MO1L1 -- EuPRAXIA: The First FEL User Facility Driven by a Plasma Accelerator
Invited Oral C - Compact Light Sources
Ralph Wolfgang Assmann (DESY, Hamburg)
The European Plasma Accelerator with eXcellence In Applications (EuPRAXIA) infrastructure* was proposed in 2014 and started its design phase in 2015 with an EU funded Design Study. By the end of 2019 the World´s first conceptual design report (CDR) for a plasma-based user facility was completed. The EuPRAXIA CDR describes the design of a compact and innovative research infrastructure that delivers ultra-short pulses of up to 5 GeV electrons, positrons, X-rays, FEL light and laser pulses to users from various fields. The project received government support from various European contries and was placed on the ESFRI roadmap of high priority European research infrastructures at end of 2021. The EuPRAXIA headquarters and one of the two construction sites is located at Frascati, Rome, in Italy. The second site will be decided among candidates in Czech Republic, Italy, Spain and UK. Presently several projects, supported by national and EU funds, are ongoing towards the implementation of this new research infrastructure. The talk will present the concept, user cases, the technical status, including successful FEL lasing***, the potential and challenges for EuPRAXIA. * https://www.eupraxia-facility.org/ ** R.W. Assmann et al., Eur. Phys. J. Special Topics 229, 3675-4284 (2020). *** R. Pompili et al. Nature 605 (2022) 7911, 659-662. Supported by the European Union´s Horizon Europe research and innovation programme under grant agreement No. 101079773 and 101073480, the Swiss government and the UKRI guarantee funds.**

MO1L2 -- Free-electron Light Interactions in Nanophotonics
Invited Oral C - Compact Light Sources
Charles Roques-Carmes (Stanford University, Stanford, California)
Nanophotonics has become over the past decades a paramount technology, enabling, among other things, the design of novel light sources, detectors, and devices controlling the polarization, spectral, and angular distribution of light. A landmark of nanophotonics is the design of nanostructured materials (metasurfaces, photonic crystals, nanoresonators, etc.) to tailor the interaction of light with matter, either by shaping light propagation at the nanoscale, or by controlling emission from atoms and molecules. In this talk, I will show how one can enhance and tailor radiation from high-energy particles, such as free electrons and x-rays with engineered nanophotonics structures. I will present a framework to model, tailor, enhance, and even optimize radiation from free electrons and other high-energy particles interacting with nanophotonic structures. I will then describe the building of a featured experimental setup to record spectrally-resolved light emission from free electrons interacting with nanophotonic structures. I will focus on the example of nanophotonic flatbands in photonic crystals, which can be used to enhance free-electron radiation and acceleration by orders of magnitude by overcoming phase-matching limitations. I will utilize our methods to demonstrate nanophotonic enhancement of coherent cathodoluminescence from free electrons and discuss new frontiers in the quantum optics of free electrons

MO1L3 -- Production and Characterization of Hard X-rays Beyond 25 keV
Invited Oral A - Linac-based Light Sources
Ye Chen, Tianyun Long (DESY, Hamburg)
Dedicated R&D programs, aimed for delivering ultra-hard X-rays beyond 25 keV for advanced user experiments, have been launched at the European XFEL. Characterization of the electron beam and the photon beam transport to the instrumentation have been carried out. Given the very first experiments, optimized SASE intensities of 0.8 mJ at 24.58 keV and 0.3 mJ at 30.24 keV, both lasing at the fundamentals, have been simultaneously demonstrated at two hard X-ray beamlines of the facility. These experiments were carried out using optimized low-emittance electron beams based on existing undulators with a 4 cm period and 16.4 GeV electron beam energy. It has also been shown, that the transport of 30 keV photon beams to the user experiments was made possible. The obtained results will be presented. Further discussions on the realization of ultra-hard X-rays using advanced techniques, as well as improved longitudinal beam diagnostics of the facility will be given in detail.

MO1L4 -- The Challenges and Benefits of Increased Application of Permanent Magnets to Future Light Sources
Invited Oral D - Key Technologies
Joel Chavanne (ESRF, Grenoble)
New storage ring based light sources have been recently constructed or are planned with the aim to reduce the horizontal emittance of the electron beam by about two orders of magnitude. It leads to a considerable increase of the brilliance of the photon beams produced at the sources installed around the storage ring. In many cases theses developments correspond to the upgrades of existing third generation facilities. The resulting accelerator lattice is a very compact arrangement of different types of magnets with demanding field properties. In addition, the need to provide energy saving solutions comes as an additional boundary condition. In this context, it looks obvious that Permanent Magnets (PMs) have been and are considered as an interesting alternative to conventional electromagnets. The ESRF Extremely Brilliant Source (EBS) in operation since beginning of 2020 is an example of the successful implantation of PM dipoles. For the majority of ongoing upgrades PMs corresponds to a large fraction of the storage ring magnets. They presently include dipole, quadrupole or combined dipole quadrupole structures. However, for PMs there is a number of specific difficulties to be addressed. These include for example the need to reach the absolute field strength for device which are not tuneable, the thermal stability or the long term stability. These different subjects will be discussed in the light of the EBS experience and the progresses made at several facilities with planned upgrades.

MO2L1 -- Future of the Multi-bend Achromat
Invited Oral B - Ring-based Light Sources
Pantaleo Raimondi (ESRF, Grenoble)
To be completed by author

MO2L2 -- Storage Ring-based Steady State Microbunching
Invited Oral B - Ring-based Light Sources
Alex Chao (TUB, Beijing)
A powerful light source is a much-in-demand tool in both the research and the industrial applications. Electrons are the easiest matter that readily emits photons, and as such using electron accelerators as light sources is a most natural approach to move forward. On the other hand, how to manipulate electrons in accelerators in increasingly sophisticated manners so as to produce the desired light most efficiently still requires innovations, as well as proof-of-principle tests of key physical principles. The Steady-State Microbunching (SSMB) mechanism has been proposed as one such approaches being under study. We present here a brief report on the basic ideas of the SSMB and its present research status.

MO2L3 -- Review of Harmonic Cavities in Fourth-generation Storage Rings
Invited Oral B - Ring-based Light Sources
Francis Jamshyd Cullinan, Ake Andersson, Pedro Tavares (MAX IV Laboratory, Lund)
Several third generation light-source storage rings have used harmonic cavities to lengthen the electron bunches. With the advent of the fourth generation however, they have become an almost universal feature as the small transverse electron beam sizes make long bunches essential for increasing Touschek lifetime and reducing emittance blow-up from intrabeam scattering. Multiple technological solutions exist for the implementation of harmonic cavities and which to use remains an open question for many facilities. This is therefore a very active area of study in which there is strong collaboration within the community. Avoiding coherent collective beam instabilities is of particular concern. In this talk, I will summarise the results obtained so far. I will also give an overview of the observations made at the MAX IV 3 GeV ring, the first fourth generation storage ring which was commissioned with normal-conducting passive harmonic cavities already installed. Finally, I will discuss potential future directions.

MO3B1 -- Obtaining Picosecond X-ray Pulses on 4th Generation Synchrotron Light Sources
Contributed Oral B - Ring-based Light Sources
Xiaobiao Huang, James A. Safranek (SLAC, Menlo Park, California), Alexander Zholents (ANL, Lemont, Illinois)
Through the 2-frequency crab cavity scheme, fourth generation storage ring light sources offer a unique opportunity to produce intense short X-ray pulses that are ideal for time-resolved user experiments. The short pulses and the high brightness photon beams are simultaneously available at all beamlines in a fully compatible operation mode. Owing to the small momentum compaction factor characteristic in fourth generation storage rings, the vertical emittance contribution due to the coupling between the longitudinal and transverse planes by the crab cavities is greatly reduced, which allows reaching short pulse duration with little constraint on the betatron tunes. We propose to use half-integer aharmonic cavity to simultaneously produce bunch lengthening and shortening in the bunch train to facilitate compatible operation of the normal and short-pulse beams. A concrete case study based on the Advanced Photon Source Upgrade (APS-U) lattice is used to demonstrate the system configuration, requirements, and beam performances.

MO3B2 -- Beam Dynamics using Harmonic Cavities with High Current per Bunch
Contributed Oral B - Ring-based Light Sources
Alexis Gamelin, Vadim Gubaidulin, Alexandre Loulergue, Patrick Marchand, Laurent Stanislas Nadolski, Ryutaro Nagaoka (SOLEIL, Gif-sur-Yvette), Naoto Yamamoto (KEK, Ibaraki)
In 4th generation synchrotron light sources, harmonic cavities (HCs) are critical components needed to achieve the required performance. They provide longer bunches, which helps to reduce statistical effects (intra-beam scattering and Touschek effect). In "timing" modes, where the bunch spacing is larger than in conventional modes and the number of particles per bunch is higher, this need is even greater. In this article, we present the beam dynamics in the high current per bunch regime and how it interacts with the single bunch collective effects. In particular, a dipole-quadrupole instability is observed above the microwave threshold and a coupling between the dipole and cavity modes is shown to limit bunch lengthening at low current. The effective gain from the use of HCs in terms of lifetime, emittance, and energy spread is also discussed.

MO3B3 -- Bunch-lengthening RF System Using Active Normal-conducting Cavities
Contributed Oral B - Ring-based Light Sources
Naoto Yamamoto, Daichi Naito, Shogo Sakanaka, Takaaki Yamaguchi (KEK, Ibaraki), Alexis Gamelin, Patrick Marchand, Ryutaro Nagaoka (SOLEIL, Gif-sur-Yvette)
Bunch lengthening using a double RF system (fundamental + harmonic cavities) is essential in preserving the extremely low emittance in fourth and future generation synchrotron light rings. Recent studies have revealed that, in many cases, unstable beam motions, as so-called "mode-0" and "periodic transient beam loading" instabilities, prevent from reaching the optimum bunch lengthening condition with low and high beam current, respectively, even in symmetric filling patterns. While reducing the R/Q is beneficial for the latter, it will worsen the former. To achieve an efficient bunch lengthening system, we proposed a promising solution based on a powered TM020-type harmonic cavity with RF feedbacks (RF-FBs)*, as reported at FLS2018. Based on this concept, we are developing both fundamental and harmonic cavities using the TM020 resonant mode, a kicker cavity having a bandwidth >5MHz***, bunch-phase monitor (BPhM) and RF-FBs. In this presentation, we describe our overall bunch lengthening system including cavity and BPhM designs. We also present particle tracking simulation results demonstrating that the bunch lengthening limitations can be alleviated by means of direct RF-FBs****. * N. Yamamoto et al., PRAB 21, 012001, 2018. ** T. Yamaguchi et al., accepted in NIM A. *** D. Naito et al, IPAC2021, MOPSB331, 2021. **** N. Yamamoto et al., IPAC23, WEPL161, 2023.**

MO3B4 -- Generating High Repetition Rate X-ray Attosecond Pulses in SAPS
Contributed Oral B - Ring-based Light Sources
Weihang Liu, Xingguang Liu, Yu Zhao (IHEP CSNS, Guangdong Province), Yi Jiao, Xiao Li, Sheng Wang (IHEP, Beijing)
Attosecond, which refers to 10^-18 seconds, is the timescale of electron motion within an atom. Accurate observation of electron motion helps deepen the understanding of microscopic quantum processes such as charge transfer in molecules, wave packet dynamics, and charge transfer in organic photovoltaic materials. To meet the needs of relevant research, the South Advanced Photon Source (SAPS), currently in the design phase, is considering the construction of an attosecond beamline. This paper presents relevant research on achieving high-repetition-rate coherent attosecond pulses on the fourth-generation storage ring at SAPS. Realizing attosecond pulses in a storage ring requires femtosecond to sub-femtosecond-level longitudinal modulation of the beam, and the modulation scheme needs to consider multiple factors to avoid a significant impact on other users. The study shows that with high-power, few-cycle lasers, and advanced beam modulation techniques, the photon flux of attosecond pulses can be significantly enhanced with a minimal impact on the brightness of synchrotron radiation. Adopting high-repetition-rate lasers and precise time delay control, the repetition rate of attosecond pulses at SAPS can reach the megahertz level. Currently, the design wavelength range for attosecond pulses covers the water window (2.3-4.4 nm), which is "transparent" to water but strongly absorbed by elements constituting living organisms. This wavelength range has significant application value in fields such as biology and chemistry.

MO3A1 -- Progress on SHINE Machine
Invited Oral A - Linac-based Light Sources
Dong Wang (SINAP, Shanghai)
SHINE (Shanghai HIgh repititioN rate hard x-ray free electron laser and Extreme light) is a superconducting linac-based free electron laser facility. It consists of a cw VHF electron gun, 75 8-cavity cryomodules, fast beam distributions, 3 FEL undulator lines as well as the photon beam lines/end-stations. In this talk we will give an introduction to the latest progress of the machine part of this project. Supported by the project funding (including the R&D and construction money that come up at same time) extensive prototyping has been conducted on major components like high rep-rate gun, cavities/cryomodules for cw linac, large cryogenic plant, fast kickers and undulators, among others. The cw beam test facility was set up to operate at cw mode for electron gun and cryomocules.

MO3A2 -- Status and Perspectives for the Swiss Free-Electron Laser (SwissFEL)
Invited Oral A - Linac-based Light Sources
Thomas Schietinger (PSI, Villigen PSI)
We summarize the status of SwissFEL, the X-ray free-electron laser at the Paul Scherrer Institute. Apart from some key operational performance figures the presentation covers the state of the experimental stations and their capabilities, gives a few scientific highlights and an overview of the use of special modes beyond SASE at our facility. Furthermore we report on progress of our seeding upgrade program on the soft X-ray line. Lastly we mention our long-term upgrade plans for a third undulator beamline in the tender and hard X-ray regime.

MO3A3 -- Status of the LCLS-II Superconducting Linac
Invited Oral A - Linac-based Light Sources
Daniel Gonnella (SLAC, Menlo Park, California)
The LCLS-II project installed a new superconducting linac into the existing SLAC tunnel to enable a high repetition rate x-ray FEL. Over the last 1.5 years, the commissioning of the new linac has taken place and been overall very successful. The status of the commissioning and experience from early operations of the new superconducting linac will be presented. US DoE

MO3A4 -- European XFEL Status Overview
Invited Oral A - Linac-based Light Sources
Matthias Scholz (DESY, Hamburg)
Since its launch in 2017, European XFEL has been operating reliably and stably, delivering photons to user experiments. The range of services, the overall performance and the provision of special operating modes have been continuously improved. Its superconducting accelerator delivers up to 27000 electron bunches per second in a 10 Hz pulsed mode to 3 undulator beamlines, which in turn can deliver photons to one of two associated instruments. The high electron beam energy of up to 17.5 GeV predestines this facility for high photon energies up to 30 keV. In addition to the default delivery modes, the user community is increasingly requesting other modes of operation such as self-seeding, very short pulses, two colours or customised bunch distributions in the individual pulse trains. We will present a brief summary of the current status of the different operating modes and give an outlook into the future.

MO3A5 -- FLASH: Status and Upgrade
Invited Oral A - Linac-based Light Sources
Siegfried Schreiber, Mathias Vogt, Johann Zemella (DESY, Hamburg)
FLASH, the Soft X-Ray and Extreme-UV Free Electron Laser at DESY, is undergoing a substantial upgrade and refurbishment project, called FLASH2020+. The project will finally enable external seeded and SASE FEL operation for a wavelength range down to 4 nm with the EEHG method. This is achieved in two long shutdowns from November 2021 to August 2022 and from June 2024 to August 2025. Key ingredient of the upgrade were installation of a laser heater, replacing two early TTF-type L-band SRF accelerating modules by modern, high-gradient XFEL-type modules, redesign of the 2nd bunch compressor, and complete redesign of the FLASH1 beam line for HGHG/EEHG seeding. This talk will report on the project and the status of FLASH after the first shutdown with emphasis on beam dynamics aspects.

MO3A6 -- Recent status of PAL-XFEL
Invited Oral A - Linac-based Light Sources
MyungHoon Cho, Intae Eom, Hoon Heo, Heung-Sik Kang, Chang-Ki Min, Inhyuk Nam, Jaehyun Park, Sang Han Park, Chi Hyun Shim, Haeryong Yang (PAL, Pohang)
Since opened to users in 2017, significant progress of PAL-XFEL has been made in operations including increasing the FEL pulse energy and the FEL photon energy, generating stable and high power self-seeding FELs, and two-color FELs. In the beamline, new instruments or endstations have been added such as the femtosecond X-ray scattering (FXS) with 800 nm laser pulse, the X-ray absorption spectroscopy (SAX), the serial femtosecond crystallography (SFX) with operation with developed noble sample-delivery-systems, Fourier-Transform Holography (FTH), and so on. Overall, beamline operation has enabled excellent scientific results through efficient user experiments. This talk will introduce recent status of PAL-XFEL and show representative experiment results shortly.

MO3A7 -- Present Status of SACLA and Plans for Future Upgrades
Invited Oral A - Linac-based Light Sources
Takahiro Inagaki, Toru Hara, Eito Iwai, Chikara Kondo, Hirokazu Maesaka, Hitoshi Tanaka (RIKEN SPring-8 Center, Hyogo)
SACLA has two XFEL beamlines, BL3 and BL2, which are driven by an 8-GeV normal-conducting C-band high-gradient accelerator and provide SASE from 4 keV to 20 keV, and an EUV-FEL beamline BL1, which is driven by an 800-MeV accelerator and provides SASE from 40 eV to 150 eV. To perform the parallel operation of BL3 and BL2 and the top-up injection into the SPring-8 storage ring, the electron gun, accelerating RF, focusing magnets, and switchyard magnets are synchronously controlled for each 60 Hz pulse. In recent years, experiments using special FELs such as reflection-type self-seeded FELs, two-color, double-pulsed FELs, ultra-short pulsed FELs and nano-focusing optics have been conducted at XFEL beamlines. In order to supply XFELs tailored to various experimental conditions, an automatic tuning system of the accelerator using machine learning has been established and is used for daily tuning. In the future, we plan to improve and precisely control the characteristics of the FEL, such as intensity, pulse duration, spectrum, photon energy, and pulse repetition rate. To achieve these goals, we are working on 1) refinement of accelerator models using electron beam monitors and machine learning, 2) development of the electron gun to increase the beam brightness, 3) development of the efficient RF acceleration. For the purpose of 3, we have started to study a new normal-conducting accelerator design, with the goal of increasing the pulse repetition rate while maintaining XFEL performance and power consumption, to be consistent with ¿Green Facility¿ declaration. In this presentation, we introduce the status and future plans for upgrading SACLA.

MO3A8 -- FERMI FEL Upgrade Plans, an Overview
Invited Oral A - Linac-based Light Sources
Simone Di Mitri, Enrico Allaria, Laura Badano, Paolo Cinquegrana, Ivan Cudin, Miltcho B. Danailov, Gerardo D'Auria, Paolo Delgiusto, Alexander Demidovich, David Garzella, Claudio Masciovecchio, Giuseppe Penco, Primoz Rebernik Ribic, Nuaman Shafqat, Paolo Sigalotti, Carlo Spezzani, Luca Sturari, Mauro Trovo (Elettra-Sincrotrone Trieste S.C.p.A., Basovizza), Luca Giannessi (Elettra-Sincrotrone Trieste S.C.p.A., Basovizza; LNF-INFN, Frascati), Giovanni De Ninno (Elettra-Sincrotrone Trieste S.C.p.A., Basovizza; University of Nova Gorica, Nova Gorica)
Short and long term upgrade plans of the FERMI free-electron laser facility at Elettra Sincrotrone Trieste, Italy, will be reported. They include the ongoing linear accelerator energy upgrade and the conversion of the first undulator line to echo-enabled harmonic generation. The upgrade of the second undulator line to a two stage echo-based fresh-bunch scheme is also under study.

MO3A9 -- Comissioning Progress and Advanced FEL Experiments at the SXFEL Facility
Invited Oral A - Linac-based Light Sources
Chao Feng, Bo Liu, Zhen Wang, Zhentang Zhao (SARI-CAS, Pudong, Shanghai)
The Shanghai soft X-ray Free-Electron Laser facility (SXFEL) is the first X-ray FEL facility in China. The construction of the SXFEL facility was finished in 2022. The output photon energy of the SXFEL can cover the whole water window range. Except for the self-amplified spontaneous emission, various seeding techniques have also been adopted for improving the performances of the SXFEL. Here we presents an overview of the SXFEL facility, including the layout and design, construction status, commissioning progress and future plans on advanced FEL experiments.

MO4B1 -- A Review on Injection Schemes
Invited Oral B - Ring-based Light Sources
Masamitsu Aiba (PSI, Villigen PSI)
Top-up injection into the storage ring is one of the main challenges of fourth generation light sources because of the limited machine aperture. Various new injection schemes have been studied over the past years, and are to be applied to newly constructed storage rings. There may not be single scheme that can be implemented into any storage ring due to the variety of specific needs and constraints. This talk presents an overview of the developments that may eventually help the storage ring designer to find the optimum scheme. The future trend of the top-up injection is also discussed.

MO4B2 -- The Plasma Injector for PETRA IV: Conceptual Design Report
Contributed Oral B - Ring-based Light Sources
Alberto Martinez de la Ossa, Ilya Agapov, Sergey A. Antipov, Reinhard Brinkmann, Ángel Ferran Pousa, Manuel Kirchen, Wim Leemans, Andreas R. Maier, Jens Osterhoff, Robert Shalloo, Maxence Thévenet, Paul Viktor Winkler (DESY, Hamburg), Soeren Jalas (University of Hamburg, Hamburg)
We present the conceptual design of an alternative injector system based on laser-plasma accelerator technology, to deliver high-quality electron bunches to PETRA IV - the future 4th generation synchrotron light source at DESY. The design consists of a laser-plasma accelerator to produce electron bunches at 6 GeV with state-of-the-art energy spread and stability, and a X-band energy compressor beamline to further reduce the overall beam energy deviations and maximize the charge injection throughput into the PETRA IV storage ring. Driven by the Petawatt upgrade of DESY's new flagship laser KALDERA, the plasma injector system can be used to top up the PETRA IV storage ring, significantly lowering the load on the conventional injector chain. Ultimately, upon further development of high-efficiency, high-power laser drivers that operate at high repetition rates, the plasma injector could potentially replace the conventional system in the future and dramatically reduce the spatial footprint and energetic cost of the whole injector complex.

MO4B3 -- Development of a Pulsed Injection Stripline for Diamond-II
Contributed Oral B - Ring-based Light Sources
Richard Fielder, Anusorn Lueangaramwong, Alun Morgan (DLS, Oxfordshire)
Diamond-II will use a single bunch aperture sharing injection scheme. This applies a strong kick to both the injected and the targeted stored bunch with a very short duration (ideally <3 ns, if disturbance to the adjacent bunches is to be avoided). We have developed a design for the stripline kickers that can meet these requirements while minimising internal reflections and beam impedance. We show an analysis of the electric and magnetic fields produced by the stripline and simulations of the effects on injected and stored beam, and analysis of the wakefields and impedance of the structure.

MO4C1 -- Ultra-bright Coherent Undulator Radiation Driven by Dielectric Laser Accelerator
Contributed Oral C - Compact Light Sources
Yen-Chieh Huang (NTHU, Hsinchu)
A dielectric laser accelerator, operating at optical frequencies and GHz pulse rate, is expected to produce attosecond electron bunches with a moderate beam current at high energy. For relativistic electrons, the attosecond bunch has a spatial length of a few nanometers, which is well suited for generating high-brightness superradiance in the VUV, EUV, and X-ray spectra. Our study shows that the brilliance of coherent undulator radiation driven by a short-bunch beam with 1~10 fC bunch charge from a dielectric laser accelerator is comparable to or higher than that of a synchrotron in the 0.1~3 keV photon energy range, even though the beam power of the dielectric laser accelerator is about a million times lower than that of a synchrotron. When the brilliance under comparison is normalized to the electron beam power, the proposed coherent undulator radiation source becomes the brightest source on earth across the whole VUV, EUV, and soft x-ray spectrum. **National Science and Technology Council under Contract MOST 111-2221-E-007-001**

MO4C2 -- Development of a Compact Light Source Using a Two-beam-acceleration Technique
Contributed Oral C - Compact Light Sources
Philippe Regis-Guy Piot (Northern Illinois University, DeKalb, Illinois)
The recent demonstration of sub-GV/m accelerating fields at X-band frequencies* offers an alternative pathway to designing a compact light source. The high fields were enabled by powering the accelerating structures using short (<10 ns) X-band RF pulses produced via a two-beam-accelerator (TBA) scheme. In this contribution, we present a conceptual design to scale the concept to a ~0.5 GeV accelerator. We present the optimization of the photoinjector and preliminary beam-dynamics modeling of the accelerator. Finally, we will discuss ongoing and planned experiments toward developing an integrated proof-of-principle experiment at Argonne National Laboratory combining the 0.5 GeV linac with a free-electron laser. * W.H. Tan, et al. DOI: 10.1103/PhysRevAccelBeams.25.083402 (2022). **This work is supported by the U.S. DOE, under award No. DE-AC02-06CH11357 with ANL. This work is partially supported by Laboratory Directed Research and Development (LDRD) funding at ANL.**

MO4C3 -- Generation of GeV Photon Energy at European X-Ray Free Electron Laser
Contributed Oral C - Compact Light Sources
Illya Drebot (INFN-Milano, Milano), Frank Zimmermann (CERN, Meyrin), Najmeh Sadat Mirian (DESY, Hamburg)
Intense high-energy photon beams (>1 GeV) with multiple outstanding characteristics, such as energy tunability, good directivity, quasi-monochromaticity, etc., offer numerous novel applications in nuclear physics, high-energy physics, and non-destructive material analysis. Potential applications of the high photon energy include protein crystallography, along with searches for Dark Photons and Axion-like Particles. European X-ray free electron laser based on superconductor linear accelerator is able to generate short high current electron bunches at megahertz intra-train repetition rate in the range of 17.5 GeV energy. We employ its capabilities and show the potential of this facility in the generation of GeV photon energy. We employ laser Compton scattering at the spreader of the south branch FEL line and simulate the generation of GeV photon energy

TU1C1 -- An Efficient Optimisation of a Burst Mode-Operated Fabry-Perot Cavity for Inverse Compton Scattering Sources
Contributed Oral C - Compact Light Sources
Vlad Musat, Eduardo Granados, Andrea Latina (CERN, Meyrin), Eric Cormier (CELIA, Talence), Giorgio Santarelli (ILE, Palaiseau Cedex)
The burst mode operation of a Fabry-Perot cavity (FPC) allows for the generation of a high intensity X-ray beam in inverse Compton scattering (ICS) sources based on linear accelerators. The geometry and injection parameters of the FPC can be optimised to maximise the scattered photon flux. A novel optimisation method is presented, with significant improvements in processing speed and accuracy. The dimensions and mirror requirements of the FPC can be derived from electron beam parameters, along with the maximum achievable effective energy in the cavity. The simplex algorithm was used to derive the geometrical parameters of the FPC with an orders of magnitude increase in computation speed with respect to the nominal Monte Carlo-based approach. The burst mode parameters of the FPC were obtained by numerically maximising the effective energy of the laser pulse in the FPC. The impact of optical losses on the FPC parameters is addressed, including thermal effects on the mirrors. Preliminary parameters of an ICS source implementing this novel optimisation are presented. The source would be able to achieve high performance photon beams intended for high energy applications.

TU1C2 -- Evolution of the Inverse Compton Scattering X-ray Source of the ELSA Accelerator
Contributed Oral C - Compact Light Sources
Abel Pires (CEA, Arpajon), Vincent Le Flanchec (CEA/DAM/DIF, Arpajon), Nicolas Delerue (Université Paris-Saclay, CNRS/IN2P3, IJCLab, Orsay)
The Inverse Compton Scattering (ICS) X-ray of ELSA accelerator at CEA-DAM, presents an efficient approach for generating X-rays with a compact linac. The source consists of a 30 MeV, 15 ps rms, up to 3 nC electron beam; and a table-top Nd:YAG laser. X-rays are produced in the 10-80 keV range, higher X-ray energies achieved with frequency doubling of the laser. The yield is increased by a factor of 8 thanks to an optical mirror system developed at CEA, folding the laser beam path and accumulating successive laser pulses. We present a new version of the device, with improvement of mechanical constraints management, adjunction of motorized mirrors, and a new imaging system. A Chirped Pulse Amplification (CPA) system was also designed, enabling higher amplification levels without exceeding laser damage threshold. The uniqueness of this CPA system lies in its use of a short wavelength bandwidth, ±250 pm after Self-Phase Modulation (SPM) broadening, and a line density of 1850 lines/mm for the gratings of the compressor. The pulse is stretched with a chirped fiber Bragg grating (CFBG) before amplification in Nd:YAG amplifiers, and compressed by a double pass grating compressor.

TU1C3 -- A Compton Light Source Based on Counter Propagating Direct Laser Acceleration Channels
Contributed Oral C - Compact Light Sources
Talia Meir, Itamar Cohen, Lior Perelmutter, Ishay Pomerantz (Tel Aviv University, Tel-Aviv), Tamir Cohen (Soreq NRC, Yavne), Alexey Arefiev, Kavin Tangtartharakul (UCSD, La Jolla, California)
For the past two decades, intense lasers have supported new schemes for generating high-energy particle beams in university-scale laboratories. With the direct laser acceleration (DLA) method, the leading part of the laser pulse ionizes the target material and forms a positively charged ion plasma channel into which electrons are injected and accelerated. A striking feature of DLA is the extremely high conversion efficiency from laser energy to MeV electrons, with reported values as high as 23%, which makes this mechanism ideal for generating large numbers of photo-nuclear reactions. DLA is well understood and reproduced in numeric simulations. However, the electron energies obtained with the highest laser intensities available nowadays, fail to meet numerical predictions. In an experimental campaign, followed by a numerical investigation, we revealed that at these higher laser intensities, the leading edge of the laser pulse may deplete the target material of its ionization electrons prematurely. We demonstrated that for efficient DLA to prevail, a target material of sufficiently high atomic number is required to maintain the injection of ionization electrons at the peak intensity of the pulse when the DLA channel is already formed. I will present a numerical study on employing this new understanding for realizing a high brightness Compton light source in two counter-propagating DLA channels. Our 3D particle-in-cell results indicate small cone-angle photon emission in the multi 10s of keV spectral range, with few-fs duration and micron-scale source size.

TU1C4 -- The CXFEL Project at Arizona State University
Contributed Oral C - Compact Light Sources
William Graves (Arizona State University, Tempe)
The CXFEL Project encompasses the Compact X-ray Light Source (CXLS) that is now commissioning in the hard x-ray energy range 4-20 keV, and the Compact X-ray Free-Electron Laser (CXFEL) designed to lase in the soft x-ray range 300 ¿ 2500 eV. CXFEL has recently completed a 3-year design phase and just received NSF funding for construction over the next 5 years. These instruments are housed in separate purpose-built laboratories and rely on inverse Compton scattering of bright electron beams on powerful lasers to produce femtosecond pulses of x-rays from very compact linacs approximately 1 m in length. Both instruments use recently developed X-band distributed-coupling, room-temperature, standing-wave linacs and photoinjectors operating at 1 kHz repetition rates and 9300 MHz RF frequency. They rely on recently developed Yb-based lasers operating at high peak and average power to produce fs pulses of 1030 nm light at 1 kHz repetition rate with pulse energy up to 400 mJ. We present the current commissioning performance and status of CXLS. We also review the design and initial construction activities of the large collaborative effort to develop the fully coherent CXFEL. **This work supported by National Science Foundation awards 2153503, 1935994, and 1632780.**

TU1B1 -- A Highly Competitive Non-Standard Lattice for a 4th Generation Light Source With Metrology and Timing Capabilities
Contributed Oral B - Ring-based Light Sources
Paul Goslawski, Michael Abo-Bakr, Michael Arlandoo, Johan Bengtsson, Karsten Holldack, Andreas Jankowiak, Bettina Christa Kuske, Jens Viefhaus (HZB, Berlin)
The PTB, Germany's national metrology institute, has relied on synchrotron radiation for metrology purposes for over 40 years and the most prominent customers are lithography systems from ASML/ZEIS. HZB is now working on a concept for a BESSY II successor, based on a 4th generation light source with an emittance of 100 pmrad @ 2.5 GeV. It is essential, that this new facility continues to serve the PTB for metrology purposes. This sets clear boundary conditions for the lattice design, in particular, the need for homogeneous bends as metrological radiation sources. Different Higher-Order-Multi-Bend-Achromat lattices have been developed, based on combined function gradient bends and homogeneous bends in a systematic lattice design approach. All lattices are linearly equivalent with the same emittance and maximum field strength. However, they differ significantly in their non-linear behavior. Based on this analysis, the choice of the BESSY III lattice type is motivated. A special focus is set also on TRIBs (Transverse Resonance Island Buckets) to operate with two orbits as a bunch separation scheme in MBAs, for different repetition rates or for the separation of short and long bunches.

TU1B2 -- Low-alpha Storage Ring Design for Steady-State Microbunching to Generate EUV Radiation
Contributed Oral B - Ring-based Light Sources
Zhilong Pan, Xiujie Deng, Wenhui Huang, Chuanxiang Tang (TUB, Beijing)
A new concept is proposed for minimizing the longitudinal emittance of a low momentum compaction factor (low-alpha) storage ring which has the capability to stably store sub-femtosecond electron bunches for the first time. This storage ring is designed for Steady-State microbunching (SSMB) to generate kW level average power EUV radiation. The proposed design approach can be applied to any quasi-isochronous storage rings to yield very high radiation power due to longitudinal coherence of the radiation. We obtain an optimal lattice design by minimizing global and local momentum compaction factors simultaneously and the result of single-particle tracking shows that the electron beam with equilibrium rms bunch length of about 40 nm can be stored in this ring. We also clarify in this type ring, the horizontal emittance will be fixed when beam energy, dipole bending angle and cell tune is fixed. In this type ring, the calculation for IBS effect will be different with traditional rings, we point out where the difference is and give a more convenient calculation for it.

TU1B3 -- Nonlinear Optics From Hybrid Dispersive Orbits
Contributed Oral B - Ring-based Light Sources
Yongjun Li, Robert Rainer, Victor Smaluk, Derong Xu (BNL, Upton, New York)
In this paper we present an expansion of the technique of characterizing nonlinear optics from off-energy orbits (NOECO) to cover harmonic sextupoles in storage rings. The existing NOECO technique has been successfully used to correct the chromatic sextupole errors on the MAX-IV machine, however, it did not account for harmonic sextupoles, which are widely used on many other machines. Through generating vertical dispersion with chromatic skew quadrupoles, a measurable dependence of nonlinear optics on harmonic sextupoles can be observed from hybrid horizontal and vertical dispersive orbits. Proof of concept of our expanded technique was accomplished by simulations and beam measurements on the National Synchrotron Light Source II (NSLS-II) storage ring. **Supported by US DoE under Contract No. DE-SC0012704**

TU1B4 -- Minimizing the Fluctuation of Resonance Driving Terms for Analyzing and Optimizing the Storage Ring Dynamic Aperture
Contributed Oral B - Ring-based Light Sources
Zhenghe Bai, Bingfeng Wei (USTC/NSRL, Hefei, Anhui), Alexandre Loulergue, Laurent Stanislas Nadolski, Ryutaro Nagaoka (SOLEIL, Gif-sur-Yvette)
Minimization of resonance driving terms (RDTs) of nonlinear elements such as sextupoles and octupoles is an essential condition for enlarging the dynamic aperture (DA) of a storage ring. In this paper, the correlation between minimizing the fluctuation of RDTs along the ring and enlarging the DA is first investigated. It is found that minimizing the RDT fluctuations is more effective than minimizing the commonly used one-turn RDTs in enlarging the DA. Furthermore, reducing low-order RDT fluctuations is beneficial for reducing both higher-order one-turn RDTs and higher-order RDT fluctuations. Then using genetic algorithms, the DA is optimized based on numerically minimizing RDT fluctuations. It is found that large DA solutions can be obtained and the optimization can be performed very fast as compared to the conventional tracking-based approach.

TU2A1 -- Coherent Free-electron Laser Pulses: The User Perspective
Invited Oral A - Linac-based Light Sources
Giovanni De Ninno (Elettra-Sincrotrone Trieste S.C.p.A., Basovizza)
Are fully-coherent pulses the Holy Grail for experiments, which aim at taking full advantage of the properties of a free-electron laser (FEL)? What are the strategies to generate and diagnose them at seeded FEL facilities? What are the requirements for experiments based on pulse shaping and coherent control? How goes it for quantum coherence and the possibility to generate FEL pulses with sub-Poissonian statistics? We will talk about all this and more.

TU2A2 -- Single Longitudinal Mode Generation in Slippage-dominated, Tapered-undulator SASE Soft X-ray FELs
Contributed Oral A - Linac-based Light Sources
Dinh Cong Nguyen, Bruce Dunham, William Lou, Christopher Mayes, Gennady Stupakov (xLight, Palo Alto)
SASE FELs operating in the soft X-ray region exhibit multiple temporal and spectral spikes with an overall spectral bandwidth of about 1.5 times the FEL rho parameter. While many ideas have been proposed to achieve fully coherent X-ray FELs, only seeded FEL, either harmonic seeding* or SASE self-seeding, has been experimentally demonstrated to narrow the output spectra of soft X-ray FELs. In this paper, we study a different method that relies on the Slippage-dominated Tapered Undulator (STU) SASE concept to produce a single longitudinal mode in a 6.7nm soft X-ray FEL driven by ~10-fs electron bunches. Although based on a similar idea of slippage enhanced SASE***, our method does not require boosting the FEL slippage through the use of chicanes. Rather, the new method relies on enhanced slippage in a tapered undulator such that only one SASE coherence length is amplified, thus producing a single spectral mode. We present numerical simulation results that demonstrate single-longitudinal-mode generation in a representative soft X-ray SASE FEL. * E. Alaria et al., Nat Photon 7 (2013) 913-918 ** D. Ratner et al., PRL 114 (2015) 050801 *** B.W.J. McNeil et al., PRL 110 (2013) 134802, and D. Xiang et al., Phys. Rev. STAB 16 (2013) 010703**

TU2A3 -- Opportunities and Challenges of the Hard X-ray Self-seeding System at the European XFEL
Contributed Oral A - Linac-based Light Sources
Shan Liu, Philipp Dijkstal, Christian Grech, Marc Walter Guetg, Vitali Kocharyan, Tianyun Long, Najmeh Sadat Mirian, Weilun Qin (DESY, Hamburg), Gianluca Geloni, Naresh Gandhi Kujala, Christoph Lechner, Svitozar Serkez, Jiawei Yan (EuXFEL, Schenefeld)
The Hard X-ray Self-seeding system (HXRSS) at the European XFEL provides users with longitudinally coherent X-ray FEL pulses with narrow bandwidth and high spectral density. With this setup we have achieved a maximum spectral density of about 1 mJ/eV at 9 keV. Combined with the MHz repetition rate, it opens up exciting new opportunities in a wide range of scientific fields. However, the increasing user demand and expectations also poses challenges in machine tuning and operation parameter ranges. We will summarize the HXRSS performance we have achieved and the user delivery experiences in the last two years.

TU2A4 -- A Low-loss 14 m Hard X-ray Bragg-reflecting Cavity, Experiments and Analysis
Contributed Oral A - Linac-based Light Sources
Rachel Anne Margraf (Stanford University, Stanford, California), Taito Osaka, Kenji Tamasaku (RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo), Aliaksei Halavanau, Jacek Krzywinski, Kenan Li, James MacArthur, Gabriel Marcus, Anne Sakdinawat, Takahiro Sato, Yanwen Sun, Diling Zhu (SLAC, Menlo Park, California), Zhirong Huang, River Robles (SLAC, Menlo Park, California; Stanford University, Stanford, California)
Bragg-reflecting cavities on the 10 s or 100 s of meter scale are a core component of proposed Cavity-Based X-ray Free-Electron Lasers (CBXFELs). While CBXFELs promise improved longitudinal coherence and spectral brightness over single-pass self-amplification of spontaneous radiation (SASE) FELs, construction and alignment of large Bragg-reflecting cavities can be difficult technical challenge. Our collaboration recently demonstrated stable operation of a low-loss 14 m 9.831 keV X-ray cavity of four Bragg-reflecting diamond mirrors*, a significant step towards a CBXFEL-scale cavity. We in-coupled X-rays from the Linac Coherent Light Source (LCLS) into our cavity via a transmission grating, then measured round-trip efficiencies approaching 88%, or >96% when neglecting losses on in-coupling and focusing optics. Additionally, we characterized transverse oscillations in the cavity, demonstrating the effectiveness of our cavity focusing. We will discuss these results, and additional new analysis, including the impact of angular pointing jitter from the input X-ray beam, and consider implications for future CBXFEL projects. * R. Margraf et al., `Low-loss Stable Storage of X-ray Free Electron Laser Pulses in a 14 m Rectangular Bragg Cavity', In Review, preprint, 2023. doi: 10.21203/rs.3.rs-2465216/v1. **This work was supported by the Department of Energy, Laboratory Directed Research and Development program at SLAC National Accelerator Laboratory, under contract DE-AC02-76SF00515.**

TU3D1 -- Developments in SRF Technology for Light Source Applications
Contributed Oral D - Key Technologies
Daniel Gonnella (SLAC, Menlo Park, California)
Significant developments in SRF technology have occurred in the last 5 years motivated by interest in light sources and future colliders. Specifically, LCLS-II and LCLS-II-HE at SLAC have driven high gradient and high Q0 R&D in SRF across the field. New understandings in doping protocols, cavity processing, and clean room procedures have enabled cryomodules to be constructed that reach previously unattainable performance. Further developments in novel cavity processing methods such as mid-temperature baking and alternate materials such as niobium-3-tin enable a new range of operations for future accelerators. Early operations from LCLS-II and EU-XFEL show that SRF technology is already being used to produce world class light source facilities. Here we present a review of the latest developments in SRF technology both in the R&D phase and in newly installed accelerators and their impact on future light source development and performance. **US DoE**

TU3D2 -- Highly Reliable RF Power Sources for Improvement of the Accelerator Availability
Contributed Oral D - Key Technologies
Marcus Lau (TRUMPF Huettinger GmbH, Freiburg)
The trend in exchanging established tube technolo-gy by solid-state based RF power amplifier for particle accelerators around the world is ongoing. Since the first installations* of such amplifier systems several concepts were developed and installed. As the RF sources are key for the accelerator availability their reliability plays a crucial role. This needs to be considered during the design phase of the overall amplifier system architecture in a new way compared to the tube technology. For tubes it is straight forward as usually one tube powers one or more cavities due to the high power provided. But this also bears the risk of a single point of failure despite the need of high voltage power supplies, continuous degradation and their availability, just to mention the most important aspects. For solid-state power amplifier many transistor units need to be combined for delivering the needed RF power to each cavity. The combining concepts and the overall system architecture finally determine the possibility of de-rating options and redundancy of transistors for compensation of failed units within the system, and thus the overall availability. Our concept for com-bining several transistors in amplifier units*** and assembling these units into racks recently has proven an outstanding performance. For 8,419 hours of opera-tional time, we had a total of 13.9 hours for not being available due to incidents. This results in a total system availability of ~99.83% for more than 980 operational amplifier units at customer site. Here, we want to demonstrate our system architec-ture and the design aspects we considered for reaching this high performance. We think that this is a crucial contribution for bringing this technology one step further to maturity. * R. Lopes et al., CWRF08, CERN Geneva, March 2008 ** E. Montesinos, I.FAST Accelerator-Industry Workshop, CERN, May, 2022 *** M. Lau et al., HIAT Conference, Darmstadt, Germany, 2022**

TU3D3 -- Application of Cryo-copper Accelerating Structures Towards Future Light Sources
Contributed Oral D - Key Technologies
Emilio Alessandro Nanni (SLAC, Menlo Park, California)
Cryogenic operation of copper accelerating structures results in increase accelerating gradients and reduced rf power requirements. The combination of cryogenic operation with distributed coupling accelerator topologies further enhances the flexibility of the designer in optimizing the performance of the accelerator. The combination of these advances creates the possibility of generating high-brightness beams in compact footprints (up to 250 MeV/m accelerating gradients). To date this technology has been explored primarily in the context of a future high energy physics facility. In this talk we will present the study of a new concept for a high gradient, high power accelerator with beam characteristics suitable to study the Higgs boson, the Cool Copper Collider (C3). We will present the latest demonstrated performance of prototype accelerators and highlight the future development path for C3 accelerator technology. In particular, we will focus on benefits to future light source concepts to decrease machine size, increase repetition rate, enable multi-bunch operation and preserve high brightness beams. Possible use cases for future light sources will be presented.

TU3D4 -- Compact HOM-damped RF Cavity for a Next Generation Light Source
Contributed Oral D - Key Technologies
Hiroyasu Ego (KEK, Ibaraki), Takashi Ohshima, Takato Tomai, Hiroshi Yamaguchi (JASRI, Hyogo), Takao Asaka (QST, Sendai, Miyagi), Nobuyuki Nishimori (QST, Tokai), Takahiro Inagaki, Hitoshi Tanaka (RIKEN SPring-8 Center, Hyogo)
A beam-accelerating RF cavity with a new HOM-damping structure was designed in order to suppress coupled-bunch instabilities in a next generation light source with an ultra-low emittance and supplying X-rays approaching their diffraction limits. The TM020 mode at 509 MHz is selected as a beam-accelerating mode because it has a high Q-value of 60,000 and a shunt impedance sufficient for beam acceleration and brings a compact HOM-damping structure to the cavity differently from massive types of cavities with waveguides or pipes extracting HOM power. Two shallow slots are cut on the cavity inner-wall and materials absorbing RF waves are directly fitted into them. They work as HOM dampers without affecting the RF properties of the beam-accelerating mode. A prototype cavity of OFHC copper was fabricated to demonstrate the HOM-damping and generating an accelerating voltage of 900 kV in the cavity. Since the cavity was successful in operation up to 135 kW, the feasibility of both the high-power operation and the damping structure was proved. Four actual cavities were produced and installed to the new 3-GeV synchrotron radiation facility, NanoTerasu in Japan.

TU3D5 -- Electron RF Injectors for Next Generation FELs
Contributed Oral D - Key Technologies
Boris Leonidovich Militsyn (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)
A modern trend in the next generation of X-ray Free Electron Lasers (FEL) is the development of tools for the investigation of dynamic processes on the (sub)atomic scale that requires photon beams with energies of 20-25 keV with a repetition rate of 1 MHz or higher. At reasonable energies of the drive linac of 8-10 GeV optimum FEL performance requires an electron beam with emittance of 0.1 mm.mrad or lower. Higher value of the emittance leads to essential degradation in FEL performance and significant increase in required undulator length. In this work we try to estimate the ultimate beam brightness and bunch repetition rate that may be achieved with existing electron injector technologies and outline possible ways of obtaining beams with the parameters required for future FELs. In particular, we will discuss possible injector designs for the ongoing UK XFEL project.

TU3B1 -- Machine Learning Applications for Performance Improvement and Developing Future Storage Ring Light Sources
Invited Oral B - Ring-based Light Sources
Simon Christian Leemann (LBNL, Berkeley)
This presentation will focus on two recent applications of Machine Learning (ML) to storage ring-based synchrotron light sources. The first example highlights improvement of storage ring performance by use of ML to stabilize the electron beam size at the source points against perturbations from insertion device (ID) motion*. The stability of the source size is improved by roughly one order of magnitude through a neural network-based feed-forward that compensates, in a model-independent manner, for ID-induced source size changes before they can occur. In the second example, ML is used to replace many-turn particle tracking in multi-objective genetic algorithms (MOGA) for the design of lattices for demanding future storage rings**. By training neural networks to give accurate predictions of nonlinear lattice properties such as dynamic aperture and momentum aperture, the overall MOGA optimization process an be substantially accelerated. Including overhead from training and iterative retraining, MOGA optimization can be accelerated through ML by up to two orders of magnitude, thereby dropping overall optimization campaign runtime even on large clusters from weeks to just hours. * Phys. Rev. Lett. 123, 194801 (2019), https://doi.org/10.1103/PhysRevLett.123.194801 ** Nucl. Instrum. Methods Phys. Res., A 1050, 168192 (2023), https://doi.org/10.1016/j.nima.2023.168192 This research is funded by the US Department of Energy (BES & ASCR Programs), and supported by the Director of the Office of Science of the US Department of Energy under Contract No. DEAC02-05CH11231.

TU3B2 -- Recent Developments of the Toolkit for Simulated Commissioning
Contributed Oral B - Ring-based Light Sources
Thorsten Hellert (LBNL, Berkeley, California)
Detailed commissioning simulations have become the main tool of error analysis during lattice design of 4th generation storage ring light sources in recent years. The Matlab based Toolkit for Simulated Commissioning provides a high fidelity error model and a user friendly interface and is currently used at several facilities around the world. This contribution will present the toolkit with the highlight on recent developments such as the integration into the ALS control system for automated startup procedures and the transcription into python, enabling large scale parallelization.

TU3B3 -- Pyapas: A New Framework for High Level Application Development at HEPS
Contributed Oral B - Ring-based Light Sources
Xiaohan Lu (IHEP CSNS, Guangdong Province), Yi Jiao (IHEP,), Hongfei Ji, Cai Meng, Yuemei Peng, Yaliang Zhao (IHEP, Beijing)
The development of high-level application (HLA) is an indispensable part of the light source construction process. With the increase in the scale and complexity of accelerators, the development of HLA will also face many new challenges, such as increased data volume, multiple data types, more parameter channels, and more complex tuning algorithms. So a new framework named Pyapas has been designed for HLA development which aims to provide a high-performance, scalable, flexible, and reliable HLA development framework to meet the needs of large-scale parameter tuning and data processing. Pyapas is designed with a modular concept, decomposing the development needs of HLA into different modules for decoupled development, and calling them through simple interfaces. In the communication module, a singleton factory class is designed to avoid duplicate creation of channel connections, and combined with Qt's signal-slot mechanism to create non-blocking communication connections, greatly improving the carrying capacity of parameter scale. While a deeply decoupled two-layer physical model module is designed to quickly switch different mathematical models to meet different online computing needs. Moreover, the design of the C/S architecture development module and the rapid creation and management module of the database is helpful for quickly developing complex programs, further enhancing the applicability of Pyapas. This paper will introduce the main feature of Pyapas

TU3B4 -- Use of Automated Commissioning Simulations for Error Tolerance Evaluation for the Advanced Photon Source Upgrade
Contributed Oral B - Ring-based Light Sources
Vadim Sajaev, Michael Borland (ANL, Lemont, Illinois)
Multi-bend achromat-based light source designs are known to have rather strong focusing and rather small vacuum chambers, which pretty much guarantees difficult commissioning. To ensure the Advanced Photon Source Upgrade* commissioning is possible, the automated commissioning simulations were developed**. The simulations start from trajectory correction in the transport line, go through first-turn correction, trajectory and orbit correction, and complete with lattice and coupling correction. In addition to ensuring smooth commissioning, these simulations proved very useful in evaluating error tolerances under the most realistic conditions. In some cases, this approach allows for significant relaxation of the tolerances. We will describe APS-U automated commissioning simulations and give examples of error tolerance evaluations. *M. Borland et al., "The Upgrade of the Advanced Photon Source", in Proc. IPAC'18, Vancouver, Canada, Apr.-May 2018, pp. 2872-2877 **V.Sajaev, "Commissioning simulations for the aps upgrade lattice," Phys. Rev. Accel. Beams, vol. 22, p. 040102, 2019 Work supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

TU4P01 -- Simulation Studies of Producing Attosecond-terawatt X-ray FEL Pulses Using Irregularly Spaced Current Peaks at SwissFEL
Poster A - Linac-based Light Sources
Guanglei Wang, Eduard Prat, Sven Reiche, Kirtsen Schnorr (PSI, Villigen PSI)
We present simulation results of a scheme to generate high-power and short FEL pulses using an electron beam with irregularly spaced current peaks. Such an electron beam produces a train of short pulses with low power in the first undulator section. In the next sections, the electron beam is delayed in a way that only one of the short pulses is continuously amplified to a very high power. The irregular spacing of the current peaks is obtained by using the ESASE mechanism, where the electron beam is modulated with a chirped optical laser and later compressed in a magnetic chicane. In comparison to previous proposals, we suggest to use a chirped electron beam to reduce the requirements on the optical laser chirp, and to transversely tilt the electron beam to select the number of current peaks able to lase for best final performance. The simulations are done for the soft X-ray beamline of SwissFEL, Athos, which has small magnetic chicanes placed within the undulator line suitable to delay the electron beam between the different amplification stages. Our simulation results show that soft X-ray FEL pulses with TW peaks power and hundreds of attoseconds pulse durations can be achieved in SwissFEL.

TU4P02 -- Measurements of Dipole and Quadrupole Wakefields From Corrugated Structures at SwissFEL
Poster A - Linac-based Light Sources
Philipp Dijkstal, Paolo Craievich, Eduard Prat (PSI, Villigen PSI), Alexander Malyzhenkov (CERN, Meyrin)
Wakefields from corrugated rectangular passive deflecting structures are a cost-effective and reliable method for temporal diagnostics, and are employed at SwissFEL* and the European XFEL**. In analytical models, the wakefield effect is described through a deflecting dipole component and a defocusing quadrupole component. For the wakefield diagnostics, knowledge of the dipole component is crucial for the accurate retrieval of the time information, while the quadrupole component is an error term. We present wakefield measurements of a structure installed after the hard X-ray beamline Aramis at SwissFEL. A non-dispersive beam monitor allows to observe the dipole effects in streaking direction, and the quadrupole effects in the perpendicular transverse plane. We compare the measurements to the wakefield model and find an overall good agreement in the dipole term, but for some cases a systematic disagreement in the quadrupole term. We expect these results to be important for the potential development of more accurate analysis models in the future. * P. Dijkstal et al., Phys. Rev. Res. 4 p.013017 (2022) ** S. Tomin et al., Proc. IPAC 2022, p.275, MOPOPT020 (2022)

TU4P03 -- High-repetition-rate Seeded Free-electron Laser Enhanced by Self-modulation
Poster A - Linac-based Light Sources
Hanxiang Yang (SINAP, Shanghai), Jiawei Yan (EuXFEL, Schenefeld), Haixiao Deng (SARI-CAS, Pudong, Shanghai)
The spectroscopic methods for the materials' ultrafast electronic and structural dynamics require fully coherent extreme ultraviolet and soft X-ray radiation with high-average brightness. Seeded free-electron lasers (FELs) are ideal sources for delivering fully coherent soft X-ray pulses. However, due to state-of-the-art laser system limitations, it is challenging to simultaneously meet the ultraviolet seed laser's requirements of sufficient energy modulation and high repetition rates. The self-modulation scheme has recently been proposed and demonstrated at the SXFEL to relax the seed laser requirements. In this contribution, we report on a series of theoretical and experimental studies on the self-modulation scheme, which promises to generate ultrashort and coherent soft X-ray pulses at MHz repetition rates.

TU4P04 -- Ultrafast FEL Generation with Optical Beat Note
Poster A - Linac-based Light Sources
Yaozong Xiao (SINAP, Shanghai)
We propose a simple scheme to compress an electron beam with an optical beat note, which can potentially achieve a bunch length much shorter than what is currently available with a conventional radio-frequency technique. Instead of an energy chirp, the optical laser induces an energy modulation whose amplitude linearly changes along the longitudinal axis, which effectively compresses the electron beam after it passes through an optimized magnetic chicane. Numerical simulations performed to demonstrate the proposed scheme show that a free electron laser pulse with the peak power of 400 MW and the pulse length of 800 attoseconds can be generated, based on the realistic parameters of Shanghai soft x-ray FEL facility with a 1.5 GeV and 800 A electron beam.

TU4P05 -- Design of the Test Platform for High Current VHF Electron Gun
Poster A - Linac-based Light Sources
Zipeng Liu, Xudong Li (SINAP, Shanghai), Houjun Qian (DESY Zeuthen, Zeuthen), Guan Shu (IHEP, Beijing), Haixiao Deng, Zenggong Jiang (SARI-CAS, Pudong, Shanghai)
A high-average-current VHF electron gun operating in the CW mode is under construction at Shanghai Advanced Research Institute, which is the key component of a kW-power-order free electron laser facility. The average current and the frequency of this electron gun is 1-10 mA and 217 MHz, respectively. To validate the performance of this instrument, a test platform has been designed. The R&D of its vacuum and diagnostics are presented in this work.

TU4P06 -- Generating High-Power, Frequency Tunable Coherent THz Pulse in an X-ray Free-Electron Laser for THz Pump and X-ray Probe Experiments
Poster A - Linac-based Light Sources
Kaiqing Zhang, Chao Feng (SSRF, Shanghai)
Precisely synchronized X-ray and strong-field coherent Terahertz (THz) enables coherent THz excitation of many fundamental modes (THz pump) and capturing the X-ray dynamic image of matters (X-ray probe), while the generation of such light source is still a challenge for the most existing techniques. In this paper, a novel X-ray free electron laser (FEL) based light source is proposed to produce synchronized high power X-ray pulse and strong field, widely frequency tunable coherent THz pulse simultaneously. The technique adopts a frequency beating laser modulated electron bunch with a Giga-electron-volt (GeV) beam energy to generate X-ray pulse and THz pulse sequentially by passing two individual undulators with different magnetic period. Theoretical analyses and numerical simulations are carried out using the beam parameters of shanghai soft X-ray free electron laser facility (SXFEL), and the results show that the technique can generate synchronized 4 nm X-ray radiation with a peak power of 1.89 GW and narrow bandwidth THz radiation with pulse energy of 1.62 mJ and tunable THz wavelength from 0.1 to 60 THz.

TU4P07 -- Design of the Beam Distribution System of SHINE
Poster A - Linac-based Light Sources
Si Chen (SSRF, Shanghai), Haixiao Deng, Xiaoxi Fu, Bo Liu (SARI-CAS, Pudong, Shanghai), Bingyang Yan (SINAP, Shanghai)
The Shanghai high-repetition-rate XFEL and extreme light facility (SHINE), as the first hard X-ray free electron laser facility in China, is now under construction. CW electron beam with up to 1 MHz bunch repetition rate from a superconducting RF linac is used to feed at least three individual undulator lines that covers a wide photon energy range (0.4 keV ~ 25 keV). In order to maximize the efficiency of the facility, a beam switchyard between the linac and undulator lines is used to enable the simultaneously operation of the three undulator lines. In this work, the schematic design of the beam switchyard for bunch-by-bunch beam separation of CW beam is described, and the current lattice design of the linac-to-undulator deflection branches and the start-to-end tracking simulation results are presented.

TU4P08 -- Design and Commissioning of the Beam Switchyard for the SXFEL-UF
Poster A - Linac-based Light Sources
Si Chen, Kaiqing Zhang (SSRF, Shanghai), Haixiao Deng, Chao Feng, Bo Liu, Tao Liu, Zheng Qi, Zhentang Zhao (SARI-CAS, Pudong, Shanghai)
As an important measure of improving the efficiency and usability of X-ray free electron laser facilities, parallel operation of multiple undulator lines realized by a beam switchyard has become a standard configuration in the recent built XFEL facilities. SXFEL-UF, the first soft X-ray free electron laser user facility in China, has finished construction and commissioning recently. The electron beams from the linac are separated and delivered alternately to the two parallel undulator beam lines through a beam switchyard. A stable and fast kicker magnet is used to achieve bunch-by-bunch separation. Optics measures are applied to mitigate the impact of various collective effects, such as coherent synchrotron radiation and micro-bunching instability, on the beam quality after passing through the deflection line of the beam switchyard. In this study, the comprehensive physical design of the beam switchyard is described and the latest results of its commissioning process are presented.

TU4P09 -- Beam Compression and Suppression of Coherent Synchrotron Radiation Effect in FODO Arc
Poster A - Linac-based Light Sources
Xiuji Chen (ShanghaiTech University, Shanghai)
In recent years, ERL-FEL (Energy Recovery Linac Free-Electron Laser) has been extensively studied for generating high-repetition-rate lasers. In this process, beam compression plays a crucial role in increasing the peak current of the beam, thereby enhancing the laser radiation power. However, the presence of the CSR (Coherent Synchrotron Radiation) effect during the beam compression process leads to a degradation of the beam quality, which limits the performance of the free-electron laser. A FODO-type arc section has been designed to compress the beam of 100 pC from 2ps@1GeV to 100 fs, while keeping the emittance growth below 0.1 microm rad.

TU4P10 -- Adapting the COMIX Polarimeter to Characterize the Angular Momentum Content of Coherent Undulator Radiation
Poster A - Linac-based Light Sources
Jenny Fraser Morgan (SLAC, Menlo Park, California)
The COMIX polarimeter is a compact polarimeter designed to characterize the polarization of light at XUV wavelengths. We describe how this device can be repurposed to characterize light with transversely structured polarization and diagnose its angular momentum content. The orbital angular momentum content of short wavelength radiation can be difficult to diagnose when multiple states are present. This technique provides a useful tool for the implementation of novel FEL schemes which involve the combination of radiation with different OAM modes emitted at the harmonics helical undulators.

TU4P11 -- Intrinsic Mono-chromatic Emission of X and Gamma-rays in Symmetric Electron-photon Beam Collisions
Poster A - Linac-based Light Sources
Illya Drebot, Alberto Bacci, Marcello Rossetti Conti, Andrea Renato Rossi, Luca Serafini (INFN-Milano, Milano), Camilla Curatolo (INFN- Sez. di Padova, Padova), Vittoria Petrillo (Universita' degli Studi di Milano & INFN, Milano)
This paper explores the transition between Compton Scattering and Inverse Compton Scattering (ICS), which is characterized by an equal exchange of energy and momentum between the colliding particles (electrons and photons). This regime has been called Symmetric Compton Scattering (SCS) and has the unique property of cancelling the energy-angle correlation of scattered photons, and, when the electron recoil is large, transferring mono-chromaticity from one colliding beam to the other, resulting in back-scattered photon beams that are intrinsically monochromatic. The paper suggests that large-recoil SCS or quasi-SCS can be used to design compact intrinsic monochromatic gamma-ray sources based on compact linacs, thus avoiding the use of GeV-class electron beams together with powerful laser/optical systems as those typically required for ICS sources.

TU4P12 -- Injection into XFELs, a Review of Trends and Challenges
Poster A - Linac-based Light Sources
Can Davut (UMAN, Manchester), Oznur Apsimon (Cockcroft Institute, Warrington, Cheshire), Julian William McKenzie, Boris Leonidovich Militsyn, Suzanna Percival (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)
This contribution will comparatively review the low-energy electron injectors for existing XFEL facilities focusing on the gun, buncher and booster sections until the magnetic compression. The technology choices parallel to the increasing demand for stricter phase space quality are presented. The current capability for beam parameters and future requirements are laid out alongside the challenges and technological bottlenecks. In light of this review, preliminary scenarios for a new generation, high repetition rate, and continuous wave injector are presented as options for the UK XFEL. Science and Technology Facilities Council, STFC

TU4P13 -- An Introduction to the UK XFEL Conceptual Design and Options Analysis
Poster A - Linac-based Light Sources
David Dunning (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)
In October 2022, the UK XFEL project entered a new phase to explore how best to deliver the advanced XFEL capabilities identified in the project's Science Case. This phase includes developing a conceptual design for a unique new machine to fulfil the required capabilities and more. It also examines the possibility of investment opportunities at existing XFELs to deliver the same aims, and a comparison of the various options will be made. The desired next-generation capabilities include transform-limited operation across the entire X-ray range with pulse durations ranging from 100 as to 100 fs; evenly spaced high rep. rate pulses for enhanced data acquisition rates; optimised multi-colour FEL pulse delivery and a full array of synchronised sources (XUV-THz sources, electron beams and high power/high energy lasers). The project also incorporates sustainability as a key criteria. This contribution gives an overview of progress to date and future plans.

TU4P14 -- Cavity-based XFEL R&D Project
Poster A - Linac-based Light Sources
Kwang-Je Kim, Jayson William John Anton, Lahsen Assoufid, Andrew Bernhard, Joseph Gagliano, Keshab Kauchha, Steven Patrick Kearney, Keenan Lang, Ryan Roger Lindberg, Peifan Liu, Sheikh Tamjid Mashrafi, Antonino Miceli, Jeong-Wan Park, Paresh Pradhan, Xianbo Shi, Deming Shu, Yuri Shvyd'ko, S. Joshua Stein, Joseph Patrick Sullivan, Marion White (ANL, Lemont, Illinois), Wayne Kevin Lewis (Osprey DCS LLC, Ocean City), Taito Osaka, Kenji Tamasaku (RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo), Harmanpreet Bassan, Courtney Curtis, Franz-Josef Decker, Georg Gassner, Aliaksei Halavanau, Zhirong Huang, Eugene Michael Kraft, Briant Lam, Gabriel Marcus, Rachel Anne Margraf, Dennis Martinez-Galarce, Jeremy A. Mock, Maria Alessandra Montironi, Heinz-Dieter Nuhn, Xavier Permanyer, Tor Raubenheimer, Shweta Saraf, Tien-Fak Tan, Diling Zhu (SLAC, Menlo Park, California), Yuan Shen Li (University of Chicago, Chicago, Illinois)
CBXFEL R&D project* aims to demonstrate low-loss operation of a 65m rectangular X-ray cavity with diamond crystal mirrors and two-pass gain for the X-ray regenerative amplifier and XFELO using the Cu-linac at SLAC. The hardware installation is proceeding toward commissioning start in 2024. Two pairs of ultra-fast e-beam kickers and two e-beam chicanes necessary to control and guide two electron bunches have been installed. Diamond crystal mirrors have been machined for strain-free mounting and drumhead X-ray outcoupling and characterized for phase errors. Tests of X-ray diagnostics and optical components have been completed. A prototype stage stack for diamond mirror positioning and alignment is assembled and will be tested for in-vacuum operation. Designs for mechanical components and integrated system controls are in their final stage. Station E for intracavity diagnostics is delivered. Energy calibration utilizing exact backscattering from C(440) and fine adjustment of the e-bunch spacing with RF frequency tuning may simplify the alignment procedure. The threshold performance goals are the measurement of 2nd pass FEL gain and a cavity roundtrip loss < 20% by the end of 2024. * G. Marcus et al., TUD04 in Proc. FEL 2019 Work supported by U.S. DOE, Office of Science, Office of BES, under Contract No. DE-AC02-06CH11357 (ANL) and DE-AC02-76SF00515 (SLAC)

TU4P15 -- Two-color XFEL Generation Using Phase Shifters of Undulators
Poster A - Linac-based Light Sources
MyungHoon Cho, Hoon Heo, Heung-Sik Kang, Gyujin Kim, Seong-Hoon Kwon, Inhyuk Nam, Chi Hyun Shim, Haeryong Yang (PAL, Pohang)
Phase-shifters at an undulator line are usually used for optimizing FEL intensity by setting 'in-phase' or matching condition between FEL pulse and electron beam phase. Setting the phases at -offset or 'out-of-phase' may suppress FEL intensity at the resonant frequency, hence the 'out-of-phase' condition is an unwanted state. However, this 'out-of-phase' setting can arise side band spectra having two frequency peaks. According to the spontaneous radiation or the low-gain FEL theory, separation of the two spectral peaks are determined by the number of undulator period. The initial two spectra are amplified exponentially along the undulator. Alternating amplification phase in the FEL phase bucket creates two micro-bunches in each FEL slice, that expected less gain slope compared to the 'in-phase' condition. This poster shows amplification of the two-color spectra, which are verified through simulations and experiments performed at PAL-XFEL.

TU4P16 -- Transverse Optics-based Control of the Microbunching Instability
Poster A - Linac-based Light Sources
Alexander Darius Brynes, Simone Di Mitri (Elettra-Sincrotrone Trieste S.C.p.A., Basovizza), Cheng-Ying Tsai (HUST, Wuhan), Giovanni Perosa (Università degli Studi di Trieste, Trieste)
A number of recent experimental and theoretical studies have investigated novel techniques for suppressing the microbunching instability in high-brightness linac-based light sources. This instability has long been studied as one of the causes of reduced longitudinal coherence in these machines, which are commonly suppressed using a laser heater. This contribution presents recent developments concerning the use of an optics-based scheme to mitigate the microbunching instability in the FERMI free-electron laser, paving the way towards reversible beam heating techniques that could improve the performance of future machines.

TU4P17 -- Non-destructive Vertical Halo-monitors on the ESRF Electron Beam
Poster B - Ring-based Light Sources
Kees Bertus Scheidt (ESRF, Grenoble)
The ESRF EBS storage ring has since spring 2022 among its electron beam diagnostics two independent units of vertical Halo-monitors. The principle and the components of this unique diagnostic will be explained in details. It uses the available X-rays in a non-used Front-End, emitted from a 0.57 T standard dipole magnet in the EBS lattice. This instrument measures the so-called "far-away" Halo level, i.e. in a zone of roughly 1-3 mm away from the beam centre, which represents 200-600 times the electron's vertical beam-size, supposedly Gaussian, of 5 um. It is measured, and expressed quantitively in picoAmp beam current, at 1 Hz rate. Both units are yielding very satisfying and well-correlated results that will be presented in details, and in relation with studies on the electron beam and the accelerator components like variation of current, filling-patterns, vertical emittance, quality of the vacuum, settings of the undulator gaps, collimators, scrapers etc. and also in direct correlation with measurements of our 128 beamloss detectors and beam lifetime.

TU4P18 -- Nonlinear Dynamics Measurements at the EBS Storage Ring
Poster B - Ring-based Light Sources
Nicola Carmignani, Lee Robert Carver, Lina Hoummi, Simone Maria Liuzzo, Thomas Perron, Simon Mathieu White (ESRF, Grenoble)
The EBS is a 4th generation synchrotron light source and it has been in user operation since August 2020 at the ESRF. Several measurements to characterise the nonlinear dynamics have been performed in 2023: nonlinear chromaticity, second order dispersion and detuning with amplitude. The results of the measurements are shown and compared with simulations.

TU4P19 -- Evolution of Equilibrium Parameters Ramp Including Collective Effects in the Diamond-II Booster
Poster B - Ring-based Light Sources
Riyasat Husain, Richard Fielder, Ian Martin (DLS, Oxfordshire), Philip Burrows (Oxford University, Oxford, Oxon)
Efficient top-up injection into the Diamond-II storage ring will require upgrading the booster lattice for a beam emittance of <20 nm rad and a bunch length of <40 ps, including when operating with high single-bunch charge. The small vacuum chamber dimensions will drive the resistive wall instability and may adversely affect equilibrium parameters along the beam energy ramp. In addition, various diagnostic and vacuum chamber components will generate geometric impedances which may further disrupt the equilibrium parameters. Based on the detailed engineering designs, impedance models of the major components have been simulated using CST Studio and included in ELEGANT tracking simulations of the booster. In addition, the effects of synchrotron radiation emission and intra-beam scattering on the equilibrium parameters during the ramp are studied.

TU4P20 -- Validation of Magnet Strength Limits From Commissioning Simulations for the Diamond-II Storage Ring
Poster B - Ring-based Light Sources
Hung-Chun Chao, Ian Martin (DLS, Oxfordshire)
To provide confidence in the future commissioning of the Diamond-II storage ring, realistic specifications for the error tolerances have been established. Based on these values, commissioning simulations have been conducted starting from on-axis injection through to the correction of beta-beating caused by insertion devices. The goal of these studies is to validate the magnet strength limits using the statistics of 200 random machines simulated. In this paper we summarise these studies and present the results at each stage. Other topics such as improvements to the magnet modelling and alternative commissioning strategies are also discussed.

TU4P21 -- Frequency Spread and Beam-Ion Instabilities in SOLEIL II
Poster B - Ring-based Light Sources
Vadim Gubaidulin, Alexis Gamelin, Ryutaro Nagaoka (SOLEIL, Gif-sur-Yvette)
Beam-ion instabilities arise when ionized residual gases are trapped in an electromagnetic potential of the electron beam. Many facilities, including Synchrotron SOLEIL, are upgrading towards fourth-generation light sources. New lattice designs in all upgrade projects reduce transverse beam emittances by orders of magnitude. This can lead to a strong beam-ion instability where the beam oscillations couple to ions oscillations, and the oscillation amplitude grows with time. A spread in the frequencies of transverse oscillations of either ions or the electron beam can mitigate beam-ion instability. The nonlinear transverse distribution of ions and the variation of lattice functions along the ring are the sources of a spread in ion oscillation frequencies. The chromaticity and amplitude-dependent tune shifts are examples of frequency spread in the electron beam. In this work, we incorporate possible sources of oscillation frequency spreads in our simulation model and compare the results with previously known analytical models.

TU4P23 -- Knot APPLE X Undulators for SLS 2.0
Poster B - Ring-based Light Sources
Thomas Schmidt, Pirmin Boehler, Mark Bruegger, Marco Calvi, Steffen Danner, Lars Huber, Andreas Keller, Marcus Schmidt (PSI, Villigen PSI)
The next generation of synchrotrons will see undulators with shorter periods and stronger magnetic fields and thus higher radiation power. Consequently, concepts for reducing on-axis heat load in particular will become more relevant. For the SLS 2.0, APPLE X undulators with a round vacuum chamber can be used due to near-axis injection. An adaptation of the Knot APPLE* concept for the SLS 2.0 APPLE X undulators is presented. *S. Sasaki, A.Miyamoto, and S. Qiao. Design study of KNOT-APPLE undulator for PES-Beamline at SSRF. volume PAC13, pages 1043¿1045, 2013.

TU4P24 -- New Compact Modular In-vacuum Undulators for SLS2.0
Poster B - Ring-based Light Sources
Thomas Schmidt, Pirmin Boehler, Mark Bruegger, Marco Calvi, Steffen Danner, Lars Huber, Haimo Joehri, Andreas Keller, Marcus Schmidt, David Stephan (PSI, Villigen PSI)
A new design for in-vacuum undulator was developed for SLS 2.0 that combines a number of new concepts: a modular, compact construction, magnetic force compensation and integrated keepers for automated field optimisation. The basis are solid vacuum chamber modules made of aluminium, which can absorb the forces and replace the classic support structure. These modules, each 0.5m long, are placed on girders according to the desired total length and connected to each other. The gap is also adjusted compactly by means of a wedge-based hydraulic drive. The magnetic forces are already compensated in the keeper, which can thus be adjusted easily via flexo elements which facilitates automated field optimisation.

TU4P25 -- SLS 2.0 Machine Protection
Poster B - Ring-based Light Sources
Felix Armborst, Maria Ilaria Besana, Jonas Kallestrup, Martin Paraliev (PSI, Villigen PSI)
Machine protection for the Swiss Light Source (SLS) is ensured by the Beam Dump Controller (BDC) triggering an emergency beam dump when the beam permit is revoked. The beam permit can be revoked by each BDC input, i.e., Machine Interlock System (MIS), Vacuum Control System (VCS), Beam Position Monitor (BPM) system, Person Safety sYStem (PSYS) and manual. For the emergency beam dump the RF phase is inverted decelerating the stored beam. Resulting losses are distributed to the thin septum and the arcs. For the SLS 2.0 with its fragile vacuum chamber combined with the small beam size and stored beam energy of 1 kJ, lost beam poses the threat of damage to, e.g., the vacuum chamber, in-vacuum undulators, superconducting super bends and the superconducting cavity. Also demagnetization of permanent magnets due to induced dose must be considered, making radiation simulations and collimation critical issues. With its multi-bend-achromat lattice and thus much lower dispersion in the arcs, tracking simulations show that coasting beams are lost within 300 us with losses localized at superconducting super bends and in-vacuum insertion devices. Due to this unfortunate loss distribution a fast and controlled emergency beam dump procedure is required. A dedicated beam dump kicker, triggered by a fast BDC within a few revolution times spreads the bunches over the dedicated beam dump. The new BDC will provide dedicated inputs for fast systems such as the low-level RF and feedback systems. The majority of the well over 6000 machine interlock signals will further be monitored by a slow, programmable-logic-controller-based machine interlock system (MIS).

TU4P26 -- Special Operational Modes for SLS 2.0
Poster B - Ring-based Light Sources
Jonas Kallestrup, Masamitsu Aiba (PSI, Villigen PSI)
The SLS 2.0 storage ring will achieve low emittance and high brightness while maintaining large dynamic aperture and lifetime comparable to the present SLS. Special operational modes are investigated to further explore the potential of the lattice. In this contribution, the first considerations on such modes for the SLS 2.0 are outlined. A promising high-brightness mode, giving up to 25% higher brightness at insertion devices with minor deterioration to dynamic and momentum aperture is presented. The use of round-beams and its impact on beam dynamics and the beamlines in the SLS 2.0 portfolio is discussed.

TU4P27 -- Progress of the HEPS Accelerator Construction and Linac Commissioning
Poster B - Ring-based Light Sources
Cai Meng, Jianshe Cao, Ping He, Yi Jiao, Jingyi Li, Weimin Pan (IHEP, Beijing)
The High Energy Photon Source (HEPS) is the first fourth-generation synchrotron radiation source in China that has been on the track for construction. The accelerator complex of the light source is composed of a 7BA storage ring, a booster injector, a Linac pre-injector, and three transfer lines. In order to provide high-bunch-charge beams for the storage ring, the booster was designed to be capable of both beam acceleration from low injection energy to extraction energy and charge accumulation at the extraction energy by means of accepting electron bunches from the storage ring. The Linac was built using S-band normal conducting structures, and can provide electron beam with pulse charge up to 7 nC. This paper reports the progress of the construction of the accelerators, including the installation of the storage ring, the pre-commissioning tests of the booster, and commissioning of the Linac. In particular, the beam commissioning of the Linac will be introduced in detail.

TU4P28 -- Laser-Electron Phase Locking in a Steady-State Microbunching Storage Ring
Poster B - Ring-based Light Sources
Xiujie Deng (TUB, Beijing)
In this paper, we present our preliminary thinking on how to keep the modulation laser and electrons phase-locked in a steady-state microbunching storage ring.

TU4P29 -- Microbunching Radiation Fluctuation and its Applications
Poster B - Ring-based Light Sources
Xiujie Deng (TUB, Beijing)
In this paper, we present some results on microbunching radiation fluctuation and its applications.

TU4P30 -- Quasi-Steaady-State Microbunching
Poster B - Ring-based Light Sources
Xiujie Deng (TUB, Beijing)
In this paper, we will report the latest progress of the ongoing experimental activities on steady-state microbunching (SSMB), i.e., a quasi steady-state microbunching in a storage ring.

TU4P31 -- A Recursive Model for Laser-Electron-Radiation Interaction in Insertion Section of SSMB Storage Ring Based on Transverse-Longitudinal Coupling Scheme
Poster C - Compact Light Sources
Cheng-Ying Tsai (HUST, Wuhan), Xiujie Deng (TUB, Beijing)
Recently a mechanism of the steady-state microbunching (SSMB) in a storage ring has been proposed and investigated. The SSMB aims to maintain the same excellent high repetition rate, close to continuous-wave operation, as the storage ring. Moreover, replacing the conventional RF cavity with a laser modulator for longitudinal focusing, the individual electron bunches can be microbunched in a steady state. The microbunched electron bunch train, with individual bunch length comparable to or shorter than the radiation wavelength, can not only produce coherent powerful synchrotron radiations but may also be subject to FEL-like collective instabilities. Our previous analysis was based on the wake-impedance model*. In this paper, we have developed a recursive model for the laser modulator in the SSMB storage ring. In particular, the transverse-longitudinal coupling scheme is assumed. Equipped with the above matrix formalism, we can construct a recursive model to account for turn-by-turn evolution, including single-particle and second moments. It is possible to obtain a simplified analytical expression to identify the stability regime or tolerance range for non-perfect cancellation. *C.-Y. Tsai, PRAB 25, 064401 (2022). C.-Y. Tsai, NIMA 1042 (2022) 167454. **X.J. Deng et al., NIMA 1019 (2021) 165859. This work is supported by the Fundamental Research Funds for the Central Universities (HUST) under Project No. 2021GCRC006 and National Natural Science Foundation of China under project No. 12275094.**

TU4P33 -- An Inverse-Compton Scattering Simulation Module for RF-Track
Poster C - Compact Light Sources
Andrea Latina (CERN, Meyrin)
A simulation module implementing Inverse-Compton scattering (ICS) was added to the tracking code RF-Track. The module consists of a special beamline element that simulates the interaction between the tracked beam and a laser beam, making RF-Track capable of simulating a complete ICS source from the electron source to the photons in one go. The description of the laser allows the user to thoroughly quality the laser in terms of wavelength, pulse energy, incoming direction (which can be arbitrary), M2 parameter, aspect ratio, polarization and whether the laser profile should be gaussian or uniform. Furthermore, as it implements fully relativistic expressions, it can simulate Compton scattering on electrons and heavier particles. A benchmark against CAIN showed that RF-Track outperforms CAIN in terms of computational speed by orders of magnitude.

TU4P34 -- Recent Developments of the cSTART Project
Poster C - Compact Light Sources
Markus Schwarz, Axel Bernhard, Erik Bründermann, Dima El Khechen, Bastian Haerer, Anton Malygin, Anke-Susanne Mueller, Michael Johannes Nasse, Gudrun Niehues, Alexander Ivanovich Papash, Robert Ruprecht, Jens Schaefer, Marcel Schuh, Nigel John Smale, Pawel Wesolowski, Christina Widmann (KIT, Karlsruhe)
The combination of a compact storage ring and a laser-plasma accelerator (LPA) can serve as the basis for future compact light sources. One challenge is the large momentum spread (~ 2%) of the electron beams delivered by the LPA. To overcome this challenge, a very large acceptance compact storage ring (VLA-cSR) was designed as part of the compact STorage ring for Accelerator Research and Technology (cSTART) project. The project will be realized at the Karlsruhe Institute of Technology (KIT, Germany). Initially, the Ferninfrarot Linac- Und Test-Experiment (FLUTE), a source of ultra-short bunches, will serve as an injector for the VLA-cSR to benchmark and emulate LPA-like beams. In a second stage, a laser-plasma accelerator will be used as an injector, which is being developed as part of the ATHENA project in collaboration with DESY and the Helmholtz Institute Jena (HIJ). The small facility footprint, the large-momentum spread bunches with charges from 1 pC to 1 nC and lengths from few fs to few ps pose challenges for the lattice design, RF system and beam diagnostics. This contribution summarizes the latest results on these challenges.

TU4P35 -- A Compact Light Source Based on Coherent Thomson Scattering of Density Modulated Electron Bunch
Poster C - Compact Light Sources
Si Chen, Zhangfeng Gao, Hanghua Xu (SSRF, Shanghai), Xiaoxi Fu (SARI-CAS, Pudong, Shanghai)
Compact light sources represent a significant direction in the current development of accelerator-driven light sources, and one important avenue is based on Thomson scattering (sometimes referred to as "inverse Compton scattering"). However, traditional Thomson scattering light sources typically exhibit incoherence, which limits their quality and application prospects. In this study, we propose harnessing the advanced density modulation principle in high-gain free-electron lasers to generate well-defined electron bunch structures within low-energy electron beams. These structured electron bunches are then scattered with a longer-wavelength laser, enabling the production of coherent Thomson scattering light in the extreme ultraviolet (EUV) to soft X-ray range. By incorporating an energy recovery linear accelerator, it becomes feasible to generate high-power coherent radiation with a smaller device footprint.

TU4P36 -- Effect of Pre-bunched Relativistic Electron Beams on the Output Power in a Two-stream Free-electron Laser
Poster C - Compact Light Sources
Nader Mahdizadeh, Babak Haghighi, Maryam Razaghzadeh (Islamic Azad University, Sabzevar), Alireza Haghpeima (Department of Physics, Basic Science, Mashhad Branch, Islamic Azad University, Mashhad, Iran, Mashhad)
The effect of pre-bunching of relativistic electron beams with considering a water-bag distribution function on the output power in a two-stream free electron laser was investigated. By solving simultaneously, a set of coupled nonlinear differential equations in one-dimensional wave-particle interaction was described. A numerical solution by the Runge-Kutta algorithm with the aid of MATLAB software was obtained. By plotting the out-put power of laser versus axial distance remarkable increases in comparison to the uniform distribution function of the electron beams has seen. Islamic Azad University, Sabzevar Branch

TU4P37 -- Reduction of Energy Jitter and Energy Spread of High-Charge Electron Bunches from Laser Plasma Accelerators
Poster C - Compact Light Sources
Xueyan Shi, Dazhang Li, Jia Wang, Haisheng Xu, Ming Zeng (IHEP, Beijing)
In recent years, the beam quality attained by laser plasma accelerators (LPAs) is getting closer to conventional RF accelerators whereupon the combination of LPAs and RF accelerators has garnered substantial research interests. An important direction is to explore the feasibility of replacing the LINAC by LPA as the injector of a booster. However, the energy stability and energy spread of LPA electron beams are still very challenging today. An idea of using magnetic chicane and dechirper was proposed and successfully implemented for bunch charge of tens of pC before. In this paper, we present a novel physical design of an LPA-based first-stage injector with the design energy of 500 MeV that combines laser-driven active plasma dechirper (APD) and passive plasma dechirper (PPD). Preliminary particle-in-cell (PIC) simulations show that the energy jitter and the energy spread of the 500 pC bunches can be reduced from ±2% and 2.39% to 0.33% and 0.8%, respectively, with high transmission efficiency (89%). This proposal provides a promising way of using the LPAs to replace the RF LINACs, and therefore, push forward the application of LPAs in real accelerator facilities.

TU4P38 -- Burst Mode Operation in the Smart*Light Inverse Compton Scattering X-Ray Source
Poster C - Compact Light Sources
Rick van den Berg, Jom Luiten, Peter Mutsaers, Daniel Ferdinand Jan Nijhof, Coen Sweers, Ids van Elk (TUE, Eindhoven)
In the Smart*Light project at Eindhoven university an inverse Compton scattering (ICS) source is being built. The ICS source consists of a 100kV DC photogun injector, a 30 MeV X-band linac, and a 10 mJ fs laser. All operating at a rep rate of 1 kHz. The next upgrade for this ICS source is operation in a so-called burst mode. In burst mode, the injector is replaced by a high repetition rate 1.5 GHz thermionic injector. Furthermore, the optical system is expanded with a Fabry-Perot cavity, enabling recycling of the femtosecond laser pulses. The combination will allow operation with 1.5 GHz, 100 nanosecond bursts of pulses at 1 kHz rep rate, increasing the x-ray yield and the brilliance by more than two orders of magnitude. The thermionic injector works by generating a continuous beam with a high current and low emittance. The continuous electron beam is then chopped into a pulsed beam by a combination of a dual-mode elliptical RF cavity and a knife-edge. Finally, a second dual-mode elliptical RF cavity compresses the pulse length of the bunches, for injection into an X-band linear accelerator. The status of the current setup Smart*Light and simulations of the upgrade are presented.

WE1L1 -- Status and Future of XFEL Source Developments
Invited Oral A - Linac-based Light Sources
Sven Reiche (PSI, Villigen PSI)
Since the first demonstration of the SASE principle in the X-ray regime, there has been an ongoing development on improving and controlling the properties of the generated X-ray FEL pulses. This presentation gives a brief status on these efforts and an outlook of possible improvements in the future.

WE1L2 -- Progress of Cavity-based X-ray Free-electron Lasers
Invited Oral A - Linac-based Light Sources
Zhirong Huang (SLAC, Menlo Park, California)
Cavity-based X-ray Free electron lasers (FELs) such as the X-ray regenerative amplifier FEL (XRAFEL)* and the X-ray FEL oscillator (XFELO) have been proposed to produce temporally coherent and stable hard X-ray pulses, especially for high-repetition rate FEL facilities. An X-ray cavity consisting of Bragg crystals will be used to recirculate the spectrally filtered X-rays for repetitive interactions with an electron bunch train and to generate high-power and narrow-bandwidth radiation. In this talk, we review the scientific motivation and recent progress of Cavity-based X-ray FELs. We discuss cavity designs, optics requirements, outcoupling schemes, and the latest experimental results. Finally, we introduce the ongoing RD projects at LCLS*** and European XFEL**** to prove the concept, as well as several Cavity-based proposals to enhance X-ray FEL's spectral brightness by another two to three orders of magnitude compared to the state of art. * Z. Huang and R.D. Ruth, Phys. Rev. Lett. 96, 144801 (2006). ** K.-J. Kim et al., Phys. Rev. Lett. 100, 244802 (2008). *** K.J. Kim et al., Cavity-based XFEL R&D Project, this workshop. **** P. Rauer et al., Phys. Rev. Accel. Beams 26, 020701 (2023).**

WE1L3 -- Enabling Technology Towards Multiline Compact XFELs
Invited Oral D - Key Technologies
John Byrd (ANL, Lemont, Illinois)
After almost 15 years of openation, XFELs are well-established light sources for addressing many problems in science. However, most FEL facilities are relatively large to reach the beam energies and geometric emittancs needed to lase at higher photon energy. Furthermore, the XFEL can only serve one or a few users at at time. At Argonne National Laboratory, we have initiated a research program to address some of these issues. We report on our program develop independent undulator arrays to allow more simultaneous users. We are developing a compact Adjustable Phase Undulator that have a compact transverse footprint and a superconducting undulator design with multiple undulators per cryostat. In addition, we report on a new concept for an ultrolow emittance electron gun which reaches fields several times higher than existing guns. This is achieved by generating <10 nsec RF pulses similar to other two-beam accelerator concepts.

WE1L4 -- Operating Liquid MetalJet X-ray Sources for Materials Research
Invited Oral D - Key Technologies
Mirko Boin (HZB, Berlin)
Even on the 100th anniversary of the death of Wilhelm Conrad Röntgen, the demand for applications of his discovery of X-rays is not diminishing. On the contrary, both academic and industrial research and development need X-ray generating devices with ever-improving properties more than ever to meet the current challenges of science and technology. For this reason, the development of next-generation synchrotrons is being driven forward and made available to users worldwide. Nevertheless, the availability of synchrotron beamtime will always remain limited, even with the most brilliant sources for ultra-fast and high-throughput experiments. That is why the operation of and research with decentralized laboratory equipment becomes just as important. This presentation will therefore focus on the latest developments in laboratory sources in the hard X-ray regime for materials research. In this context, Helmholtz-Zentrum Berlin (HZB) has commissioned EXCILLUM's new high-flux MetalJet X-ray devices providing photon energies up to 70 keV and 160 keV, respectively. The presentation will give a summary of the technical specifications of these sources utilizing a liquid metal as anode material and the diffractometer lab installations operated with them at HZB. Selected experimental examples are shown providing an overview of applications performed at the MetalJet measuring stations - ranging from residual stress analysis on technical parts to real-time measurements on thin films for photovoltaics applying angle- and energy-dispersive diffraction as well as studies in the field of time-resolved imaging. A comparison to synchrotron measurements is made to benchmark the performance of the available setups. In conclusion, the effort and expenses required to operate such X-ray devices for in-house research and user service measurements are summarized.

WE2A1 -- Modified Maxwell-Bloch Equations for X-ray Amplified Spontaneous Emission in X-ray Lasers
Contributed Oral A - Linac-based Light Sources
Kwang-Je Kim, Ryan Roger Lindberg, Jeong-Wan Park (ANL, Lemont, Illinois)
Observations of stimulated emission in atomic media pumped by X-ray FELs have shown that X-ray lasers may be possible using the physical process referred to amplified spontaneous emission(ASE). The coherence and stability of an ASE-based X-ray laser can be improved in an X-ray laser oscillator (XLO)* by employing an X-ray cavity as in the X-ray FEL oscillator (XFELO). We present a Hamiltonian-based, 3D theory in paraxial approximation. Assuming factorization of operator products, the ensemble-averaged Heisenberg equations become Maxwell-Bloch equations which provide a correct description of the stimulated emission. The spontaneous emission is accounted for by adding a random noise term to the atomic coherence, which is uniquely determined from the fact that factorization does not apply for products of operators associated with the same atom. Our theory reproduces the results of the previous 1D theory ** and extends it in including the 3D diffraction effects, in including the seed field, and in incorporating the noise in more versatile way*. It provides a sound numerical framework to evaluate an X-ray laser, either in single pass or oscillator configurations. *A. Halavanau,et al., PNSA 117, 27 (2020). **A. Benediktovitch, et al., Phys. Rev. A 99, 013839 (2019) *** J.-W. Park, K.-J. Kim, and R. Lindberg, Phys. Rev. Lett., submitted This work is supported by the U.S. Department of Energy, Office of Science under Contract No. DE-AC02-06CH11357.**

WE2A2 -- An Analytical Method for Longitudinal Phase Space Backtracking
Contributed Oral A - Linac-based Light Sources
Nicholas Sigmund Sudar, Yuantao Ding (SLAC, Menlo Park, California)
Electron beam driven light sources require a longitudinal phase space exhibiting narrow energy spread and high peak current. In linear accelerators this is typically realized by employing multiple stages of bunch compression coupled with various techniques to shape the electron beam chirp. Increases in repetition rate limit many of these manipulations due to the high average beam power. This encourages manipulation of the electron beam properties at the source or low energy area of the accelerator. However, determining the upstream phase space properties that will lead to a particular final phase space proves difficult due to the many free variables of the accelerator and collective effects. Here we present an analytical method for tracking polynomial coefficients describing the final electron beam chirp and current profile backwards to an upstream point in the accelerator. This is written to arbitrary polynomial order and includes analytical expressions for collective effects. The method is applied to the LCLS-II linac, tracking from the undulator entrance back to the injector exit. The example case provided here leads to a 4 kA peak current flat top distribution and 0.1% RMS energy spread at the undulator entrance, representing a significant increase in the LCLS-II beam brightness. Forward tracking in Elegant of the found ideal distribution at the injector exit and accelerator configuration shows good comparison.

WE2A3 -- A Wiggler-based THz Source at LCLS-II and Studies for a 150-m THz Transport Line for Pump-probe Experiments
Contributed Oral A - Linac-based Light Sources
Meredith Henstridge, Alan Stephen Fisher, Matthias Clemens Hoffmann, Zhirong Huang (SLAC, Menlo Park, California)
Ultrafast THz pulses with energies of several µJ drive exotic non-equilibrium phenomena in complex materials, yet many of the underlying microscopic mechanisms remain unknown. Current strong-field THz sources rely mostly on difference-frequency mixing of near-infrared laser pulses in crystals at few-kHz repetition rates, but the extension of such sources to higher repetition rates suffers from reduced pulse energies and crystal damage. Here, we present a wiggler-based THz scheme capable of delivering 3-30 THz pulses with energies of 100 µJ at the 100 kHz rate supported by LCLS-II. Two time-delayed electron bunches independently drive the wiggler and x-ray undulator to generate precisely synchronized and optimized x-ray and THz pulses for pump-probe experiments. We built a model transport line to address the significant challenge of transporting the THz emission over the minimum 150-m distance necessary to reach the experimental halls. This concept, scaled to 12-m, has been tested with the 28 THz output of a CO2 laser. Results indicate that the THz emission can be transported over 150-m with an efficiency near 90%. Further testing is underway at 3.5 THz with a quantum-cascade laser.

WE2A4 -- Scaling of Beam Collective Effects with Bunch Charge in the CompacLight Free-electron Laser
Contributed Oral A - Linac-based Light Sources
Simone Di Mitri, Gerardo D'Auria, Regina Alexandra Rochow (Elettra-Sincrotrone Trieste S.C.p.A., Basovizza), Avni Aksoy (Ankara University, Golbasi), Andrea Latina, Xiaowei Wu, Walter Wuensch (CERN, Meyrin), James Clarke, David Dunning, Neil Thompson (Cockcroft Institute, Warrington, Cheshire; STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Federico Nguyen (ENEA C.R. Frascati, Frascati (Roma)), Michele Croia (ENEA Casaccia, Roma), Markus Aicheler (HIP, University of Helsinki), David Alesini, Marco Diomede, Massimo Ferrario, Alessandro Gallo, Anna Giribono, Jessica Scifo, Bruno Spataro, Cristina Vaccarezza, Alessandro Vannozzi (LNF-INFN, Frascati), Graeme Burt (Lancaster University, Lancaster), Hector Mauricio Castaneda Cortes (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Andrea Mostacci (Sapienza University of Rome, Rome), Vitaliy Goryashko (Uppsala University, Uppsala)
The CompactLight European consortium is designing a state-of-the-art X-ray free-electron laser driven by radiofrequency X-band technology. Rooted in experimental data on photo-injector performance in the recent literature, this study estimates analytically and numerically the performance of the CompactLight delivery system for bunch charges in the range 75-300 pC. Space-charge forces in the injector, linac transverse wakefield, and coherent synchrotron radiation in bunch compressors are all taken into account. The study confirms efficient lasing in the soft X-rays regime with pulse energies up to hundreds of microjoules at repetition rates as high as 1 kHz.

WE2C1 -- Population Inversion X-ray Laser Oscillator at LCLS and LCLS-II
Contributed Oral C - Compact Light Sources
Aliaksei Halavanau, Andy Aquila, Uwe Bergmann, Claudio Pellegrini (SLAC, Menlo Park, California), Andrei Benediktovitch (DESY, Hamburg), Nina Rohringer (Max Planck Institute for the Physics of Complex Systems, Dresden), Nathan Majernik (UCLA, Los Angeles, California), Noah Welke (UW-Madison/PD, Madison, Wisconsin)
The advancement of X-ray Free Electron Lasers (XFELs) has created revolutionary new research opportunities, owing to their high peak and average power, transverse coherence, and short pulse duration. Despite their remarkable capabilities, XFEL pulses lack longitudinal coherence and are not transform-limited, which limits their utilization, e.g. in quantum optics and precision interferometry. We explore the development of coherent, transform-limited pulses through alternative strategies, namely, X-ray lasers based on population inversion. We propose a novel approach relying on the principle of stimulated emission in the hard X-ray regime, using the XFEL as a pump. We will specifically discuss the case of the X-ray Laser Oscillator (XLO) at the LCLS copper linac and the planed LCLS-II-HE. Our recent work has shown the feasibility and performance characteristics of these systems, which can operate over a broad wavelength range from 5 to 12 keV. Future applications at LCLS-II-HE might allow for transform-limited XLO pulses with repetition rates up to tens of kHz. We show that XLO is experimentally feasible and discuss its projected performance and photon pulse properties operating at the Copper K-alpha1 line. Finally, we discuss possible first experiments with XLO.

WE2C2 -- Harmonic Generation from keV-electron-excited Nano-grating
Contributed Oral C - Compact Light Sources
Yen-Chieh Huang (NTHU, Hsinchu)
There has been a recent interest in using free electrons to interact with photonic structures and generate light. The envisaged dielectric accelerator on a chip is a low-current electron source driven by a laser. The generated electron beam contains a few electrons in each optical cycle repeating at the driver laser frequency. We perform a feasibility study in this paper on the harmonic generation of a periodic array of single electrons with keV energy atop a dielectric grating waveguide. The device is a 31 um long silicon grating on top of a glass substrate, having a 400 nm thickness and 310-nm period. The structure is designed to have a Bragg resonance at 1.5 um in wavelength or 0.2 PHz in frequency for the radiation mode. We use the simulation code CST to study the radiation from a periodic array of 25 electrons. The electrons have 50 keV energy, injected one by one at 0.1 PHz at 100 nm above the grating. The transit time of the 50 keV electrons over the 31 um long silicon grating is 0.25 ps. Cherenkov radiation is guided in the silicon waveguide layer. Smith-Purcell (SP) radiation is generated in the vacuum region above the grating. We show in simulation a ring-down of the generated coherent radiations from both ends of the grating waveguide, indicating that a grating waveguide is a good Bragg resonator. The field pattern in the waveguide region satisfies the Bragg condition, i.e. structure periodicity = half of the longitudinal wavelength. The Fourier transform of the generated radiation wave has a narrow radiation spectrum at 0.2 PHz. A discrete spectrum of SP radiation mediated by the waveguide modes is also observed from simulation in the vacuum space above the grating waveguide. This study shows the feasibility of generating harmonic radiation from a nano-photonic structure driven by keV periodic electrons. MOST 111-2221-E-007-001, Taiwan

WE3A1 -- High Pulse Rate Experiments at the European X-ray Free-electron Laser
Invited Oral A - Linac-based Light Sources
Romain Letrun (EuXFEL, Schenefeld)
The rise of superconducting accelerator technology has brought forth an increase in the pulse rate produced by X-ray free-electron lasers (XFELs) by two orders of magnitude*, up to now, with a further increase on the horizon at new and existing facilities. The high pulse rate has opened up new opportunities for the scientific community, not only in terms of the volume of data that can be acquired, but also in the design of experiments that leverage the high pulse rate. However, these advances come with new challenges, such as replenishing the sample fast enough between X-ray pulses and ensuring high repetition rate detection of the signals produced. This presentation will give an overview of experiments performed to date at the Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (SPB/SFX) instrument that have taken advantage of the high number of pulses and repetition rate provided by the European XFEL and illustrate how some of the key challenges have been addressed. An outlook to future developments and wishes from the user community regarding increased duty cycle operation will also be discussed. * Decking, W. et al. Nat. Photonics 14, 391 (2020) ** Mancuso, A. P. et al. J. Synchrotron Radiat. 26, 660 (2019)**

WE3A2 -- Beam on Demand for Superconducting Based Free-electron Lasers
Contributed Oral A - Linac-based Light Sources
Zhen Zhang, Zhirong Huang (SLAC, Menlo Park, California)
The multiplexing capabilities of superconducting-based X-ray free-electron lasers (FELs) have garnered significant attention in recent years. The need for wide-ranging photon properties from multiple undulator lines calls for more flexible beam manipulation techniques. To fully realize the potential of superconducting-based FEL facilities, the concept of "beam on demand" has been introduced, offering tailored beam properties for each undulator line at the desired repetition rate. In this work, we present the efforts made at LCLS-II to enhance its multiplexing capabilities, including (1) development of a normal conducting cavity, known as a chirper, to achieve shot-by-shot control of beam compression; and (2) proposal of a multiplexed configuration for the LCLS-II injector to deliver low-emittance electron beams of varying beam charges at high repetition rates. The implementation of these techniques can significantly enhance the flexibility and improve the performance of the facility.

WE3A3 -- Multi-FELOs Driven by a Common Electron Beam
Contributed Oral A - Linac-based Light Sources
Cheng-Ying Tsai (HUST, Wuhan), Yuhong Zhang (JLab, Newport News, Virginia)
Generating an FEL requires a high-brightness electron beam. To produce multiple FELs, the linac beam must be shared to enable one beam driving an undulator. This leads to a reduced average current and compromised FEL performance. Recently, a concept of multiple FELs driven by one electron beam was proposed, which enables reduction of equipment and improvement of productivity. We present here a simulation study based on an extended 1D FEL oscillator model to demonstrate this concept. The system consists of two FEL oscillators arranged side-by-side and one electron beam passing through them. As such, the second, downstream oscillator is driven by bunches already been used once, while the first oscillator always receives fresh bunches from the linac. The study shows lasing could be achieved for both oscillators, their radiation intensities at saturation are comparable, thus meet needs of users. The concept also enables a potential application using a circulator ring such that an oscillator can be driven alternately by fresh linac bunches from and used bunches in the circulator ring. Extending the concept to cases of more than two FEL oscillators driven by one beam is also explored.

WE3A4 -- Energy Recovery Linac Based Multi-pointing Fully Coherent Light Source
Contributed Oral A - Linac-based Light Sources
Zhen Wang, Chao Feng, Zhentang Zhao (SARI-CAS, Pudong, Shanghai)
Energy recovery linac (ERL) holds great promise for generating high repetition-rate and high brightness electron beams.In this paper, we consider the combination of ERL with the recently proposed anglerangular-dispersion induced microbunching technique to generate fully coherent radiation pulses with high average brightness and tunable pulse length.Besides, we design a multiplexed emitting system, which consists of multi-bend achromats (MBAs), matching sections and radiators to support multi-beamline operation in the long straight section of the ERL.Theory and simulation have been carried out and the results indicate that the microbunching and beam quality maintains well after four times of bending, indicating the continuously radiation with the wavelength of 13.5 nm and the peak power of 2 MW.

WE3A5 -- Development of Multi-alkali Antimonides Photocathodes for High-brightness Photoinjectors
Contributed Oral A - Linac-based Light Sources
Sandeep Kumar Mohanty, Mikhail Krasilnikov, Anne Oppelt, Frank Stephan (DESY Zeuthen, Zeuthen), Laura Monaco, Daniele Sertore (INFN/LASA, Segrate (MI)), Carlo Pagani (INFN/LASA, Segrate (MI); Università degli Studi di Milano & INFN, Segrate), Wolfgang Carl Albert Hillert (University of Hamburg, Hamburg)
Multi-alkali antimonide photocathodes can have high quantum efficiency similar to UV-sensitive (Cs2Te) photocathodes but with the advantages of photoemission sensitivity in the green wavelength and a significant reduction in the mean transverse energy of photoelectrons. In order to optimize and better understand the photo emissive film properties of K-Cs-Sb photocathodes, a batch of two photocathodes with different thicknesses was grown on molybdenum substrates via a sequential deposition method in a new preparation system at INFN LASA. During the deposition, a "multi-wavelengths" diagnostic, i.e., the measurements of the real-time photocurrent and reflectivity at different wavelengths, has been applied during the photocathode film growth.In addition, in the framework of density functional theory (DFT), we investigated the electronic and optical properties of K(_2)CsSb material. This allowed us to establish a correlation between the calculated and measured optical properties, such as reflectivity. In this report, we present and discuss the experimental results obtained from the two different thickness K(_2)CsSb photocathodes, along with the DFT results of K(_2)CsSb material. This work was supported by the European XFEL re-search and development program.

WE3A6 -- A High Brightness Travelling-wave C-Band Photogun for a Brightness Upgrade to Swissfel
Contributed Oral A - Linac-based Light Sources
Thomas Geoffrey Lucas (PSI, Villigen PSI)
One of the performance limiting factors of the next generation of XFELs is the generation of high brightness electron bunches. The current generation of S-band RF photoguns have reached their brightness limit. To continue to push brightness boundaries, a new photogun concept is needed. This contribution presents the design of a novel travelling-wave RF photogun that operates in the C-band regime. Beam dynamics simulations of this photogun illustrate that it can achieve a 5D beam brightness five times greater than the SwissFEL standing-wave gun. With the increased beam brightness, it is expected that intrabeam scattering (IBS) will play a more significant role through increasing the sliced energy spread (SES). Calculations of the IBS-induced SES illustrate that the increase in SES does not completely undo the brightness gain. We present the evolution of the SES over the injector and discuss how it influences the concept of optimising the beam brightness of an injector. Finally, this novel design also offers a path forward into higher repetition rate operation through its low attenuation, travelling-wave philosophy. This opens up the possibilities of operation into the kHz regime. This project has received funding from the European Unions Horizon 2020 Research and Innovation program under GA No101004730.

WE3D1 -- Femtosecond Synchronization of Large Scale FELs - Achievements, Limitations and Mitigation Paths
Contributed Oral D - Key Technologies
Holger Schlarb, Marie Kristin Czwalinna, Sebastian Schulz (DESY, Hamburg)
Over the past decade, synchronization of large-scale accelerators has advanced from picosecond stability reaching nowadays few femtoseconds only. Driver behind these developments are Free-Electron Lasers, requiring high electron beam compression factor for lasing and the production of ultra-short photon pulses for precision time-evolution experiments in pump-probe laser arrangements. The high control demand of FELs on their electron beam phase space and arrival time triggered a series of key technology development in the accelerator community. These developments span for state-of-the-art RF components, pushing the limits on precision RF cavity control, ultra-stable optical reference distributions to novel new beam diagnostic techniques, all aiming to reach femtosecond beam and pump-probe stabilities. In this presentation, an introduction to key elements causing beam arrival time instabilities and synchronization losses is given. Using EuXFEL and FLASH at example, achievable performance with currently available technologies are summarized. Limitations towards single digit femtosecond or even attosecond synchronization are discussed together with possible mitigation paths.

WE3D2 -- Advanced Electron Beam Diagnostics for FELs
Contributed Oral D - Key Technologies
Patrick Krejcik (SLAC, Menlo Park, California)
The critical electron beam instrumentation needs for FELs are identified - high-resolution beam position and alignment, emittance and energy spread, and longitudinal profile measurements. The performance limitations for each are discussed and state-of-the-art techniques from several FEL light source facilities will be presented. New challenges for integrating instrumentation in SC undulators are also addressed. A survey of proposals for advanced techniques will be included, especially those focusing on sub-fs resolution for longitudinal measurements and synchronization for attosecond science.

WE3D3 -- Beam Diagnostics for Ultra-low Emittance Storage Rings
Contributed Oral D - Key Technologies
Volker Schlott (PSI, Villigen PSI)
Multi-bend achromat (MBA) lattices have enabled the realization of ultra-low emittance storage rings as diffraction-limited synchrotron radiation sources providing much higher photon brilliance and coherence in the wavelength range of hard x-rays than third generation user facilities. While advances in technology and continuous upgrading of state-of-the-art diagnostics systems have already led to outstanding performance levels of beam instrumentation at the present generation of light sources, more stringent demands on beam stability and control induce a number of technical improvements and stimulate advanced concepts of combining electron and photon beam-based signals. Based on diagnostics requirements for diffraction-limited light sources, this talk will give an overview of new electron and photon beam instrumentation developments and highlight beam stabilization concepts aiming for the exploitation of the full capacity of fourth generation synchrotron radiation user facilities.

WE4P01 -- Numerical Simulation Studies of Superconducting Afterburner Operation for European XFEL
Poster A - Linac-based Light Sources
Christoph Lechner, Sara Casalbuoni, Gianluca Geloni, Svitozar Serkez, Harald Sinn (EuXFEL, Schenefeld), Evgeny Schneidmiller (DESY, Hamburg)
European XFEL is a multi-beamline x-ray free-electron laser (FEL) user facility driven by a superconducting linear accelerator with a nominal photon energy range from 250 eV to 25 keV. To extend the photon energy range towards harder x-rays, an afterburner undulator based on superconducting undulator (SCU) technology is currently being planned. This afterburner undulator would be installed at the end of the already operating SASE2 hard X-ray FEL beamline, emitting at a harmonic (or at the fundamental) of the upstream undulator system. In this contribution we describe numerical simulations of the potential photon output.

WE4P02 -- High-Duty-Cycle Operations at European XFEL
Poster A - Linac-based Light Sources
Matthias Scholz, Julien Branlard, Winfried Decking, Nicholas Walker (DESY, Hamburg)
The European XFEL has been in operation since 2017, when the photon pulse delivery for the first user experiments started. Currently, three FEL undulator beamlines are supplied by a common linear accelerator, two in the hard X-ray and one in the soft X-ray range. The maximum electron beam energy of up to 17.5 GeV is achieved using superconducting accelerator technology, which allows an effektive beam pulse length of 600 us to be delivered at a 10 Hz repetition rate, resulting in a duty cycle of 0.6%. Up to 2700 bunches can be accelerated per pulse at an internal pulse repetition rate of up to 4.5 MHz. The majority of the photon users take advantage of these unique capabilities of the long pulse trains. In order to even better represent the interests of the user groups, we are discussing various options for operating the RF linac in an adapted mode with a higher duty cycle. The considered options cover the range from duty cycles of 1% up to CW. For the pulsed modes, we are discussing different combinations of pulse rates and pulse lengths to understand which is the best combination at the given duty cycle. The studies also include possible effects on other components of the facility. The results of these considerations, summarised under the heading "High-Duty-Cycle Operations", are intended as recommendations for a possible major update of the European XFEL.

WE4P04 -- Intra-train RF Modulations for Interleaved FEL Beam Delivery at the European XFEL
Poster A - Linac-based Light Sources
Bolko Beutner, Julien Branlard, Nicholas Walker (DESY, Hamburg)
At he European XFEL bunch trains of max 600 microsecond length are produced with up to 4.5 MHz bunch spacing in variable patterns. The hard X-ray line SASE1 and the soft X-ray line SASE3 share one beam path and bunches for both lines are delivered in a so-called interleaved mode. In this interleaved mode bunches for both lines are typically separated by up to 2.2 MHz. For each undulator line an individual tuning of the bunch compression is required for optimal FEL performance in SASE and especially in special modes like non-linear compression. While it is already established to use different RF parameters on the RF pulse in so-called beam regions it is not suitable for the interleaved mode since such operation required a transition time of around 50 microsecond. It is however possible introduce on a small scale fast modulations of the RF pulse to allow for separate tuning in interleaved modes. These modulations can be adjusted in frequency and amplitude, their tuning range is eventually limited by the available klystron power. We will discuss and present RF and beam related studies of these modulations as a preparation for interleaved beam FEL delivery.

WE4P05 -- Self-seeded Free-electron Lasers with Orbital Angular Momentum
Poster A - Linac-based Light Sources
Jiawei Yan, Gianluca Geloni (EuXFEL, Schenefeld)
X-ray beams with orbital angular momentum (OAM) have emerged as a powerful tool for investigating matter. Various x-ray free-electron laser (XFEL) operation modes capable of generating OAM light have been suggested, but most of these methods necessitate the use of external laser systems, helical undulators, or XFEL oscillators. As such, a compelling interest has surfaced to produce intense OAM light employing planar undulators via the widely used Self-Amplified Spontaneous Emission (SASE) or self-seeding operation modes. This presentation will discuss the Self-Seeded FEL with OAM (SSOAM) method that we recently proposed*. This novel approach aims to generate intense x-ray vortices while overcoming the constraints of traditional techniques. * Jiawei Yan, and Gianluca Geloni, "Self-seeded free-electron lasers with orbital angular momentum", Advanced Photonics Nexus 2.3 (2023) 036001

WE4P06 -- Bayesian Optimization-driven Automated Commissioning of X-ray Free-electron Lasers
Poster A - Linac-based Light Sources
Jiawei Yan (EuXFEL, Schenefeld), Farzad Jafarinia (DESY, Hamburg)
This work presents the application of Bayesian Optimization in the automated commissioning of X-ray Free-Electron Lasers (XFELs). The intricacies of XFELs have necessitated a complex tuning process that often requires significant time and expertise. We leverage Bayesian Optimization, a robust machine learning technique, to efficiently explore and optimize this nonlinear system. The preliminary results from tests conducted on the European XFEL demonstrate the potential of this methodology in enhancing XFEL pulse qualities.

WE4P07 -- Longitudinal Phase Space Diagnostics with Corrugated Structure at the European XFEL
Poster A - Linac-based Light Sources
Philipp Dijkstal, Nina Golubeva, Sergey Tomin (DESY, Hamburg)
Longitudinal phase space (LPS) control at the European XFEL is facilitated by direct diagnostics after the undulator section. A one-sided corrugated wakefield structure is installed after the SASE2 hard X-ray undulator beamline, and can nonlinearly streak the electron beam. This device is now routinely used for diagnostics, particularly for machine development and beam setup of special modes such as self-seeding. In this contribution we show example LPS and FEL power profile measurements, and estimate the time and energy resolution.

WE4P08 -- Longitudinal Phase Space Manipulation Studies for the Generation of Short X-ray FEL Pules at the European XFEL
Poster A - Linac-based Light Sources
Philipp Dijkstal, Ye Chen, Marc Walter Guetg, Weilun Qin, Sergey Tomin (DESY, Hamburg), Gianluca Geloni, Jiawei Yan (EuXFEL, Schenefeld)
In preparation of the ASPECT project* we performed preliminary experiments at the SASE2 hard X-ray beamline at the European XFEL. ASPECT is a project for sub-fs FEL pulse generation based on the chirp/taper and ESASE methods. To generate the required electron beam energy chirp, an external laser for the electron beam energy modulation is foreseen. An alternative solution, not requiring an external laser, is self-modulation with coherent synchrotron radiation and space charge. For the self-modulation methods we performed simulations and experimental studies to explore the capabilities of the existing facility to generate short FEL pulses at the standard 250 pC bunch charge. In experiments we employed the recently developed wakefield streaking LPS diagnostics**, as well as spectral photon beam diagnostics. * contribution 2103 by J. Yan et al. ** contribution 2308 by P. Dijkstal et al.

WE4P09 -- Terahertz Radiation and Joule Heating of Corrugated Structure at Shine Facility
Poster A - Linac-based Light Sources
Jun-Jie Guo (Zhangjiang Lab, Shanghai), Haixiao Deng, Duan Gu, Meng Zhang (SARI-CAS, Pudong, Shanghai)
Corrugated structure modules are being proposed for installation after the end of the linac and before the undulator regions of SHINE facility, where it has been used for energy chirp control and as a fast kicker for two color operation of the FEL.When ultra-relativistic bunch of electrons passing through corrugated structure will generate strong wakefield, we find most of the wake power lost by the beam is radiated out to the sides of the corrugated structure in the form of THz waves, and the remaining part casue Joule heating load on the corrugated structure wall. In this paper, we estimate the Terahertz radiation power and Joule power loss of the corrugated structure in SHINE facility.

WE4P10 -- Cavity-based X-ray Free-electron Laser Proposal for the SHINE
Poster A - Linac-based Light Sources
Nanshun Huang (Zhangjiang Lab, Shanghai), Haixiao Deng (SARI-CAS, Pudong, Shanghai)
The cavity-based X-ray free-electron laser (XFEL) is a promising for producing fully coherent pulses with a bandwidth of a few meV and very stable intensity. In contrast, the currently existing self-amplified spontaneous emission (SASE) XFEL generates ultra-short pulses with chaotic spectra. Generally, cavity-based XFEL can provide spectral brightness three orders of magnitude higher than that of the SASE mode, opening new doors for cutting-edge scientific research. With the development of superconducting MHz repetition rate XFEL facilities, such as European-XFEL, LCLS-II, and SHINE, cavity-based XFEL operation becomes more achievable. In this paper, we propose Megahertz cavity-enhanced x-ray Generation (MING) based on Chinaḉs first hard XFEL facility, SHINE, i.e., MING@SHINE.

WE4P11 -- Automatic Online Optimization at the SXFEL Facility
Poster A - Linac-based Light Sources
Nanshun Huang (Zhangjiang Lab, Shanghai), Haixiao Deng, Chao Feng, Tao Liu (SARI-CAS, Pudong, Shanghai)
The commissioning phase of short-wavelength FEL is often lengthy due to the optimization of thousands of control variables. These variables are frequently interdependent and have non-linear correlations with FEL performance, which makes optimization of such a complex system challenging, particularly for soft XFEL. Additionally, FEL inherently suffers from shot-to-shot intensity jitter, which necessitates online optimization in the presence of strong noise. In this study, we report the results of our experiments using an evolutionary strategy algorithm to enhance FEL intensity despite large intensity jitter.

WE4P12 -- Upgrades of High Level Applications on Shanghai Soft X-ray FEL facility
Poster A - Linac-based Light Sources
Hang Luo, Duan Gu, Zhen Wang (SARI-CAS, Pudong, Shanghai), Kaiqing Zhang (SSRF, Shanghai)
The Shanghai soft X-ray free electron laser facility has made significant progress in recent years with the rapid, upgraded iterations of the High Level software, including but not limited to energy matching, orbit's feedback and load, beam optimization, etc. These tools are key components in operation and experiment of free electron laser facility. Some key applications are presented in this paper.

WE4P13 -- Physics Design and Beam Dynamics Optimization of the SHINE Accelerator
Poster A - Linac-based Light Sources
Duan Gu (SARI-CAS, Pudong, Shanghai)
Shanghai High Repetition Rate X-ray Free Electron Laser and Extreme Light Facility (SHINE) is a hard X-ray FEL facility which is driven by a superconducting Linac, aims to provide high repetition rate pulses up to 1 MHz. In this study, we present the comprehensive physics design of the SHINE accelerator and systematically demonstrate the procedures and considerations of beam dynamics optimizations. Start-to-end simulation results show that based on this design, a 100 pC beam with normalized projected emittance less than 0.5 mm mrad and over 1500A flat-top beam current can be attained which fully meet the requirments of FEL lines. Furthermore, optimizations of additional working points are studied in order to enable advanced FEL schemes.

WE4P14 -- Progress of the X-Ray Self-seeding Monochromator at the SHINE
Poster A - Linac-based Light Sources
Tao Liu, Haixiao Deng, Chao Feng, Wei Liu (SARI-CAS, Pudong, Shanghai), Kaiqing Zhang (SSRF, Shanghai)
Self-seeding is one of the FEL baseline modes at the SHINE, which is able to generate fully coherent X-ray FEL pulse and has been operated at several X-ray FEL facilities worldwide. For a wider spectrum coverage of the fully coherent X-ray radiation, the grating and crystal based monochromators as the critical parts of the X-ray self-seeding are adopted at the facility. Currently the scheme design and the technological design of the monochromators have been carried out, and we will introduce the progress of the schemes from the basic physical design to the technological design in this manuscript.

WE4P15 -- Multi-color FEL Generation Through a Chirped Electron Beam Bunch Train
Poster A - Linac-based Light Sources
Zheng Qi (SARI-CAS, Pudong, Shanghai)
We demonstrate a simple method to generate two-color or multi-color soft x-ray FEL pulses. This method mainly uses a chirped electron beam working together with an EEHG alike modulator and chicane setup to produce electron beam bunch trains. And these bunch trains can be used to generate multi-color FEL pulses. By tuning the configurations and parameters of the method, we can easily adjust the property of the multi-color FEL pulse.

WE4P17 -- Design Concept for a High Repetition Rate VUV FEL
Poster A - Linac-based Light Sources
Pavel Evtushenko, J. Michael Klopf, Ulf Lehnert (HZDR, Dresden), Peter Michel (HZDR, Dresden; Rostock University, Rostock)
While significant progress has been made in the development of FELs toward ever-shorter wavelengths, less attention has been directed toward FEL sources of VUV/XUV radiation. This part of the spectrum though offers an ideal tool to advance the understanding of the dynamic processes in matter such as light-driven charge transfer, phase changes, and chemical reactions. Synchrotron sources have long provided exceptional resolution of electronic distributions and bonding characteristics, but they are limited to measurements of slow dynamics or equilibrium processes. Laser-based HHG sources can deliver the ultrashort pulses needed for higher temporal resolution, but do not match FEL sources for spectral brightness. We present here a conceptual design for a VUV FEL with exceptionally high stability and spectral brightness, while operating at a high repetition rate*. The VUV FEL is based on an HGHG configuration, utilizing the intracavity field of an oscillator FEL as the seed to provide the necessary modulation before radiation at a higher harmonic. The continuous tunability, high spectral brightness, and stability of an oscillator FEL provides an ideal seed source. The design relies on continuous operation at a high rep. rate, which is achieved with a multi-pass CW SRF linac. The concept is designed to provide transform-limited pulses with a tuning range of 50-250 nm (5-25 eV) in the fundamental at up to 30 µJ/pulse. The high rep. rate is ideal for 'photon-hungry' experiments, such as reaction dynamics in gas phase chemical reactions relevant for combustion, catalysis, and astrochemistry. In combination with other sources, such as accelerator driven THz sources, such an FEL can help answer questions surrounding light-driven phase changes and pave the way toward coherent control of complex chemical and biological processes. * M. Helm, et al., EPJ Plus 138, 158 (2023).

WE4P18 -- Preliminary Design of Higher-Order Achromat Lattice for the Upgrade of the Taiwan Photon Source
Poster B - Ring-based Light Sources
Nuan-Ya Huang, Mau-Sen Chiu, Ping Jung Chou, Gwo-Huei Luo, Hung-Jen Tsai, Fan-Hsin Tseng (NSRRC, Hsinchu)
We plan to upgrade the Taiwan Photon Source (TPS) for a green design with energy saving as the prime objective. The upgrade design is dubbed TPS-II. To accommodate the constraints imposed by the existing TPS tunnel, we choose the design of higher-order achromat (HOA) lattice which is composed of the 5BA and 4BA cells. The HOA lattice produces a natural beam emittance about 160 pm-rad. The on-momentum dynamic aperture (DA) is about 5 mm and the estimated Touschek life time is about 6.7 hours at total beam current of 500 mA. As a result of the ultralow beam emittance, the brightness and coherence fraction of the photon beam are improved with a factor of several tens especially in the photon wavelength around 0.1 nm. The challenges and preliminary results of this HOA lattice design will be presented.

WE4P19 -- Study of Orbit Correction by Machine Learning at the TPS Storage Ring
Poster B - Ring-based Light Sources
Mau-Sen Chiu, Ping Jung Chou (NSRRC, Hsinchu)
Taiwan photon source (TPS) is a 3rd generation of synchrotron light source of 3 GeV. To stabilize the electron orbit, it is equipped with fast orbit feedback and slow orbit correctors. The orbit correction method is by the orbit response matrix and singular value decomposition (SVD). In recent years, machine learning techniques are widely used to accelerator control. We shall present the results of orbit correction by machine learning in TPS storage ring.

WE4P20 -- Alignment Results of Tandem EPUs at the Taiwan Photon Source
Poster B - Ring-based Light Sources
Yi-Chih Liu, Chia-Mu Cheng, Ting-Yi Chung, Yuan-Ming Hsiao, Fan-Hsin Tseng (NSRRC, Hsinchu)
Taiwan Photon Source (TPS) has been open to user operation since 2016. We report the alignment results of tandem EPUs in one double mini-beta y long straight section. The goal is to increase the brilliance of the synchrotron lights produced by the tandem EPUs through well-alignment and using a phase shifter to achieve both spatial and temporal coherence. The calculated brilliance gain of the tandem EPUs is compared, and the difference between the measured and numerical results is analyzed.

WE4P21 -- Some Beam Dynamic Issues in the HALF Storage Ring
Poster B - Ring-based Light Sources
Jingyu Tang (USTC,SNST, Anhui), Zhenghe Bai, Gangwen Liu, Yihao Mo, Penghui Yang, Zhouyu Zhao (USTC/NSRL, Hefei, Anhui)
HALF (Hefei Advanced Light Facility) is a fourth-generation synchrotron light source that just started the construction in 2023. With 2.2 GeV in energy, 350 mA in beam current and 83 pm.rad in emittance, the HALF storage ring faces several beam dynamics challenges. This presentation gives the recent study on some of these issues, in particular the beam collimation and the influence and compensation of the insertion devices. For the beam collimation, different beam loss mechanisms have been studied, and the Touschek scattering and beam dumping are considered the two major effects in designing the collimation system. Then two collimators with movable horizontal blades and fixed passive vertical blades are being designed, with the main focus on the collimation efficiency and impedance. For the influence of the insertion devices, it is found that some of the long-period undulators have high impact on the beam dynamic aperture due to low beam energy and originally small dynamic aperture. The local compensation methods for both linear and non-linear effects have been studied. Instead of the traditional compensation method by electrical wires, two combined magnets with quadrupole and octupole fields at the two ID ends are found more effective in restoring the dynamic aperture.

WE4P22 -- Optics Measurements Based on 3D-Driven Beam Excitation in PETRA III
Poster B - Ring-based Light Sources
Lukas Malina, Joachim Keil, Gajendra Kumar Sahoo, Michaela Schaumann (DESY, Hamburg), Nicola Carmignani (ESRF, Grenoble)
One of the ways to measure beam optics in storage rings is to employ turn-by-turn (TBT) beam position monitor (BPM) data of transversely excited beams. In synchrotron light sources, such a technique is often not used, primarily because of the need for a lengthy BPM setup in spite of a significantly faster measurement. Beam optics is then inferred from orbit response matrix (ORM) measurement. This paper demonstrates a solution to the BPM setup and measurements of optical parameters based on transverse and 3D-driven beam excitations in PETRA III. We compare the optical parameters measured from TBT BPM data to those inferred from ORM. Finally, we report on developing high-level controls application, automation of the measurement procedure and its requirements on the control system.

WE4P23 -- Python Library for Simulated Commissioning of Storage-ring Accelerators
Poster B - Ring-based Light Sources
Lukas Malina, Bianca Veglia (DESY, Hamburg), Lina Hoummi, Simone Maria Liuzzo (ESRF, Grenoble), Thorsten Hellert (LBNL, Berkeley, California)
Simulations of the commissioning procedure became vital to the storage-ring lattice design process. The achievable tolerances on lattice imperfections, such as equipment misalignments or magnet gradient errors, would, without correction, prohibit reaching the design parameters. We present a Python library which includes an extensive set of error sources in the accelerator lattice and provides a variety of correction algorithms to commission a storage ring. The underlying beam dynamics simulations are performed with pyAT. This project builds upon previous works and expands them in the direction of realistic control room experience and software maintainability. The performance is demonstrated using example commissioning studies, and further development plans are discussed.

WE4P24 -- Optics for an Electron Cooler for the EIC Based on an Electron Storage Ring
Poster B - Ring-based Light Sources
Jorg Kewisch, Alexei V. Fedotov, Xiaofeng Gu, Yichao Jing, Dmitry Kayran, Igor Pinayev, Sergei Seletskiy (BNL, Upton, New York)
An electron cooler based on a storage ring is one of the options to improve the luminosity in the Electron-Ion Collider (EIC). The transverse emittance of the electrons in the cooler is driven by the quantum excitation in dipoles and wigglers, as well as by both beam-beam scattering with the ions and intra-beam scattering of the electrons in the regions with a non-zero dispersion. The resulting demand to minimize a dispersion conflicts with the need of a sufficient dispersion in sextupoles for chromaticity correction. In this report we discuss our studies of several approaches to electron ring lattice, including those typically used in light sources, and present resulting compromise between various requirements. **Supported by the US Department of Energy, Contract DE-SC0012704**

WE4P25 -- Nonlinear Dependence of Storage Ring Emittance on Chromaticity
Poster B - Ring-based Light Sources
Jingyi Tang, Xiaobiao Huang (SLAC, Menlo Park, California)
We present an unusual case where the equilibrium emittance of a storage ring exhibits strong, quadratic dependence on the chromaticity. For this case, beam motions in the vertical and longitudinal directions are coupled through crab cavities. Previous study* has shown that the linear y-z coupling gives rise to contribution to the vertical emittance. Simulation and analysis show that the nonlinear coupling due to the vertical chromaticity causes a nonlinear dependence on the latter. In the analysis, the nonlinear decoupling transformation is found through the normal form approach and is verified with particle tracking. The nonlinear emittance dependence predicted by the analysis agrees with simulation. The findings have important implications for the 2-frequency crab cavity short pulse scheme, and may be potentially relevant in colliders that employ crab cavities in the interaction region. * J. Tang, X. Huang, PRAB 25, 074002 (2022), https://journals.aps.org/prab/pdf/10.1103/PhysRevAccelBeams.25.074002

WE4P26 -- High Average Power EUV from FEL Oscillator in Storage Ring
Poster B - Ring-based Light Sources
Changchao He (SINAP, Shanghai)
Generating high average power extreme ultraviolet (EUV) radiation is one of the key technologies for the large-scale production of smaller process integrated circuits. Here, a scheme is proposed that a storage ring is combined with a FEL oscillator as an EUV light source. In our scheme, the storage ring has the advantage of high repetition rates and therefore can significantly increase the average power of light source. In the FEL oscillator, a small part of EUV light is reflected as seeding source. The electron beam is balanced between the radiation damping of the storage ring and the radiation of the FEL oscillator. We also discuss the methods to further increase the output power of extreme ultraviolet light in this research.

WE4P27 -- Simulation Study of S-Bend Photocathode Gun for 4th Generation Storage Ring in Korea
Poster B - Ring-based Light Sources
Chang-Ki Min, Woo Jun Byeon, Taekyun Ha, Sung-Ju Park, Yong Jung Park (PAL, Pohang)
The global trend towards the development and construction of 4GSR (4th Generation Storage Ring) facilities has been increasing. Research on photocathode guns, which are devices used to generate high-quality electron beams, has been actively carried out to achieve excellent electron beam quality and performance. As a result, there is a growing adoption of photocathode guns in accelerators worldwide. In line with this global trend, the 4GSR facility currently under construction in Korea is also planning to incorporate photocathode guns. In this study, a preliminary design of an S-bend photocathode gun applicable to the Korea-4GSR facility operating in multi-bunch mode was performed. To facilitate the design process, the structure of a PAL-XFEL (Pohang Accelerator Laboratory X-ray Free-Electron Laser) 1.6-cell gun was modified, and corresponding simulations were performed to analyze its electromagnetic characteristics. The dimensions of the cavity, which provide a resonant frequency of 2997.56 MHz, were determined based on the simulation results obtained from the SUPERFISH code. Subsequently, optimization was carried out through the analysis of electromagnetic characteristics. **This research were supported in part by the korean Government MSIT(Multipurpose Synchrotron Radiation Construction Project).**

WE4P29 -- Design Study of a Booster Ring for a Fourth-Generation Storage Ring Light Source
Poster B - Ring-based Light Sources
Chong Shik Park (Korea University Sejong Campus, Sejong)
This study focuses on simulating the design of a booster ring for a fourth-generation storage ring light source, considering the magnetic field ramping process. The objective is to optimize the booster ring's parameters for improved performance during the ramping operation. The simulation evaluates various design choices, such as beam optics, magnetic field configurations, and lattice structures, while taking into account synchrotron radiation, space charge, and collective instabilities. By analyzing the beam emittance growth, beam lifetime, and stability under different operational scenarios, the study explores strategies to mitigate collective effects, minimize beam loss, and optimize beam quality during the magnetic field ramping process. The simulation results provide valuable insights for engineering and optimizing the booster ring, considering the specific challenges associated with magnetic field ramping.

WE4P31 -- Deterministic Approach to the Lattice Design of BESSY III
Poster B - Ring-based Light Sources
Bettina Christa Kuske, Paul Goslawski (HZB, Berlin)
Since 2021 HZB pursues the design of a 2.5 GeV storage ring as a successor of BESSY II in Berlin. The user's demand for diffraction-limited radiation at 1 keV corresponds to an emittance of 100 pm, making an MBA lattice indispensable. The envisaged location limits the circumference to ~350 m. MBA lattices are composed of smaller substructures that can be analyzed and optimized separately, before combining them into one super period. The prerequisite for this approach is a clear idea of the goal parameters and their prioritization, as the design process is dominated by permanent decisions between different options. The resulting generic baseline lattice for BESSY III is a simple structure with few non-linear elements, already fulfilling all goal parameters and showing a very compatible nonlinear behavior. This is our starting point for further optimizations including swarm or MOGA approaches. **Work supported by German Bundesministerium für Bildung und Forschung, Land Berlin, and grants of Helmholtz Association**

WE4P32 -- Quasi-Invariants Based Technique to Increase Dynamical Aperture
Poster B - Ring-based Light Sources
Jorge Fuentes, Armando Antillón, Jorge Hernandez, Edgar Sanchez (UNAM, Cuernavaca, Morelos), Alain Flores, Matías Moreno (Rejected,)
A technique for increasing the electron stability zone in a light source storage ring is described. The technique is based on the construction of a quasi-invariant polynomial in a neighborhood close to the origin of the phase space. A system of coupled differential equations for the functions involved in the quasi-invariant is obtained and solved with periodic boundary conditions. The problem of increasing the dynamic aperture is formulated in terms of an objective function, to be optimized, that quantifies the separation between the corresponding ellipse of the linear dynamics and a branch of roots of the quasi-invariant polynomial*. The optimization was performed with genetic algorithms. This technique has been applied to a one-dimensional unit cell model of 1.2 nmrad emittance, representing a third-generation light source, showing that, when compared with tracking simulations obtained with OPA, an increase in the dynamic aperture is obtained. Unit cell models of fourth-generation light sources are under study, and there is evidence that similar results could be obtained. * Nonlinear Dynamics, 2022, https://doi.org/10.1007/s11071-022-07675-1 ** Scientific Reports, 2023, https://doi.org/10.1038/s41598-023-27732-y** **This work was supported by UNAM-PAPIIT IN108522 and CONAHCYT CF-2023-I-119. E.A.S. is grateful to CONAHCYT for funding a postdoctoral fellowship.**

WE4P33 -- Design of 166.6 MHz HOM Damped Copper Cavity for the Southern Advanced Photon Source
Poster D - Key Technologies
Junyu Zhu (IHEP, Beijing)
The Southern Advanced Photon Source (SAPS) is a mid-energy fourth generation synchrotron light source aiming to achieve emittance below 50 pm.rad. It is expected to adopt on-axis injection schemes due to a very small dynamic aperture. Low frequency rf systems are required for a large separation between RF buckets due to the limitations of kicker technology. A 166.6 MHz HOM damped copper cavity was designed for the main cavity of storage ring. In this paper, we present the simulation studies of cavity including electromagnetic, HOMs, mechanical, and thermal calculations. A compact beam line absorber was adopted to damp HOMs. The simulation results show that it can effectively suppress the HOMs, but has no effect on the accelerating performance.

WE4P34 -- Cathode-to-injection Simulation of the Advanced Photon Source lLnac
Poster D - Key Technologies
Philippe Regis-Guy Piot (Northern Illinois University, DeKalb, Illinois), Yine Sun (ANL, Lemont, Illinois)
Understanding the beam dynamics in the Advanced Photon Source linac including collective effect is critical to high-charge operation. In this paper, we present a model combing the thermionic RF gun, alpha magnet, and linac in the OPAL-t framework*. Simulation and optimization of the beam dynamics over a wide range of charge is discussed. * http://amas.web.psi.ch/opal/Documentation/master/ **This work is supported by the U.S. DOE, under award No. DE-AC02-06CH11357 with ANL.**

WE4P36 -- The Cryogenic Undulator Upgrade Programme at Diamond Light Source
Poster D - Key Technologies
Zena Patel, wui cheng, Angela George, Stephen Hale, Ronaldo Mercado, Ali Ramezani Moghaddam, Martin Reeves, Geetanjali Sharma, Sumit Tripathi (DLS, Oxfordshire), Marco Vincenzo Marziani (University of Cape Town, Cape Town)
Diamond Light Source has installed four 2 m long, 17.6 mm period Cryogenic Permanent Magnet Undulators (CPMUs) as upgrades for crystallography beamlines since 2020, with two more planned within the next year. The CPMUs provide 2 - 3 times more brightness and 2 - 4 times more flux than their pure permanent magnet (PPM) counterparts. They have been designed, built, and measured in-house. All four have a 4 mm minimum operating gap and are almost identical in their construction: the main difference being an increase in the number of in-vacuum magnet beam support points from four to five, between CPMU-1 and CPMUs 2 - 4, to better facilitate shimming, particularly at cold temperatures. The ability to shim at cryogenic temperatures necessitated the development of an in-vacuum measurement system. The details of the measurement system will be presented alongside the mechanical and cryogenic design of the undulators; including issues with the magnet foils, and the shimming procedures and tools used to reach the tight magnetic specifications at room temperature and at 77 K.

WE4P37 -- Development of Laser Interferometer for Hall Probe Alignment and Measurement of Undulator
Poster D - Key Technologies
Saif Mohd Khan, Ganeswar Mishra (Devi Ahilya University, Indore), Mona Gehlot (DESY, Hamburg), Shreya Mishra (Devi Ahilya Vishwa Vidyalaya, Indore)
In the Hall probe Magnetic measurement method the field mapping is done along the length of the undulator. The field integral and phase error computed from the field mapping works as the figure of merit of the undulator. In this paper, we discuss the working of a laser interferometer for precise Hall probe alignment. A new user friendly software based on MATLAB has been developed. The phase error and magnetic field integrals are calculated for both taper and untaper U50 undulator of the Laser and Insertion Device Application (LIDA) Laboratory.

WE4P38 -- Pulsed Wire Measurement of 20 mm Period Hybrid Undulator and Effects of Dispersion
Poster D - Key Technologies
Saif Mohd Khan, Ganeswar Mishra (Devi Ahilya University, Indore), Mona Gehlot (DESY, Hamburg)
In the pulsed wire method, a thin wire is stretched along the undulator axis with a sensor located near the undulator end. When a current flows through the wire, the Lorentz force on the wire sets up a travelling wave that is picked up by a sensor. Sensor output v. time gives the field integral v. position along the undulator length. We investigate pulsed wire measurements of field integrals and phase error of a 20 mm-period, 500 mm-long undulator and discuss variation in performance with Hall probe data, without any dispersion correction algorithm. Dispersion in the wire introduces dispersion corrected pulse lengths for the field integral measurements. Two field integrals of the undulator were measured with an accuracy close to 2 Gcm and 2 Gcm2 with the Hall probe result. The contributions of dispersion to the phase error of the undulator are analyzed. The dispersion assisted phase advance in the undulator in the pulsed wire is measured with a higher slope in comparison to the Hall probe data. Dispersion limited optical phase growth along the undulator length causes period length fluctuations and yields a discrepancy in the phase error computation in comparison to Hall probe data.

TH1D1 -- Application of Superconducting Undulator Technology for Hard X-ray Production at European XFEL
Contributed Oral D - Key Technologies
Barbara Marchetti, Suren Abeghyan, Johann Eduardo Baader, Sara Casalbuoni, Massimiliano Di Felice, Gianluca Geloni, Vanessa Grattoni, Daniele La Civita, Christoph Lechner, Svitozar Serkez, Harald Sinn, Maurizio Vannoni, Mikhail Yakopov, Pawel Ziolkowski (EuXFEL, Schenefeld), Serena Barbanotti, Winfried Decking, Hans-Joerg Eckoldt, Axel Hauberg, Kay Jensch, Sven Lederer, Lutz Lilje, Shan Liu, Rajinikumar Ramalingam, Tobias Schnautz, Riko Wichmann, Torsten Wohlenberg, Igor Zagorodnov, Rene Zimmermann (DESY, Hamburg), Uwe Englisch (EuXFEL, Hamburg), Andreas Wolfgang Grau (KIT, Karlsruhe), Andrew Potter (The University of Liverpool, Liverpool; Cockcroft Institute, Warrington, Cheshire)
The advancement of superconducting undulator (SCU) technology is of strategic importance for the future development of the European XFEL facility. To build the know-how to implement superconducting undulators for its future upgrades, several projects are ongoing: a prototype SCU module (S-PRESSO) for an afterburner in the hard X-ray undulator line SASE2 is being procured; two test stands (SUNDAE1 and SUNDAE2) for the characterization of SCU are being developed; advanced SCU coils are designed and manufactured in house. In this presentation, we describe the status and plans of those projects and highlight their expected performances.

TH1D2 -- Bulk Superconductor and its Application for Insertion Device
Contributed Oral D - Key Technologies
Toshiteru Kii (Kyoto University, Kyoto)
High-field short-period undulator will be one of the key technologies for the future light sources. Various approaches have been continued under the limitation of materials for permanent/superconducting magnets. A use of bulk superconductor is attractive for its high current density under existence of high magnetic field. The critical current density for rare-earth barium copper oxide (REBCO) bulk superconductor exceeds 10 kA/mm2 even at 10 K in a field range below about 3 T and exceeds 20 kA/mm2 at 4.2 K. In order to utilize the quite high current density in the bulk REBCO and to generate periodic magnetic field we proposed bulk superconductor staggered array undulator in 2006*. Recently we have developed the third undulaor prototype which consists of 6T solenoid and 6 period of bulk REBCO array, and successfully demonstrated periodic field amplitude of 2.22 T for period length of 10 mm and undulator gap of 4.0 mm at 7 K. In the presentation, we will summarize properties and performances of bulk REBCO superconductors and discuss on the performance of bulk superconductor staggered array undulator and potential as an insertion device for the future light sources. * T. Kii et al.: Proc. FEL2006 (2006) p. 653. **This work was supported by KAKENHI JP17H01127 and JP22H03870**

TH1D3 -- SCU Development at the LCLS for Future FELs
Contributed Oral D - Key Technologies
Patrick Krejcik, Gary Bouchard, Georg Gassner, Zhirong Huang, Eugene Michael Kraft, Briant Lam, Maria Alessandra Montironi, Christopher Dennis Nantista, Dinh Cong Nguyen, Heinz-Dieter Nuhn, Zachary Wolf, Zhen Zhang (SLAC, Menlo Park, California), John Byrd, Joel D. Fuerst, Efim Gluskin, Yury Ivanyushenkov, Matthew Thomas Kasa, Maofei Qian, Yuko Shiroyanagi (ANL, Lemont, Illinois), Xavier Permanyer (ESS, Lund)
A joint SLAC/ANL development program is underway at the LCLS to demonstrate the advantages of SCUs for FEL beamlines. SCUs offer significant advantages for future FEL beam lines in gain length, wavelength reach, and tunability. The program leverages the storage ring SCUs developed at ANL and addresses the issues of integration in FELs and attaining the necessary micron precision for BBA. Our new modular cryomodule design is extendable to a full-length FEL and integrates the additional FEL components such as the phase shifter, quadrupole and RFBPM into the cold mass to achieve a high packing fraction and minimize the average gain length. Initially, 2 such cryomodules will be installed as afterburners at the end of the existing hard x-ray FEL beam line at the LCLS in order to measure the gain length and validate the beam based alignment procedure based on precision motion control of the cold mass internal to the cryomodule. We report on the status of the testing of these critical components on our precision alignment test stand, and discuss future plans for multiple FEL beamlines to be housed in a single cryomodule as part of the future LCLS expansion program for more user stations.

TH1D4 -- Bi-periodic Undulator: Innovative Insertion Device for SOLEIL II
Contributed Oral D - Key Technologies
Angela Potet, Frederic Blache, Pascale Brunelle, Marie-Emmanuelle Couprie, Carlos de Oliveira, Olivier Marcouillé, Arnaud Mary, Thibaut Mutin, Amor Nadji, Keihan Tavakoli (SOLEIL, Gif-sur-Yvette)
SOLEIL II project will lead to optimize the production of photons by a modification of the present facility. The storage ring will be redesigned to reduce electron beam emittance, increase photon beam flux and brightness, and improve beamline resolution. The number of magnetic elements will be increased and the space reserved for insertion devices will be decreased by 30%. SOLEIL magnetic group searches for solutions to generate different magnetic periods in a smaller space to maintain the full spectral domain. Bi-Periodic undulator is an innovative and compact device allowing the use of two selectable magnetic periodicities by superimposition of magnets. The magnetic period can be switched from one value to its triple value by mechanical shift of magnetic arrays. A magnetic design has been performed and the construction of a prototype, including magnetic measurements and corrections, is under progress. The prototype will be installed in the storage ring with the goal to verify the feasibility of the model and to characterize the system. The magnetic fields, the radiation produced and the electron beam dynamics will be considered to have a complete knowledge on this undulator.

TH2A1 -- Dechirper System for Fresh-slice Applications at the European XFEL
Contributed Oral A - Linac-based Light Sources
Weilun Qin, Winfried Decking, Marc Walter Guetg, Shan Liu, Torsten Wohlenberg, Igor Zagorodnov (DESY, Hamburg), Jun-Jie Guo (DESY, Hamburg; SINAP, Shanghai; University of Chinese Academy of Sciences, Beijing), Erion Gjonaj (TEMF, TU Darmstadt, Darmstadt)
Fresh-slice lasing using dechirper induced time-dependent orbit oscillation is capable of producing high intensity two-color XFEL pulses and high power short pulses at femtosecond level. At the European XFEL, a dechirper system for fresh-slice applications for both the hard x-ray beamline SASE1 and the soft x-ray SASE3 beamline is being developed. In this contribution, we present the novel design of the wakefield structure and initial commissioning efforts.

TH2A2 -- Generation of Intense Attosecond Pulses at the European XFEL
Contributed Oral A - Linac-based Light Sources
Jiawei Yan, Gianluca Geloni, Christoph Lechner, Svitozar Serkez (EuXFEL, Schenefeld), Ye Chen, Philipp Dijkstal, Marc Walter Guetg, Evgeny Schneidmiller (DESY, Hamburg)
X-ray free-electron lasers (XFELs) have paved the way for significant advancements in attosecond science by generating intense, ultrashort pulses. We are currently developing AttoSecond Pulses with eSASE and Chirp-Taper schemes (ASPECT) project at the European XFEL, designed to exploit these capabilities. In its initial stages, ASPECT will be used to produce attosecond-long pulses at two out of the three SASE lines at the European XFEL: SASE1 and SASE3, dedicated to producing hard and soft x-rays respectively. In this presentation, we will report design studies and preliminary experimental results at the European XFEL.

TH2A3 -- Progress on Fresh-slice Multi-stage Amplification at SwissFEL
Contributed Oral A - Linac-based Light Sources
Guanglei Wang, Eduard Prat, Sven Reiche, Kirtsen Schnorr (PSI, Villigen PSI)
We present the progress of generating high-power and short FEL pulses using the fresh-slice multi-stage amplification scheme at Athos, the soft X-ray beamline of SwissFEL. We use a transversely tilted electron beam traveling through the unique Athos layout with magnetic chicanes between every two undulator modules. The tail of the bunch produces a short pulse in the first amplification stage. The rest of the electron beam further amplifies the short FEL pulse in up to three additional stages. Our results show the production of FEL radiation with pulse energies of several hundreds of microjoules and pulse durations of about one femtosecond. This operation mode will allow us to advance the scientific opportunities of nonlinear optics and imaging experiments.

TH2C1 -- The COXINEL Seeded Free Electron Laser Driven by the Laser Plasma Accelerator at HZDR
Invited Oral C - Compact Light Sources
Marie-Emmanuelle Couprie, Thomas Andre, Anthony Berlioux, Philippe Berteaud, Frederic Blache, Francois Bouvet, Fabien Briquez, Carlos de Oliveira, Yannick Dietrich, Jean-Pierre Duval, Moussa El Ajjouri, Christian Herbeaux, Nicolas Hubert, Charles Agbehonou Kitegi, Marie Labat, Stephane Le, Bruno Leluan, Alexandre Loulergue, Fabrice Marteau, Manh-Huy Nguyen, Driss Oumbarek Espinos, Damien Pereira, Jean-Paul Ricaud, Patrick Rommeluere, Mourad Sebdaoui, Keihan Tavakoli, Mathieu Valléau, Marc Vandenberghe, José Vétéran (SOLEIL, Gif-sur-Yvette), Stefan Bock, Yen-Yu Chang, Alexander Debus, Christoph Eisenmann, Rene Gebhardt, Amin Ghaith, Simon Grams, Uwe Helbig, Arie Irman, Michael Kuntzsch, Richard Guntram Pausch, Thomas Püschel, Susanne Schoebel, Ulrich Schramm, Klaus Steiniger, Patrick Ufer (HZDR, Dresden), Igor Andriyash, Julien Gautier, Jean-Philippe Goddet, Olena Kononenko, Guillaume Lambert, Jean-Philippe Rousseau, Amar Tafzi, Cedric Thaury (LOA, Palaiseau), Eléonore Roussel (PhLAM/CERLA, Villeneuve d'Ascq), Maxwell LaBerge (The University of Texas at Austin, Austin, Texas), Victor Malka (Weizmann Institute of Science, Rehovot)
Laser Plasma Accelerators know a tremendous development these recent years. Being able to reach up to ~100 GV/m, they open new perspectives for compact accelerators. Their performance can be qualified by a Free Electron Laser Application. We report here on the COXINEL seeded Free Electron Laser in the UV using the using high-quality electron beam generated by the 150 TW DRACO laser. The COXINEL line developed at Synchrotron SOLEIL (France) is first introduced. First electron beam transport and undulator radiation observation using electrons from the Laser Plasma Accelerator developed at Laboratoire d'Optique Appliquée (France) are described. Then, we present the first COXINEL results driven by the DRACO laser high performance plasma accelerator after its move to Helmholtz-Zentrum Dresden-Rossendorf (HZDR) (Germany): proper electron beam transport, undulator seed and undulator radiation temporal, spectral and spatial overlaps, allowing the seeded Free Electron Laser to be observed in the UV. Good agreement is found between measurements and simulations.

TH2C2 -- Development of Laser-Driven Plasma Accelerator Undulator Radiation Source at ELI-Beamlines
Contributed Oral C - Compact Light Sources
Alexander Yu. Molodozhentsev (Czech Republic Academy of Sciences, Prague), Jonathan Tyler Green, Konstantin Kruchinin (ELI-BEAMS, Prague)
Over the last decade, the mechanism of the laser-plasma acceleration of electrons was studied intensively by many experimental teams aiming to achieve high-energy, high-quality electron beams required to generate high-brilliance incoherent and, as the next step, coherent undulator photon radiation for wide-range applications. The laser-driven plasma accelerator based compact undulator radiation source is currently under commissioning at ELI-Beamlines (Institute of Physics CAS, Czech Republic) in the frame of the LUIS project, which aims to deliver stable and reliable incoherent photon beam with a wavelength around 5 nm to an user-station. As the result of this project, the electron beam parameters should be improved to generate the coherent photon radiation reaching the saturation of the photon pulse energy in a single-unit dedicated undulator (LPA-based FEL). An overview of the current status of the LUIS project will be presented, including the high-power high-repetition rate laser, acceleration of the electron beam in the plasma channel, the electron and photon beam-lines with relevant diagnostics. Challenges and future development beyond the LUIS project also being discussed.

TH2C3 -- A Novel X-ray Free-electron Laser Scheme Based on Cascaded Laser Wakefield Accelerators
Contributed Oral C - Compact Light Sources
Heng Yuan Xiao, Jianfei Hua, Fei Li, Wei Lu (TUB, Beijing)
Laser wakefield accelerators (LWFA) present great potential to drive a free-electron laser (FEL) in a compact footprint because of the extremely high accelerating gradient. However, there are still many obstacles to overcome before the LWFA-driven FEL device can truly achieve exponential amplification and saturated output. These problems include how to resolve the phase slippage effect caused by the fs-level length of LWFA beams, and how to stably generate high-quality beams and preserve the quality during the transport. In this presentation, a novel scheme of X-ray FEL based on cascaded LWFAs is proposed aiming at addressing the above issues. High-quality electron beams with stable central energy and relatively long beam length can be generated using staged LWFAs. With a dedicated beamline design, the longitudinal phase space, beam length and inter-stage coupling are optimized, and start-to-end simulations show that such beams can drive the XFEL to saturation. In addition, the proposed scheme also possesses the capability to adjust FEL radiation bandwidth through precise longitudinal phase space steering. Our scheme provides a highly viable new route to realize LWFA-driven compact XFEL devices.

TH3B1 -- Development of the In-vacuum APPLE II Undulators at HZB
Contributed Oral B - Ring-based Light Sources
Atoosa Meseck, Johannes Bahrdt, Simon Gaebel, Stefan Gottschlich, Stefan Grimmer, Carsten Kuhn, Florian Laube, Ed Christopher Maurice Rial, Michael Scheer, Paul Ignatius Volz (HZB, Berlin)
HZB is working on a concept for BESSY III, the successor to BESSY II. It is planned to be a 4th generation synchrotron light source with an emittance of about 100 pm rad and an energy of 2.5 GeV. BESSY III will be equipped with advanced undulators to provide users with tailor-made light. Since polarisation control in the soft X-ray region is important for BESSY users, a variety of APPLE II undulators are planned, such as conventional (in-air), in-vacuum, cryogenic in-vacuum and double-period in-vacuum APPLE undulators (DoPUs). HZB has a long and successful tradition in the design, construction, and operation of conventional APPLE II devices. Currently, the first in-vacuum APPLE II undulator (IVUE32) is being built at HZB. In addition, the technical design of the cryogenic version of the In-Vacuum APPLE II (Cryo-APPLE) is progressing; construction will start at HZB in the next few years. This paper reports on the status of the In-Vacuum APPLE II and the Cryo-APPLE and outlines future development plans.

TH3B2 -- Novel X-Ray Beam Position Monitor for Coherent Soft X-Ray Beamlines
Contributed Oral B - Ring-based Light Sources
Boris Podobedov, Daniel Mihai Bacescu, Christopher Eng, Steve Hulbert, Claudio Mazzoli, Christie Nelson (BNL, Upton, New York), Dmitri Donetski, Kevin Kucharczyk, Jinghe Liu, Ricardo Lutchman, Jingze Zhao (Stony Brook University, Stony Brook, New York)
A novel soft X-ray BPM (sXBPM) for high-power white beams of synchrotron undulator radiation is being developed through a joint effort of BNL/NSLS-II and Stony Brook University. In our approach, custom-made multi-pixel GaAs detector arrays are placed into the outer portions of the X-ray beam, and the beam position is inferred from the pixel photocurrents. Our goal is to achieve micron-scale positional and ~50 nrad angular resolution without interfering with user experiments, especially the most sensitive ones exploiting coherent properties of the beam. To this end, an elaborate mechanical system has been designed, fabricated, and installed in the 23-ID canted undulator beamline first optical enclosure, which allows positioning of the detectors with micron-scale accuracy, and provisions for possible intercepts of kW-level beam in abnormal conditions. Separately, GaAs detectors with specially tailored spectral response have been designed, fabricated, and tested in the soft and hard X-ray regions at two NSLS-II beamlines. In this talk we plan to give an overview of the sXBPM system and present the first results from the high-power white X-ray beam.

TH3B3 -- Transverse Gradient Undulator for a Storage Ring X-Ray Free-Electron Laser Oscillator
Contributed Oral B - Ring-based Light Sources
Yuan Shen Li (University of Chicago, Chicago, Illinois), Kwang-Je Kim, Ryan Roger Lindberg (ANL, Lemont, Illinois)
The X-ray free-electron laser oscillator (XFELO) has the potential to greatly surpass current SASE-FELs in terms of peak power and photon coherence. Although a large, 4th generation storage ring (4GSR) is promising as a diver for an XFELO operation, meeting the requisite electron energy spread remains a challenge. The transverse gradient undulator (TGU) is a potential solution to this issue*. Using low-gain TGU theory, we derive optimal beam parameters for a hypothetical XFELO in a straight section of PETRA-IV and discuss potential implementation challenges associated with the ring-FEL coupling, namely FEL beam degradation and gain modulation. The need for a by-pass and fast kickers is obviated by equipping a higher charge (4 nC) to sixteen equidistant electron bunches for XFELO interaction. RF is used to control the FEL duty cycle and allow the XFELO bunches to damp before resuming the FEL interaction. Detailed multi-stage numerical simulation was used to compute the projected performance. * T. I. Smith, L. R. Elias, J. M. J. Madey, and D. A. G. Deacon, J. Appl. Phys. 50, 4580 (1979). ** Y. S. Li, R. R. Lindberg, and K.-J. Kim, Phys. Rev. AB 26, p. 030702 (2023).** **This work is supported by the U.S. Department of Energy, Office of Science under Contract No. DE-AC02-06CH11357**

TH3B4 -- Generation of Multi X-Ray Pulses with Tunable Separation in Electron Storage Rings
Contributed Oral B - Ring-based Light Sources
Haisheng Xu, Na Wang, Jingye Xu (IHEP, Beijing)
Synchrotron light sources, which can provide high brightness X-ray pulses to different users simultaneously, are demonstrated as a kind of very powerful tool for scientific research in many areas. Among the possible applications of synchrotron light sources, time resolved experiments are interesting for many users and usually require special operation modes. However, the time structures of X-ray pulses generated by a synchrotron light source are usually limited to integer times of the RF period, which is typically several nanoseconds (e.g., 2 ns RF period time corresponding to 500 MHz RF frequency). Here, we propose a novel scheme to take advantage of transverse deflecting cavities and over-stretching conditions of the higher harmonic cavities to ensure the transverse and longitudinal tunability of the two micro bunches in the same RF bucket. By applying this scheme, two X-ray pulses with tunable transverse displacement (mm level) and time delay (hundreds of ps level) can be provided to the scientific users for their X-ray pump X-ray probe experiments or X-ray probe X-ray probe experiments. The key setting parameters to generate the two X-ray pulses are given here. The classical "single-bunch" instabilities under the over-stretching conditions were also studied and presented.

TH3D1 -- Larmor Radius Effect on IFEL Accelerator With Staggered Undulator
Contributed Oral D - Key Technologies
Roma Khullar, Ganeswar Mishra (Devi Ahilya University, Indore)
In this paper, the theory of inverse free electron (IFEL) accelerator using staggered undulator has been discussed. The important contribution of staggered undulator parameter and the finite larmour radius effect on energy saturation, saturation length and accelerating gradient of the IFEL accelerator are included in the analysis. Considering the synchrotron radiation losses, the IFEL accelerator equations are derived. Key words- undulator, inverse free electron laser accelerator, accelerator

TH3D2 -- Beam losses and radiation studies for advanced operation schemes at the European XFEL
Contributed Oral D - Key Technologies
Andrew Potter, Andrzej Wolski (The University of Liverpool, Liverpool), Winfried Decking, Albrecht Leuschner, Shan Liu (DESY, Hamburg), Sara Casalbuoni, Suren Karabekyan, Harald Sinn, Frederik Wolff-Fabris (EuXFEL, Schenefeld), Frank Jackson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)
European XFEL is the first free electron laser operating at MHz repetition rate with electron beam energy up to 17.5 GeV. The high repetition rate together with the high electron beam energy provides unique opportunities for users in different domains. To further extend the operation schemes, some upgrades have already been implemented and several more are planned. The advanced operation schemes may require devices inserted into the beam like slotted foil or narrow vacuum chambers such as for the corrugated structure, the Apple-X undulator, and the superconducting undulator. Due to the high beam power generated by the superconducting linac, there are concerns about increased radiation loads. Therefore, simulations and measurements have been carried out to study the radiation dose rates that may be generated. We give an overview of the simulations and measurements for the above mentioned schemes.

TH3D3 -- How Can Machine Learning Help Future Light Sources?
Contributed Oral D - Key Technologies
Andrea Santamaria Garcia, Erik Bruendermann, Anke-Susanne Mueller, Johannes Leonhard Steinmann, Chenran Xu (KIT, Karlsruhe), Michele Caselle, Luca Scomparin (KIT, Eggenstein-Leopoldshafen)
Future light sources aim to produce light with a higher brilliance and coherence, which requires high-brightness electron beams. The increased density of electrons due to the reduced emittance gives place to instabilities, and in general a more complex accelerator operation. Machine learning methods can help future facilities with ambitious goals in a variety of ways, like for example automatically tuning the accelerator and enabling a rapid change of operation mode to serve different beamlines, by predicting beam properties without interfering with the beam and saving valuable beam time, or by tailoring the emitted light to the user's needs in real time. In this talk I will present different machine learning use cases in existing light sources, their challenges, and what can we expect in the future.

TH3D4 -- DFCSR: A Fast Calculation of 2D/3D Coherent Synchrotron Radiation in Relativistic Beams
Contributed Oral D - Key Technologies
Jingyi Tang, Zhirong Huang, Gennady Stupakov (SLAC, Menlo Park, California)
Coherent Synchrotron Radiation (CSR) is regarded as one of the most important reasons that limits beam brightness in modern accelerators. Current numerical packages containing CSR wake fields generally use 1D models, which can become invalid in electron beams with very high brightness. On the other hand, the existing 2D or 3D codes are often slow. Here we report DFCSR, a novel particle tracking code that can simulate 2D/3D CSR and space charge wakes in relativistic electron beams 2 or 3 orders of magnitude faster than conventional models like CSRtrack. We performed benchmark simulations based on FACET-II beams, where electron beams are compressed to reach 300 kA peak current. The tracking code is written in Python and C programming languages with human-friendly input styles and is open-sourced on GitHub. It can serve as a powerful simulation tool for the design of next-generation accelerators.

TH3D5 -- Building Digital Models with thor_scsi: An Evolutionary Approach
Contributed Oral D - Key Technologies
Waheedullah Sulaiman Khail, Paul Goslawski, Pierre Schnizer (HZB, Berlin)
Tracy is used as a computing core for digital models for synchrotron light sources since SLS. It inspired the accelerator toolbox, which is using (largely) Tracy's Hamiltonian propagators. This Tracy code was refactored using modern software paradigms. It started with the Tracy III code base, reorganized its structure, and rebased it on a modern (cx+2a) coding style next to well-tested math libraries: but it is still using the tested Tracy propagators and code. This new code was renamed to thor-scsi, as its API was significantly reworked from the ones that Tracy II has established. Furthermore, a modern Python interfaces is provided, which is is based on pybind11. This new interface allows implementing beam line components using the Python language or tracking state spaces using truncated power series. Digital shadows or twins are essential ingredients for building 4th generation light sources. Based on the modernized thor_scsi code we built an EPICS IOC exporting required thor_scsi externals as EPICS variables. While it focuses on HZB's current BESSY II and MLS, it is designed flexibly to extend to the BESSY III and MLS II project or similar light sources.

TH4A1 -- Progress Towards X-ray Free-electron Laser Driven by Plasma Wakefield Accelerator at SXFEL
Contributed Oral A - Linac-based Light Sources
Fei Li, Jianfei Hua, Wei Lu, Zhi Song, Heng Yuan Xiao (TUB, Beijing), Chao Feng, Zhen Wang, Zhentang Zhao (SARI-CAS, Pudong, Shanghai), Tianliang Zhang (Tsinghua University, Beijing)
Free-electron lasers (FEL) are unique light source for various applications in structural biology, chemistry and condense physics. Plasma-based accelerators can provide ultrahigh accelerating gradient which is 3~4 orders of magnitude higher than conventional technology, holding the potential for a revolution in particle accelerators. This novel technology therefore has been given high expectations for the development of compact free-electron lasers. SXFEL is a single-pass FEL user facility that provides 2~10 nm radiation for fundamental and applied research. In frame of this report, we present concept and design of a large-bandwidth XFEL based on a plasma wakefield accelerator (PWFA) driven by SXFEL electron beams. An ultrabroad bandwidth is achieved by chirping the electron beam in a hollow-channel plasma and simulations demonstrate that a spectral bandwidth of up to 24% can be obtained in this scheme. We will also present the recent progress on the construction of PWFA-based XFEL experimental station at SXFEL, and the preliminary experimental results on the PWFA and FEL radiation generation.

TH4A2 -- A Compact Inverse Compton Scattering Source Based on X-band Technology and Cavity-enhanced High Average Power Ultrafast Lasers
Contributed Oral A - Linac-based Light Sources
Andrea Latina, Roberto Corsini, Luke Aidan Dyks, Eduardo Granados, Alexej Grudiev, Vlad Musat, Steinar Stapnes, Walter Wuensch (CERN, Meyrin), Eric Cormier (CELIA, Talence), Giorgio Santarelli (ILE, Palaiseau Cedex)
A high-pulse-current injector followed by a short high-gradient X-band linac is considered as a driver for a compact Inverse Compton Scattering (ICS) source. We show that using a high-power Ultra-short Pulse laser operating in burst mode and a Fabry-Pérot enhancement cavity, X-rays with flux values over 10^13 ph/sec and energies up to MeV are achievable. The resulting high-intensity and high-energy X-rays allow various applications, including cancer therapy, tomography, and nuclear waste management. A preliminary conceptual design of such a compact ICS source is presented, together with simulations of the expected performance.

TH4A3 -- An Active Q-switched X-ray Regenerative Amplifier Free-electron Lasers
Contributed Oral A - Linac-based Light Sources
Jingyi Tang, Erik Hemsing, Zhirong Huang, Zhen Zhang (SLAC, Menlo Park, California)
Despite tremendous progress in x-ray free-electron laser (FEL) science over the last decade, future applications still demand fully coherent, stable X-rays that have not been demonstrated in existing X-ray FEL facilities. In this Letter, we describe an active Q-switched X-ray regenerative amplifier FEL (XRAFEL) to produce fully coherent, high-brightness, hard X-rays. By using simple electron beam phase space manipulation, we show this scheme is very flexible in controlling the X-ray cavity quality factor Q and hence the output radiation. We report both theoretical and numerical studies on this scheme with a wide range of accelerator, X-ray cavity, and undulator parameters

TH4A4 -- A Proposal for Generating Fully Coherent X-ray FEL with Femtosecond Pulse Based on Fresh-Slice
Contributed Oral A - Linac-based Light Sources
Zhangfeng Gao (SSRF, Shanghai), Jiawei Yan (EuXFEL, Schenefeld)
This study aims to propose a new principle for generating fully coherent femtosecond X-ray pulse on the Shanghai soft X-ray Free Electron Laser User Facility (SXFEL-UF), which was based on fresh-slice technique. The electron beam was kicked transversely to get a time-related transverse tilt. The sub-10-femtosecond bunch was achieved first because of the spatiotemporal synchronization effect of the seed laser modulation. Then the FEL pulse duration was even shorter because of harmonic lasing. In the cascaded HGHG mode, the laser generated by the beam tail modulated the beam head in the second stage to reach higher harmonics, while in the EEHG mode, the same part of the electron beam was modulated twice. The influence of emittance and energy chirp of the electron beam on the scheme was analyzed, and the instability caused by transverse position jitter and energy jitter of the chirped beam was evaluated. The relationship between the pulse duration and the transverse deflection of the beam is verified. The scheme is also explored to generate linearly polarized femtosecond pulse at 6 nm and circularly polarized femtosecond pulse at 3 nm simultaneously.

TH4D1 -- Overview and Challenges of the Vacuum Systems of Diffraction Limited Storage Rings
Contributed Oral D - Key Technologies
Marek Jerzy Grabski, Eshraq Al-Dmour (MAX IV Laboratory, Lund)
Three diffraction limited storage rings are operational and over ten are in design or construction, several approaches were adapted for the design of their vacuum systems, with the majority have to manage common challenges to achieve the design parameters of those machines. Here we will present the various design approaches adapted by the various facilities together with the challenges and solutions deployed.

TH4D2 -- An Ultra-high Vacuum, High-gradient RF Gun and Advanced Photocathode Studies
Contributed Oral D - Key Technologies
Renkai Li, Huaibi Chen, Yingchao Du, Peng-Wei Huang, Wenhui Huang, Jiaru Shi, Chuanxiang Tang, Xiaoyang Zhang, Lianmin Zheng (TUB, Beijing)
Photoinjectors are critical in defining the beam brightness and lasing performance of linac-based light sources. To further improve photoinjectors, one of the promising R&D opportunities is to combine high acceleration gradient with advanced photocathodes that feature low MTE, high QE, and visible light excitation, but unfortunately stringent vacuum conditions. Here we report on developing a new type of high-gradient S-band photocathode rf gun that can achieve one order of magnitude improvement of the vacuum level at the cathode and thus utilize various advanced semiconductor photocathodes. This gun serves as a testbed for exploring high-gradient-compatible photocathodes and new paradigms for optimizing and operating photoinjectors that enhance future light sources. **Work supported by the National Key Research and Development Program of China No. 2022YFA1603400 and the Tsinghua University Initiative Scientific Research Program No. 20197050028, 20191081195.**

TH4D3 -- Status of Advanced Photocathodes for SRF Guns
Contributed Oral D - Key Technologies
Rong Xiang (HZDR, Dresden)
As well known, the quality of the photocathodes is critical for the stability and reliability of photo-injector operation. Especially for the superconducting rf guns, the photocathode is one of the most important parts. In last years, thanks to the developed photocathode technology, several SRF guns were successfully operated or tested for the beam generation at kHz-MHz repetition rate. In this review, the achievements as well as open questions for the cathode requirements of the reliable SRF gun operation will be reviewed, and the possible improvement from photocathodes point of view for the future application will be discussed.