Electrical control of circular polarization in birefringent spin vertical cavity surface emitting laser

Laboratories and groups for the position:

Institut Jean Lamour, Département P2M
Equipe 104: Nanomatériaux pour Optoelectronique
Nancy, France

Semiconductor Optoelectronic Devices
Paderborn University
Paderborn, Germany

Name and email of supervisors:
Director of thesis: Yuan Lu (Institut Jean Lamour, France), e-mail: yuan.lu@univ-lorraine.fr
Co-director of thesis: Nils Gerhardt (Paderborn University, Germany), e-mail: nils.gerhardt@uni-paderborn.de

Spin vertical cavity surface emitting lasers (spin-VCSELs) reveal unprecedented advantages of spintronics for applications beyond magnetoresistance and have the potential to form a new generation of optical communication systems [1,2]. Till now, the circular polarization is controlled by switching the magnetization thanks to an external magnetic field. For future applications, it is essential to get rid of any external magnetic field. A possible solution could be to switch electrically the magnetization via the spin-orbit torque (SOT) effect [3]. However, the control of the circular polarization by modulating electrically the spin-injection direction remains still a challenging issue.

References:
[1] M. Lindemann, G. Xu, T. Pusch, R. Michalzik, M. R. Hofmann, I. Žutić & N. C. Gerhardt, "Ultrafast spin-lasers", Nature 568, 212–215 (2019).

[2] I. Žutić, G. Xu, M. Lindemann, P. E. Faria Junior, J. Lee, V. Labinac, K. Stojšić, G. M. Sipahi, M. R. Hofmann, N. C. Gerhardt, "Spin-lasers: spintronics beyond magnetoresistance", Solid State Communications 316–317, 113949 (2020).

[3] P. A. Dainone, N. F. Prestes, P. Renucci, A. Bouché, M. Morassi, X. Devaux, M. Lindemann, J.-M. George, H. Jaffrès, A. Lemaitre, B. Xu, M. Stoffel, T. Chen, L. Lombez, D. Lagarde, G. Cong, T. Ma, P. Pigeat, M. Vergnat, H. Rinnert, X. Marie, X. Han, S. Mangin, J.-C. Rojas-Sanchez, J.-P. Wang, M. C. Beard, N. C. Gerhardt, I. Žutić & Y. Lu, "Controlling the helicity of light by electrical magnetization switching", Nature 627, 783-788 (2024).

The objective of this PhD thesis is to investigate the electrical control of spin injection in a birefringent spin-VCSEL by employing novel spin injectors that exhibit spin–orbit torque (SOT) effects. The project will involve close collaboration with the research group of Nils Gerhardt at Paderborn University (Germany), which has recognized expertise in spin-laser characterization. During the three-year PhD program, the candidate will spend one year within Prof. Gerhardt's group, focusing on advanced spin-laser characterization techniques. Beyond demonstrating electrical control of spin injection in spin-VCSELs, this project aims to deepen the understanding of the underlying physical mechanisms, including spin–orbit torque, spin injection, and spin dynamics in spin lasers.

The main tasks of the PhD student will be as below:
1) Growth of a perpendicularly magnetized spin injector structure on a GaAs based ½ VCSEL;
2) Device fabrication and demonstration of the electrical switching of the injector magnetization;
3) Polarization resolved electroluminescence characterization of birefringent SOT spin-VCSEL.

The team "Nanomaterials and Optics" (team 104) of the Institut Jean Lamour (IJL) is internationally recognized for its expertise in semiconductor spintronics. The development of spin-VECSELs will also benefit from the platform TUBE, a 70 m long, ultra-high vacuum interconnected system and from the MiNaLor cleanroom. The device fabrication will be performed in the MiNaLor cleanroom. The candidate will also spend one year in the lab of Semiconductor Optoelectronic Devices, Paderborn University (Germany) to characterize spin-VCSEL devices.

The candidate should have a good knowledge in condensed matter physics particularly in semiconductor and magnetism. Creativity, rigor, and taste for teamwork are qualities that will be highly appreciated. Good communication skills (English) are also required.

Documents required: 1. An up-to-date CV; 2. The academic transcripts for M1 and M2 or for the 4th and 5th years for engineering students; 3. A cover letter from the student explaining their motivation for the subject (requirement for a signed commitment); 4. Letters of recommendation (optional).

More info for group activity:
https://nanooptospin.ijl.cnrs.fr/spintronics-with-semiconductors/
More info for project:
https://spindatacom.eu/

Salary: 2300€/month, gross salary

Application deadline: May 31, 2026

PhD starting date: Oct. 1, 2026