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Accelerator Physics at NSLS-II: Research Accomplishments in 2022

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Abstract

NSLS-II accelerator physicists are working on scientific support of the NSLS-II operations and start-up of the accelerator systems including Storage Ring, Injector, beam diagnostics, and top-off injection; improvement of beam stability and orbit feedbacks; commissioning of a superconducting wiggler for the HEX beamline; development of a new operation mode for time-resolved experiments. The routine lattice characterization is continued to keep tracking the machine, the storage ring lattice model including strong coupling is developed, and seasonal variations of the ring circumference are studied. The collaboration with the EIC project is ongoing. In the frameworks of three LDRD projects, the physicists are working on the lattice development, studies of collective effects, and specifications of alignment and stability for the NSLS-II accelerator upgrade; novel methods of lattice design and optimization; studies of free-electron laser options; ultrafast electron diffraction and microscopy. Research accomplishments achieved in 2022, are summarized in this report.

1 Introduction

In 2022, NSLS-II accelerator physicists were working on scientific support of the NSLS-II operations and start-up including Storage Ring, Injector, beam diagnostics, and top-off injection. New members of the team were trained on how to use high-level applications for lattice characterization and correction. We continued routine lattice characterization to keep tracking the storage ring and elaborated advanced techniques of linear and nonlinear lattice characterization. We worked on the storage ring lattice model including the lattice with strong coupling and seasonal variation of the ring circumference affecting the beam dynamics. The accelerator physicists also contributed to the development of orbit feedbacks and the improvement of beam stability, operations with high beam current, commissioning of a superconducting wiggler for the HEX beamline, and development of a new operation mode for time-resolved experiments.

At the same time, we worked on a number of R&D topics. The Accelerator Physics group was leading three LDRD projects: 20-041 “Conceptual Design Options for Future Upgrade of NSLS-II Facility”, 22-028 “Assessment of FEL options for NSLS-II upgrade”, and 22-029 “Towards ultrafast electron microscope with nanometer resolution”. In the frameworks of these projects, the physicists are working on the lattice development, studies of collective effects, and specifications of alignment and stability for the NSLS-II accelerator upgrade; novel methods of lattice design and optimization; studies of free-electron laser options; ultrafast electron diffraction and microscopy.

We have active collaboration with the EIC project on the electron storage ring lattice design and optimization, beam diagnostics, and RF system.

This is a list of major projects and activities in 2022:

- Support of NSLS-II operations and start-up
- Lattice characterization and modeling
- Studies for operations with high beam current
- Commissioning of the HEX superconducting wiggler
- New operation mode for time-resolved experiments
- High-brightness upgrade of NSLS-II
- Studies of free-electron lasers
- Novel methods of lattice design and optimization
- Machine learning in accelerator physics
- Impedance calculation and measurement
- Theory of coupled-bunch instability
- Ultra-fast electron diffraction and microscopy
- Support of the EIC project

2 Support of NSLS-II operations and start-up

In 2022, NSLS-II accelerator physicists gained more expertise and contributed to the machine start-up after shutdowns and maintenance, including Storage Ring, Injector, beam diagnostics, and top-off injection.

We carried out a full Booster optimization including the Linac-to-Booster transport line steering, injection matching, and correction of the Booster orbit and sextupoles. As a result, the Booster injection and acceleration efficiency were significantly improved.

We performed a series of top-off injection studies. A python3 script and a CSS page to control the bunch fill pattern were developed and tested. The electron gun calibration data was collected and post-processed. We completed the top-off safety analysis for the ARI/SXN beamline (ID9). We have done the online optimization of the injection kickers to reduce large injection transients observed by beamline users after the kicker hardware replacement. The injection transient was reduced from 0.76 mm down to 0.05 mm, and the top-off injection was significantly improved.

We explored a way to the reduction of orbit corrector strengths with degeneracy [1]. Due to the small phase advance between the NSLS-II slow orbit correctors and lattice periodicity, almost each of the 180 correctors has some degeneracy with its neighboring ones. The degeneracy of two correctors was quantitatively measured with the Pearson correlation coefficient of their orbit response vectors observed at 180 beam position monitors. The disadvantage is that a pair of highly degenerated correctors might fight with each other and then result in an over-correction. On the other hand, we can take advantage of it to weaken the highest-strength correctors by shifting some part of their contributions to the degenerated neighbors. This method was experimentally tested, several largest corrector peaks were reduced, and the sum current of all correctors was lowered too.

Accelerator physicists participated in the calibration of both BM and 3PW pinhole cameras using the newly implemented function of high-precision encoders installed on the camera movers. Processing of the 3PW pinhole camera data resulted in the calibration coefficient of 0.43 μm/pixel for both horizontal and vertical directions, which agrees well with the design value of 0.432 μm/pixel.

We presented a summary of physic basics for defining a safe beam envelope at the mini-review focused on a better understanding of the current state and subsequent optimization of Active Interlock. We discussed the definition of beam envelopes, the comprehensive approach to synchrotron radiation protection, and our methods to define a reasonable beam deviation envelope for ray tracing compared to the experience of other light sources. The summary was included as a section in the Active Interlock System Report.

A summary of the beam deviation envelope review and cross-check was published in a technical note [2].

NSLS-II accelerator physicists developed and tested the Unified Orbit Feedback [3] to improve long-term orbit stability. The new system has been successfully implemented into NSLS-II user operations.

3 Lattice characterization and modeling

We continued routine lattice characterization using HLA common tools to keep tracking the machine and to get every accelerator physicist ready to help with the machine start-up and troubleshooting. New team members were trained on how to use high-level applications for lattice characterization and correction.

We studied the NSLS-II storage ring lattice with strong coupling [4]. The stop-band width of the coupling resonance was measured for two cases: 1) with the well-corrected coupling using skew quadrupoles, and 2) with all skew quadrupoles switched off. The injection efficiency was observed to vary randomly during shifting the tune close to the coupling resonance. It might suggest the nonlinear lattice needs to be re-optimized for a strongly coupled linear lattice.

We explored the use of the off-energy turn-by-turn BPM data to calibrate sextupoles. The technique looks applicable for chromatic sextupoles located in the high-dispersion sections. For calibration and correction of harmonic sextupoles located in the dispersion-free sections, a new technique was proposed based on measuring the nonlinear optics on off-energy and vertically dispersive orbits. To implement this technique, continuous beam excitation by the bunch-by-bunch feedback is required.

We proposed to modify the LOCOM (Linear Optics and coupling Correction with closed Orbit Modulation) technique by implementing the use of AC beam excitation by fast orbit correctors. This method is based on the modulation of the closed orbit in an appropriate pattern to sample the linear optics, using two correctors in each transverse plane. Then the orbit modulation data are fitted to the lattice model to fit the orbit response matrix. Using AC beam excitation by fast correctors, we expect an improvement in the measurement resolution because of the narrow bandwidth and a better signal-to-noise ratio. We carried out a few beam studies for the AC-LOCOM implementation. For the fast corrector pair, the amplitude and phase of the driving signals were optimized to achieve full coverage of the phase space.

We continued the study of seasonal variations of the ring circumference affecting the beam energy, lattice, and tune shift with amplitude. The tune shift with amplitude as a function of the RF frequency was measured twice a year to compare the data.

4 Studies for operations with high beam current

By request from the Vacuum Group, we calculated the impedance and beam-induced power for several components of the NSLS-II vacuum chamber including bellows, flange RF shims, and ID chamber. The results provide important information on beam-induced heating of the vacuum chamber during operations at 500 mA of the beam current.

We studied the impedance and related beam-induced heating issues of the titanium-coated ceramic vacuum chambers [5]. Such chambers are installed in the pulse kicker magnets at NSLS-II and other light sources. The impedance of the two-layer electromagnetic system is calculated using the field matching theory and compared with the IW2D code. We found for the typical coating thickness of a few microns, most power is dissipated in the titanium coating. The longitudinal averaged two-dimensional power density does not depend on the vertical direction and is Gaussian-distributed along the horizontal direction with a standard deviation equal to the thickness of the ceramics. This simplified model of the power density can be used as input for ANSYS simulations for thermal analysis and comparison with measurements.

5 Commissioning of the HEX superconducting wiggler

A superconducting wiggler (SCW) installed at NSLS-II for the HEX beamline induces significant distortion of the ring optics. We explored possible ways of compensation for these adverse effects and decided to develop a lookup table to compensate for the lattice perturbations. The optics feed-forward table for HEX SCW was developed and tested. The lattice distortion was measured for both ramp-up and ramp-down modes, and the results were consistent. Based on the measurement results, the local optics correction were computed using 6 neighboring quadrupoles. At the nominal HEX SCW current of 440 A, the vertical beta function distortion was 9.4% before correction and 3.5% after correction. The injection efficiency was verified with the corrected optics.

6 New operation mode for time-resolved experiments

We explored the NSLS-II potential for experiments focused on time-resolved studies in the picosecond to nanosecond time scales, revealing the dynamical behavior of systems after being excited away from equilibrium [6]. For the time-resolved experiments, we need to develop a new operation mode for the NSLS-II storage ring with several high-intensity bunches. To suppress collective beam instabilities, we combine the bunch-by-bunch feedback and a lattice with higher chromaticity. High chromaticity provides fast damping of coherent beam oscillations, thus helping to stabilize the beam with a reduced gain of the bunch-by-bunch feedback. We accumulated 400 mA of the beam current keeping the vertical emittance of 8 pm with negligible excitation by the feedback. With high chromaticity and lower feedback gain, the beam current of 11.3 mA was accumulated in the single-bunch mode, the beam intensity was limited by vacuum. The major problem is the short lifetime of the high-intensity bunches, so we need frequent injections. A top-off injection algorithm for a fill pattern with multiple high-intensity bunches is being developed. We carried out the first experiments with the CHX beamline to test a new fill pattern with 15 equidistantly distributed bunches, the total current was about 44 mA. The CHX beamline alignment was complete, and several sets of data were taken for time resolution measurements.

7 High-brightness upgrade of NSLS-II

We are working on the ongoing LDRD 20-041 project "Conceptual Design Options for Future Upgrade of NSLS-II Facility". In previous years, we completed our studies of the medium-scale project and the project with a high-intensity beam. The conclusion is the medium-scale upgrade does not provide the brightness required by the users in the next decades and the high-intensity upgrade is not optimal due to performance risks and high cost.

Now we focus on the development of the low-emittance ring providing the maximal brightness. In 2022, the study topics included the development of standardized software tools for lattice design and optimization, the design of a low-emittance achromat cell based on complex bend magnets, studies of collective effects, and specifications of alignment and stability.

We completed the design of a hybrid multi-bend achromat lattice providing the emittance of 31 pm and dynamic aperture sufficient for off-axis injection. We provided a list of key RF-related parameters of this lattice candidate to start the assessment of the RF system specifications.

We developed a methodology for the design of complex bend lattices to simultaneously satisfy constraints of low emittance, low chromaticity, long straight sections, and a maximum of free space inside the lattice. A random-walking code driven by Elegant was developed to optimize the central complex bend. We explored how a transverse gradient can reduce beam emittance in the complex bend lattice. We reviewed several studies (CERN, PSI, ELETTRA SLS) of the optimum field profile of longitudinal-gradient dipoles and explored possible ways to implement longitudinal gradients in complex bends for NSLS-II Upgrade.

For a few options of the complex bend vacuum chamber with various antechamber heights, we calculated the impedance and beam-induced power to optimize the chamber design.

We completed a review of the alignment and stability specifications used at modern light sources across the world to develop an efficient model for a low-emittance upgrade of NSLS-II, a summary was presented at IPAC-2022 [7].

8 Studies of free-electron lasers

In the framework of the LDRD project 22-028 "Assessment of FEL options for NSLS-II upgrade" we explore two free-electron laser (FEL) options for NSLS-II upgrade: hard X-ray free-electron laser oscillator (XFELO) and soft X-ray echo-enabled high harmonic generation (EEHG).

Using the small-gain formula derived for harmonic lasing and strong focusing, we optimized the XFELO parameters to achieve 20% single-pass gain keeping the dispersion as low as 3 cm because the design of the XFELO section is very challenging if a high dispersion is required. We studied the X-ray mirror parameters, relations between reflectivity and angular divergence, and output coupling. Assuming the divergence angle is limited by the Darwin width in only one of the transverse directions, we found a solution to design the X-ray cavity with a total loss that can be reduced to 5%. This will significantly reduce the required gain of the XFELO.

For EEHG, we implemented a modeling tool providing optimized parameters for generating the 6D phase space distribution [8]. With GENESIS simulations, we optimized energy modulation to maximize coherent radiation power and mitigate de-bunching caused by the beam energy spread. We designed an NSLS-II EEHG beamline using two straight sections to seed coherent extreme-ultraviolet (EUV) and soft X-ray emission with a nearly MHz repetition rate and improved spectral brightness by a factor of about 100. We demonstrated a standardized design of the EEHG beamline for the radiation wavelength of 1.25 to 5 nm. The design is applicable to most of the current and future 4th generation synchrotron light sources [9]. We designed a novel two-color pump-probe scheme via a twin-pulse-seed EUV to soft X-ray EEHG in synchrotron light sources. We implemented a generalized numerical model that can predict the EEHG beamline performance for all synchrotron light sources.

We have summarized the key parameters of the NSLS-IIU FEL options to discuss with the user community and develop the scientific case.

9 Novel methods of lattice design and optimization

We developed a method to design linear lattices for round beams in electron storage rings using the linear matrices analysis [10, 11, 12]. Light source operation with round beams is preferable for some user experiments and it can significantly improve beam lifetime in low-emittance rings, so this option is considered by several projects of diffraction-limited light sources. A conventional method of obtaining a round beam in an electron storage ring is to shift betatron tunes to a linear difference resonance. The linearly-coupled beam dynamics is usually analyzed using perturbation theories having certain limitations. To calculate exact beam sizes for round-beam lattice design, we adopt the solution by linear matrices (SLIM) analysis. The SLIM formalism for combined-function bending magnets, and for planar wigglers and undulators, was also derived. This analysis can deal with a general linearly-coupled accelerator lattice, and the effects of various coupling sources can be studied within a self-consistent frame. Both the on-resonance and off-resonance schemes to obtain round beams were studied with examples.

Nonlinear beam dynamics in the 4D Henon Map was studied using the square matrix method [13]. The Henon Map representing a linear lattice with a single sextupole kick has been extensively studied due to its chaotic behavior. The idea is to create an iterative process that transforms nonlinear perturbed trajectories into rigid rotations. The convergence of iteration relates to the resonance structure and can be used as an indicator of the dynamic aperture. The square matrix method plays a critical role in using the iteration method near resonances and expands the area of convergence.

We made progress on the development of a "convergence map" [14] based on the square matrix method. The convergence map is similar to but different from a frequency map based on particle tracking, it provides information about the stability border of the dynamic aperture. We applied the convergence map to the nonlinear optimization of the NSLS-II lattice and compared the results with the frequency map. We confirmed the new method may be used for nonlinear lattice optimization, taking advantage of the high computation speed (about 30 to 300 times faster than tracking-based techniques) to explore horizontal, vertical, and off-momentum phase space.

10 Machine learning in accelerator physics

We applied machine learning (ML) techniques to explore a way for the fully automated operation of an ultrafast electron diffraction (UED) facility [15]. A two-stage machine learning model based on self-consistent start-to-end simulations has been implemented to demonstrate the feasibility of automatic UED operation and real-time monitoring of the performance. This model provides the machine parameters with adequate precision and real-time electron beam parameters from single-shot nondestructive diagnostics. Based on a deep understanding of the principal relations between the electron beam parameters and the Bragg-diffraction patterns, we applied the hidden symmetry as model constraints, successfully improving the accuracy of energy spread prediction and making the beam divergence prediction faster. The concept demonstrated in the proof-of-principle simulations is directly applicable to automating a real UED instrument in experiments. The two-stage approach can be also extended to other types of accelerator facilities.

11 Impedance calculation and measurement

A well-estimated impedance budget is a crucial part of the design of high-performance accelerator facilities with intense beams. Computation of wake functions and impedances for a given accelerator component is typically a complex task that requires a numerical solution of Maxwell's equations for a certain particle distribution. Even with the most powerful computers, the computation of wakefields generated by short bunches in long structures is quite challenging. We cross-checked two electromagnetic solvers, GdfidL and ECHO3D, by simulation of the geometric impedance of several components of the NSLS-II vacuum chamber to test the consistency and precision of the models [16]. The longitudinal impedance and loss factor calculated by both codes show very good agreement. For high-resolution wakefields in complex 3D geometries, we observed that GdfidL is computationally heavy and memory-consuming, contrary the same accuracy is achievable in ECHO3D with a coarser mesh. The disadvantage of ECHO3D is the limited wake length due to the huge size of output files, which is troublesome for post-processing.

The AC orbit bump technique of local kick factor measurement was developed at NSLS-II a few years ago. It is based on local sine-wave excitation of the electron beam by four fast correctors adjacent to the impedance location. We have implemented reference bunches and the time gate function of NSLS-II beam position monitors, allowing us to measure the intensity-dependent AC orbits simultaneously [17]. As a result, we are able to obtain the impedance-driven orbit distortion in a single measurement, significantly improving the accuracy and reducing the time of the measurement. We tested the improved method by measuring the kick factor of an in-vacuum undulator. The r.m.s error of the measured AC orbit distortion was reduced from about 0.040 μm to 0.005μm.

12 Theory of coupled-bunch instability

We have completed the development of a general theory of transverse coupled-bunch instability for arbitrary multi-bunch configurations [18]. The theoretical framework is based on the general eigenvalue analysis based on the formulas of the complex frequency shifts for the uniform multi-bunch configuration case. For a uniform bunch-filling pattern with a gap of missing bunches, the theoretical results are in good agreement with the results of experimental studies of the transverse coupled-bunch instability driven by the resistive-wall impedance. The closed formulas derived for some special cases will be useful for benchmarking computer codes modeling the coupled-bunch instability.

13 Ultra-fast electron diffraction and microscopy

In the framework of the LDRD project 22-029 "Towards ultrafast electron microscope with nanometer resolution" started this year, we explored a pre-conceptual design of a UEM based on an electron beam with MeV-range energy providing a magnification of 10000 and nanometer resolution. This instrument is expected to be useful for many applications in life science (3D-imaging of large thick bio-samples) as well as material science (visualizing structural dynamics in real time and real space). We completed comprehensive start-to-end computer simulations to address the critical problems of the high-resolution MeV UEM design: aberration control; energy spread reduction; imaging of thick bio-samples; mechanical stability; RF stability.

Our theoretical analysis shows the resolution of 1 nm is achievable with the beam emittance of 10^{-8} m and energy spread of 10^{-5} including the space charge and stochastic scattering effects. We completed computer simulations using our recently proposed monochromator to explore possible ways of reducing the beam energy spread to 10^{-5}.

Using the multi-slice wave-optics computer code, we numerically simulated the interaction of MeV electrons with a simplified transistor chip model and low-Z nanoparticles embedded in amorphous ice. We simulated a few examples of electron-sample interaction for the beam energy of 200 keV, 500 keV, 1000 keV, and 3000 keV using an open-source MuSTEM multislice electron microscopy simulation code and benchmarked the results with analytical calculations.

We completed the measurement of the ATF UED beam jitter and concluded that the present quality of the ATF beam makes it impossible to complete the commissioning of the UEM, which has been built in frameworks of LDRD 19-016. So, we consider a change of the commissioning scope focusing on the resolution measurement and benchmarking our simulation code with experimental results.

We presented a review of developing ultrafast Megaelectron-volt electron microscopy at the 2022 North American Particle Accelerator Conference [19].

We published our results of interferometric bunch length measurements of 3 MeV pico-coulomb electron beams in the Journal of Applied Physics [20].

14 Support of the EIC project

We provided support for the Electron-Ion Collider (EIC) project in the frameworks of two MOUs with the EIC Directorate [21, 22, 23, 24, 25, 26].

One MOU is focused on re-matching a few non-collision straight sections of the EIC Electron Storage Ring to minimize the number of independently powered quadrupole magnets. For two straight sections, the number of required power supply circuits was reduced in order to reduce the overall cost. The results were documented in a report and presented at the EIC Electron Storage Ring Coordination Meeting and at the EIC lattice workshop.

The purpose of the second MOU led by the NSLS-II Diagnostic and Instrumentation Group is to make progress with the conceptual and preliminary design of the synchrotron light monitors, x-ray monitors, and streak camera instrumentation systems in the EIC baseline located at the 400 MeV Linac, Rapid-Cycling Synchrotron, and Electron Storage Ring. A theoretical assessment of two beam monitors for EIC has been completed: 1) A novel scheme to measure the bunch length in the EIC Linac using Cherenkov radiation; 2) A bunch length monitor system for the EIC Linac-to-RCS transport line.

Simulations of transient beam loading effects on beam dynamics in the 10 GeV EIC Electron Storage Ring have been completed and documented [27]. The studies were carried out with time-dependent Vlasov-Fokker-Planck simulations performed with the parallel particle tracking code SPACE providing a self-consistent simulation of the beam dynamics in arbitrary multi-bunch configurations. Stable settings for 18 RF cavities under heavy beam loading were found, and an option of operation with a passive third-harmonic cavity system was explored too.

15 Summary

In 2022, NSLS-II accelerator physicists were working on scientific support for operations and start-up [1, 2, 3, 28]; routine lattice characterization using HLA common tools; studies of the storage ring lattice with strong coupling [4]; exploring possible use of the off-energy turn-by-turn BPM data to calibrate sextupoles; improvement of the LOCOM (Linear Optics and coupling Correction with closed Orbit Modulation) technique by implementing AC beam excitation; and studies for operations with high beam current including impedance calculation for a few vacuum chamber components (bellows, flange RF shims, ID chamber) and study of the beam-induced heating of the titanium-coated ceramic vacuum chambers [5]. We supported the commissioning of the HEX superconducting wiggler: the optics feed-forward table was developed, tested, and implemented in operations.

We completed studies for a possible new operation mode of NSLS-II for time-resolved experiments. A single-bunch current of 11 mA was accumulated with higher chromaticity and lower feedback gain, first experiments with the CHX beamline to test a new 15-bunch fill pattern were carried out. Technical details of timing mode implementation at NSLS-II were elaborated taking into account recent results of accelerator studies. The results are summarized in the report "Time-resolved Experiments at NSLS-II: motivation and machine capabilities".

We were working on the low-emittance lattice design for the NSLS-II upgrade (LDRD) including the development of standardized software tools, the design of a complex bend achromat cell, calculation of impedances, and specification of alignment and stability requirements [7]. Two FEL options for the NSLS-II upgrade were explored: XFELO and EEHG [8, 9].

We developed novel methods of lattice design and optimization: a method to design linear lattices for round beams [10, 11, 12], a data-driven chaos indicator to study nonlinear dynamics [29, 30], and convergence map technique for fast calculation of dynamic apertures [14]. The square matrix method was applied to the 4D Henon Map [13].

Automating the operation of a UED facility using machine learning was proposed [15].

We have done a cross-check of GdfidL and ECHO3D electromagnetic solvers [16] and improved the AC orbit bump technique of local kick factor measurement [17]. A theory of transverse coupled-bunch instability for arbitrary multibunch configurations was completed [18].

We worked on developing ultrafast MeV electron diffraction and microscopy (LDRD) [19, 20].

In frameworks of two MOUs with the Electron-Ion Collider Directorate, we supported lattice design, RF and beam diagnostics development for the EIC project [21, 22, 23, 24, 25, 26, 27].

The main results have been published in peer-reviewed journals and presented at the 13th International Particle Accelerator Conference and the 2022 North American Particle Accelerator Conference. Figure 1 shows the statistics of journal articles and conference reports published by NSLS-II accelerator physicists in FY14-FY22.

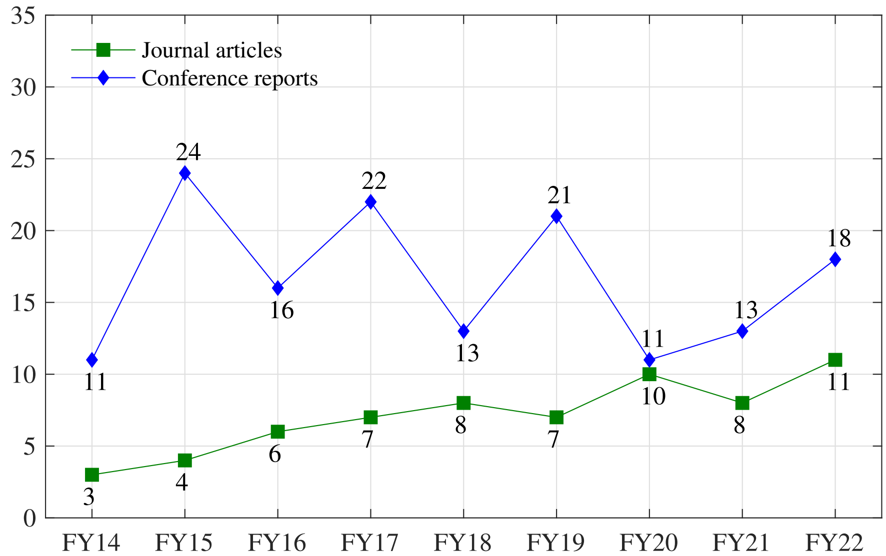

Figure 1: Number of journal articles and conference reports published in FY14-FY22

References

[1] Y. Li, *Reduction of orbit corrector strengths with degeneracy*, BNL-223399-2022-TECH (NSLSII-ASD-TN-377), 2022.

[2] Y. Li, *Review and Double-check of technote "Reasonable Beam Deviation Envelope for Ray-tracing"*, BNL-222770-2022-TECH (NSLSII-ASD-TN-373), 2022.

[3] Y. Hidaka, G.M. Wang, Y. Tian, R. Smith, Y. Li, X. Yang, *Unified Orbit Feedback at NSLS-II*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEPA71.

[4] Y. Li, V. Smaluk, R. Rainer, *Characterization of Fully Coupled Linear Optics With Turn-by-turn Data*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEPA74.

[5] G. Bassi, A. Khan, B. Kosciuk, V. Smaluk, R. Todd, C. Hetzel, M. Seegitz, A. Blednykh, *Analysis of Beam-induced Heating of the NSLS-II Ceramic Vacuum Chambers*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEPA72.

[6] G. Wang, G. Bassi, B. Bacha, G.L. Carr, X. Chen, Y. Hidaka, W. Hu, Y. Hu, G. Kwon, D. Leshchev, Y. Li, C. Mazzoli, D. Padrazo, R. Rainer, J. Rose, J. Sadowski, V. Smaluk, Y. Tian, L. Wiegart, G. Williams, X. Xiao, X. Yang, *Time-resolved Experiments at NSLS II: Motivation and Machine Capabilities*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEPA81.

[7] A. Khan, S.K. Sharma, V.V. Smaluk, *Review of Alignment and Stability Tolerances for Advanced Light Sources*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, MOPOTK054.

[8] X. Yang, G. Penn, L.H. Yu, V. Smaluk, T. Shaftan, *Optimization of echo-enabled harmonic generation toward coherent EUV and soft X-ray free-electron laser at NSLS-II*, Scientific Reports 12 (2022) 9437.

[9] X. Yang, G. Penn, V. Smaluk, X. Huang, L.H. Yu, T. Shaftan, *Toward fully coherent soft x-ray free-electron laser via echo-enabled harmonic generation in fourth generation synchrotron light sources*, Review of Scientific Instruments 93/11 (2022) 113101.

[10] Y. Li, R. Rainer, *Designing linear lattices for round beam in electron storage rings using the solution by linear matrices analysis*, Phys. Rev. Acc. Beams 25 (2022) 040702.

[11] Y. Li, R. Rainer, *Designing Linear Lattices for Round Beam in Electron Storage Rings Using SLIM*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, MOPOTK055.

[12] Y. Li, R. Rainer, *Designing linear lattices for round beam in electron storage rings using the solution by linear matrices analysis*, BNL-222910-2022-TECH (NSLSII-ASD-TN-374), 2022.

[13] K. Anderson, Y. Hao, L.H. Yu, *Study of Nonlinear Dynamics in the 4-D Henon Map Using the Square Matrix Method and Iterative Methods*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, MOPA81.

[14] L.H. Yu, Y. Hidaka, F. Plassard, V. Smaluk, Y. Hao, *Progress on Convergence Map Based on Square Matrix for Nonlinear Lattice Optimization*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEPA80.

[15] Z. Zhang, X. Yang, X. Huang, T. Shaftan, V. Smaluk, M. Song, W. Wan, L. Wu, Y. Zhu, *Toward fully automated UED operation using two-stage machine learning model*, Scientific Reports 12 (2022) 4240.

[16] A. Khan, V. Smaluk, M. Seegitz, R. Todd, A. Blednykh, *Numerical Studies of Geometric Impedance at NSLS-II With Gdfidl and ECHO3D*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEPA73.

[17] V. Smaluk, X. Yang, K. Ha, Y. Tian, A. Khan, R. Todd, M. Seegitz, A. Blednykh, *Improvement of the AC orbit bump method of local kick factor measurement using reference bunches*, Nucl. Instrum. Meth. A 1029 (2022) 166417.

[18] G. Bassi, A. Blednykh, V. Smaluk, *Coupled-bunch instability for arbitrary multibunch configurations*, Phys. Rev. Acc. Beams 25 (2022) 014402.

[19] X. Yang, T.V. Shaftan, V.V. Smaluk, Y. Zhu, P. Musumeci, W. Wan, *Current Status of Developing Ultrafast Megaelectron-volt Electron Microscope*, in Proc. of the 5th North American Particle Accelerator Conf. (NAPAC'22), Albuquerque, NM, 2022, WEZE1.

[20] X. Yang, L.H. Yu, V. Smaluk, T. Shaftan, L. Doom, B. Kosciuk, W.X. Cheng, B. Bacha, D. Padrazo, J.J. Li, M. Babzien, M. Fedurin, G.L. Carr, Y.M. Zhu, *Interferometric Bunch Length Measurements of 3 MeV Picocoulomb Electron Beams*, Journal of Applied Physics 131 (2022) 084901.

[21] Y. Cai, Y. Nosochkov, J.S. Berg, J. Kewisch, Y. Li, D. Marx, C. Montag, S. Tepikian, F. Willeke, G. Hoffstaetter, J. Unger, *Optimization of chromatic optics in the electron storage ring of the Electron-Ion Collider*, Phys. Rev. Acc. Beams 25 (2022) 071001.

[22] C. Montag, E.C. Aschenauer, G. Bassi, J. Beebe-Wang, J.S. Berg, M. Blaskiewicz, A. Blednykh, J.M. Brennan, S. Brooks, K.A. Brown, Z. Conway, K.A. Drees, A.V. Fedotov, W. Fischer, C. Folz, D. Gassner, X. Gu, R. Gupta, Y. Hao, C. Hetzel, D. Holmes, H. Huang, J. Jamilkowski, J. Kewisch, Y. Li, C. Liu, H. Lovelace III, Y. Luo, G. Mahler, D. Marx, F. Meot, M. Minty, S. Nayak, R.B. Palmer, B. Parker, S. Peggs, B. Podobedov, V. Ptitsyn, V.H. Ranjbar, G. Robert-Demolaize, M. Sangroula, S. Seletskiy, K.S. Smith, S. Tepikian, R. Than, P. Thieberger, N. Tsoupas, J. Tuozzolo, S. Verdu-Andres, E. Wang, D. Weiss, F.J. Willeke, H. Witte, Q. Wu, D. Xu, W. Xu, A. Zaltsman, S. Benson, B.R.P. Gamage, J. Grames, T. Michalski, E. Nissen, J. Preble, R. Rimmer, T. Satogata, A. Seryi, M. Wiseman, W. Wittmer, V. Morozov, F. Lin, E. Gianfelice-Wendt, Y. Cai, Y. Nosochkov, G. Stupakov, M. Sullivan, G. Hoffstaetter, D. Sagan, M. Signorelli, J. Unger, *Electron-Ion Collider Design Status*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, WEPOPT044.

[23] D. Marx, J.S. Berg, J. Kewisch, Y. Li, C. Montag, V. Ptitsyn, S. Tepikian, F. Willeke, D. Xu, G.H. Hoffstaetter, D. Sagan, M.G. Signorelli, J. Unger, V. Morozov, Y. Cai, Y. Nosochkov, B.R.P. Gamage, *Designing the EIC Electron Storage Ring Lattice for a Wide Energy Range*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, WEPOPT042.

[24] D. Xu, E.C. Aschenauer, G. Bassi, J. Beebe-Wang, J.S. Berg, W. Bergan, M. Blaskiewicz, A. Blednykh, J.M. Brennan, S. Brooks, K.A. Brown, Z. Conway, K.A. Drees, A.V. Fedotov, W. Fischer, C. Folz, D. Gassner, X. Gu, R. Gupta, Y. Hao, C. Hetzel, D. Holmes, H. Huang, J. Kewisch, Y. Li, C. Liu, H. Lovelace III, Y. Luo, G. Mahler, D. Marx, F. Meot, M. Minty, C. Montag, S. Nayak, R.B. Palmer, B. Parker, S. Peggs, B. Podobedov, V. Ptitsyn, V.H. Ranjbar, G. Robert-Demolaize, M. Sangroula, S. Seletskiy, K.S. Smith, S. Tepikian, R. Than, P. Thieberger, N. Tsoupas, J. Tuozzolo, S. Verdu-Andres, E. Wang, D. Weiss, F.J. Willeke, H. Witte, Q. Wu, W. Xu, A. Zaltsman, S. Benson, B.R.P. Gamage, J. Grames, T. Michalski, E. Nissen, J. Preble, R. Rimmer, T. Satogata, A. Seryi, M. Wiseman, W. Wittmer, V. Morozov, F. Lin, E. Gianfelice-Wendt, Y. Cai, Y. Nosochkov, G. Stupakov, M. Sullivan, J. Qiang, G. Hoffstaetter, D. Sagan, M. Signorelli, J. Unger, *EIC Beam Dynamics Challenges*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, WEIXGD1.

[25] Y. Nosochkov, Y. Cai, J.S. Berg, J. Kewisch, Y. Li, D. Marx, C. Montag, S. Tepikian, H. Witte, G.H. Hoffstaetter, J. Unger, *Dynamic Aperture of the EIC Electron Storage*

Ring, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, WEPOPT043.

[26] Y. Cai, Y.M. Nosochkov, J.S. Berg, J. Kewisch, Y. Li, D. Marx, C. Montag, S. Tepikian, F.J. Willeke, G.H. Hoffstaetter, J.E. Unger, *Chromatic Correction of the EIC Electron Ring Lattice*, in Proc. of the 5th North American Particle Accelerator Conf. (NA-PAC'22), Albuquerque, NM, 2022, MOYD6.

[27] G. Bassi, *Beam Dynamics Simulations of Transient Beam Loading Effects in the 10GeV EIC Electron Storage Ring*, BNL-223541-2022-TECH (NSLSII-ASD-TN-379), 2022.

[28] X. Yang, G. Wang, V. Smaluk, L.H. Yu, T. Shaftan, Y. Li, F. Plassard, S. Buda, Y. Hidaka, D. Durfee, Y. Tian, Y. Hu, K. Ha, A. Derbenev, B. Bacha, C. Danneil, D. Padrazo, *Online Optimization of NSLS-II Dynamic Aperture and Injection Transient*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, TUPOPT064.

[29] Y. Li, J. Wan, A. Liu, Y. Jiao, R. Rainer, *Data-driven chaos indicator for nonlinear dynamics and applications on storage ring lattice design*, Nucl. Instrum. Meth. A 1024 (2022) 166060.

[30] Y. Li, R. Rainer, J. Wan, Y. Jiao, A. Liu, *Data-driven Chaos Indicator for Nonlinear Dynamics and Applications on Storage Ring Lattice Design*, in Proc. of the 13th Int. Particle Accelerator Conf. (IPAC'22), Bangkok, Thailand, 2022, MOPOTK056.