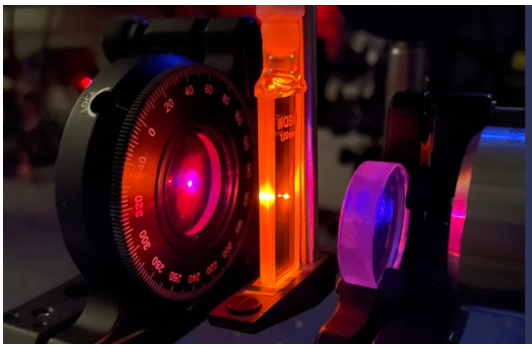


LPL Laboratoire de Physique des Lasers

UNIVERSITÉ SORBONNE PARIS NORD

PAL Organic Photonics And Lasers group

Self-Pulsing Organic Microcavity Lasers and Polariton Lasers for Ultrafast Photonic Information Processing

PhD proposal | Organic photonics & lasers group

Context and objectives

Organic semiconductors have transformed display technology through OLEDs, now ubiquitous in smartphones. Their potential also extends to lasers: organic semiconductor lasers could provide compact, wavelength-tunable and potentially low-cost coherent light sources [1]. Yet important challenges remain, notably electrical pumping, continuous-wave operation and the controlled generation of ultrashort optical pulses [2,3].

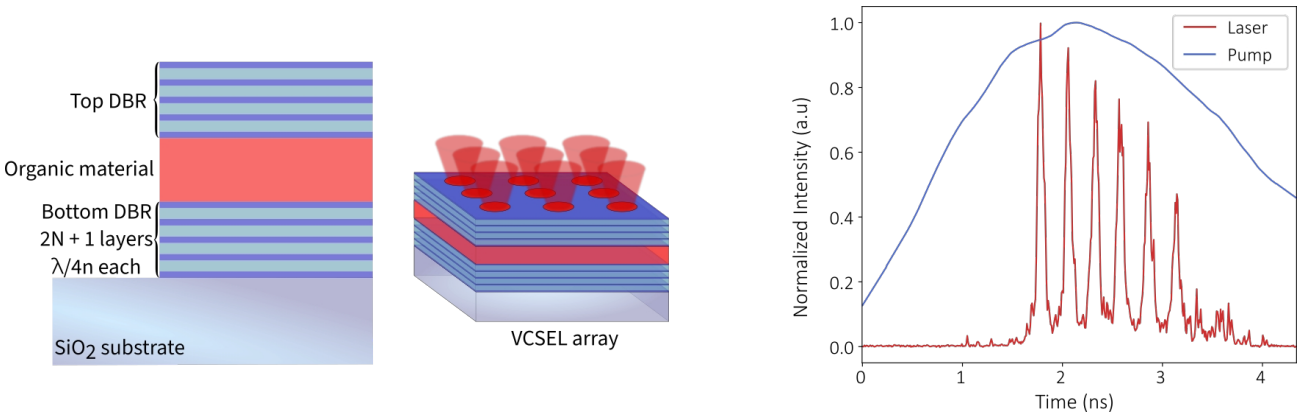
This PhD will investigate an intriguing possibility: **can an organic microcavity laser spontaneously emit a regular train of very short light pulses, without external modulation?** Such self-pulsing can arise when a saturable absorber—a material that becomes less absorbing at high optical intensity—is incorporated into a laser cavity. The interplay between gain, absorption and cavity dynamics may then produce sustained optical oscillations [4].

Our team has recently observed relaxation oscillations in organic microcavity lasers for the first time, providing an experimental starting point for this research. A longer-term ambition is to approach GHz pulse repetition rates and sub-100-ps durations, although these performances remain to be demonstrated.

Interestingly, organic semiconductors present the unique ability to generate **polariton Bose-Einstein condensates at room temperature**, due to their high exciton binding energies. These "polariton lasers" based on the same architecture present very different features compared to photon lasers, have theoretically lower thresholds, and can also exhibit relaxation oscillations even if the underlying physics is different [5]

Why does this matter for optical computing?

In neuromorphic computing, information is processed through networks inspired by biological neurons, which communicate using short electrical spikes. In photonic versions, optical pulses can carry signals between interconnected devices. Lasers are promising candidates because their nonlinear dynamics can produce threshold responses, oscillations and spike-like transients. Inorganic VCSELs, including devices with saturable absorbers, have already shown neuron-like behaviours relevant to photonic information processing [6].



Left : Schematic representation of a Vertical Cavity Surface-Emitting Laser (VCSEL), that can work either in weak coupling (standard photon lasing) or strong coupling (polariton lasing). Right : Our first experimental demonstration of spiking behavior at the onset of lasing in an organic semiconductor microcavity

Could organic lasers offer similar functionalities? Their singlet and triplet excited states, and the interactions between them, introduce distinctive timescales and nonlinearities. Understanding whether these features can be used to control optical spikes is a central scientific motivation of this project.

What will you do during the PhD?

1 | Demonstrate self-pulsing. The main experimental goal is to design, fabricate and characterize organic VCSEL-type microcavities incorporating a saturable absorber. You will investigate how absorber dynamics and semiconductor photophysics govern pulse formation. Experiments will be complemented by numerical modelling to guide device design.

2 | Explore the strong coupling regime in organic microcavities and how this affects the self-pulsing dynamics.

3 | Explore photonic-neuron functionalities. Building on the laser results, you will study how the devices respond to optical perturbations and whether their nonlinear dynamics can generate and control spike-like signals. The aim is not to build a complete neural network, but to assess the feasibility of elementary functions relevant to future organic photonic neuromorphic architectures.

Research environment and international opportunities

The thesis will take place at the Laboratoire de Physique des Lasers, Université Sorbonne Paris Nord, 93430 Villetaneuse. The candidate will work with the Organic Photonic And Lasers (OPAL) team. The team has a strong connection with Pr Adachi's world-leading group at Kyushu University, Japan, within the framework of an International Research Lab (Ophelia), and is a founding member of the International Research Network OSCAR. In this context, research stays in Japan during the PhD thesis will be encouraged.

Who should apply?

We welcome students with a Master or engineering degree in photonics, quantum devices, optical physics or fundamental physics. A solid grounding in optics and laser physics is essential; experimental experience is appreciated. No prior expertise in organic chemistry or cleanroom fabrication is required. Good written and spoken English is expected.

Practical information

Supervisors: Dr. Tristan Guezennec, Prof. Sébastien Forget and Prof. Sébastien Chénais. An associated M2 research internship is available, you are encouraged to join the team for the internship before the PhD. Please send your resume to tristan.guezennec@univ-paris13.fr; sebastien.forget@univ-paris13.fr; sebastien.chenais@univ-paris13.fr

References:

[1] S. Chénais and S. Forget, « Recent advances in solid-state organic lasers » , Polymer International, 61, 3, 2011.

[2] Yoshida, K., Gong, J., Kanibolotsky, A.L. et al. « Electrically driven organic laser using integrated OLED pumping ». Nature 621, 746–752 (2023)

[3] Zhang, L., Zhao, B., Wang, T. et al. « Continuous-wave organic laser enabled by monolayer molecular crystal. » Nat Commun 17, 7061 (2026).

[4] S. F. Lim et al. « Self-pulsating and bistable VCSEL with controllable intracavity quantum-well saturable absorber » Electron. Lett, 33, 20, 1997

[5] A. Opala *et al.,* "Theory of relaxation oscillations in exciton-polariton condensates", Phys. Rev. B 98, 195312, 2018

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