

Karanpreet Singh

Doctoral Researcher (MSCA) — Physical Learning & Neuromorphic Computing

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Education

Doctorate in Physics — Université libre de Bruxelles 2026–present

MSCA POSTDIGITAL+ Doctoral Network (EU-funded)

Proposed thesis: Information Processing in Physical Systems. Supervisor: Dr. Serge Massar.

Master of Science in Physics — Queen's University, Canada 2021–2024

Carl Reinhardt Fellow · GPA 3.93

Thesis: Design and Optimization of Inverse Phononic Crystals in Gallium Arsenide for Enhanced Surface Acoustic Waveguiding. Supervisor: Dr. James Stotz.

Relevant coursework: Machine Learning / Deep Learning; Introduction to Nanophotonics.

Bachelor of Science in Physics (Honours) — LP University, India 2016–2019

LPU NEST Scholar · Graduated with Distinction

Thesis: Space Debris Removal via Multi-Gaussian High-Intensity Laser Beams. Supervisor: Naveen Gupta.

Publications

1. **Singh, K.**, Willson, G. and Stotz, J.A.H. (2025). “A Phononic Crystal Waveguide Using Surface Waves Below the Sound Cone.” *Applied Physics Letters* **126**(2), 022204. doi:10.1063/5.0246477
2. **Singh, K.**, Willson, G. and Stotz, J.A.H. (2025). “Optimizing Phononic Crystal Waveguides for Enhanced SAW Confinement.” *Physica Status Solidi (b)*. doi:10.1002/pssb.202400609
3. **Singh, K.** and Gupta, N. (2018). “Nonlinear optical response of periodic lattice of metallic nanoparticles to ultraintense laser beams.” *AIP Conference Proceedings* **2115**(1), 030175. doi:10.1063/1.5113014
4. **Singh, K. et al.** Training out-of-equilibrium chemical networks. *Manuscript in preparation*, 2026.

Conferences & Invited Roles

- **Session chair**, Mini-symposium “Training of Physical Neural Networks Beyond Backpropagation,” POSTDIGITAL+, Université libre de Bruxelles, January 2026.
- **Plenary session chair**, International Workshop on Machine Learning, AI and Neuromorphic Computing, POSTDIGITAL+, Universitat de les Illes Balears, Palma de Mallorca, May 2026.
- **Participant**, 92nd Workshop on Unconventional Computing, International School of Solid State Physics, Ettore Majorana Foundation, Erice, Italy, April 2026.
- **Singh, K.** and Stotz, J.A.H. (2024). “Optimizing Inverse Phononic Crystals on GaAs for Surface Acoustic Waveguiding.” 36th International Conference on the Physics of Semiconductors (ICPS), Ottawa, Canada.
- Gupta, N., **Singh, K.** and Kumar, S. (2019). “Realization of an all-optical transistor by nonlinear refraction of laser beams through a periodic lattice of gold nanoparticles.” Int. Conf. on Advances in Nanomaterials and Devices for Energy and Environment, Gwalior, India.
- Kumar, S., Gupta, N. and **Singh, K.** (2019). “Third harmonic generation of a q-Gaussian laser beam

interacting with a random distribution of C₆₀ molecules.” Int. Conf. on Advances in Nanomaterials and Devices for Energy and Environment, Gwalior, India.

Research Experience

Doctoral Researcher — Université libre de Bruxelles

2026–present

- Developing learning algorithms for out-of-equilibrium chemical reaction networks, extending equilibrium-propagation-family methods to driven systems whose linearised dynamics are non-symmetric.
- Doctoral project on photonic reservoir computing within the POSTDIGITAL+ Marie Skłodowska-Curie Doctoral Network.

Research Assistant — Queen’s University, Kingston, ON

2021–2024

- Led the design and modelling of inverse phononic crystal waveguides in GaAs enabling high-confinement surface acoustic wave propagation for spin transport.
- Designed elliptical-cylinder inclusion geometries achieving over ten orders of magnitude reduction in energy loss to the bulk relative to previous designs.
- Performed eigenfrequency and dispersion analysis by finite element modelling in COMSOL Multiphysics for Rayleigh-like modes in anisotropic microstructured substrates.
- Optimized waveguide width, inclusion aspect ratio and depth for lateral and vertical confinement under fabrication constraints.
- Developed cleanroom-compatible fabrication recipes and fabricated interdigital transducers in a Class 1000 cleanroom. Awarded the **MicroFAB Access grant** by CMC Microsystems.
- Published two first-author peer-reviewed articles and presented at international conferences.

Teaching Assistant — Queen’s University, Kingston, ON

2021–2024

- Delivered tutorials for Engineering Practices 1, introducing physics laboratories and engineering design process.
- Led problem-solving sessions for Electricity and Magnetism, covering oscillations, electromagnetic theory and wave propagation.

Supervision

Vasco Fiorni — Master’s thesis internship, Université libre de Bruxelles

2026

- *Implémentation de l’algorithme de propagation d’équilibre dans des réseaux chimiques de dimérisation* — “Implementation of the equilibrium propagation algorithm in chemical dimerisation networks.”
- Supervised alongside Bortolo Moggetti (principal supervisor) and Dimitri Vanden Abeele.

Selected Projects

Design and Modelling of an Optical Neuron System for SoC Applications

2023

SiEPIC Active Silicon Photonics Fabrication Workshop

- Designed a photonic neuron on the broadcast-and-weight paradigm with wavelength-multiplexed inputs and microring-resonator weight banks.
- Modelled waveguide and resonator components in Ansys Lumerical MODE; integrated system-level architecture in INTERCONNECT.
- Simulated photodetection and activation using Mach–Zehnder modulators to capture CTRNN

dynamics in Cadence Virtuoso.

- Fabricated through AMF Singapore, aligning component specifications with foundry constraints.

FDTD Simulation for Nanophotonic Applications

2022

Implemented finite-difference time-domain methods from first principles: update equations, perfectly matched layer boundaries, and TE/TM-polarized wave propagation in periodic media.

Time-Series Modelling with LSTM Neural Networks

2020

Applied recurrent architectures to financial time series to investigate the limits of predictive performance in nonlinear, noisy systems.

Technical Skills

- **Simulation & design:** Ansys Lumerical (MODE, INTERCONNECT), COMSOL Multiphysics (FEM), Cadence Virtuoso, KLayout, MATLAB
- **Scientific programming & ML:** Python (NumPy, SciPy, PyTorch, TensorFlow); numerical integration of stiff dynamical systems; gradient estimation for physical learning
- **Numerical methods:** Eigenmode analysis, dispersion modelling, parameter optimization for photonic and phononic structures
- **Fabrication:** Hands-on experience with cleanroom tooling and techniques (Class 1000)
- **Other:** Linux, Git, $\text{\LaTeX}$, VS Code

Memberships & Outreach

- Student member, Optica and SPIE
- Judge, Frontenac, Lennox and Addington Science Fair, Kingston, ON (2023)
- Presented meteorite specimens to the public at Science Rendezvous, Kingston, ON (2022)