analysis of image current. This poster will present the simulation result on the reconstruction and the design of prototype device for the beam test planned at the injector test facility (ITF) of PAL in the future.

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Development of methods for electron beam focal spot positioning

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Abstract

There are various X-ray facilities based on pulsed linear electron accelerators in the world [1,2,3]. Accelerated electrons are focused on the converter target to create x-rays. The implementation of the multi-pulse mode in such facilities is a demanded task. One way is to use several targets separated in space. The beam of electrons after the first pulse is focused on the neighboring target. Thus, the urgent task is to study of different methods for electron beam focal spot positioning. This paper describes two different approaches, which are under development in BINP.

The first approach is based on the use of dipole pulsed magnets. The beam is focused by a conical solenoid before it hits the target converter. The main component of the magnetic field created by the dipole corrector magnets is directed perpendicular to the beam direction. Using numerical modeling, the design of such correction system was optimized. According to the numerical modeling, it is possible to shift the focal spot up to 4 mm without significant increasing of its size. Based on the obtained data, a dipole magnet prototype was developed. The prototype was tested experimentally on a facility with beam energy of 4 MeV and current up to 1 kA. Shift of the beam focal spot about 6 mm was observed. The size of the focal spot was also nearly unchanged.

Dipole magnet allows us to change the position of the beam focus only along one axis. However, realization of the multi-pulse mode require beam positioning in two or even three dimensions. The use of several dipole magnets is a rather inconvenient solution. Thus, the second approach for the beam focal spot positioning based on a modification of the Double-Helix Dipole (DHD) design was proposed. If a different current is applied to the windings with different slopes, then in addition to the transverse component of the magnetic field, a longitudinal component will be created. Such corrector placed in the edge field of the focusing solenoid allows us to shift the beam focal spot position along the longitudinal and transverse coordinate. Correction in three axes can be achieved by sequentially placing a second pair of inclined windings rotated 90 degrees. The DHD design was optimized numerically in term of requirements of compactness, low inductance and beam focal spot quality. During computer simulation, it was shown that even when using single-turn windings, the field quality remains acceptable, in order to maintain the size of the focal spot.

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Off-axis beam injection in the PAL-4GSR using existing 3 GeV PLS-II linac

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Abstract

One of the most recognizable features of the PAL-4GSR (Pohang Accelerator Laboratory 4th Generation Storage Ring) is a large dynamic aperture. With this feature, conventional off-axis injection is possible on the storage ring. Among the small emittance storage ring (below 100 pm), PAL-4GSR is a rare ring that the off-axis injection is possible. Off-axis injection method had been well demonstrated and the current technology is enough for supporting this scheme. Therefore, some 4th generation storage rings adopted off-axis injection if it is possible. This paper demonstrates the off-axis beam injection scheme on the PAL-4GSR using existing PLS-II 3 GeV linear accelerator. In the simulation, the 100 % injection efficiency was attained in the condition of 6 mm offset of injected beam from stored beam.

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Status and High Power Test of RISP RFQ at Off-site Test Facility

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Abstract

RISP (Rare Isotope Science Project) has been developed a radio frequency quadrupole (RFQ) linear accelerator to accelerate heavy ions. Before accelerator building construction was completed, the RFQ was fabricated and installed at the off-site test facility. By the preliminary beam test, the design, fabrication, and tuning results of the RFQ were verified.

The RFQ has been conditioned to 70 kW in pulse mode and 50 kW for cw mode without beam, which is sufficient to accelerate the key performance parameter beams, 40Ar10+ . However, CW performance at maximum voltage could not be performed in the off-site test facility due to insufficient cooling water availability.

The injector system including the RFQ will be transported to the project site for installation. The commissioning of the injector system is expected to begin in early 2020. In this paper, the development status and reinstallation plan were summarized.

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Electron beam test for the RAON EBIS charge breeder

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Abstract

The RAON is a heavy ion accelerator facility, which is under construction in Korea for the Rare Isotope Science Project (RISP). An Electron Beam Ion Source (EBIS) will be used for charge breeding of RI beams in the Isotope Separation On-Line (ISOL) system for the RAON. The mass-to-charge ratio (A/Q) of the RI beams after the charge breeding is in between 2 and 6. The RAON EBIS 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. Initial component tests of the EBIS charge breeder have been done, and an assembly of the RAON EBIS was completed. Before an off-line test of RAON EBIS, the electron beam transfer test with ion trap region has been performed. In this paper, current development status and electron beam test results of the RAON EBIS charge breeder will be presented in detail.

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Development of a Radio-Frequency System for a Radio-Frequency Quadrupole Cooler Buncher in the RISP

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Abstract

Radioactive ion beams produced from the Isotope Separation On-Line (ISOL) method in the Rare isotope Accelerator complex for On-line experiment (RAON) are to be delivered with a beam emittance of around 3 π•mm•mrad, an energy spread of less than 10 eV, and a short beam bunch width of around 10 μs by full width to meet the requirements of an Electron Beam Ion Source (EBIS) charge breeder. A radio-frequency quadrupole cooler buncher (RFQ-CB) will be used to meet the beam quality requirements mentioned above. In the RFQ-CB, the radial confinement force to the beam is produced by radio-frequency (RF) voltages of the RFQ electrodes, and the axial force is produced by the DC voltages distributed along the segment electrodes. The trapped ions are cooled by collisions with the helium buffer gas. By simulation using SIMION code, we were able to obtain various parameters such as buffer gas pressures at different sections, the required RF and DC voltages, and the resulting beam emittance and energy spread, etc. To obtain a bunching capacity of 108 ions/bunch for various ion species, we attempted to build an RF system with a maximum RF amplitude of ~7 kV and a frequency range of 1–10 MHz. We designed and tested the prototype RF system with a helical resonator, high-voltage probes, and a 100-W high-power RF amplifier. In this presentation, the test results of the prototype RF system are described.

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Preliminary design of vacuum system for a 4th generation storage ring in Korea

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Abstract

A fourth generation storage ring is planed to be constructed in Korea near future. A lattice with a hybrid-7BA archromat for the low emittance storage ring is being designed at Pohang Accelerator Laboratory. A vacuum system for this lattice is also in the study. Main challanges are maintaining ultra-high vacuum inside small aperture vacuum chambers and dissipating high heat loads from the synchrotron radiation within tight spaces for the vacuum system. We propose a vacuum system with extruded vacuum chambers with pill-type getters as distributed pumps.

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Preliminary test of various element ion beam extraction from metal vapour vacuum arc source

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Abstract

The MEVVA ion source can produce metal plasma by vacuum arc discharge and it can be extracted. The characteristic of the MEVVA ion source is its production of high-current metal ion beam. The MEVVA ion source can produce plasma over 50 of the solid metal elements of the Periodic Table as well as semi-metal (Graphite) and semi-conductors (Si. Ge). When vacuum arc discharge occurs causes a high current arc discharge between cathode and anode, the current is concentrated to very small point on the cathode surface, which is called the cathode spot. The current density of the cathode spot is 106-108 A/cm2, it can produce the metal plasma. In this study, we have conducted preliminary test for ion beam extraction with the various cathode type.

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Tapering Study of a Coherent Undulator Beamline for New Advanced Synchrotron Light Source in Korea

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UST/KAERI

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Abstract

Recently, a plan to construct a new advanced synchrotron light source is under discussion in Korea. For the project, the Korean government has allocated $1.2M budget to the design study of a new advanced synchrotron light source. The new advanced synchrotron light source will be the Diffraction Limited Storage Ring (DLSR), which is based on the MBA lattice. For the new synchrotron light source, we would like to build a special 40 m long coherent undulator beamline, which can deliver high-intensity coherent radiation at the hard X-ray region. We have performed numerous beam dynamics simulations with GENESIS and SIMPLEX codes to design the coherent undulator beamline and to increase the power of the radiation by applying the tapering technology. In this presentation, we report the simulation result of tapering of the coherent undulator beamline.

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Status of Superconducting RF Electron LINAC for neutron Time-Of-Flight Facility at KAERI

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KAERI

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PAL

Hyeri LEE, Ingyo JEONG

UST/KAERI

Abstract

The Korea Atomic Energy Research Institute (KAERI) is carrying out the research of neutron Time-Of-Flight using 20 MeV superconducting RF (SRF) electron linear accelerators (LINAC). SRF LINAC has advantages of acceleration efficiency and operation stability through continuous wave operation mode. It is proper to generate high-flux neutron in neutron Time-Of-Flight (nTOF) facility with low-noise level. However, this machine has aged more than 15 years, we have been doing an upgrade project for performance evaluation from 2018. This paper describes a status of SRF electron LINAC for nTOF facility at KAERI. We studied design features of SRF LINAC with sub-systems and investigated their roles for nTOF facility. For performance evaluation, we developed a digital low-level RF feedback system for increasing resolution and accuracy of feedback control. Finally, we measured RF characteristic results of SRF cavity and RF sub-systems to compare with design parameters.

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Design of 6 GeV Diffraction-Limited Storage Ring

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Abstract

Recently, the demand of a new advanced synchrotron light source is rapidly growing in Korea. Several Korean local governments such as Chungbuk-do and Jeonnam-do have been actively preparing to host the new light source in their own province. The Korean government also has allocated $1.2M budget in 2020 to prepare Conceptual Design Report (CDR) for the new advanced synchrotron light source, which will be an Multi-Bend Achromat (MBA) based Diffraction Limited Storage Ring (DLSR). In this paper, we describe design concepts and performance of one possible 6 GeV storage ring with a circumference of 1300 m for the new advanced synchrotron light source.

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Optimization of 4 GeV Storage Ring with Multi-Bend Achromat (MBA) Lattice

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Abstract

Recently, a plan to construct a new advanced synchrotron light source is under discussion in Korea to improve R&D capability of advanced material developments. Accordingly, the various designs for the storage ring are needed to produce high-brightness synchrotron radiation. The future accelerator R&D team at KAERI has been studying various designs of the 4th generation synchrotron light source with the Multi-Bend Achromat (MBA) lattice. One of them is a 4 GeV storage ring with the circumference of 1.3 km, which has the 7-Bend-Achromat (7BA) lattice to obtain a pm-scale natural emittance for the new light source. The ring has been optimized by the ELEGANT code simulation, and we got the natural emittance of 15 pm. In this paper, we present the lattice design and the ELEGANT code optimization. The radiation characteristics for the bending magnets and the various insertion devices are evaluated as well.

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Beam Dynamics Simulation Study for the Design of the Axial Injection System

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Abstract

Due to high current and low beam energy, there are large beam losses caused by space charge effects in the axial injection system. Therefore, the injection system is one of critical parts in a cyclotron system to achieve high intensity operations. In this study, we performed beam dynamics simulations for the design of an axial injection system in the cyclotron, which consists of buncher, Farady cup, Einzel lens, solenoid, and quadrupole doublet. In order to minimize beam loss in the system and to increase the transport efficiency, multi-particle beam dynamics simulation codes, TRACK and CASINO, are used in the system design.

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Interferometric Beam Size Measurement System Upgrades in PLS-2

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Abstract

The default electron beam size measurement method in the PLS-2 storage ring at is the interferometer system installed at the dedicated diagnostic beamline named 1B. The radiated photon beam at the bending magnet forms visible interferogram on CMOS sensor after passing through the X and Y double-slits and the image is taken and analyzed for the beam size calculation. We replaced the old VGA CCD camera and its analog DAQ system with new digital CMOS camera and new DAQ machine having 32 cores CPU, in order to achieve fast, precise and complicated image analysis. After the upgrade, a vibration of interferogram image analysis was performed by comparing to the vacuum chamber vibration measurement. Real time image analysis code using curve fitting method was developed taking full advantage of multi-core CPU for accurate beam size calculation. In this paper, we introduce the hardware upgrade details and describe newly performed analysis results.

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Design studies of 2nd Generation ECRIS for Accelerator Mass Spectrometry

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Abstract

ECR ion source researchers of Korea Basic Science Institute are started the development of 2nd generation ECR ion source for positive ion mass spectrometer after development of 28GHz ECR ion source. The positive ion mass spectrometry is supporting micro-dosing researches for biology and medicine. Specially, we are interesting about mass spectrometry of boron isotope and drug delivery research using boron isotope. We are designing of ion source for boron isotope. We has been working for useful information using ECR ion source of Korea University Sejong Campus. From several feasibility studies, we obtained design information. In this presentation, we will introduce concept of positive ion mass spectrometry system using 2nd generation ECRIS. We want to discuss about optimal design for 2nd generation ECRIS.

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Characteristics of Synchrotron Radiation of the Fourth-generation Storage Rings

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Abstract

Fourth-generation storage rings (4GSR) based on multi-bend achromat (MBA) lattices promise to deliver stable x-ray beams with much higher brightness and coherence than existing third-generation light sources. The basic ingredient in achieving higher brightness is a further reduction of the electron beam emittance in storage rings dedicated to light sources. These 4GSR lattices can lead to 1 to 2 orders of magnitude reduction in the beam emittance by employing the MBA, where many dipoles per cell are used to keep the dispersion function low inside the dipoles. The low emittance beam is transported to the beam line through the insertion device or super-bend which is a permanent magnet with 2T magnetic field. In this presentation, we will introduce the characteristics of synchrotron radiation of 4GSR compared to present third-generation sources, PLS-II.

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Progress of the Fast Protection System in the RAON

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Abstract

Rare Isotope Science Project (RISP) under the Institute for Basic Science (IBS) in Korea is building a rare isotope accelerator facility with beam energy of 200 Mev / u and beam output of 400 kW. The main function of the Machine Protection System is to protect the components of the accelerator from beam damage. Accelerator components typically take a very long time to replace or recover and are expensive to replace.Machine protection systems minimize accelerator downtime to maximize operational availability and protect the components of the accelerator from beam damage. This poster presents the progress from Fast Protection Systems for RAON accelerators with EPICS and the application of the accelerator.

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Current Status of the Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility

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Abstract

Based on linear accelerators (linacs) of the Tokai Radioactive Ion Accelerator Complex (TRIAC) given from the high energy accelerator research organization (KEK), Japan, a heavy ion beam irradiation facility has been constructed at Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea, for nuclear/fusion materials research and development. This facility, first called Daejeon Ion Accelerator Complex (DIAC) and later renamed Korea Atomic Energy Research Institute Heavy Ion Irradiation Facility (KAHIF), produces heavy ion beams with energies up to about 1 MeV/nucleon. Since 2015, the construction of the facility, performance testing of the beamline components, the first helium and argon ion beam acceleration tests, and acquisition of the radiation safety license have been successfully completed. Heavy ion beams in the KAHIF now serve a vast range of scientific users in the fields of nuclear/fusion engineering by simulating reactor environments.

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Development Progress of EPICS-based Control System for Fusion-Oriented Test Facilities in KAERI

Dae-sik CHANG, Suk-kwon KIM, Sung-ryul HUH, Byung-hoon OH, Eo-hwak LEE, Dong-won LEE

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Abstract

There are many fusion-oriented test facilities, such as Heavy Ion Irradiation facility (KAHIF), Korea Heat Load Test facility by using Electron Beam (KoHLT-EB) and Helium Cooling System (HCS) for the development and testing of fusion reactor materials in KAERI (Korea Atomic Energy Research Institute). The facilities are individually controlled the Experimental Physics and Industrial Control System (EPICS) through the network and can be integrated and operated as one system if necessary. All experimental data has been already integrated and managed. The other experimental devices, such as the Compact Fusion Neutron Source (CFNS), are also controlled by the EPICS-base control system to obtain the reliable operation of remote control and data acquisition systems. The detailed system structure and network architecture are introduced in this presentation.

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Analysis and Tuning Results of The Pulse Energy Doubler

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Abstract

The Pohang Accelerator Laboratory X-ray Free Electron Laser(PAL-XFEL) is operating the pulse energy doubler at the maximum input peak power of 80MW, with a pulse length of 4μs, and at a repetition rate of 60Hz. The pulse energy doubler is one of the important devices that increases the peak output power of the 2.856 GHz high frequency generated by the Klystron. The device receives a 4μs length for high frequency power from the klystron and reduces the length of the pulse output to 1μs. However, the maximum peak output power can be increased four times. The total of 42 pulsed energy doublers are installed in the PAL-XFEL RF system. It consists of two resonators and one 3dB coupler. The amount of heat generated depends on the operation repetition frequency. There are two ways to prevent it. Change the water temperature of the cavity cooling system or adjust the volume of each resonator. We installed the systems that can remotely adjust the resonator volume by connecting a motor to each resonator. This paper shows the results of using the pulse energy doubler efficiently. All sections were tuned to 60Hz using a resonator volume controller. In addition, it can adjust 10 ~ 60Hz by changing the temperature of cooling system.

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Beam Utilization

ICABU 2019

Structural and electronic properties of ZnO and Ti/Mn:ZnO thin films grown on flexible polyimide

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Abstract

Thin films of ZnO and Ti/Mn doped ZnO were grown on flexible polyimide substrate at different deposition parameters using sputtering technique. The structural and electronic properties of these grown samples were studied. Grazing incidence X-ray diffraction (GIXRD) results confirmed the hexagonal wurtzi te symmetry of pure and Ti/Mn doped ZnO flexible thin films samples.

The estimated values of lattice parameters and crystallite size presented a reliance on doping as well as deposition parameters. A significantly suppression in the crystallite size was resulted by oxygen presence during sputtering. Doping (Ti/Mn) and deposition parameters induced changes in the electronic structure of flexible ZnO thin films were also realized through X-ray absorption measurements.

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Current Status of RFT-30 Cyclotron and Its Applications

Eun Je Lee, Young Bae Kong, Ho Seung Song, Min Goo Hur, Jun Young Lee, Seung Dae Yang, Jeong Hoon Park

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Abstract

RFT-30 cyclotron has been developed not only for the production of radioisotopes (RIs) and their applications, but also for proton beam utilization to various research fields including material science, bio science, and so on. In this research, various positron-emitting RIs including F-18, Zr-89, Ge-68, Cu-64, Co-57, and Sc-44 were successfully produced using RFT-30 cyclotron at KAERI. We are trying to optimize irradiation conditions for RI production and following processes after the irradiation. Produced RIs can be used for the user service as well as for our own research purpose. In the future, research on the production of other useful RIs and the performance improvement for mass-production will be carried out. In addition, we are also providing proton and neutron irradiation services. Proton beam irradiation is used to the research field such as the modification and radiation hardness test of electronic devices, radiation breeding, and so on. On the other hand, neutrons produced by the proton irradiation of a Be target are used to the research field including neutron detector and neutron shielding.

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Efficiency improved diced crystal based von-Hamos Spectrometer for X-ray Spectroscopy

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Abstract

A von-Hamos spectrometer having cylindrical bent analyzer of different crystallographic orientations Si(111), Si(110) and Si(100) is presented. The diced crystal analyzers of 200mm length and 150mm radius of curvature are prepared for high efficiency of spectrometer. Si crystal strips of 2mm width in focusing direction are glued on cylindrical shaped aluminum substrate. We measured the spectrometer efficiency and energy resolution at different x-ray energies. Higher efficiency compared to 100mm analyzer makes this spectrometer advantageous for x-ray emission spectroscopy.

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Design of preclinical irradiation platform with upwards-pointing beam using the C-band LINAC

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DIRAMS

Abstract

Recent biological studies with ultra-high dose-rate irradiation (>40 Gy/sec) presented to kill the tumors with reducing the side-effect of normal tissues. The radiotherapy community expects that these features will suggest the next coming therapy methode. In order to understand their radiobiological mechanisms and transfer this knowledge to the clinical application, we proposed the preclinical irradiator based on the DIRAMS C-band standing-wave LINAC. This irradiator focused on the vitro studies of cells and also small animals of mice. In order to reduce the air-gap effect in the dish for cell study, this irradiator was designed with upwards-pointing beam without magnets and also the allowed maximum beam energy up to 9 MeV depending on the accelerating column which will be fabricated at the DIRAMS. The overall size of the irradiator is 1200(W)x850(L)x1000(H) mm3 and a sample-dish will be located on a height of 1400 mm from the bottom. The electron beam with a diameter of 15 cm will irradiate the sample at 30 cm distance from the electron-scattering foil. In this paper, we present the designed irradiator, and discuss the optimization of space-saved structure and also features to improve the specialized preclinical experiment. (This work was supported by the Dongnam Institute of Radiological & Medical Sciences (DIRAMS) grant funded by the Korea government (MSIT). (No. 50495-2019))

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Proton decay of 21Na for 20Ne energy levels

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Abstract

The 24Mg(p,α)21Na transfer reaction was studied previously for spectroscopic of the radionuclide 21Na [Cha et al., Phys. Rev. C 96, 025810 (2017)] using a 31 MeV proton beam at the Holifield Radioactive Ion Beam Facility at Oak Ridge National Laboratory. Angular distributions of the alpha particles from the reaction were measured by a silicon detector array. The empirical angular distributions were then compared with theoretical Distorted Wave Born Approximation calculations to constrain spins of observed levels in 21Na. In the present work, coincident protons emitted from the decay of states in 21Na above ~5.4 MeV were studied. Six known energy levels in 20Ne were well reproduced through the analysis. Details of the data analysis will be presented together with preliminary results.

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Research of TVS characteristics with a surface flashover trigger device

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Abstract

Triggered vacuum switch (TVS) has been applied in high pulsed power systems. It is a high power switch operated by plasma. The initial plasma is ignited at a trigger device by surface flashover mechanism and the main plasma is discharged at a main electrode by the ignited plasma. The operational characteristics of trigger jitter, main jitter, and delay are dominantly affected by the trigger device. We have measured the characteristics with the trigger device employed a ring electrode up to 20 kV. Each measurement is progressed for 100 shots. Measured trigger jitter, main jitter and delay are in the order of few microseconds. In the next, we will continue the research of characteristics with a new trigger pulse generator having hundreds of nanoseconds rise time.

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Design of Inductive energy storage based high voltage pulse modulator for TVS and plasma applications

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Abstract

This paper describes the design of an inductive energy storage based high voltage pulse modulator for TVS(Triggered Vacuum Switch) and plasma applications. The proposed pulse modulator consists of only two components(transformer and switch) and can generate pulse with very high step-up ratio of voltage. Operating principle is based on flyback converter that store the energy on magnetizing inductance and transfer it to secondary side of transformer by opening switch. From this design, the trigger circuit(20 kV, 100 mJ/pulse) for TVS is implemented, and tests with an actual TVS (3.3 kJ) is conducted. In addition, using proposed design procedure, four versions of pulse modulator (2 kV, 8 kV, 20 kV, 40 kV) are designed and applied for variable plasma applications. The detailed design of the proposed pulse modulator, experimental results with TVS, and plasma applicaitions are discussed in following paper.

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Performance of Gamma-ray Detection System Consisting of a 4-fold 32-segmented High-Purity Germanium Detector and a BGO/CsI(Tl) Compton Suppressor

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RISP/IBS

Byul MOON

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Abstract

Gamma rays are important probes for the detailed structure of nuclei. Their energies can be measured in high precision by using a high-purity germanium detector (HPGeDet). However, in gamma-ray energy spectrum obtained with HPGeDets, low intensity peaks are often unidentified by the background which is due to Compton scattering of gamma rays of higher energy. To overcome this problem, a Compton suppressor, which is made of BGO(or CsI(Tl), NaI) detectors, surrounds HPGeDet. The signal provided by the interaction of scattered gamma rays with the Compton suppressor is used to veto the incomplete signal in the HPGeDet. Recently the gamma-ray detection system, consisting of a 4-fold 32 segmented High-Purity Ge detector and a BGO/CsI(Tl) Compton suppressor, was developed at Rare Isotope Science Project(RISP) in Institute for Basic Science(IBS). In this presentation, we'll show the results on the gamma-ray measurements conducted with a 137Cs standard source and will discuss on the Compton suppression performance of the gamma-ray detection system.

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Dosimetry system for medical and biological applications of the electron linear accelerator

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Abstract

In medical and biological applications of electron linear accelerators (LINACs), evaluations of depth doses and dose rates for irradiation beams are important to deliver accurate doses to biological samples. For the optimal dose delivery, dosimetric parameters should be measured by a dosimetry system. The dosimetry system consists of radiochromic films and film analysis devices, ionization chambers, electrometers, solid-water phantoms and small water phantom. The most probable energy and the mean energy for electron beams can be determined by the depth dose curves measured in the solid-water phantoms. The dose rates for electron and X-ray beams are measured by the calibrated ionization chambers in the water phantom. The dosimetric parameters for the electron LINAC at the DIRAMS have been presented. (This work was supported by the Dongnam Institute of Radiological & Medical Sciences (DIRAMS) grant funded by the Korea government (MSIT) (No. 50598-2019 and No. 50495-2019).)

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Optimization of Surface Muon Production on Graphite Target by 600 MeV Proton

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Abstract

The graphite target was studied to optimize the dimension of the target to produce a sufficient number of surface muons in thermally stable condition, for the muon facility at Rare Isotope Science Project.

Main purpose of the simulations is to determine the graphite target geometry and the proton beam size for surface muon production when 600 MeV proton beam is bombarded to the target. Thus, the simulations were performed in the various target dimensions and beam sizes. Calculations of surface muon yield by MCNP6.1 and Geant4 were compared to get the conservative result. Based on the results, radiative cooled rotating ring-shaped target was designed, which has advantages in cool-down; low temperature gradient in target and no necessity of liquid coolant-cooling system. The stress and temperature distribution are calculated using ANSYS for the target integrity.

The optimized target has an inner radius of 18 cm, an outer radius of 20 cm and a thickness of 0.5 cm. In this geometry, the proper full width at half maximum of the proton beam is 2.75 mm in X direction and 6.73 mm in Y direction. The maximum temperature is 1738.6°C and the maximum stress in the target is 1.7236 MPa, which guarantee the safety during the replacement cycle of the target.

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Ion optical design of the muon facility at RAON in Korea

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Abstract

Ion beam optics design was performed to determine specifications of electromagnets of proton transport line to material science facilities and of surface muon beam line at the RAON accelerator. The beam optics was calculated with the program GICOSY up to 5th order.

The distribution of position and divergence of 600 MeV proton was assumed to be Gaussian and the initial beam emittance was 0.125 ϖ mm mrad. The final proton beamline design was carried out by adjusting the distance between components and optimizing the magnetic field of the electromagnets.

The proton beam size at muon production target was 2.75 mm FWHM in x-axis and 6.73 mm FWHM in y-axis and was adequate to meet requirements to produce the maximum yield of surface muon at the target.

The surface muon beam transport line design was then performed. The beam line consists of 2 solenoids, 2 dipoles with a deflection angle of ±70□, 8 quadrupoles and a 1.8 m Wien filter. The initial muon beam size at the target is 6 cm in x-axis and 2 cm in y-axis.

After passing through the beam line, the intensity of the muon beam is expected to reach 1.58□107 per second in a circle of 3 cm radius.

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Benchmark calculation to verify the platform to calculate the cross section

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Abstract

Since the cross section of a nuclear reaction is defined as the probability that a nuclear reaction will occur, measuring the cross section is very important in order to understand the production yield of the radioactive isotopes. In general, after the proton beam is irradiated into the targets, the targets activated are measured using the HPGe detector in order to measure the amount of the radioactivity of the target material produced. Since the procedure to calculate the cross section from the raw data measured using HPGe is the time-consuming task to cause mistakes, the platform with the algorithm to perform the calculation of the cross section automatically is needed and this platform has been currently developed. In order to verify the platform to calculate the cross section from raw data, the benchmark calculation to compare the data result published with the result calculated by this platform should be also applied. In this research, the calculation result of the cross section made by the platform would be compared with the result of the cross section published.

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Design of the RFT-30 Raster Scanning Alternating Current Magnet

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Abstract

A RFT-30 cyclotron has four beam lines (BL 1-1, 1-2, 2-1, 2-2) and among them, BL 1-1 is used to produce radioisotopes such as Zr-89 and Ge-68 by irradiating proton beam. When the high beam current with small beam size is irradiated on the target, it can be melted down or broken by heat generation. In order to prevent this phenomenon, wobbler magnet or combination of alternating current (AC) magnet is generally used. AC magnet is the device to control the beam size by magnetic field which is generated by AC current. Intensity of the magnetic field depends on core material as well as current, frequency and voltage. In this paper, we performed the design of AC magnet to control the beam efficiently. In addition, we confirmed the beam characteristics including beam trajectory when the proton beam passes through the magnet.

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Comparative Study and Optimization of 82Sr Purification Method to Establish the Most Suitable Procedure for KOMAC

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KOMAC/KAERI

Abstract

Rubidium (Rb), an alkali metal cation, behaves biologically like potassium, and concentrates in myocardial tissue. Rb has rapid blood clearance profile thus allowing the use of 82Rb with an ultra-short physical half-life of 75 s for non-invasive evaluation of poorly perfused myocardial regions from cardiovascular disease. 82Rb can be obtained from a generator system through decay of its 25-day half-life parent 82Sr. However, the 82Sr parent is difficult to prepare, because in routine generator production, certain purity is required to fulfil the specifications of the product. Here, we describe our studies on comparison and optimization of 82Sr purification method to investigate the most efficient procedure for our facilities.

Acknowledgement

This work has been supported through KOMAC (Korea Multi-purpose Accelerator Complex) operation fund of KAERI by MSIP (Ministry of Science and ICT and Future Planning).

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First Report on Radiocarbon Dating by Accelerator Mass Spectrometry (AMS) at KOMAC

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KOMAC/KAERI

Abstract

Accelerator mass spectrometry (AMS) is an ultra-sensitive means for measuring low concentrations of natural isotopic abundances of both radioisotopes and stable isotopes. AMS allows to measure low isotopic ratios in the range of 10-12 and 10-16 by counting and identifying atoms in an accelerated ion beam. The main advantage of AMS compared to traditional mass spectrometry methods is the use of smaller samples (mg and even sub-mg size). AMS can be applied in the technique of 14C dating in the fields of archeology and geology. The archetypal example is 14C which has a half-life of 5730 years and an abundance in living organisms of 10-12 relative to stable 12C. Using AMS, the radiocarbon age of a sample less than 10,000 years-old can be determined with a precision of 0.5% in a few minutes using 1 mg or less of sample.

Currently, we are trying to install 3-MV AMS system at KOMAC. To confirm the feasibility of 3-MV AMS system, we conducted a careful investigation of initial radiocarbon analysis utilizing our current system and then compared with the results obtained from other institutes.

Acknowledgement

This work has been supported through KOMAC (Korea Multi-purpose Accelerator Complex) operation fund of KAERI by MSIP (Ministry of Science and ICT and Future Planning).

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Carbon-foil Thickness Measurements with Low Energy Electron Beam

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Abstract

As a charge stripper, thin carbon-foil is widely used for negative hydrogen cyclotrons. The requirements for the optimum thickness of charge stripper foils are high transmission rate, high charge stripping yield, and long lifetime for the irradiation of beam. In this work, a series of experiment and calculation were performed to investigate the feasibility of thin-film thickness measurement using a low energy electron beam. The use of a low energy electron beam (up to 30 keV) for estimating the thickness by measuring transmitted electrons is described. Three carbon foils with thickness of 4, 5, and 6um were employ in this measurement. All the measurements were carried under vacuum of 1x10-6 mbar. Calculations using CASINO were performed to obtain transmission rate produced by electron beams at up to 30 keV to compare with the measurements. It was concluded that a low energy electron beam would be a valuable tool to determine non-destructively the thickness of carbon thin foils.

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Investigation of dependency of the output factor on field size in the passive scattering proton therapy

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Abstract

It is well known that the dose calculation in the passive scattering proton therapy based on analytic algorithms can't include all physical phenomena occurred on the pathway. Therefore, the monitor unit for delivering a specific dose generally has to be decided by measuring the output factor (dose per monitor unit) in the treatment field. The output factor depends on the field characteristics. In this study, dependency of the output factor on field size for the passive scattering proton therapy at the national cancer center were investigated experimentally. Measurements of the output factor were performed in solid water phantoms for various beam ranges, and Monte Carlo simulations were performed for additional analysis of the results. Reduction of the output factor depending on the beam ranges were serious in small fields but it decreased weakly in relatively large fields. The results indicate the field dependency on the shallow depths are complicated due to contribution of the scatters so that it is hard to be predicted by the model in specific conditions.

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Simulation of Surface Muon Production by 600 MeV Proton on Graphite Target in Various Physics Models

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Abstract

Surface muon yield for the new disk-shaped graphite target of the μSR facility at Rare Isotope Science Project (RISP) was evaluated using MCNP6.1 and Geant4.10.5.1 in various physics model.

Simulations were carried out using 5 different physics models which are widely applied for high-energy proton-nucleus collision. The physics models were as follows: BERT-ABLA and INCL-ABLA in MCNP6.1, QGSP_BERT, QGSP_BIC, and QGSP_INCLXX in Geant4. First, in order to establish the reliability of the simulation process, surface muon yield using simple box shaped target (40 × 6 × 40 mm3) was calculated and compared to the data reported in PSI[1]. Then, the simulations using disk-shaped target were performed to predict the surface muon yield of the μSR facility at RISP.

In the simulation result, all physics models except QGSP_BERT showed the highest and lowest surface muon yield at side and forward direction, respectively. The result using QGSP_INCLXX model showed the most similar result to the data from PSI and also has the best linearity for each direction. Considering that the result with QGSP_INCLXX have 6% higher surface muon yield than PSI data at the side direction, the number of surface muons was expected to be 7.335 × 109 at the entrance of the μSR facility's beamline, under condition of 100 kW proton beam.

[1] F. Berg, L. Desorgher, A. Fuchs, et al., Physical Review Accelerators and Beams, 024701 (2016)

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Concept Design of Fast Neutron Detectors for 100 MeV Neutron Source in KOMAC

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Abstract

Neutron detector for measurement of fast neutron produced from 100 MeV pulsed proton beam colliding a neutron target is designed with Geant4 Monte-Carlo simulation. The detector is designed to measure neutron energy from 10 MeV to 100 MeV. There are two concept of designs: TOF spectrometer and proton recoil telescope. TOF spectrometer consists of two scintillators located 15 m apart from each other. One with LaBr3 scintillator is to indicate gamma flash, and another one with NE-213 scintillator to measure the neutron's time of flight. On the other hand, proton recoil spectrometer is relatively compact, and consists of two stages. The first stage with thin silicon diode detector detects proton converted from front window with polyethylene layer by (n,p) reaction, then the second stage with 4 inch liquid scintillator reflects the proton energy by fully stopping the particle. The detectors are innately very sensitive to The two different concept of neutron detector will be simultaneously operated in measurement of the neutron source in KOMAC to complement and verify each other's credibility.

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Application of the PHITS Monte Carlo simulation in dose calculations for the Beam Irradiation System of the RAON

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KIRAMS

Abstract

The Rare isotope Accelerator complex for ON-line experiments (RAON) is a accelerator facility which will provide various ions and rare isotope beams with high energy working towards its completion of installation up to 2021. The target performance of the Beam Irradiation System (BIS), that is one of the RAON's experimental facilities and will be used for biomedical sciences, is to deliver dose less than 3 % accuracy, to have maximum irradiation area of 200 x 200 mm2 and dose rate over 2 Gy/sec. The BIS has a goal to transfer dose to a target by active scanning method with pencil beam from the RAON. It includes magnets (for beam transportation, size control, fast scanning), diagnostic devices (like a screen monitor, ion chambers), ripple and ridge filters (for beam dose distribution control). In this study, we specifically modeled the BIS through the PHITS (Particle and Heavy Ion Transport code System) version 3.10 code with MK (Microdosimetric Kinetic) model. To calculate dose distribution in water target, we adopted C-ion beam profile from the RAON as source beam. We estimated the effects of Bragg-peak shape according to the structure change of a ripple filter and derived the weight sets of Bragg peak forming SOBP (Spread-Out Bragg Peak). And these results were taken into consideration for designing ridge filter. Because initial beam of the RAON will be a pulse of 1 Hz having 50 microseconds pulse width, it may be difficult to apply active scanning by pencil beam. In consideration of passive irradiation environment as alternative method, we evaluated characteristics of beam spread by scatters presumed to be inserted in beamline and examined the possibility about the ultra-high dose rate FLASH irradiation.

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R&Ds on improved trigger RPCs for large-scale accelerator-based high-energy physics experiments

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Abstract

In this presentation, we report a new detector R&D on trigger RPCs for future large-scale accelerator-based high-energy physics experiments. The goal of the present research is to achieve functionally improved trigger RPCs with a two-dimensional strip readout method whose time resolution is better than 500 ps. Here, we introduce the design of a prototype RPC detector and report the result of the detector performance for cosmic muons measured using a precision 64-channel multi-hit TDC.

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Optimization of the proton transport line to the muon production target at RAON

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Abstract

The configuration of a 600 MeV proton beam line to the muon production target at RAON was optimized to improve the performance of μSR facility at RAON. The existing proton beam line, which has a mirror symmetric configuration with four 22.5 degree bending magnets and 18 quadrupoles, and a 13 m long drift space at the end of the beam line. A design study was carried out in order to finalize specification of the magnets and satisfy the beam size requirement at the muon target (2.70 mm (x) × 6.75 mm (y) in FWHM). Particularly, following three cases were studied to meet the beam size requirements at the target.

Case 1. a quadrupole doublet is added into the drift section.

Case 2. a quadrupole triplet is added into the drift section.

Case 3. no quadrupole is added into the drift section.

Ion optics calculations were performed using GICOSY up to 5th order taking into account fringe fields. The distance and the magnetic field of the electromagnet were adjusted under various fitting conditions and the transmission rate was evaluated using the transfer matrix method in each case.

In the result, Case 1 and 2 showed the beam size of 2.75 mm (x) × 6.73 mm (y) and 2.73 mm (x) × 9.88 mm (y), respectively, at the target. In Case 3, the beam size was 2.70 mm (x) and 15.8 mm (y). The transmission rate was 100% in every case. It would be more advantageous to add a quadrupole doublet in the drift section so as to maximize muon production at the target.

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Beamline Design Study for Biomedical Research in RAON facility

Garam HAHN

PAL

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KIRAMS

Abstract

Beam Irradiation System (BIS) is a beamline of Rare isotope Accelerator complex for ON-line experiments (RAON) in Rare Isotope Science Project (RISP) in South Korea. BIS is designed to provide a precisely controlled therapeutic heavy-ion beam which is similar to the beam that modern heavy-ion therapy machines provide, by using 332.2 MeV/u carbon ion beam. In order to realize this biomedical research beamline, we adopted to use the fast raster scanning technique with irradiation area of 200 mm by 200 mm, beam scanning speed of 30 m/s, variable iso-symmetric beam diameter of 4.0 mm to 10.0 mm as FWHM. Two scanning dipole magnets, with low inductance of 0.83 mH and 1.07 mH and thin iron lamination thickness of 0.35 mm, were used for two dimensional fast beam scanning and quadrupole triplet was used for the beam size control. In this paper, we describe (1) optics design procedure, (2) magnet simulation and its field evaluation result and (3) realistic 3-dimensional multi-particle tracking using the obtained magnetic field maps.

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Fast X-ray Projection Microscopy at Beamline 9D of the Pohang Light Source-II

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POSTECH
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Abstract

X-ray imaging technologies are widely utilized in a variety of research areas, including steel, electronic devices, machinery, and food. Especially, synchrotron x-rays have highly collimated property as well as high intensity and high flux, therefore high resolution image could be acquired. In addition, phase contrast imaging thanks to characteristics of synchrotron light is also available. Currently, real time investigation of materials or in-situ analysis become more and more important for the dynamic characteristics analysis and research of samples, consequently, high speed imaging methodology is necessary. Even though there are dedicated bio-medical imaging and x-ray nano-imaging beamline in Pohang Light Source-[U+2161](PLS-II) which is the unique synchrotron facility in Korea, a novel white beam based imaging system was newly installed to improve fast imaging capability. Using white beam X-rays from a PLS-II bending magnet, the microscope achieves micron-spatial resolutions at sub-millisecond exposure, which allows X-ray projection movie taking at a frame rate over 1000 frames per second and computed tomographic (CT) scanning in less than a second. It is also benefited from edge-enhancement that improves imaging contrast for soft materials and micro-fluids. Using the microscope, we captured deformation of water droplet upon impact on a membrane with 500 ms exposure and visualized three-dimensional pore structure within a sandstone at 1.5-micron spatial resolutions. These characteristics of synchrotron white beam imaging system could be expected for the observation and analysis of dynamic behavior such as microfluidics, power-driven component with high speed, or other materials.

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Development and preliminary Test of In-Air Faraday Cup for Beam Irradiation Facility

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Abstract

Faraday cup is one of the popular devices to measure beam current of charged particles such as proton and heavy ion. In classical, faraday cup measures beam current in a vacuum. In this work, a faraday cup has been devised to measure beam intensity of an atmospheric beam irradiation facility. A cup material was chosen aluminum. According to the theoretical and experimental results, the secondary electron yield for 20MeV proton on aluminum is about 8% which can cause measurement error. Therefore, cup shaped stopper was selected and to prevent secondary electron from leaving the cup, permanent magnets were used. And vacuum environment was needed to prevent distortion of the signal from the cup. Thickness of stopper was determined by using SRIM code calculating range of proton. To determine proper dimension of cup and magnet, secondary electron emission and trajectory in the cup was simulated using CST Studio package. After fabrication of the faraday cup, vacuum test was conducted. Detailed results of the experiment and future plan will be reported.

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Development of Polystyrene phantom for measuring FWHM & Penumbra

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Abstract

This paper was conducted to using Polystyrene phantom for measuring FWHM & penumbra. And comparing differences in three phantoms about FWHM&penumbra. It was necessary information of beam distributions about treatment plan for radiosurgery in gamma knife. The radius of the Polystyrene phantom was determined to be 7.88cm, and PMMA phantom was determined to be 6.93cm because of corresponds to water depth of 8 g/cm2 . The results of the Polystyrene phantom measured FWHM & penumbra data in this paper.

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On-line test facility for Li-8 beam production at KOMAC

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Abstract

On-line test facility to produce a Li-8 beam has been developed at KOMAC. The facility is established in a target room(TR104) of 100 MeV proton linac. This facility consists of a target/ion source (TIS), a TIS heating system, Li-8 beam optics devices, high voltage power supplies for electrostatic beam optics and utilities such as a cooling and a vacuum system. Also, a remote control and monitoring system are set up. Furthermore, a high energy beta ray telescope detector was installed to characterize the Li-8 beam. A target material is boron nitride and 24 pieces of 1 mm thick disk targets were utilized. Tantalum target heater was heated up to 1800oC by 1300 amperes of heater current and a surface ion source was heated up to 2000oC by 400 amperes of ion source heating current. The Li-8 ion beam can be accelerated over than 30 kV by a triode system. For the on-line test, the 100 MeV proton beam was delivered to the TR104 and the current was measured by the Faraday cup placed in front of TIS.

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Field Size Dependent Range Modulation for Proton Radiosurgery

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Samsung Medical Center

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Abstract

The dose uniformity of the Spread Of Bragg Peak (SOBP) region of proton beam fields is dependent on field sizes. The depth dose distribution in the distal edge of SOBP begins to be pulled down at a depth where the radius of the proton beam field is smaller than the lateral penumbra. To improve the dose uniformity in the degraded SOBP of small diameter proton beam, we have examined the properties of small proton beam fields using several small diameter blocks and set up the new beam current modulation (BCM) parameters, which compensate for the degraded SOBP. By the modification of beam intensity data in BCM files, the dose uniformity of the degraded SOBP for small fields could be improved. The floating BCM data can provide the new degree of freedom to optimize the small field dose distribution for proton radiosurgery.

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Preliminary Test of Monitoring Chamber at Low-Flux Proton Irradiation Test Facility of KOMAC

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KOMAC/KAERI

Abstract

In Korea Multi-purpose Accelerator Complex (KOMAC) of Korea Atomic Energy Research Institute (KAERI), a proton LINAC for 20 MeV and 100 MeV is in operation and provides the proton beam for various applications since 2013. Nowadays, many users for single event effects (SEE) studies in space/terrestrial radiation effect test applications were requested the flux density of a beam to be as low as possible. Accordingly, a new beam line for low-flux applications was developed and started beam service to a user since 2018. The new beam line can provide a very low-flux of about 105 p/cm2/s, excellent uniformity within ± 10% in a large beam area of 100 mm × 100 mm, and wide range of proton energies from 20 MeV to 100 MeV. Recently, the low-flux proton irradiation room has been upgraded with new beam diagnostics instruments and a new control interface for efficient beam tuning process and the improved beam quality assurance. Notably, a monitoring chamber, a large size plane parallel transmission chamber, was installed as the new beam diagnostics to monitor the fluence in real-time. Preliminary tests of the monitoring chamber were performed in comparison with the other reference ionization chamber, such as repeatability and linearity according to the beam fluence, responsiveness to repetition rate, and flux dependency. In this study, the details on the test results of the monitoring chamber will be presented

Acknowledgement

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Copper Sharp Tip CNT emitters for Micro-focusing Miniature X-ray tube

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Abstract

Small electronic devices such as mobile phones, computers and laptops are becoming compact and high-performance. As a result, semiconductors and secondary batteries, which are major components of small electronic devices, become smaller. In this situation, TSV of semiconductor and secondary batteries are composed of products in μm units, so slight deviations can cause defects of device. Therefore, non-destructive test is essential. The Micro-focus X-ray tube, which is commonly commercialized for non-destructive testing, is large size because it uses electromagnet and other components for focusing electrons. Therefore, the field of view (FOV) is small because it is difficult to use more than one this device in the non-destructive process. If several miniature X-ray tubes are installed in the non-destructive test device, FOV can be broadened. However, in the case of developed miniature X-ray tube, focal spot is large compared to commercialized micro-focus X-ray tube, so focal spot of miniature X-ray tube should be reduced for reduction of image blurring. The author developed micro-focus miniature X-ray tube with a sharp Copper Tip that can focus the electron beam instead of the flat tip used for the commonly used miniature X-ray tube. Sharp copper tip is manufactured using anodic electrochemical etching. With copper wire connected to anode, it was immersed in 2M KCl solution and then applied a voltage of 30V. In this process, electrochemical etching occurs in copper wire, forming sharp copper tip. Sharp copper tip is dipped in CNT paste which is prepared by adding CNT and brazing filler in dichlorobenzene, and then dry for about 10 minutes in the air. After this process, CNT paste is screen printed on the end of the Sharp Copper Tip when heated to 925 °C in a vacuum. CNT paste dot which is screen printed on sharp copper tip is about 10 times smaller than the flat tip. This shows that CNT dot on sharp copper tip produce smaller electron beam diameter.

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Zr-89 Labeled PAMAM Dendrimers 5G without Chelator for Cancer Diagnostic Agent

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Abstract

To simplify and effectively synthesize Zr-89 produced from 30 MeV cyclotron as a diagnostic agent for PET, we studied the chelator free labeling method using polyamideamine (PAMAM) dendrimer 5G. PAMAM dendrimers are promising nanomaterials because they are biocompatible and can carry drugs stably at the terminal amine sites. Zr-89 is a radioisotope that can be used as a diagnostic radionuclide using PET since it emits positron and has a relatively long half-life and is suitable for long-term study of drug delivery system. without chelating, and confirming the yield and proceeding with biological evaluation PAMAM dendrimers 5G and $ZrCl4$ were purchased from Sigma-Aldrich and Zr-89 was supplied by Korea atomic energy research institute. A simple method is as follows:1) Zirconium is introduced at room temperature using a chelator at the terminal amine sites of the dendrimer, and 2) zirconium is introduced into the dendrimer at room temperature without chelating, and confirming the yield and proceeding with biological evaluation. The zirconium-bound dendrimers without chelator showed higher yields and showed a high label stability of 98% after the introduction of Zr-89. Cellular uptake of MDA-MB-231 cells was up to 40% ID. PET studies using mouse also showed that dendrimers without chelator accumulate in the liver and spleen. Conclusion The Zr-89 labeled dendrimer without chelator showed high stability in combination with the dendrimer and further intended to introduce ligand to target cancer to confirm its development as a cancer diagnostic agent.

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Characterizationof Spread-Out Bragg Peak of Proton Beam produced by a Ridge Filterat Proton Irradiation Test Facility of KOMAC

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KOMAC/KAERI

Abstract

The Korea Multi-purpose Accelerator Complex (KOMAC) has been operating a 100 MeV linac proton accelerator since 2013, and has provided proton beam irradiation services to users in target rooms of the TR23, TR102 and TR103. The TR23 and TR103 are target rooms for a general purpose beam irradiation, and the TR102 is for a low beam irradiation.

To irradiate samples with uniform dose per sample depth, it needs an absorber for a spread-out bragg peak (SOBP). The absorber for SOBP is usually used a two types; The rotating type depends on time, and the ridge type is independent of time variables. In the TR102, we designed and installed a ridge filter which has a dimension of 150*150*40 and made of AL6061 material. The ridge filter is installed between the beam window and the sample. The SOBP induce by ridge filter was characterized at the proton energies of 57, 69 and 100 MeV. The depth-dose profile of the incident proton beam in the matter was measured using a Gafchromic EBT3 film and a wedge type plastic phantom. The results will be discussed in detail in this study.

Acknowledgement

This work has been supported though KOMAC (Korea Multi-purpose Accelerator Complex) operation fund of KAERI by MSIT (Ministry of Science and ICT).

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Re-installation of 3 MV Tandem Accelerator at KOMAC

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KOMAC, KAERI

Abstract

The 3 MV Cockcroft-Walton type tandem accelerator manufactured by High Voltage Engineering Europa B.V. in Netherlands, which was usually operated as the accelerator mass spectrometer (AMS), especially for the radiocarbon dating, was moved to KOMAC, KAERI in Gyeongju from Seoul National University in 2017. It stopped working due to serious problems caused by the construction work in SNU. And now it is in repair and re-installation at KOMAC. Most components, such as the control system, the vacuum systems, the ion source, and the electric and magnetic field system for the beam transport, work properly. However, there is serious problem with 3 MV high voltage power system. The Q-factor of the power system is 25% lower than normal value (>1,000). And because of spark event at the terminal, the high voltage cannot go over 1.4 MV. So, the total beam line is tested at the terminal voltage 1.2 MV as the carbon mass analyzer for radiocarbon dating. For the system calibration, the oxalic acid II standard sample (NIST SRM 4990C) is used. In this presentation, the status of the repair and re-installation of this 3 MV tandem accelerator and the accelerator mass spectrometer system will be shown.

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Radiographical Simulation of Dual-Energy X-ray Tube with MCNP Code

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Hyeri Lee[1,3], Chihyung Kim[1], and Pikad Buaphad[1,3]

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Abstract

X-ray is a powerful tool used in many applications such as medical X-ray imaging, baggage screening, and crystallography analysis. Recently, Future Accelerator R&D Team at KAERI has been developing an advanced 60/40 keV dual-energy X-ray tube, which is helpful to improve quality of medical images. In this paper, we describe the working principle of our dual energy X-ray tube, selection of target materials such as tungsten, molybdenum and rhodium, and selection of filter materials such as aluminum, molybdenum, and rhodium by performing radiographical simulations with MCNP code.

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Measurement of Neutron Energy Spectrum using Organic Scintillators at Beam Dump of 100 MeV Proton Linear Accelerator in KOMAC

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Abstract

This paper presents the experimental results of neutron spectrum measurements with organic scintillators at copper beam dump of the 100 MeV proton linear accelerator in Korea Multi-Purpose Accelerator Complex (KOMAC). For the measurement of fast neutrons generated by proton-copper nuclear reaction, two organic scintillators made of stilbene crystal and liquid EJ-309 combined with photomultipliers and fast digitizers are utilized. Both detectors are installed inside radiation shielding structures to mitigate back-scattered neutrons as well as secondary gamma-rays, facing conical-shaped 100 MeV proton beam dump. The neutron transport is calculated using two Monte-Carlo codes, MCNP6 and GEANT4, with proper physical model and nuclear data library, as well as the appropriate consideration of the detailed geometrical factors in the vicinity of beam-dump and neutron detectors. Each pulse signal measured in the detectors is analyzed to identify whether it is induced by neutron or gamma-ray in mixed radiation field using pulse shape discrimination technique. For the operation of beam current of 5 mA and duty of 0.2%, the neutron yield is measured to be approximately 0.9×□10□^10 n/s, which is a half of the numerically estimated value. In addition, both the measured and estimated neutron energy spectrum are compared with the cosmic-ray induced atmospheric neutron spectrum. The results presented here are crucial not only for providing energy-calibrated neutrons to industrial companies who are interested in cosmic-ray induced damage, but also preparing the quantitative utilization in accordance with international standard at the KOMAC fast neutron facility.

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Monte Carlo investigation of dose enhancement due to gold nanoparticles in particle beam therapy

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National Cancer Center

Abstract

Purpose: We investigated the dose enhancement effect due to gold nanoparticles in particle beam (12C, 4He, proton) irradiation. Methods: For the Monte Carlo simulation, TOPAS version 3.1 patch 03 was used. Firstly, 12C ion scanning beams of mono-energetic 283.33 MeV/u, 4He ion scanning beams of mono-energetic 150.0 MeV/u, and proton 150 MeV were irradiated to a water-filled phantom (30 x 30 x 30 cm3), and secondary particle information generated near the Bragg peak was recorded in a phase space file.

Secondly, the obtained phase spaces file were squeezed to nanometer scale (50 nm) to irradiate gold and water nanoparticles of 50 nm diameter located at the center of 4 x 4 x 4 mm3 water-filled cube phantom. Dose enhancement ratio (DER) was calculated with a 1 nm thickness of a concentric shell-shaped detector placed up to 50 nm from the nanoparticle surface. The DER was computed at every 1 nm distance from the surface of the nanoparticle.

Results: Computed gold nanoparticle DER at 1 nm from the nanoparticle surface was 4.89, 4.86, and 4.69 results for proton, 4He, 12C particle beam respectively. The DER was rapidly decreased from the gold nanoparticle surface.

Conclusion: Gold nanomaterials have the potential to be used as a radiosensitizer in particle beam therapy. When using gold nanoparticle in particle beam therapy, the dose enhancement effect of the gold nanoparticles absorbed within the tumor cell would be delivery more therapeutic dose. Acknowledgment This work was supported by the Institution Inherent Research Project funded by the Korean National Cancer Center (KNCC). (1810273-2)

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Proton Beam-Induced p53-Mediated Cell Cycle Arrest in HepG2 Hepatocellular Carcinoma Cells

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Abstract

A proton beam (PB) is used to treat various cancers. In the present study, we evaluated the effect of PB on HepG2 hepatocellular carcinoma cells. The results showed that p53 phosphorylation at Ser15 was significantly induced by PB irradiation in a dose-dependent manner. Furthermore, increases of p21 expression and H2A.X phosphorylation by PB were observed at 24 h and 48 h after irradiation in a dose-dependent manner. In contrast, PB did not alter the expressions of Bcl-xL or AIF expression or caspase-3 or PARP cleavage. In addition, PB suppressed ERK phosphorylation, enhanced p38 phosphorylation at 24 h and 48 h after irradiation, and induced G2/M phase cell cycle arrest. In addition, although no significant decrease in HepG2 cell viability was observed at 72 h after irradiation 0.5 to 16 Gy, a colony forming assay showed that PB irradiation induced cell death. Summarizing, this investigation demonstrates PB irradiation induces early stage G2/M cell cycle arrest mediated by the inductions of p21 expression mediated with p53 phosphorylation regulated by the ERK and p38 signaling pathways leading to cell death observed in colony forming assay. In conclusion, although PB irradiation was found to cause late cell death, a proton beam-sensitizing strategy is needed because proton beam-induced early stage G2/M cell cycle arrest may enable the development of resistance to proton beam irradiation.

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Preliminary Study on Synthesis of Bio-compatible Graphene Quantum Dots by Ion-beam Irradiation

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Abstract

A fantastic two-dimensional (2D) carbon material, graphene, has recently attracted remarkable attention due to its wide range of possible applications in transistors, supercapacitors, gas sensors, solar cells, and flexible displays. Because of its promising potential applications, not only graphene but also graphene based nanostructures such as graphene nanoribbons and epitaxial graphene have been also widely studied. Graphene quantum dots (GQDs) which indicate graphene sheets less than tens of nanometer attracted researchers because they exhibit unique optical and electronical properties due to quantum confinement and edge effects. GQDs have many advantages compared with other carbon nanomaterials because they have outstanding biocompatibility, low toxicity, good solubility, and high surface area which lead them to have versatile applications: sensors, bio-imaging, drug delivery, and photo-catalysts. Generally, GQDs are formed through top-down approaches by cutting, exfoliation, and cage-opening carbonic precursors such as graphite, graphene, graphene oxide, fullerenes, and carbon fiber, into smaller pieces using chemical methods. The methods have their unique advantages, but they typically require the use of strong oxidants (such as $KMnO_4$ and $KClO_3$) and acids (such as H_2SO_4, HNO_3, and HCl) which limited GQDs (synthesized by conventional chemical methods) to apply to utilization in bio-fields. Furthermore, currently, there is still no universal approach for the preparation of GQDs without byproduct and well-size and property controlled GQDs. Here, we present preliminary study on synthesis of bio-compatible GQDs by ion beam irradiation methods at Korea Multi-purpose Accelerator Complex (KOMAC). It is a simple and convenient route to highly pure GQDs by ion beam irradiation. After fabrication of GQDs, only GQDs are remained without any impurities and byproducts. Additionally, the size and properties of GQDs are easily controlled by changing the conditions of ion beam irradiation and thermal annealing.

Acknowledgement

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Development of an analytical separation method for two isotopes 67Cu and 67Ga

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Abstract

In this work, we have developed a new analytical separation method for the overlapping gamma-ray spectra of the two isotopes 67Cu and 67Ga. Recently, we developed an analytical separation method for the two isotopes [1], from which we obtained the cross-sections for the natZn(p, x)67Cu and natZn(p, x)67Ga reactions. The data obtained by this separation method were in good agreement with the previous literature. However, we found the method may have a chance to make a substantial error, as the half-life difference between two isotopes becomes grow. Although the two isotopes of 67Cu and 67Ga have similar half-lives, the newly developed method may give more exact cross-section data, thanks to a concrete formalism with fully considered variables. [1] J. K. Park, M.-H. Jung, Y. S. Hwang, C. Kim, W.-J Cho, S.-C. Yang, Nucl. Instrum. Methods Phys. Res. B 449, 35-39 (2019)

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ESR study on nitrogen ion-irradiated SmFe12 thin films

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Abstract

Iron-rich compounds with the tetragonal ThMn12-type structure may meet current demands for rare-earth-lean permanent magnets. In this study, we have investigated the paramagnetic spins in SmFe12 thin films before and after N+ beam irradiation by employing an electron spin resonance (ESR) spectroscopy. To analyze complex hyperfine lines, we simulated the data and found that two distinct kinds of nuclei with nucleus spin I =5/2 and 7/2 create the signals with 6 lines and 8 lines, respectively. To understand which nuclei correspond to these lines, we analyzed expected impurities in these films by using a secondary ion mass spectroscopy. Furthermore, the ESR spectra of the films before and after N+ beam irradiation would be compared and discussed in this study.

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Surface Wettability and Color Control of Oxide Materials by Helium Ion Beam

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Abstract

When materials are irradiated with high-energy charged particles such as proton and heavy ions, nuclear reactions can happen. Because of the high linear energy transfer (LET) characteristic of them, nuclear reactions usually occur near the surface of materials. Therefore, surface properties of materials can be changed by irradiation-induced nuclear reactions.

Wettability is one of the most important surface properties relating to various phenomena including adhesion, painting, lubrication, and so on. If hydrophobic functional groups such as hydrocarbon (-CHn) or fluorocarbon (-CFn) are produced on hydrophilic surfaces, they can be converted to hydrophobic surfaces.

In this study, we irradiated high-energy helium ion beam onto oxide materials such as Al2O3 and SiO2, which have many oxygen atoms in them, and then measured their wettability. 19F atoms were produced on the surface by 16O(α, n)19Ne reaction and following β+ decay as well as 16O(α, p)19F reaction. These fluorine atoms resulted in the increase of the contact angle of oxide materials' surfaces. In addition, color of surfaces could also be changed by the high-energy helium ion beam.

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Wear resistance effect on High temperature ion implanted AlCrN Film

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Abstract

Aluminum chromium nitride (AlCrN) is a well-known and efficient wear resistant coating and is widely used to extend the lifetime of cutting tools. The research for wear resistant of AlCrN coated HSSs is continuously developed in many applications like punching and trimming tools. Overall, all former studies have shown that wear and friction of implanted PVD coated films (TiN, AlCrN, CrN etc.) improve after ion-beam treatment, irrespective of the type of species or implantation energy regime. In this paper, the results of field tests concerning one special application, the improvement of punch lifetime by high temperature ion implantation, will be described. An increase in punch lifetime does not only save tools but also reduces the machine down-time because of the longer intervals between replacement of the punches. Also, nitrogen ion implantation was performed for punch at high temperature at 300[U+2103] in order to investigate thermally-activated diffusion effect.

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Study of hydrogen permeation in tungsten irradiated with helium Ions

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Abstract

Tungsten, one of the candidate materials for plasma-facing components (PFC) in fusion reactors, is exposed to an environment of plasmas of hydrogen and its isotopes. Thus, the permeation behaviors of hydrogen isotopes in PFC have been considered to be closely related to the safety issues. In this study, tungsten samples were irradiated with helium ions using an inductively coupled plasma (ICP) ion source, and were performed hydrogen permeation experiments for the sample in temperature range of 650–850 °C. Tungsten was supplied by Goodfellow. The tungsten was fabricated into disks (20 mm in diameter and 0.1 mm in thickness), and the fluence and accelerating voltage were ~3×1021 He/m2 and 3.0 kV, respectively. The hydrogen permeability was determined by using a hydrogen-isotope permeation measurement system at Dankook university. The results of this work are presented and also compared with our earlier results for virgin tungsten.

Acknowledgments

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Study of deuterium retention in ARAA irradiated with helium and deuterium ions

Woo Jun BYEON, Seung Jeong NOH, Sang-woon YOON, Hee Jeong SEO, Hee Soo KIM

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Abstract

During the fusion process, reduced activation ferritic/martensitic (RAFM) steel, a candidate for the fusion structural material is exposed to ions of hydrogen isotopes and helium. Deuterium retention in an advanced reduced activation alloy (ARAA), an RAFM steel under development at the Korea Atomic Energy Research Institute, was measured by using thermal desorption spectroscopy system clustered with an inductively coupled plasma ion source. The samples were baked at 900 C and then sequentially irradiated with helium (1.4 keV or 7.0 kev) and deuterium (1.7 keV) ions at room temperature. Detailed results are provided in the presentation. Acknowledgments “This work was supported by the National Research Foundation of Korea (Project No. 2018R1A2B6002797).”

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Optical and structural properties of ion implanted diamond

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Abstract

NV color center in diamond is a promising candidate for quantum bit (Qubit), and it can be also used for biomarker, single photon source, magnetic sensor, etc. In order to realize quantum computer, the position and properties of NV color center should be controlled. NV color center is typically made using N[U+FF0B]ion implantation and annealing process. And the color center axis can be also controlled using hydrogen ion implantation process. Ion implantation was conducted using gas ion implanter at KOMAC (Korea multipurpose accelerator complex). In order to fabricate NV color center, 100 keV N+ ions were implanted into the CVD diamond. After N+ ion implantation, the samples were annealed at high temperature for creating NV color center. 200 keV hydrogen ions were also implanted into CVD diamond in order to create internal stress field induced by expansion of H2 bubble. Optical properties of NV color center were observed using photoluminescence measurement. Observing the internal stress field was conducted using Raman spectroscopy and X-ray diffraction. We have fabricated NV color center and generated internal stress field successfully. However, because we used (100) diamond, we were not able to control the color center axis.

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Effects of proton beam irradiation on energy metabolism in a human colorectal adenocarcinoma cell line

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Abstract

Purpose : Proton radiotherapy has been established as a highly effective modality used in the local control of tumor growth. Although proton radiotherapy is used worldwide to treat several types of cancer clinically with great success due to superior targeting and energy deposition, the detailed regulatory mechanisms underlying the functions of proton radiation are not yet well understood.

Methods : Accordingly, in the present study, to determine the effects of proton beams on mitochondrial energy metabolism, we investigated: mitochondrial DNA (mtDNA) mass; the gene expression of mitochondrial transcription factors, functional regulators, and dynamic-related regulators; and the phosphorylation of the signaling molecules that participate in mitochondrial biogenesis. Results: Both the mtDNA/nuclear DNA (nDNA) ratio and the mitochondria staining assays showed that proton beam irradiation increases mitochondrial biogenesis in 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced aggressive HT-29 cells. Simultaneously, proton beam irradiation increases the gene expression of the mitochondrial transcription factors PGC-1α, NRF1, ERRα, and mtTFA, the dynamic regulators DRP1, OPA1, TIMM44, and TOM40, and the functional regulators CytC, ATP5B and CPT1-α. Furthermore, proton beam irradiation increases the phosphorylation of AMPK, an important molecule involved in mitochondrial biogenesis that is an energy sensor and is regulated by the AMP/ATP ratio. Conclusions: Based on these findings, we suggest that proton beam irradiation inhibits metastatic potential by increasing mitochondrial biogenesis and function in TPA-induced aggressive HT-29 cells. [This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (NRF-2017M2B2A4049593)]

Key words : Colorectal cancer, Proton radiotherapy, Energy metabolism

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Temperature-dependent Structural and Electrical Properties of Ion-implanted VO_2 films

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Abstract

VO_2 shows a sharp metal-to-insulator-transition (MIT) behavior near 70℃, accompanying with a first-order structural phase transition. There are still ongoing arguments whether the MIT of VO_2 is induced by the structural phase transition. Previous studies suggested that a dimerization of V-V chains mignt be a critical in the MIT phenomenon of VO_2. Therefore, the local structural properties around V atoms in VO_2 are crucially important. X-ray absorption fine structure (XAFS) is a unique local probe to detect structural and chemical properties around a selected species atom. We examined the local structural property changes around a V atoms from ion-implanted VO_2 films using in-situ XAFS measurements and simultaneously measured electrical properties of the films as a function of temperature. XAFS measurements demonstrated that the structural disorder as well as bond lengths of V-O and V-V pairs on ion-implanted VO_2 films were significantly changed, compared with pristine VO2 films. The Tc of VO_2 was lowered by 10℃ for both heating and cooling, compared to that of untouched VO_2. The transition region of VO_2 was expanded by ion implanted. The electrical property changes of ion-implanted VO_2 was mainly caused by structural property changes because no changing effects were observed. We will quantitatively discuss the electrical property changes of ion-implanted VO_2 films, comparing to the local structural changes.

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Study on the Ion Beam Analysis for the Metal Ion Beam Irradiated Samples

Kye-Ryung KIM, Yong-Sub CHO, Seung-Ho LEE, Nam-Woo KANG

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Abstract

For the analysis of metal ion beam irradiated samples, RBS (Rutherford Backscattering Spectrometry) and SIMS (Secondary Ion Mass Sepectrometry) have been widely used because of their good sensitivities and ability of depth-profiling of elements in the material. In this paper, we compare the results of metal ion beam irradiated Si wafer samples using RBS and SIMS. The samples were made by the metal ion beam irradiation by using a MEVVA (MEtal Vapor Vacuum Arc) Ion Source which can produce high current pulsed metal ion beam from Li to U with multiple charge states. Our MEVVA ion source has the maximum acceleration voltage and beam current of 80 kV and 5 mA. Metal ion beams such as Cr, Cu, Y, W were irradiated to the Si wafer with 55 kV acceleration voltage and 1~3 mA beam current. The ions have different charge states and the average charge state numbers of Cu, Cr, Y, W are 2.1, 2.0, 2.3, 3.1. Then their average energies are 115.5, 110.0, 126.5, 170.5 keV. We used the RBS system was installed at the 1.7 MV tandem accelerator of KOMAC (Korea Multi-purpose Accelerator Complex), KAERI and the D-SIMS of KIST (Korea Institute of Science and Technology).

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Photostable and Biocompatible Polymer Sunscreen Ingredients Fabricated by Electron Irradiation

Sang Yoon LEE, Hyung San LIM, Na Eun LEE, Sung Oh CHO

Korea Advanced Institute of Science and Technology

Abstract

We present a novel approach to preparing non-toxic sunscreen active ingredients by electron irradiation of poly(methyl methacrylate) (PMMA) and polystyrene (PS) nanoparticles. Electron irradiation modifies the molecular structure of the polymers, generating conjugated aliphatic carbon-carbon double bonds in PMMA and conjugated aromatic rings in PS. The conjugation length increases as the electron fluence increases, leading to hyperchromic and bathochromic shifts in the UV-vis absorption spectra of the irradiated polymer nanoparticles. Consequently, the irradiated polymer nanoparticles become capable of UV absorption and the UV absorbing properties are improved with increasing electron fluence. The UV-screening performance and photostability of the electron-irradiated polymer nanoparticles are found to be superior to those of commercially available sunscreen ingredients. In addition, in vitro cytotoxicity and phototoxicity test results show that the irradiated polymer nanoparticles exhibit excellent biocompatibility.

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Permeation of hydrogen and deuterium in Er2O3 thin film on a type 316L stainless steel substrate

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Abstract

In a fusion reactor, protonic plasma of hydrogen, deuterium and/or tritium are used as fusion fuel. However, due to their small atomic size, such particles easily permeate through the fuel lines. Therefore, it is desired to achieve permeation blocking barrier on the surfaces of fuel system. In the recent years, a metal-oxide film can be used as a hydrogen-isotope permeation barrier in the fuel circulation system for nuclear fusion. We fabricated Er2O3 thin film on a type 316L stainless-steel substrate by using a metal-organic chemical vapor deposition technique for the purpose of hydrogen-isotope permeation barrier. Electron microscopy based imaging and energy-dispersive X-ray spectroscopy measurements indicate a sound film quality together with X-ray diffraction experiments. We also measured deuterium permeation in the film at high temperatures ranging from 600℃ to 800℃. The permeation reduction was most apparent at 650℃. Above 800℃, we confirmed that the film was damaged and did not work as a permeation barrier.

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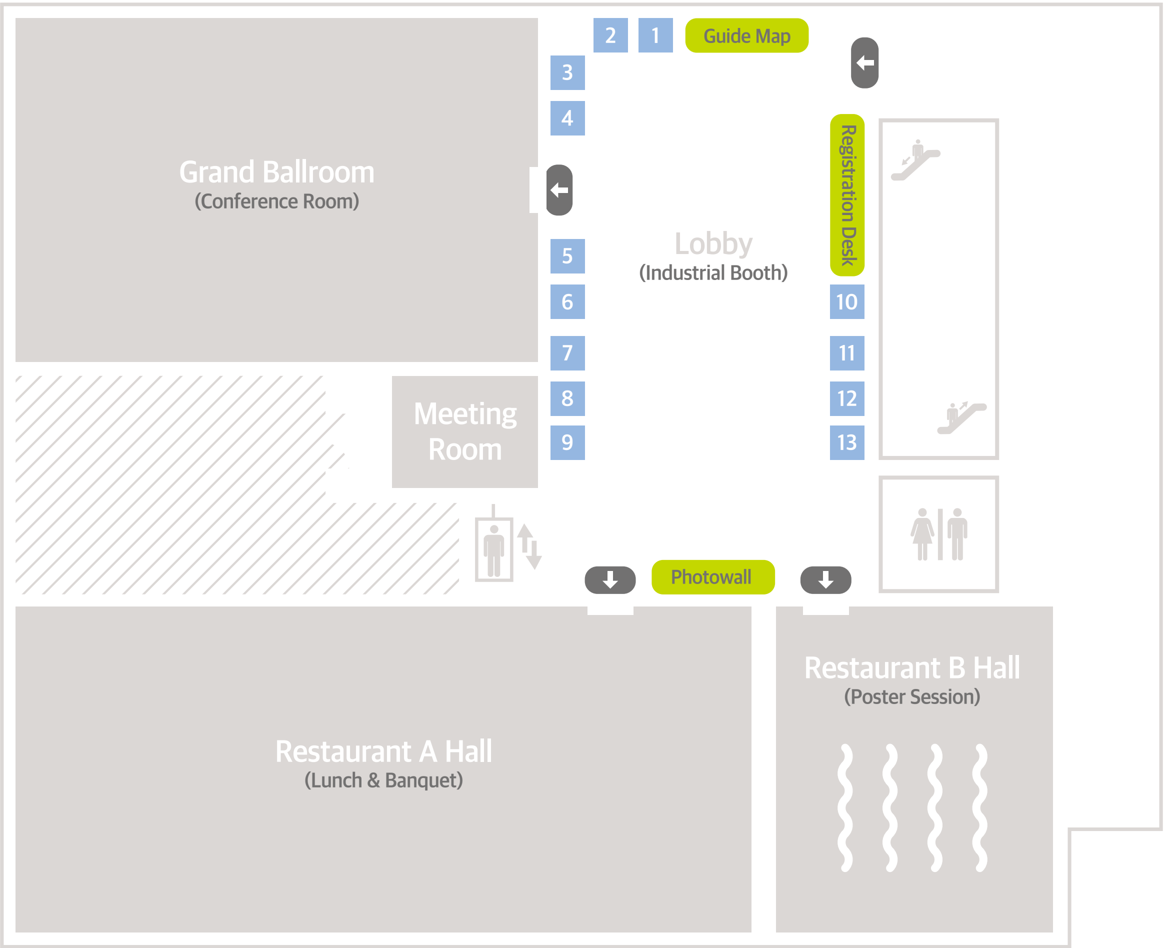

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Ampegon Power Electronics AG cooperates with industrial partners to implement novel and more efficient processes. We offer pulsed vacuum arc power supplies and a wide range of RF amplifiers and power supplies for specialized industries.

Ampegon Power Electronics AG is the leading designer, manufacturer and integrator of AM/DRM radio broadcast systems worldwide. We offer the complete system including transmitters, antennas, tower and masts and a wide range of auxiliary equipment including adjacent power plants.

Futurecast is agency who represent Ampegon Power Electronics in Korea. He support sales and technical issues to Korean customers with help of Ampegon Power Electronics AG.


High Voltage Power Supplies


RF Amplifiers


Long Pulse High Power Modulators


Short Pulse High Power Modulators


Digital LLRF Systems


Test Loads Science

Exhibitor's Information

Canon Electron Tubes & Devices Co., Ltd.

CEO	Hironori Nakamuta
Website	https://etd.canon/
Address	1385 Shimoishigami ,Otawara Tochigi , Japan

As of November 1th 2018 our company name has changed to Canon Electron Tubes & evices Co,.Ltd. (formerly known as Toshiba Electron Tube & Devices Co,.Ltd.).We will continue to provide products same as before.
We are leading company of the RF sources for the scientific accelerator projects in the world.
We provides pulsed high peak power klystrons , CW klystrons with electromagnets , and PM klystrons, multi beam klystrons for high efficiency.
And also, our window/coupler has been adopted for the variety particle accelerator fields worldwide.

BS&B Safety Systems

CEO	Tiffen Kenneally
Website	www.bsbsystems.com
Address	7455 East 46th Street Tulsa, OK 74145-6379

BS&B Safety Systems leads the world in the design and manufacture of overpressure relief devices. BS&B set the standards in the pressure relief industry. The company has been responsible for originating patents on all rupture disk designs and continues its commitment to innovation.
Since designing the first rupture disk (bursting disc) in 1931, BS&B Safety Systems, continues to set the standard. Our commitment to technology, high quality manufacturing and quality by design, has earned us the ISO 9001 Quality System Certification.

BS&B Safety Systems, offers a worldwide network of engineering, manufacturing and support services including

- Technical Support
- Customer Service Support
- Fast-Track Shipping Services
- Complimentary Product Seminars
- On-Site Installation Services
- On-Site Supervision Services
- On-Site Audit and Recommendation Services
- Maintenance Training Program
- Field Engineering Services
- High Volume Manufacturing Capabilities
- Customize Designed Rupture Disks (Bursting Discs)

BS&B Safety Systems manufacturing facilities operate and test according to national, international standards and codes including ASME VIII, AD Merkblatt A1 and EN ISO 4126-2: Bursting disc safety devices
We are an international company with locations in North America (USA, Mexico and Canada), in EMEA (Ireland, Netherlands, Germany, UK, Russia, UAE), South America (Brazil), APAC (Singapore, Malaysia, Korea, Japan, China, India)

Exhibitor's Information

SUNGSAN E&C Co.,Ltd.

CEO	SeongTae Kim
Website	www.RFzone.com
Address	A-1004, Daewoo-Technopark 261, Doyak-ro, Wonmi-Gu, Bucheon-City, Kyeonggi-Do, Lorea

Sungsan E&C is the RF Leader in Korea and Export-oriented Company

Since its establishment in 2001, Sungsan has been developing and exporting **broadband amplifiers** using **GaN device and linear HPAs** using several linearization technologies such as Analog pre-distortion and feedforward.

Since 2010, in an effort to shift their focus from amplifier modules to amplifier systems, Sungsan has been successfully proposing broadband high power amplifier solutions for **EMC lab testing and for heavy-ion accelerator fields**.

Website : www.RFzone.com
Foundation : May, 2001
Location : Republic of Korea
Work force: 45 Workers, 2018 Now
E-mail : sungsan@rfzone.com

DAWONSYS

CEO	Park Sun Soon
Website	www.dawonsys.com
Address	485, Sihwahosu-ro, Danwon-gu, Ansan-si, Gyeonggi-do, Republic of Korea

DAWONSYS is a company specialized in the manufacture and technology of nuclear fusion and accelerator, Plasma system, Industrial rectifier, Induction Heating system, Railway Vehicle in korea.


Pulse modulator / PAL-XFEL


MPS(Magnet power supply) / PAL-XFEL


CCPS(Capacitor charge power supply)

RF SSPA(Solid state power amplifier)

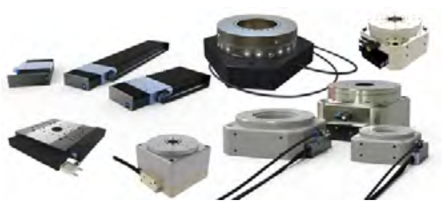
Exhibitor's Information

Limotion Systems

CEO	Taeyang Heo
Website	www.limotionsystems.com
Address	1023 10F 45, Jojeong-daero, Hanam-si, Gyeonggi-do, Republic of Korea 12918

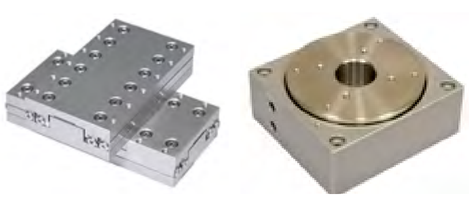
Limotion Systems is high-tech company specialized in the development of machines that require advanced motion performance. We can cover all precise motion with Piezo nano stage, Piezo motor stage, Linear stage, airbearing stage, Hexapod system, DC servo and Stepping motor stages.

Airbearing Stage can freely improve position accuracy without mechanical friction.

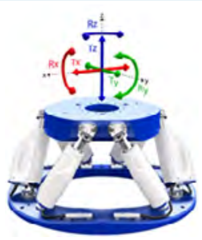


Piezo Nano stage can take advantage of fast response and nanometer resolution.

Piezo Motor stage can take advantage of long stroke and nanometer resolution by using ultrasound principle.



A Hexapod is a parallel kinematic structure composed of a mobile platform linked to a fixed platform with 6 actuators. This design allows to move an object placed on the mobile platform with 6 DOF(Degrees of Freedom).



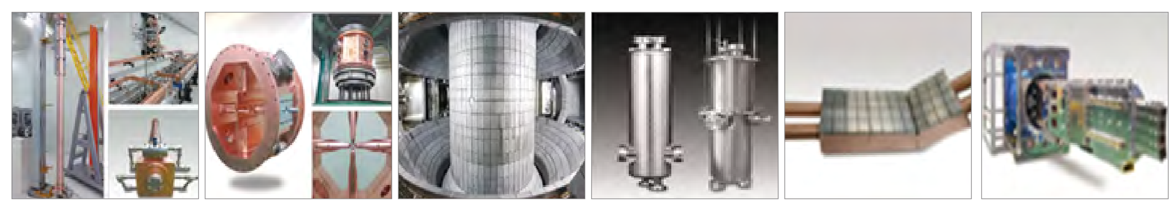
VITZRONEXTECH CO., LTD.

CEO	Byong-Ho Rhee
Website	www.vitzrotech.com
Address	327, Byeolmang-ro, Danwon-gu, Ansan-si, Gyeonggi-do, 15603, Korea

VitzroNextech is the company specialized in the manufacture of the Accelerator in Korea. Especially, we have the best technology for Linear Accelerator in Korea. Also, VitzroNextech has the management system for material, design, manufacture, installation and service area, etc. Based on our management system, we are trying to firm the top position as the specialized accelerator manufacturer by participating in domestic accelerator market (such as proton accelerator, heavy ion accelerator, photon accelerator) and overseas market.

In addition, VitzroNextech has participated in Nuclear Fusion business. We participated in KSTAR (Korea Superconducting Tokamak Advance Research) project by manufacturing Plasma Facing Component (PFC), which protects Tokamak from ultra-high temperature plasma. VitzroNextech is trying to lead the latest technology in Nuclear Fusion business by accumulating experiences.

In plasma business, VitzroNextech has the best technology and know-how for plasma system design, manufacture, diagnosis, measurement, operation technology, etc. based on high power device infrastructure, government support and our own R&D activities. VitzroNextech has constructed plasma system and waste disposal and application devices. And, we have researched and developed high-power plasma system for coal gasification and ultra-high temperature, thermal protection material manufacture. In addition, we have participated in the project for the future energy such as Integrated Gasification Combined Cycle (IGCC).



Exhibitor's Information

SY SCIENCE/R-DEC

CEO	Sungyong Jang
Website	www.syscience.co.kr
Address	#223, 74 Mallijae-ro, Mapo-gu, Seoul, KOREA

RAON USERS ASSOCIATION

CEO	문창범
Website	http://raonusers.org
Address	대전광역시 유성구 유성대로1689번길 70

The RAON facility is a rare isotope accelerator facility, which will be the major large-scale research facility of the IBS (Institute of Basic Science). The Korean government decided the construction of RAON at 2009 and the official activity for RAON construction started at 2011. When constructed, this will become a basis facility of the next generation in pure science research. The RAON accelerator facility will provide coner stones of fundamental science research in Korea in a wide range of research topics including the synthesis of new elements, evolution of the universe, research in the formation of new materials, application to bio-medical sciences, etc. The purpose of this project is to promote this facility to a world class institute so that it can offer the research opportunities to world-wide scientists. The RAON Users Association is an aggregation of the researchers who are doing investigation in the research area using rare isotope beams. The purpose of this association is to support research activities in this field. We strongly welcome you to join us if you are interested in this research activities. Even if you are not an expert in this field, you are welcome to join us as a special member if you have an interest in rare isotope accelerators and related research. We expect your contribution to the development of fundamental science in Korea.

중이온가속기는 기초과학연구원의 핵심 시설로서 2009년 과학벨트 내 대표적인 대형연구시설로서 건설하기로 결정이 이루어 졌으며 2011년 본격적인 사업이 시작되어 장차 우리나라 차세대 기초과학연구의 기반 시설로 성장하기를 목표로 하고 있습니다. 중이온 가속시설은 새로운 원소의 생성, 우주의 진화, 신물질 연구와 의생명과학에의 응용을 비롯하여 아주 넓은 분야에서 우리나라 기초연구를 선도해 나갈 기반을 제공하며 이 분야에서 세계 첨단의 연구를 수행할 기회를 우리나라 연구진뿐 아니라 아시아와 세계 각지의 연구진에게도 부여할 것입니다.
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RAON USERS ASSOCIATION
RARE ISOTOPE ACCELERATOR

Memo

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