Prof. Carlos Silva Acuña.

Advancing Microcavity Research: Prof. Carlos Silva Acuña Marks a Milestone with HARPIA

Carlos Silva Acuña is a Full Professor in the Department of Physics at the Université de Montréal and an expert in the field of ultrafast and nonlinear spectroscopy of advanced materials. He is also a Fellow of the Royal Society of Chemistry and the American Physical Society, underscoring his contributions to the scientific community.

Prof. Silva leads the **Canada Excellence Research Chair (CERC) in Light-Matter Interactions**, where his research group focuses on understanding quantum dynamics and photonic properties in matter, particularly in semiconductor microcavities in the strong light-matter coupling regimes, and on strongly correlated quantum materials. The CERC group's research seeks to uncover the properties of microscopic systems composed of interacting light-induced particles in solid-state environments. Their goal is to advance the understanding of light-matter interactions and contribute to the development of new materials for photonics and quantum technologies. The team employs both coherent and incoherent spectroscopy techniques to probe these complex systems.

Prof. Silva has been a valued customer of Light Conversion for almost a decade, relying on their laser systems to support his team's pioneering research. Coincidently, Prof. Silva was among the first users of the **HARPIA** spectroscopy system, while his latest acquisition celebrates the milestone of Light Conversion's 100th **HARPIA** system shipment.

Advancing microcavity dynamics studies

Semiconductor microcavities are nanoscale optical cavities formed by sandwiching a thin semiconductor layer – usually only a few nanometers thick - between two highly reflective mirrors. These structures confine light photons within extremely small volumes, enabling strong interactions between light and the electronic states within the semiconductor. This confinement gives rise to unique quantum effects, such as polaritons - hybrid light-matter quasi-particles. Research into semiconductor microcavities is important because it advances our understanding of light-matter interactions at the nanoscale, which is essential for developing future photonic and quantum devices, including ultra-efficient lasers, quantum information systems, and energy-efficient optical circuits.

The newly acquired **HARPIA** spectroscopy system, combined with a hybrid **ORPHEUS-F** optical parametric amplifier (OPA), will enable Professor Silva's team to perform advanced pump-probe experiments within a Fourier microscope setup. Using a high-numerical-aperture cryogenic microscope capable of cooling samples down to 4 K temperature, the team plans to investigate the transient photoreflectivity of optical microcavities. This setup allows them to pump and then probe the reflectivity of these microcavities and image it in the Fourier space, effectively mapping the full dispersion relation in a single measurement.

In addition to the primary pump-probe experiment, the team will use a second pump module (**HARPIA-TB**) to perform luminescence correlation experiments within the microcavity. This setup enables them to excite the microcavity with two variably delayed pulses, measuring the resulting photoluminescence across the entire dispersion relation. By introducing two interacting photoexcitations, they can observe changes in the luminescence intensity that result from nonlinear dynamical interactions within the system. Depending on the nature of these interactions, the total luminescence may increase or decrease, providing valuable insights into the underlying nonlinear properties of the microcavity.

Although Prof. Silva's team has previously performed Fourier space imaging, this marks the first time it will be incorporated into ultrafast experiments. Their earlier 2D and pump-probe spectroscopy measurements lacked strict angular resolution, but the new setup allows them to capture dynamic processes across the full dispersion relation in a single experiment, optimizing previous methods.

To enhance the sensitivity of these experiments, the team is also integrating a lock-in camera - a relatively new technology - into the system. The camera features dual-phase demodulation at each pixel, effectively functioning as an array of individual lock-in amplifiers

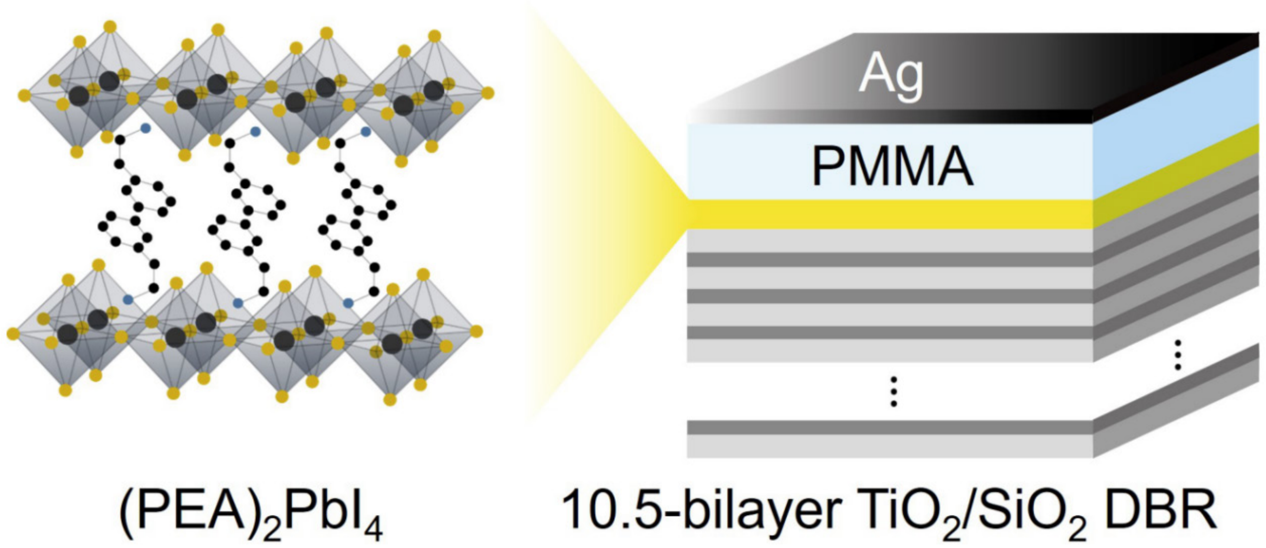

Figure 2. $(PEA)_2PbI_4$ Fabry-Pérot microcavity. The microcavity consists of a bottom quarter-wave distributed Bragg reflector (comprising 10.5 bilayers of TiO_2/SiO_2 represented in dark and light gray, respectively, with a central wavelength of 520 nm), a 60-nm $(PEA)_2PbI_4$ film, a 125-nm poly(methylmethacrylate) spacer layer, and a 40-nm Ag film serving as a semi-transparent top mirror.[1]

and enabling high-sensitivity transient imaging. By combining this advanced imaging with **HARPIA**'s ultrafast capabilities, Prof. Silva's group is poised to showcase a novel experimental approach that is currently underrepresented in scientific literature.

Long-standing relationship

Over the past decade, Professor's Carlos Silva research has relied heavily on Light Conversion's systems. The first acquisition, an early **PHAROS** laser, marked the beginning of a long-standing collaboration. "We might have bought the first **ORPHEUS-N-3H** ever," Prof. Silva recalls, noting the hands-on troubleshooting they navigated alongside Light Conversion's support team.

This initial setup, which included a **PHAROS** laser with two **ORPHEUS-N** non-collinear OPAS, proved instrumental for coherent spectroscopy studies. Over time, the team expanded their resources with an additional **PHAROS** paired with a collinear **ORPHEUS** OPA and the HERA spectroscopy system (current **HARPIA-TA** with **HARPIA-TF** module), which also drove home-built NOPAs. These tools have enabled much of their recent published work, spanning coherent, 2D, and incoherent spectroscopy. "One of the most impactful papers using our HERA system was in Nature Materials in 2019," Silva highlights, referencing a **high-resolution resonant impulsive stimulated Raman spectroscopy study on two-dimensional lead halide perovskites** that has gained notable citations.[2] In 2023, they added a series of important transient absorption publications on **conjugated polymers** to their portfolio.[3]

Next-up - Coherent Terahertz Spectroscopy

With the addition of their latest **HARPIA** system, Professor Carlos Silva's research group at the Université de Montréal will now operate two ultrafast spectroscopy laboratories powered by Light Conversion's laser systems. Prof. Silva hints at further expansion: "Pending a proposal decision, we plan to establish a third laboratory centered on coherent terahertz spectroscopy. Coherent spectroscopy has become a central tool for us, enabling us to employ the visible, near-infrared, mid-infrared, and soon, we hope, terahertz regions."

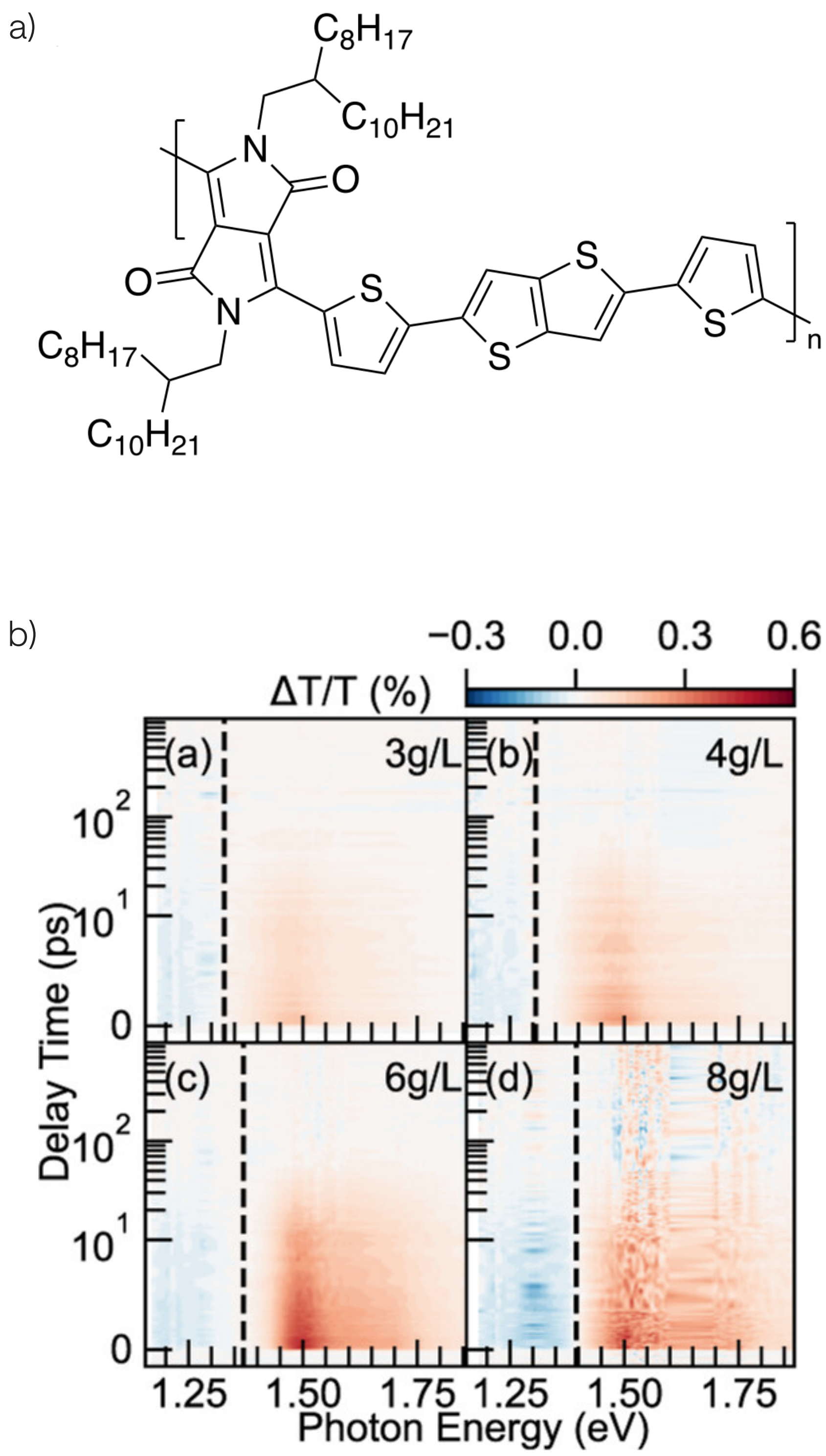

Figure 3. (a) Molecular structure of DPP-DTT, a push-pull polymer designed for applications in thin-film transistors. (b) Transient absorption spectral maps showing the differential transmission signals of films cast from solutions of various DPP-DTT concentrations. The samples were pumped with a 760 nm pulsed beam at a fluence of 5 μJ/cm^2 generated using Light Conversion's **PHAROS** femtosecond laser and **ORPHEUS** OPA. The transient absorption spectral maps were measured using the HERA spectroscopy system.[3]

Reflecting on how Light Conversion's systems have influenced his research strategy, Silva notes, "I've built many lasers in my life, and there were times I wondered if we were better off building them ourselves." However, he emphasizes the transformative impact Light Conversion has had on his team's work, stating that their systems have "freed up our resources to focus on sophisticated science and theoretical modeling." This shift has allowed his students to invest more time in analysis and less in the technical challenges of data acquisition.

Follow their achievements

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