ERL2024

69th ICFA Advanced Beam Dynamics Workshop

on Energy Recovery Linacs

List of Abstracts

September 24th Oral presentations

【TUO01】Status of cERL

Author: *Miho Shimada (KEK)*

Compact ERL (cERL) is a test facility in KEK. Its aim is to develop basic technologies for energy recovery linacs with low emittance, high-current CW beam for a future large-scale ERL.
Our recent activities are, establishment of 1 mA class CW high-current operation with energy-recovery mode, demonstration of MIR-SASE-FEL, promotion of industrial applications with the electron irradiation line.
We plan facility upgrade for technology developments aiming for EUV-FEL facility for future semiconductor fabrication.

【TUO02】CBETA: Achievements, Challenges, Status, and Plans

Author: *J. Scott Berg (Brookhaven National Laboratory)*

The Cornell-BNL ERL Test Accelerator, CBETA, is an energy recovery linac (ERL) capable of accelerating electrons to 150 MeV in 4 linac passes. It uses a fixed field alternating gradient return arc to return all 4 energies, from 42 to 150 MeV, to the linac. CBETA was operated in two modes, with one accelerating pass to 42 MeV and with four accelerating passes to 150 MeV. I describe the unique features of CBETA, and summarize what was achieved in our studies. I will outline some of the difficulties we faced which we would like to address in future operations. Finally, I will describe some possible future studies using CBETA.

【TUO03】Status of the S-DALINAC with focus on ERL operation

Author: *Michaela Arnold (TU Darmstadt)*

Co-authors: *Adrian Brauch, Manuel Dutine, Joachim Enders, Ruben Grewe, Lars Juergensen, Maximilian Meier, Fatemeh Sadat Moujani Ghomi, Norbert Pietralla, Felix Schliessmann, Dominic Schneider, Alexander Smushkin*

The superconducting Darmstadt linear accelerator S-DALINAC [1] is a thrice-recirculating electron accelerator at TU Darmstadt. Since its establishment in 1991 the S-DALINAC was mainly developed and operated by students. Besides the conventional acceleration scheme serving various nuclear-physics experiments, the accelerator can also be operated as an energy-recovery linac (ERL). The S-DALINAC achieved one-turn [2] and high-transmission multi-turn energy recovery [3]. Dedicated beam dynamics simulations as well as beam diagnostic devices are essential for the operation. This contribution will give an overview of the facility with a focus on the ERL activities. A setup for laser Compton backscattering is under commissioning and will be introduced. Options for a successor ERL will be discussed.

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【TUO04】Status of the ERL project bERLinPro: Final comissioning preparations

Author: *Axel Neumann (HZB)*

The energy recovery linac (ERL) at Helmholtz-Zentrum Berlin (HZB) is in the final stage of preparing for beam commissioning of the injector beam line this fall. This injector consists of a 1.4xlamba/2 cell SRF photo-injector and a three two cell Booster cryomodule, the latter based on a modified design of the Cornell injector cavity shape. The injector was designed for a final beam current of 100 mA and an injection energy of 6.5 MeV into the 50 MeV recirculator.
This year, the SRF gun went through the cool-down procedure twice with the bERLinPro cryoplant and an RF test of the cryo-module took place at 2K to demonstrate enough performance level to continue to prepare for beam operation radiation safety permit. The first SRF gun type will be able, limited by the power couplers, to produce about 5-10 mA beam current for energies from 2 to 3 MeV. High current 1.3 GHz repetition rate operation can be demonstrated in macro-pulse mode, as the klystron delivers enough power overhead for transient beam-loading compensation. Also, bERLinPro is one of two facilities being demonstrators for the ERL roadmap of high energy physics, that it will serve to study within the EU Horizon iSAS program how to improve sustainability and thus power consumption for large scale SRF based accelerator experiments.
In this talk, a summary of the activities since last ERL workshop, the current comissioning preparations and a short overview of the iSAS activities will be given.

【TUO05】MESA facility report

Author: *Timo Stengler (University Mainz)*

MESA (Mainz Energy-recovering Superconducting Accelerator) is under construction at Johannes Gutenberg-Universität Mainz for high-precision particle physics experiments. It operates in external beam (EB) mode and energy recovery linac (ERL) mode. In EB mode, it delivers at 155 MeV a 0.15 mA beam with polarized electrons. In ERL mode, it will provide at 105 MeV a 1 mA polarized beam, upgradeable to 10 mA unpolarized.

MESA's construction involves new and existing but refurbished underground halls, a recirculating lattice with normal conducting pre-accelerator and superconducting main-accelerator modules. The injector is prioritized in this stage of beam commissioning.

This talk will show the status of the accelerator and give an overview of the current installation and comissioning achievements.

【TUO06】PERLE Status and Plans

Author: *Walid Kaabi (IJCLab-CNRS)*

PERLE, a Powerful Energy Recovery Linac for Experiments, emerged from the design of the Large
Hadron Electron Collider and the FCC-eh, as a three-turn racetrack configuration with a linac in each straight. The European roadmap for accelerator R&D identified PERLE as the ideal next-generation ERL facility with which a new generation of HEP colliders, beyond ep, can be prepared. PERLE will serve as a hub for the validation and exploration of a broad range of accelerator phenomena in an unexplored operational power regime (10 MW), and will support the development of sustainable technology for efficient ERL operation at future energy and intensity frontier machines as foreseen in the iSAS European proposal.

We will report on the status of the project, main development outcomes, the phasing adopted strategy and the plans for the upcoming years.

【TUO07】Progress on Terahertz Light Production at TRIUMF e-Linac

Authors: *Hui Wen Koay (TRIUMF), Victor Verzilov, Thomas Planche, Jens Lassen, Stephanie Radel, Friedhelm Ames, Yu. Bylinskii, Robert Laxdal, Oliver Kester*

In addition to the TRIUMF 520 MeV cyclotron, the superconducting e-Linac serves as a new primary beam driver of the Advanced Rare Isotope Laboratory (ARIEL) project, delivering high-power electron beams to generate neutron-rich rare isotope beams (RIB) through photo-fission. Electron beams are initially produced by a thermionic gun at 300 keV, and are subsequently accelerated in a superconducting linear accelerator to 30 MeV. Present gun capacity is specified at up to 15 pC per bunch at a repetition rate of 650 MHz. The minimum bunch length can be reduced to a few millimeters with the current buncher and injector system. This holds substantial potential as a source of terahertz (THz) radiation. This work discusses the first demonstration of THz light production and detection from the ARIEL e-Linac. To produce more intense THz light for broader future applications, an upgrade of the current e-Linac beamline to include a magnetic compressor is under consideration. This study encompasses preliminary parameters and simulations of bunch compression to estimate the coherent synchrotron radiation production towards a future photo-gun driven THz source.

【TUO08】BriXSino: an ERL proposed facility at INFN Milan LASA Laboratory

Authors: *Alberto Bacci, Luigi Faillace, Alessandro Gallo, Dario give (INFN-LASA), Laura Monaco, Rocco Paparella, Marcello Rossetti Conti, Daniele Sertore*

BriXSinO is a small research infrastructure based on super-conductive accelerators with very high energy sustainability, oriented towards the frontier of high intensity in high average power electron beams, according to the innovative double Energy Recovery Linac (E.R.L.) scheme direction of circulation. The objectives of BriXSinO are twofold: to develop a new generation of particle accelerators that are energetically sustainable, and to generate coherent radiation beams in the THz and of materials, thanks to the very high fluxes and average radiation powers generated.

In this presentation the scientific reasons set out above will be discussed and the status relating to the construction of a high brightness electron source for BriXSinO under development at the LASA in Segrate (Milan-Italy) will be discussed.

【TUO09】Sustainability implications for high energy colliders

Author: *Vladimir Litvinenko (Stony Brook University)*

High energy colliders are frequently associated with significant environmental impact resulting from their large size – and associated construction – high power needed to operate them and radiation. In this talk I will review main environmental impact parameters of high energy colliders with focus on advantages provided by energy recovery and recycling collided particles. I will finish my presentation with discussion of key R&D direction that can maker SRF recycling colliders the best and most affordable option for future colliders.

【TUO10】Advancements and Challenges in Large-Scale Cryogenics for Accelerator Facilities

Author: *Nusair Hasan (Michigan State University)*

Co-authors: *Fabio Casagrande, Venkatarao Ganni*

Large-scale 4.5 K and 2.0 K helium cryogenic systems are a foundational support system for modern superconducting accelerator facilities. These are highly energy intensive systems. Large-scale efficient helium systems presently require approx. 800 W/W of cooling at 2 Kelvin (30 mbar) and 250 W/W at 4.5K. Due to the nature of the application, these systems require very high reliability (24/7/365 operation). Over the last few decades, progressive and synergistic advancements in cryogenic system operating efficiency and reliability have been made – starting from development of warm compressor skids with wide range operation, to development and implementation of the Ganni floating pressure process for efficient and high turn-down of the refrigeration systems to match the actual loads (NASA-JSC, 12 GeV-JLab, FRIB etc.). These design and developments are successfully utilized with high turn-down capacity and substantial energy savings for large-scale helium cryogenic systems at many US Labs. The design and successful implementation of superconducting magnet quench recovery and management helped preservation of helium inventory and improved beam availability. There are still several challenges, e.g. efficient and reliable operation of small-scale 2.0 K cryogenic systems, helium recovery and purification systems that can affect reliable cryogenic system operation. In this talk, the operational experience, progress made to date, recent challenges, and the path forward are discussed.

【TUO11】Challenges and breakthroughs in recent RF Solid State PA design by Radial Combiner design with Initiatives for SDGs

Author: *Reichiro Kobana (R&K)*

R&K, an independent company, has achieved production of 2.3 million 1.9GHz microwave power amplifiers for mobile-comm's-base-stations and then also supplies wideband power amplifiers for automobile EMC testing for domestic automobile industries. Then 16 years ago, we started designing and producing some hundreds kW RF SSA for accelerator applications as alternatives to Klystron / tube. The measure characteristics of SSA is a possibility to design a band in a very wide frequency range available from few MHz to 14 GHz, and its upgradability of max-power in few kW to few MW design even after system completed. Recently, SSA is being recognized the significant advantages over vacuum tubes in terms of size, low power consumption, higher efficiency, low cost, and adaptive power design. In addition to these, we have learnt that SSA has very low phase noise and low envelope noise that cannot be achieved with vacuum tubes.

【TUO12】Machine learning for high current beam operation at cERL

Author: *Masakazu Kurata (KEK)*

Co-authors: *Yosuke Honda, Koay Huiwen, Ryukou Kato, Takashi Obina, Hidenori Sagehashi, Hiroshi Sakai, Miho Shimada, Mami Shiozawa, Olga Tanaka, Takanori Tanikawa, Masahiro Yamamoto*

The compact ERL (cERL) is operated at the mid-energy region around 17 MeV, facilitating beam studies on industrial applications since 2017.
One of the R&D issues is the high average beam current operation, which is carried out with a low bunch charge (0.77pC).
In 2023, machine learning was employed to optimize the beam tuning process, with the objective of maintaining a high current beam
while reducing radiation levels. The application of machine learning is a promising approach to realize automatic tuning.
We will present the current status of the machine learning study for beam tuning at cERL.

【TUO13】Beam Dynamics of the Strong Hadron Cooler ERL at the Electron-Ion Collider

Author: *Kirsten Deitrick (Thomas Jefferson National Accelerator Facility)*

Co-authors: *Stephen Benson, William Bergan, Joseph Conway, Ralf Eichhorn, Alexei Fedotov, Colwyn Gulliford, Dmitry Kayran, Christopher Mayes, Isurumali Neththikumara, Todd Satogata, Nicholas Sereno, Sadiq Setiniyaz, Karl Smolenski, Nicholas Taylor, Erdong Wang, Ningdong Wang, Derong Xu*

The Strong Hadron Cooler Energy Recovery Linac (SHC-ERL) for the Electron-Ion Collider (EIC) is required to produce an electron beam with a bunch charge of 1 nC, an average current of 100 mA, and a beam energy of both 150 and 55 MeV, with strict requirements for the transverse emittance, slice energy spread, and longitudinal distribution. This talk covers the design in detail, including preliminary considerations of higher order effects and diagnostics.

【TUO14】PERLE design and beam dynamics studies

Author: *Alex Fomin (IJCLab)*

Co-authors: *Rasha Abukeshek, Alex Bogacz, Coline Guyot, Walid Kaabi, Julien Michaud, Connor Monaghan, Luc Perrot, Achille Stocchi*

PERLE (Powerful ERL for Experiments) is an innovative ERL test facility designed to explore a wide range of accelerator phenomena and validate technical choices for the next generation of ERLs, intended for future electron collider projects like LHeC and FCC-eh. Its primary objective is to investigate high current (20 mA), continuous wave, multi-pass operations using superconducting cavities at 802 MHz. PERLE is planned to undergo three phases of installation and operation: a single turn, three turns at 250 MeV, and three turns at 500 MeV, which is the target objective of the project. The three-turn configurations will feature two low beta insertions for X-ray production using Compton back-scattering and for electron scattering off radioactive ions. The lattice design for all configurations of PERLE accounts for upgradability, and the efficiency of the machine is verified with beam dynamics studies.

【TUO15】Impact of filling patterns on BBU in ERLs

Authors: *Robert Apsimon (Lancaster University/Cockcroft Institute), Sadiq Setiniyaz*

In this paper, we explore the complex the impact of bunch injection filling patterns on beam break-up (BBU) instabilities in energy recovery linacs (ERLs) and explore the sensitive of changes to the bunch train on the resulting BBU threshold currents. We study the impact on PERLE, exploring the allowed potential filling patterns and show that the dominant HOM is also dependent on filling pattern.

【TUO16】Beam Diagnostics for the Multi-Turn ERL Operation at the S-DALINAC

Author: *Manuel Dutine (Technische Universitat Darmstadt)*

Co-authors: *Michaela Arnold, Adrian Brauch, Ruben Grewe, Lars Juergensen, Norbert Pietralla, Felix Schliessmann, Dominic Schneider*

The S-DALINAC is a thrice-recirculating electron accelerator operating in cw-mode at a frequency of 3 GHz. Due to the implementation of a path-length adjustment system capable of a 360° phase shift, it is possible to operate the accelerator as an Energy-Recovery LINAC (ERL) additionally to the conventional beam operation. The multi-turn ERL operation has been demonstrated in 2021. While operating the accelerator in this mode, there are two beams in the same beamline, the once accelerated and the once decelerated beam, with a longitudinal phase difference of 180° and possibly deviant transversal positions. The measurement of beam parameters must be non-destructive, otherwise the operating mode cannot be maintained. The status and first measurement results of multiple beam diagnostics units, such as a 6 GHz resonant cavity Beam Position Monitor (cBPM) and a wire scanner, will be shown. Further diagnostic devices for optimization of the ERL operation will be discussed.

【TUO17】Improved techniques for space charge dominated beamline design

Author: *Marcello Rossetti Conti (INFN-MI)*

This work explores a innovative beamline design approach using GIOTTO and RotnSlice, advanced AI-based optimization suite. GIOTTO employs cutting-edge algorithms for multi-objective genetic optimizations of space charge dominated beamlines, enhancing beam quality and parameter exploration. RotnSlice complements GIOTTO by introducing techniques for dispersion evaluation, phase space slicing, and dispersion evaluation.

We exploited these codes to design the high-brightness injector for BriXSinO ERL. Its innovative design uses two subharmonic bunchers for distributed beam gymnastics, achieving notable results: lower-output energy (4.5 MeV) at high bunch charge (100 pC) and beam parameters comparable to established ERL projects. Additionally, GIOTTO and RotnSlice enable dispersion closure in a space charge dominated dogleg. These codes were successfully applied in experiments or projects such as EuPRAXIA@SPARC_LAB, FCC-ee and ACTIS, optimizing complex dispersive paths, tailoring combed beams and enhancing positron capture.

These tools facilitate the use of simulation codes like ASTRA for dispersive path designs, showcasing their versatility and advanced capabilities in beam dynamics research.

This presentation points out the central role of GIOTTO and RotnSlice in advancing space charge dominated beamline design and optimization methodologies, illustrating their effectiveness in both established and cutting-edge experimental setups.

September 25th Oral presentations

【WEO01】Injector optics design and optimization for cERL

Author: *Olga Tanaka (KEK)*

Co-authors: *Masakazu Kurata, Masahiro Yamamoto*

The Compact Energy Recovery Linac (cERL) at KEK is a testbed for developing and exploring applications of ERL technologies. While aiming for IR-FEL generation in recirculation mode during FY2021, the injector energy was limited to 3.5 MeV due to the ratio between injection and recirculation beam energies. For the FY2023 CW operation, cERL operated with a 450 kV gun voltage, 2.9 MeV injector energy, 0.77 pC bunch charge, and a 3 ps RMS single Gaussian laser pulse. In contrast, FEL operation used a higher injector energy (3.5 MeV), increased bunch charge (60 pC), and a 40 ps single Gaussian laser pulse at 81.25 MHz. This report details injector optimization strategies and results for various operational modes, initial conditions, and injector optics preparation, all aimed at enhancing cERL's performance and achieving its operational goals.

【WEO02】Mechanisms for commissioning and implementation of the SEALab beam modes: from modelling to optimisation strategies

Author: *Emily Jayne Brookes (HZB)*

The SEALab facility in Berlin is home to an R&D superconducting radio-frequency photoinjector setup and beamline which aims to produce electrons for use in a wide range of applications from Energy Recovery Linacs to Ultrafast Electron Diffraction to water treatment. Commissioning of this machine is currently underway, with first beam expected within the year. Commissioning the accelerator to achieve this range of applications from a single machine requires flexibility in the injector and precise control of the individual and distinctive beam modes. An integral component to providing insights into the beam dynamics in these situations is the incorporation of computational models. Thus, a 6-dimensional analytical model, particle-in-cell simulations and machine learning surrogate models have been developed for SEALab, and each have an important role in commissioning and operating the machine. These models are paired with optimisation algorithms to aid during the setup and operation of the accelerator. This presentation demonstrates the range of models developed and their areas of influence on the wide range of applications of the SEALab machine.

【WEO03】Optimisation of space charge induced emittance growth in the PERLE injector

Authors: *Alex Fomin, Julien Michaud, Connor Monaghan (University of Liverpool, IJCLab/CNRS), Carsten Welsch*

A high current and high bunch charge is the requirement of the PERLE (Powerful Energy Recovery Linac for Experiments) project. A 20 mA electron beam will be injected into the ERL at 7 MeV with a total bunch charge of 500 pC. From production in the 350 keV DC photogun to injection, there is significant contribution to the emittance growth from the space charge forces. A traditional method of emittance compensation is implemented here with specific consideration given to complex characteristics of the transverse and longitudinal phase space. The genetic algorithm NSGA-III is used to perform the optimisation of the large design space, including theoretical laser distributions which reduce the emittance.

【WEO04】Fast envelope tracking for high intensity low energy electrons

Author: *Hui Wen Koay (TRIUMF)*

Co-authors: *Thomas Planche, Rick Baartman, Olga Tanaka, Masahiro Yamamoto, Masakazu Kurata, Miho Shimada, Takashi Obina, Hiroshi Sakai*

Particle-in-cell (PIC) tracking codes such as GPT and ASTRA are commonly used for simulating and understanding the initial stages of electron beam creation and acceleration, typically up to the first few hundred kilovolts. However, these simulations are often slow and require precise input of details that are not essentially needed. An alternative is envelope tracking using numerical integration, which offers rapid results and is handy in early-stage design.
This study presents beam dynamics simulations from two electron sources: the photocathode gun at cERL-KEK and the thermionic gun at TRIUMF e-Linac. It compares results from both methods and validates them against experimental data.

In these two cases, despite being orders of magnitude faster than conventional multi-particle PIC codes, the envelope method delivers comparably accurate results for rms measures of beam dimensions, even under strong space charge.

【WEO05】Phasing and Calibration of the Main Linac Cryomodule Cavities for the CBETA Energy Recovery Linac

Author: *J. Scott Berg (Brookhaven National Laboratory)*

I describe the method used for calibration and phasing of the Main Linac Cryomodule (MLC) for the CBETA energy recovery linac at Cornell University. The cavities are powered one at a time, and the phase of each cavity is set to a uniformly spaced set of values over a full 360 degree range, with cavity voltages set to one or more values. For each cavity, voltage, and phase, arrival time measurements are taken at BPMs upstream and downstream of the linac. No magnets lie between the linac and the BPMs. These measurements are used to obtain a least-squares fit the parameters of a model. The model is based on integrating through a fieldmap that was generated from a finite element computation. The parameters to be fit are the scaling factors between the programmed and actual cavity voltages, the offset between the programmed and actual cavity phases, and the the energy of the beam coming into the linac. The fitting process is accelerated by constructing a good initial guess for the parameters, and by computing the arrival time and its derivatives to the parameters so that Newton's method can be used to solve for the fitting parameters.

【WEO06】High-Performance Operation of a Direct-Current and Superconducting Radio-Frequency Combined Photocathode Gun

Author: *Senlin Huang (Peking University)*

Co-authors: *Liwen Feng, Jiankui Hao, Haoyan Jia, Tianyi Li, Lin Lin, Juntao Liu, Kexin Liu, Zhongqi Liu, Shengwen Quan, Fang Wang, Tianyi Wang, Huamu Xie, Hang Xu, Xiang Zhang, Yonglong Zhao, Feng Zhu*

Superconducting radio-frequency (SRF) guns are promising candidates to deliver high brightness continuous-wave (CW) electron beams for new generations of coherent linac light sources, ultrafast electron diffractions, MeV pulsed beam applications, etc. To solve the compatibility problem of semiconductor photocathodes, a hybrid gun combining a direct-current gap and an SRF cavity has been developed. The gun, employing K2CsSb photocathodes driven by a green laser, has been brought into stable CW operation with a dark current below 100 pA, delivering electron beams at an energy gain of 2.4 MeV, an electron bunch charge of 100 pC, and a repetition rate of 1 MHz. A normalized beam emittance of 0.54 mm-mrad has been achieved at the bunch charge of 100 pC and peak current of about 6 A. CW operation at 81.25 MHz repetition rate has also been tested with the maximum average beam current reaching 3 mA.

【WEO07】Operating experience with Cs_2Te cathodes and driving the SRF gun up to 1mA CW

Author: *Andre Arnold (HZDR)*

At the electron accelerator for beams with high brilliance and low emittance (ELBE), the second version of a superconducting radio-frequency (SRF) photoinjector was brought into operation in 2014. After a period of commissioning, a gradual transfer to routine operation took place in 2017, so that now more than 1800h of user beam are generated every year. In addition to this routine operation with a few tens of microamperes, another important goal, the generation of an average current of 1 mA, which is high for electron linear accelerators, could now be demonstrated with our SRF gun. At the same time, this beam was already accelerated to almost 30 MeV by the ELBE LINAC and irradiated in one of the IR-FELs. This is particularly important with regard to the successor of the ELBE accelerator called DALI, which will be also fed by an SRF gun with a high average current. The contribution presents the most important steps for achieving the full beam current and summarizes related measurement results and findings. No fundamental difficulties were identified.

【WEO08】Operational experience with CsK_2Sb and GaAs photocathodes in a high gradient CW SRF gun

Author: *Vladimir Litvinenko (Stony Brook University)*

I will report on record-breaking performance of CW SRF 113 MHz gun built at Brookhaven National Laboratory for Coherent electron Coolin experiment. This photoelectron gun normally operates with the room-temperature CsK_2Sb photocathodes inside cryogenic 4K quarter-wave cavity. It generates 1.2 5 MeV CW electron beam with quality sufficient for hard-X-ray FELs at 100 pC per bunch. Nominal operation set-up for CeC operation used electron bunches of 1.5 nC, but the gun is capable of generating charges per bunch as high 20 nC. With few exceptions, QE lifetime of CsK_2Sb photocathodes in our SRF gun is measured in months. Recently we tested two GaAs photocathodes at accelerating voltages as high as 1.35 MV, charge per bunch above 1 nC and lifetime measured in weeks. In addition of presenting successes with our SRF gun, I will discuss number of faults and near disasters we experienced during in nearly 10 years of its operation as well as methods we developed to recover and even further improve the gun's performance.

【WEO09】Development of Photocathodes for high spin polarized electron sources at Brookhaven National Laboratory

Author: *Luca Cultrera (BNL)*

Co-authors: *Mohamed Boukhicha, Samuel Hawkins, Aaron Muhowski, Victor Patel, Pallavi Saha*

Photocathodes capable of producing highly spin polarized electrons beams are required for both high energy and nuclear physics experiments. In this talk, we report on the commissioning of a new UHV vacuum system for photocathode characterization, which includes a retarding field Mott polarimeter for the measurement of electron spin polarization. We will illustrate the design of III-Vs superlattice structures equipped with Distributed Bragg Reflector and present the measurements of electron spin polarization and quantum efficiency of emitted electrons from these structures.

【WEO10】LCLS-II injector performance

Author: *Feng Zhou (SLAC)*

LCLS-II has started users operation and recently has ramped up the e-beam rate to 8kHz for operation. This talk is to present technical progresses of the LCLS-II injector including achieved high-brightness e-beam performance, effective dark current mitigation, and Cs_2Te cathode performance.

【WEO11】Design, fabrication, and beam commissioning of a 216.667 MHz CW VHF electron gun

Authors: *Haixiao Deng, Zenggong Jiang, Xudong Li, Zipeng Liu, Houjun Qian (Zhangjiang Lab), Guan Shu, Wenyan Zhang, Yubin Zhao, Zhi Zhao, Xiang Zheng*

Both normal conducting and superconducting CW VHF guns are under development for high repetition rate free electron lasers and electron ion cooling. Up to now, 1 MHz repetition rate beam of 0.3 mA average current was demonstrated with the APEX project at LBNL. In this paper, we present a new average current record with the VHF gun technology, 3 mA at 9 MHz. The development process of a 216.667 MHz normal conducting VHF gun will be described, including design, fabrication and beam commissioning.

【WEO12】High average current HVDC electron gun for EIC hadron cooling

Author: *Erdong Wang (Brookhaven national lab)*

One essential R&D project of the EIC is developing an electron gun to generate a high average current, high-brightness electron beam for the hadron cooler, which is necessary to maintain hadron beam quality and achieve the high collider luminosity goal of 10^{34} s^{-1} cm^{-2}. The gun must deliver a high average current of 98.5 mA, approximately 1 mm-mrad normalized transverse emittance, and a bunch charge of 1 nC to 2.5 nC. In this talk, we describe the high voltage design of a DC gun with an operating voltage of 500 kV, conditioned up to 600 kV. Unique features of this gun include the use of inverted ceramic at this voltage level, active cooling for the cathode, and the use of large/single crystal multi-alkali cathodes grown on a silicon-carbide substrate. High current brightness electron sources are also critical for other future facilities, including high-intensity gamma sources, future e^+e^- colliders, and extremely deep UV sources for the semiconductor industry.

【WEO13】Preparation of cERL DC-gun upgrade for 10mA CW beam operation

Author: *Masahiro Yamamoto (KEK)*

Co-authors: *Nao Higashi, Yosuke Honda, Masakazu Kurata, Shinya Nagahashi, Takashi Nogami, Hiroshi Sakai, Olga Tanaka, Takanori Tanikawa, Takashi Uchiyama*

The compact-ERL has been operating a 1mA CW beam since 2016, and has successfully operated a 1mA CW beam under insertion device installation conditions in 2023. With a view to future industrial applications, we are proceeding to address several problems that electron guns have faced in order to achieve higher current operation. The main problems are the vacuum leakage problem caused using a titanium vacuum vessel, which was introduced to achieve an extreme high vacuum, and the problem of insufficient output power of the high-voltage power supply. We will report on the troubles we encountered in dealing with these problems and the solutions to them. We will also report on the preparations that are currently being made for the beam control and stable operation of the 10 mA CW beam supply.

September 26th Oral presentations

【THO01】PERLE Potential Applications

Author: *Walid Kaabi (IJCLab-CNRS)*

PERLE, a Powerful Energy Recovery Linac for Experiments, is a multi-turn ERL in a racetrack configuration featuring a linac in each straight in its final configuration. With its three turns, PERLE reach in a cost-efficient way an energy of 500 MeV, for the 20mA beam generated at the electron source. In addition to exploring new accelerator phenomena in unprecedently explored power regime for an ERL, PERLE will be also offer opportunities to host novel low-energy high-intensity experiments as X-ray production by Campton backscattering and electron-radioactive ion scattering.

We will present these two potential applications for PERLE, with the impact on the layout and the footprint of the machine.

【THO02】Design Overview of the Strong Hadron Cooler ERL at the Electron-Ion Collider

Author: *Kirsten Deitrick (Thomas Jefferson National Accelerator Facility)*

Co-authors: *Stephen Benson, William Bergan, Joseph Conway, Ralf Eichhorn, Alexei Fedotov, Colwyn Gulliford, Dmitry Kayran, Christopher Mayes, Isurumali Neththikumara, Todd Satogata, Nicholas Sereno, Sadiq Setiniyaz, Karl Smolenski, Nicholas Taylor, Erdong Wang, Ningdong Wang, Derong Xu*

The Electron-Ion Collider (EIC) is currently under development to be built at Brookhaven National Lab and requires cooling during collisions in order to mitigate the hadron beam emittance degradation due to intra-beam scattering and beam-beam effects. An Energy Recovery Linac (ERL) is being designed to deliver the necessary electron beam for Coherent electron Cooling (CeC) of the hadron beam, with an electron bunch charge of 1 nC and an average current of 100 mA; two modes of operation are being developed for 150 and 55 MeV electrons, corresponding to 275 and 100 GeV protons. The injector of this Strong Hadron Cooler ERL (SHC-ERL) is shared with the Pre-cooler ERL, which cools lower energy proton beams via bunched beam cooling, as used in the Low Energy RHIC electron Cooling (LEReC). This talk introduces the layout and presents a high-level overview of the design.

【THO03】Future e+e- colliders using recycling energy-recovery linacs

Author: *Vladimir Litvinenko (Stony Brook University)*

I will discuss potential offered by Energy-Recovery Linacs (ERLs) and particle recycling for boosting luminosity in high-energy electron-positron and lepton-hadron colliders. ERL-based colliders have promise not only of significantly higher luminosity, but also of higher energy efficiency measured in units of luminosity divided by the consumed AC power. Addition of recycling collided particles and their recuperations in damping ring removes insane ILC/CLIC appetite for fresh positions and offers high degrees of polarization in colliding beams.

Presentation will cover similarities and distinctions between linear and re-circulating ERL concepts with focus on their costs, energy efficiency and energy reach. Two examples of HIGS ERL-based factory located in LHC and FCC tunnels will be compared with two concepts of linear ERL colliders.

I will finish talk with discussion of possible technical breakthroughs which can make SRF ERL technology more affordable and more attractive.

【THO04】Electron cooler for high-energy hadrons in the EIC based on ERL

Author: *Dmitry Kayran (Brookhaven National Laboratory)*

Co-authors: *Alexei Fedotov, Sergei Seletskiy*

The Electron Ion Collider (EIC) performance will benefit from cooling of the stored ions at three collision energies. Such a cooling must counteract the emittance growth driven by both the IBS and beam-beam effects. A non-magnetized bunched beam electron cooler is one of the possible approaches to cooling colliding ions. In this paper we use an energy recovery linac and several recirculations of electron beam to provide cooling at all collision energies. We describe the bunch quality requirements, challenges and design aspects of such electron cooler.

【THO05】ILC Upgrade with Energy Revovery

Author: *Kaoru Yokoya (KEK)*

The energy upgrade of ILC (International Linear Collider) has been discussed in many places. We discuss here a possible upgrade path of the luminosity using the concept of the energy recovery, in particular at the center-of-mass energy 500 GeV where the self coupling of the Higgs particle is visible. There are a few types of proposals egergy recovery linear colliders. Though there are many R&D issues for the realization, an improvement of two orders of magnitude may be within the scope.

【THO06】Applications of the SRF Photoinjector of SEALAB

Author: *Thorsten Kamps (HZB)*

The SRF photoinjector of SEALAB is dedicated to accelerator physics research and development with a focus on SRF technologies and pilot beam applications of high-brightness beams.

【THO07】Accelerator development plan in KEK toward the High-power EUV-FEL light source for future lithography

Author: *Hiroshi Kawata (KEK)*

Co-authors: *Yosuke Honda, Ryukou Kato, Shinichiro Michizono, Norio Nakamura, Takashi Obina, Hiroshi Sakai, Miho Shimada, Olga Tanaka, Takanori Tanikawa, Yasunori Tanimoto, Kimichika Tsuchiya, Masahiro Yamamoto*

It is important to develop the high power EUV light source up to or more than 1 kW to realize the 2nm node and beyond, and to reduce stochastic variation. This light source also must have performances of the polarization and wavelength tunability and cost reduction of the running cost per scanner for future lithography [1]. To this end, an energy recovery linac (ERL)-based free electron laser (FEL) is a candidate, so that our group has done some feasibility studies from the viewpoint of accelerator technology [2]. However, there are several remained accelerator elements should be developed, before starting the real prototype EUV-FEL light source for a real lithography demonstration as follows; 1) prototype cryomodule, in which 4 pieces of 9cell SRF high field gradient cavity are installed, 2) Long-term stable supply of high-current, high-brightness beams of 500 kV and 10 mA from the DC electron gun, and 3) the cost-effective polarization tunable undulator system. At the workshop, the outline of these accelerator elements development plan will be presented and further milestone toward the plot type of the EUV-FEL construction will be discussed.

References

[1] “INTERNATIONAL ROADMAP FOR DEVICES AND SYSTEMS™ 2022 EDITION LITHOGRAPHY”, https://irds.ieee.org/images/files/pdf/2022/2022IRDS_Litho.pdf.

[2] for example: Hiroshi Kawata, et. al., J. Micro/Nanopattern. Mater. Metrol., Vol. 21(2), 021210, (2022).

【THO08】High Harmonic Frequency Combs Based on an Infrared FEL Oscillator

Author: *Ryoichi Hajima (QST)*

VUV frequency combs have diverse applications in science and technology, enabling precision spectroscopy that allows for the study of atomic and molecular structures with unprecedented accuracy. These frequency combs can be generated through high harmonic generation (HHG). This talk discusses the concept of high harmonic frequency combs based on an infrared FEL oscillator driven by an energy-recovery linac. In an FEL oscillator operating in the superradiant regime, a train of high-intensity pulses is generated at a high repetition rate exceeding 10 MHz. The carrier-envelope phase of the FEL pulses can be stabilized by an external seed laser or the coherent radiation of the electron bunches. VUV frequency combs are realized by HHG using these CEP-stable FEL pulses. For the energy-recovery operation, mitigating the large energy spread in the deceleration beam is crucial.

【THO09】Development of regenerative-amplifier FEL at the compact ERL

Author: *Takanori Tanikawa (KEK)*

Co-authors: *Yosuke Honda, Ryukou Kato, Norio Nakamura, Hiroshi Sakai, Miho Shimada, Masahiro Yamamoto*

The compact ERL has been built in 2013 at High Energy Accelerator Research Organization (KEK) to a test machine of an energy recovery linac. Afterwards, two undulators have been installed in the compact ERL and a first light amplification (free-electron laser: FEL) in mid-infrared range has been observed in 2021. However, the intensity of light has not been achieved to the intensity saturation because of not enough undulator length. Since we are considering for industrial applications using it, the intensity has to be improved. There are several methods to improve the intensity, and we have decided to try a “regenerative-amplifier (RA) FEL” scheme and now it is under the development. In this presentation, we will report the status and plan of RA-FEL development at the compact ERL.

【THO10】ERL potential as a gamma-ray source

Author: *Dmitry Kayran (Brookhaven National Laboratory)*

The backscattering Compton sources promise high intensity, monoenergetic and high brightness γ-ray beams. Combination of high current Energy Recovery Linacs (ERLs) with the high power lasers (both the “conventional” and FEL with only 100 kW of intra-cavity power) opens possibility of generating a few order of magnitude higher flux of gamma-rays then currently available. In this talk we discuss benefits and requirements for such ERL. Also, we make estimates for currently existed and planned ERLs to utilize backscattering Compton effect for producing high-flux gamma-ray beams. Such sources can find applications expanding from high energy and nuclear physics to medical application and potentially disposal of radioactive waste.

【THO11】Investigating permanent magnet resiliency to radiation – a study at Jefferson Lab's CEBAF

Author: *Ryan Bodenstein (Thomas Jefferson National Accelerator Facility)*

Co-authors: *Kirsten Deitrick, Bamunuvita Gamage, Joseph Gubeli, David Hamlette, Joseph Meyers, Edith Nissen, Neil Wilson*

Jefferson Lab is currently studying the feasibility of an energy upgrade based on FFA technology. The concept will use a pair of permanent magnet-based multipass recirculation arcs to increase the total number of passes through the current linacs. The increased number of recirculations will increase the final achievable nominal energy to over 20 GeV. No existing Fixed Field Alternating Gradient (FFA) machines have ever approached the energy levels proposed for this upgrade. This raises concerns as to the radiation hardness of the permanent magnet materials to be used. The lab has therefore provided a two-year Laboratory Directed Research and Development (LDRD) grant to study the permanent magnet materials in a radiation environment similar to those in which they will operate. Samples of permanent magnet materials (namely neodymium iron boron and samarium cobalt) will be installed around the CEBAF facility in a variety of different radiation environments, along with appropriate dosimetry. Over time, as allowed by the CEBAF operational schedule, we will measure the magnetic degradation and radiation doses at each location. We will then use this data, along with data from other similar studies, to extrapolate the degradation these materials may experience over time when operating in the upgraded CEBAF facility.

【THO12】Fast reactive tuner research and developments at HZB

Author: *Nicholas Shipman (HZB)*

FRTs are ultra fast non-mechanical cavity tuners which can dramatically reduce RF power consumption and are particularly suited to low/zero beam loading applications such as ERLs. HZB is developing such an FRT to work at 1.3GHz which would be suitable for Microphonics compensation of bERLinPro main LINAC cavities but could equally be used for other 1.3GHz systems. This research effort is part of the broader ISAS project which aims to develop the technological readiness of cutting edge energy saving techniques for accelerators.

This talk will outline the FRT project at HZB and the progress and results achieved to date.

【THO13】Mechanical Polishing of Nb_3Sn Thin Film Cavities

Author: *Eric Viklund (FNAL)*

Co-authors: *David Burk, Grigory Eremeev, Sam Posen, David Seidman, Brad Tennis*

Nb_3Sn thin film SRF cavities are an important area of study for accelerator technology. Nb_3Sn cavities achieve a higher quality factor than Nb cavities and can theoretically achieve higher accelerating gradients. These properties make Nb_3Sn cavities well suited for the next generation of particle accelerators. In this study we will show a new method of polishing for Nb_3Sn cavities known as centrifugal barrel polishing (CBP). Using this method, Nb_3Sn coated samples are polished to a surface roughness comparable to a traditional electropolished (EP) Nb cavity. We find that CBP can improve the maximum accelerating gradient of a Nb_3Sn cavity when paired with an additional Sn recoating step. This Sn recoating step is theorized to repair damage caused by the CBP such as cracks. We also find that the recoating step can repair Nb_3Sn cavities that have been degraded by deformation. By studying Nb_3Sn coated wires, we find evidence of a self-healing mechanism present in Nb3Sn that leads to deposition of new Nb_3Sn within cracks during the recoating step. These two processes, CBP and Sn recoating, allow the creation of higher performance Nb_3Sn cavities and unlock a new way to repair damaged Nb_3Sn cavities. Thus, bringing us one step closer to implementing Nb_3Sn cavities in next generation particle accelerators.

【THO14】Status and Testing of the High Current SRF Cavity for BESSY VSR

Author: *Adolfo Velez (HZB)*

Co-authors: *Hans-Walter Glock, Felix Glöckner, Jens Knobloch, Andranik Tsakanian, Nora Wunderer*

The BESSY Variable pulse-length Storage Ring (VSR) Demo project aims to provide short and long pulses simultaneously in a single storage ring, a capability essential for advanced synchrotron radiation experiments. A critical component in achieving this goal is the development high current Continuous Wave (CW) Superconducting Radio Frequency (SRF) cavities operating at 1.5 GHz for 300 mA beams. This paper presents the current status, fabrication and results from the 1sr delivered prototype by Reseach Instruments and tested at SupraLab HZB.The second prototype is scheduled for delivery by the end of the year, to validate the design and functionality.

【THO15】PERLE cavity development at IJCLab

Author: *Akira Miyazaki (CNRS/IN2P3/IJCLab)*

We are developing 5-cell cavities for a PERLE cryomodule within the framework of the EU project called iSAS. The cavities were originally designed by JLAB to be at one of the FCC frequencies of 801.58 MHz. This frequency range is an open research domain. We are investigating several recipes to achieve a very challenging goal of Q0=3e10 at 22 MV/m. We selected mid-T baking as the 1st option to apply; however, other recipes are still under debate. IJCLab is equipped with a vacuum furnace with a cryogenic pumping and has used it for hydrogen degassing of 29 ESS spoke cavities with titanium jackets. The performance of these spoke cavities have been beyond the ESS specification. However, advanced heat treatment like mid-T bake is a new challenge in our facility. In this talk, we show the first test result of a prototype 1.3 GHz 1-cell cavity after mid-T bake in our furnace. We also summarise the strategy and status of cavity fabrication for the PERLE/iSAS project.

【THO16】1.3 GHz 3-cell superconducting cavity for high current beam acceleration

Author: *Xuan Huang (Shanghai Institute of Applied Physics)*

The energy recovery linac (ERL)-based extreme ultraviolet (EUV) light source is a continuous wave machine with a beam current of 10 mA. A 1.3 GHz 3-cell cavity has been designed for the high-power injector, which is a key component of the EUV light source. The beam tube was enlarged to damp high order modes (HOMs) and avoid beam instability. In this paper, we present the cavity design, including the beam tube length and the fundamental power coupler. Additionally, we calculated the damping of HOMs and estimated the high HOM power resulting from the 10 mA beam.

September 27th Oral presentations

【FRO01】Status of Supercondtucting Thin Films on Higher Order Mode Antennas at MESA to increase the CW Perfomance

Author: *Paul Plattner (JGU Mainz)*

Co-authors: *Florian Hug, Timo Stengler*

The Mainz Energy-recovering Superconducting Accelerator (MESA), an energy-recovering (ER) LINAC, is currently under construction at the Institute for Nuclear physics at the Johannes Gutenberg-Universität Mainz, Germany. In the ER operation mode, continuous wave (CW) beam is accelerated from 5 MeV up to 105 MeV. The energy gain of the beam is provided through 2 enhanced ELBE-type cryomodules containing two 1.3 GHz 9-cell TESLA cavities each. By pushing the limits of the beam current up to 10 mA, a quench can occur at the higher order modes (HOM) antennas. The quench is caused by the increased power deposition induced by the electron beam in ER mode. Calculations have shown that an upgrade from 1 mA to 10 mA can increase the deposited power in the HOMs up to 3080 mW. From this power approximately 30% will be present at the HOM feedthrough and can be used as a thermal input. Previous simulations have shown a power limit of 95 mW, which includes the power of a recirculating beam at 1 mA but is exceeded at 10 mA. A solution to increase the power limit is to coat the antennas with a superconducting thin films which provides higher critical fields, temperature, and currents. Nb_3Sn and NbTiN are the material candidates. First simulations shown an increased power limit, which includes the limits for MESA. The first coated HOM antennas will be tested in an ELBE-type cryomodule*, which is currently under refurbishment.

【FRO02】Development of CW 100 kW high power coupler for conduction cooled SRF accelerators

Author: *Pragya Nama (KEK/Sokendai)*

Co-authors: *Eiji Kako, Ashish Kumar, Hiroshi Sakai, Kensei Umemori*

For high current (~100 mA) conduction cooled SRF accelerators, a major challenge lies in the power handling capacity of the input coupler. Additionally, the high total heat load imposed at the low temperature region (4 K) by the input coupler poses another significant obstacle. This talk will provide details of the development of continuous wave (CW) 100 kW class high power input coupler for a conduction cooled L-band Nb_3Sn cavity-based cryomodule. RF, thermal and mechanical simulations were conducted to design the input coupler for 100 kW power transmission achieving S1,1 = -45 dB at 1.3 GHz frequency, with total heat load at 4 K region is about 1 W. The coupler fabrication process is currently underway, and the high-power RF test will follow in the near future.

【FRO03】SRF Photo-Injector Development at MSU

Author: *Taro Konomi (FRIB)*

A superconducting radio-frequency photo-injector (SRF-PI) can in principle operate in continuous-wave (CW) mode at high gradients with ultra-high vacuum. Using low mean-transverse-energy photocathodes, SRF-PIs could provide high-brightness, high-repetition-rate beams with long cathode lifetimes. For these reasons, an SRF-PI has been adopted for the proposed Low Emittance Injector addition to the SLAC Linac Coherent Light Source II High-Energy (LCLS-II-HE) Upgrade, which would operate in CW with bunch rates of up to 1 MHz. A 185.7 MHz quarter-wave gun cavity and cryomodule are being developed by the Facility for Rare Isotope Beam at Michigan State University (FRIB/MSU) in collaboration with HZDR, ANL, and SLAC with the goal of achieving at least a 30 MV/m photocathode gradient. A cryomodule test of the first prototype gun cavity and cold tests of a second cavity are underway at FRIB/MSU. Both cavities have met the gradient goal in cold tests in which a photocathode was not installed. This paper reports on the cavity and cryomodule test results so far.

【FRO04】LCLS-II SRF commissioning and early operational experience

Author: *Sebastian Aderhold (SLAC National Accelerator Laboratory)*

The LCLS-II project has installed a new superconducting linac at SLAC National Accelerator Laboratory to enable free electron laser science at repetition rates up to 1 MHz. The installed 35 1.3 GHz cryomodules will produce an electron beam with energy of up to 4 GeV. The installation and commissioning of the cryomodules and warm beamline sections is complete and the results have been excellent. The talk will focus on these results, primarily the performance of the SRF cavities in the installed linac, demonstrating no loss in performance from the installation compared with cryomodule acceptance testing at Fermilab and Jefferson Lab. We also report on the early operational experience, including beam availability and cavity failure modes.

【FRO05】Investigating Superconducting Cavity Faults and Instabilities at China Accelerator Facility for Superheavy Elements

Authors: *Feng Qiu (IMP), Yuan He, jinying ma*

Co-authors: *Yuan He, feng qiu*

Built upon the foundation of the existing superconducting radio frequency (SRF) linear accelerator known as CAFe, the CAFe2 (China Accelerator Facility for Superheavy Elements) facility has been developed for research on superheavy elements and material irradiation. In 2023, this facility achieved stable operation with a beam current of 14.8 particle microamperes (μA), setting a new world record among similar facilities. Operational experience indicates that faults in the SRF cavities are the primary source of issues for the accelerator, particularly quench (thermal breakdown) and Ponderomotive instabilities, which are recognized as the most significant concerns at CAFe2.

We have summarized and characterized several observed quenching events at CAFe2 and developed classical cavity model-based and machine learning-based quench classification methods. The validation of these models was confirmed during the experimental study. Additionally, we systematically researched two types of instabilities caused by Ponderomotive effects (oscillatory instability and monotonic instability). Through model simulations and online experiments, we identified boundary conditions triggering SRF cavity faults and proposed corresponding mitigation strategies. We will present the latest experimental results in this report.

【FRO06】Long-term Stable Operation of cERL Cryomodules

Author: *Kensei Umemori (KEK)*

I will present about the long-term stable operation of cERL injector and main linac cryomodules. Update plan of main linac cryomodule with high-Q cavities are also introduced.

【FRO07】Cryomodule Construction of Two 1.3 GHz 2-cell Cavities with double-feed couplers for DALS Injector

Author: *Quan Zhou (Dalian Institute of Chemical Physics, Chinese Academy of Sciences)*

The Dalian Advanced Light Source (DALS) beam test platform accelerates an electron beam with a current of 0.1 mA to a kinetic energy of 100 MeV and performs beam diagnostics. Following the electron gun, the first superconducting module on the DALS platform is a 1.3 GHz 2-cell superconducting cavity with double feed couplers (Module CM00). This module is designed to elevate the energy of low-energy electron beams (300-750 keV) to high energy (4 MeV) while maintaining a low beam emittance (nominal 0.56 mm-mrad).

This report primarily describes the structure, assembly process, and current installation progress of the CM00 module. The module's primary structure includes essential beam components such as the superconducting cavity, tuner, and coupler, as well as the cryogenic system comprising components like the cold screen, POST, and low-temperature pipelines. The integration of various sensors controlled by a PID diagram is also crucial to its functionality. The assembly process includes initial module assembly tooling and preparation in a Class 100 clean room, cavity string assembly within the clean room, and final module assembly outside the clean room. Finally, the report provides a comprehensive update on the current module installation progress and outlines the forthcoming plans for beam test platform installation and module testing.

Poster presentations (September 26th)

【THP01】Optics Misalignment and Orbit Correction for PERLE Accelerator

Author: *Rasha Abukeshek (CNRS/IN2P3, IJCLab, University Paris-Saclay)*

Co-authors: *Hadil Abualrob, Alex Bogacz, Alex Fomin, Walid Kaabi, Julien Michaud, Luc Perrot, Achille Stocchi*

PERLE (Powerful Energy Recovery LINAC for Experiment) is a high-power Energy Recovery LINAC (ERL) facility with 20 mA beam current and 500 MeV final energy, initially operating at 250 MeV, through three accelerating and three decelerating passes. PERLE aims to validate the ERL technical choices for the future LHeC. It will host experiments such as Compton back-scattering for X-ray production, and electron-nucleus (eN) scattering for nuclear physics research. This work studies misalignments in the magnets and analyzes their impact on the stored beam. In particular, transverse misalignments in quadrupole magnets are examined, with misalignment values taken from a normal distribution with a standard deviation of 100 μm. The misalignment effect on the beam orbit identifies key locations for Beam Position Monitors (BPM). Corrector magnets are incorporated into the lattice near the BPM positions to address the effect of these misalignments on the beam orbit. The Singular Value Decomposition (SVD) optimization method in the BMAD code is employed to determine the optimal correction scheme and the necessary range of the correction strength.

【THP02】Energy balance in the energy-recovery operation at cERL

Author: *Yosuke Honda (KEK)*

Co-authors: *Masakazu Kurata, Hiroshi Sakai, Miho Shimada*

At cERL, We have successfully operated 1mA-class beam operation in the energy-recovery mode in the operational period of November 2003.
The effective RF power load of the main linac cavities were measured in the beam operation under different settings of the circumference and accelerating phase. The experimental data were compared with a simple calculation.

【THP03】Longitudinal matching of the PERLE 250 MeV ERL

Author: *Julien Michaud (IJCLab, CNRS)*

As a high-power and high-current (5MW and 20mA) Energy Recovery Linac, PERLE will have to demonstrate energy recuperation in never-achieved conditions. The three-pass structure, which reaches a final energy of 250 MeV, presents several challenges. Previous studies have shown that multi-pass energy recovery can lead to significant losses in efficiency.
It is of significant importance to study in detail the longitudinal dynamics of the bunches along the 6 passes, especially during the deceleration process. I will show the first results of longitudinal matching of the 250 MeV version of PERLE and its effect on the beam distributions.

【THP04】Updates on the PERLE injector

Author: *Raphaël Roux (IJCLab)*

The PERLE project aims to build at a first stage a multi-turn ERL at 250 MeV and 20 mA at IJCLab site at Orsay campus-France. Its first objective is to be a demonstrator for high power ERL, mainly in the perspective of the LHeC project which foresees an ERL at 50 GeV, 20 mA. The specifications of the PERLE's injector are to provide a beam of 20 mA at 7 MeV for an emittance below 6 mm mrad and a bunch length of 3 mm. The injector is still in a design phase. Nevertheless, important equipment as the electron gun and its laser system were already purchased. We will present the design of the room temperature bunching cavity, carried out by our collaborator ESS-Bilbao laboratory, in addition to the 4 single cell cavities booster. Finally, we will show the injector performances thanks to the beam dynamics simulations with the existing components as well as with the designed ones.

【THP05】Preliminary design and beam dynamics simulation studies of the photo injectors for the EicC

Author: *Quantang Zhao (Institute of Modern Physics, Chinese Academy of Sciences)*

Co-authors: *Xiaoxiao Yuan, Xin Yang, Zimin Zhang, Jiancheng Yang, Hongwei Zhao*

A project for a polarized electron-ion collider in China (EicC) is planned based on the high intensity heavy ion accelerator facility (HIAF), which is currently under construction. According to the electron beam parameters from the white-paper of EicC, two electron injectors are required, one is polarized electron beam and another one is for energy recovery linac (ERL) based electron cooling (e-cooler). For the polarized electron beam, a DC high voltage photocathode gun is used; for e-cooler ERL, a quarter wave length resonator (QWR) SRF photocathode gun is considered. The preliminary considerations and designs of both injectors with beam dynamics simulation studies are presented here.

【THP06】Nb_3Sn Cavity R&D based on vapor deposition method at KEK

Author: *Hayato Ito (KEK)*

Co-authors: *Hiroshi Sakai, Kensei Umemori, Tomohiro Yamada*

Nb_3Sn is one of the most promising materials for the next generation of superconducting RF (SRF) cavities. One reason is that Nb_3Sn cavities can achieve high Q-values at 4 K, whereas conventional Nb cavities need to be cooled down to 2 K, enabling the SRF cavity operation with conduction cooling without the need for LHe. KEK started Nb_3Sn deposition tests on the single-cell cavity based on the Sn vapor diffusion method around 2019 and has steadily improved the cavity performance. We will report the results of deposition tests on samples and RF measurements of single-cell Nb_3Sn cavities.

【THP07】Virtual cavity probe for the real-time identification of cavity burst-noise type in superconducting radio-frequency systems

Author: *Jinying Ma (Institute of Modern Physics, Chinese Academy of Sciences)*

Co-authors: *Yuan He, feng qiu*

Burst-noise events are primary trip sources at the China Accelerator Facility for Superheavy Elements (CAFE2), characterized by rapid bursts in the cavity pick-up signal, which can be categorized into three distinct types: flashover, electronic quench (E-quench), and partial E-quench. We have designed an algorithm to identify these burst-noise event types in real time, enabling the real-time discrimination of the three types of burst-noise events. This algorithm is based on a virtual cavity probe constructed with the forward and reflected signals of the cavity and is integrated into a field-programmable gate array (FPGA). Additionally, we introduce an innovative method for calibrating the transmission delay in channels. This FPGA-based low-level radio-frequency algorithm effectively identifies burst-noise event types in real time. Its effectiveness has been validated at the CAFE2 facility, establishing the basis for implementing tailored corrective measures for distinct burst-noise events.

【THP08】Design of a Conduction-Cooled 2.856 GHz Nb_3Sn SRF Cavity and Compact Cryomodule for Electron Accelerator

Author: *Safwan Shanab (KEK)*

Co-authors: *Kensei Umemori, Hiroshi Sakai, Shigeru Kashiwagi, Tomohiro Yamada, Hayato Ito*

Nb_3Sn cavities have shown higher efficiency at 4K compared to pure niobium cavities when cooled using a conduction cooling system. This increased efficiency makes them suitable for more compact and cost-effective accelerator. Conduction-cooled SRF cavities, operating at 4K, do not require large-scale helium refrigerator systems, enhancing the compactness and efficiency of accelerator. Currently, a conduction cooling cryomodule is under development. A 2.856 GHz Nb_3Sn SRF cavity and a compact module design have been created for an SRF electron accelerator. This poster presents the design of the 2.856 GHz cavity and the development of the compact cryomodule, which includes a cryo-cooler, cavity cooling system, tuner, and thermal and magnetic shielding.

【THP09】Commissioning of bERLinPro ERL injector from an LLRF perspective

Authors: *Pablo Echevarria, Axel Neumann, Andriy Ushakov (Helmholtz Zentrum Berlin)*

This year, bERLinPro finally started its commissioning stage with operation of the SRF photo-injector gun. After a first trial cooldown to check the cryo-plant interfacing to the cryo-module, the SRF gun was cooled down a second time in May this year for a first RF test at 2K.

In this contribution, we will discuss the control of the twin coupler driven SRF gun from an LLRF point of view, the first data we have received by driving the cavity via a phase-locked loop system and some futher tests dedicated to a normal-conducting transverse deflecting cavity for longitudinal beam diagnostics.

These measurements contribute to prepare for the first beam operation to be scheduled for about October this year.

【THP10】Development of an Electric/Permanent Hybrid Magnet for Sustainable Accelerator

Author: *Yao Lu (Hiroshima Univ.)*

Co-authors: *Miho Shimada, Hiroshi Miyauchi, Takashi Obina, Kentaro Harada, Yoshifumi Takshima, Masahiro Katoh*

Permanent magnet is a reasonable option to replace electromagnet in accelerator systems to save power consumption of accelerator facility. We are doing research about electric/permanent hybrid magnet for sustainable accelerators, which would be capable of field adjustability and energy-saving. Such a magnet allows accelerator to operate in different energy. To solve potential issues towards operation, a permanent dipole magnet developed at Nagoya University is used to investigate the thermal effect generated by the coils and hysteresis effect in the magnet. For precise control of the magnetic field strength, an active feedback system uses the real-time temperature of the permanent magnet to adjust the coil current. The relationship between the temperature and magnetic field was studied by an environment with temperature controller. For the design of a model magnet, we studied the strategy of designing electric/permanent hybrid permanent magnet, which should maintain a balance between magnetic resistance and magnetic field strength. The experimental result and design will be presented.

【THP11】Design study of the cavity dumping for SANKEN THz-FEL and the possibility of applying it to the ERL system

Author: *Keigo Kawase (QST)*

A long wavelength free-electron laser (FEL) driven by the low energy electron beam can be taken as an oscillator layout. Then, it can make a fully coherent optical pulse. In the case of most oscillator FELs, the FEL beam is extracted through a small coupling hole at the center of the resonator mirror or by using a scraper mirror inserted in the resonator. Thus, the available intensity is a few % of that inside the resonator. The methods to use an intense pulse by inserting a gas target in the resonator and cavity dumping with a reflective switch driven by an intense laser pulse have been developed so far at the normal conducting FELs. Especially the cavity dumping can pick an intense single-pulse off from the micropulse train. Then, it is suitable to conduct the experiment using an intense laser pulse without the accumulation effects of the pulse train. The cavity dumping is also useful for the CW FEL with the superconducting accelerator because it can drive the intense FEL pulses with the repetition frequency of kHz order. It is developing at ELBE FEL in Dresden. I will show the recent design study of the cavity dumping for the THz FEL at SNKEN, Osaka University, and discuss the possibility of introducing it to the low-energy ERL like cERL at KEK.