SPINEX

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<p style="color: rgb(210, 45, 64); font-size: 19px;">Spin-Exciton coupling in hybrid nanostructure</p>

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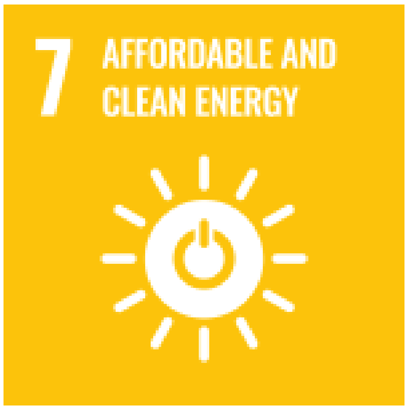
Precise control over the coupling between spin and excitons can be achieved by engineering the interface between materials with magnetic and quantum dots with semiconducting properties. The most promising approach to achieve this is by designing core-shell nanoparticles at the nanoscale, where their high surface-to-volume ratios allow for unprecedented manipulation of the spin-excitonic coupling. Our goal is to synthesize highly controlled, homogeneous bi-phasic core-shell nanoparticles with tailored interfaces that unlock novel synergy within a single, integrated architecture. Our ultimate ambition is to master the interface-driven coupling mechanisms, achieving full control over the properties of magnetic quantum dot core-shell nanoparticles accompanied by in depth characterization using cutting-edge in situ and ex-situ techniques, such as polarized neutron scattering experiments, revealing critical insights into spin arrangements, chemical distribution, interfacial strain, and magnetic order at the interface. Our key ambitious objectives are threefold: (1) to elucidate the fundamental mechanisms governing interfacial coupling at the microscopic level, (2) to achieve precise control over the synthesis of the core-shell interface, and (3) to leverage this knowledge for the targeted enhancement of coupled properties across multiple applications. By advancing the synthesis and understanding of multiphase core-shell nanomaterials, this project has the potential to deliver breakthrough innovations in next-generation opto-spintronics, quantum information systems, energy-efficient optoelectronics, and next-generation biomedical technologies.

<p style="color: dark blue; font-size: 18px;font-weight: bold;">Sustainable Development Goals</p>



4 QUALITY EDUCATION

Meet the Project

If you had to explain your project to someone outside your field, how would you describe it in three sentences?

My project, SPINEX, explores a radical idea: using a flash of light to switch the magnetic state of a material – like a switch, but governed by quantum physics. To do this, I study how excitons (tiny energy packets born when light is absorbed) interact with the magnetic spin of electrons – an intrinsic quantum "compass needle" inside each particle. Ultimately, this research will lay the foundation for a new class of light-responsive magnetic nanomaterials, driving innovation across quantum information systems, energy-efficient optoelectronics, and next-generation biomedical technologies.

What fascinates you most about the topic of your research project?

Imagine a world where the internet cannot be hacked, computers run on a fraction of today's energy, doctors can deliver medicine directly to diseased cells without harming healthy ones, and solar panels capture nearly every photon that touches them. That world is not science fiction – it is the horizon this research is moving toward. All of this becomes possible by understanding spin–exciton coupling inside core-shell magnetic quantum dots, a tiny, engineered nanostructures where light and magnetism meet at the atomic scale. At this scale, the ordinary rules of physics give way to quantum behaviour, and that is precisely where the most exciting discoveries live.

This research lays the foundation to computers that are faster and far more energy-efficient, since they would use spins and light instead of just electrical currents. It will form the groundwork for quantum communication systems – completely secure networks, where any attempt to intercept the communication, changes the quantum state of the system and reveals the intruder. These quantum dots can be used in medicine. They will help doctors deliver drugs directly to diseased cells, reducing side effects. By controlling light and magnetism at this tiny scale, it is possible to make better solar panels and light-based devices, turning more sunlight into usable energy and improving everyday technologies.

This project is not only about fundamental physics, it is about taking a decisive step toward a safer, smarter, and more sustainable future. That is what captured my imagination and keeps me at the bench every day.

How does your research contribute specifically to achieving the UN Sustainable Development Goals?

SPINEX contributes directly to three United Nations Sustainable Development Goals by translating quantum-scale discoveries into real-world technologies.

On the energy front (SDG 7), understanding spin–exciton coupling enables the design of energy-efficient devices and next-generation light-harvesting systems. Replacing conventional silicon electronics with spin-based (spintronic) architectures could dramatically cut the energy consumed by computers and data centers, reducing carbon emissions at a global scale and accelerating the transition to green energy.
For innovation and infrastructure (SDG 9), the ability to control magnetism with light unlocks entirely new device families: opto-spintronic sensors, neuromorphic computing chips that mimic the brain, and quantum information processors. As global data consumption continues to surge, spintronic devices promise to be faster, smaller, more reliable, and vastly more energy-efficient than anything built on conventional electronics.

Finally, for quality education (SDG 4), SPINEX places cutting-edge interdisciplinary science spanning condensed matter physics, photonics, materials science, and quantum information at the heart of the next generation's training. This research grows the global community of scientists equipped to tackle sustainable challenges, contributing knowledge that will underpin tomorrow's green and quantum economy.

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