BNL-219887-2020-TECH

NSLSII-ASD-TN-339

Accelerator Physics at NSLS-II: Research Accomplishments in 2019

V. Smaluk

December 2019

Photon Sciences

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Basic Energy Sciences (BES) (SC-22)

Accelerator physics at NSLS-II: research accomplishments in 2019

V. Smaluk, G. Bassi, A. Blednykh, Y. Li, B. Podobedov, X. Yang, L.H. Yu

Dec. 30, 2019

Abstract

NSLS-II Accelerator Physics group provides scientific support for user operations, as well as for improvements and developments of the accelerator systems. In parallel to the facility support, the accelerator physicists are working on studies of topical scientific problems: development of novel lattices; studies of collective effects and beam-induced heating; advanced computations including machine learning; ultrafast electron diffraction and microscopy (LDRD). The group also made important contributions to the electron-ion collider project at BNL and to the APS upgrade project (MOUs). Research accomplishments of the NSLS-II Accelerator Physics group achieved in 2019, are summarized in this report.

1 Introduction

In 2019, the NSLS-II Accelerator Physics group provided scientific support of user operations and contributed to further improvement of machine performance and reliability. The NSLS-II reliability was above 95%; the beam stability was maintained at the design level, the Fast Orbit Feedback performance was significantly improved. The machine was routinely operated with a beam current of 400 mA. For the first time, 500 mA of circulating beam current was demonstrated.

In parallel with the facility support, NSLS-II accelerator physicists were working on a number of research and development projects. Advanced studies of possible high-brightness and high-flux upgrade of NSLS-II are in progress. The LDRD on ultrafast electron diffraction has been completed with the results exceeding expectations. A new LDRD on the ultrafast electron microscopy is in progress. Within the framework of several MOUs, the Accelerator Physics group also contributed to the Electron-Ion Collider R&D at BNL and to the APS upgrade project.

Principal study topics are listed below::

- HLA common tools program and beam diagnostics cross-training.
- 500 mA of beam current.

- Storage Ring lattice model with wigglers and undulators.
- Improvement of orbit stability.
- Online optimization of Injector and Storage Ring.
- Beam-induced heating of NSLS-II vacuum chamber.
- Collective effects and impedances.
- Lattice development for NSLS-II upgrade.
- High-flux options of NSLS-II upgrade.
- Machine learning in accelerator physics.
- Ultra-fast electron diffraction and microscopy.
- Studies of beam-beam interaction, impedances, and ion effects for Electron-Ion Collider.
- Studies of impedances, collective effects, and beam-induce heating for APS upgrade.

A brief description of the research and development works carried out by NSLS-II accelerator physicists in 2019 is presented in the next chapters.

2 HLA common tools program and beam diagnostics cross-training

The HLA common tools program is in good progress. A basic set of tools for measurement and correction of the beam orbit, lattice functions, linear coupling, betatron tunes, and chromaticity was developed in the past year. Now every accelerator physicist has been trained on how to use these tools and is ready to work independently on the lattice characterization and correction. A standard procedure of routine lattice characterization has been developed and implemented. We continue the program of routine lattice characterization using HLA common tools to keep tracking the machine status and to let every accelerator physicist get their skills updated. In addition to the basic set, new software tools were developed and tested: generation of local orbit bumps in straight sections; emittance measurement in the Linac-to-Booster transport line; measurement of ID feedforward tables; Fast Orbit Feedback interface. The accelerator physicists were trained on the use of new HLAs. All the HLA common tools are uploaded to a GitLab-based library [1].

Significant progress was achieved in cross-training physicists on beam diagnostic instrumentation. The training sessions on the following beam diagnostic systems were arranged in 2019: bunch-by-bunch feedback system, X-ray pinhole camera, gated camera, and streak-camera. Familiarizing accelerator physicists with the beam diagnostic instruments and techniques increases their capabilities to carry out machine troubleshooting and beam studies.

3 500 mA of beam current

A beam current of 500 mA circulating in the NSLS-II storage ring was achieved for the first time. Since the vacuum chamber components were designed with minimized impedance and the high-current effects were thoroughly studied while the operating beam current was gradually increased in the past few years, no significant issues were observed. The beam-induced heating of the vacuum chamber and other collective effects were studied experimentally and compared with the numerical model. The temperature of NSLS-II vacuum chamber components did not exceed 65° C. No coupled-bunch, single-bunch, or ion-driven instability was observed at 500 mA with the standard settings of the bunch-by-bunch feedback. The experimental results are in agreement with theoretical and numerical predictions.

4 Storage Ring lattice model with wigglers and undulators

Currently, 20 light-generating insertion devices (IDs) are installed in the NSLS-II storage ring: 3 damping wigglers and 17 undulators of various types. A lattice model of the ring with all the IDs has been developed and tested. The lattice distortion introduced by each insertion device is locally compensated using six quadrupole magnets located nearby. Beam-based measurements of the beam emittance, energy spread, and radiation energy loss were carried out using NSLS-II optical diagnostics and the Coherent Hard X-ray beamline. A minimum horizontal emittance of 0.76 nm was measured with all the IDs. The measured values of the emittance, radiation energy loss and energy spread show a good agreement with analytical formulae and numerical simulations. The results are published in Physical Review Accelerators and Beams [2].

5 Improvement of orbit stability

The bandwidth of the NSLS-II Fast Orbit Feedback system (FOFB) has been characterized and improved [3]. A stage-to-stage latency characterization was implemented for the FOFB system. Based on the latency measurement, two leading contributors were found: extra 100 μs delay in the BPM firmware and a slowdown of FOFB calculations. All the BPM firmware has been upgraded to fix the first problem, and the system performance is clearly improved: the bandwidth has been increased by 40% in the horizontal plane and by 50% in the vertical plane. Further improvement is expected after completion of the Cell Controller upgrade. The long-term orbit stability was further improved by the upgrade of local bump generating software, implementation of the RF frequency feedback, and including X-ray BPMs in a local feedback [4]. An input/output controller software for routine monitoring of the spectral density of orbit oscillations has been developed and implemented in operations [5].

6 Online optimization of Injector and Storage Ring

In the frameworks of the Facility Improvement Project "Methods of online optimization of NSLS-II storage ring concurrent with user operations", a code implementing the Robust Conjugate-Gradient (RCDS) algorithm has been developed, tested, and applied for optimization of the NSLS-II injection kickers and sextupoles. Improvement of the dynamic aperture by the RCDS optimization of sextupoles was experimentally demonstrated, the results were reported at the IPAC-2019 conference. To address the unexpected problem of significant timing jitter of the injection kickers, the trigger boards were upgraded. The upgrade resulted in a reduction of the jitter from 4 ns down to the noise level. Accelerator physicists work together with the Power Supply group on implementing adjustable waveforms of the kicker pulses.

7 Beam-induced heating of NSLS-II vacuum chamber

Beam-induced heating of several components of the NSLS-II vacuum chamber including RF-shielded flanges, ceramics chambers, and stripline kickers, was studied [6, 7]. The temperature of many vacuum chamber components is routinely monitored from the beginning of the NSLS-II commissioning. Although beam-induced heating was not an issue for most of more than 700 RF-shielded flanges installed in the NSLS-II storage ring, some of them demonstrated anomalously high temperatures during high-current studies. As it was found, the local overheating resulted from a poor contact of the RF spring with a surface of the flange. Heat transfer analysis for the flanges is complete, the results were presented at the IPAC-2019 conference [8]. The flange temperature returned to normal after replacement of the defected RF springs and modification of the installation procedure. Experimental studies of the test stripline electrodes installed in the NSLS-II storage ring are complete. The beam-induced power was estimated from the measured temperature as a function of beam current. The loss factor and power were compared with the results of numerical simulations and with the analytical formulae, the data are in reasonable agreement. Beam-induced heating of the ceramic chamber is a major concern for alternative injection schemes using nonlinear kicker magnets. The beam power loss is proportional to the longitudinal impedance, which was calculated using the field matching technique via modeling the ceramic chamber with metallic coating as a pair of parallel plates. The power loss as a function of the thickness of the metal coating was calculated to optimize the ceramic chamber design [9].

8 Collective effects and impedances

Studies of longitudinal beam dynamics in storage rings in the presence of a higher-harmonic cavity (HHC) are complete, the results are published in the International Journal of Modern Physics [10]. General conditions for HHC operations, both in active or passive modes, are reviewed. As it was found, optimal conditions for bunch lengthening in the case of uniform multi-bunch filling can be exactly satisfied with a normal-conducting HHC, whereas the optimal conditions can be met only approximately with a super-conducting HHC. For NSLS-II, the stability and performance of the system in the presence of an ion-cleaning gap in the bunch filling were analyzed using the self-consistent solver of the Vlasov-Fokker-Planck equation.

The coupled-bunch instability driven by the resistive wall impedance was studied for multibunch configurations with a gap in the uniform filling. Measurements of the instability thresholds performed at the NSLS-II storage ring were compared with the predictions of a general theoretical eigenmode analysis based on the known formulas of the complex frequency shifts for the uniform multibunch configuration case. The results are published in [11].

Experience obtained at many accelerator facilities shows the beam-based measurements of the machine impedance are often different from the pre-computed impedance budgets [12]. The broadband longitudinal impedance measured using several diagnostic instruments and measurement techniques was compared with the numerically simulated impedance budget of NSLS-II. Possible reasons for the discrepancy are discussed in [13].

9 Lattice development for NSLS-II upgrade

Several lattice options for the future high-brightness and high-flux upgrade of NSLS-II are considered. The triple-bend achromat (TBA) option provides a 300 pm horizontal beam emittance re-using as many present magnets as possible [14, 15]. New design concepts, such as longitudinal-gradient bends and reverse bends, are implemented in the lattice. An interleaved sextupole scheme using a cross-cell betatron phase cancellation provides the dynamic aperture sufficient for the conventional off-axis injection. At the same time, the energy acceptance is large enough to provide a sufficiently long beam lifetime. Another option is based on the Complex Bend, a new lattice element recently proposed at NSLS-II [16, 17, 18]. This lattice provides a 65 pm emittance, which is about 30 times lower than the emittance of the actual DBA lattice (without damping wigglers). The quadrupole gradient of the complex bend does not exceed 250 T/m, so it can be built using permanent magnet technology. The layout of the straight sections and of the high-beta and low-beta matching sections is kept unchanged to minimize the hardware modifications and to reduce the cost of the upgrade [19, 20].

10 High-flux options of NSLS-II upgrade

A principal possibility of the NSLS-II high-flux upgrade with the electron beam current much higher than 500 mA was analyzed [21]. Several options are considered: 2 A in the existing tunnel; 5 A in the existing tunnel; 5 A in a greenfield new storage ring. A new lattice with lower emittance and new hardware is assumed for the upgraded machine. The following effects were explored: beam-induced heating in long low-gap in-vacuum undulators (normal- or superconducting); bunch lengthening caused by harmonic cavities; single-bunch and multi-bunch instabilities; beam lifetime and Injector requirements; radiation heat load in front-ends and absorbers.

11 Machine learning in accelerator physics

An improved repopulation technique has been developed for the genetic algorithm enhanced by machine learning. The new repopulation technique significantly improves the quality of newly populated candidates by excluding the less competitive seeds introduced by the old repopulation algorithm. This technique was validated and applied to the nonlinear lattice optimization for the High Energy Photon Source storage ring [22].

With a Bayesian approach, the linear optics correction algorithm for storage rings was revisited [23]. A complete linear optics model is simplified as "likelihood functions" and "prior probability distributions". Under some assumptions, the least square algorithm and then the Jacobian matrix approach were re-derived. A new technique has been developed to resolve degenerated quadrupole errors when observed at a few select beam position monitors.

Using a Bayesian Gaussian regression, a systematic method to analyze requirements for a beam position monitor system in a storage ring was developed. This approach was demonstrated by using turn-by-turn data of beam position monitors to reconstruct a linear optics model and to predict the brightness degradation for a ring-based light source [24].

12 Ultra-fast electron diffraction and microscopy

The LDRD project 16-010 (ultrafast electron diffraction, UED) is complete with the results exceeding expectations. The main results of this project are published in the high-rated journal Scientific Reports [25] and were reported at the IPAC-2019 conference [26]. This work was highlighted in BNL News. A new transverse focusing system based on electromagnetic quadrupole lenses was designed, installed, and commissioned. Optimization of the quadrupoles resulted in a significant improvement of the diffraction image with 3 times brighter and 2 times sharper peaks. A length of the 3-MeV electron beam was measured by the interferometric technique using coherent terahertz radiation registered by a sensitive quasi-optical detector [27].

For the current LDRD project "Demonstration of feasibility of sub-nm, picosecond electron microscope for the life sciences", the lattice design is complete including magnet specifications, alignment tolerances, and tunability. A talk covering the accelerator physics topics of the LDRD has been presented at the Preliminary Design Review and discussed with the invited experts.

A new beam diagnostic method has been developed for MeV ultrafast electron diffraction and microscopy. As a part of the preparation for the electron microscope commissioning, an experiment to measure the shot-to-shot energy jitter of the UED beam has been proposed, planned, and completed. The method and its application are described in an article published in Scientific Reports [28].

13 Studies of beam-beam interaction, impedances, and ion effects for Electron-Ion Collider

Under MOUs with the Collider-Accelerator Department, the NSLS-II accelerator physicists carried out crucial studies of the beam-beam interaction, impedances, ion effects, and non-linear lattice optimization for the BNL electron-ion collider [29, 30].

An essential upgrade of the BBSS code, the main tool to simulate beam-beam effects, has been completed by implementing efficient parallelization. For the linac-ring option, analysis of the transverse disruption and linear mismatch effects in the electron beam is complete. The results are documented in a technical note [32] and were presented at IPAC-2019 [33].

The eRHIC Interaction Region chamber design was optimized to avoid the generation of trapped modes and to reduce the beam-induced heat load. To reduce the power loss caused by resonance modes, a modification of the regular chamber design with the same vacuum chamber cross-section in the arcs and in the straight sections was proposed. Optimization of the pumping slots decreased the loss factor by at least a factor of two. An increase of the bunch length by a higher-harmonic cavity was proposed to reduce the heat load. The results are documented in a technical note [34].

Ion-induced instabilities were simulated for eRHIC and NSLS-II lattices (for future cross-checking with experiment). A cross-check of computer codes for simulation of ion instabilities was done, several bugs were fixed. A new method to estimate the residual gas concentration using measured gas-scattering lifetime has been developed. The ion concentrations obtained by this method more accurately reflect the concentrations on the electron beam path, so this method will be used for future ion instability studies. The results were reported at the NAPAC-2019 conference [35].

14 Studies of impedances, collective effects, and beam-induce heating for APS upgrade

Impedances and collective effects for the APS upgrade project were studied under an MOU with Argonne National Laboratory. The APS-Upgrade lattice requires strong magnets and small vacuum chambers, so the impedance is of significant concern. Vacuum chamber components with significant contribution to the ring impedance were modeled including photon absorbers, beam position monitors, and flange joints. Longitudinal collective effects of beam dynamics were also studied [36].

The APS-U bellows/BPM assembly was installed in NSLS-II for a beam test arranged under a contract with Argonne National Laboratory. The temperature measurements were carried out with varied beam current using an infrared camera and resistive temperature detectors. Significant local heating of the bellows was observed, the most probable heat source was identified: a poor contact of the RF fingers installed on both sides of the BPM assembly. The local impedance was also measured by the AC orbit bump method to be compared with the numerical simulations. The results are summarized in a report [37], which was discussed with ANL experts and was found very useful and comprehensive. Successful completion of this test confirmed the high reputation of NSLS-II experts.

15 Summary

In 2019, the Accelerator Physics group was providing scientific support for NSLS-II operations and developments including HLA common tools program [1]; routine lattice characterization; development of the Storage Ring lattice model with IDs [2]; demonstration of 500 mA beam current; characterization and improvement of the orbit stability [3, 4, 5, 38, 39]; online optimization of the Injector and Storage Ring. A key contribution was made to the presentation about high beam current studies for the Accelerator Vulnerability Mitigation and Mature Performance Review.

At the same time, NSLS-II accelerator physicists are productively working on many research and development projects: analysis of beam-induced heating of NSLS-II vacuum chamber [6, 8, 9]; studies of impedances and collective effects [10, 13]; application of machine learning to accelerator physics [23, 24]; development of novel beam diagnostics techniques [40], application of square matrix theory to the nonlinear optimization of NSLS-II [41], theoretical studies of free electron lasers [42]. Exploring high-brightness and high-flux options for the future upgrade of NSLS-II is in progress [14, 19, 16, 17, 21]. Under several MOUs, the Accelerator Physics group made significant contributions to the BNL electron-ion collider R&D, a very important accelerator project for the entire laboratory [32, 29, 33, 34, 35]. Good results have been achieved in ultra-fast electron diffraction and microscopy LDRD projects [25, 26, 27, 28]. Collaboration with Argonne National Laboratory was ongoing, the beam test of the APS-U bellows/BPM assembly at NSLS-II has been completed and found very useful [37]. The results are published in peer-reviewed journals and were presented at national and international conferences. Figure 1 shows the statistics of journal articles and conference reports published by NSLS-II accelerator physicists in 2015-2019.

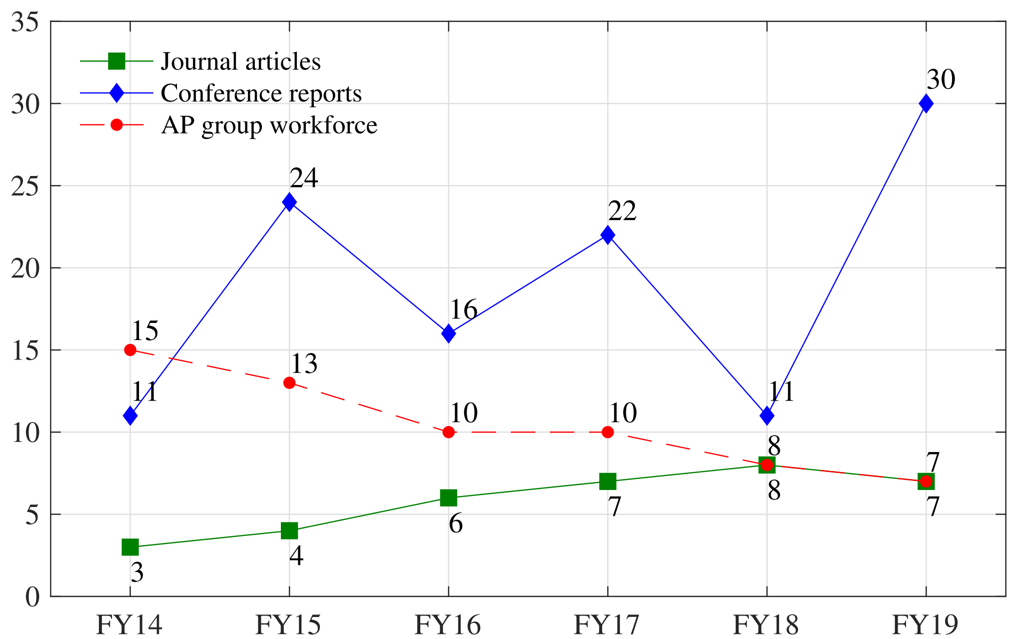

Figure 1: Number of journal articles and conference reports published by the NSLS-II Accelerator Physics group in FY14-FY19.

References

[1] https://gitlab.nsls2.bnl.gov/hlatools.

[2] V. Smaluk, Y. Li, Y. Hidaka, T. Tanabe, O. Chubar, L Wiegart, A. Blednykh, B. Bacha, T. Shaftan, *Effect of undulators on magnet lattice and emittance*, Phys. Rev. Acc. Beams 22, 124001 (2019).

[3] S. Kongtawong, X. Yang, K. Ha, Y. Tian, L.H. Yu, J. Ricciardelli, D. Padrazo, M. Maggipinto, T. Shaftan, *NSLS-II FOFB performance improvement in 2019*, BNL-212313-2019-TECH (NSLSII-ASD-TN-320), 2019.

[4] Y. Hidaka, A. Caracappa, Y. Hu, B. Podobedov, R. Smith, Y. Tian, G. Wang, *Improvements in Long-Term Orbit Stability at NSLS-II*, in Proceedings of IPAC-19, Melbourne (2019), THPRB104.

[5] B. Podobedov, A.A. Derbenev, K. Ha, T.V. Shaftan, *Continuous Monitoring of Spectral Features of Electron Beam Orbit Motion at NSLS-II*, in Proceedings of NAPAC'19, Lansing (2019), WEPLM05.

[6] A. Blednykh, G. Bassi, C. Hetzel, B.N. Kosciuk, D. Padrazo, T.V. Shaftan, V.V. Smaluk, G.M. Wang, *Temperature Measurements of the NSLS-II Vacuum Components*, in Proceedings of NAPAC'19, Lansing (2019), TUPLM36.

[7] B. Bacha, V. Smaluk, A. Blednykh, *Measurement of beam-induced power in the NSLS-II diagnostic stripline*, BNL-212240-2019-TECH (NSLSII-ASD-TN-318), 2019.

[8] A. Blednykh, B. Bacha, G. Bassi, C. Hetzel, B.N. Kosciuk, T.V. Shaftan, V.V. Smaluk, G.M. Wang, *Impedance of the flange joints with the RF contact spring in NSLS-II*, in Proceedings of IPAC-19, Melbourne (2019), TUPGW082.

[9] R.P. Fliller, G. Bassi, A. Blednykh, C. Hetzel, V.V. Smaluk, C.J. Spataro, P. Zuhoski, *Alternative Injection Schemes to the NSLS-II Using Nonlinear Injection Magnets*, in Proceedings of NAPAC'19, Lansing (2019), MOPLM01.

[10] G. Bassi, J. Tagger, *Longitudinal beam dynamics with a higher-harmonic cavity for bunch lengthening*, International Journal of Modern Physics A (2019).

[11] G. Bassi, A. Blednykh, V. Smaluk, *Analysis of the coupled-bunch instability for arbitrary multibunch configurations with application to the NSLS-II storage ring*, Nonlinear Dynamics and Collective Effects in Particle Beam Physics, pp. 123–129 (2019).

[12] B. Salvant, D. Amorim, S.A. Antipov, S. Arsenyev, M.S. Beck, N. Biancacci, O.S. Bruning, J.V. Campelo, E. Carideo, F. Caspers, A. Farricker, A. Grudiev, T. Kaltenbacher, E. Koukovini-Platia, P. Kramer, A. Lasheen, M. Migliorati, N. Mounet, E. Metral, N. Nasr Esfahani, S. Persichelli, B.K. Popovic, T.L. Rijoff, G. Rumolo, E.N. Shaposhnikova, V.G. Vaccaro, C. Vollinger, N. Wang, C. Zannini, B. Zotter, D. Amorim, T. Dalascu, M. Migliorati, R. Nagaoka, V.V. Smaluk, B. Spataro, N. Wang, S.M. White,

Building the impedance model of a real machine, in Proceedings of IPAC-19, Melbourne (2019), WEYPLS1.

[13] V.V. Smaluk, B. Bacha, G. Bassi, A. Blednykh, *Beam-based Measurement of Broadband Longitudinal Impedance at NSLS-II*, in Proceedings of IPAC-19, Melbourne (2019), MOPGW122.

[14] Y. Li, A. He, T. Shaftan, V. Smaluk, B. Kosciuk, Z. Bai, L. Wang, *A Cross-Cell Interleaved Nonlinear Lattice for Potential NSLS-II Upgrade*, J. Phys.: Conf. Ser. 1350, 012119 (2019).

[15] Y. Li, A. He, T. Shaftan, V. Smaluk, B. Kosciuk, Z. Bai, L. Wang, *A Cross-Cell Interleaved Nonlinear Lattice for Potential NSLS-II Upgrade*, in Proceedings of IPAC-19, Melbourne (2019), MOPGW115.

[16] T. Shaftan, G. Wang, V. Smaluk, Y. Hidaka, O. Chubar, T. Tanabe, J. Choi, *Complex Bend II*, BNL-211223-2019-TECH (NSLSII-ASD-TN-291), 2019.

[17] G. Wang, T. Shaftan, V. Smaluk, Y. Hidaka, O. Chubar, T. Tanabe, J. Choi, S. Sharma, C. Spataro, N.A. Mesentsev, *Complex bend. II. A new optics solution*, Phys. Rev. Acc. Beams 22, 110703 (2019).

[18] G.M. Wang, J. Choi, O.V. Chubar, Y. Hidaka, T.V. Shaftan, S.K. Sharma, V.V. Smaluk, C.J. Spataro, T. Tanabe, N.A. Mesentsev, *Reaching low emittance in synchrotron light sources by using complex bends*, in Proceedings of NAPAC'19, Lansing (2019), TUZBB2.

[19] V. Smaluk, T. Shaftan, *Realizing low-emittance lattice solutions with Complex Bends*, J. Phys.: Conf. Ser. 1350, 012044 (2019).

[20] V. Smaluk, T. Shaftan, *Realizing low-emittance lattice solutions with Complex Bends*, in Proceedings of IPAC-19, Melbourne (2019), TUPRB105.

[21] V. Smaluk, G. Bassi, A. Blednykh, C. Hetzel, S. Sharma, T. Shaftan, *Assessment of a High-Intensity Synchrotron Light Source*, BNL-212368-2019-TECH (NSLSII-ASD-TN-322), 2019.

[22] J. Wan, P. Chu, Y. Jiao, Y. Li, *Improvement of machine learning enhanced genetic algorithm for nonlinear beam dynamics optimization*, Nucl. Instrum. Meth. A 946, 162683 (2019).

[23] Y. Li, R. Rainer, W. Cheng, *Bayesian approach for linear optics correction*, Phys. Rev. Acc. Beams 22, 012804 (2019).

[24] Y. Li, W.X. Cheng, R.S. Rainer, Y. Hao, *Analysis of Beam Position Monitor Requirements with Bayesian Gaussian Regression*, in Proceedings of NAPAC'19, Lansing (2019), THXBA2.

[25] X. Yang, L. Yu, V. Smaluk, G. Wang, Y. Hidaka, T. Shaftan, L. Doom, D. Padrazo, J. Li, M. Fedurin, W. Wan, Y. Zhu, *A compact tunable quadrupole lens for brighter and sharper ultra-fast electron diffraction imaging*, Scientific Reports 9, 5115 (2019).

[26] X. Yang, L. Doom, M.G. Fedurin, Y. Hidaka, J.J. Li, D. Padrazo, T.V. Shaftan, V.V. Smaluk, G.M. Wang, L.-H. Yu, Y. Zhu, W. Wan, *Tuning Quadrupoles for Brighter and Sharper Ultra-fast Electron Diffraction Imaging*, in Proceedings of IPAC-19, Melbourne (2019), THPMP053.

[27] X. Yang, M. Babzien, B. Bacha, G.L. Carr, W.X. Cheng, L. Doom, M.G. Fedurin, B.N. Kosciuk, J.J. Li, D. Padrazo, T.V. Shaftan, V.V. Smaluk, C. Swinson, L.-H. Yu, Y. Zhu, *Interferometric Measurement of Bunch Length of a 3 MeV Picocoulomb Electron Beam*, in Proceedings of IPAC-19, Melbourne (2019), WEPGW114.

[28] X. Yang, J. Li, M. Fedurin, V. Smaluk, L.H. Yu, L. Wu, W. Wan, Y. Zhu, T. Shaftan, *A novel nondestructive diagnostic method for mega-electron-volt ultrafast electron diffraction*, Scientific Reports, 17223 (2019).

[29] C. Montag, G. Bassi, J. Beebe-Wang, J.S. Berg, M. Blaskiewicz, A. Blednykh, J.M. Brennan, S. Brooks, K.A. Brown, K.A. Drees, A.V. Fedotov, W. Fischer, D. Gassner, W. Guo, Y. Hao, A. Hershcovitch, C. Hetzel, D. Holmes, H. Huang, W.A. Jackson, J. Kewisch, Y. Li, C. Liu, H. Lovelace III, Y. Luo, F. Meot, M. Minty, R.B. Palmer, B. Parker, S. Peggs, V. Ptitsyn, V.H. Ranjbar, G. Robert-Demolaize, S. Seletskiy, V. Smaluk, K.S. Smith, S. Tepikian, P. Thieberger, D. Trbojevic, N. Tsoupas, S. Verdu-Andres, W.-T. Weng, F.J. Willeke, H. Witte, Q. Wu, W. Xu, A. Zaltsman, W. Zhang, E. Gianfelice-Wendt, *eRHIC Design Overview*, in Proceedings of IPAC-19, Melbourne (2019), MOZZPLS1.

[30] C. Montag, M. Blaskiewicz, C. Hetzel, D. Holmes, Y. Li, H. Lovelace, V. Ptitsyn, K.S. Smith, S. Tepikian, F. Willeke, H. Witte, W. Xu, E. Gianfelice-Wendt, *eRHIC Electron Ring Design Status*, in Proceedings of IPAC-19, Melbourne (2019), MOPRB093.

[31] C. Montag, G. Bassi, J. Beebe-Wang, J.S. Berg, M. Blaskiewicz, A. Blednykh, J.M. Brennan, S.J. Brooks, K.A. Brown, K.A. Drees, A.V. Fedotov, W. Fischer, D.M. Gassner, Y. Hao, A. Hershcovitch, C. Hetzel, D. Holmes, H. Huang, W.A. Jackson, J. Kewisch, Y. Li, C. Liu, H. Lovelace III, Y. Luo, F. Meot, M.G. Minty, R.B. Palmer, B. Parker, S. Peggs, V. Ptitsyn, V.H. Ranjbar, G. Robert-Demolaize, S. Seletskiy, V.V. Smaluk, K.S. Smith, S. Tepikian, P. Thieberger, D. Trbojevic, N. Tsoupas, W.-T. Weng, F.J. Willeke, H. Witte, Q. Wu, W. Xu, A. Zaltsman, W. Zhang, E. Gianfelice-Wendt, Y. Cai, Y. Nosochkov. *eRHIC Design Update*, in Proceedings of NAPAC'19, Lansing (2019), MOYBA4.

[32] G. Bassi, *Proton Beam Emittance Growth due to Centroid Fluctuations in Strongly Disrupted Electron Bunches in the Linac-Ring eRHIC*, BNL-211544-2019-TECH (NSLSII-ASD-TN-300), 2019.

[33] Y. Luo, G. Bassi, M. Blaskiewicz, W. Fischer, Y. Hao, C. Montag, V. Ptitsyn, V.V. Smaluk, F.J. Willeke, K. Ohmi, J. Qiang, *Combined Strong-strong and Weak-strong Beam-beam Simulations for Crabbed Collision in eRHIC*, in Proceedings of IPAC-19, Melbourne (2019), MOPRB091.

[34] A. Blednykh, M. Blaskiewicz, C. Hetzel, *Impedance optimization for EIC*, BNL-212482-2019-TECH (EIC/70), 2019.

[35] B. Podobedov, M. Blaskiewicz, *Connecting Gas-scattering Lifetime and Ion Instabilities*, in Proceedings of NAPAC'19, Lansing (2019), TUPLM25.

[36] R.R. Lindberg, A. Blednykh, *Impedance Considerations for the APS Upgrade*, in Proceedings of NAPAC'19, Lansing (2019), MOPLM20.

[37] A. Blednykh, B. Bacha, G. Bassi, L. Doom, C. Hetzel, R. Fliller, D. Padrazo, S. Sharma, V. Smaluk, R. Smith, T. Shaftan, G. Wang, G. Fries, *APS-U Bellows/BPM Assembly Test in NSLS-II*, BNL-212080-2019-TECH (NSLSII-ASD-TN-314), 2019.

[38] Y. Hidaka, W.X. Cheng, L. Doom, R.P. Fliller, G. Ganetis, J. Gosman, C. Hetzel, R.A. Hubbard, D. Padrazo Jr, B. Podobedov, J. Rose, T.V. Shaftan, S.K. Sharma, V.V. Smaluk, T. Tanabe, Y. Tian, G.M. Wang, C.H. Yu, *Investigation on Mysterious Long-term Orbit Drift at NSLS-II*, in Proceedings of IPAC-19, Melbourne (2019), WEPGW102.

[39] Y. Hidaka, B. Kosciuk, B. Podobedov, J. Rank, T. Tanabe, *A New Orbit Feedforward Table Generation Method for Insertion Devices*, in Proceedings of IPAC-19, Melbourne (2019), WEPGW101.

[40] W. Cheng, Y. Li, K. Ha, B. Bacha, R. Rainer, *Measurement and analysis of fast transient instabilities*, Nucl. Instrum. Meth. A 944, 162566 (2019).

[41] L.-H. Yu, Y. Li, L. Yang, *Theory of square matrix for nonlinear optimization, and application to NSLS-II*, Nonlinear Dynamics and Collective Effects in Particle Beam Physics, pp. 12–22 (2019).

[42] L.H. Yu, T. Shaftan, *Towards coherent X-ray free-electron lasers*, Nature Photonics 13, 513-515 (2019).