COLTON FRUHLING

Curriculum Vitae

Sept. 2024

Quantum and Nanophotonics Lab
Birck Nanotechnology Center
Purdue University
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Lafayette, IN 47905
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PERSONAL WEBSITE

Research Milestones

1. Characterized extremely nonlinear Thomson scattering beyond the perturbative regime, placing lower-bound on radiation reaction (Nature Photonics, 11 (8), 514–520. 2017)
2. First demonstration of coherent random lasing in quasi-2D perovskites proposing a facile integration of optical sources (Laser & Photonics Reviews, 17 (4), 2200314. 2023)
3. Characterization of dominant emission contributions leading to the development of lasing model for thin-film quasi-2D perovskites (ACS Photonics, 11 (6), 2206–2214. 2024)
4. Invention of an all-optical compact attosecond streak camera (patent and paper)

Collaborations

Studies of Time-Varying Media
The Technion, Israel – 2020 - present
Mordechai Segev

Carrier Dynamics and Lasing in Perovskites
Purdue University, IN – 2021-present
Letian Dou

Nonlinear Optical Properties of MXenes
Drexel University, PA – 2023-present
Yury Gogosti

Investigation of Transient Dynamics in Optical Materials
Argonne National Lab, IL – 2021-present
Richard Schaller

Polarization Resolved Nonlinear Thomson Scattering
Brigham Young University, UT – 2020
Justin Peatross

Education

2014-2021 **University of Nebraska – Lincoln**
PhD, Physics and Astronomy
Dissertation: Fundamental Studies of Nonlinear Thomson Scattering
Advisor: Prof. Donald Umstadter

2010-2014 **Colorado State University**
BS, Physics and Astronomy
Graduated with Honors
Advisor: Prof. Kristen Buchanan

Experience

2021-present **Postdoctoral Researcher**
Purdue University: nanolasing, ultrafast optical characterization, perovskites, time-varying, media time-refraction

2014-2021 **Graduate Research Assistant**
University of Nebraska – Lincoln: highly nonlinear Thomson scattering, polarization resolved Thomson scattering, laser wakefield acceleration, x-ray and nuclear science

2010-2014 **Undergraduate Researcher**
Colorado State University: spin waves, magneto-optical Kerr effect

Grants

Opening New Frontiers of Epsilon-Near-Zero Optics 2022
(2022 continuation). Award number: DESC0017717

Patents

Chowdhury, S. N., Nyga, P., Kildishev, A. V., Boltasseva, A., Shalaev, V. M., Simon, J., Pagadala, K., Nowak, M. P., **Fruhling, C.**, & Prokopeva, L. J. (05/09/2023). *PLASMONIC COLOR PRINTING USING RANDOM METAL FILMS AND FABRY-PÉROT RESONANT STRUCTURES PRODUCED THEREBY* (Patent 63/501,079). **- Provisional**

Fruhling, C., Shalaev, V. M., Boltasseva, A., Ozlu, M. G., & Mkhitaryan, V. (05/02/2023). *All-Optical Epsilon-Near-Zero Enabled Streak Camera* (Patent 63/463,530). **- Provisional**

Refereed Publications

(1) Jaffray, W.; Stengel, S.; Biancalana, F.; **Fruhling, C.**; Ozlu, M.; Boltasseva, A.; Shalaev, V. M.; Ferrera, M. Spatio-Spectral Optical Fission in Time-Varying Subwavelength Layers. arXiv June 18, 2024. https://doi.org/10.48550/arXiv.2406.04917.

(2) Ozlu, M. G.; Mkhitaryan, V.; **Fruhling, C.**; Boltasseva, A.; Shalaev, V. M. Floquet Engineering of Polaritonic Amplification in Dispersive Photonic Time Crystals. arXiv August 1, 2024. https://doi.org/10.48550/arXiv.2408.00552.

(3**) Fruhling, C**.; Ozlu, M. G.; Segal, O.; Segev, M.; Shalaev, V. M. Time Refraction Near the Critical Angle and Attosecond Streaking. In Preparation 2023.

(4) Wang, K.; Lin, Z.-Y.; De, A.; Kocoj, C.; Shao, W.; Yang, H.; He, Z.; Coffey, A. H.; **Fruhling, C**.; Tang, Y.; Varadharajan, D.; Zhu, C.; Zhao, Y. S.; Boltasseva, A.; Shalaev, V. M.; Guo, P.; Savoie, B. M.; Dou, L. Two-Dimensional Lattice Confined Single-Molegule-Like Aggregates. Nature 2024. https://doi.org//10.1038/s41586-024-07925-9.

(5) Chowdhury, S. N.[*]; **Fruhling, C.**[*]; Diroll, B. T.; Wang, K.; Prokopeva, L. J.; Marinova, M. M.; Dou, L.; Schaller, R. D.; Kildishev, A. V.; Boltasseva, A.; Shalaev, V. M. Photophysics and Carrier Dynamics of Lasing in Quasi-2D Lead Halide Perovskites. ACS Photonics 2024, 11 (6), 2206–2214. https://doi.org/10.1021/acsphotonics.3c01791.

(6) Shao, W.; Kim, J. H.; Simon, J.; Nian, Z.; Baek, S.-D.; Lu, Y.; **Fruhling, C.**; Yang, H.; Wang, K.; Park, J. Y.; Huang, L.; Yu, Y.; Boltasseva, A.; Savoie, B. M.; Shalaev, V. M.; Dou, L. Molecular Templating of Layered Halide Perovskite Nanowires. Science 2024, 384 (6699), 1000–1006. https://doi.org/10.1126/science.adl0920.

(7) Thakur, A.; Highland, W.; Wyatt, B.; Xu, J.; Chandran, N.; Zhang, B.; Hood, Z.; Adhikari, S.; Oveisi, E.; Pacakova, B.; **others.** Theory-Guided Synthesis of a 2D Tungsten Titanium MXene from a Covalently Bonded Layered Carbide for Electrocatalysis. CHemRxiv 2024. https://doi.org/10.26434/chemrxiv-2024-dprbn.

(8) Chowdhury, S. N.; Simon, J.; Nowak, M. P.; Pagadala, K.; Nyga, P.; **Fruhling, C.**; Bravo, E. G.; Maćkowski, S.; Shalaev, V. M.; Kildishev, A. V.; others. Wide-Range Angle-Sensitive Plasmonic Color Printing on Lossy-Resonator Substrates. Advanced Optical Materials 2024, 12 (4), 2301678.

(9) Simon, J.; **Fruhling, C.**; Kim, H.; Gogotsi, Y.; Boltasseva, A. MXenes for Optics and Photonics. Optics & Photonics News, OPN 2023, 34 (11), 42–49. https://doi.org/10.1364/OPN.34.11.000042.

(10) Lustig, E.; Segal, O.; Saha, S.; **Fruhling, C**.; Shalaev, V. M.; Boltasseva, A.; Segev, M. Photonic Time-Crystals - Fundamental Concepts [Invited]. Opt. Express, OE 2023, 31 (6), 9165–9170. https://doi.org/10.1364/OE.479367.

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(12) Wang, K.; Lin, Z.-Y.; De, A.; Kocoj, C.; Shao, W.; Yang, H.; Coffey, A.; **Fruhling, C**.; Tang, Y.; Zhu, C.; Boltasseva, A.; Shalaev, V. M.; Guo, P.; Savoie, B.; Dou, L. Two-Dimensional Lattice Confined Single-Molecule-Like Aggregates. Submitted to Nature 2023.

(13) Sychev, D. V.; Chen, P.; Yang, M.; **Fruhling, C**.; Lagutchev, A.; Kildishev, A. V.; Boltasseva, A.; Shalaev, V. M. All-Optical Modulation with Single-Photons Using Electron Avalanche. arXiv preprint arXiv:2312.11686 2023.

(14) **Fruhling, C**.; Wang, K.; Chowdhury, S.; Xu, X.; Simon, J.; Kildishev, A.; Dou, L.; Meng, X.; Boltasseva, A.; Shalaev, V. M. Coherent Random Lasing in Subwavelength Quasi-2D Perovskites. Laser & Photonics Reviews 2023, 17 (4), 2200314. https://doi.org/10.1002/lpor.202200314.

(15) **Fruhling, C**.; Ozlu, M. G.; Saha, S.; Boltasseva, A.; Shalaev, V. M. Understanding All-Optical Switching at the Epsilon-near-Zero Point: A Tutorial Review. Appl. Phys. B 2022, 128 (2), 34. https://doi.org/10.1007/s00340-022-07756-4.

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(17) **Fruhling, C**.; Wang, J.; Umstadter, D.; Schulzke, C.; Romero, M.; Ware, M.; Peatross, J. Experimental Observation of Polarization-Resolved Nonlinear Thomson Scattering of Elliptically Polarized Light. Phys. Rev. A 2021, 104 (5), 053519. https://doi.org/10.1103/PhysRevA.104.053519.

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(20) Haden, D.; Golovin, G.; Yan, W.; **Fruhling, C**.; Zhang, P.; Zhao, B.; Banerjee, S.; Umstadter, D. High Energy X-Ray Compton Spectroscopy via Iterative Reconstruction. Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 2020, 951, 163032. https://doi.org/10.1016/j.nima.2019.163032.

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Conference Proceedings

(1) **Fruhling, C.**; Boltasseva, A.; Dou, L.; Shalaev, V. M. Lasing Dynamics in Dimensionality Control Quasi-2D Perovskites [Invited]. In Metamaterials, Metadevices, and Metasystems 2024; 2024.

(2) Segal, O.; Lyubarov, M.; **Fruhling, C.**; Boltasseva, A.; Shalaev, V. M.; Segev, M. Mapping the Temporal Evolution of the Refractive Index in Few-Femtosecond Time-Varying Media. In CLEO; 2024.

(3) Simon, J.; Reigle, B.; **Fruhling, C.**; Zhang, D.; Ippolito, S.; Kim, H.; Shalaev, V.; Gogotsi, Y.; Boltasseva, A. Anisotropic and Nonlinear Optical Properties of 2D Transition Metal Carbides and Nitrides (Mxenes). In CLEO: Science and innovations; Optica Publishing Group, 2024; pp SF2R-7.

(4) Ozlu, M. G.; Mkhitaryan, V.; **Fruhling, C.**; Boltasseva, A.; Shalaev, V. M. Floquet Analysis of Photonic Time Crystals with Polaritonic Band Structures. In CLEO; 2024.

(5) **Fruhling, C.**; Ozlu, M. G.; Boltasseva, A.; Shalaev, V. M. Angular Deflection and Frequency Translation near the Critical Angle in Finite Time-Varying Media. In CLEO: Applications and technology; Optica Publishing Group, 2024; pp JW2A-35.

(6) Kildishev, A. V.; Chowdhury, S. N.; Prokopeva, L. J.; Simon, J.; Pagadala, K.; Nowak, M. P.; Nyga, P.; **Fruhling, C.**; Shalaev, V. M.; Boltasseva, A. Semicontinuous Silver Films: Plasmonic Color Printing and Advanced Disordered Media Modeling. In Plasmonics: Design, Materials, Fabrication, Characterization, and Applications XXI; SPIE, 2023; Vol. PC12648, p PC1264809. https://doi.org/10.1117/12.2677827.

(7) Sychev, D. V.; Chen, P.; Yang, M.; **Fruhling, C.**; Lagutchev, A.; Boltasseva, A.; Shalaev, V. All-Optical Switching with Few Photons Using an Electron Avalanche Multiplication. In Optics and Photonics for Information Processing XVII; SPIE, 2023; Vol. 12673, pp 169–170. https://doi.org/10.1117/12.2677787.

(8) Prokopeva, L. J.; Chowdhury, S.; Nyga, P.; Pagadala, K.; Simon, J.; Nowak, M. P.; Frühling, C.; Maćkowski, S.; Kildishev, A. V. Semi-Continuous Metal Films with Inhomogeneous Broadening: Experiment-Based Statistical Convoluted Models for Plasmonic Colours. In Conference on Lasers and Electro-Optics/Europe (CLEO/Europe 2023) and European Quantum Electronics Conference (EQEC 2023) (2023), paper ce_p_26; Optica Publishing Group, 2023; p ce_p_26.

(9) Chowdhury, S. N.; Simon, J.; Nowak, M. P.; Prokopeva, L. J.; Pagadala, K.; **Fruhling, C.**; Nyga, P.; Bravo, E. G.; Kildishev, A. V.; Shalaev, V. M.; Boltasseva, A. Wide-Range Angle-Sensitive Plasmonic Color Printing with a Lossy Resonator. In CLEO 2023 (2023), paper ATu3R.4; Optica Publishing Group, 2023; p ATu3R.4. https://doi.org/10.1364/CLEO_AT.2023.ATu3R.4.

(10) **Fruhling, C.**; Ozlu, M. G.; Mkhitaryan, V.; Boltasseva, A.; Shalaev, V. M. Spatio-Temporal Refraction at Near-Total Internal Reflection. In Waves in Time-Varying Media; 2023.

(11) **Fruhling, C.**; Wang, K.; Chowdhury, S. N.; Kildishev, A. V.; Meng, X.; Dou, L.; Shalaev, V. M.; Boltasseva, A. Random Lasing in Quasi-2D Lead-Halide Perovskite (Conference Presentation). In Metamaterials, Metadevices, and Metasystems 2022; SPIE, 2022; Vol. PC12195, p PC121950O. https://doi.org/10.1117/12.2632846.

(12) **Fruhling, C.**; Wang, K.; Chowdhury, S.; Kildishev, A. V.; Meng, X.; Dou, L.; Boltasseva, A.; Shalaev, V. M. Demonstration of Coherent Random Lasing in Optically Thin Quasi-2D Lead-Halide Perovskite. In CLEO; 2022; p FTh5D.1.

(13) **Fruhling, C.**; Ozlu, M.; Saha, S.; Boltasseva, A.; Shalaev, V. A Guide to All-Optical Switching with Epsilon-near-Zero Materials. In APS march meeting abstracts; 2022; Vol. 2022, pp Y33-002.

(14) **Fruhling, C.**; Schulzke, C.; Romero, M.; Wang, J.; Ware, M.; Peatross, J.; Umstadter, D. Measurements of Nonlinear Thomson Scattering Radiation Patterns from Elliptical Light with Polarization Resolution. In Conference on Lasers and Electro-Optics (2021), paper JTu3A.23; Optica Publishing Group, 2021; p JTu3A.23. https://doi.org/10.1364/CLEO_AT.2021.JTu3A.23.

(15) **Fruhling, C.** Measuring Attosecond Electron Pulses with Coherent Nonlinear Thomson Scattering. In APS Division of Plasma Physics Meeting Abstracts; APS Meeting Abstracts; 2020; Vol. 2020, p NI01.004.

(16) Chen, S.; Zhang, P.; Golovin, G.; Zhao, B.; **Fruhling, C.**; Haden, D.; Yan, W.; Liu, C.; Banerjee, S.; Miller, C.; Clarke, S.; Pozzi, S.; Umstadter, D. P. High-Energy Radiography of Dense Material with High Flux Inverse-Compton x-Ray Source (Conference Presentation). In Advances in Laboratory-based X-Ray Sources, Optics, and Applications VI; SPIE, 2017; Vol. 10387, p 103870C. https://doi.org/10.1117/12.2276736.

(17) Zhao, B.; Yan, W.; Zhang, P.; Banerjee, S.; Golovin, G.; **Fruhling, C.**; Haden, D.; Zhang, J.; Liu, C.; Chen, S.; Umstadter, D. A System to Control the Energy of a High-Power Laser System with Application to X-Ray Generation at Ultra-High Intensity. In Frontiers in Optics 2016 (2016), paper JW4A.97; Optica Publishing Group, 2016; p JW4A.97. https://doi.org/10.1364/FIO.2016.JW4A.97.

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(19) Yan, W.; Golovin, G.; Haden, D.; **Fruhling, C.**; Zhang, P.; Zhang, J.; Zhao, B.; Liu, C.; Chen, S.; Banerjee, S.; others. Highly Nonlinear Inverse Compton Scattering. In High intensity lasers and high field phenomena; Optica Publishing Group, 2016; pp HM3B-3.

(20) Yan, W.; Golovin, G.; **Fruhling, C.**; Haden, D.; Zhang, P.; Zhang, J.; Zhao, B.; Liu, C.; Chen, S.; Banerjee, S.; others. Experimental Observation of Multiphoton Thomson Scattering. In Frontiers in optics; Optica Publishing Group, 2016; pp FTu1C-2.

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Co-Advised Students

2021-2023	Sarah Chowdhury	Graduated in 2023 and accepted position at IBM
2021 - present	Mustafa Ozlu	Defended Master's degree and is continuing to PhD.
2021 - present	Jeffrey Simon	2nd year PhD student

Honors and Awards

GAANN Fellowship 2015-2017
Awarded to graduate students with excellent academic records pursuing Ph. D

Best Poster Presentation 2017
High-power Laser Workshop: *Stanford Linear Accelerator Center*

Synergistic Activities

Judge of Research Events 2023-2024
- 2023 Lafayette Regional Science and Engineering Fair
- 2024 Spring Undergraduate Research Conference

Departmental Representative in Graduate Student Assembly 2020-2021
Physics Department at University of Nebraska-Lincoln

Hosted Prominent Visiting Professors 2023
Nobel laureate Alain Aspect
Planning of schedules and escorting to meetings

Founding Member and Vice-President of Financial Affairs if Phi Kappa Theta Fraternity 2010-2014
– Colorado Chi Sigma chapter

Teaching Experience

Graduate Student Mentoring 2019-present
Act as a daily advisor to graduate students

Tutoring 2019-2020
Physics 212: Introductory to Electricity and Magnetism

Recitation Teaching Assistant 2015-2016
Physics 212: Introductory to Electricity and Magnetism: designed mini-lectures including class discussions and example problems

Lab Teaching Assistant 2014
Physics 211: Classical Mechanics: managed team-centered experiments

Outreach

Greater Lafayette Regional Soccer Association - Coach 2022-2024
Instructed approximately 10 players individualizing approach for different skill levels

2022 Lafayette Regional Science and Engineering Fair – Judge 2022
Provided encouraging feedback to young scientists (4^{th} - 6^{th} grade)

Sunday with the Scientists 2017
Shared high-powered laser physics is the Lincoln, NE community. Prepared demonstrations of diffraction gratings and pulsed lasers

Saturday Science 2015
Led elementary aged students in hands-on experiments

References

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