Cameron J. R. Duncan

EDUCATION

Degrees

Cornell University, Ithaca, N.Y., U.S.A.	2022	Doctor of Philosophy (Physics) *Thesis title: Ultrafast Electron Diffraction with High Six-Dimensional Brightness*
	2019	Master of Science (Physics)
University of Sydney, Sydney, N.S.W., Australia	2019	Master of Philosophy (Physics) *Thesis title: Quantum phases of a bosonic generalization of the Moore-Read ansatz*
	2016	Bachelor of Science (Mathematics, Physics) with First Class Honours and University Medal
	2012	Bachelor of Laws with First Class Honours
	2009	Bachelor of Arts (Philosophy) with First Class Honours

Specialized coursework — *U.S. Particle Accelerator School*

UC San Diego, San Diego, Ca., U.S.A.	2020	Photocathode Physics
	2020	High Brightness Electron Injectors and Applications
Northern Illinois U, DeKalb, Il., U.S.A.	2019	Accelerator Physics

RESEARCH EXPERIENCE

Assegnista di Ricerca, Vanacore Group, UNIMIB — **January 2023 – Present**
Postdoctoral Associate, Cornell Bright Beams Lab — **June 2022 – November 2022**

Graduate Research Assistant, Cornell Bright Beams Lab — **January 2018 – May 2022**

Jared Maxson, advisor — *Cornell University, Ithaca, N.Y., U.S.A.*

Skills: ✦ ultrafast electron diffraction (UED) sample chamber design and assembly ✦ UED sample transfer ✦ UHV vacuum techniques ✦ UED experimental design, data acquisition and analysis ✦ multi-slice electron scattering simulation ✦ high peak and average power laser operation ✦ nonlinear optics ✦ electron beam optics design, assembly and operation ✦ beam dynamics simulation with space charge ✦ control system software programming (C++, Python, EPICS) ✦ beam diagnostics and data analysis ✦ radio-frequency cavity design, control and power delivery

Graduate Research Assistant, Fermilab Muon G Minus 2 April – December 2017

Skills: ✦ FPGA programming (Verilog, VHDL) for GHz trigger timing and control
✦ muon storage ring operation

JOURNAL PUBLICATIONS

7. **CJR Duncan**, M Kaemingk, WH Li, MB Andorf, AC Bartnik, A Galdi, M Gordon, CA Pennington, IV Bazarov, HJ Zeng, F Liu, D Luo, A Sood, AM Lindenberg, MW Tate, DA Muller, J Thom-Levy, SM Gruner, JM Maxson, "Multi-scale time-resolved electron diffraction: A case study in moiré materials," *Ultramicroscopy* **253** 113771 (2023)
Impact: presents the first ultrafast electron diffraction experiments to deploy a hybrid pixel array direct electron detector, and shows that its single-particle sensitivity, high dynamic range and 1 kHz frame rate enable new probe modalities in electron-based structural dynamics. Measurements on a WSe/MoSe 2D heterobilayer resolve the weak features of diffuse scattering and moiré superlattice structure without saturating the zero order peak.

6. M Gordon, WH Li, MB Andorf, AC Bartnik, **CJR Duncan**, M Kaemingk, CA Pennington, IV Bazarov, Y-K Kim, JM Maxson, "Four-dimensional emittance measurements of ultrafast electron diffraction optics corrected up to sextupole order" *Physical Review Accelerators and Beams* **25**(8) 084001 (2022)
Impact: users of electron beams want minimum beam emittance. The paper reports the performance of a new aberration correction system that further minimizes the emittance of the Cornell beam-line, results that will be useful for other beam operators.
Contribution: helped design, construct and operate the beam-line.

5. WH Li†, **CJR Duncan†**, MB Andorf, AC Bartnik, E Bianco, L Cultrera, A Galdi, M Gordon, M Kaemingk, CA Pennington, LF Kourkoutis, IV Bazarov, JM Maxson, "A kiloelectron-volt ultrafast electron micro-diffraction apparatus using low emittance semiconductor photocathodes" *Structural Dynamics* **9**(2) 024302 (2022)
† These two authors contributed equally
Impact: a featured article in Structural Dynamics, the paper reports the design and performance of a time-resolved electron diffraction apparatus capable of producing intense bunches with simultaneously single digit micrometer probe size, long coherence length, and 200 fs rms time resolution.
Contribution: leader of the ultrafast electron diffraction experiments, design and assembly of the sample chamber, lead diffraction data collection and analysis, wrote 50% of the manuscript.

4. **CJR Duncan**, DA Muller, JM Maxson, "Lossless monochromation for electron microscopy with pulsed photoemission
sources and radio-frequency cavities", *Physical Review Applied* **14**(1) 014060 (2020)
Impact: ultrafast energy loss spectroscopy is an emerging experimental technique, but energy resolution is severely limited. Monochromation with a conventional slit is infeasible because of low average beam current. We present a lossless monochromator design and report simulations showing orders-of-magnitude greater beam current on

target than state-of-the-art monochromators for the same space-time-energy resolution.

3. WF Bergan, IV Bazarov, **CJR Duncan,** DB Liarte, DL Rubin, JP Sethna, "Online storage ring optimization using
dimension-reduction and genetic algorithms", *Physical Review Accelerators and Beams* **22**(5) 054601 (2019)
Impact: Particle storage rings are a rich application domain for online optimization algorithms. The paper investigates algorithms that restrict the search space to a small number of linear combinations of parameters ("knobs") which contain most of the effect on our chosen objective (the vertical emittance), thus enabling efficient tuning.
Contribution: design and coding of multi-objective genetic algorithm, data analysis to benchmark algorithm performance, wrote 30% of the manuscript.

2. Y Zhao, **CJR Duncan**, BT Kuhlmey, CM de Sterke, "Phase matching in hyperbolic wire media for nonlinear frequency
conversion", *Optics Express* **23**(26) 33733 (2015)
Impact: efficient nonlinear frequency conversion requires a phase matching condition to be satisfied. The paper analyzes the dispersion of the modes of hyperbolic wire metamaterials and demonstrates that phase matching at infrared wavelengths can be achieved with a variety of constituent materials, such as GaAs, in which phase matching cannot easily be achieved by conventional means.
Contribution: developed analytical models used in the paper.

1. **CJR Duncan**, L Perret, S Palomba, M Lapine, BT Kuhlmey, C Martijn de Sterke, "New avenues for phase matching in
nonlinear hyperbolic metamaterials", *Scientific Reports* **5**(1) 1 (2015)
Impact: the paper demonstrates that hyperbolic phase matching can be achieved with a wide range of material parameters, offering access to the use of nonlinear media for which phase matching cannot be achieved by other means.

CONFERENCE PROCEEDINGS

12. **CJR Duncan**, GM Vanacore, "Exploring time-of-flight energy filtering possibilities for ultrafast electron single-pixel imaging", *Proc. IPAC'23* (2023)

11. **CJR Duncan**, M Kaemingk, A Bartnik, M Gordon, W Li, JM Maxson, "High angular magnification for accessing structural information in Ultrafast Electron Diffraction", *Proc. IPAC'23* (2023)

10. D Ma, CY Zhang, YT Shao, Z Baraissov, **CJR Duncan**, A Hanuka, A Edelen, JM Maxon, DA Muller, "Physics-informed Bayesian Optimization of an Electron Microscope", Microscopy and Microanalysis **29**(S1) 1875 (2023)

9. A Bartnik, **CJR** Duncan, M Andorf, M Kaemingk, M Gordon, JM Maxson, "A UV Pump Laser System for Micro-UED at Cornell", *Proc. IPAC'23* (2023)

8. C Zhang, YT Shao, Z Baraissov, **CJR Duncan**, A Hanuka, AL Edelen, JM Maxson, DA Muller, "Bayesian Optimization for Multi-dimensional Alignment: Tuning Aberration Correctors and Ptychographic Reconstructions", , *Microscopy and Microanalysi*s **28**(S1) 3146 (2022)

7. C Zhang, Z Baraissov, **CJR Duncan**, A Hanuka, A Edelen, JM Maxson, DA Muller, "Aberration corrector tuning with machine-learning-based emittance measurements and bayesian optimization", *Microscopy and Microanalysi*s **27**(S1) 810 (2021)

6. **CJR Duncan**, P Cueva, JM Maxson, DA Muller, "Improving energy resolution and compensating chromatic aberration with a TM010 microwave cavity", *Proc. NAPAC'19* (2019)

5. WH Li, MB Andorf, IV Bazarov, Luca Cultrera, **CJR Duncan**, A Galdi, JM Maxson, CA Pennington, "Ultrafast nonlinear photoemission from alkali antimonide photocathodes", *Proc. NAPAC'19* (2019)

4. **CJR Duncan**, MB Andorf, V Khachatryan, Colwyn Gulliford, JM Maxson, DL Rubin, IV Bazarov, "A generic software platform for rapid prototyping of online control algorithms", *Proc. IPAC'19* (2019)

3. WF Bergan, IV Bazarov, **CJR Duncan**, DL Rubin, "Applications of dimension-reduction to various accelerator physics problems", *Proc. IPAC'19* (2019)

2. WF Bergan, IV Bazarov, **CJR Duncan,** D Liarte, DL Rubin, JP Sethna, "Use of dimension-reduction techniques with multi-objective genetic algorithms to improve the vertical emittance and orbit at CESR", Proc. *IPAC'18* (2018)

1. CM de Sterke, **CJR Duncan,** L Perret, S Palomba, M Lapine, BT Kuhlmey, "Phase matching in layered hyperbolic metamaterials", *European Quantum Electronics Conference* (2015)

INVITED TALKS

2. "Resolving structural dynamics at multiple length and time scales", **Physics and Applications of High Brightness Beams 2023 (San Sebastian, June 2023)**

1. "Alkali antimonide photocathode performance in ultrafast electron microdiffraction"**, Photocathode Physics for Photoinjectors 2021 (Virtual, November 2021)**

CONTRIBUTED TALK

"Exploring a time-of-flight method for high coherence electron ghost imaging", **CMD30, FisMat 2023 (Milano, September 2023)**

PATENT

CJR Duncan, JM Maxson, DA Muller, A monochromator device and methods of use thereof,

WIPO WO2021046187A1 (2019)

FELLOWSHIPS AWARDS AND PRIZES

US Particle Accelerator Travel Award	**January 2022**
Cornell University Fellowship	**Fall 2019 — Spring 2020**
Australian Postgraduate Award	**January — August 2016**
Alumni Scholarship, University of Sydney	**2016**
University Medal, University of Sydney (prize for an undergraduate thesis of outstanding merit)	**2016**
Honours Scholarship, University of Sydney	**January – December 2015**

TEACHING EXPERIENCE

Guest Lecturer, Mechanics and Special Relativity, Cornell University	**Fall 2022**
Teaching Assistant, Electromagnetism for Engineers, Cornell University	**Spring 2017**
Teaching Assistant, Introduction to Physics, Cornell University	**Fall 2016**