

# Karanpreet Singh

**Doctoral Researcher (MSCA) — Physical Learning & Neuromorphic Computing**

Université libre de Bruxelles, Brussels, Belgium

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## Education

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**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

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1. **Singh, K. et al.** Training out-of-equilibrium chemical networks. *Manuscript in preparation*, 2026.
2. **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](https://doi.org/10.1063/5.0246477)
3. **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](https://doi.org/10.1002/pssb.202400609)
4. **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](https://doi.org/10.1063/1.5113014)

## Conferences & Invited Roles

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- **Plenary session chair**, International Workshop on Machine Learning, AI and Neuromorphic Computing, POSTDIGITAL+, Universitat de les Illes Balears, Palma de Mallorca, May 2026.
- **Poster**, “Learning with Chemical Dimerization Networks: Robustness to Global Variations,” **Singh, K.**, Moggetti, B.M. and Massar, S. 92<sup>nd</sup> Workshop on Unconventional Computing, International School of Solid State Physics, Ettore Majorana Foundation, Erice, Italy, April 2026.
- **Session chair**, Mini-symposium “Training of Physical Neural Networks Beyond Backpropagation,” POSTDIGITAL+, Université libre de Bruxelles, January 2026.
- **Poster**, “Optimizing Inverse Phononic Crystals on GaAs for Surface Acoustic Waveguiding,” **Singh, K.** and Stotz, J.A.H. 36<sup>th</sup> International Conference on the Physics of Semiconductors (ICPS), Ottawa, Canada, 2024.
- **Poster**, “Self-phase modulation of a quadruple-Gaussian laser beam in a periodic lattice of gold nanoparticles,” Gupta, N. and **Singh, K.** National Conference on Innovations in Applied Sciences and Engineering, NIT Jalandhar, India, 2019.

- **Poster**, “Nonlinear optics of multi-Gaussian laser beams interacting with a periodic lattice of gold nanoparticles,” Gupta, N. and **Singh, K.** National conference, Guru Nanak Dev University, Amritsar, India, 2019.
- **Co-author**, “Realization of an all-optical transistor by nonlinear refraction of laser beams through a periodic lattice of gold nanoparticles,” Gupta, N., **Singh, K.** and Kumar, S. Int. Conf. on Advances in Nanomaterials and Devices for Energy and Environment, Gwalior, India, 2019.
- **Co-author**, “Third harmonic generation of a q-Gaussian laser beam interacting with a random distribution of C<sub>60</sub> molecules,” Kumar, S., Gupta, N. and **Singh, K.** Int. Conf. on Advances in Nanomaterials and Devices for Energy and Environment, Gwalior, India, 2019.

## Supervision

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**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 Mognetti (principal supervisor) and Dimitri Vanden Abeele.

## Research Experience

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**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.

## Selected Projects

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### 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

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- **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

## Schools & Training

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- Radio Astronomy Winter School, IUCAA & NCRA-TIFR, Pune, India, December 2019.
- Astrowin 19 — Winter School on Astronomy, Hyderabad, India, February 2019.

## Memberships & Outreach

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- 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)