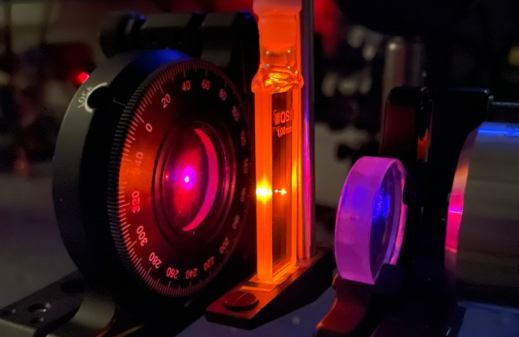


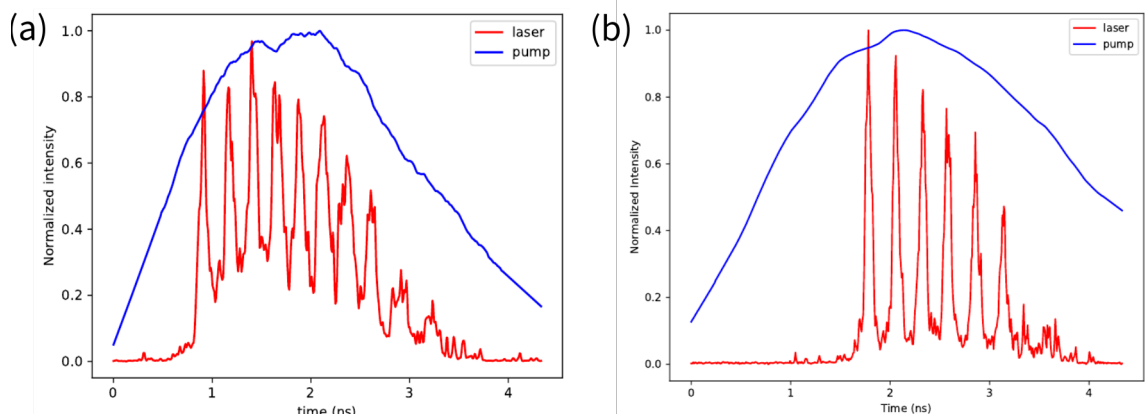


Master thesis proposal: Study of self-pulsing in organic solid-state lasers

Keywords: Optics; Lasers; Photonics; Organic semiconductors

Context: Organic optoelectronics and photonics is an emerging field that has led to several recent breakthroughs in photovoltaics, solid-state lighting, and displays. Organic light-emitting diodes (OLEDs), which rely on the luminescence of organic semiconductors, are already used in most commercial smartphone displays owing to their remarkable internal quantum efficiencies, approaching 100%. In contrast, organic solid-state lasers (OSSLs), which rely on stimulated rather than spontaneous emission, remain significantly less developed¹, despite their potential advantages over inorganic lasers, including ease of fabrication, broad emission spectra, wavelength tunability across the visible range, and biocompatibility. Moreover, the increasing availability of blue laser diodes now provides convenient pump sources for OSSLs. In particular, continuous-wave (CW) operation has not yet been demonstrated in an OSSL. Beyond conventional applications requiring CW lasers, the absence of continuous laser emission also hinders the development of mode-locked OSSLs, which are essential for generating ultrashort pulses. This technological bottleneck currently limits the use of OSSLs in applications requiring picosecond- or femtosecond-duration pulses.

In this context, our team recently demonstrated for the first time the generation of relaxation oscillations in two OSSL architectures: distributed feedback (DFB) lasers and vertical cavity surface emitting lasers (VCSELs). As a known feature of class-B lasers, relaxation oscillations can serve as an alternative to mode locking for the generation of short pulses. Indeed, these are generated spontaneously with durations of less than a hundred picoseconds in the form of a train of a few pulses. To achieve controlled pulse emission, a promising solution would be to incorporate a saturable absorber into the laser cavity. If correctly dimensioned, this could modulate the losses of the cavity, hence leading to a self-sustained emission of pulses, an effect known as self-pulsing in inorganic VCSELs². Options for saturable absorbers could range from monoatomic layers of graphene³ to metallic metasurfaces⁴, among others. These developments could pave the way for the development of compact and affordable solutions for generating short pulses in the visible spectrum.



Experimental demonstration of spiking/relaxation oscillations in (a) a VCSEL and (b) a DFB laser

Objectives of the internship: In this context, the candidate will be involved in various steps:

- Study of the impact of saturable absorber characteristics on organic microcavities. Based on a numerical model of organic lasers developed by the team, this study will also help identify the key material parameters required for the development of self-pulsed lasers.
- Integration of saturable absorbers into micro-cavities. The lasers will be fabricated using physical vapour deposition (PVD) techniques in the university's cleanroom.
- Experimental characterization of the fabricated lasers. This task will initially be carried out using a Fourier-plane spectrometer developed by the team, followed by time-resolved measurements. The results will be compared with the numerical model developed in order to refine the code.

At the end of the internship, a PhD position may be offered. Building on the preliminary results obtained during the internship, the PhD project would explore in greater depth different approaches for the generation of short pulses from OSSLS. For instance, the student could investigate alternative approaches to achieve a mode-locking regime in an OSSL. More ambitious research directions could also include the development of self-pulsed photonic crystal surface-emitting lasers (PCSELS), study of cavity-solitons in organic lasers, or the investigation of the ultrafast dynamics of photon–exciton strong coupling in organic microcavities. Multiple stays in Japan are probable within the PhD, through collaborations with Pr. Adachi's laboratory at Kyushu University.

Applicant profile: Applicants must be in 2nd year of master's degree, or final year of engineering school. A strong background in laser physics and photonics is mandatory. A first successful experience in experimental physics/optics is encouraged. No particular knowledge of organic chemistry or clean room fabrication techniques is required, as these can be acquired during the internship. Good level in english – speaking, writing and understanding – is required. Finally, experience with Python for numerical computing and/or experiment automation would be an advantage.

Internship supervisors: Dr. Tristan Guezennec, Pr. Sébastien Forget, Pr. Sébastien Chénais

Internship context and location: The internship will take place at the [Laboratoire de Physique des Lasers](#), Université Sorbonne Paris Nord, 93430 Villetaneuse. The intern will work in the Organic Photonic And Lasers (OPAL) team. The team is composed of five permanent researchers, and three PhD students. The team is working with a French-Japanese International Research Laboratory – [Ophelia](#) – with IPCM (Sorbonne University, France) and Opera (Kyushu University, Japan), and is also part of Oscar, an International Research Network for organic semiconductors.

Possibility for a Doctoral thesis: Yes, funding is already secured.

References:

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

² S. F. Lim et al. « *Self-pulsating and bistable VCSEL with controllable intracavity quantum-well saturable absorber* » Electron. Lett, 33, 20, 1997

³ Q. Bao et al. « *Atomic-layer graphene as a Saturable Absorber for Ultrafast Pulsed Lasers* », Adv Funct Material 19, 19, 2009.

⁴ J. Wang et al. « *Saturable plasmonic metasurfaces for laser mode-locking* », Light Sci. Appl., 9, 1, 2020.

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