Hubert Curien Laboratory

2023

yearbook

Laboratoire Hubert Curien
UMR • CNRS • 5516 • Saint-Étienne

E D I T O

It is with great pleasure that I present to you our latest Yearbook, showcasing the activities of the members and teams of the Hubert Curien Laboratory throughout the year 2023. This publication shares recent facts, news and achievements of our lab, reflecting our strong commitment to collaboration and innovation towards excellence in research.

After providing an overview of our laboratory, we dedicate a section of this document to a few subjects that have particularly marked the past year. We highlight the official establishment of our Inria MALICE project-team on December 1st, 2023, which constitutes a significant milestone in the history of our laboratory. This initiative, the first of its kind in the Saint-Étienne area, underscores our dedication to pushing the boundaries of our research and fostering interdisciplinarity within our community. Beyond this accomplishment, our Yearbook aims to capture the dynamism of our teams, as evidenced by their active involvement in numerous scientific and innovation projects, and by the publication of outstanding research in international journals. As last year, we have allocated space in this edition to our partners in education, highlighting the integral role of training, research and innovation in our mission. We also feature some of our members' individual accomplishments, with special recognition for our two newly appointed members of the Institut Universitaire de France. With the addition of several new members, including four researchers and two administrative staff, our laboratory continues to evolve, enriching our intellectual community and expanding our collective impact.

Regardless of your background, whether you are a collaborator, a stakeholder in our region's development or an organization sharing our professional interests, we invite you to explore this Yearbook and hope that you will find inspiration and value in its contents.

Once again, I would like to express my gratitude to our institutional affiliations: the University Jean Monnet, the CNRS, and the Institut d'Optique Graduate School. Their support and partnership are instrumental in enabling our laboratory to thrive and excel.

I would like to thank our communication manager, Elisabeth Reby, who has coordinated the content of this document while in charge of its design. Finally, I extend special thanks to all the members of our laboratory, whose individual and collective endeavors contribute to our lab's success.

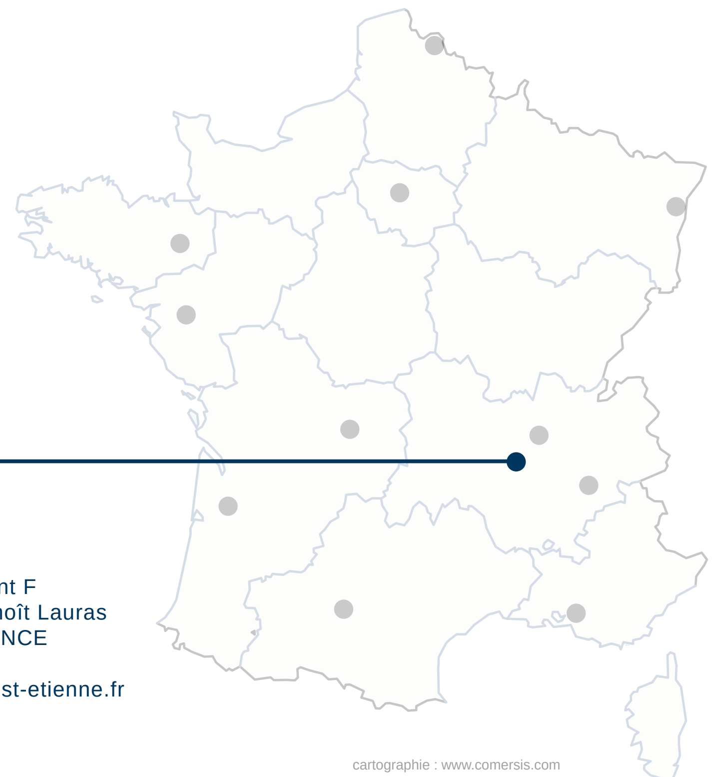
Florence Garrelie
Director of the Hubert Curien Laboratory

CONTENT

THE LAB

LOCATION

The Laboratoire Hubert Curien is a joint research unit of the University Jean Monnet Saint-Etienne and the CNRS, with the Institut d'Optique Graduate School as secondary institutional sponsor. It is located in Saint-Etienne, the 2nd largest city of the Auvergne - Rhône-Alpes Region, in an environement particularly favourable to the development of its research and entrepreneurial activities.



Université Jean Monnet Saint-Etienne

Laboratoire Hubert Curien
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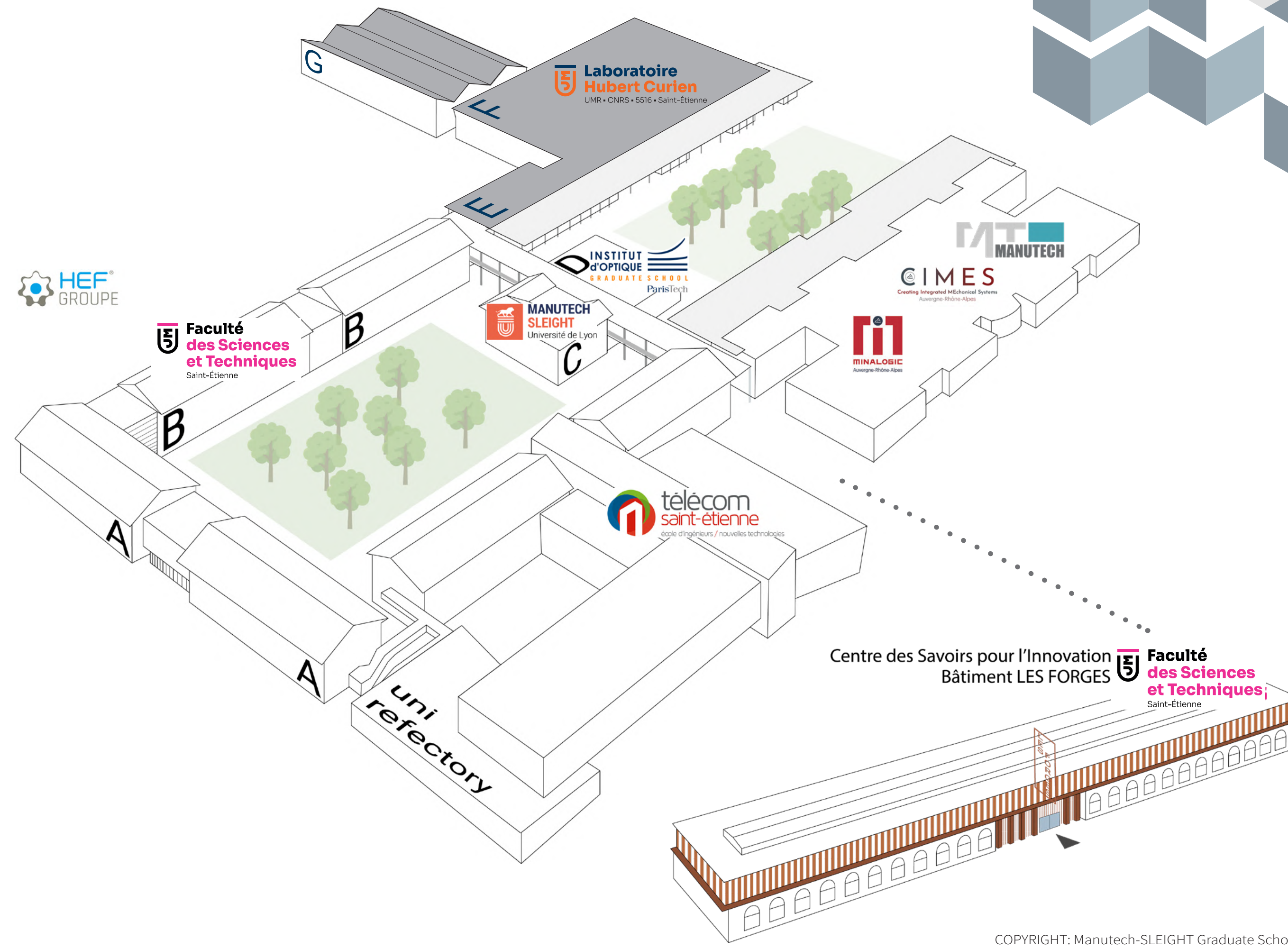
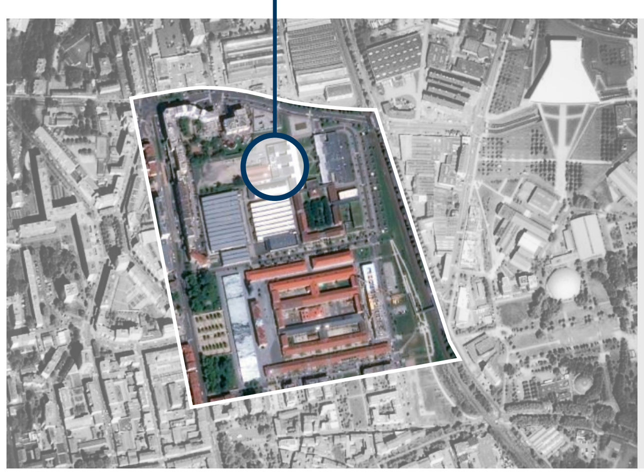
Laboratoire Hubert Curien
UMR CNRS 5516, Bâtiment F
18 Rue du Professeur Benoît Lauras
42000 Saint-Etienne, FRANCE
Tel : +33 (0)4 77 91 57 80
email : lab.h.curien@univ-st-etienne.fr

cartographie : www.comersis.com

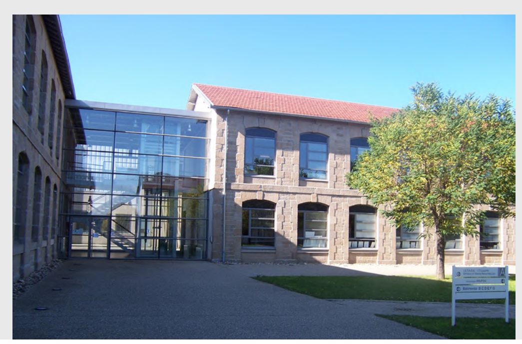


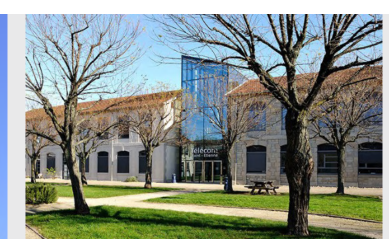
The Manufacture Campus houses the university's Faculty of Science & Technology, its Physics & Computer Science departments as well as its «Télécom Saint-Etienne» engineering school. It was selected by the Institut Optique Graduate School to set up an antenna outside the Paris area. Minalogic and Cimes, 2 local industrial «competivity clusters» occupy the site, together with the Economic Interest Group GIE Manutech USD. The companies HEF R&D (surface engineering and micro/nanostructuring) and Keranova (design of ultrafast laser-based surgical ophthalmology equipment) have established their premises on the site, reinforcing the status of the Manufacture Campus as an emblem of an ecosystem that closely links the university and the business world.



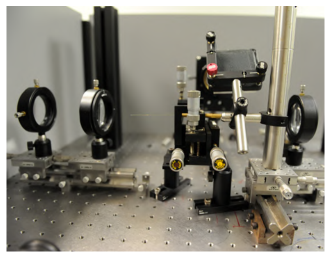
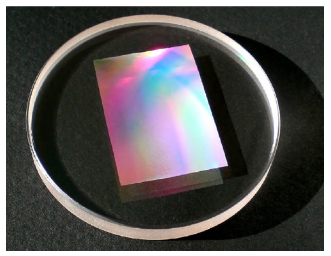
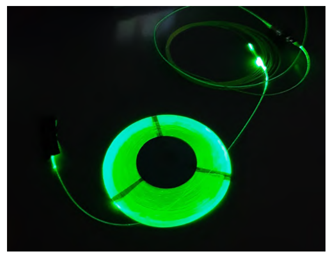
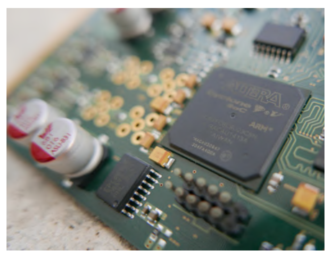
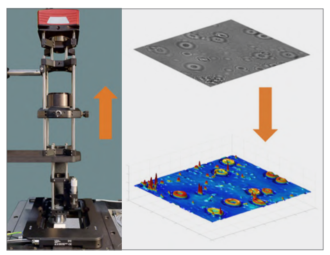
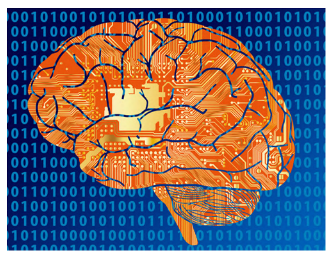
Manufacture Campus aerial view
(Imagery ©2023 CNES / Airbus, Maxar Technologies, Map data ©2023)

The Hubert Curien Laboratory is situated at the heart of the «Manufacture Campus», established on the historic site of the former Saint-Etienne's arms factory. The lab benefits from exceptional surroundings including cultural, industrial, teaching and research activities as well as housing, sport and leisure facilities.



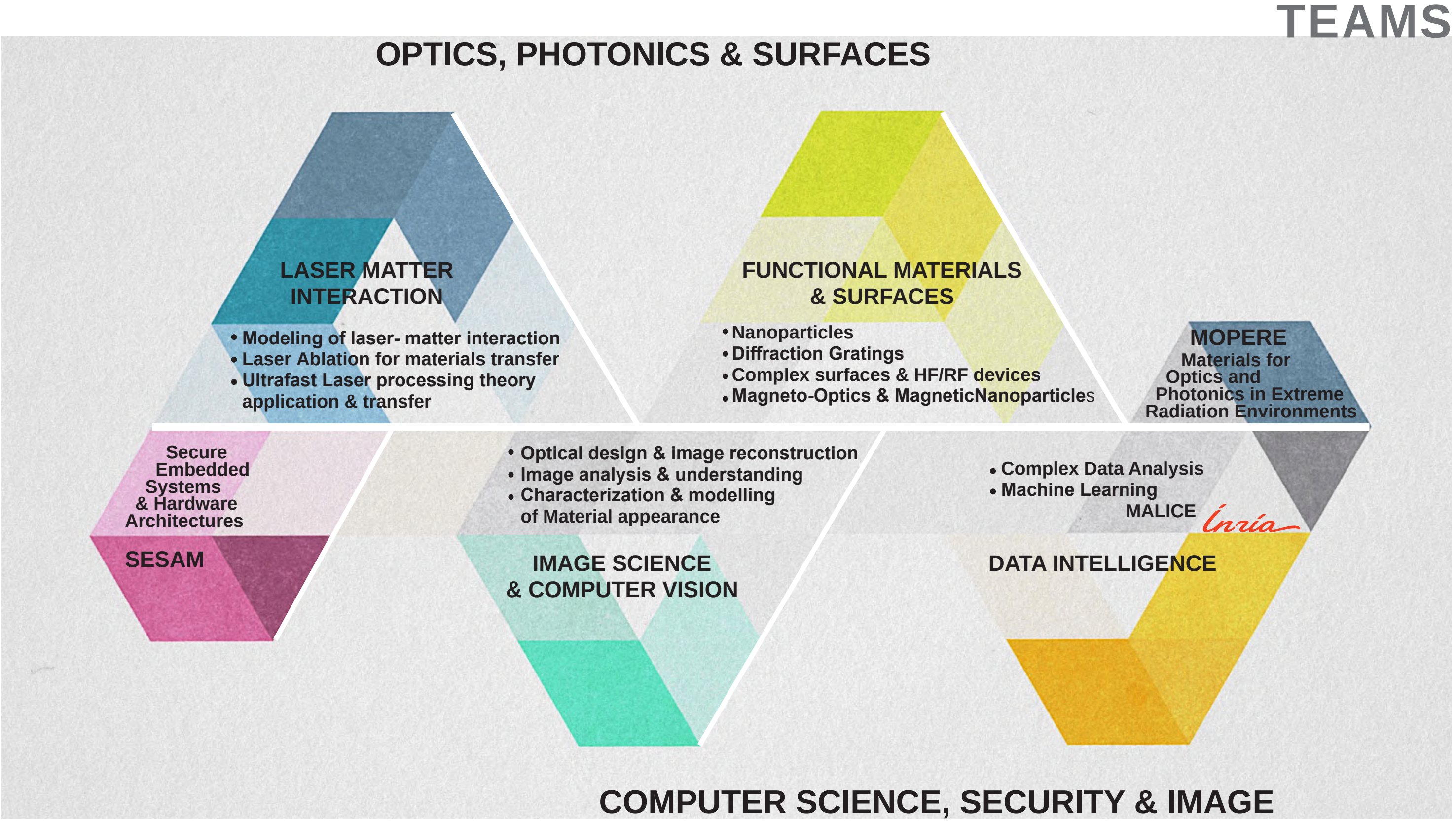


OUR ACTIVITIES
at a glance

The lab covers a spectrum of research activities structured around 2 scientific departments: «Optics, Photonics & Surfaces» and «Computer Science, Security & Image». Our main expertise lies in Surface engineering, 2D & 3D materials' micro/nano structuring, Ultrafast laser processing, Electromagnetic modelling, Material resistance in harsh environments, Machine learning, Complex data analysis, Unconventional imaging, Computer vision, Material appearance and Hardware security. Many research projects at the interface of these disciplines lead to innovations and scientific breakthroughs.

TEAMS



KEY FIGURES
year 2023

- **121** permanent staff members
- **94** researchers
- **27** Post-docs
- **27** engineers, technicians & admin
- **97** PhD students
- **230** international publications on average per year
- **6** experimental platforms
- **136** research contracts
- **2** industrial joint labs
- implication in **3** LabEx
- **1** graduate school (EUR)
- implication in **5** PEPR
- **7** coordinated international masters

our place within the Lyon / Saint-Etienne ECOSYSTEM

The Hubert Curien Laboratory is involved in several programs of excellence that have enabled the emergence of a large consortium of public and private partners in the Lyon/Saint-Etienne area. These programs contribute to an emulating spirit of interaction within our economic environment. Three of these programs revolve around our «Manutech» brand. A LabEx was created in 2011 with 3 private companies undertaking R&D activities, whilst the founding of an EquipEx that same year operates today under the form of an Economic Interest Group involving 3 industrial partners and 4 research institutions. The setup of a Graduate School (EUR) in 2018 was done in collaboration with several partners and research laboratories from our region. Futhermore, our lab participates in the activities of various research federations that have been set up in the Lyon/Saint-Etienne area.

MANUTECH SLEIGHT Université de Lyon

Manutech-SLEIGHT Graduate School - Surfaces Light EngineerinG Health and SocieTy
Our lab has largely contributed to the setup of this Graduate School (Ecole Universitaire de Recherche) which provides an international integrated MSC/Ph.D. program in the domain of Surfaces Light EngineerinG Health and SocieTy. It brings together a consortium of 12 public and private partners located in the Lyon/Saint-Etienne area, including 7 academic institutions (Universities, Engineering Schools), 2 national research organisations and 3 economic stakeholders, with the main goal to weave links between education and research.

LABEX MILYON UNIVERSITÉ DE LYON

LABEX MILYON - Mathématiques et Informatique Fondamentale
Our institution is part of this group of Mathematics and Computer Science labs gathering 450 researchers from 5 research units of the Lyon/Saint-Etienne area (ICJ, UMPA, LP, LIP, Hubert Curien Laboratory). MILYON focuses on 4 key objectives, including excellence in research (with multidisciplinary scientific projects), education (with innovative research-oriented curriculums), outreach (disseminating scientific culture among the general public) and transfer of technology to the Industry (through research partnerships, training or internships).

LABEX PRIMES UNIVERSITÉ DE LYON

LABEX PRIMES - Physics, Radiobiology, Medical Imaging and Simulation
The Hubert Curien Lab participates in the LABEX PRIMES, supported today by the Institut de Physique Nucléaire of Lyon (IPN-L, radiation for radiotherapy and imaging) and the CREATIS laboratory (medical imaging). Gathering more than 190 expert researchers from 16 academic institutions as well as several clinical partners, PRIMES' primary objective is to develop new concepts and methods for the exploration, diagnosis and therapy of cancer, and aging-related pathologies.

LABEX MANUTECH-SISE UNIVERSITÉ DE LYON

LABEX Manutech-SISE - Surface Interface Science Engineering
Manutech SISE is a "Laboratoire d'Excellence" governed by the Université de Lyon and coordinated by the Hubert Curien Lab. It brings together the complementary skills of 6 academic labs (Hubert Curien Lab, LTDS, Georges Friedel Lab, LaMCoS, LMI, MATEIS) and several other institutions and companies involved in surface and interface-oriented themes, including IREIS, GIE MANUTECH-USD, CIMES, CETIM and the EUR Manutech-SLEIGHT.

MANUTECH

Manutech USD GIE - Groupement d'Intérêt Économique
The Manutech USD GIE gathers public research and industry stakeholders around an EQUIPEX (EQUIPement d'EXcellence Manutech USD - Ultrafast Surface Design) which the Hubert Curien Laboratory helped create in 2011. The GIE's main objective is to explore and exploit scientific and industrial possibilities offered by femtosecond lasers, providing solutions for surface texturing. Our lab is historically and heavily involved in the GIE. Several of our reseachers and engineers have developed or are developing activities around the Manutech-USD platform.

Ingénierie Lyon - Saint-Etienne Inge LySE

IngeLySE - Fédération de recherche en ingénierie de Lyon - Saint Etienne.
The IngeLyse research federation brings together 24 laboratories representing nearly 2300 researchers, lecturers, technical staff and Ph.D. students under the supervision of the INSIS Institute, the CNRS and the Université de Lyon. It is the largest group of research units in France, covering most of the existing engineering scientific disciplines. The role of the IngeLyse Federation is to animate the vast array of skills represented by these laboratories, and facilitate the interaction between different disciplines in order to enable the emergence of technological innovations.

FRAMA

FRAMA - Fédération de Recherche André-Marie Ampère
Together with 5 other CNRS affiliated research units (CRAL, IP2I, INL, ILM, LP-ENSL), our laboratory is a member of FRAMA, a structure which mission is to organise, lead and coordinate research activities in physics and astrophysics in Lyon and Saint-Étienne. The main objectives of FRAMA are to coordinate common scientific actions, enable inter-laboratory projects, promote interactions between labs and other disciplines, organise seminars and conferences, support science through calls for innovative projects, financially support technological platforms and facilitate their development.

Fédération Informatique de Lyon

FIL - Fédération Informatique de Lyon
Supported by the CNRS and the Inria Institute, the FIL gathers around 870 members from 5 research labs (LIRIS, LIP, CITI, CREATIS, Hubert Curien) and aims to address the many societal challenges raised by computer science & digital technology. Its main objectives are to promote scientific exchanges and common actions, reinforce the computer science discipline's visibility around Lyon, be a privileged interlocutor for local and national authorities, enable coordinated responses to calls for proposals, and increase the attractiveness of the discipline in the region.

INSTITUT CARNOT Télécom & Société numérique

Institut Carnot TSN - Télécom et Société numérique
Our lab is a member of the Institut Carnot TSN through the Télécom Saint Etienne Engineering School. Carnot is a label of excellence awarded by the Ministry of Higher Education, Research & Innovation, encouraging research work by public labs in partnership with socio-economic stakeholders. It is organised around several Institutes working on the same theme. As a major player in R&D and digital innovation, the Carnot TSN facilitates companies' access to the skills of its 11 affiliated research establishments.

our technical PLATFORMS

Most research activities of the Hubert Curien Laboratory are supported by several technology platforms fitted with specific state-of-the-art experimental tools. The equipment is operated, supervised and maintained by experienced technical and scientific staff working closely with our research teams.

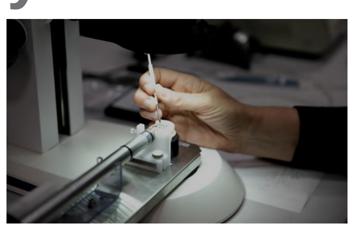
NanoSaintÉtienne

Our *Renatech+* affiliated NanoSaintÉtienne platform includes planar technology instruments dedicated to 4 main activities: gratings elaboration, thin film deposition, substrates processing and profile analysis. Managed by a team of 7 people, this micro-nano technological facility is open to industrial and academic partners.

Spectroscopic Characterization

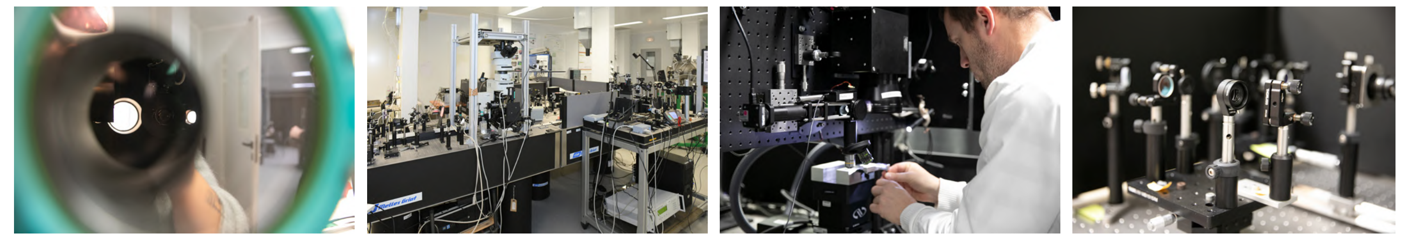
Our Spectroscopic Characterization platform is dedicated to laser inscription and spectral analysis by laser excitation (Raman and photoluminescence). It is equipped with spectroscopy and micro-nano-structuring instruments.

Electron Microscopy



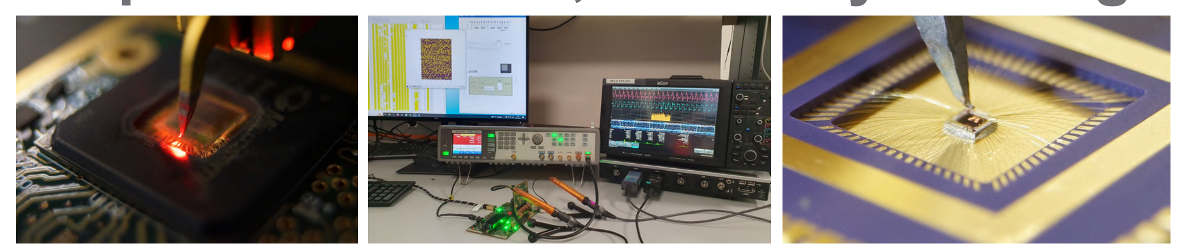
Our Electron Microscopy platform is dedicated to improve the knowledge of condensed matter structure from atomic to microscopic scale, in order to support the activities of our research teams. It is fitted with state-of-the-art equipment, including a CLYM affiliated JEOL NeoARM 200F Transmission Electron Microscope (TEM) - equipped with EDS and EELS - and a JEOL IT 800 SHL Scanning Electron Microscope (SEM).

Femtosecond Laser



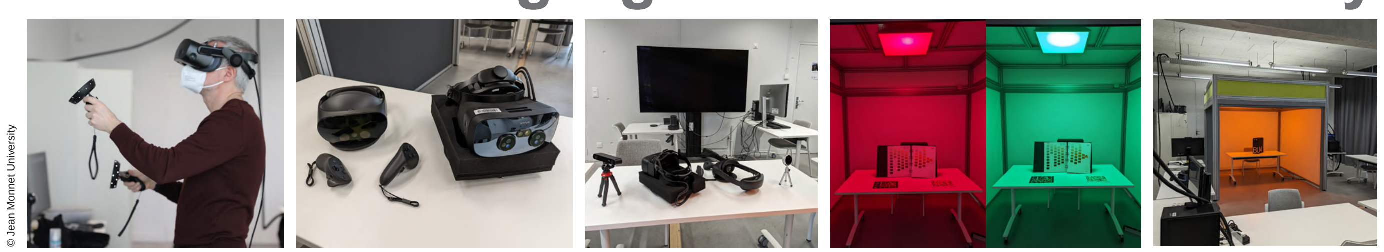
Our Femtosecond Laser platform is fitted with 6 ultrashort lasers working at different wavelengths, repetition rate and energy, including all working environments. The platform operates various devices around the ultrafast lasers, such as OPA for wavelength tunability, burst modes and variable frequencies, high-precision stages and scanners, spatial, temporal and polarization shaping of ultrashort laser pulses, or ultrafast spectroscopy systems. This facility mainly supports the scientific activities of our Optics, Photonics and Surfaces Department teams.

Computer Science, Security & Image



Our Computer Science, Security & Image platform mainly offers support and services to our SESAM, Data Intelligence, and Image Science & Computer Vision teams. The available equipment includes various tools such as a computer cluster (incl. GPUs and CPUs), cameras, lenses, laser/lighting systems. It is also equipped with high performance oscilloscopes, arbitrary waveform generators, a real-time spectrum analyzer, a climate chamber for stress and stability tests, and several testbenches for cryptographic applications. The platform provides help desk, training and user support activities.

IXR - Imaging and Extended Reality



© Jean Monnet University

Managed by the Université Jean Monnet, the IXR platform is a modular space located within the Centre des Savoirs pour l'Innovation. It provides equipment dedicated to Imaging and eXtended Reality with AR/MR/VR devices, innovative screens, and a wide range of imaging sensors: color, stereo, LIDAR, multi- and hyper-spectral, 360° and 3D scanners. Sensors, screens and XR devices can be combined with innovative lighting, such as a 24-channel spectral light and a motion capture system.

2023 HIGHLIGHTS

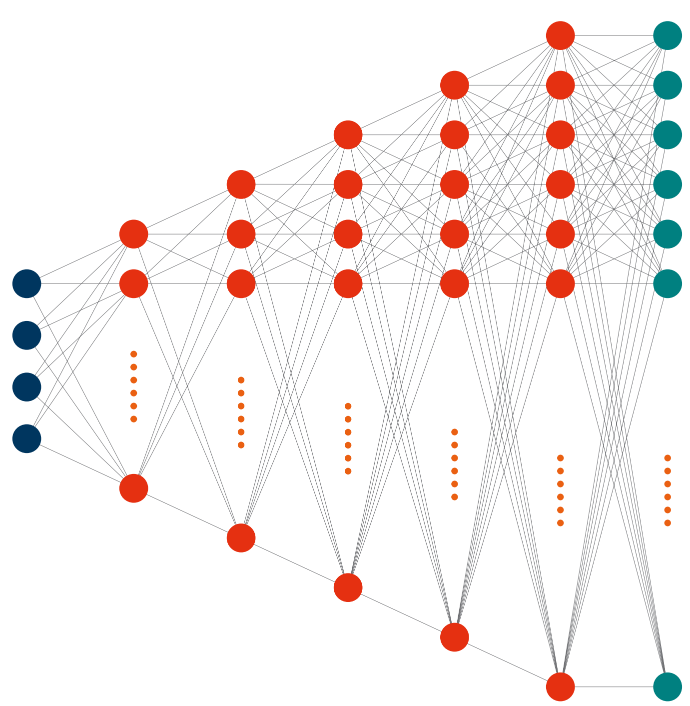
As last year, 2023 was marked by several significant events and projects for the Hubert Curien Laboratory. Six of the most important subjects are presented in the following pages.

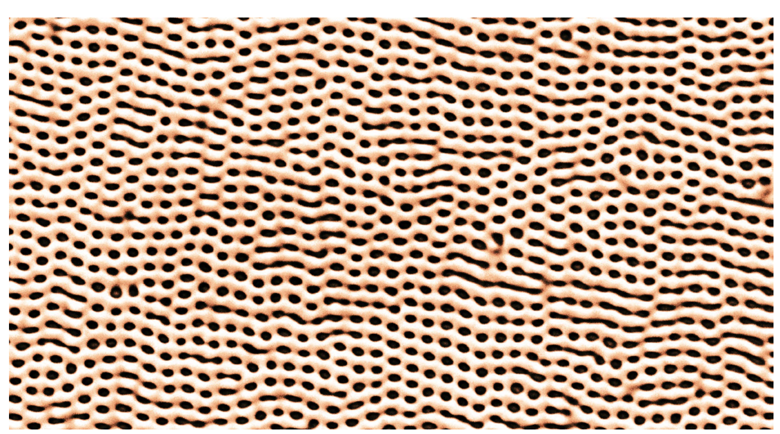
MALICE
MAchine Learning with Integration of surfaCe Engineering knowledge: Theory and Algorithm

A new Inria project-team for our lab

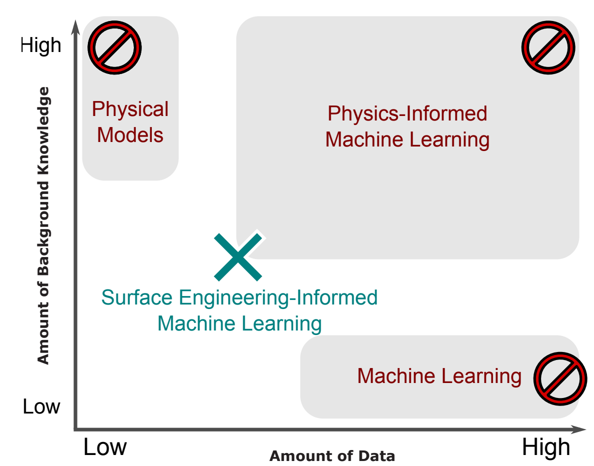
Data intelligence team
Inria Project-team MALICE
Head: Marc Sebban

The Hubert Curien Laboratory is proud to announce the recent establishment of an Inria project-team, named "MALICE", as a new part of our Data Intelligence group. This marks the addition of a 16th team to the Inria Lyon Centre, and the first to be located in the Saint-Etienne area. The ambition is to drive methodological advancements at the interface between Machine Learning and Surface Engineering by combining the expertise available in our lab in statistical learning and laser-matter interaction. In doing so, the MALICE project aligns with the Inria Lyon Centre's strategy to foster new interdisciplinary research initiatives, particularly in the fields of digital and engineering. The project also fits within an ongoing decade of significant interest in the deep learning field, which stems from the successful use of recent advances by the machine learning community to address a wide range of real-world applications, notably for our understanding of multi-scale physics. However, while machine learning in interdisciplinary projects is typically used as a tool at the service of other domains, the particularity of the MALICE project lies in a design intended to be mutually beneficial to both fields involved.





On the one hand, surface engineering raises numerous machine learning challenges, including limited access to training data, the availability of only partial and incomplete background knowledge, the need to derive theoretical generalization guarantees for models learned from both data and physical knowledge, as well as the strong necessity to transfer knowledge from one learned dynamical system to another. On the other hand, the advances that will be made in machine learning will improve our understanding of the physics underlying the mechanisms of laser/radiation-matter interaction, thus enabling to tackle numerous societal issues encountered across various sectors of industry.
The scientific advances intended to be achieved within the scope of the project should be directly exploitable for a wide range of applications related to surface engineering and laser-matter interaction, including but not limited to automotive, healthcare, biotechnology, pharmaceutical, energy, environmental, security and space industries. Mastering the underlying physics of light coupling (the phenomenon that occurs when a light pulse interacts with a material's surface) would indeed enhance one's capability to impart specific properties to a material. Various optical effects could for instance be created on glass depending on the mode of observation; the structure and texture of tissues could be manipulated to influence the behavior of biological cells/bacteria/viruses; surface materials could be adapted to control friction and adherence, for example to improve the efficiency of motor engines.
The distinctive feature of the Hubert Curien laboratory, which brings together experts in both machine learning and surface engineering, is the catalyst for this new venture. Collaborative work between our Data Intelligence, Laser-Matter Interaction, Functional Materials & Surfaces teams began several years ago, and has already led to the publication of several articles in prestigious physics journals. Four ongoing Ph.D. theses are being co-supervised by both a physicist and a machine learner from the MALICE team. The objective for MALICE over the next few years will be to maintain this dynamic of interaction between both Machine Learning and Surface Engineering disciplines, in order to initiate new collaborations on other aspects of Surface Engineering. This should be facilitated by the recent addition of two new researchers to our lab and the MALICE project-team, which currently includes the following permanent staff members: Marc Sebban (team leader), Amaury Habrard, Benjamin Girault, Jordan Frecon, Rémi Eyraud, Rémi Emonet and Farah Cherfaoui. The team will soon be completed by Quentin Bertrand, who is expected to join us in July 2024. From a strategic standpoint, the project will contribute to strengthening our collaborations with the machine learning community at the local, national and international levels, as well as our long-established partnership with major international economic players and governmental organizations.



The black tears of Soulages' paintings

Image Science & Computer Vision team
Local Scientific Head: Mathieu Hébert (Laboratoire Hubert Curien)

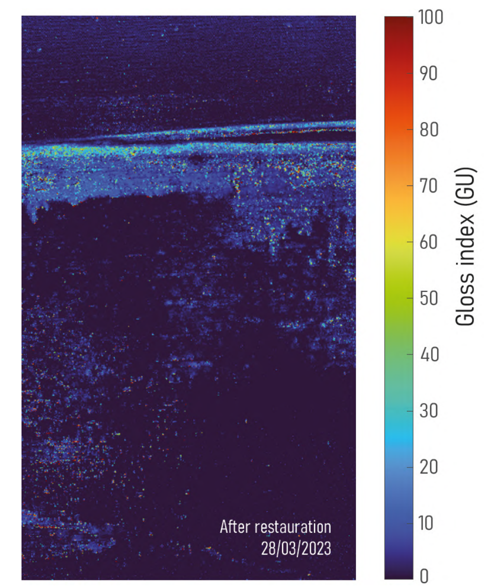
Above: Pauline de La Grandière at work at the Musée des Abattoirs de Toulouse © Pauline de La Grandière

The master has gone, and his paintings are shedding black tears. In truth, they have been doing so for some time, as have a few artworks created by other artists who worked in Paris during the 1950s and 1960s, such as Willem De Kooning, Jean-Paul Riopelle or Joan Mitchell. Experts describe the phenomenon affecting three of Soulages' paintings as a colored, oily discharge seeping from areas of thickly applied material on the canvas when they are typically prone to dryness and cracks. This occurrence seems to be the result of complex physico-chemical reactions that a team led by Pauline Hélou de La Grandière - a restorer specializing in Soulages' works and currently pursuing a Ph.D. focused on the study of Soulages' paintings to define a conservation strategy - is attempting to understand and prevent. «What is flowing is not the paint but the oil used as a binder», she explains. For all the artworks affected by this occurrence, several factors are converging and could potentially provide an explanation: the color pigments acquired from the same sellers, the lead white used in the canvas primer, the presence of sulfide particles in the heating system due to the harsh winter of 1959 in Paris, the application of various quick varnishes shortly after the completion of the paintings, and their transportation by boat in high humidity and darkness.

Much has been said about the use of black in Pierre Soulages' artwork, but as the artist himself once stated, 'Black is not my instrument; it is rather the light reflected from the black.' This is undoubtedly the reason why his paintings have long fascinated many physicists. In 2022, as part of Pauline Hélou de La Grandière's Ph.D. research, an imaging measurement campaign was conducted on some of Soulages' artworks to capture either the light diffused by the black paint, which tends to absorb it, or the light re-emitted by materials after absorbing photons of higher energy. This work aims to establish a survey of the paintings in their current state while they are still 'evolving' under the effect of the observed alterations. The measurements were taken using various devices and techniques, including multispectral photoluminescence imaging and white LED stereophotometry. One of these devices, a gloss scanner, has been in development since 2020 under the direction of Mathieu Hébert from our Image Science & Computer Vision team. Mathieu has been working with several students from the Institut d'Optique Graduate School as well as Yann Pozzi, former student of the University Jean Monnet's Advanced Imaging and Material Appearance (AIMA) master track.

The particularity of Mathieu's scanner doesn't lie in its ability to measure gloss parameters, as this can be done with a glossmeter, but in its capability to map these parameters across the entire surface of a painting without making any physical contact with it. Although the device is currently only in its prototype stage, it is intended to be perfected over the coming years for potential applications on different types of surfaces and in various domains. The idea for this scanner originated from several collaborations with members of various industry sectors such as automotive, building materials or luxury items, with whom Mathieu, as a specialist in surface appearance, regularly works. For these manufacturers, the ability to scan and record the gloss properties of their products on a large scale could be an invaluable tool for quality control, replacing a visual inspection process with a more reliable digital one. «The leather industry in particular has significant potential. By scanning the object's glossiness, we can ensure that all pieces have a consistent appearance», explains Mathieu Hébert.
Pauline Hélou de La Grandière's thesis work, titled «NOIRœS» (New interdisciplinary tools for the restoration of Soulages' works), is being conducted under the supervision of Lionel Simonot from the Institut P' in Poitiers and Mathieu Thoury, from the IPANEMA research platform. As part of the new 'Soulages et la lumière' chair that will be launched in September 2024 by the Paris-Saclay and Jean Monnet University Foundations, Mathieu Hébert will supervise a thesis on the development and application of the gloss scanner, and participate to two other theses on topics related to Soulages' masterpieces: material analysis of the paintings by optical imaging - project led by Mathieu Thoury from IPANEMA, and Lionel Simonot from the University of Poitiers - and the surprising optical properties of the famous stained-glass windows at Conques Abbey - project led by Jean-Jacques Greffet from the Institut d'Optique, and Kevin Vynck from the CNRS.

Watch the CNRS video:
«Les noirs de Soulages en lumière»



Above left: Gloss mapping measurement by Yann Pozzi and Mathieu Hébert, with Pauline Hélou de La Grandière; Musée des Abattoirs de Toulouse © Lionel Simonot.
Right: Example of a gloss map, resulting from the scanned portion of one of Soulages' paintings

Teaching Matter to Move

Understanding the underlying physics of laser-matter interaction

Data Intelligence and Laser-Matter Interaction teams

With the publication in May 2023 of an article combining the work of our Data Intelligence and Laser-Matter Interaction teams, research in our laboratory has reached a new milestone. Moreover, the work has been published in the prestigious Physical Review Letters journal, from the American Physical Society. This is an opportunity for first author and post-doctoral fellow Eduardo Brandão to talk about the fascinating world of physics-guided machine learning.

Eduardo Brandão. «Self-organization is a fundamental process that governs the emergence of complex structures in nature. It has long fascinated scientists, with pioneers such as Alan Turing and Ilya Prigogine having made significant contributions to its understanding. From the cloud formations on Jupiter to how the leopard got his spots, self-organization shapes the world around us.

Self-organization has recently been put forward as an explanation for the formation of patterns on surfaces by laser irradiation [Acta Mater. 194, 93 (2020), Nanoscale 12, 6609 (2020)]. The irradiation of a rough surface with ultrafast laser pulses can induce spontaneous self-organization of matter into dissipative structures with nanoscale reliefs. These surface patterns emerge from symmetry-breaking dynamical processes that occur in Rayleigh-Bénard-like instabilities. They hold great promise for various applications, particularly in the biomedical field.

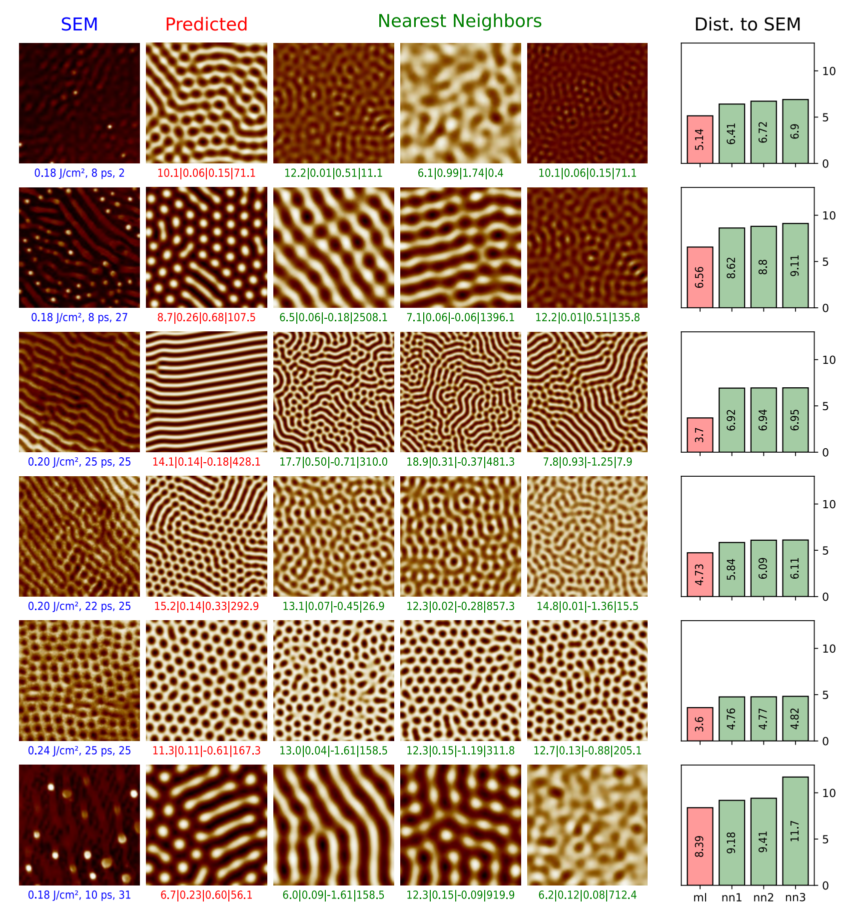
To harness this potential, it is crucial to understand the underlying mechanisms that govern their formation. Achieving control over the patterns' uniformity, symmetry and size opens up exciting possibilities for precise surface functionalization at the nanoscale.

In a recent study published in Physical Review Letters (PRL) titled "Learning complexity to guide light-induced self-organized nanopatterns" we were able to characterize and predict the formation of nanoscale patterns using a stochastic Swift-Hohenberg (SH) model combined with a physics-guided machine learning strategy. The SH model, which is variational in time and conservative in space, played a central role in identifying the dominant stable modes for specific laser parameters, regardless of the initial roughness conditions.

The process of pattern formation through laser irradiation is inherently complex, making it challenging to establish an explicit relationship between laser parameters and observed structures. In such cases, machine learning approaches are often employed to learn from data. In femtosecond laser-induced self-organization, however, obtaining the required time-series data to recover the underlying process and build accurate predictive models is impossible due to the reduced timescale of the pattern formation process. We faced the fundamental limitation of having access to only a single time observation: a scanning electron microscope (SEM) image of the material's surface at solidification time. To further complicate matters, SEM imaging at this scale is fastidious, which makes data scarce, on the order of tens of observations.

Learning complexity to guide light-induced self-organized nanopatterns
Eduardo Brandao, Anthony Nakhoul, Stefan Duffner, Rémi Emonet, Florence Garrelie, Amaury Habrard, François Jacquenet, Florent Pigeon, Marc Sebban and Jean-Philippe Colombier.
Phys. Rev. Lett. 130, 226201. Published 30th May 2023

To learn a complex relationship from a few data, we projected data into a lower-dimensional feature space ("pattern space"), namely the features of a deep convolutional neural network (the VGG model), which are translation equivariant and retain scale information. By reducing the dimensionality of the problem, we effectively addressed the data scarcity issue. Additionally, we used an important insight about self-organization processes: since these processes create order, the initial conditions are mostly redundant in the sense that, for a given set of laser parameters, in pattern space, every reasonable initial condition leads to the same point.



Leveraging this simplifying aspect enabled us to learn the relationship between laser parameters and patterns, using the limited SEM image data and a SH model, and demonstrating that ultrafast laser-induced surface patterns at the nanoscale can be effectively modeled using a scale-invariant generalized Swift-Hohenberg equation.

Incorporating machine learning and physical knowledge allowed us to learn the complex relationship between irradiation conditions and patterns. This enables us to predict patterns in unexplored regions of the laser parameter space, and even potentially create new ones: in a sense, to teach matter how to move. Being able to do so drastically reduces the need for extensive experimental efforts.

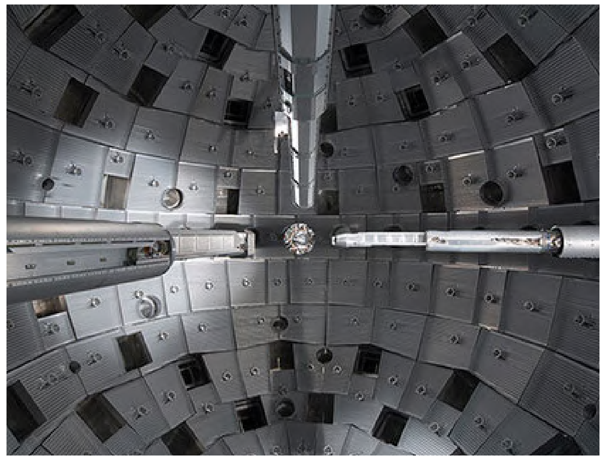
Moreover, our methodology can be extended to other self-organization processes to predict laser-induced structure formation, even with limited and non-time series data. The ability to identify relevant laser parameter regions and predict novel patterns holds great potential for supervised local manipulation of matter using timely-controlled optical fields in laser manufacturing.»

The great expertise we have in our lab, both in machine learning and laser-matter interaction, has enabled us to be amongst the first scientists to use physical information to guide the training of machine learning models. The variety of novel types of patterns being developed by our researchers at the nanoscale, combined with this new methodology, opens the way to infinite possibilities with extraordinary potential for applications, especially in the biomedical field.»

Inertial Confinement Fusion

Our lab's star-powered contribution to the pursuit of a clean and safe energy

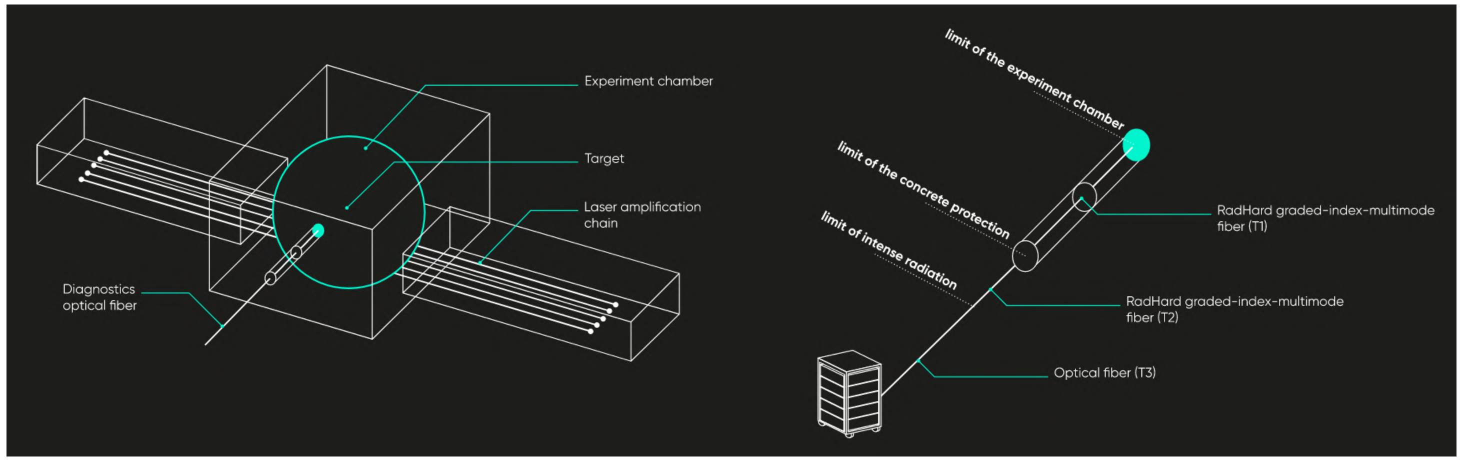
The process of nuclear fusion is the one that powers the core of stars, including the Sun. For decades now, physicists have been working on the possibility of replicating this process on a smaller scale on Earth, with the aim of providing a clean and virtually limitless source of energy. Unlike nuclear fission, which involves splitting an atomic nucleus into two smaller parts, nuclear fusion consists in combining light atomic nuclei to form heavier ones. This process, which releases a considerable amount of energy, also presents key advantages in terms of radioactive waste reduction and increased safety. To achieve fusion, researchers focus on different methods. Most laboratories (such as ITER) rely on a magnetic confinement fusion approach, by which a fuel (hydrogen) is held in place by powerful magnets, and heated to over a hundred million degrees for a period long enough for atomic nuclei to fuse. Another method, called Inertial Confinement Fusion (ICF), involves using high-power lasers to rapidly and uniformly compress small amounts of fusion fuel (hydrogen isotopes). The goal is not only to produce energy, but more importantly, to produce more energy than is consumed: this is the "net energy gain" that all experts in the fusion field are striving for.



The inertial confinement fusion is the technique that was used in the National Ignition Facility at the Lawrence Livermore National Laboratory (California, US) in December 2022, for an experiment that received wide media attention. LLNL-NIF researchers announced that they had produced about 2.5 megajoules of energy, approximately 120% of the 2.1 megajoules of laser energy. In other words, the researchers had generated more energy in a fusion reaction than was used to initiate it, achieving a net energy gain for the first time. Although far from industrial-scale reproduction, it marked a new milestone.

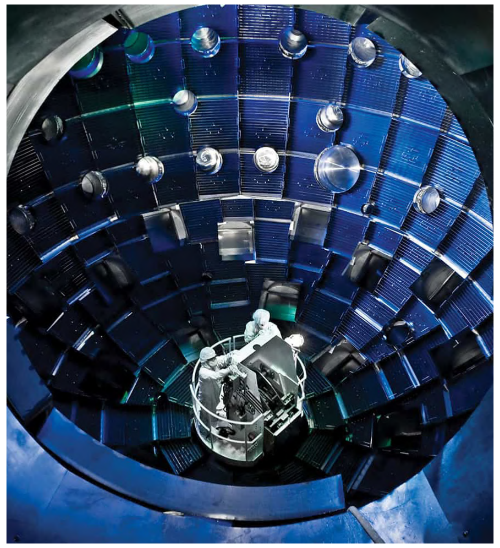
At the heart of the NIF installation and its French equivalent, the LMJ Laser MégaJoule built at CEA CESTA near Bordeaux, powerful lasers emit a very intense and short combined light pulse directed outward to strike the outer surface of a millimeter-sized target containing deuterium and tritium. The pulse generates a shockwave that rapidly compresses the target, leading to an increase in temperature and pressure inside. This, in turn, triggers the fusion reactions between deuterium and tritium nuclei, releasing a large amount of energy, primarily in the form of X-rays, γ-rays and 14 MeV neutrons. As specialized sophisticated measuring instruments, the plasma and laser diagnostics installed into the facility experimental halls are able to collect data from the experiment in real-time, ensuring, among other parameters, an accurate synchronization and shaping of the pulse laser beams operating at 3ω (351 nm) [Rev. Sci. Instrum. 79, 10F301 (2008)]. To achieve this, the laser diagnostics exploit specialty multimode optical fibers to recover laser beams' key characteristics. The effective transmission of the measurement data through the optical fibers relies on an unaltered temporal shaping of the laser beam (implying a fine control of the fibers' dispersion), a very low optical attenuation in the ultraviolet (below 0.2 dB/km) and, more critically, on a high resistance to the extreme radiation levels these fibers are subjected to during ignition experiments. This is where and when our lab gets involved in one of the most talked-about research experiments of the last decade.

Left: inside the CEA-LMJ experiment chamber (© CEA DAM)
Below: CEA-LMJ setup (schematic drawing by Exail)



MOPERE team
Scientific Head: Sylvain Girard

Below Left: Photograph of the LLNL-NIF facility Target Chamber (© Lawrence Livermore National Laboratory)
Right: Sylvain Girard recently visited the Lawrence Livermore National Laboratory's NIF facility and its teams, accompanied by colleagues Vincent Goiffon (ISAE SUPAERO) and Philippe Paillet (CEA DAM).



In standard MultiMode Step-Index (MMSI) optical fibers, the signal propagates through different optical modes at different speeds, meaning that its temporal information, which is critical for the laser diagnostics, cannot be preserved. For laser diagnostics, MultiMode Graded-Index (MMGI) optical fibers - with a core doped to achieve the adequate refractive index profile - are required in order to preserve the signal's temporal information. The MMGI optical fibers used for radiation monitoring at the NIF and LMJ laser facilities are unique. They are indeed the only fibers currently on the market optimized for the transmission of 3ω light with low dispersion, and sufficiently robust to endure the pulsed radiation environment associated with ignition experiments. These fibers have been developed within the framework of the LabH6 Joint Lab, uniting our MOPERE team and the industrial Exail (former iXblue), in close collaboration with the teams of CEA DAM (CESTA and DIF). This multimode fiber (with a large core diameter of several hundredths of microns doped with Fluorine) is highly transparent to UV light, in order to capture and transmit the maximum data possible while exhibiting both unique radiation-resistance and low temporal dispersion. As pointed out by Nicolas Beck, R&D engineer at CEA, in an article published by Exail on their website: "Before Exail, only a laboratory had succeeded in producing graded-index fibers matching all our strict specifications, but the fibers were not radiation hardened. With Exail's radiation resistant fibers, we can now guarantee the quality and accuracy of the data collected at any point of the experiment, in particular in the experiment chamber where radiation levels are extreme».

Exail attributes the development and success of their highly specific type of optical fibers to their collaboration with our team of researchers through the LabH6 joint lab. Indeed, the lab performed numerous studies to identify the basic mechanisms and point defects at the origin of the fiber degradation in the ultraviolet domain, combining radiation tests - in Saint-Etienne and CEA facilities - and experimentations with different spectroscopic techniques [Reviews in Physics, 4, 100032 (2019)]. Building on this knowledge, the LabH6 envisions new techniques to improve the radiation hardness of these multimode optical fibers, while preserving their unique optical properties at 3ω. Since its creation, the LabH6 team have been working on various products not only for the nuclear research and industry use, but also finding applications to the health and space sectors, with notably the LUMINA radiation dosimeter now onboard the International Space Station. Together with the CEA and Exail, the team's efforts are currently concentrating on the development of fiber-based dosimetry systems able to monitor the dose distribution inside the experimental hall of Megajoule class lasers [IEEE Sensors Journal, 22, (2022) and Sensors, 22, 3192, (2022)]. The head of our MOPERE team Sylvain Girard had the opportunity to visit the NIF facility in July 2023, on the occasion of a seminar on radiation effects on electronics and photonics. For this meeting, Sylvain was invited by the Lawrence Livermore National Lab (LLNL) to present a paper on the "Basics of Radiation Effects in Silica-based Optical Fibers", and discuss the increasing radiation constraints within the context of ignition shots' diagnostics.

CIRCULIGHT
CIRCUlating LIGHT on any photonic platform

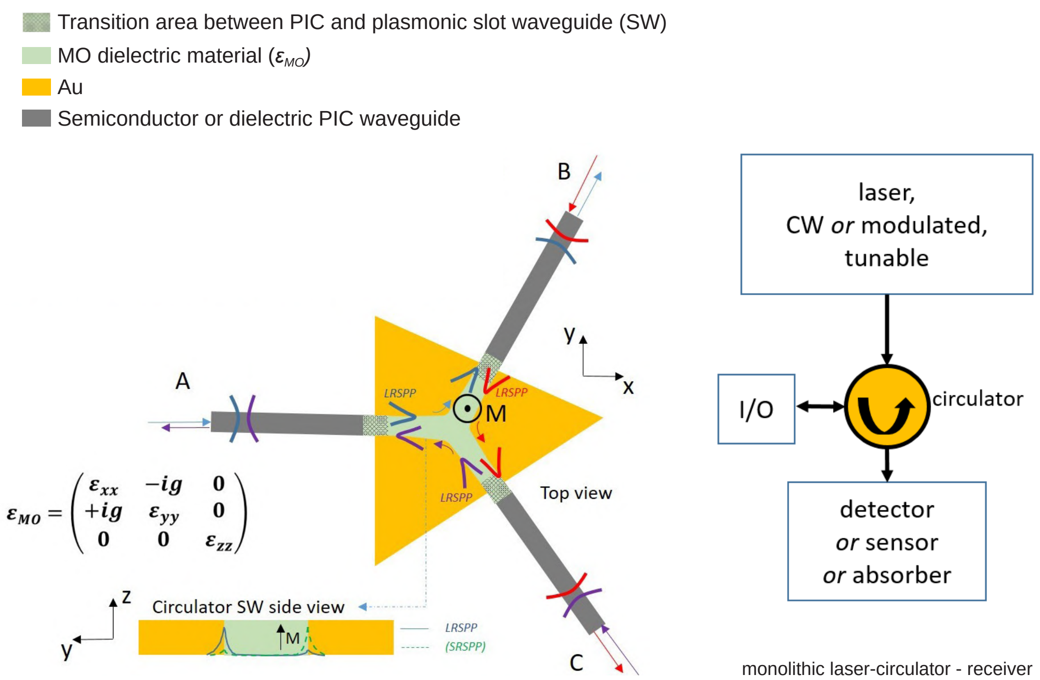
Functional Materials & Surfaces team
Local team: François Royer (Scientific Head)
Marie-Françoise Blanc-Mignon, Damien Jamon and Laure Bsawmaii

Despite the ongoing trend towards increased interdisciplinary collaboration in scientific research, very few projects involve teams from fields as diverse as Physics and Social Sciences. This is the angle taken for the newly accepted HORIZON-EIC CIRCULIGHT project, aiming at groundbreaking advancements in Photonic Integrated Circuit (PIC) capabilities. These advancements are poised to revolutionize a wide range of applications holding significant economic and societal value in sectors such as datacom, healthcare, food and farming.
As part of the CIRCULIGHT project, an innovative technology is to be developed that will lay the groundwork for a new class of highly functional, miniaturized, low-cost and low power-consuming PICs, substantially contributing to environmental protection and enhanced quality of life.
The excessive and increasing energy consumption generated by our societies' modes of communication, control or detection equipment strongly contributes to environmental pollution and rapid global warming. Replacing dissipative and heating electronic systems with low-loss, low-power photonic circuits could circumvent this problem, however requires making PICs competitive in terms of fabrication cost, functionality and compactness. The key to achieving this lies in the implementation of a truly integrated optical circulator, a central non-reciprocal (NR) device that would protect active and passive integrated functions from each other, distribute light between them, and allow very large-scale integration of photonic components within diversified PIC architectures. The practical realization of such a structure would be a world-first, for which a new research path is being explored by the CIRCULIGHT team. It will be based on the development of a radically new Magneto-BiPlasmonic (MBP) effect associated with a magneto-optical (MO) nanoparticle-composite sol-gel material.
The CIRCULIGHT consortium is made of 7 academic partners and 2 Small and Medium-sized Enterprises (SMEs): the CNRS (C2N Photonics lab, France); VSB Technical University of Ostrava (IT4Innovations National Supercomputing Center, Czech Republic); Université Jean Monnet (Hubert Curien Laboratory's Functional Materials & Surfaces team); Politecnico di Bari (Department of Electrical and Information Engineering, Italy); TU/e Eindhoven (Department of Electrical Engineering, and the Department of Industrial Engineering & Innovation Sciences, Netherlands); UCL (Electronic and Electrical Engineering Department, UK); the University of Wuppertal (Chair of Materials Science and Additive Manufacturing, Germany); as well as SMART Photonics BV and PhotonFirst Technologies BV (Netherlands). The project is being coordinated by the CNRS, and will be locally headed by François Royer, lead of our Magneto-Optical research group.

Optical isolators or circulators require the use of magneto-optical material, as light propagation in the presence of such materials becomes non-reciprocal due to the time-reversal symmetry breaking caused by magnetization, which is an axial time-odd vector field. However, the most commonly used MO material, garnet oxide Ce:YIG, cannot easily be embedded in photonic integrated circuits, because of its large lattice mismatch with classical optical substrates (silicon, III-V semiconductor, ...), and its high activation temperature requirement (700°C). Different strategies are currently being followed to deal with this technological roadblock. For example, very promising monolithic integrations of Ce- YIG on Si or SiN substrates have been realized by pulsed laser deposition, but the thermal budget is not compatible with active optical functions that may be present on the optical chip. The MO nanocomposite sol-gel material proposed in CIRCULIGHT solves the deposition issue of all the current solutions, because of its low processing temperature (100°C), and its ability to fill gold slot waveguides. It will be used to provide the magneto- biplasmonics effects, which result from the interaction between MO material and coupled plasmonic (SPP) modes, leading to the asymmetry in the supermodes profiles, and finally non- reciprocal propagation in the circulator.
Over the course of three and a half years, the CIRCULIGHT team is tasked with designing a generic circulator, developing an MO composite material, optimizing its refractive index and properties at 1.5μm and 1.3μm, developing the technologies for applying the MBP circulator to photonic integration platforms (demonstration carried out on 2 platforms: IMOS InP membrane-based, and III-V on silicon), evaluating and analyzing the performance of the fabricated circulators (either in their stand-alone version or within integrated circuits of both platforms), and finally realizing proof-of-concept devices (monolithically integrated laser-circulator-receiver).

European Commission

horizon europe
Le programme européen pour la recherche et l'innovation



monolithic laser-circulator - receiver

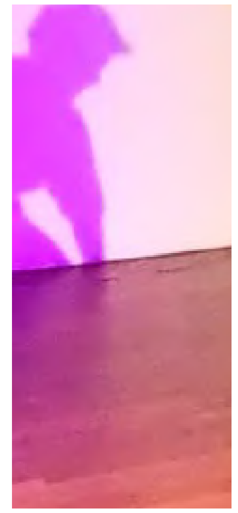
Working alongside the research groups providing all necessary skills and expertise related to material sciences, photonics, plasmonics and PICs technology, the TU/e Eindhoven's Department of Industrial Engineering & Innovation Sciences will guide and facilitate the industrial exploitation of the circulator. They will feed back societal needs and requirements into the technology development process, starting from its inception. The early involvement of both SMEs in the proof-of-concept will ensure a future new technology optimally adapted to industrial exploitation. The novel technology is expected to accelerate the implementation of all-photonic systems. Lightweight, low energy consumption and multi-functional PICs will be developed, increasing or creating markets related to optical fiber communications, data processing, sensing, neuromorphic computing, medical diagnosis and food industry (labs-on-chip), among others. Replacing electronic systems by all-photonic data processing circuits in data centers for example would at least halve energy waste (notably for cooling). Low-consuming, light-weighted and high-complexity photonic devices could be used in mobile systems (mobile phones, vehicles) to increase individual connectivity and at the same time double the energy autonomy of portable systems.
Our laboratory's magneto-optical research group has initiated such nanocomposite approach belonging to MO material several years ago. The potential of this material has already been demonstrated through the realization of an integrated MO converter, 1D resonant MO devices, 3D magneto-photonic devices, or infiltrated MO fibers sensors. Being part of the scientific core of this project definitively proves the added-value of such approach. Finally, through the CIRCULIGHT project, the group will address the main challenge in the field of photonic integrated devices, i.e. the realization of integrated optical isolators or circulators, a goal that has been pursued for more than 30 years.

PREMIERE

project

Performing arts in a new era

Image Science & Computer Vision team
Local Scientific Head: Alain Trémeau
Damien Muselet
Philippe Colantoni



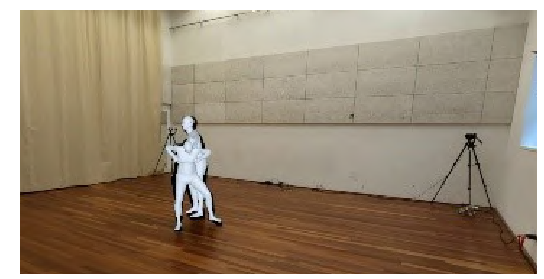
Started in October 2022 by a group involving our Image Science & Computer Vision team and a consortium including the Athena Research Center, ARGO Theatre (Greece), AHK, ICK Dans Amsterdam (Netherlands), the Forum Dança, Coliseu Porto Ageas, FITEI Theater, Medidata.Net, (Portugal), La Tempesta, the Instituto Stocos (Spain) and CYENS (Cyprus), the PREMIERE project is an illustration of the growing importance of the interrelationships between AI and XR technology developments. Focusing on dance and theatre, PREMIERE seeks to modernize the performing arts by using advanced digital technologies to support the whole lifecycle of performances: from their production and curation by both amateurs and professionals, to their delivery and understanding from the audience, as well as their analysis and interpretation by art scholars. The overall goal of PREMIERE is thus to develop and validate a comprehensive eco-system of digital applications, powered by leading-edge AI, XR and 3D technologies. It is designed to fulfill the needs of diverse end-user communities involved in the main stages of the performing arts productions' lifecycle, including amateur and professional performers, performance art producers and curators, spectators and scholars. Among the many objectives that were set for the project, our lab was put in charge of two challenging aspects: 3D scene analysis and understanding, as well as 3D pose trajectories estimation in complex scenes.

The 3D scene analysis and understanding task involved creating a dataset of live performances representatives of complex dance or theatre events (with multiple persons), using several cameras positioned at different points of views. The annotation (labelling) of these audio-visual contents will enable our team to test, compare and retrain Convolutional Neural Networks (CNN) and Deep Learning methods. The 3D pose trajectories estimation in complex scenes involved building a 3D model of moving people in these audio-visual contents, from the different views available. Our lab's team then evaluated the potential of the investigated and implemented methods. The most promising 3D scene analysis and understanding methods - including multi-people pose and motion estimation, segmentation and tracking methods, action parsing methods - were tested, compared and evaluated. Experimental results obtained from single-view methods (and archives) and multi-views methods were compared and analysed.
Another challenge addressed the building of a 3D model for static elements present in audio-visual archives. Our lab's researchers tested, compared and evaluated the most efficient 3D scene analysis and understanding methods, including object detection methods, segmentation or tracking methods. In the next six months, these 3D representations of static elements will be integrated as additional data for the algorithms used in the analysis, understanding and 3D reconstruction of audio-visual contents.

European Commission

Follow the team's progress on their blog

Another aspect currently under investigation is the definition of a set of generic methods and tools that could be generalised or transferred to other audio-visual contents or study cases - depending of the complexity of their content - beyond those explored as part of the PREMIERE project. The objective will be to evaluate the efficiency and performance of the methods investigated and implemented, in order to establish a set of rules linked to various factors (events' content, costume elements, lighting conditions, data quality, etc.) which will help determine the functionalities that could be extended to other events with minimal modifications, those that would require adaptations, or those that would be unusable. In the next steps, our lab's team will further investigate the potential of individual object pose (such as human body or hands) and methods such as motion estimation, human body pose trajectories estimation, tracking (methods based on 3D keypoint detection, kinematic skeleton, bounding box, semantic segmentation, 3D template model), action parsing, etc. The focus will extend to finding solutions for handling inter-object occlusions, abrupt motion changes, appearance changes due to varying lighting conditions between viewpoints, low contrast with the background, missing detections resulting from non-rigid deformation of clothing, truncations of persons, or interactions between people.
The team's ability to proficiently use, parameterize and optimize deep learning networks and models relies heavily on a diverse set of cutting-edge architectures, algorithms and tools encompassing a wide range of video processing tasks, including 2D pose estimation, 3D pose, tracking and trajectories estimations. While the efficiency of the selected architectures, algorithms and tools has been demonstrated, their robustness to challenges such as occlusion, motion blur, frame rate, noise, etc. has not been fully investigated, especially in the context of contemporary dance. The team's objective is therefore to propose a framework that leverages the limits of existing approaches.
The PREMIERE project, supported by a HORIZON-CL2-2021-HERITAGE-01-04 grant (Project ID: 101061303), is headed on our side by Alain Trémeau. Two other members of our Image Science & Computer Vision team, Damien Muselet and Philippe Colantoni, bring their expertise to this project, expected to run until the end of the year 2025.



Illustrations above:
Examples of 3D reconstruction
of human bodies for complex poses.
Images from the PREMIERE Dance Motion Dataset.

RESEARCH CONTRACTS & PARTNERSHIPS

Our lab is consistently pursuing a policy of very active engagement in national and international projects.
In this section, we compile our on-going projects supported by the European Commission, the ANR, the Auvergne-Rhone-Alpes Region and by our industrial partners. A small selection of these projects are also developped here.

In 2023, our research teams were working on approximately 140 funded projects, including 11 European and 35 ANR contracts, as well as 11 Auvergne-Rhône-Alpes region-financed projects. Several of our doctoral students are working under CIFRE or other industrial contract theses.

ongoing 2023 ANR PROJECTS

Project acronym	*title*	Ref. no: ANR-	Team
CAPTAIN	*Optical sensors for air quality monitoring (gaz NO_2, O_3)*	18-CE04-0008	FMS
HYPERSOL	*Interfaces management of Hybrid Perovskite based Solar cells*	18-CE05-0021	ISCV
MIXUP	*Color images multiplexing by laser structuring of plasmonic materials for security and personalization of ID cards*	18-CE39-0010	FMS
HORUS	*High Optical Resolution for Unlabelled Samples*	18-CE45-0010	ISCV
MEGALIT	*Metal Glasses functionalization by ultrashort Laser-Induced topology and phase Transition*	18-CE08-0018	LMI
APRIORI	*A PAC-Bayesian Representation Learning Perspective*	18-CE23-0015	DI
SMARtLEDs	*Self-organized multifunctional multi-material structures for LED lighting*	19-CE08-0001	FMS
ARCHI-SEC	*Micro-Architectural Security*	19-CE39-0008	SESAM
COSWOT	*Constrained Semantic Web of Things*	19-CE23-0012	DI
INTRALAS	*Unraveling intra-pulse dynamics and fast energy transfer in silica glass - a pathway for smart processing using ultrafast lasers*	19-CE30-0036	LMI
ROIi	*Rey's Ornament Image investigation*	20-CE38-0005	ISCV
TAUDOS	*Theory and Algorithms for the Understanding of Deep learning On Sequential data*	20-CE23-0020	DI
MUDIALBOT	*Multi-party perceptually-active situated Dialog for human-robot interaction*	20-CE33-0008	ISCV
GESPAD	*Ge-based Single Photon Avalanche Diodes: from comprehensive characterization to advanced simulation*	20-CE24-0004	ISCV
FIDELIO	*Fiber-based In-vivo Realtime Dosimetry for Pulsed Radiotherapy*	20-CE19-0024	MOPERE
NOEMR	*Nano-structured smart hybrid polymeric composites with internal architecture towards improving ultra-high absorbance of ElectroMagnetic Radiation*	20-CE06-0003	FMS
DIKÉ	*Bias, fairness and ethics of compressed NLP models*	21-CE23-0026	DI
CRUMBLE	*Chromium-based coatings for lasers*	21-CE24-0034	FMS
UNDERNEATH	*Understanding Deep Neural Networks with Game Theory*	21-CE23-0022	DI
ASTRAL	*Statistical learning for multi-dimensional SAR imagery*	21-ASTR-011	ISCV
NITRURATION	*Manufacturing process of micro-nanostructured metal nitrides*	21-CE08-0042	FMS
DENSE	*Dense structures on the nanoscale*	21-CE08-0005	LMI
POP	*Power-OFF laser attacks on security Primitives*	21-CE39-0004	SESAM
SAFE	*Controlling networks with safety bounded & interpretable machine learning*	21-CE25-0005	DI
AWOCAT	*Toward a switchable bio-activity of metallic glass surfaces by ultrashort laser irradiation*	22-CE08-0030	LMI
COULEURS	*Resonant Microstructured luminescent layers*	22-CE39-0013	FMS
LAST_FLOW	*Femtosecond Laser Structuration for Functionalization of Optical Windows*	22-CE24-0026	FMS
PROPHY	*Algorithmic protections against physical attacks*	22-CE39-0008	SESAM
ATICS	*Advanced Three-dimensional Imaging of Complex particulate Systems*	23-CE51-0023	ISCV
FAMOUS	*Fair Multimodal Learning*	23-CE23-0019	DI
FLUOSICCA	*Double fluorescent Staining of the Ocular Surface in dry eye disease*	23-CE19-0022	ISCV
LAMORSIM	*Laser-forming of ultrathin amorphized Si layer for microelectronics applications*	23-CE08-0029	FMS + DI
SCAMA	*Secure-by-Design Computing Against Microarchitectural Attacks*	23-CE39-0011	SESAM
SLICID	*Secured laser printing of color images in identity documents*	23-CE39-0006	FMS + DI
VO2Random	*Vanadium Dioxide-Based Films for Randomizing Integrated Circuits Photonic Emission and Absorption*	23-CE39-0004	LMI + FMS + SESAM

KEY TO TEAMS:

FMS	**Functional Materials & Surfaces**
MOPERE	**Materials for Optics & Photonics in Extreme Radiation Environment**
LMI	**Laser Matter Interaction**
ISCV	**Image Science & Computer Vision**
DI	**Data Intelligence**
SESAM	**Secure Embedded Systems & Hardware Architectures**

39 ongoing 2023 **INDUSTRIAL PROJECTS**
18 ongoing 2023 **CIFRE thesis**

ongoing 2023 EUROPEAN COMMISSION PROJECTS

Project acronym	*title*	Team
RADNEXT	*RADiation facility Network for the EXploration of effects for indusTry and research*	MOPERE
PREMIERE	*Performing arts in a new era: AI and XR tools for better understanding, preservation, enjoyment and accessibility*	ISCV
EURIPIDES/PENTA FA 4.0	*Key for reliable electronic devices in smart mobility and industrial production*	ISCV
SWISSMODICS	*Development of a Sensor with WIde Spectrum Sensitivity for MOnitoring of Damage and Defects In Composite Structures*	MOPERE
PHOTONHUB	*Services to support your innovation in Photonics*	MOPERE
EURAD (MODATS)	*European Joint Programme on Radioactive Waste Management*	MOPERE
LASERIMPLANT	*Laser-induced hierarchical micro-/nano-structures for controlled cell adhesion at implants*	LMI
ACTPHAST 4 R	*Access CenTer for PHotonics InnovAtion Solutions and Technology*	FMS
ACTPHAST 4,0	*Access CenTer for PHotonics InnovAtion Solutions and Technology*	FMS
GREAT	*Grating Reflectors Enabled laser Applications and Training*	FMS
SERECO	*Semantic, Reasoning and Coordination - Creation of a Franco-German doctoral college*	DI

ongoing 2023 AURA REGION PROJECTS (Auvergne-Rhône-Alpes)

Project acronym	*title*	Team
SLIM	*Innovative Laser Additive Synthesis for Magnetic Materials*	FMS
PAI 2021	*Lighting and mixed reality for the assistance of the visually impaired*	ISCV
FORMEL	*Functional transformation of metallic glass surfaces by laser irradiation*	LMI
PAI 2019	*Light-surface interaction: from nanostructuring to functional detection*	LMI
DIAGHOLO	*Microbiological Diagnosis by Holographic microscopy*	ISCV
SECURE-RISC-V	*Secure version of the Risc-V architecture*	SESAM
BOOSTER VISIOFEM	*Vision-assisted non-planar machining of surfaces*	ISCV
MICROSOLEN	*Direct Microstructuring of Sol-gel layers for Energy*	FMS
CAPTHY	*Optical Sensors for Hydrogen detection*	FMS
BOOSTER QABOT	*Question Answering & Chatbot*	DI
COCOLI	*Color Constancy in various Lighting environments using new sensors/display devices*	ISCV

new 2023 ANR projects

In 2023, a total of 7 projects submitted by the Hubert Curien Laboratory were selected for an ANR AAP 2023 funding. The list of these projects reflects the variety and quality of the research carried out in our lab.

PRC PROJECT: ATICS
Project coordinator: LMFA Lab
Partners: IUSTI, CEA Marcoule, Hubert Curien Lab
Lab's PI: Corinne Fournier
Image Science & Computer Vision team

ATICS - "Advanced Three-dimensional Imaging of Complex particulate Systems"
The main objective of this project is to develop a set of advanced, robust tools and methods for light scattering and reconstruction, enhancing the practical capabilities of Digital Holography. It will be applied in various Fluid Mechanics experiments, ranging from microscopic to large field-of-view setups.

PRCE PROJECT: FAMOUS
Project coordinator: Laboratoire d'Informatique et Sytèmes
Partners: INT-Marseille , LITIS-Rouen, Euranova, Hubert Curien Lab
Lab's PI: Emilie Morvant
Data Intelligence team

FAMOUS - "Fair Multimodal Learning"
The aim of this project is to address the issue of fair machine learning in the context of multimodal learning. Such framework could improve monomodal methods, in order to avoid unfair models. FAMOUS not only covers theoretical but also practical aspects, with the design of methods and a focus on graph-structured data, as well as the creation of datasets.

PRC PROJECT: FLUOSICCA
Project coordinator: BiiO Lab
Partners: Institute of Chemistry & Processes for Energy, Environment & Health, LISM, Hubert Curien Lab
Lab's PI: Baptiste Moine
Image Science & Computer Vision team

FLUOSICCA - "Double Fluorescent Staining of the Ocular Surface in Dry Eye disease"
The ANR FLUOSICCA project aims to address dry eye disease, which affects the quality of life for millions of people worldwide. To enable early diagnosis of this condition, four research labs (Lab BiiO and Lab Hubert Curien in Saint-Etienne, LISM in Marseille, ICPEES in Strasbourg) have teamed up to develop fluorescent biomarkers specific to dry eye disease, and a dedicated biomicroscope for their detection.

PRCE PROJECT: LAMORSIM
Project coordinator: Hubert Curien Lab
Partners: LP3, STMicroelectronics
Lab's coordinator: Tatiana Itina
Laser Matter Interaction + Data Intelligence teams

LAMORSIM - "Laser Forming of Ultrathin Amorphised Si Layer for Microelectronics Applications"
In the highly demanding field of microelectronics, the laser-based treatment of essential components of micro and nano-electronic devices is to be developed as an alternative to existing methods. This project brings together two academic and one industrial partners who will experimentally and numerically study interactions of ultrashort laser pulses to develop efficient Si nanolayer amorphization regimes.

PRC PROJECT: SCAMA
Project coordinator: Telecom Paris
Partners: LabSTICC, LIRMM, Hubert Curien Lab
Lab's PI: Brice Colombier
SESAM team

SCAMA - "Secure-by-Design Computing Against Microarchitectural Attacks"
The SCAMA project aims at designing countermeasures against micro-architectural attacks on complex system-on-chips. The team will integrate the security constraint as early as possible in the design flow, to obtain the best trade-off between security and performance. Both hardware and software aspects will be considered.

PRCE PROJECT: SLICID
Project coordinator: Hubert Curien Lab
Partners: HID Global CID SAS, IREIS, Institut Fresnel, ILM
Lab's coordinator: Nathalie Destouches
Functional Materials & Surfaces + Data Intelligence teams

SLICID - "Secured Laser Printing of Color Images in Identity Documents"
The objective of this project is to develop innovative secure laser printing solutions for visual authentication of physical ID documents. The laser-engraved nanostructures will provide highly contrasted and angle-controlled colors as well as images secured by multiplexing, in order to ensure authentication with the naked eye, anti-counterfeiting and anti-forgery capabilities not currently offered by any other color marking technique.

PRC PROJECT: VO2Random
Project coordinator: Hubert Curien Lab
Partner: Institut Jean Lamour
Lab's coordinator: Florent Bourquard
Laser Matter Interaction + Functional Materials & Surfaces + SESAM teams

VO2Random - "Vanadium Dioxide-Based Films for Randomizing Integrated Circuits Photonic Emission and Absorption"
As part of the VO2Random project, the team proposes to coat electronic chips substrates with vanadium dioxide based thermochromic thin films. Coupled with the heat generated when accessing the encrypted data, this will randomize their optical properties, and thus prevent the extraction of information via the "photonic" channel that exploits transistors fluorescence and absorption.

PEPR projects

Many members of the Hubert Curien Laboratory are involved in the follow-up of the «France 2030» programs, initiated in 2021 by the French Governement. As such, Priority Research Programs and Equipment (PEPR) aim to build or consolidate French leadership in scientific fields linked to technological, economic, societal, health or environmental transformation, which are considered as priorities on a national and European levels. We present here a list of the selected programs in which our lab is involved.

PEPRs exist in 2 forms: "national acceleration strategy PEPRs" and "exploratory PEPRs". These programs benefit from a state financial support, and are managed by the National Research Agency (ANR). Each scheme is either an existing, already mature project for which a contract binding a coordinating establishment and the ANR is established, or a project selected following an open call for proposals (AAP) or calls for expressions of interest (AMI), and related to the program's thematic.

National Acceleration Strategy PEPRs:
These PEPRs support transformations already underway with well-identified products, services, uses and actors. Approximately 20 acceleration strategy PEPRs have been identified, most of which are piloted or co-piloted by the CNRS.

Cybersecurity PEPR:
With a budget of 65M€, this PEPR aims to support upstream cybersecurity research by exploring new avenues potentially leading to breakthrough innovations to the benefit of the French sector.
The Laboratoire Hubert Curien's SESAM team is involved in this program through the 550k€ "Secure architectures for embedded digital systems" (ARSENE) project, headed by Lilian Bossuet. The project focuses on hardware security and heavily constrained processors for embedded computing, such as headsets or on-board computer systems in cars.

Quantum Technologies PEPR:
For reasons of national and European sovereignty, the French state is seizing on the problem of quantum technologies' development. It seeks to reach the highest level of international scientific and industrial competition, and hopes for France and Europe to gain their independence in this key area thanks to a 150M€ program that should enable the development of its own solutions.
With his «Post-quantum padlock for web browser» project, SESAM's team leader Lilian Bossuet is contributing to resolving the problematic of this program.

Electronics PEPR:
Electronics is a core issue regarding the digital functionalities of products and services in our societies. This 86M€ program is aimed at generating innovations to accelerate growth and relocate the manufacturing of certain products to France or Europe.
Our NanoSaintEtienne (RENATECH+) platform will benefit from part of the 39M€ of this PEPR dedicated to support the equipment of the CNRS RENATECH / RENATECH+ infrastructures.

Our lab is also involved in the Artificial Intelligence PEPR and the TASE-Advanced Energy Systems Technologies PEPR.

Exploratory PEPRs
With these PEPRs, the State intends to support the exploration of emerging transformations' potentials. Projects should here follow a scientific policy alignment with national and European interests, with potential multiple outcomes.

Origins PEPR:
This 45 M€ PEPR intends to remove scientific barriers related to the study of life and the universe, with a view towards multiple implications on the national technological expertise and, consequently, on the country's economy, health and environment.
Our lab is involved in this program as part of a work package, led by Loïc Denis, grouping AI activities for the processing of multivariate data for the detection and characterization of exoplanets and disks. His «Unsupervised A0 Control» and «AI Data Analysis» projects are featured pages 38 and 39.

Luma PEPR - Promoting Light-Matter Interactions:
Light, omnipresent in our natural and technological environment, is the subject of this 40M€ program. Luma aims to study, understand and develop this unique tool as a means of exploring and controlling physico-chemical and biological systems, at the interfaces between physics, chemistry, engineering and life sciences, and between health and environmental / climate science.
This program is divided into 4 major work packages: Moonshot projects, Infrastructure, Innovation/incubators and Management/coordinated actions. Nathalie Destouches, together with Dario Bassani from ISM Bordeaux, is co-hosting the Moonshot Project MP2 "Smart Photoprocesses at Ultimate Space and Time Resolutions". The 3 teams of our Optics, Photonics & Surfaces department are involved in this program. This PEPR will also fund the access (50 days/year) to the lab's technology platforms.

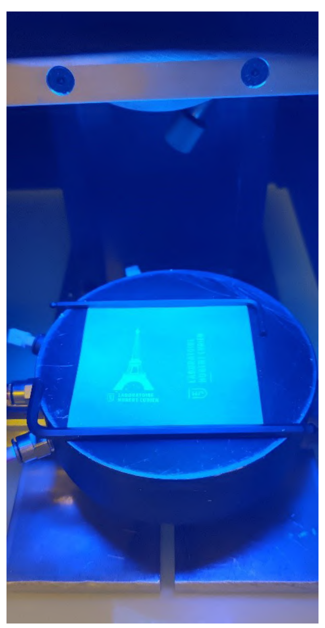
Our lab further contributes to the Diademe - Integrated Devices for Accelerating the Deployment of Emerging Materials PEPR and the Spin - SPINtronics innovations for a frugal, agile and sustainable digital technology PEPR.

This section showcases a selection of collaborative projects that members of the Hubert Curien Laboratory are either leading or actively participating in.

COULEURS *ANR project*

Functional Materials & Surfaces team
Local Scientific Head: Yves Jourlin

Start Date: February 2023
Contract duration: 4 years
Partners:
Hubert Curien Lab
+ Institut Pascal
+ Institut de Chimie de Clermont-Ferrand
(Univ. Clermont Auvergne)
Total budget: 394 k€



With a cost of €60 billion across 13 sectors of the European economy, counterfeiting constitutes one of the most significant challenges of the 21st century. Besides the substantial financial losses it incurs, counterfeiting also poses significant legal risks, particularly when a counterfeit product leads to a disaster, such as a public health crisis.
The COULEURS project (Resonant microstrUctured Luminous layers) is part of optical security components (level 1 to 3). The innovative aspect of the project lies in its methodology, which combines two optical effects: luminescent layers (phosphors) and resonant gratings (0-order surface microstructuring). This combination produces a unique effect, resulting from interactions that generate additional colors difficult to replicate. Ultimately, the research team aims to establish solid theoretical and technological foundations to develop relevant demonstrators. These demonstrators, in the form of patterns/logos with distinctive visual effects, could then be presented to government services (such as IN Groupe, former National Printing Office, customs services, etc.) and/or industrial partners (including luxury goods manufacturers, spirits, pharmaceuticals, and health sectors).
The COULEURS project (ANR-22-CE39-0013) fully aligns with the expectations of the H17 axis of AAPG2022, as it directly addresses global security concerns through innovative technological solutions (optical components) for protecting, securing, and tracing documents (such as fiduciary and identity documents, driving licenses, etc.) and products (including pharmaceuticals and luxury goods), thereby mitigating counterfeiting, fraud, and illicit trafficking, including terrorism.
This project is being coordinated by the Hubert Curien Laboratory. It is led by Yves Jourlin, who brings expertise in diffractive optics and resonant gratings, working in close collaboration with the Institut de Chimie de Clermont-Ferrand, specializing in phosphors-based layers, and the Institut Pascal, responsible for modeling combined optical effects. Marie Traynar, a Ph.D. student recruited in October 2023, will be co-supervised by the Hubert Curien Lab and the Institut de Chimie de Clermont-Ferrand.

CAPTAIN & CAPTHY *projects*

Functional Materials & Surfaces team
Local Scientific contact: Yves Jourlin

Start Date: December 2018
Contract duration: 52 months
Partners:
Hubert Curien Lab
+ Institut Pascal
(Univ. Clermont Auvergne)
+ SILSEF
+ ENVEA, Cairpol division
+ Minalogic
Total budget: 398 k€

Start Date: February 2022
Contract duration: 36 months
Partners:
Hubert Curien Lab
+ Institut Pascal
(Univ. Clermont Auvergne)
+ NAPA Technology
+ EFS
+ STAUBLI
Total budget: 186 k€

Since 2019 and in collaboration with the Institut Pascal (IP) - research lab of the Université Clermont Auvergne - the Hubert Curien Laboratory has been aiming to develop original and efficient plasmonic gas sensors. This partnership focuses on two main applications: air quality control with the monitoring of gaseous pollutants, and industrial safety, particularly the detection of hydrogen leakage.
The skills in nano-patterned structures and plasmonic effect of the team led by Yves Jourlin at the Hubert Curien Laboratory, associated with the expertise on sensing materials and gas microsensor of Jérôme BRUNET's team at the Institut Pascal are the pillars of this collaboration. The scientific strategy revolves around exciting plasmon modes (SPR-Surface Plasmon Resonance) on a microstructured optical network, layered with nanometric functional films selected for their sensing properties towards the target pollutants. Such an approach has been successfully applied in the now completed CAPTAIN project and is currently being further developed as part of the ongoing CAPTHY project.

The CAPTAIN project aimed to develop optical sensors for air quality control, with a focus on measurement of nitrogen dioxide NO_2 and ozone O_3 concentrations in the air. Supported financially by the ANR and endorsed by Minalogic, this project also involved two industrial partners (SILSEF and ENVEA). Hugo Bruhier and Thiaka Gueye, two co-supervised students working on the project, successfully defended their Ph.D. thesis in June and July 2023, respectively. The work resulted in the publication of four scientific articles and in the team's participation in various international conferences.
The CAPTHY project, on the other hand, focuses on investigating the feasibility and potential of plasmonic detectors for detecting gaseous hydrogen leakage. Leveraging the well-established permeability of palladium towards hydrogen, a thin film of this chemical element will be layered onto SPR transducers. Funded by the AURA region, the CAPTHY project is supported by three industrial partners (NAPA technology, EFS, STAUBLI), and has facilitated the recruitment in January 2022 of Pascal Giraud, a co-supervised Ph.D. student based at the Hubert Curien Laboratory.

This section showcases a selection of collaborative projects that members of the Hubert Curien Laboratory are either leading or actively participating in.

UNSUPERVISED AO CONTROL & AI DATA ANALYSIS projects *PEPR Origins*

UNSUPERVISED AO CONTROL

Image Science & Computer Vision team

Scientific contact: Loic Denis
Contract duration: 6 years
Start Date: March 2024
Partners: Hubert Curien Lab
+ Centre de Recherche Astrophysique de Lyon (CRAL)
+ Institut d'Optique Graduate School (IOGS)
+ ONERA (DOTA)
+ LESIA
Total budget: 1,3 M€

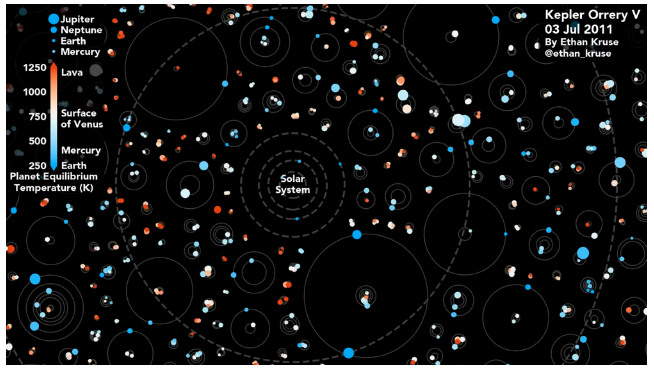
Our lab's long-established collaboration with the Observatory of Lyon originated from the realization that methods developed in astronomy for the detection of sources using nulling interferometry could be used to significantly improve the analysis of diffraction patterns in holographic imaging. Our work has led to novel data processing techniques that reached unprecedented accuracy and demonstrated the ability to track spherical objects beyond the camera boundaries, thanks to the spreading of information produced by the diffraction phenomenon, and a careful numerical inversion of this physical process. Image reconstruction methods were further developed with the Observatory of Lyon in holographic microscopy, enhancing bacteria identification for biomedical diagnosis. Since 2005, our collaboration has led to the co-supervision of several Ph.D. thesis and supported a number of research projects (ANR MITIV, AURA project DIAGHOLO, CNRS MITI projects DETECTION and RECONSTRUCTION). The teams also collaborated on projects for the optical design of an adaptive optics system and a coronagraph at the Thai observatory NARIT.

AI DATA ANALYSIS

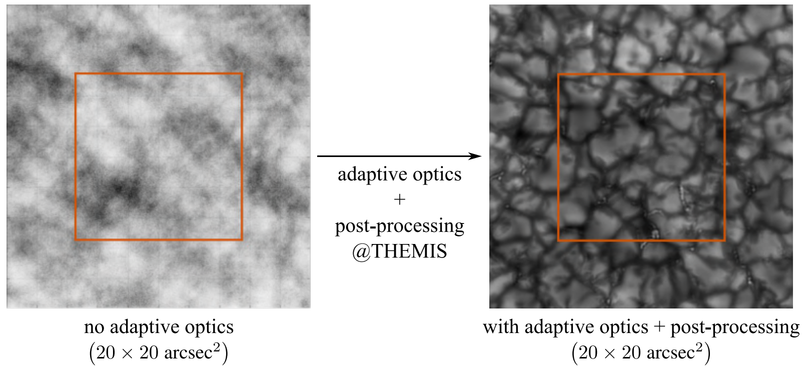
Local Scientific Head: Loic Denis
Contract duration: 6 years
Start Date: November 2023
Partners: Hubert Curien Lab
+ 10 UMRs (CRAL, LESIA, IPAG, IRAP, Lagrange, Lab. Physique ENS Lyon, LAM, GIPSA, IMS, L2S)
+ INRIA (THOTH, WILLOW)
+ ONERA (DOTA)
Total budget: 1,5 M€

Most recently, two research projects supported by the PEPR ORIGINS "From planets to life" program (2023-2029) have been launched, and will be jointly undertaken. The first one, "Unsupervised Predictive Control for Adaptive Optics", is being led by the CRAL and focuses on data processing techniques for improved adaptive optics systems. The project will notably address challenges facing the upcoming European Southern Observatory's Extremely Large Telescope under construction in Chile. The "AI data analysis" PEPR project will be led by our lab and will seek the development of artificial intelligence methods for the detection of exoplanets. Data science has become a key element in astronomy for the optimal extraction of information from astronomical observations. Given the technological challenge of detecting and analyzing the extremely weak signature from planets outside the solar system, powerful telescopes, extremely sensitive instruments, and AI-based image analysis are necessary.
Our work with the CRAL is an illustration of a very productive pluri-disciplinary collaboration leading to notable progress both from a methodological point of view in data science in imaging, and in practical applications within astrophysics and biomedical imaging.

The VLT in Chile
© Claude DELHAYE/CNRS photo library



A few planetary systems detected by the Kepler satellite



The adaptive optics developed by the CRAL for THEMIS (a solar telescope operating on the island of Tenerife) relies on advanced data processing and real-time control

This section showcases a selection of collaborative projects that members of the Hubert Curien Laboratory are either leading or actively participating in.

Tech4Diet project

Computer Vision and Machine Learning to treat obesity

Tech4Diet

Data Intelligence team
Local Scientific contact: Marc Sebban
Contract duration: 5 years
Start Date: December 2018
Partners: Laboratoire Hubert Curien
+ Alicante University, Spain (Coordinator)
+ Rennes 1 University, France
Total budget: 100 k€

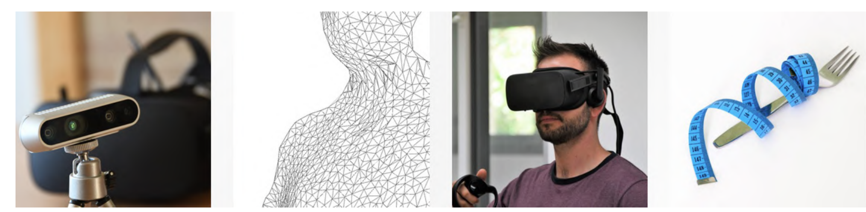
GOBIERNO DE ESPAÑA — MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

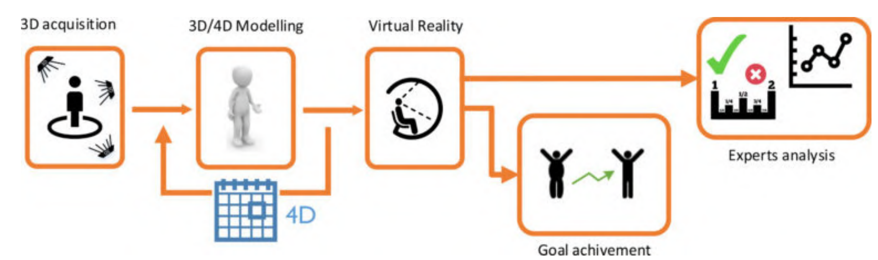
Universitat d'Alacant
Universidad de Alicante

European Commission

The non-adherence to obesity treatments is one of the main causes of their failure, turning obesity into a chronic disease in many countries of the world. The Tech4Diet project aims to take advantage of the most recent technological advances in 4D modelling and virtual reality to help tackle this issue. By building a 4D visual representation model of the human body for its morphological evolution analysis, the team is looking to enhance a patient's cognitive experience during the weight loss process, which has been shown to be an essential part of any obesity treatment's success.
The new system will provide immersive virtual reality visualizations and simulations of the treatment's effect, studying, in turn, how these realistic visualizations affect the patient's adherence to the treatment. Additionally, tools based on the model are being developed to facilitate the study of new indices based on anthropometric measurements and their evolution over time. A doctor could have access to multidimensional measurements extracted from the model, while a 3D archive of the entire evolution would be available throughout the process. Using low-cost technology is one of the conditions that would allow the tool to be put into practice, for example in health centres or nutritionists' clinics. However, the suggested methodology for obtaining the representation model of the morphological changes poses a significant scientific challenge. The use of wide-spectrum 3D acquisition technologies (RGBD), with characteristics of versatility, portability and ergonomics, involves addressing unresolved issues to this day regarding fundamental aspects of articulated and deformable registration methods.

Members of our Data Intelligence team Marc Sebban and Amaury Habrard are contributing to the project through their expertise in Machine Learning, and more specifically, in Optimal Transport and Transfer Learning.
This collaboration with the University of Alicante, initiated in 2018, has already led to several scientific publications and the development of a new software called «Tech4DScanserver» (registrated in Spain).
The project is supported by the Spanish State Research Agency (AEI), the European Regional Development Fund (ERDF - project TIN2017-89069-R), as well as the University of Alicante.





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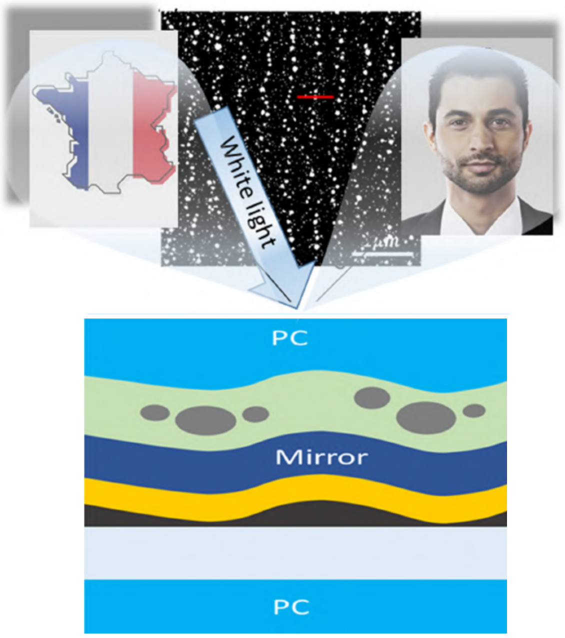


SLICID *ANR Project*

Functional Materials & Surfaces
+ Data Intelligence teams
Coordinator: Nathalie Destouches
Start Date: November 2023
Contract duration: 4 years
Partners: Hubert Curien Lab
+ Fresnel Institute
+ Institut Lumière Matière
+ IREIS HEF
+ HID Global CID
Total budget: 684 k€

SLICID «Secured laser printing of color images in identity documents» is a project (ANR-23-CE39-0006) based on a combination of academic and industrial expertise that aims at developing competitive and innovative secure laser printing solutions for the visual authentication of physical ID documents.
The laser-engraved nanostructures will provide highly contrasted and angle-controlled colors as well as images secured by multiplexing, in order to ensure authentication with the naked eye, anti-counterfeiting and anti-forgery capabilities not currently offered by any other color marking techniques.
In doing so, SLICID will provide:

- The marking of color images inside plastic documents with low cost laser technology, high speed writing, easy implementation and no ink.
- High color saturation and tolerant observation angles, to ensure high image quality compatible with the users' expectations.

By reducing the need for consumables required by current printing techniques, the project's results and the developed technology are expected to have a positive impact on the environmental aspects of ID documents production. Furthermore, the additional security provided by the proposed technology will improve the protection of citizens' identity against falsification.

Post-quantum cryptography
2 new CIFRE contracts

SESAM team
Coordinator: Lilian Bossuet
Contract duration: 36 months
Start Date: October 2023
Partners: Laboratoire Hubert Curien (Coordinator)
+ Hensoldt France
+ Continental Group
Total budget: 350 k€

The evolution of cryptographic standards from public key cryptography (RSA, ECC) to post-quantum cryptography is already in motion. The choice of new primitives will soon be made and the transition will happen in the next few years. The objective of the lab's SESAM team is to play a driving role in this evolution and ensure that industrial partners are able to efficiently embed the new cryptographic standards into their products. In this context, the team has signed two new CIFRE thesis contracts (one classic ANRT and one AID defense CIFRE) with two industrial partners from two different applicative domains: CONTINENTAL, an automotive equipment manufacturer developing pioneering technologies and services for a sustainable and connected mobility for people and their goods, and with HENSOLDT, a global high-tech pioneer for defense and security electronics, and a market leader in civilian and military sensor solutions. The main focus of these two Ph.D. theses will be to develop efficient hardware implementations of post-quantum cryptographic schemes with a reduced footprint, in an embedded context. This work will complement the research currently conducted in our lab as part of two funded Ph.D. thesis within the framework of the PEPR Quantum Technologies' PQ-TLS project.
The expected results will undoubtedly and significantly contribute to the implementation of post-quantum cryptographic schemes in the near future, asserting the position of our SESAM team as a leading force in the field.

This section showcases a selection of collaborative projects that members of the Hubert Curien Laboratory are either leading or actively participating in.

GLACIER *project*

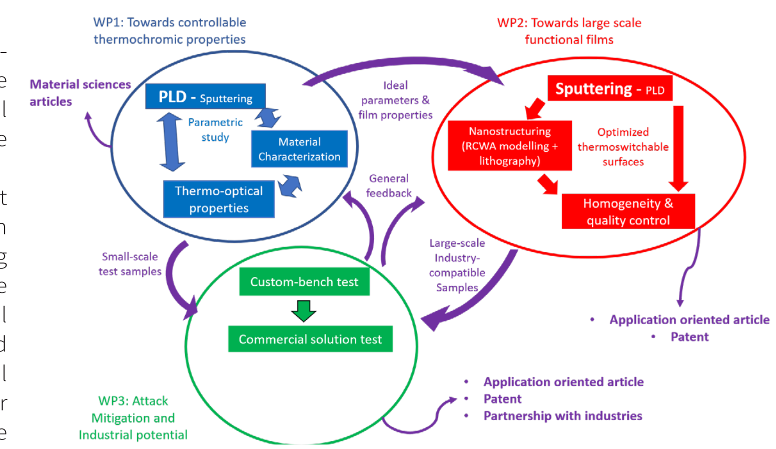
Laser-Matter Interaction team
Local Scientific contact: Razvan Stoian
Contract duration: 3 years
Start Date: July 2023
Partners: Hubert Curien Lab
+ HEF Groupe-IREIS (Project Coordinator)
+ GIE Manutech USD
+ VISIOSHAPE
+ Total budget: 2.7 M€

Thin film removal and glass cutting constitute key steps in the manufacturing of various products in a range of highly strategic markets, spanning from optics to electronics to photonics. However and in order to enhance their strength and fineness, materials are becoming increasingly harder, which makes cutting more and more complex or even impossible using conventional techniques such as diamond or water jet cutting.
In response to this challenge, the GLACIER project aims at exploring laser technologies to achieve fine cuts without damaging the material. Specifically, the objective is to develop a comprehensive versatile ultrafast laser process, along with the design of a machine tailored for an advanced glass-cutting industrial-level solution.
The project is led by a consortium of 4 partners, all based in the Saint-Etienne area: the company IREIS, Projet coordinator and a subsidiary of the HEF Group, the GIE Manutech USD, the company VISIOSHAPE, and the University Jean Monnet (Hubert Curien Lab). This partnership was formed within the framework of the I-Démo program in the Auvergne-Rhône-Alpes region, a call for projects jointly launched and funded by the French Government and the Region as part of the France 2030 initiative, and open to consortiums comprising at least 2 companies and 1 research partner. The project supports the strong dynamic in play towards developing the photonics industry in the Saint-Etienne region. The products and applications targeted by the GLACIER project include medical devices (for diagnostics), photonics and optical components for electronics, display screens, semiconductors and transportation (for autonomous vehicles).

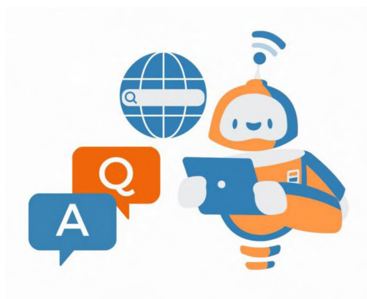
VO2Random *ANR project*

Laser-Matter Interaction team
Coordinator: Florent Bourquard
Contract duration: 4 years
Start Date: December 2023
Partners: Hubert Curien Lab (Coordinator)
+ Institut Jean Lamour (IJL), Université de Lorraine
Total budget: 400 k€

The "Vanadium Dioxide-Based Films for Randomizing Integrated Circuits Photonic Emission and Absorption - VO2Random" project aims to devise a new method to prevent the use of a "photonic channel" to bypass cryptography-based microchip protection. As such attacks rely on either observing the natural emission from transistors or triggering a state change by irradiating them with a laser, the team's idea and objective is to produce a coating for microchips' substrates which optical properties will change more or less randomly during an attack.
To achieve this, the team will rely on a thermochromic material (vanadium dioxide) which temperature transition properties and optical transmission will be adapted using doping and optimization of the thin film processing conditions.
This project involves three groups from the Hubert Curien Laboratory: our Laser-Matter Interaction team, responsible for producing and characterizing the thin films, our SESAM team (using their expertise in microelectronics and material security), as well as our Functional Material & Surfaces team (tasked with enhancing transition effects by adding optical functions). The teams at the Institut Jean Lamour will explore alternative methods for producing the thermochromic thin films, with a focus on large surface functionalization compatible with industrial processing for the micro-electronics sector.
The ANR-funded VO2Random project (ANR-23-CE39-0004) was selected within the CE39 "Global security" evaluation committee framework, as part of the AAPG 2023.



This section showcases a selection of collaborative projects that members of the Hubert Curien Laboratory are either leading or actively participating in.



QABOT project

Data Intelligence team
Scientific Head: Antoine Gourru
Contract duration: 2 years
Start Date: July 2022
Partners: Hubert Curien Lab
+ Wikit
+ The QA Company
Total budget: 625 k€

Deep Learning-powered conversational agents, such as large language models (LLMs) like ChatGPT or CoPilot, are increasingly employed to aid users, and are becoming more integrated into our daily lives. Conversely, in the question-answer (QA) paradigm, users ask questions, and systems retrieve relevant answers by discerning pertinent text within a documents corpus.
The aim of the QABOT project, resulting from the R&D Booster program funded by BPI France and the Auvergne Rhone Alpes Region, is to merge these technologies, a non-trivial task given that LLMs aren't inherently optimized for database querying or specialized in QA tasks. Consequently, advanced adaptation of LLMs or devising resource-efficient utilization of these models becomes imperative in this context.
In this effort to connect these areas, the Hubert Curien Laboratory offers scientific support to two industrial partners, Wikit (located in Lyon) and The QA Company (located in Saint-Etienne), and explores how existing fine-tuning methods impact catastrophic forgetting and hallucination.
The QA Company is a startup founded in 2019 by Pierre Maret, professor of Computer Science and researcher in Data Intelligence within our lab, together with his former doctoral student Dennis Diefenbach. The company has developped a Question Answering system i.e. a software, specifically designed to help organizations and teams access internal information quickly and efficiently.

LAMORSIM *ANR project*

Laser-Matter Interaction team

Coordinator: Tatiana Itina
Start Date: January 2024
Contract duration: 42 months
Partners:
Laboratoire Hubert Curien
+ Laboratoire Laser, Plasmas et Procédés Photoniques (LP3 , Marseille)
+ ST-Microelectronics (Crolles)
Total budget: 954 k€

Microelectronic components are extremely important parts of virtually all modern devices, and the corresponding market is expected to keep growing. With a constantly increasing demand for such components, further development and optimization of their fabrication processes are essential. Silicon remains the predominant material used in microelectronic devices fabrication, involving over 900 process steps for advanced technologies. Particularly, contact silicides are fundamental building blocks of micro and nanoelectronic devices, extensively integrated into Complementary Metal Oxide Semiconductors (CMOS) transistors as contacts at source, drain, and gate. To achieve this, ultrathin silicides layers (between 10 and 20 nm) are commonly required, currently obtained through a Pre-Amorphization process using ion Implantation (PAI) of silicon surface before reactive metal deposition. Given the influence of the amorphous layer properties on the silicidation, better control over the pre-amorphization process is highly desirable.
Following an approach so far unexplored, the ANR LAMORSIM project - Laser-forming of ultrathin amorphized Si layer for microelectronics applications (ANR-23-CE08-0029) - aims to investigate femtosecond laser-based treatments, both experimentally and numerically, as an efficient alternative process holding promises to meet the highly demanding requirements of the microelectronics sector. Laser systems offer attractive possibilities for precise surface and in-volume modification of various materials, including semiconductors. Several questions are still under discussion for this recently started project, particularly regarding the choice of laser-induced excitation conditions to achieve the desired materials response, the dependency on laser parameters - especially wavelength (NIR-VIS-UV) and pulse duration - and process optimization. Three partners are leveraging their expertise and complementary to address the project's scientific objectives: an experimental group (LP3), a numerical group (LabHC-Lasermode), and an industrial partner (STMicroelectronics). Together, they are working to meet the industry's demands and develop a new femtosecond laser-based technology, thus expanding the scope of laser applications in microelectronics.

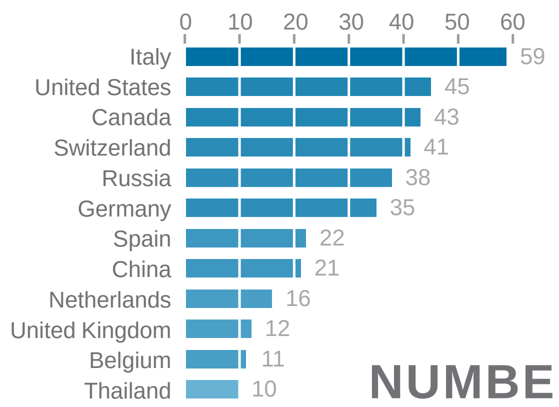
RESEARCH

SCIENTIFIC PUBLICATIONS

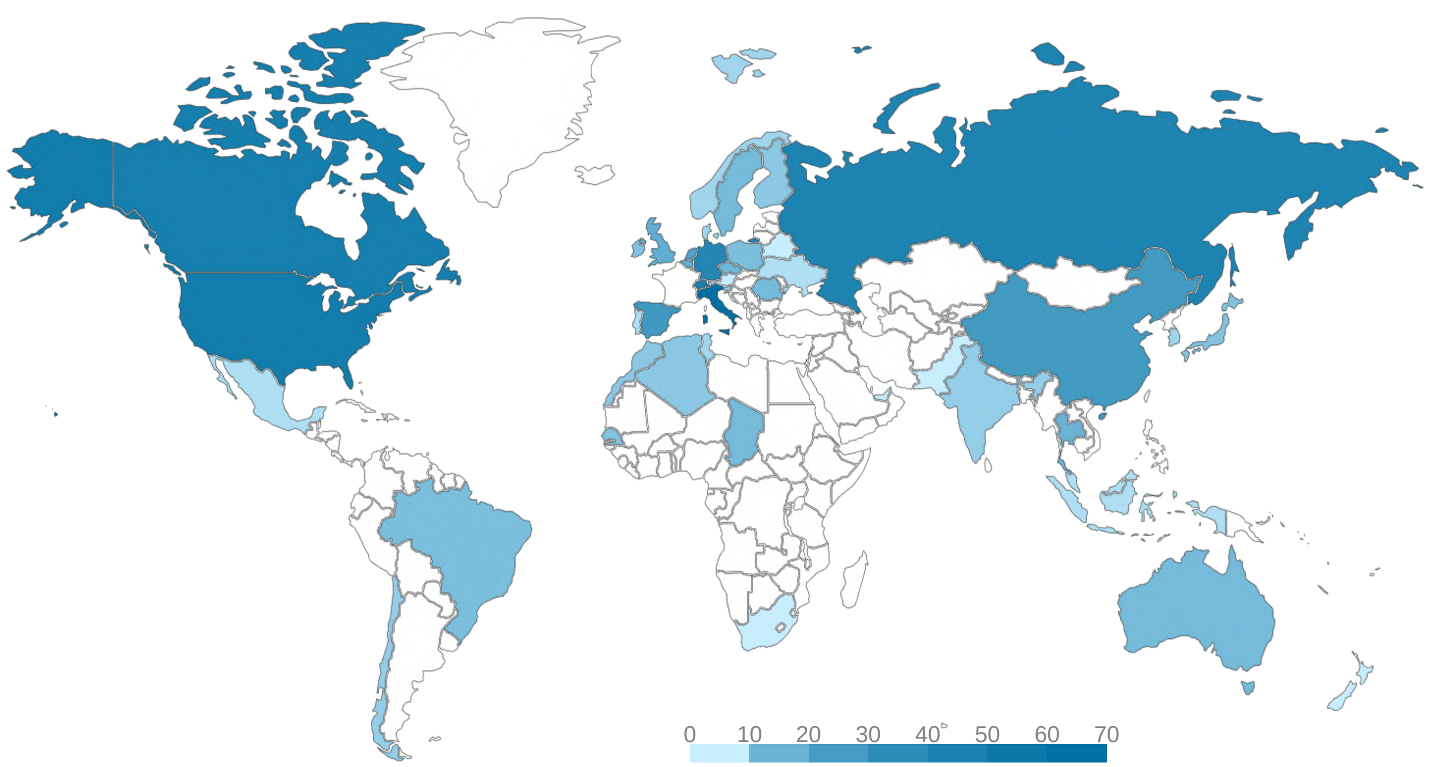
The Hubert Curien Laboratory is an internationally recognised and highly productive research institution. The following pages present an overview of our international publishing influence, as well as a selection of a few key papers published over the year 2023.

PUBLICATIONS
overview

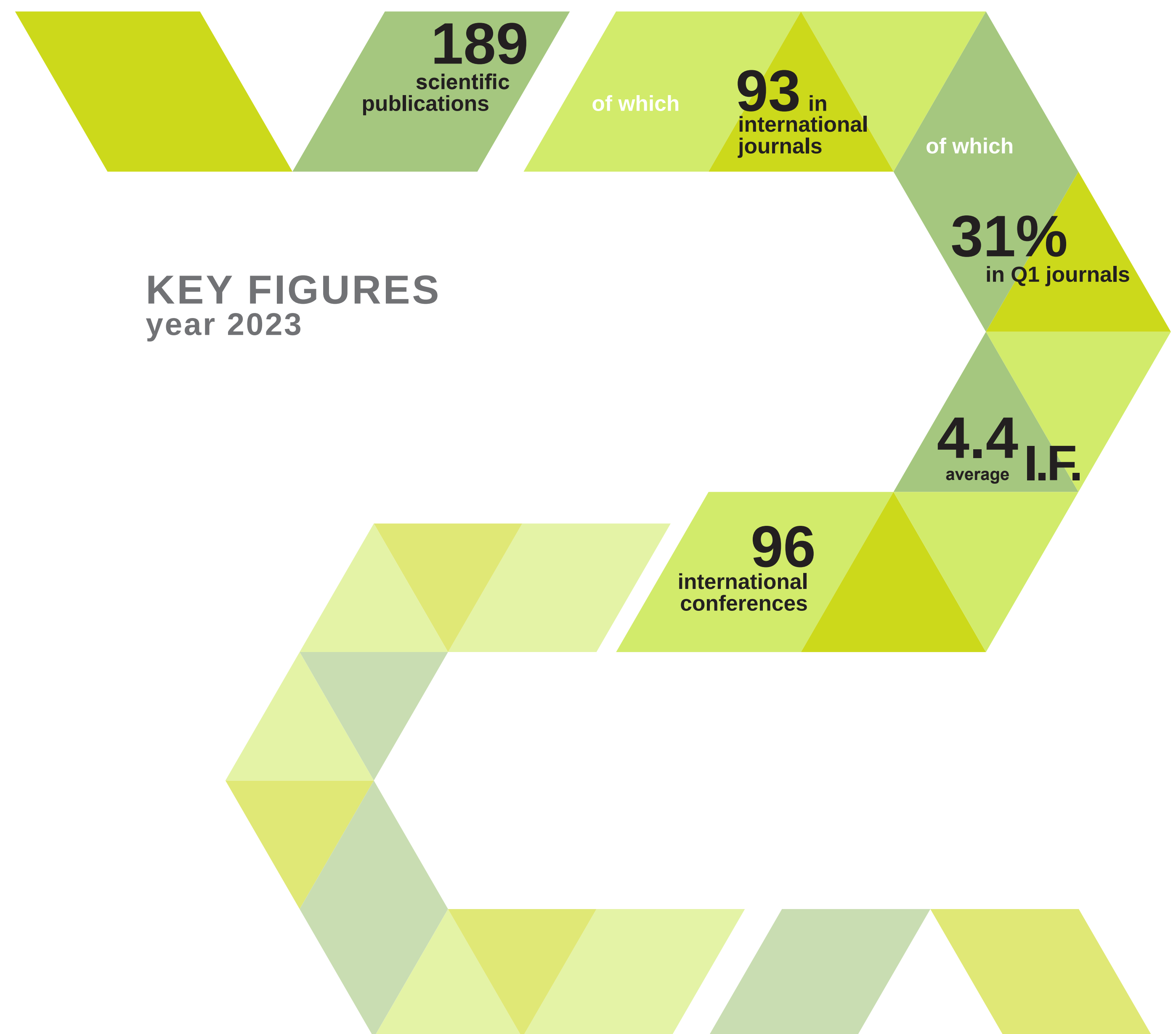
Our research collaborations are considerably spreading beyond the national stage to reach all continents.
Below are some graphics illustrating the geographical location of the institutions we have published with since 2019, also indicating the number of publications by individual country.



NUMBER of publications with an author from this country
last 5-year period - 2019 to 2023 (non-exhaustive list)



KEY FIGURES
year 2023



New Journal of Physics

Large Reciprocal Magneto-Optical Effect Induced by all-Dielectric Resonant Gratings based on a Magnetic Nanocomposite

Laure Bsawmaii, Emilie Gamet, Yaya Lefkir, Sophie Neveu, Damien Jamon and Francois Royer.

NJP publishes scientific articles that spans the entire field of physics, encompassing pure, applied, theoretical and experimental research, as well as interdisciplinary topics. A paper by our Functional Materials & Surfaces team appeared in its June 2023 edition, presenting a novel kind of reciprocal magneto-optical effect.

Main magneto-optical (MO) effects, such as the Faraday Effect, are usually non-reciprocal. It means that the light intensity or polarization are odd in magnetic field. Such non-reciprocity is the basic element of optical isolators. MO reciprocal effects (even in magnetic field) also exist but they are at least one or two orders of magnitude lower than non-reciprocal ones.
In this paper, a novel kind of large reciprocal MO effect was evidenced using an all-dielectric resonant grating patterned on a magnetic nanocomposite layer (Fig.1a). This nanocomposite is made of magnetic nanoparticles ($CoFe_2O_4$, Fig.1b) embedded into a silica matrix by sol-gel process. The demonstrated MO effect is defined as a reciprocal modification of the reflected intensity of light under a transverse magnetic field (inset Fig.c).
In a first attempt to explain its origin using RCWA simulations, this effect is attributed to a magneto-induced optical anisotropy related to the magnetostrictive property of the magnetic $CoFe_2O_4$ nanoparticles.

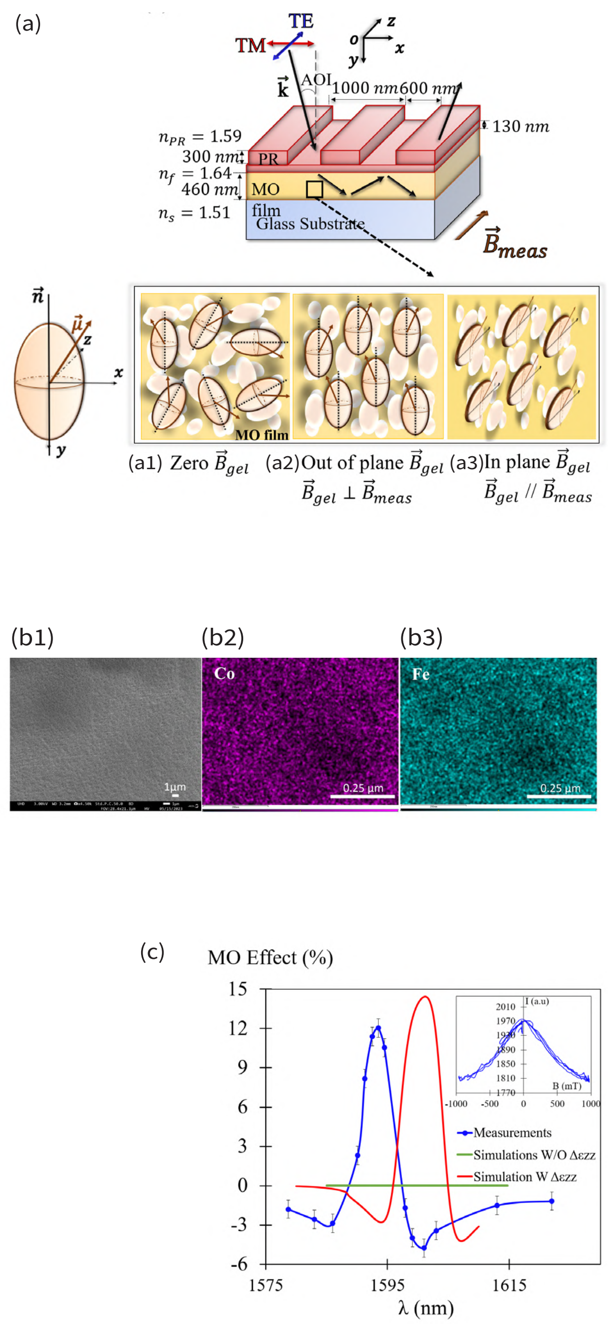


Figure 1, right:

(a) Schematic illustration of the studied MO structure and nanoparticle. $\vec{\mu}$ illustrates the magnetic moment and $\vec{n}$ defines the anisotropy axis identical to the easy axis of magnetization of the nanoparticle.

(a1) to (a3) correspond to the MO films deposited under (a1) zero, (a2) out of plane, (a3) in-plane gelation magnetic field.

(b1) SEM images of a reference composite thin film with 26% of nanoparticles.
(b2) and (b3) EDS analysis of Co and Fe respectively in the film.

(c) Measurements and numerical simulations of the reciprocal MO spectra for TE polarization at AOI=4.5° for out of-plane gelation field sample.
Red and green curves in (c) correspond respectively to the simulations with (W) and without (W/O), considering the magneto-induced anisotropy $\Delta\varepsilon_{zz}$.
Inset (c): measurements of reflected intensity loop at λ= 1591 nm.

New J. Phys. Vol.25, Issue 6 (2023), Article no. 063021

The European Physical Journal - Special Topics (2023)

Coherent acoustic pulse emission by ensembles of plasmonic nanoparticles

Balint Eles, Aurélien Crut, Natalia Del Fatti, Julien Lumeau, Antonin Moreau, Vincenzo De Michele, Youcef Ouerdane and Nathalie Destouches.

In March 2023, an article co-authored by our Functional Materials & Surfaces team was published in a Special Topics issue of The European Physical Journal. The EPJ - Special Topic of this edition was covering the scope of Ultrafast Phenomena from attosecond to picosecond timescales: theory and experiments.

When a metallic nanoparticle is exposed to laser light, it absorbs the light energy and heats up. This increase in temperature causes the nanoparticle to expand or swell, exerting pressure on the surrounding material. As a result, a pressure pulse is generated in the surrounding matrix, which travels through the material as an acoustic pulse at the speed of sound. To study and understand this phenomenon, researchers have predominantly used optical methods. They have investigated the acoustic vibrations of metal nanostructures by examining their size and shape variations, and how these factors influence the dynamics. Additionally, thin metal films and individual metal nanoparticles have been shown to function as optoacoustic transducers, meaning they can convert optical excitation into acoustic waves. Researchers have been able to detect the propagating acoustic waves produced by these nanostructures when optically excited.

However, when it comes to ensembles of nanoparticles with diverse sizes and shapes, which are situated randomly on a glass substrate, the situation becomes more complex. This scenario lies between a continuous film and a single nanoparticle, and it is not immediately clear whether detectable coherent acoustic pulses can be generated in such systems. The research described in this work demonstrates that ensembles of randomly distributed nanoparticles on a glass substrate can indeed produce propagating acoustic pulses in the substrate. The experimental evidence for this phenomenon was obtained by studying silver nanoparticles grown on a glass substrate using time-resolved measurements, where an oscillatory signal transient on ps time scale can reveal the propagation of the acoustic pulses. Furthermore, the study delves into understanding the conditions necessary for the acoustic pulse emission in nanoparticle ensembles to resemble that achieved with a continuous film. To shed light on this matter, a simplified yet informative model was developed, combining analytical calculations and numerical simulations.
This model helps clarify the factors that affect the coherence of the acoustic waves generated by the assembly of nanoparticles with different sizes and shapes.

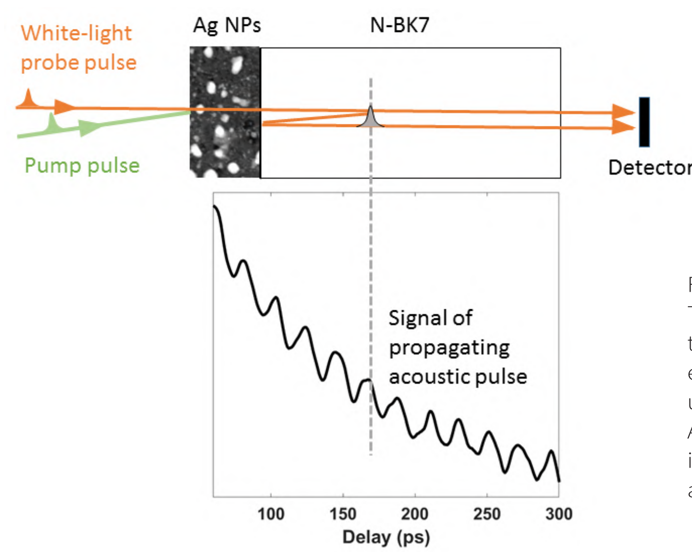


Figure left:
The experimental arrangement for detecting the acoustic pulse propagation in the substrate emitted by a metallic nanoparticles ensemble using pump-probe technique.
A typical time-resolved signal is shown for illustration, where the oscillations reveal the acoustic pulse propagation.

Eur. Phys. J. Spec. Top., Vol. 232, Issue 13 (2023), pp. 2221-2230

Optics Letters

Common-mode plasmon sensing scheme as a high-sensitivity compact SPR sensor

Hugo Bruhier, Julie Dutems, Emilie Laffont, Nicolas Crespo-Monteiro, Isabelle Verrier, Olivier Parriaux, Pierre Berini and Yves Jourlin.

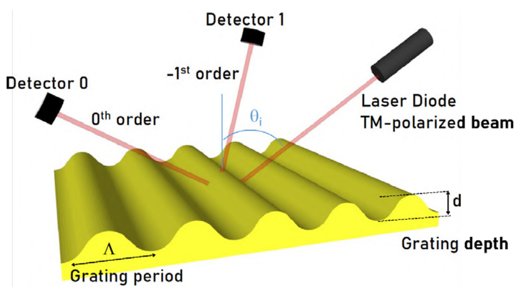


Illustration above: Diagram illustrating the measurement principle of the sensor.

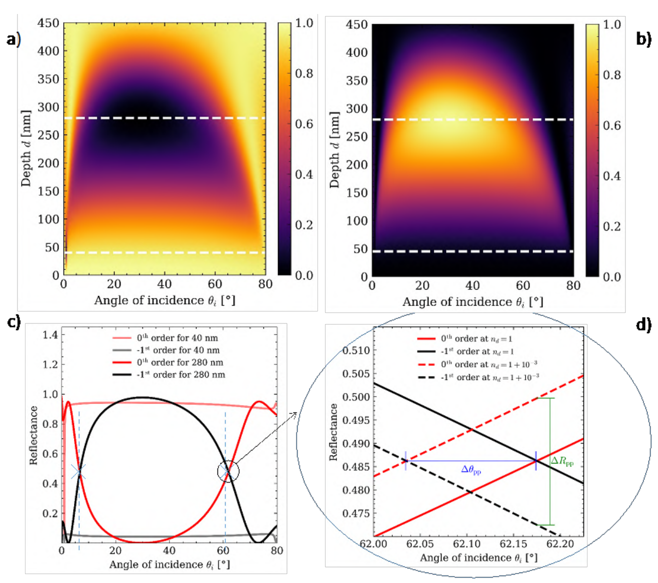
Figures below:

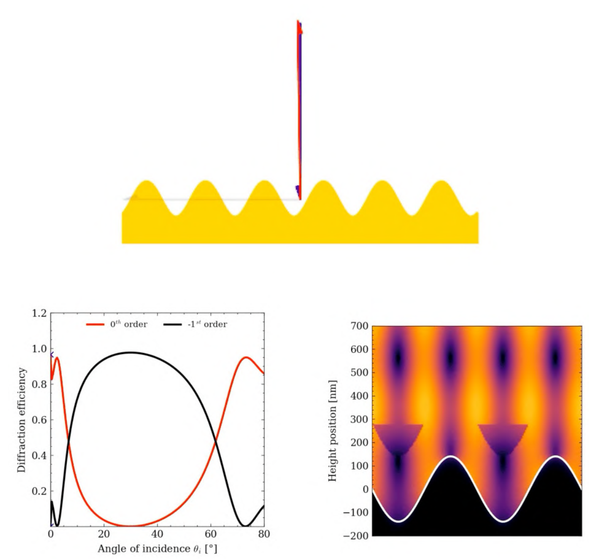
Left: Diffraction efficiency as a function of depth and angle of incidence for:
(a) 0th order,
(b) -1st order for a sinusoidal gold grating in air,
(c) angular spectrum of reflected 0th and -1st orders, and
(d) zoom on the intersection point with a refractive index change in the medium surrounding the grating.

Right: Video demonstrating the operating principle of energy transfer between the 0th and -1st diffraction orders.

A paper by our Functional Materials & Surfaces team was published in 2023 in Optics Letters, a biweekly journal covering the latest research in optical science.

This letter establishes the proof of concept and experimental demonstration of using a new type of plasmonic sensor (SPR) for gas detection. It is based on an energy transfer effect between the 0th and -1st orders of a deep metallic diffraction grating probed by a polarized monochromatic TM wave propagating in a dielectric. This principle, discovered a few years ago during the study of a diffractive structure intended for anti-counterfeiting functionality (Jean Sauvage Vincent, doctoral thesis at the University Jean Monnet de Saint-Etienne, 2013 «Les modes de plasmon sur film métallique ondulé, appliqués aux documents de sécurité»), relies on measuring the efficiency difference between these two orders, which varies depending on the refractive index of the medium surrounding the grating. Thus, any physicochemical change inducing this variation in the dielectric medium can be detected. In this paper, the team demonstrates that it is possible to measure a refractive index change using a simple device with a detection limit of $2x10^{-7}$, comparable to the state-of-the-art SPR sensors, by changing the air pressure in an enclosure containing the diffractive structure. The associated principle, experimental method and signal processing are described, and the presented results demonstrate the capability of this device to operate as a highly sensitive optical sensor. This work was carried out within the framework of the ANR CAPTAIN project (ANR-18-CE04-0008), the LABEX MANUTECH-SISE (ANR-10-LABX-0075), and the EUR MANUTECH-SLEIGHT (ANR-17-EURE-0026) using the resources of the NanoSaintEtienne technological platform of the CNRS RENATECH+ network.





Optics Letters, Vol.48, Issue 14 (2023), pp.3733-3736

Nanophotonics

A chiral microchip laser using anisotropic grating mirrors for single mode emission

Fangfang Li, Shawn Lapointe, Théo Courval, Marina Fetisova, Thomas Kämpfe, Isabelle Verrier, Yves Jourlin, Petri Karvinen, Markku Kuittinen and Jean-François Bisson.

One of the top journals in its field, Nanophotonics focuses on the interaction of photons with nano-structures, such as carbon nano-tubes, nano metal particles, nano crystals, semiconductor nano dots, photonic crystals, tissue and DNA. A paper by members of our Functional Materials & Surfaces team was selected to appear in one of their April 2023 issues.

This paper emerges from the European project GREAT, and results from a strong scientific collaboration between the University of Moncton (with J. F. Bisson having spent part of the year 2022 as an invited Professor in our lab), the University of Eastern Finland and the Hubert Curien Laboratory (Y. Jourlin).
It provides the theoretical background for a new design of nanostructured mirrors, consisting of diffraction gratings on top of Bragg mirrors (multi layers). These mirrors induce a near π phase shift between the different reflected amplitudes that exist between transverse electric (TE) and magnetic (TM) reflected polarization states, at normal incidence. Experimental demonstration of this nanostructured layer is achieved for the single-mode emission of a Yb:YAG laser emitting at a wavelength of 1030 nm. Potential applications for this novel and unusually simple design target single mode laser emission at high power from a miniature device, which is the key for applications requiring very small spaces, particularly in photonic integrated circuits. It could also be used in laser-based free-space communications on air- or space-borne platforms, light detection and ranging (LiDAR) for the automotive industry, as well as remote sensing.

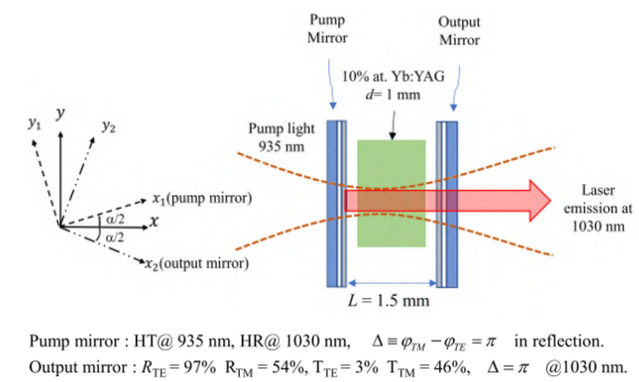


Figure 1 above:
Sketch of the chiral microchip laser equipped with anisotropic mirrors, with their specifications.

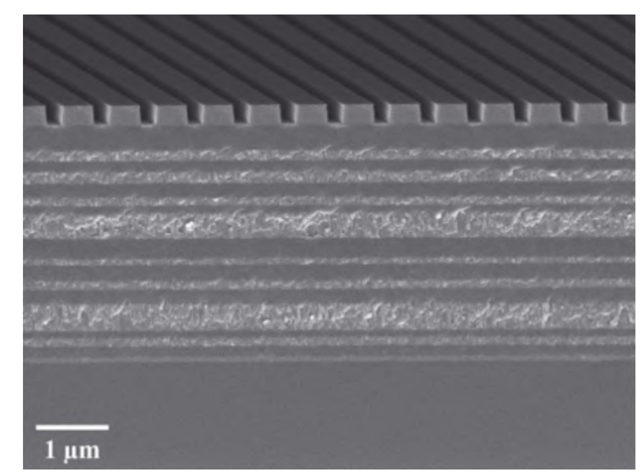


Figure 2 above:
Scanning electron micrograph cross-section image of a representative output mirror.

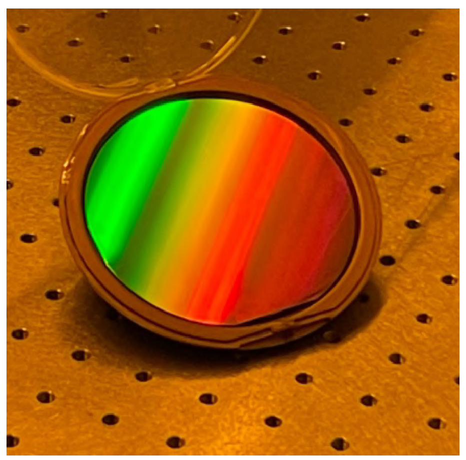
Nanophotonics, Vol. 12, Issue 9 (2023), pp. 413

Optics Express

Quantitative investigation on a period variation reduction method for the fabrication of large-area gratings using two-spherical-beam laser interference lithography

Ratish Rao Nagaraj Rao, Florian Bienert, Michael Moeller, Danish Bashir, Alina Hamri, Frederic Celle, Emilie Gamet, Marwan Abdou Ahmed and Yves Jourlin.

Optics Express is an open-access journal publishing peer-reviewed articles that emphasize scientific and technology innovations in all aspects of optics and photonics. A paper published in the journal by our Functional Materials & Surfaces team presents an innovative setup for the fabrication of large dimension diffraction gratings.

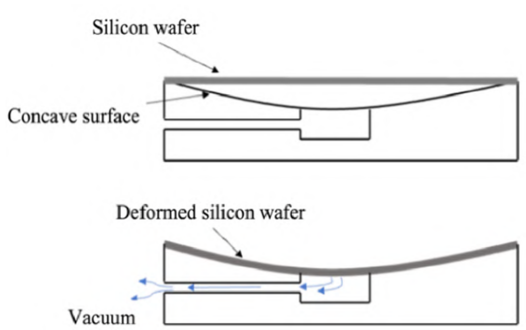


Grating structures are of great interest in laser applications and nanotechnology, finding applications as antireflective mirrors or optical filters for controlling the wavelength and polarization of light. Various methodologies exist for generating such structures, e.g. nanoimprint and electron-beam lithography techniques, however these have limitations in terms of patterning area, time, cost, and throughput. In contrast, Laser Interference Lithography (LIL) presents an expedient and cost-effective means of creating large-area grating structures, but a careful optimization is required to ensure uniformity across the entire area in terms of grating period, line width and groove depth.

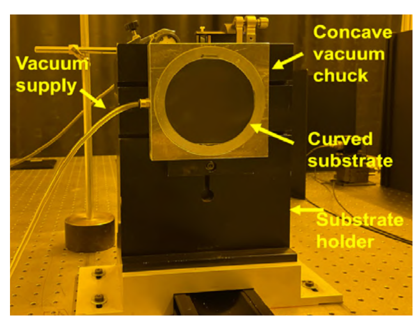
This article demonstrates the possibility of manufacturing large diffraction gratings of high coherence, using a new proposed two-spherical-beam LIL setup which includes a deformed chuck and vacuum support that causes substrate deformation during exposure. It presents the latest results of Ratish Rao's doctoral thesis, done as part of the GREAT European project.

Illustration left:
Photograph of fabricated photoresist grating on a 4-inch silicon wafer of thickness 525 µm, using concave vacuum chuck holder by two-spherical-beam 442 nm LIL setup, with an exposure time of 3 minutes and developing time of 5 seconds at 21°C.

Illustrations below:
(a) Sketch of the bending process of a silicon wafer by concave vacuum chuck.
(b) Image of concave vacuum chuck mounted on substrate holder stand with silicon wafer curved using vacuum supply.



(a)



(b)

Opt. Express Vol. 31, Issue 1 (2023), pp. 371-380

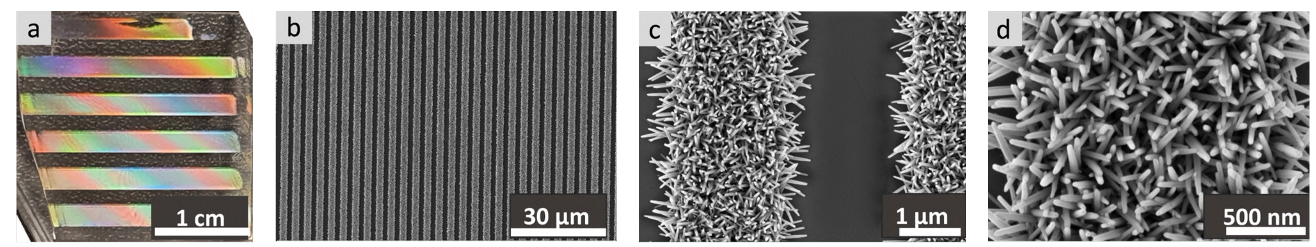
Advanced Optical Materials

Study of the photoluminescence enhancement observed in ZnO nanowire gratings optimally grown by hydrothermal method

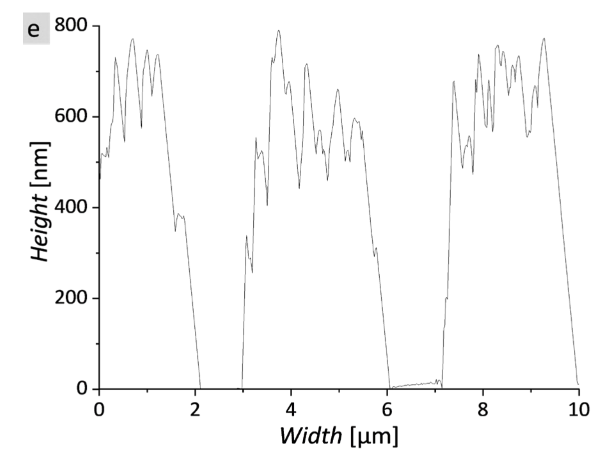
Aubry Martin, Audrey Potdevin, François Réveret, Emmanuel Centeno, Rafik Smaali, Fatima Omeis, David Riassetto, Elena Kachan, Yves Jourlin, Geneviève Chadeyron and Michel Langlet .

Advanced Optical Materials is an interdisciplinary forum for peer-reviewed papers on materials science which focuses on all aspects of light-matter interactions. In July 2023, an article published by our Functional Materials & Surfaces team was presenting the development of a novel ZnO nanowire (NW) architecture using a soft chemistry approach.

This article highlights the significant outcomes of the ANR SMARt-LED project (ANR-19-CE08-0001), coordinated by the ICCF in Clermont-Ferrand, which aimed to develop multifunctional layers for LED lighting applications. The project's objectives revolved around enhancing the spectral and spatial extraction of light within LED-based lighting or display devices. This was achieved by combining the commonly used YAG:Ce phosphor in current devices with ZnO nanowires, structured in a controlled arrangement in terms of periodicity and pattern. Adding ZnO nanowires to the phosphor helps improving the spectral emission profile, particularly by optimizing the weak red component of YAG:Ce.



Figures:
ZnO NW gratings on 2.5 x 2.5 cm^2 quartz substrate, illustrated by:
(a) macroscopic photography,
(b) (c) (d) low to high magnification SEM images,
(e) AFM profile.



Adv. Opt. Mater., Vol. 11, Issue 20 (2023), Article no. 2300695

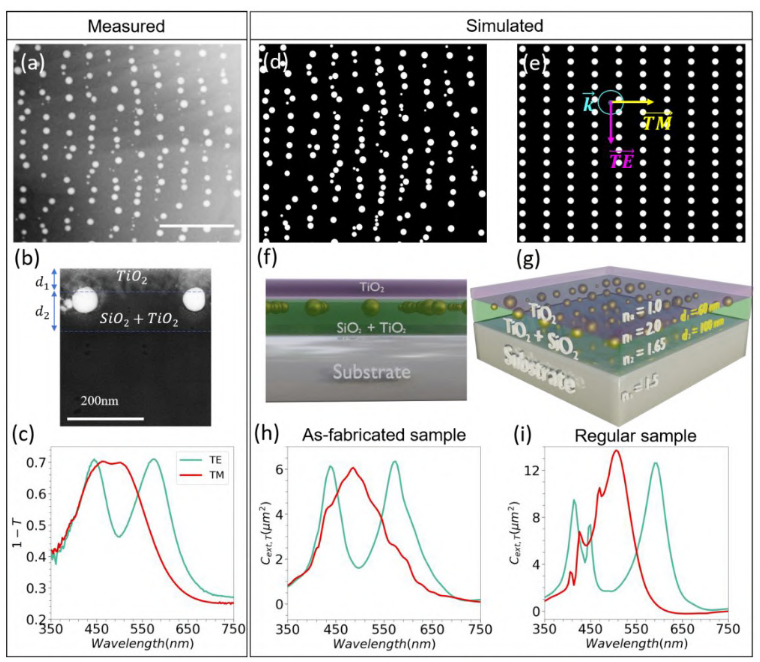
Nanoscale

Hybridization between plasmonic and photonic modes in laser-induced self-organized quasi-random plasmonic metasurfaces

Van Doan Le, Yaya Lefkir and Nathalie Destouches.

In November 2023, a paper by our Functional Materials & Surfaces team was published in Nanoscale, a journal that has established itself as a platform for high-quality, cross-community research that bridges the various disciplines involved with nanoscience and nanotechnology. The article explores the coupling between plasmonic and excited guided modes induced by laser in quasi-random metallic particles.

In our quest to use laser processing to fabricate large-area functional plasmonic metasurfaces, we need to understand exactly how disorder and heterogeneity inherent in laser-induced self-assembly mechanisms affect the optical response of quasi-periodic nanoparticle gratings. During his Ph.D. work, Van Doan Le has performed a thorough analysis of the hybridization process between localized surface plasmon modes and propagating photonic modes upon the introduction of disorder and different sizes of nanoparticles. He showed that the inhomogeneity inherent in the manufacturing process, although noticeable at the nanometer level, has low impact on the overall interaction with light. Thus, laser processing appears to be a powerful technology for the fabrication of useful functional metamaterials in spite of intrinsic imperfections.



Figures left: Laser-induced plasmonic metasurfaces made of metallic nanoparticles deposited on, or close to waveguides can exhibit hybridized plasmonic and photonic modes.

Nanoscale, Vol.15, Issue 47 (2023), pp.19339-19350

Materials Today Advances

Innovative process to obtain thin films and micro-nanostructured ZrN films from a photo-structurable ZrO_2 sol-gel using rapid thermal nitridation

Victor Vallejo-Otero, Nicolas Crespo-Monteiro, Arnaud Valour, Christophe Donnet, Stéphanie Reynaud, Nadège Ollier, Marie-Françoise Blanc Mignon, Jean-Pierre Chatelon, Yannick Bleu, Emilie Gamet and Yves Jourlin.

Materials Today Advances is a journal covering all aspects of materials science and related disciplines. It includes fundamental and applied research, focusing on broad impact studies crossing traditional subject boundaries. In their 2023 September edition, an article by our Functional Materials & Surfaces team presenting an innovative technique for producing micro-nanostructured ZrN films without the need for an etching process was published.

Zirconium nitride (ZrN) has attracted considerable attention in recent years, in particular for its plasmonic behavior in the visible-NIR region. In addition to its interesting plasmonic properties, ZrN exhibits outstanding mechanical qualities (hardness and Young's modulus are approx. 20 GPa and 350 GPa respectively), has good resistance to corrosion and oxidation, low resistivity (approx. 50 μΩ.cm) and high thermal stability (melting point is approx. 2800 °C). ZrN thin films are usually produced by vapor deposition techniques in advanced vacuum, such as atomic layer deposition (ALD), chemical vapor deposition (CVD, MOCVD, PECVD), ion-plated, magnetron sputtering, vacuum arc deposition, under ammonia or nitrogen atmosphere. Even though these deposition techniques are widely used, they are expensive and time consuming. Furthermore, these techniques make structuring very difficult due to the mechanical and electrical properties of ZrN. An alternative to these techniques is the complete nitridation of ZrO2 into ZrN and, to our knowledge, very few studies have been conducted to date on this subject. In the current state of the art, nitridation of ZrN requires a long reaction time at high temperature with a reductant. In this paper, we present a new Rapid Thermal Nitridation (RTN) process that produces ZrN from a ZrO2 photo-structurable sol-gel by nitridation with ammonia gas. Requiring neither an extended firing time nor additional reductant, this versatile technique enables a rapid, easy and inexpensive production of ZrN thin films. The micro-nanostructuring of the ZrN layer also constitutes a challenge. Only a few authors have indeed reported processes to pattern ZrN films. E-beam lithography and dry etching, or scanning probe microscopy oxidation and hydrofluoric acid etching have been used for this purpose, however these techniques are expensive, time consuming, and require the use of toxic products. Conversely, sol-gel ZrO2 can be easily structured by UV exposure, thereby allowing to produce ZrN micro-nanostructured thin films on flat, curved and large dimension substrates after nitridation.

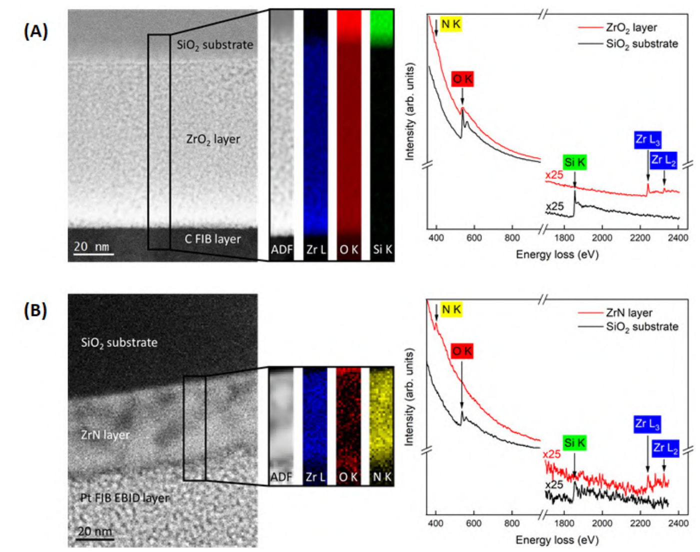


Figure 1 above:

(A) Left: Cross-sectional HRTEM of ZrO_2 xerogel thin film, annular dark field (ADF), element mapping images of Zr, O and N. Right: corresponding EELS spectra of SiO_2 substrate and ZrO_2 xerogel layer.

(B) Left: Cross-sectional HRTEM of ZrN thin film, annular dark field (ADF), element mapping images of Zr, O and N. Right: corresponding EELS spectra of SiO_2 substrate and ZrN layer.

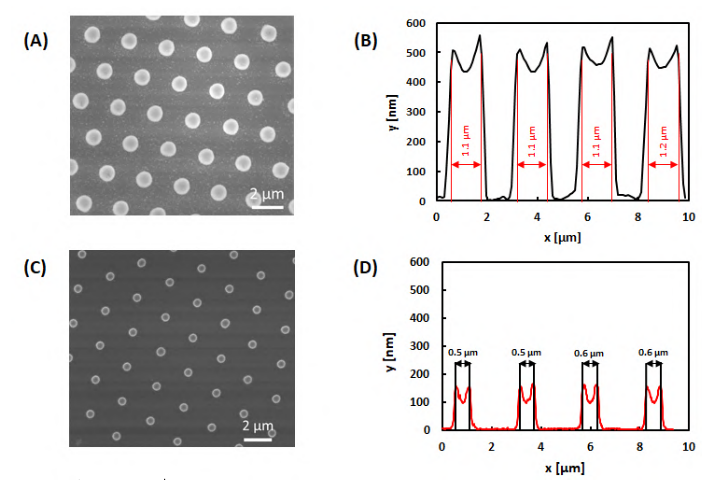


Figure 2 above:

(A) SEM image and
(B) AFM profile of structured ZrO xerogel.
(C) SEM image and
(D) AFM profile of structured ZrN.

Mater. Today Adv., Vol.20 (2023), Article no. 100430

Electronics

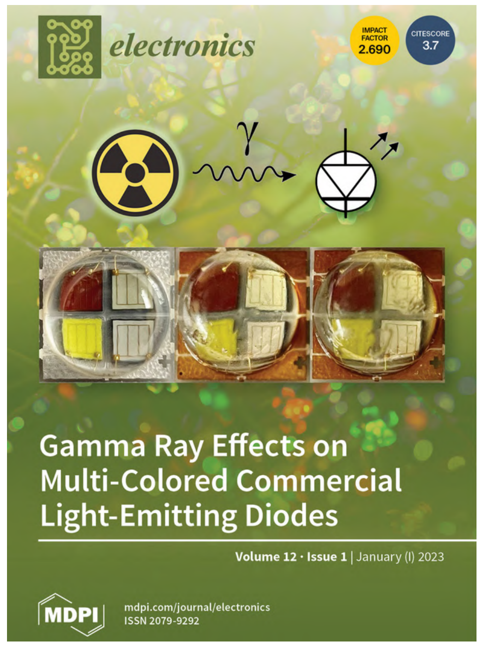
Gamma Ray Effects on Multi-Colored Commercial Light-Emitting Diodes at MGy Level

Luca Weninger, Raphaël Clerc, Matteo Ferrari, Adriana Morana, Timothé Allanche, Roberto Pecorella, Aziz Boukenter, Youcef Ouerdane, Emmanuel Marin, Olivier Duhamel, Marc Gaillardin, Philippe Paillet and Sylvain Girard.

An invited paper recently published by our MOPERE team in the special issue 'Radiation Tolerant Electronics, Vol. III' of the journal Electronics was selected amongst 252 articles to appear on the cover of their January 2023 issue. In the article, the most recent results regarding the effects of radiation on Light-Emitting Diodes are presented and discussed. The work was done in collaboration with the CEA DAM.

Within the context of a constantly growing optoelectronic market, an increasing number of optoelectronic devices are being studied for applications in radiation-rich environments. Among them, the behavior of light-emitting diodes (LEDs) under irradiation has not yet been fully investigated, due to the complexity of radiation effects in the very dense multilayer architectures constituting a LED. Indeed, a LED includes a high number of layers with very different radiation-induced responses (e.g. materials, quantum wells, reflective layers and lenses). In this paper, an experimental approach is being used to investigate the evolution of the optical properties of commercial LEDs as a function of their exposure to γ-rays, up to the large total ionizing dose of 2 MGy(air). The studied devices include four LEDs of different colors in the same package: red, green, blue and white. The presence of the four diodes in the same package allows a direct comparison of the responses of different technologies' responses, as the proximity between the diodes ensures a uniformity of their irradiation conditions. The main performance investigated in this work is the external quantum efficiency, providing an overall estimate of the inefficiencies inside a LED, from the electrons injected to power it on to the photons which exit its lens. The efficiency of all tested LEDs was reduced due to radiation, especially for red ones. The loss of efficiency can be explained by a radiation-induced increase in the number of traps inside the diodes. Red LEDs' higher radiation sensitivity has been observed before, and it can be explained by the different technologies and materials used to achieve these emitted wavelengths. Another important outcome of the study relates to the radiation stability of the opto-mechanical properties of the lens encasing the device. The collected results show no significant effect on these properties following the lenses' irradiation. By contrast, exposition to γ-rays compromised their mechanical properties, with some lenses breaking, or at least showing signs of structural weakness.

This study represents one of the first published works on the radiation resistance of commercial LEDs. The collected results and used methodologies pave the way for future investigations on radiation tolerant LEDs, which will become increasingly necessary for high-radiation applications.



Left:
Electronics Journal's January issue cover

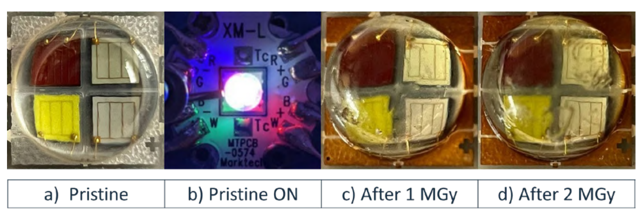
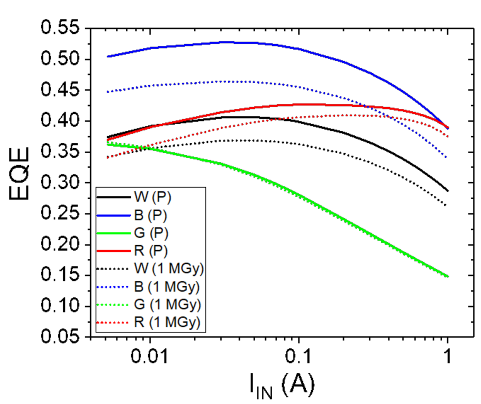


Figure 1 above:
The LED structure in different conditions:
The unirradiated sample is shown in its OFF (a) and ON (b) state.
The LEDs depicted in the two rightmost pictures have been irradiated at the reported doses of 1 MGy (c) and 2 MGy (d).

Figure 2 right:
EQE vs. current of a sample before (solid lines) and after (dashed lines) 1 MGy of absorbed dose divided by color.



Electronics, Vol.12, Issue 1 (2023), pp. 81

IEEE Journal of Lightwave Technology

Use of Rayleigh-OFDR to estimate the bias drift induced by quasi-static and homogeneous temperature variation of a free-standing fiber-gyro coil

Hugo Boiron, Jérémie Pillon, Emmanuel Marin, Maxime Rattier, Emmanuelle Peter, Adriana Morana, Nominoë Lorrière, Frédéric Guattari, Sylvain Girard and Hervé C. Lefèvre.

The Journal of Lightwave Technology is a biweekly peer-reviewed scientific edition covering optical guided-wave science, technology, and engineering. A new method for measuring the thermal stress limiting the performance of a Fiber Optic Gyroscope was experimented by our MOPERE team and published in the Journal's March 2023 edition.

In this paper we have presented a new experimental method to estimate, at the component level, the thermal bias drift induced in a Fiber Optic Gyroscope (FOG) sensing coil, before its final assembly. It is based on Rayleigh-Optical Frequency Domain Reflectometry (Rayleigh-OFDR) that measures exactly what is involved in thermal transient creating bias drift in a FOG coil: optical phase variation, independently of its precise origin. We introduced the Mohr coefficient to characterize the elasto-optic effect that is activated when the coil is subjected to a homogenous variation of temperature. This coefficient has been measured for a 32-layer coil with a total length of 400m and a mean diameter of 44mm, under a temperature ramp ranging from -20°C to 80°C. It has been found that the Mohr coefficient M depends on temperature, due to the modification in the thermomechanical properties of the coil materials. At T=20°C, M=»-» 0.77±0.05 (°/h)/(°C/min) which is the right order of magnitude for this kind of coil. The propagation of uncertainty has been described to fully characterize the ability of the Rayleigh-OFDR method, to forecast the Mohr coefficient. The same order of magnitude of the uncertainty has been found experimentally and theoretically, showing that measurement uncertainty originates from the OFDR instrument optical white noise.

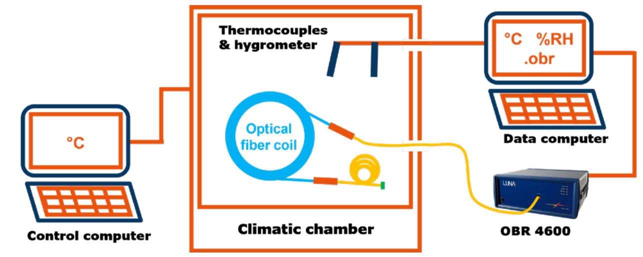


Figure 1:
Experimental setup

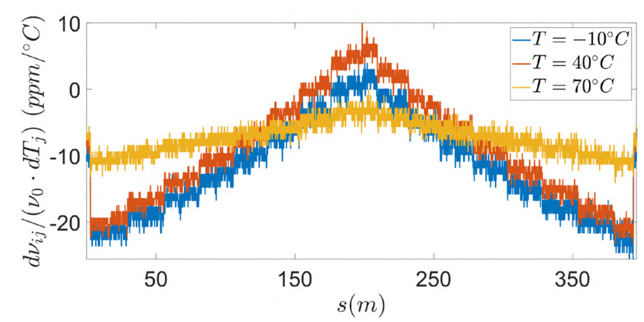


Figure 2:
Strain pattern of the coil at three different temperatures

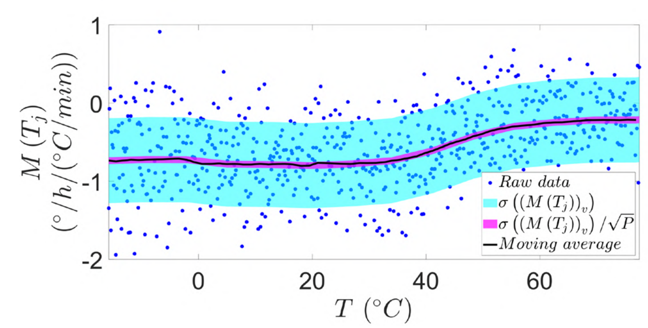


Figure 3:
Thermo-bias depending on temperature

Journal of Lightwave Technology, Vol. 41, Issue 15 (2023), pp. 5146 - 5152

Photonics

Influence of Adhesive Bonding on the Dynamic and Static Strain Transfers of Fibre Optic Sensors

Chloé Landreau, Adriana Morana, Nicolas Ponthus, Thomas Le Gall, Jacques Charvin, Sylvain Girard and Emmanuel Marin.

Photonics is a monthly international peer-reviewed scientific journal that publishes high impact fundamental research and applications related to optics and photonics. A paper was published by our MOPERE team in their September 2023 edition.

To effectively monitor the mechanical health of structures, it is essential to have reliable and accurate measuring instruments. In this article, we focus on the measurement of mechanical strains. These measurements can be carried out using optical fibres, which offer numerous advantages over the strain gauges traditionally used: they are small and lightweight, withstand wide temperature ranges, are insensitive to electromagnetic perturbations and allow wavelength and/or time-multiplexed measurements.
The question addressed here relates to the bonding of optical fibres to the structure to be monitored: is the strain measured by the optical fibre identical to the strain of the structure? In other words, does the adhesive correctly transmit the information (i.e. the strain) from the structure to the fibre?
We therefore carried out experimental tests using four adhesives (chemically and mechanically different) on three different types of optical fibres (acrylate-coated, polyimide-coated and uncoated). Measurements of optical fibre strain were carried out using two methods (Bragg gratings and Rayleigh scattering), both statically and dynamically. In addition, an analytical model was developed in order to better understand the factors involved in the strain transfer process between the structure and the bonded optical fibre.

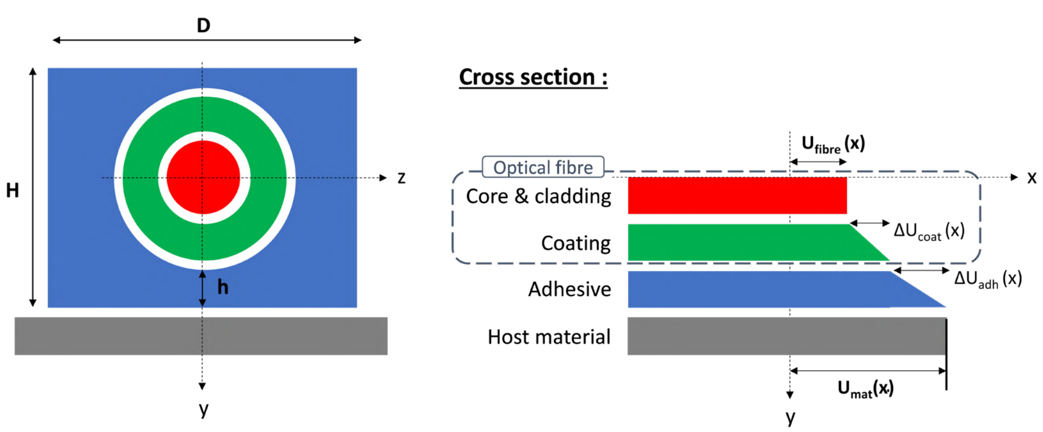


Figure 1 above:
Schematic illustration of an optical fibre bonded to the surface of a structure, used to develop the analytical model describing the strain transfer process.

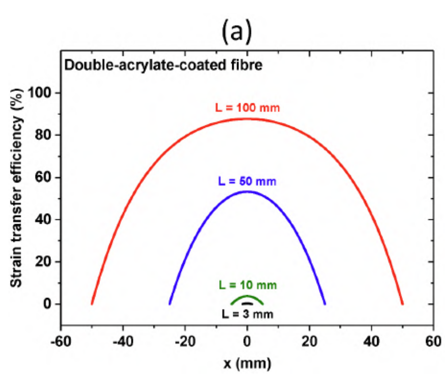


Figure 2 left:
Simulated strain transfer efficiency between the surface of a structure and an acrylate-coated optical fibre bonded with an epoxy adhesive, for different bonding lengths.

Photonics, Vol.10, Issue 9 (2023) Article no. 996

IEEE Transactions on Nuclear Science

Radiation Effects on Si-Photonics-Integrated Passive Devices: Postirradiation Measurements

Imène Reghioua, Sylvain Girard, Adriana Morana, Damien Lambert, Jonathan Faugier-Tovar, Philippe Grosse, Stéphanie Garcia, Munique Kazar-Mendes, Matteo Ferrari, Philippe Paillet and Bertrand Szelag.

The IEEE Transactions on Nuclear Science is a monthly publication of the NPSS Society covering the theory, technology and applications related to nuclear science and engineering. An article by Imène Reghioua fom the CEA Leti Technology Research Institute, co-authored by several members of our MOPERE team, was published in their August 2023 edition.

The interest in integrated silicon photonics technologies is constantly growing as they offer the potential to design more reliable, low-cost key optical functions for implementation in a wide range of application fields, such as data communication, sensing, etc. Within the context of harsh environments, only a few studies have already been carried out on the vulnerability under radiation of few of these components, essentially for applications at CERN or space.

In this work, we investigate the permanent radiation effects, up to more than 1 MGy(Si) dose, on several passive components: different types of waveguides, grating couplers, micro-ring resonators, Mach–Zehnder interferometers and echelle grating de-multiplexers. Globally, our investigation reveals the high intrinsic radiation tolerance of this technology compared to microelectronics at these high levels of dose. Moreover, thanks to mode simulation, the permanent radiation-induced attenuation of the waveguides was associated with the interaction of the guided mode, with defects located at the core/cladding interface. The mRib waveguides having a better mode core confinement explains why they showed the best radiation resistance levels.
This work is the first result of a collaboration between the Hubert Curien Laboratory, CEA DAM and CEA Leti.

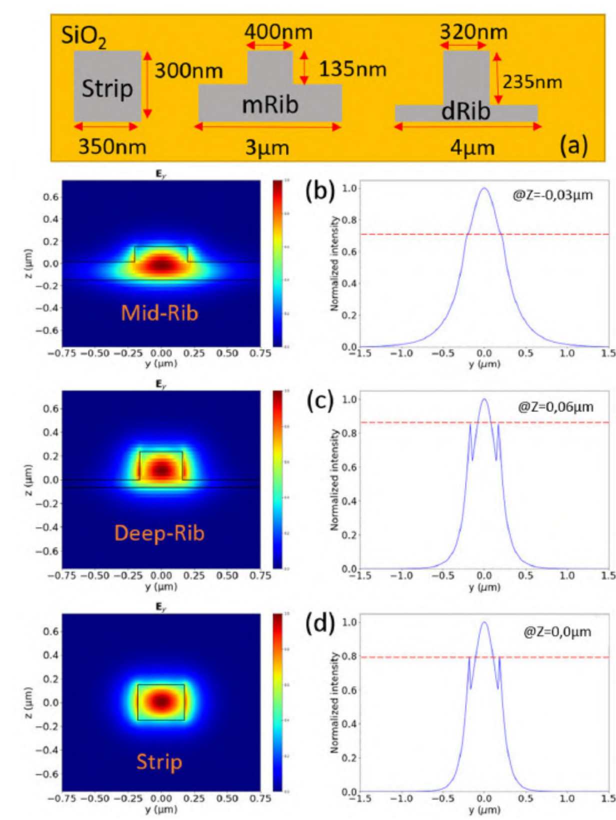


Figure right:
Cross sections of the three types of waveguides available on the CEA-LETI's silicon photonics platform:

(b)–(d) Simulation of electric field intensity (TE polarization) at 1310 nm in the mRib, dRib, and strip waveguide designs, respectively, and their 1-D horizontal profiles.
The red dashed lines represent the maximum of the electric field intensity at the sidewalls.

This figure highlights the interaction of the guided light with the interface core/cladding that is minimal for the mRib waveguide.

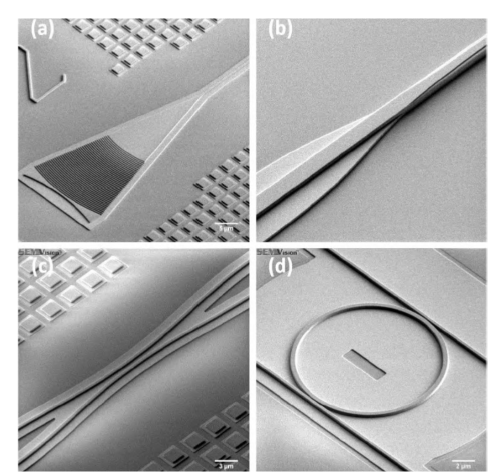


Figure left:
SEM pictures of the tested devices:
(a) grating coupler,
(b) mRib to strip transition,
(c) DC,
(d) ring resonator.

IEEE Transactions on Nuclear Science, Vol.70, Issue 8 (2023), pp. 1973-1981

- Scientific publications -

Materials

Towards Room Temperature Phase Transition of W-Doped VO_2 Thin Films Deposited by Pulsed Laser Deposition: Thermochromic, Surface, and Structural Analysis

Yannick Bleu, Florent Bourquard, Vincent Barnier, Anne-Sophie Loir, Florence Garrelie and Christophe Donnet.

Materials is an open access journal that publishes papers advancing the understanding of the relationship between the structure, properties and functions of various materials. In January 2023, an article by members of our Laser-Matter Interaction team was selected to appear in the Editor's Choice section.

Electronic components such as integrated circuits (Figure 1) and optical components such as switch and filters require a higher degree of protection. This can be done through a thermally activated control of received or emitted radiations, at various temperatures. In integrated circuits, IR radiations are used for "hearing" passive and active attacks by fault injections. In optical filters, switches and fibers, the reflection and transmission properties require a reversible dependence with temperature, at specific wavelengths. The metal / insulating transition of vanadium oxide (VO_2), associated to a significant change of emissivity and refraction index, was explored in the perspective of such applications.

This publication is part of the PROTECT project's scientific production, supported by the LABEX MANUTECH-SISE. Three of our lab's research teams were involved in this transversal project: Laser Matter Interaction, Functional Materials & Surfaces, and SESAM, combining skills in design, film synthesis and optical characterizations. The paper targeted the doping of VO_2 thin films to reach both lower and more dispersed metal/insulator transition temperatures, in order to make attacks more random in integrated circuits. Tungsten-doped VO_2 layers were synthetized by pulsed laser deposition. Their spectral behavior, both in reflection and transmission, were quantified versus temperature. Depending on the doping concentration and nanostructure of the synthetized film, the obtained metal/insulator transition temperatures extend over a wide range of temperatures: 26°, 41°, 57° and 71°C (Figure 2). The proof details the understanding of such dependence, on the basis of the films' investigations by complementary analytical probes: Angular Resolved XPS, Raman, SEM, AFM (Figure 3).
Such a modulation could help randomize the behavior of protective films in integrated circuits, or control the optical components' switch.

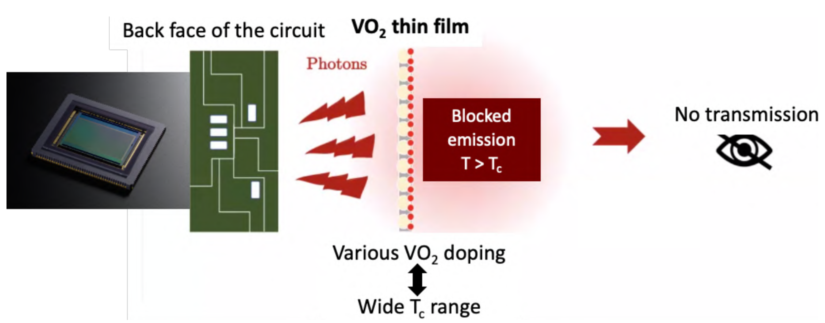


Figure 1

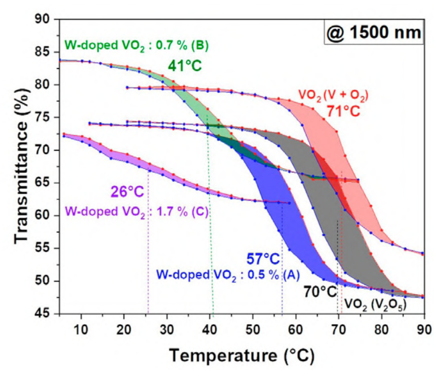


Figure 2

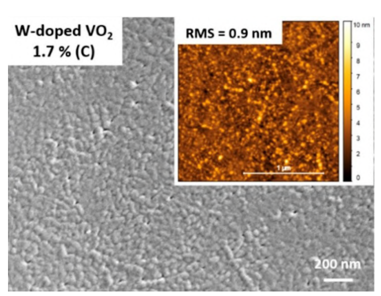


Figure 3

Figure 1: Protection of electronic circuits from passive attacks localized in the back face, by thermochromic VO_2 thin films.

Figure 2: Hysteresis loops derived from the temperature-dependent transmittance of the undoped and W-doped (A, B, and C) VO_2 thin films at a wavelength of 1500 nm.

Figure 3: SEM and AFM images of the W-doped VO_2 thin films exhibiting a metal/insulator temperature near room temperature (26°C).

Materials, Vol.16, Issue 1 (2023), pp. 461

Optics Letters

Development of a 3D ultrafast laser written near-infrared spectro-interferometer

G. Martin, G. Zhang, M. Bonduelle, R. Allaw, M. Callejo, A. Morand, A. Rodenas, G. Cheng, R. Stoian, and C. d'Amico.

In May 2023, an article co-authored by our Laser-Matter Interaction team was published in Optics Letters, a biweekly peer-reviewed scientific journal covering all topics pertaining to optics and photonics.

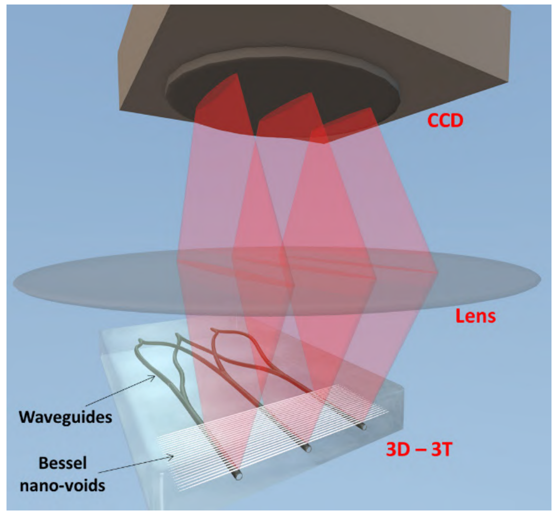


Figure 1 above:
Schematic of the complete implementation of the 3D – 3T spectro-interferometer. The CCD is positioned at a distance of 2f with respect to the waveguides, where f is the focal length of the lens. The lens realizes therefore the Fourier Transform of the signal extracted from the waveguides by the Bessel nano-structures.

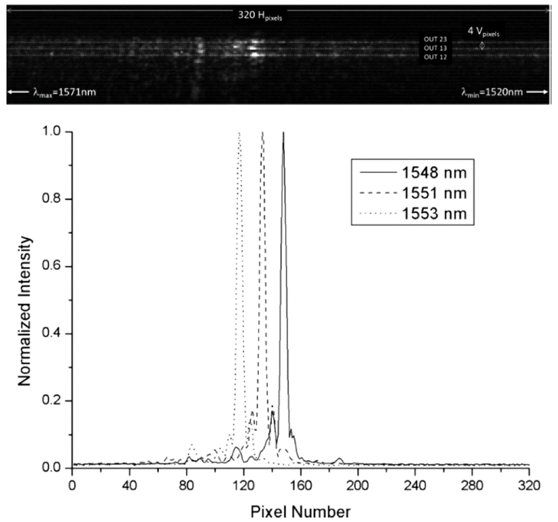


Figure 2 above:
Top: Diffracted peak obtained on the CCD after monochromatic injection in the waveguides, showing the vertical separation for the three waveguides.
Bottom: intensity detected on the camera along the horizontal direction for waveguide OUT12 (corresponding to the left output on the schematic of figure 1), as a function of wavelength.

Integrated optical beam combiners are considered as a good approach to mitigate problems of stability, weight, and compactness of astronomical interferometric instruments (such as "AMBER", "FIRST", etc.) by packing several optical functions in one monolithic chip. In this article, the team describes the realization of a complete 3D three telescopes (3T) spectro-interferometer, in bulk SiO_2, using an advanced direct ultrafast laser photo-inscription technique which employs advanced beam engineering methods based on temporal and spatial pulse shaping. The fabricated device integrates hybrid optical functions such as waveguides (positive index change) and periodic scattering nanocenters (nanovoids). It allows the pairwise combination and direct detection of the signals coming from three different telescopes, and can be used for closure phase measurements in stellar interferometry applications. The 3D aspect of the design presents a big advantage with respect to planar devices fabricated by 2D lithography, as in-plane X-crossing of waveguides can be avoided, reducing so cross talk, as well as increasing the compactness and the performance of the device. This is a very important result in the context of multi-telescope interferometry, as it demonstrates the possibility of conception and fabrication of 3D complex beam combiners of limited dimensions.
The technique allows to sample the signal efficiently with an innovative grating concept (periodic elongated nanostructures generated by focusing Bessel beams) and reconstruct the spectral information by Fourier Transform (see Figures 1 and 2). The team has validated different technological parameters in order to develop single-mode waveguides and high-efficiency embedded gratings in the near-IR. The obtained device shows good wideband contrast and satisfactory transmission losses (1.7 dB/cm). Furthermore, the spectral resolution of the developed compact spectro-interferometer should be of higher magnitude than of existing instruments, as for example the "FIRST" instrument. Three-dimensional design using direct ultrafast laser photo-inscription is probably the best option to address the problem of differential phase and high-contrast interferometry. Indeed with this technique, high number of beam combinations are required, in-plane crossings and cross talk need to be avoided, stray light is compulsory while keeping a reduced chip size. This work is the result of a collaboration between our laboratory (for the fabrication of the 3D device in bulk fused silica), the "Institut de Microélectronique Electromagnétisme et Photonique, the LAboratoire d'Hyperfréquences et de Caractérisation (IMEP-LAHC)", and the "Institut de Planétologie et d'Astrophysique de Grenoble (IPAG)" (for the concept design and characterization of the prototype). The team's next step will be to create a more complex device (typically five or more inputs) in order to prepare for the next generation of beam combiners, such as 6T VEGA/CHARA instruments, or the pupil remapper 5T FIRST/SUBARU, for which some preliminary work has already been done.

Optics Letters, Vol. 48, Issue 9 (2023), pp. 2253-2256

The European Physical Journal - Special Topics (2023)

First-principles study of ultrafast bandgap dynamics in laser-excited α-quartz

Elena Kachan, Arshak Tsaturyan, Razvan Stoian and Jean-Philippe Colombier.

A paper published in Janu ry 2023 by our Laser-Matter Interaction team has been included in The European Physical Journal Special Topics issue dedicated to «Ultrafast Phenomena from attosecond to picosecond timescales: theory and experiments».

Research on the interaction between ultrafast lasers and wide-bandgap insulators significantly impacts the advancement of modern technologies such as optical data storage, integrated photonics and ultrafast signal processing. The challenge lies in accurately estimating the redistribution of laser energy and the rate of photo-excitation, as strong-field phenomena occur on extremely short timescales. The article builds upon existing theories of strong-field ionization, and incorporates improvements that consider the non-stability of the electronic structure during laser irradiation. Advanced theoretical methods are used to demonstrate that when α-quartz is exposed to high-intensity lasers, its bandgap (a property related to the material's electronic structure) undergoes significant modifications, which aligns with previous hypotheses.
This discovery has implications for enhancing photoionization control and gaining a deeper understanding of the material's transient optical properties.

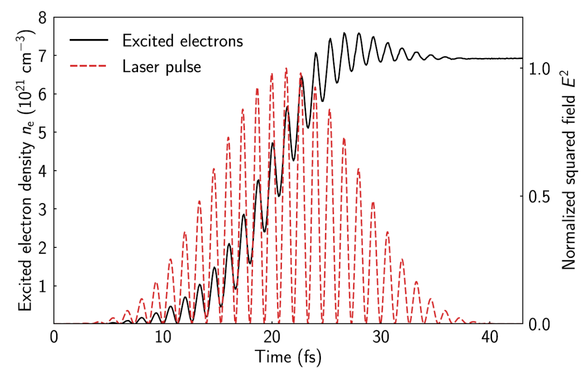


Figure 1: Evolution of excited electron density (solid line) and normalized squared laser electric field E2 (dashed line) inside α-quartz irradiated by a laser pulse with 15-fs pulse duration, fluence 2.2 J/cm2 and wavelength 800 nm, calculated using TDDFT.

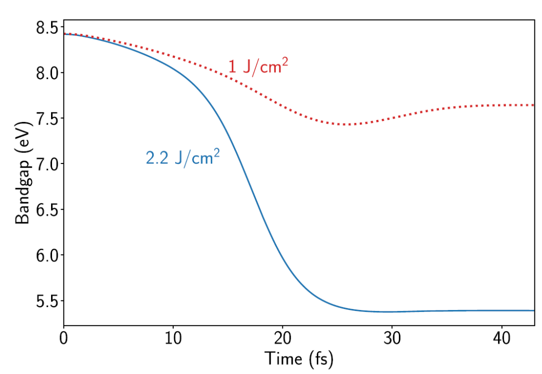


Figure 2: Bandgap evolution during 15-fs (FWHM) laser pulse at 800-nm wavelength,
and two fluences 2.2 J/cm2 (solid line),
and 1 J/cm2 (dotted line).

Eur. Phys. J. Spec. Top., Vol.232 (2023), pp. 2241-2245

Scientific Reports

Nondestructive inspection of surface nanostructuring using label-free optical super-resolution imaging

Alberto Aguilar, Alain Abou Khalil, David Pallares Aldeiturriaga, Xxx Sedao, Cyril Mauclair and Pierre Bon.

An article co-authored by our Laser-Matter Interaction team regarding the Re-scan Confocal Reflectance Microscopy optical technique was published last year in the multi-disciplinary journal Scientific Reports, from the publishers of Nature.

Figure 1

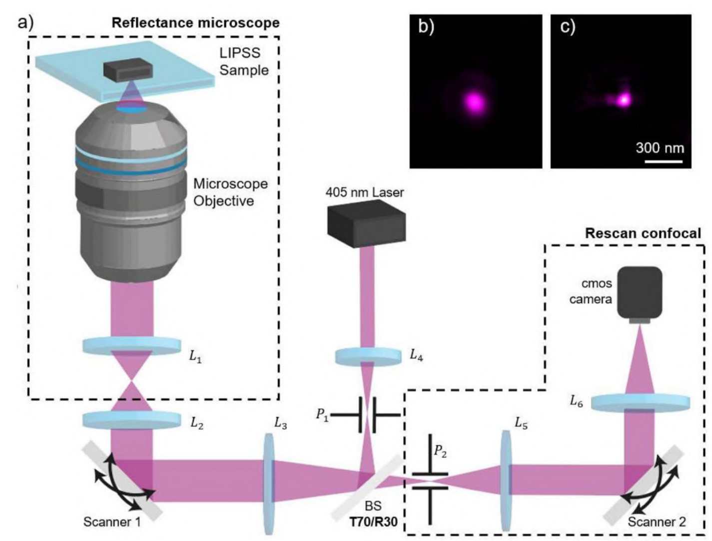


Figure 1 above:
Optical imaging setup and resolution of the system.
(a) Schematic of the optical setup,
(b) Conventional reflectance confocal microscope PSF,
(c) Re-scanned confocal microscope PSF.

Very small structures (down to the sub-micrometric scale, one hair cut into hundreds of pieces) have a profound effect on surface properties. This is demonstrated by the spectacular self-cleaning effect of the lotus leaves, or can be observed on the Morpho butterfly whose famous blue color is related to diffractive effects on sub-micrometric surface structures. While laser pulses can reproduce these types of structures on surfaces, their typical size below the optical diffraction limit makes it particularly challenging to measure them with precision.
By using a super resolution optical technique called «Re-scan Confocal Reflectance Microscopy (Re-scan CRM)», researchers from the Hubert Curien Laboratory, the Manutech-USD (St-Etienne) and the XLIM (Limoges) have succeeded in characterizing laser-induced structures down to 0.1µm. With femtosecond laser pulses in the ultraviolet range (257nm), Laser Induced Periodic Surface Structures (LIPSS) with a typical period of 100nm were achieved on a titanium alloy surface, a material with a high degree of biocompatibility and widely used for medical implants. Contrary to most super resolution microscopy techniques that exploit fluorescence, the re-scan CRM doesn't require any chemical label. Moreover, as the re-scan CRM is an optical technique, it can be easily combined to femtosecond laser optical beam path. The re-scan CRM has thus the great potential to enable live characterization of laser induced sub-micrometric structures during their production.

Figure 2

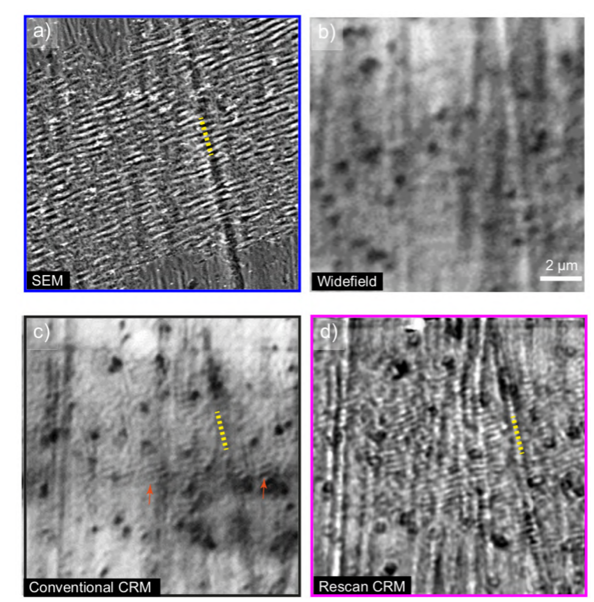


Figure 2 right:
LIPSS of 170nm period over titanium alloy surface created by fs laser and analyzed with different imaging techniques:
(a) SEM,
(b) Widefield imaging,
(c) Conventional CRM,
(the orange arrows indicate visible LIPSS of period >180 nm),
(d) Re-scan CRM.

Sci. Rep., Vol. 13 (2023), Article no. 6008

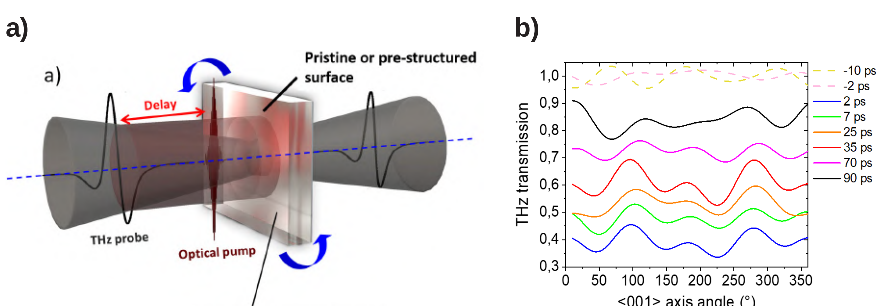
Optics Express

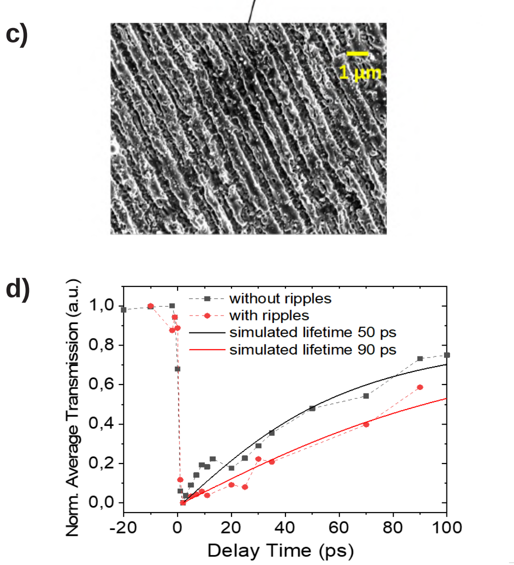
Ultrafast laser-induced plasma anisotropy in pristine and surface pre-structured zinc telluride, probed by terahertz pulses

Daiwei Zhang, Xxx Sedao, Nicolas Faure, Yannick Bleu, Razvan Stoian, and Ciro D'Amico

An article by our Laser-Matter Interaction team was published in July 2023 in Optics Express, an open-access journal dedicated to scientific and technology innovations in all aspects of optics and photonics.

'Terahertz Time – Domain Spectroscopy (THz-TDS)' is a very powerful method of non-invasive in situ charge transport phenomena analysis which, with respect to more conventional optical spectroscopy techniques, has the major advantage of accessing the complete information (amplitude and phase) of the material dielectric response. The THz-TDS technique has been developed for the first time in our lab as part of Daiwei Zhang's Ph.D. research project, where it was used to detect and study charge transport anisotropies developed within the ultrafast electronic excitation of nanostructured samples by ultrafast laser pulses. The generated THz pulses have a duration of approx. 2 picoseconds, and a spectral bandwidth between 0.2 THz and 3 THz (1 THz = 10^{12} s^{-1} correspond to a wavelength of 300 µm). Here the THz pulses are used as a probe (Fig. 1a) for studying the anisotropic relaxation dynamics of two-photon absorption (TPA) generated free carriers in a bulk Zinc Telluride (ZnTe) crystal, with electron densities as low as $10^{13}$$cm^{-3}$. Transient anisotropy induced within the TPA process itself, and consisting in an oscillation of the THz signal transmitted by TPA generated free carriers as a function of the crystal orientation (Fig. 1b), has been analyzed for pristine and surface pre-structured ZnTe as a function of the delay between optical pump and THz probe pulses.





Pre-structuring the surface sample with ripples (Fig. 1c) showed a strong influence on the THz signal transmitted by the photo-generated free carriers and the corresponding anisotropy, due to its sensitivity to the optical pump pulse intensity and polarization state, which are strongly influenced by the introduction of the surface structures. The charge relaxation dynamics following the electronic excitation clearly show two distinct lifetimes, a long one of approx. 1.5 ns, and a short one of approx. 50 ps in absence of ripples, which increases up to 90 ps in presence of ripples, as seen in Fig. 2d. Only the fast decay is significantly influenced by ripples. This indicates that the fast decay could be related to phenomena happening on the surface or close to it, as for example carrier trapping on impurities due to structural defects, or transient surface reflectivity change induced by the optical pump. This type of analysis is applied here for surface pre-structured ZnTe semi-insulating crystal, but could be used in principle for any material. Analyzing the influence of laser structuring on transport properties can have an important impact for future applications in the domains of ultrafast laser-processed functional engineered surfaces and materials.

Figure 1:

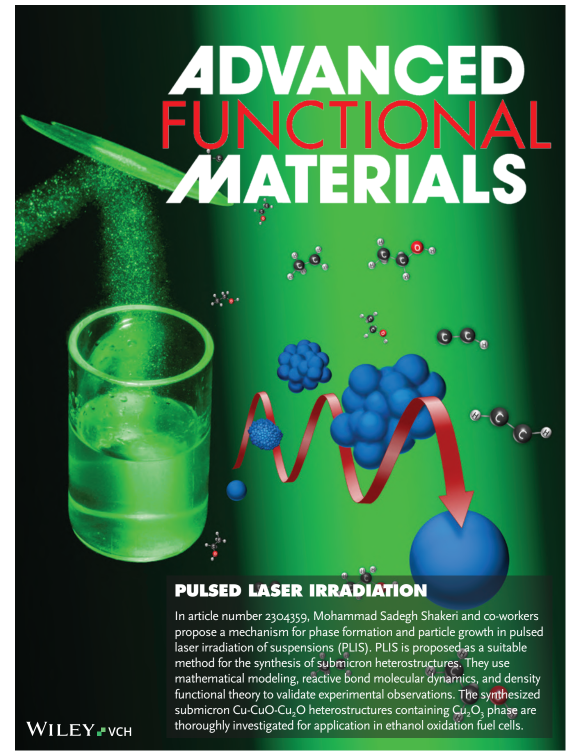
a) Pump-probe method employed for detecting photo-induced charge anisotropies;
b) THz transmission oscillation as a function of the crystal orientation, for several optical pump delay, with optical pump polarization set to horizontal, and fluence of 0.14 mJ/cm² (the negative delay time means the pump arrives after the probe, and the observed oscillations are only due to noise);
c) Scanning electron microscopy (SEM) images of the ripples photowritten on the ZnTe surfaces;
d) Normalized THz transmission by free carrier (averaged over 360° crystal orientation) in absence (dark squares and dashed line) and in presence (red circles and dashed line) of surface ripples. The solid lines correspond to theoretical simulations of exponential decays with 50 ps (dark solid line) and 90 ps (red solid line) lifetimes.

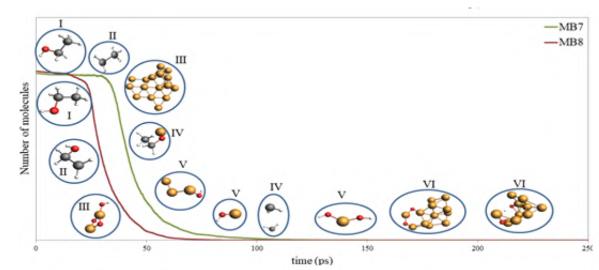
Opt. Express, Vol. 31, Issue 15 (2023), pp. 24054-24066

Advanced Functional Materials

Alternative local melting-solidification of suspended nanoparticles for heterostructure formation enabled by pulsed laser irradiation

Mohammad Sadegh Shakeri, Zaneta Swiatkowska-Warkocka, Oliwia Polit, Tatiana Itina, Alexey Maximenko, Joanna Depciuch, Jacek Gurgul, Marzena Mitura-Nowak, Marcin Perzanowski, Andrzej Dziedzic and Jarosław Nęcki





Illustrations above:

Top: Advanced Functional Materials Journal's October 2023 issue cover

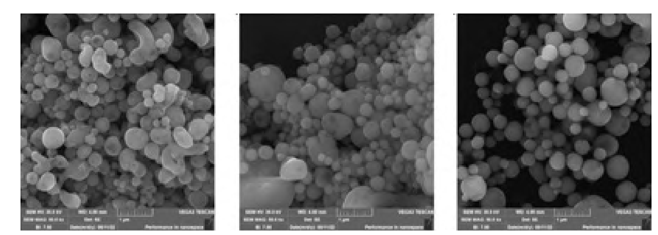
Bottom: Timeline of new species formation on the decomposition curves of ethanol for the Cu-ethanol and CuO-ethanol systems obtained from the simulation, where
(I) ethanol absorption,
(II) hydroxyl cleavage,
(III) formation of Cu clusters,
(IV) surface oxidation,
(V) further decomposition of the solvent, and
(VI) net oxidation

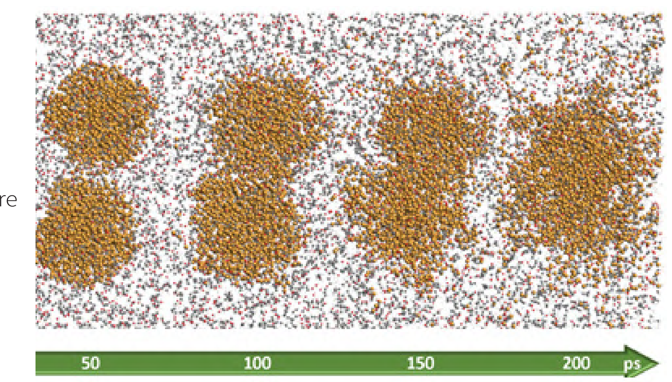
In October 2023, an article co-authored by Tatiana Itina, a member of our Laser-Matter Interaction team, featured on the frontispiece of Advanced Functional Materials, a journal publishing outstanding research on improving the chemical and physical properties of materials.

In their article, the team puts forward a mechanism for nanoparticle phase change, sintering and growth in pulsed laser irradiation of suspensions (PLIS). Using atomistic simulations such as reactive bond molecular dynamics and density functional theory, as well as experimental observations, PLIS is shown to be promising for the synthesis of submicron heterostructures. The synthesized submicron Cu-CuO-Cu_2O heterostructures containing Cu_2O_3 phase are thoroughly investigated for application in ethanol oxidation fuel cells.
The article is the outcome of a follow-up study conducted by a Franco-Polish team, building upon their previous work in the now-completed project carried out within the framework of the PHC POLONIUM program.

Illustration below:

SEM images of CuO-ethanol samples (upper road) and reactive MD simulation results (lower road) showing. The increasing trend of particle size with laser fluence is clearly visible.





Adv. Funct. Mater. , Vol. 33, Issue 43 (2023), Article no. 2304359

Acta Materialia

Dynamics of Cu-Zr metallic glass devitrification under ultrafast laser excitation revealed by atomistic modeling

Djafar Iabbaden, Jonathan Amodeo, Claudio Fusco, Florence Garrelie and Jean-Philippe Colombier

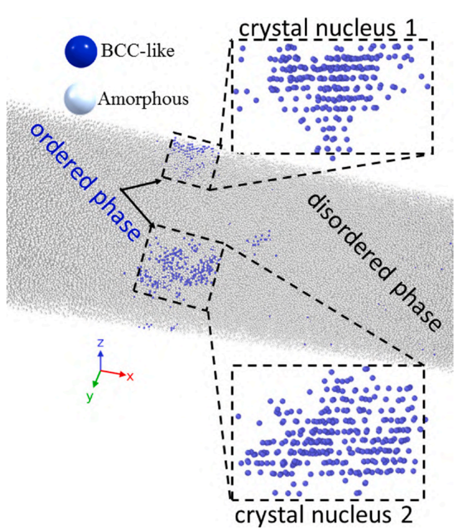
An article by our Laser-Matter Interaction team was recently published in Acta Materialia, a journal dedicated to original papers and commissioned overviews that advance the in-depth understanding of the relationship between the processing, structure and properties of inorganic materials.

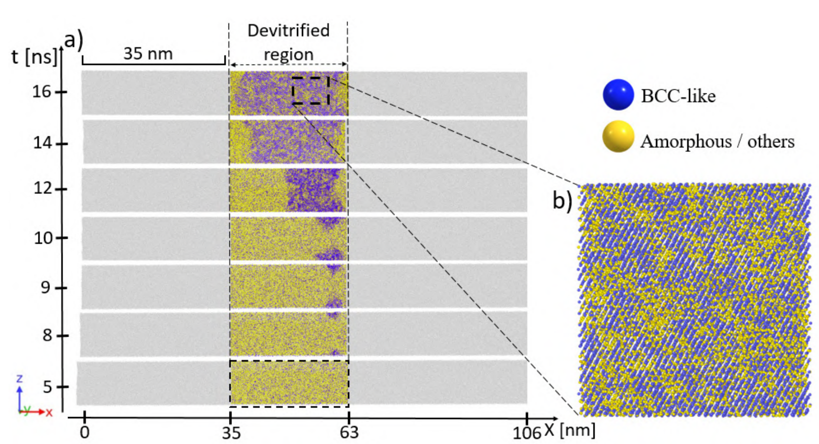
The article explores the use of ultrafast lasers to induce nanocrystals embedded in amorphous alloys, particularly metallic glasses. These materials have unique properties, but conventional methods for controlled crystallization have limitations. The study focuses on CuZr metallic glasses and investigates how ultrafast laser irradiation can induce structural changes up to devitrification. Theoretical models and simulations are used to understand laser conditions, composition effects, and devitrification mechanisms.
The article emphasizes the challenges in achieving controlled crystallization and discusses potential applications, such as creating composites using laser irradiation in a single-step process.
This work was supported by the ANR MEGALIT project (ANR-18-CE08-0018).

Illustrations below:

Left:
Nucleation of BCC-like nuclei (~15 atomic plans) within the amorphous α-Cu21.9Zr78.1 at ~8 ns after the laser-energy deposition.

Right:
(a) α-Cu21.9Zr78.1 atomic configurations after ultrafast laser irradiation as a function of time.
(b) Magnification of a devitrified subdomain at t=16 ns.
The atoms are colored according to their local atomic structure computed using the PTM algorithm.
Atoms colored in gray rely to hidden amorphous and liquid domains.





Acta Mater., Vol. 263, (2024), Article no. 119487

Materials Today Communications

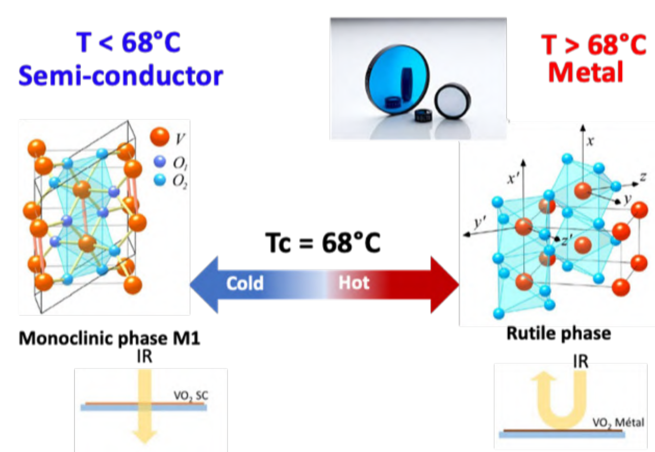
Polymorphism of VO_2 thin film: M1, T, and M2 single phase synthesis using pulsed laser deposition

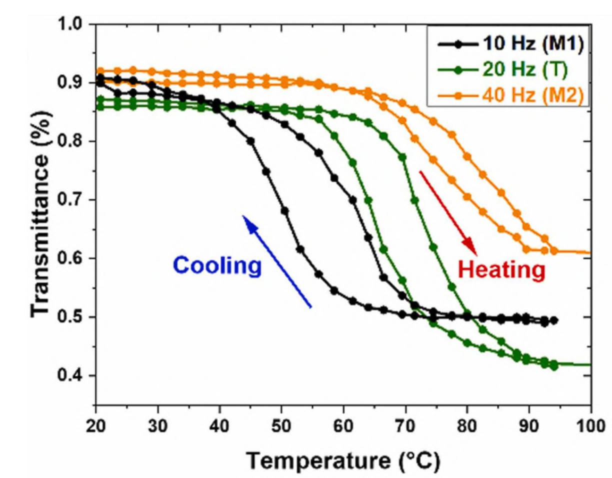
Yannick Bleu, Florent Bourquard, Konstantinos Misdanitis, Anthony Poulet, Anne-Sophie Loir, Florence Garrelie and Christophe Donnet.

Materials Today Communications is a journal that covers all aspects of materials science research, and in which members of our Laser-Matter Interaction team published their latest results obtained as part of the LABEX MANUTECH-SISE-supported PROTECT project.

In materials science, some materials are known to be more or less conductive of electrical charges, while others are electrical insulators. What is fascinating from the point of view of scientific knowledge are the materials that can transit from one state to another, depending on the environment in which they are located. This is the case for materials that have a metal-insulating transition (MIT) at a certain temperature. For certain technological applications, it is all the more interesting that this transition temperature is close to the ambient temperature. The metal-insulator transition also plays on other than electronic properties, such as the optical transmission or reflection properties of light, at different wavelengths.
Vanadium oxide (VO_2) exists under many stoichiometries and crystalline phases. The VO_2 has a metal-insulating transition around 70°C, which makes it suitable for switching its optoelectronic properties on either side of this transition. VO_2 thin films were synthetized by pulse laser deposition (PLD), a physical vapor deposition technique that focuses a nanosecond or femtosecond pulse laser on a target. The laser-matter interaction induces the emission of a plasma plume carrying neutral and ionized species, which condense on a substrate in the form of a thin sub-micron thick layer.

This publication targeted the effect of laser repetition rate impinging on a vanadium-based oxide target, on the nature of the crystalline phases of the VO_2 thin film. The VO_2 "cold" insulating phase is called "monoclinic" (M1), whereas the "hot" phase metallic phase is called "rutile" (R). The transition M1 to R upon heating follows complex mechanisms, including intermediate transition phases such as a second monoclinic one (M2) and a tetragonal one (T). By adjusting the laser frequency at different values (10, 20 and 40 Hz), the team demonstrated the ability of PLD to obtain those intermediate phases in a controlled and reproducible way, affecting the MIT temperature at different values (56°, 71°, 81°C). How is this possible? As the laser repetition rate increases, the laser overlap also increases. Consequently and at the highest repetition rate, the interval between two consecutive pulses is shorter, and the ablated target has less time to cool down between each laser pulse than at lower repetition rates. Therefore, the dependence of the laser pulse overlaps with the repetition rate results in the production of different plasma compositions during ablation, which gives rise to different VO_2 phases.
As these different phases are associated with different nanostructures, nanomechanical and optical properties, this work could pave the way for the development of novel functional polymorphic VO_2 with tunable IMT and functionalities.





Illustrations above:

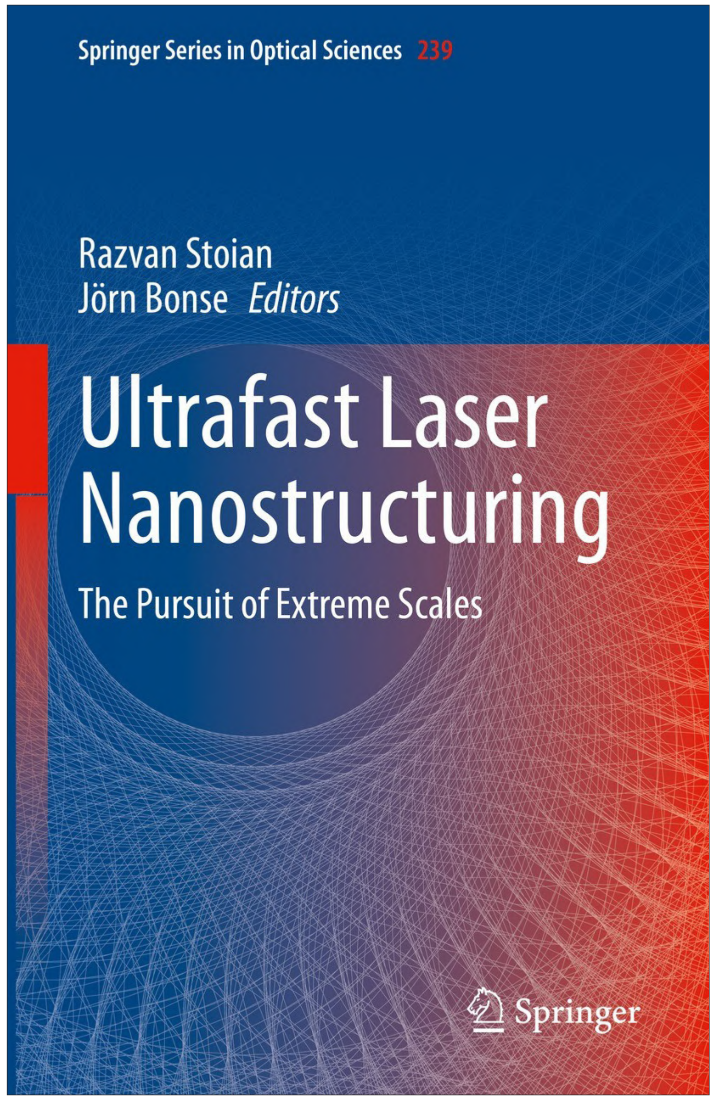
Left: Temperature-dependent IR transmittance with hysteresis curves at 2000 nm of the three VO_2 phases.

Right: Metal-Insulator transition (MIT) of VO_2 crystals, depending on the temperature.

Mater. Today Commun., Vol. 35, (2023), Article no. 105564

Ultrafast Laser Nanostructuring - The Pursuit of Extreme Scales

A new book edited by Razvan Stoian and Jörn Bonse



The Head of the Laser-Matter Interaction group at the Hubert Curien Laboratory, Razvan Stoian, has teamed up with Dr Jörn Bonse, researcher at the BAM Institute in Berlin, to edit a three-volume book dedicated to the field of extreme laser nanostructuring. The book, released in April 2023, is part of the Springer Series in Optical Sciences which provides a selection of research monographs in a broad range of topics related to optics, such as lasers and quantum optics, ultrafast phenomena, optical spectroscopy techniques, optoelectronics, information optics, applied laser technology and industrial applications.

Laser pulses are commonly used to shape and structure matter in a variety of scientific, technological and daily-life applications. The development of laser engineering has led to impressive advancements in laser processing, allowing materials to be assigned new functions and properties by modifying their mechanical, electrical or optical characteristics. These advancements, specifically those related to resolution and precision, have historically depended on the reduction of the laser pulse duration, thus underlining the importance of the process spatio-temporality. In this context, one might ask if there is actually «any fundamental limit in the processing resolution, a barrier defined by the intrinsic properties of light and matter?».
Razvan Stoian and Jörn Bonse have called upon the contribution of leading experts in the field to help answer this «inherently multidisciplinary» question, offering an insightful overview of the current endeavours to achieve laser processing resolution beyond the diffraction limit. Starting with the fundamental principles and concepts of light-matter interaction, the three-part structure of the book progressively leads the reader towards an understanding of research works in the fields of nanophotonics, nanofluidics, optical sensing, biomedical science, for tested applications in various areas of material processing and nanosurgery.
As with all volumes of the Springer Series in Optical Sciences, the book is aimed at any research scientist or engineer requiring an up-to-date reference book in the subject field. It is also intended to be a useful resource for graduate students in laser processing, materials engineering and nanoscience.

https://doi.org/10.1007/978-3-031-14752-4

Content

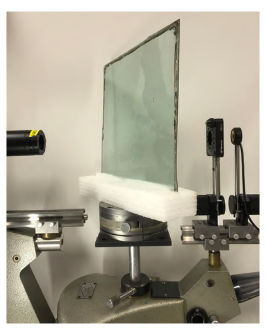
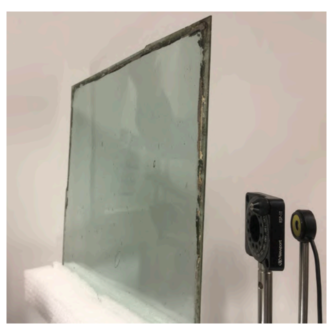
Journal of the Optical Society of America A

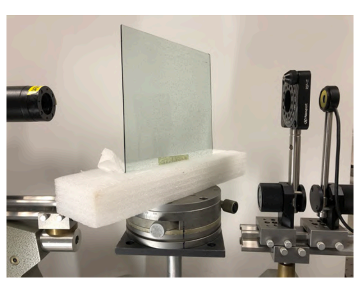
Photometric properties of piles of glass plates: retrospective

Lionel Simonot and Mathieu Hebert.

JOSA A publishes peer-reviewed papers related to developments in any field of classical optics, image science, and vision. The journal has recently introduced occasional retrospectives that present a historical overview of an area in optics, or an interdisciplinary area in which optical concepts are heavily employed. With the view that «understanding historic developments may help us keep an open mind regarding contemporary developments, provide us with new perspectives on seemingly settled subjects, and even facilitate the adoption of methods and concepts developed in another area for new applications» the editors intend to offer a new and novel platform for accumulating and disseminating historically significant information for the optical sciences. Lionel Simonot from the Institut P' (Université de Poitiers) and Mathieu Hébert, member of our Image Science & Computer Vision team, submitted a paper that was published in May 2023 as the inaugural retrospective article of JOSA A.

Who was the first scientist to be interested in studying the stacking of glass plates, their reflectance, transmittance, absorptance and polarization effect? Looking back in history, it is surprising to see how much these objects have captured the interest of optical scientists and how often they have been used in major theoretical and experimental advances. They were first employed in the 18th century by the inventors of photometry (Lambert, Bouguer, Beer), at a time when measurements of light quantities were made with the naked eye by comparing the power of a light source with that of a reference source modulated by these glass piles. They were then studied by the great names of 19th-century optics (Brewster, Arago, Stokes, Rayleigh), by the 2022 Nobel laureate in Physics, Alain Aspect, who used them as a high-transmissivity polarizer, and in the last decade, by researchers from the Hubert Curien Laboratory who developed and applied a mathematical formalism to the study of stacked glass plates. This paper retraces 300 years of research history in optics, documenting the evolution of knowledge while, however, considering the quality of the available materials. For instance, if the first studies conducted in the 18th century could not take into account the influence of light polarization - as it was only discovered in the following century - the quality of the highly colored glass of the time allowed their incomplete theories to be nevertheless consistent with the experiments.




Illustrations:
Experimental setup. The glass panes analyzed during the study date back to the 18th century. They were kindly brought over to our lab by Véronique Kientzy from the Centre de recherches sur les Monuments historiques (Ministère de la Culture / Médiathèque du patrimoine de la photographie).
The measurements made confirmed our hypothesis regarding the quality of the glass that was used by the photometry pioneers.

Journal of the Optical Society of America A, Vol.40, Issue 5 (2023), pp.803-815

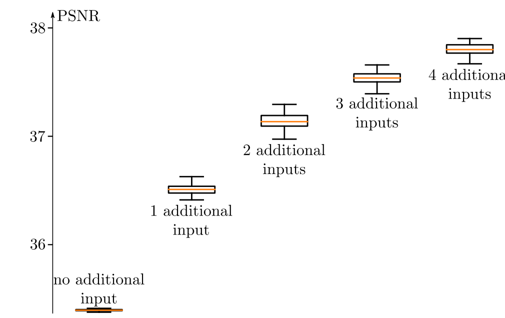
IEEE Transactions on Geoscience and Remote Sensing (TGRS)

Multitemporal Speckle Reduction With Self-Supervised Deep Neural Networks

Inès Meraoumia, Emanuele Dalsasso, Loïc Denis, Rémy Abergel and Florence Tupin.

In January 2023, our Image Science & Computer Vision team published a paper in IEEE Transactions on Geoscience and Remote Sensing (TGRS). The journal publishes technical papers disclosing new and significant research related to the theory, concepts, and techniques of science and engineering as applied to sensing the land, oceans, atmosphere, and space.

Nowadays, several satellites continuously produce Synthetic Aperture Radar (SAR) images of the Earth. These images provide crucial information to monitor the forests, oceans, glaciers, and urban areas all over the world. While optical satellites are useless in the presence of clouds, SAR satellites see through the clouds and are therefore very useful to detect and analyze changes. Yet, a fundamental difficulty of SAR imaging comes from the phenomenon of speckle which strongly impacts the quality of the images. This paper extends our recent self-supervised training strategy «MERLIN», based on the decomposition of complex-valued SAR images into pairs of real-valued images with statistically independent speckle, to multi-temporal filtering. We developed a statistical model of sequences of SAR images and proved that deep neural networks could learn how to suppress speckle using only noisy data. Compared to single-image speckle reduction, multi-temporal speckle filtering better preserves small structures such as roads or boundaries between fields, without introducing noticeable artifacts when changes occur in the time series. This work results from a collaboration with the LTCI at Télécom Paris and the MAP5 at the Université Paris Cité.



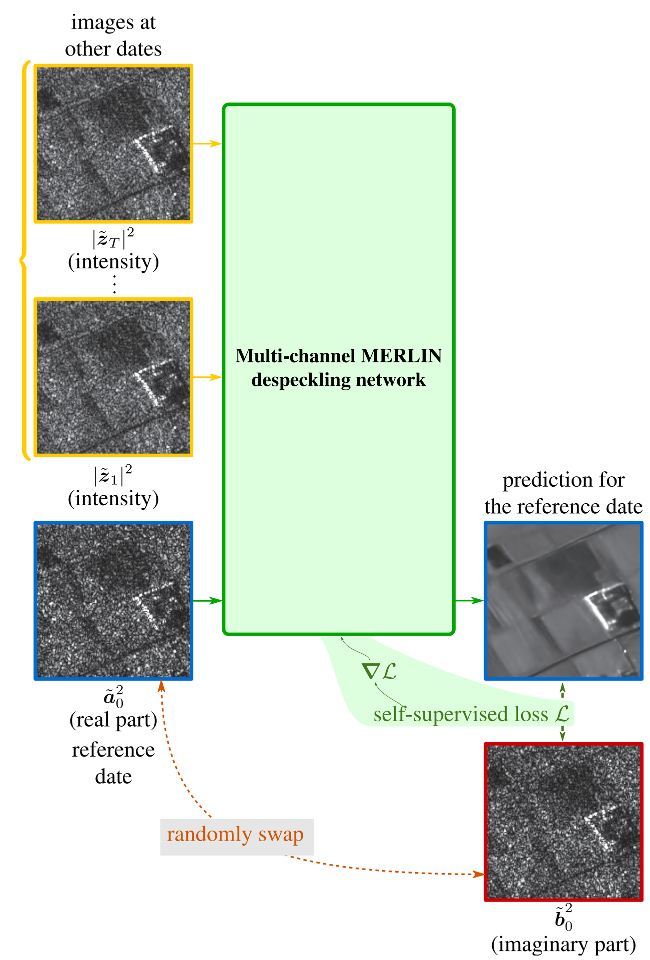


Figure 1 above:
When additional images are provided to the neural network, the quality of its prediction improves, as measured on these numerical simulations by the PSNR criterion (the higher the better).

Figure 2 right:
Our neural network (green box) takes several images as input (yellow) in addition to half of the information of the reference image (blue). It produces a restored image (blue image on the right) that can be compared to the other half of the reference image (red). This guides the training of the network.

The code of the trained models and supplementary results are freely available at the following address:
https://gitlab.telecom-paris.fr/users/sign_in

IEEE Transactions on Geoscience and Remote Sensing, Vol. 61 (2023), pp. 1-14

International Conference on Computer Vision Theory and Applications - VISAPP 2023

Toward few pixel annotations for 3D segmentation of material from electron tomography

Cyril Li, Christophe Ducottet, Sylvain Desroziers and Maxime Moreaud.

As part of the 2023 VISAPP conference, an annual event that gathers researchers, engineers and practitioners to discuss computer vision application systems, our Image Science & Computer Vision team presented an article suggesting a new method for the segmentation of 3D volume of material obtained via electron tomography.
Electron tomography (ET) is a powerful technique for the 3D reconstruction of materials at the nanometer scale. It can be used to characterize the properties of catalysts used in the energy sector. Analysis of these materials requires automatic segmentation of the images, i.e. obtaining a map of the image in which each voxel is annotated as belonging either to the material or to the background. However, ET images are noisy and contain reconstruction artifacts, making automatic segmentation difficult. Deep learning methods have made considerable progress in this field but these approaches require training a deep network on large, fully annotated datasets.

The cost of annotating full volumes at voxel level is significant, and such datasets are not available for ET. In this work, we propose a new semi-supervised method, taking into account the small amount of annotated data available. An expert annotates a small portion of one slice of the volume, then our deep model is trained using both the few available annotated pixels and the whole volume. At inference, the model can predict accurate labels for the whole volume. The key component is to use contrastive learning which can fully exploit partially-labeled data making different kind of pixel pairs for learning the model (Figure 1). Experiments on real ET data show that an accurate segmentation is possible with only one slice and 6% of annotated pixels in this slice (Figure 2). Three examples of reconstructed volumes are given in Figure 3. This work is the result of a collaboration between the Hubert Curien Laboratory, the IFP Energies nouvelles and Manufacture Française des Pneumatiques Michelin. It is supported by the Labex MILYON.

Image below:
Example of a slice of a volume of zeolite (resolution of 1nm/voxel). The blue part is the annotated region.

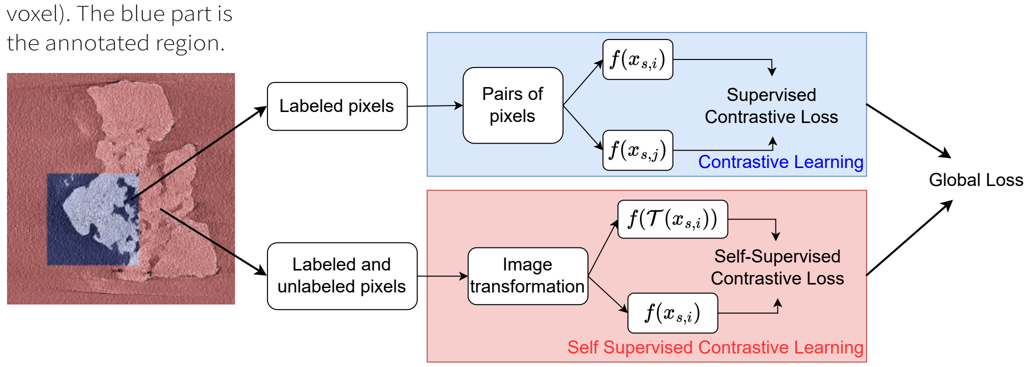
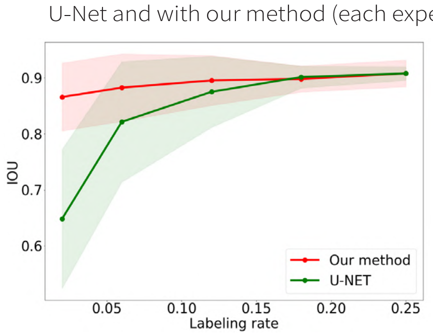


Figure 1 left:
For labeled pixels, pairs of pixels are constructed and are used in a contrastive loss. For labeled and unlabeled pixels, the training image and the transformed version of itself are used as a positive pairs in a self-learning contrastive loss. Both losses are added in the global loss.

Figure 2 below:
IOU of our method (red) and U-Net (green) when reconstructing the segmentation mask for the volume with one partially labeled training slice for different labeling rates. The green and red areas represent the standard deviation of the results with U-Net and with our method (each experiment is repeated 5 times).



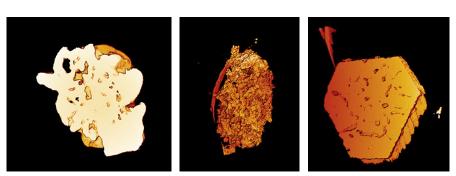


Figure 3 left:
3D reconstructions of the segmentation map of zeolites (1) (2) and γ-alumina (3). The volume (1) is cut to render the inner structure of the volume. 6% of one slice have been taken to train the model used for each volume.

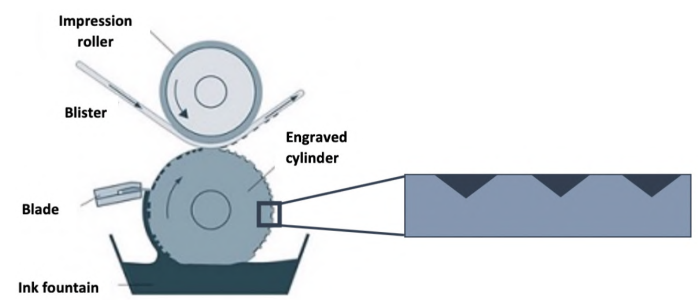
International Conference on Computer Vision Theory and Applications - VISAPP 2023s

Printed Packaging Authentication: Similarity Metric Learning for Rotogravure Manufacture Process Identification

Tetiana Yemelianenko, Alain Trémeau and Iuliia Tkachenko.

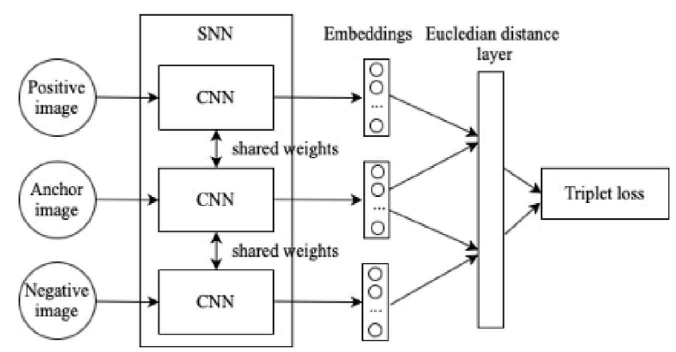
A second paper was presented by our Image Science & Computer Vision team during the 2023 VISAPP conference, this time delving into the problem of rotogravure press identification and printed support identification using similarity metric learning.

Many solutions have been suggested so far for the authentication of valuable documents and packaging, including watermarks, bar codes and QR codes. However, the printing of these markers remains costly, and their authentication process is not easy. The development of printing protection techniques is the objective of the research team involved in the PackMark project (IFCPAR-7127), supported by the Indo-French Center for the Promotion of Advanced Research.



Above: Illustration of the rotogravure printing process. The ink printed on aluminium foils is carried out by cells engraved on a cylinder specifically designed for the artwork to be printed.

Below: Architecture of the triplet Siamese Neural Network used to perform press identification.



The main features investigated as part of this project were:

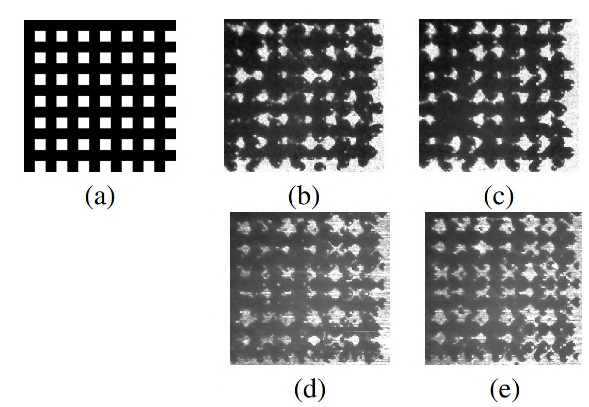
1. easy integration and generation processes,
2. low cost,
3. fast and automatic verification process,
4. use of rotogravure printing on blister foils,
5. use of variable data printer on foil,
6. characterization of common devices for verification (scanners, smartphones),
7. reliable verification by any user,
8. good level of global security and impossibility of fraud.

One of the objectives was the characterization of the rotogravure printing process and the demonstration of the uniqueness of printed glyph. The work was mainly focused on:

1. the impacts of printer and cylinder signatures to the printed pattern ;
2. the development of an authentication system based on cylinder signature;
3. the definition of a standard pattern or of a graphical code for the authentication of blister medicine foils.

The team's aim was not to define the specific profile of the used printer, but rather to demonstrate that each printed pattern (e.g. the letter 'a') has the same «signature» as another identical pattern printed exactly from the same cylinder location, while another identical pattern printed on another cylinder location will have a different «signature».

Below: Example of a regular test pattern:
(a) printed using two presses (b-d and c-e) and two types of cylinder engraving process (a chemical etching engraved cylinder (b-c) and an electro-mechanically engraved cylinder (d-e).



Scientific Reports

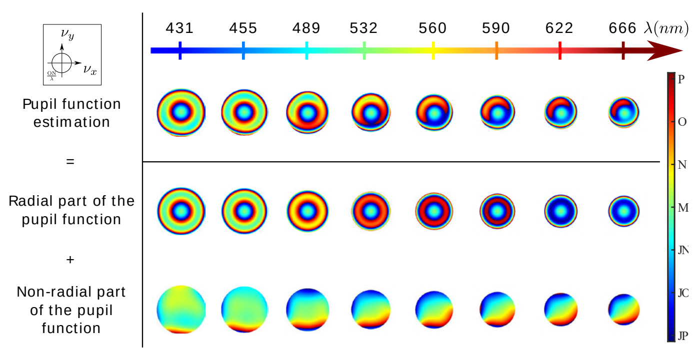
Multispectral in-line hologram reconstruction with aberration compensation applied to Gram-stained bacteria microscopy

Dylan Brault, Thomas Olivier, Nicolas Faure, Sophie Dixneuf, Chloé Kolytcheff, Elodie Charmette, Ferréol Soulez and Corinne Fournier.

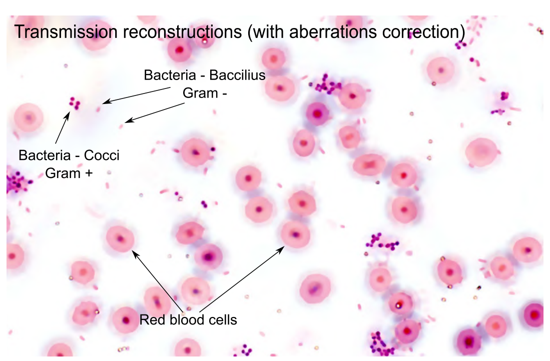
A paper was published in September 2023 by our Image Science & Computer Vision team in Scientific Reports, a Nature journal dedicated to research from across all areas of the natural sciences, psychology, medicine and engineering. Result of a collaboration between the CRAL, the BIOASTER Institute, world-wide leader of in vitro diagnostics bioMérieux and our lab, the article paves the way to an automated microscopy analysis system, with a view to improve clinical microbiology diagnostics.

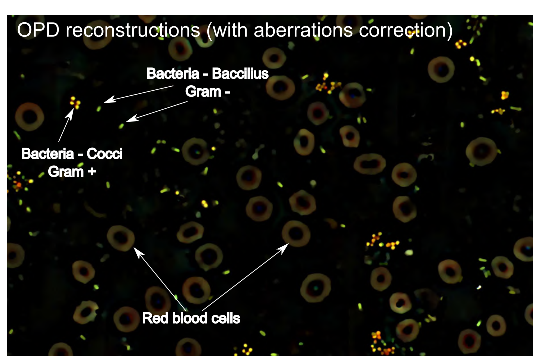
The Gram stain test, commonly used in microbiology labs to assist in medical diagnostics, requires analysis using high-resolution color microscopy. Currently, this test is neither standardized nor automated, which can lead to reading errors that can have a significant impact on patient care. In this context, we have proposed the use of holographic color microscopy as well as advanced image processing algorithms, to enable a reproducible analysis of samples and move towards an automated system. The advantage of holographic imaging is that it provides not only color information on the sample but also phase information. We have proposed harnessing the full potential of Inverse Problems approaches to self-calibrate the microscope and reconstruct samples in both transmittance and phase, reducing the imaging artifacts traditionally observed in standard white-light microscopy and holographic microscopy (such as aberrations, dispersion effects, halos, variable field focusing, etc.).

Figure below: Examples of the pupil function estimated for the whole set of wavelengths.
For easier visualization of the aberrations, the radial components (defocus and spherical aberrations) and non-radial components (tilt, coma, astigmatism, trefoil and quadrafoil) are presented separately at the bottom of the figure.



Below:
Illustration of transmittance and Optical Phase Difference color reconstructions of a sample containing two types of bacteria.





Sci. Rep., Vol. 13 (2023), Article no. 14437

Multimedia Tools and Applications

A 3D pose estimation framework for preterm infants hospitalized in the Neonatal Unit

Ameur Soualmi, Christophe Ducottet, Hugues Patural, Antoine Giraud and Olivier Alata.

Multimedia Tools and Applications is a journal dedicated to the publication of research articles focusing on multimedia development, system support tools, and case studies of multimedia applications. In 2023, our Image Science & Computer Vision team published a paper exploring babies' movements, written in collaboration with a team from the CHU Saint-Etienne Neonatal Unit's SAINBIOSE laboratory.

From birth, the movements of a baby and, particularly, those of each of its segments (arms, legs, trunk), carry essential information related to the baby's neuro-anatomical and functional cerebral integrity. However, this information has been so far neglected as an early predictive marker of later development, mainly due to three factors: the absence of large banks of recordings integrating 3D videos to allow an analysis of the individual's movement in all three planes of space, inadequate analysis tools, and a lack of interaction between the medical world and that of signal processing and artificial intelligence scientists. This paper presents several contributions made during Ameur Soualmi's Ph.D. for the analysis of the movements of preterm infants hospitalized in the Neonatal Unit: (1) the first framework for 3D infant pose estimation from stereoscopic images ; (2) a fully annotated dataset of real preterm infants' images with a clinical protocol ; (3) the main state-of-the-art convolutional neural network (CNN) architectures for 2D pose estimation retrained with the new dataset ; (4) an evaluation of these models for 2D and 3D infant pose estimation, providing a new baseline in this field.

Illustration below: 3D infant pose estimation framework based on stereoscopic camera which acquired two views, left view and right view. Thanks to triangulation, the 3D pose is obtained from the left and right 2D poses.

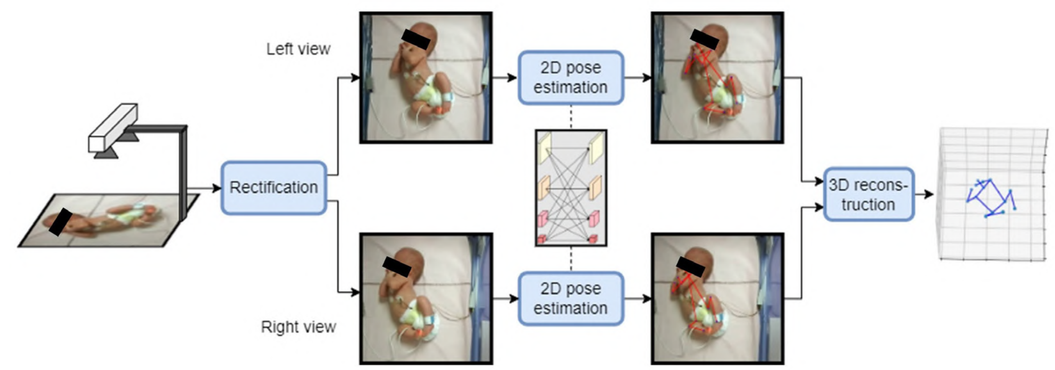


Illustration right:
A subset of our infants' images dataset collected in a clinical environment. The wide variety of poses taken by babies can be observed.

Multimed. Tools Appl., Vol. 83, (2024), pp. 24383-24400

Materials Horizons

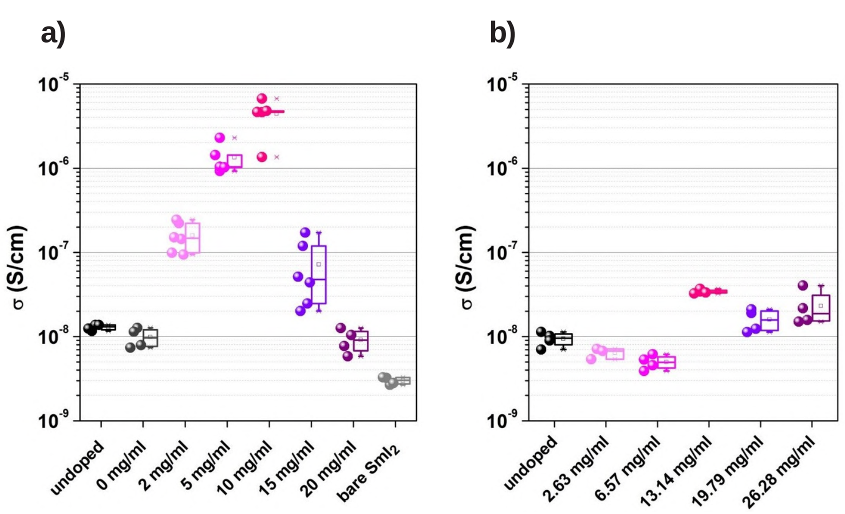
Redox-active ions unlock substitutional doping in halide perovskites

Zuzanna Molenda, Bastien Politi, Raphaël Clerc, Mamatimin Abbas, Sylvain Chambon, Dario M. Bassani and Lionel Hirsch

Our Image Science & Computer Vision team has contributed to a paper reporting the first ever effective doping of halide perovskites. Published in the journal Materials Horizons from the Royal Society of Chemistry, the experiment results are paving the way for low-cost, highly- efficient solar cells and LEDs.

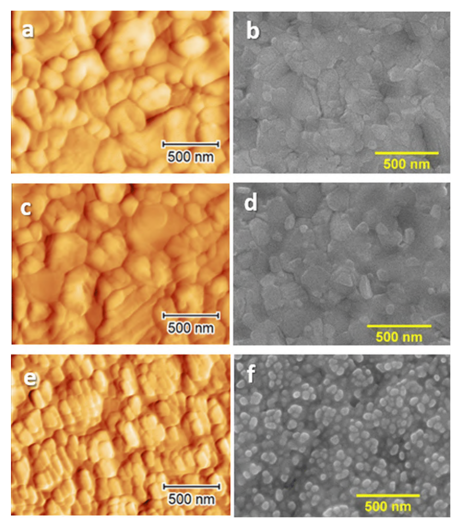
Semiconductors, crucial to electronic devices, derive their performance from a process called doping, wherein specific atoms in their crystalline structure are replaced with elements that either release (N) or capture (P) electrons. While silicon, the most widely used semiconductor, has well-understood doping mechanisms, the process remains more intricate for other materials. This is the case for Halide perovskites for instance, which high energy conversion efficiency make them a predilection material for the development of solar cells. In perovskites, the crystalline structure is held together by ionic bonds, unlike silicon's covalent bonds. This poses challenges for traditional doping methods since replacing one ion with another capable of releasing (N) or capturing (P) an electron could disrupt the delicate balance with its opposite ion (either anion or cation). To overcome this issue, the authors introduced a solution involving metastable ions. Specifically, samarium (Sm) was injected into the crystalline structure as Sm^{2+}, replacing lead ions (Pb^{2+}). Upon insertion, Sm^{2+} oxidizes to Sm^{3+}, serving as an N-type dopant without compromising the crystalline structure.
In this collaborative effort with the Integration from Material to System (IMS) Laboratory and the Institut des Sciences Moléculaires (ISM), our Image Science & Computer team has successfully achieved the first effective N doping of halide perovskites. This breakthrough resulted in an increase in the material's conductivity by more than three orders of magnitude.

Figures below
Measurement of perovskite conductivity as a function of:
a) SmI_2 (dopant),
b) SmI3 (no effect)
demonstrating a three-order-of magnitude increase at 10 mg/ml.



Surface images below:
(a), (c), and (e): AFM
(b), (d), and (f): SEM, of:

(a) and (b): undoped MAPI films,
(c) MAPI treated with the dopant solvent,
and (d) MAPI doped with 10 mg mL−1 SmI2.



Characterization of the 10 mg mL−1 doped MHP surface shows significantly different topologies than those of the undoped sample. While on the surface of the undoped perovskite grains are clearly seen, the doped layer is covered with the oval-like shared grains of a much smaller size. As expected, the sample treated with only solvent did not show any alteration in morphology to the untreated sample.

Mater. Horiz., Issue 8 (2023), pp. 2709-3176

IEEE Geoscience and Remote Sensing Letters

A Deep Learning Approach for SAR Tomographic Imaging of Forested Areas

Zoé Berenger, Loïc Denis, Florence Tupin, Laurent Ferro-Famil and Yue Huang.

IEEE Geoscience and Remote Sensing Letters publish short papers relating to the theory, concepts and techniques of science and engineering as applied to sensing the Earth, oceans, atmosphere and space, and to the processing, interpretation, and dissemination of this information. In 2023, the journal recently published an article by our Image Science & Computer Vision team, presenting a novel neural network-based approach for tomographic SAR reconstruction of forested areas.

The CO_2 storage capacity of biomass is an important parameter in climate models. However, estimation of the biomass of equatorial, tropical and boreal forests is currently limited to a few on-site measurements. A dedicated satellite will be launched in 2024 by ESA - European Space Agency - to carry out periodic worldwide measurements by combining several radar images and using advanced data processing.
The aim of this work was to develop a fast reconstruction method, greatly improving the reconstruction of the forest backscattering profile from which it is possible to estimate vegetation height and biomass. An auto-encoder network was trained using physically realistic simulations. Application to airborne data shows good robustness of the authors' proposed algorithm, and a huge acceleration compared to the state of the art, the proposed method being 200 times faster than an iterative technique based on wavelet decomposition.

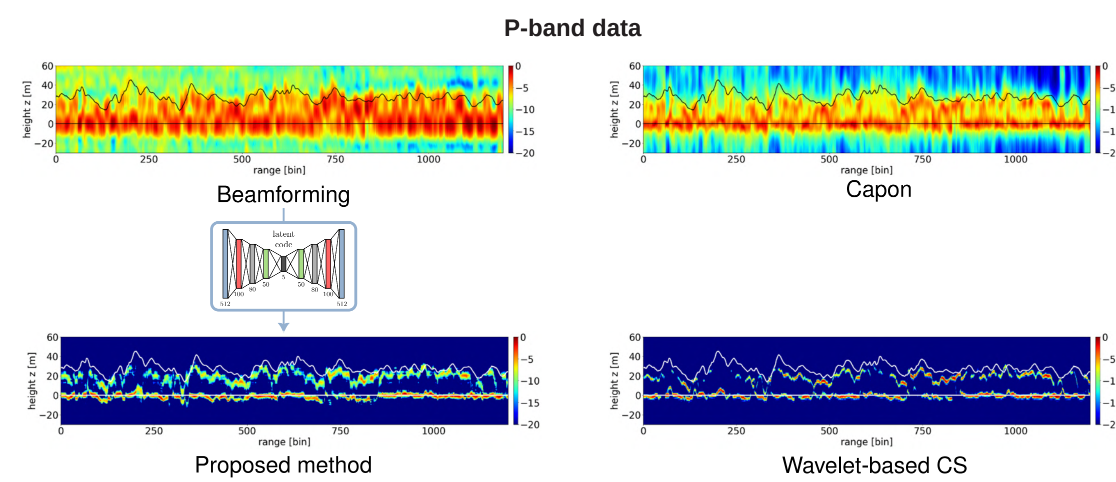


Illustration above:
Tomographic profile estimated over a boreal forest at P-band, using the authors' improved proposed neural network-based approach (left-hand side) or standard techniques (right-hand side).

IEEE Geosci. Remote Sens. Lett., Vol. 20 (2023)

Scientific Data

FOPPA: an open database of French public procurement award notices from 2010-2020

Lucas Potin, Vincent Labatut, Rosa Figueiredo, Christine Largeron and Pierre-Henri Morand.

Scientific Data is a journal published by Nature, and dedicated to descriptions of datasets and research - from all areas of natural sciences, medicine, engineering and social sciences - that advances the sharing and reuse of research data. In 2023, our Data Intelligence team published a paper presenting the partial results of their research conducted within the framework of the DeCoMaP ANR project (ANR-19-CE38-0004), in collaboration with the LBNC, LIA, CRA labs and the company Datactivist. The project aims at the automation of detection fraud in the public procurement process.

Amongst DeCoMaP's initial goals was the set up a comprehensive database of corruption and fraud cases, through the collection of empirical pieces of evidence from various and heterogeneous legal sources, from primary and secondary source documents, as well as a survey of procurement experts. The published document describes the constitution of the FOPPA database, which relies on a subset of the TED database that contains French public procurement notices published from 2010 to 2020. These data sets contain a number of issues, the most serious one lying in the missing unique IDs of the most involved agents. The team puts forward a method by which these issues can be resolved, thus enabling the constitution of a usable database.

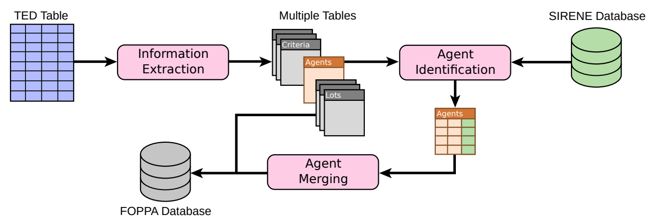


Figure 1 above:
Overview of the method proposed to correct and complete the raw TED data and constitute the FOPPA database.

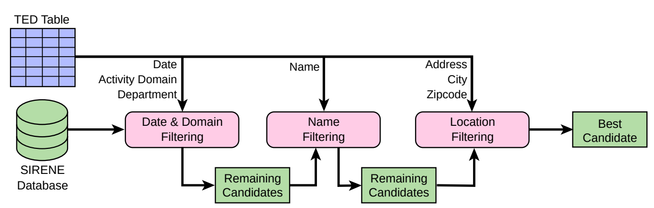


Figure 2 above:
Successive filtering phases applied to match TED agents with SIRENE entries, as a part of the Agent Identification step from Figure 1.

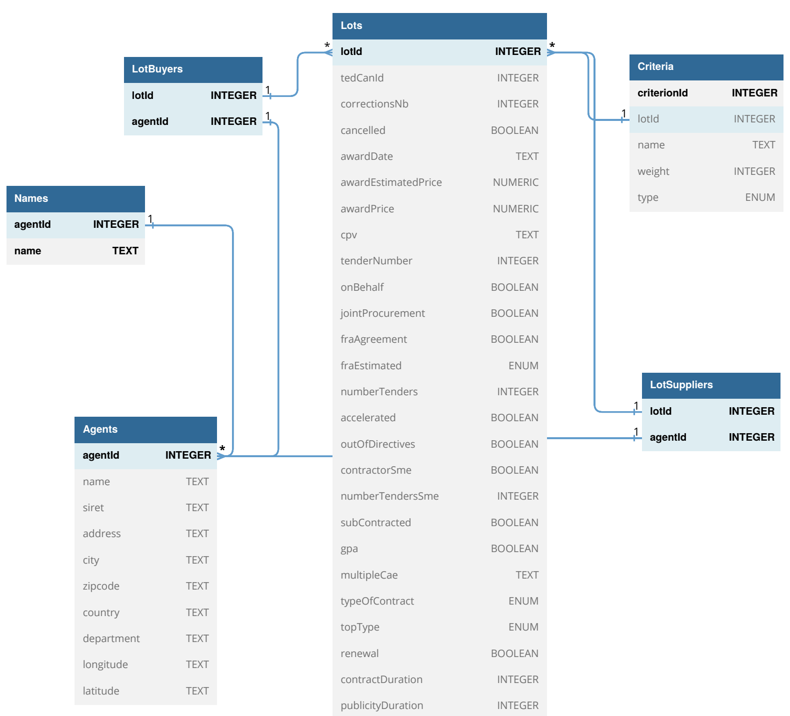


Illustration left:
Structure of the FOPPA database, shown as an Entity-Relation diagram.

Scientific Data, Vol.10 (2023), Article no. 303

International Conference on Learning Representations - ICLR 2023

Proposal-Contrastive Pretraining for Object Detection from Fewer Data

Quentin Bouniot, Romaric Audigier, Angelique Loesch and Amaury Habrard.

As part of the 11th ICLR held in 2023 in Kigali, Rwanda, our Data Intelligence team presented their latest work on unsupervised contrastive representation learning for frugal object detection. The article was ranked amongst the top 25% of the papers presented at the conference. This work considers the problem of object detection where the goal is to predict the localization and class of each instance of objects in an image. An unsupervised pretraining method for transformer-based detectors using a fixed pretrained backbone, called Proposal Selection Contrast (ProSeCo), is presented. The proposed approach helps achieving better performance when fine-tuning the model with fewer training data afterwards. ProSeCo makes use of two copies of the detection model following a student-teacher framework. The aim is to alleviate the discrepancy between features used for pretraining by maintaining copies of the whole detection model. The first one is referred to as the teacher model in charge of the object proposals embeddings, and is updated through an Exponential Moving Average (EMA) of the second copy, the student model, making the object predictions. This latter network is trained by a contrastive learning approach leveraging the high number of object embeddings that can be obtained from the detectors. The idea is to move closer pairs of embeddings of sufficiently similar predictions for a same object in the image (positive pairs), while pushing away pairs of embeddings of different objects (negative pairs). In addition to the absence of batch normalization in the architectures, working directly with the large number of object embeddings obtained from transformer-based detectors reduces the need for a large batch size. The contrastive loss commonly used in pretraining is further adapted to take into account the locations of the object proposals in the image, which is crucial in object detection. Furthermore, the localization task is independently learned through a separate regularization task using region proposals generated by the Selective Search algorithm.

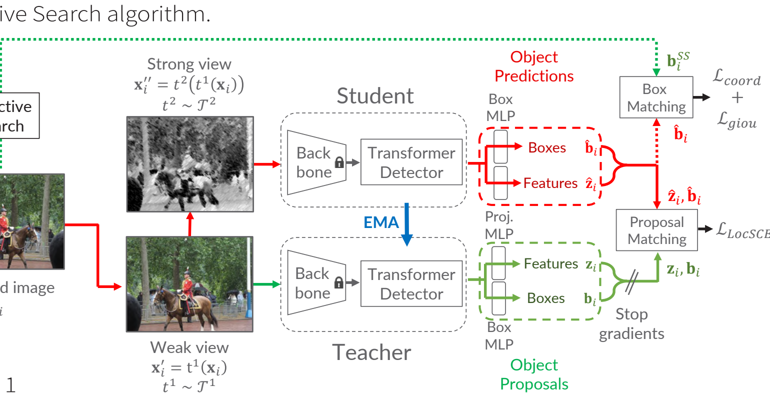


Figure 1

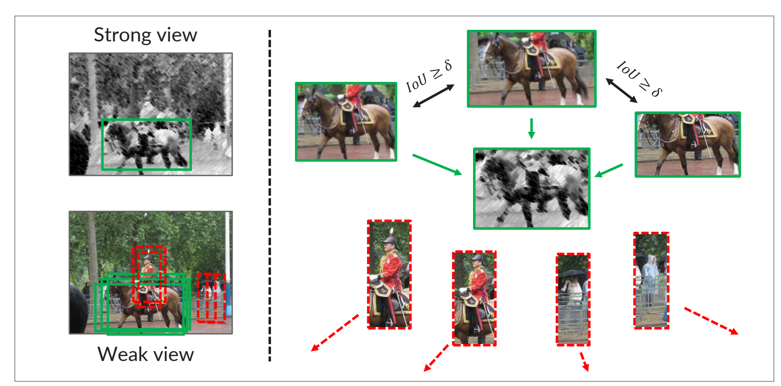


Figure 2

Figure 1: Overview of the ProSeCo method for unsupervised pretraining. The «coord» and «giou» losses measure the adequation between the localization of the boxes; the LocSCE loss corresponds to the contrastive loss proposed in the paper. For each input image, K random boxes are computed using the Selective Search algorithm, and two different views are generated through an asymmetric set of weak augmentations $\mathcal{T}^1$ and strong augmentations $\mathcal{T}^2$. Then, object predictions are obtained from the student model for the strongly augmented view, and object proposals from the teacher model with the weakly augmented view. Finally, the boxes predicted by the student are matched with the boxes sampled from Selective Search to compute the localization losses $\mathcal{L}_{coord}$ and $\mathcal{L}_{giou}$ and the full predictions are matched with the object proposals to compute our improved contrastive loss $\mathcal{L}_{LocSCE}$.

Figure 2: Illustration of the effect of the used localized contrastive loss. Predictions of the student and teacher models are contrasted with each other according to their localization and similarity to leverage the large number of object embeddings obtained from transformer-based detectors. To introduce the object locations information, overlapping proposals (in green) in each weak view, according to an Intersection over Union (IoU) threshold δ, are also considered as positive along with the matched proposal. Proposals that neither match nor overlap the matched proposal are considered as negative (in red) in the contrastive loss.

Table 1 below:
Performance (mAP in %) when finetuning the pretrained models on the Mini-COCO benchmark.

Pretraining	Detector	Mini-COCO		
		1% (1.2k)	5% (5.9k)	10% (11.8k)
Supervised	Def. DETR	13.0	23.6	28.6
SwAV[5]	Def. DETR	13.3	24.5	29.5
SCRL[6]	Def. DETR	16.4	26.2	30.6
DETReg[7]	Def. DETR	15.9	26.1	30.9
Supervised	Mask R-CNN	–	19.4	24.7
SoCo*[8]	Mask R-CNN	–	26.8	31.1
ProSeCo (Ours)	Def. DETR	**18.0**	**28.8**	**32.8**

The Eleventh International Conference on Learning Representations, 2023.

The 2023 ACM Web Conference

Wikidata as a seed for Web Extraction

Kunpeng Guo, Dennis Diefenbach, Antoine Gourru and Christophe Gravier.

The Web Conference (formerly WWW Conference) is an annual international event around the topic of the World Wide Web's future directions. Its 2023 edition was an opportunity for our Data Intelligence team to present a new Web extraction framework for improving the quality of KG graphs.

Wikidata is known to be one of the largest knowledge graphs (KGs) in the world, with over 17 billion triples about various topics to date. In April 2023, it counted more than 254-million-page views across 3 million different devices all over the world. As a KG with such high popularity, it receives each month over 20 million edits from its active editors and contributors. However, the Wikidata KG is still far from complete. For instance, only 2% of newspaper entities in Wikidata have their «publisher» information filled. A high-quality KG such as Wikidata is beneficial to people's daily life applications and NLP down-stream tasks. This work aims to contribute to the completeness of Wikidata KG, by leveraging the diverse Web data and proposing a «WebExtractor» framework which automatically extracts new facts from websites, and later contribute them to the Wikidata KG.

The process is as follows:

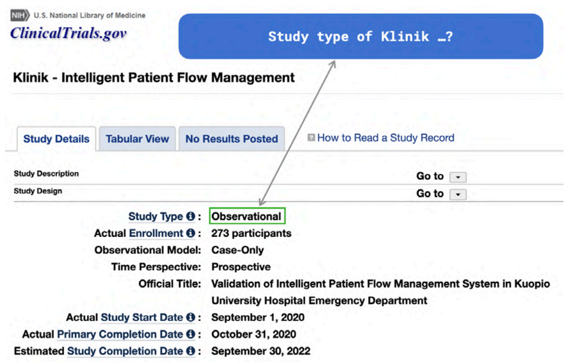
- On Wikidata, there is a special data type called «external identifier», which will point to external data sources e.g. Linkedin Profile, ORCID, Google Scholar ID. These are presented in formats ranging from structured or semi-structured to un-structured.
- We cast the problem to locate useful information to an extractive question-answering problem.
- By examining the interconnections between the triples on the Wikidata KG and the data presented on the website, the researchers collect training data to build the neural-network model to understand the structure of the website, and further grasp the pattern to locate the information they are looking for.

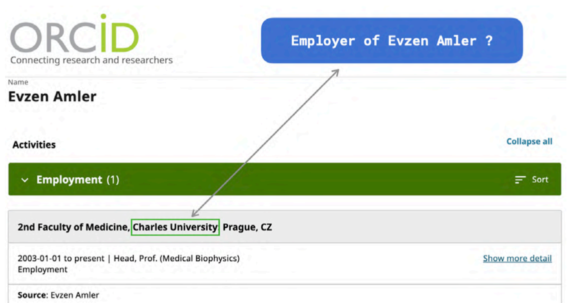
To conclude, the proposed WebExtractor framework is a one that uses Wikidata as a seed to extract facts from the Web. The team has shown that the use of QA technologies allows to - with distant supervision - generate extractors for website domains connected to Wikidata, in order to aggregate knowledge across the Web. Despite handcrafted extractors, QA extractors can:

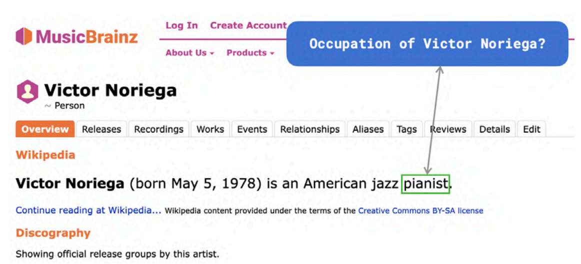
1. be trained using the data already present in Wikidata, and without any human intervention,
2. extract content present between HTML tags, but also exploit the natural language understanding capabilities of language models to extract more fine-grained information.

The experiments show how this technique performs under different training data scenarios. In full-trained settings, the researcchers can achieve high performances. Moreover, the Roberta-Base-WebExtractor model fine-tuned for Web extraction can also achieve good performances for few-shot and zero-shot scenarios.

Illustrations below:
Top: Web extraction from a well-structured field
Centre: Web extraction from a semi-structured field
Bottom: Web extraction from an unstructured field







WWW '23: Proceedings of the ACM Web Conference 2023, April 2023, pp. 2402–2411

European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases- ECML PKDD 2023

Is my Neural Net driven by the MDL Principle?

Eduardo Brandao, Rémi Emonet, Amaury Habrard, Francois Jacquenet, Marc Sebban and Stefan Duffner.

A paper by our Data Intelligence team was presented at Europe's top Machine Learning and Data Mining conference, held in Turin, Italy, from 18th to 22nd September 2023.

New data often traces out regularities found in past observations. In the context of supervised machine learning we learn to model these regularities by minimizing some loss function, and evaluating it on observed and unobserved data. The difference between risk in the training data and new observations is known as the generalization gap, and measures the quality of our model. If it is small, the model has found regularities - learned - in a way that is consistent with available data but which also apply to data that we are yet to encounter. Sufficiently complex models with a large number of parameters can find regularities in any data, and even in random noise! The generalization gap can be shown to increase with model complexity and in order to reduce it, we control model complexity through a form of regularization by explicitly reducing the number of model parameters, or e.g. using techniques such as dropout or batch normalization. Surprisingly, neural networks (NN) trained by stochastic gradient descent (SGD) generalize well despite possessing a higher number of parameters than training data, even without explicit regularization. An elegant explanation for this is that SGD implicitly controls model complexity during learning, resulting in networks that are simpler than their number of parameters suggests. It is therefore puzzling that NN classifiers trained by SGD are able to perfectly fit pure random noise, even while explicitly using regularization. In pure random noise, there is no signal to learn a rule from, and to reduce the generalization gap we must reduce *training performance*. Since common regularization methods are unable to achieve this, using them to control model expressiveness does not address generalization: as famously stated in Zhang et al., we need to «rethink generalization».

To do so we offer the following insight: to learn, from noisy observations, regularities that apply to data that we are yet to encounter, we must do so in a noise insensitive way: we must learn from signal rather than from noise. This can be stated in terms of a minimum description length principle (MDL), a principle of model selection proposed by Rissanen which is a formalization of Occam's Razor. It states the problem of learning from data in terms of finding regularities that we can use to compress it: *choose the model that provides the shortest description of data, comprising the model itself.*
Our novel formulation addresses conceptual difficulties in MDL, using both the signal and the noise in the training data, to implicitly define model complexity unambiguously:
Choose the model whose representation of the data can be used to compress the signal, but not the noise.
This statement has a significant impact on the distribution of the singular values of the point Jacobian matrices of a NN. Networks that learn from noise maximize singular values in arbitrary directions, in order to capture the fake «signal» in local directions. As a result, the spectrum is uniformly distributed. On the other hand, NN that learn from signal but not from noise tend to capture local regularities in the signal by maximizing singular values in directions aligned with the data. In the limit of infinite epochs, this results in a spectrum distributed according to a power law, with a large proportion of small singular values and a fat tail.
We were able to propose a capacity metric based upon Our MDL principle, which is generally applicable to learned representations, and we gave experimental evidence that neural networks are indeed driven by the MDL principle. Future research could contribute to a deeper understanding of the MDL principle, its implications for neural networks and its connection to generalization in machine learning.

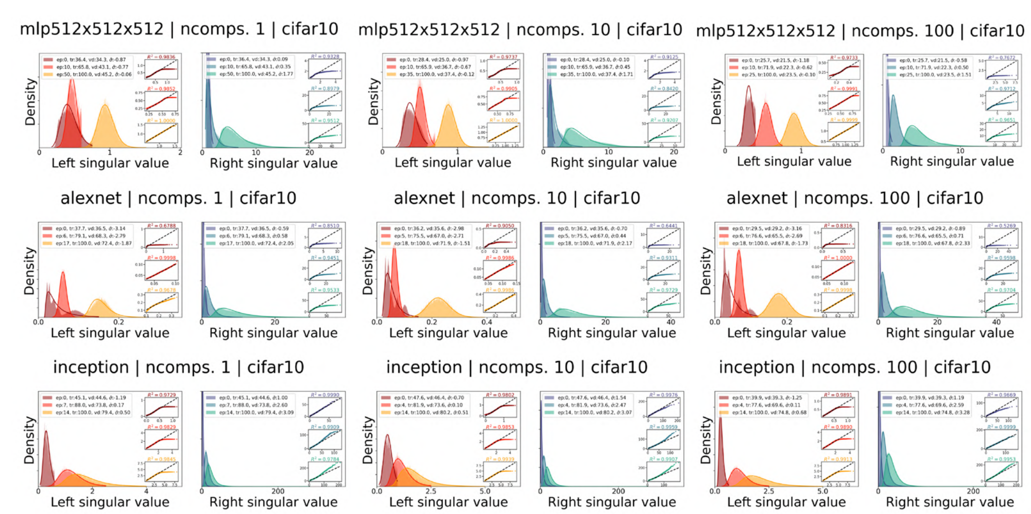


Figure left:
Model point Jacobian spectral distributions as a function of label noise, from first epoch to overfit, with best fit lognormal plot superimposed on each histogram, and corresponding probability plots and lines of best fit on the right.

ECML-PKDD, European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases, 2023

European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases- ECML PKDD 2023

Pattern Mining for Anomaly Detection in Graphs: Application to Fraud in Public Procurement

Lucas Potin, Rosa Figueiredo, Vincent Labatut and Christine Largeron.

A paper was presented by our Data Intelligence team at the ECML PKDD 2023 conference, pursuing the group's work on the subject of fraud detection in public procurement.

In this paper, the team presents a new general supervised framework that relies on pattern extraction to detect anomalous graphs in a collection of attributed graphs where nodes, as well as links, are characterized by attribute values. The researchers demonstrate how this new framework, called 'PANG', can be used to detect frauds in public procurement when coupled with a classical supervised classifier such as SVM, by applying it to a public procurement database (FOPPA). In this application, which motivated the team's framework, the presence of many missing values for red flags prevents from accurately identifying fraud directly from tabular data. The experiments confirm that the use of graphs enables to overcome this problem. They also show that a clear advantage of this approach lies in the explicability of the discriminative patterns that can be associated with human behaviors and thus interpreted, as in cases such as favoritism.

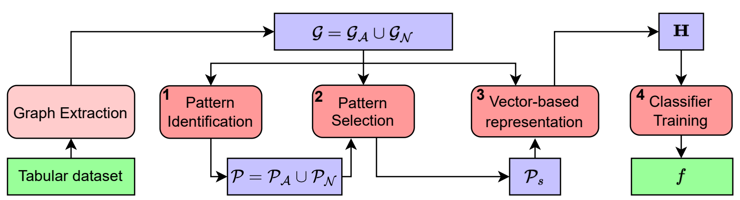


Figure 1: Framework of PANG

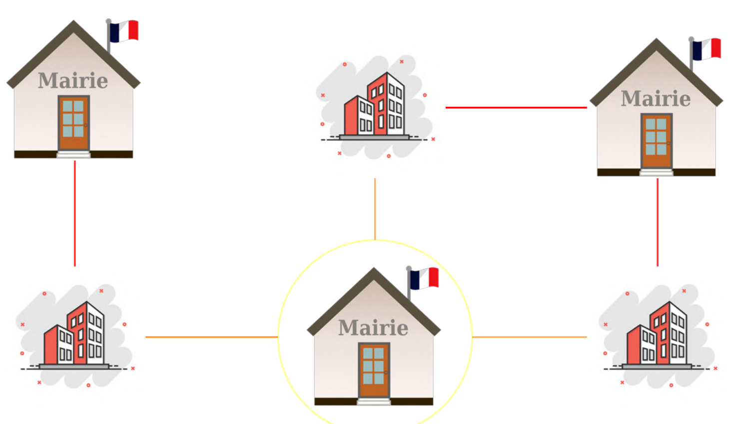


Figure 2: Application to fraud detection in public procurement

ECML-PKDD, European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases, 2023

Machine Learning

A General Framework for the Practical Disintegration of PAC-Bayesian Bounds

Paul Viallard, Pascal Germain, Amaury Habrard and Emilie Morvant.

A paper by our Data Intelligence team that was published in October 2023 in the journal Machine Learning was presented at ECML PKDD 2023, Europe's top Machine Learning and Data Mining Conference. The paper introduces new theoretical guarantees regarding the performance of machine learning models. For example, we can imagine training a machine learning model to recognize if an image contains a cat or a horse; see Figure 1. However, training the model on the learning sample doesn't ensure its accurate recognition of novel images it hasn't previously encountered. This problem is known as the generalization phenomenon; see Figure 2. The paper presents new theoretical guarantees for estimating the number of errors the model makes on new instances. Specifically, the authors establish guarantees for machine learning models trained through a learning algorithm containing internal randomness. In this context, the team proves theoretical guarantees referred to as "disintegrated PAC-Bayesian bound" with the following structure (see Theorem 2 in Figure 3 for a complete formal example):

$$\textit{Errors on new examples}(\text{model}) \leq \textit{Errors on the learning sample}(\text{model}) + \textit{complexity}(\textit{algorithm's randomness}).$$

Depending on the term "complexity", these bounds are interesting as they provide an estimate of the model's error count on new examples (which is unknown since we don't know future examples ...).
Indeed, computing "*Errors on the learning sample*(model) + complexity(algorithm's randomness)" provides the maximal number of errors the model can make on new examples. The originality of this paper lies in its departure from previous works that rely on "PAC-Bayesian bound" depending on all possible randomness a learning algorithm can include. After proving these theoretical guarantees, the team derived new learning algorithms aimed at obtaining a machine learning model with good theoretical guarantees, i.e., models with a low number of errors on new examples (according to the "disintegrated PAC-Bayesian bound"). Notably, the authors conducted experiments on neural network models.

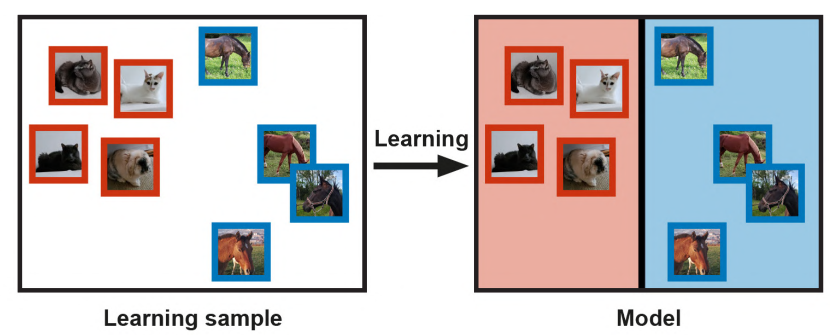


Figure 1, left: We start with a learning sample constituted of images, each labeled either as a "cat" (framed in red) or as a "horse" (framed in blue).
Then, the goal is to learn a model that recognizes an image by assigning to it a label (i.e., "cat" or "horse"). To recognize an image, the model checks if the image is in a red or a blue area. If an image is in a red area, the model assigns the label "cat" and when a image is in the blue area, the model assigns the label "horse".

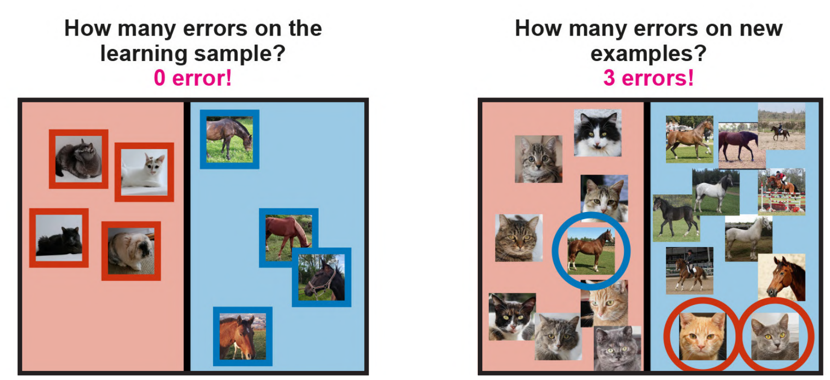


Figure 2, left: Illustration of the generalization phenomenon. While the model makes no error on the learning sample, it is possible that it does not recognize correctly new examples (i.e., new images).

Figure 3, right: Illustration of a bound that we derived in the paper.

Theorem 2 (General Disintegrated PAC-Bayes Bound) *For any distribution $\mathcal{D}$ on $\mathcal{Z}$, for any hypothesis set $\mathcal{H}$, for any prior distribution $\mathcal{P} \in \mathcal{M}^*(\mathcal{H})$, for any measurable function $\phi: \mathcal{H} \times \mathcal{Z}^m \to \mathbb{R}_+^*$, for any $\alpha > 1$, for any $\delta \in (0, 1]$, for any algorithm $A: \mathcal{Z}^m \times \mathcal{M}^*(\mathcal{H}) \to \mathcal{M}(\mathcal{H})$, we have*

$$\underset{\mathcal{S}\sim\mathcal{D}^m, h\sim\mathcal{Q}_\mathcal{S}}{\mathbb{P}}\left(\frac{\alpha}{\alpha-1}\ln(\phi(h,\mathcal{S})) \leq \frac{2\alpha-1}{\alpha-1}\ln\frac{2}{\delta} + D_\alpha(\mathcal{Q}_\mathcal{S}\|\mathcal{P}) + \ln\left[\underset{\mathcal{S}'\sim\mathcal{D}^m}{\mathbb{E}}\ \underset{h'\sim\mathcal{P}}{\mathbb{E}}\left(\phi(h',\mathcal{S}')^{\frac{\alpha}{\alpha-1}}\right)\right]\right) \geq 1-\delta,$$

Mach. Learn., Vol. 113, (2024), pp. 519-604

ISPRS Journal of Photogrammetry and Remote Sensing

End-to-End Learned Early Classification of Time Series for In-Season Crop Type Mapping

Marc Rußwurm, Nicolas Courty, Rémi Emonet, Sébastien Lefèvre, Devis Tuia and Romain Tavenard.

The International Society for Photogrammetry and Remote Sensing publishes a monthly journal that serves as a communication channel for scientists and professionals working in disciplines involving photogrammetry, remote sensing, spatial information systems and computer vision. In 2023, our Data Intelligence team published a paper which presents a deep time series classification model applied to satellite images, offering early predictions while enhancing their accuracy.

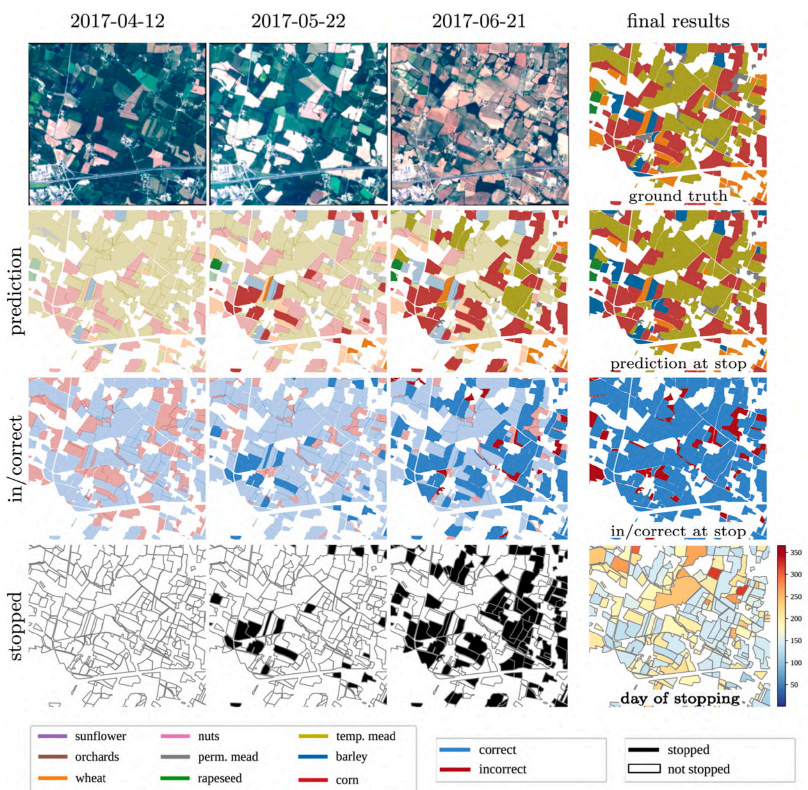
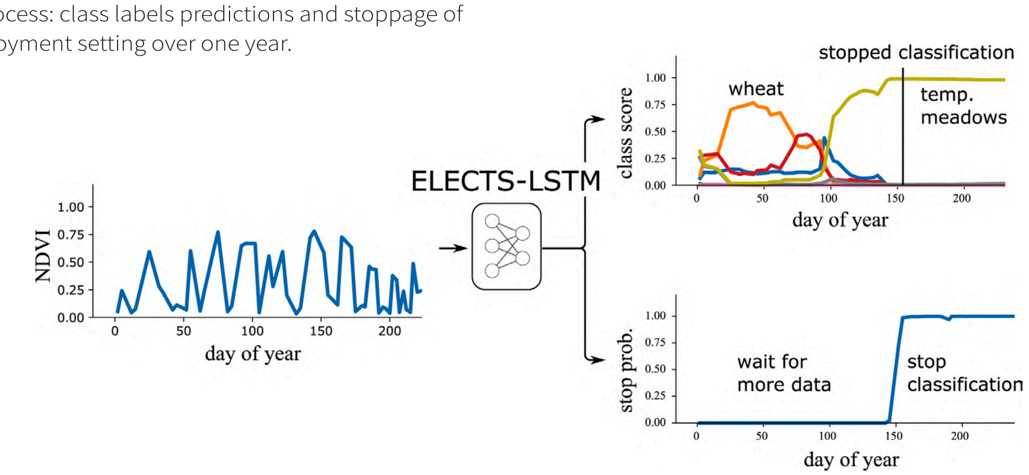


Figure 1 above:
llustration of the model process: class labels predictions and stoppage of individual fields, for a deployment setting over one year.

Machine learning is widely used for making predictions, including in the context of time series data. As a practical example, we can consider the classification of crop types for large-scale agricultural monitoring and yield prediction. From yearly multi-spectral satellite images it is indeed possible to predict the type of crop cultivated in a given field, information that is particularly useful for post-hoc statistics and analysis. A less common machine learning task consists in "early classification" of time series, where the objective is not only to make an accurate prediction (here of the crop type) but also to make it as early as possible. For instance, a rapeseed (colza) field will exhibit a strong yellow color during its flowering phase, typically occurring from April to mid-May. The prediction of the crop type can therefore be made early and accurately, so that the automated system can be used not only for post-hoc analysis but also for continuous monitoring and early decision making.

In this article, we introduce a generic approach for early time-series classification. Our method builds on any existing sequential model, and augments it so that it learns to predict, at each time step, both a class distribution and a stopping probability. This stopping probability can be viewed as a measure of the model's confidence. We evaluate and illustrate the effectiveness and efficiency of our approach using existing crop classification datasets.

Figure 2 below:
Illustration of the ELECTS method



Conference on Empirical Methods in Natural Language Processing EMNLP 2023

Fair Text Classification with Wasserstein Independence

Thibaud Leteno, Antoine Gourru, Charlotte Laclau, Rémi Emonet and Christophe Gravier.

A paper by our Data Intelligence team was presented at the 2023 Conference on Empirical Methods in Natural Language Processing, held in Singapore in December 2023. Discussions during this event revolved around Large Language Models and the Future of NLP, whilst our team's presentation focused on bias and fairness of such models.

One of the major challenges that has emerged in both academic and industrial research concerns the fairness of automatic models such as large language models, i.e. their ability to prevent predictions related to individuals from being based on sensitive attributes, including gender and ethnicity. In this article, we focus on the problem of fairness in the domain of Natural Language Processing (NLP).

While many studies already report biases in NLP systems, these issues become even more significant with the advent of publicly-ready AI-powered NLP systems such as ChatGPT or Google Bard, making the need for fair NLP solutions even more compelling. This paper presents a novel method for mitigating biases in neural text classification. Considering the difficulty of distinguishing fair from unfair information in an NLP model, we take inspiration from adversarial training to induce Wasserstein independence between representations learned to predict our target label and a «demonic model» that predicts some sensitive attribute. Our proposition overcomes a major shortcoming of prior studies: it does not rely on the availability of sensitive attributes (e.g., gender) at training time, a constraint that is more compatible with recent regulations such as the new European ones, which enforce more stringent requirements for the collection and utilization of protected attributes.

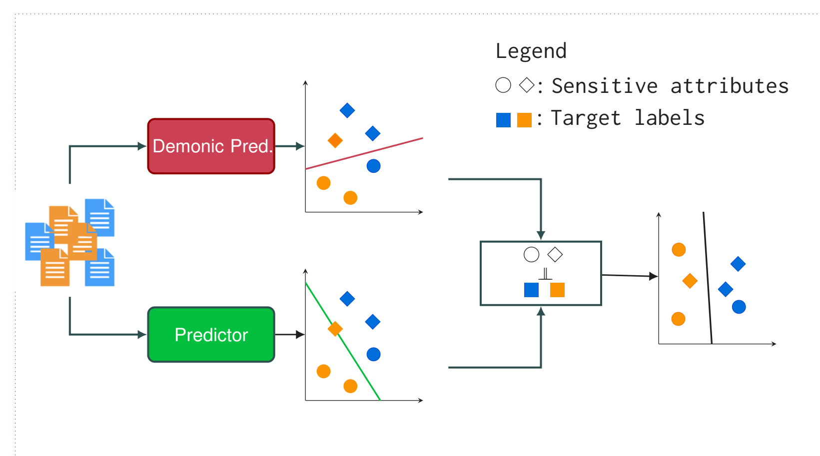


Figure above:
Our method, called "WFC", modifies the representation space of documents so that it becomes fairer when training a classifier on top.
To achieve this, it makes it independent of a ''demonic'' model that predicts the sensitive attribute.

IEEE International Symposium on Hardware Oriented Security and Trust, HOST 2023

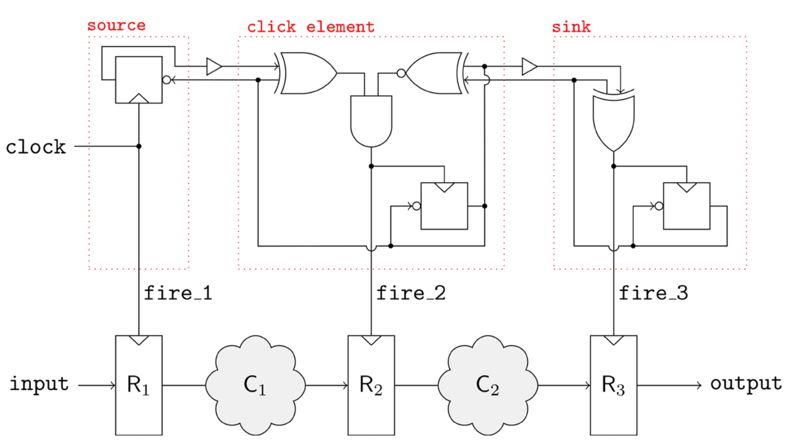
Low-Latency Masking with Arbitrary Protection Order Based on Click-Elements

Mateus Simões, Lilian Bossuet, Nicolas Bruneau, Vincent Grosso, Patrick Haddad and Thomas Sarno.

The IEEE HOST Symposium is an international event that aims to facilitate the rapid growth of hardware-based security research and development. For this paper on hardware countermeasure against side-channel attacks, first author and member of our SESAM team Mateus Simões received the conference's Best Student Paper Award.

In collaboration with STMicroelectronics, the team has studied architectural solutions to improve the latency of masking countermeasures. Indeed, side-channel attacks represent a threat to electronic systems designed to manipulate encrypted data. This class of security exploit allows an adversary to obtain sensitive information by observing the physical properties of a cryptographic device. In this manner, side-channel traces such as power consumption and electromagnetic emanation can be statistically analyzed to reveal secret data - e.g. the cipher key. To avoid side-channel attacks, various countermeasures exist. Masking, the most relevant among these solutions, splits secret data into several random shares, rendering more complex to predict the side-channel behavior of a cryptographic device.

Despite its sound formal proof of security, implementing a secure masking scheme is not a straightforward task. To satisfy different design and security properties, an effective masking raises the latency of masked modules, i.e. the number of clock cycles needed to finish processing the data. In addition, the protected design requires higher area overhead due to the increase of the implementation complexity. However, with the increasing proliferation of IoT devices, secure low-latency and area-efficient cryptographic modules become necessary to satisfy commercial demands. In this context, the work proposes a generic approach to design low-latency and area-efficient masking, built upon the asynchronous hardware design methodologies. This hardware design methodology uses the so-called click element (see Figure 1), to produce local clock pulses, triggering its correspondent register at the appropriate time, and eliminating the need of a global clock signal within the data path. To meet the timing requirements of a given circuit, the adaptive delay matching technique is applied (see Figure 2) to synthesize the masked designs, achieving single-cycle evaluation of complex cryptographic functions with low implementation overhead.



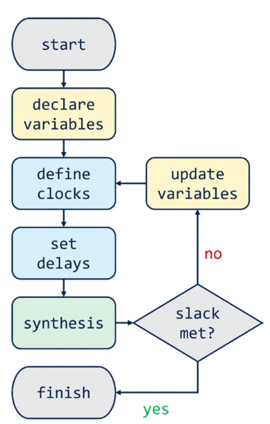


Figure 1 above:
A simple pipeline with click elements.

Figure 2 above:
Synthesis flow with adaptive delay matching process.

2023 IEEE International Symposium on Hardware Oriented Security and Trust (HOST), San Jose, CA, USA, 2023, pp. 36-47

Constructive Side-Channel Analysis and Secure Design, COSADE 2023

Punctured Syndrome Decoding Problem

Vincent Grosso, Pierre-Louis Cayrel, Brice Colombier and Vlad-Florin Drăgoi.

Every year since 2010, the Constructive Side-Channel Analysis and Secure Design (COSADE) workshop provides an international platform for researchers, academics and industry participants to present their work on Side-channel analysis (SCA) and implementation attacks. An article by members of our SESAM team was presented during the two-day workshop that took place in April 2023 in Munich.

On a daily basis, newspapers report new breakthroughs in quantum computing, further increasing the likelihood of constructing a large-scale quantum computer in the coming years. These computers threaten the security of classical cryptographic algorithms, so much that the European Union Agency for Cybersecurity encourages all private data-sensitive technologies to start considering mitigation to quantum-resistant cryptographic solutions. The "Post-Quantum Cryptography" competition, initiated by the National Institute of Standards and Technology, aims to select cryptographic algorithms resistant to the quantum threat.

This competition not only allows the development of cryptanalysis techniques but also encourages research on implementing post-quantum algorithms on constrained devices. In this context, it has become essential to evaluate the physical security of implementation in constrained devices (post-quantum cryptography and physical security are two topics studied by our SESAM team). As part of this work, we have developed a new attack path by melding techniques from the physical security realm (mainly T-statistic) and the post-quantum cryptanalysis realm (mainly Information set decoding algorithm). Our approach allows us to present more efficient attacks than the current state of the art for large register microcontrollers and noisier cases.

This work was done in collaboration with Vlad-Florin Dragoi from the University of Arad, Romania, and within the framework of the PEPR Quantique. It was funded by a French national grant managed by the Agence Nationale de la Recherche - ANR (project PQ-TLS reference ANR-22-PETQ-0008) through the France 2030 program.

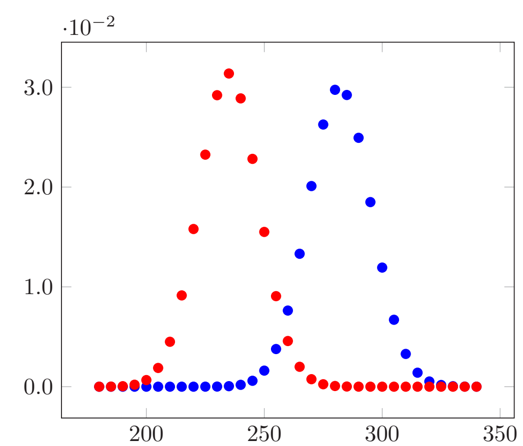
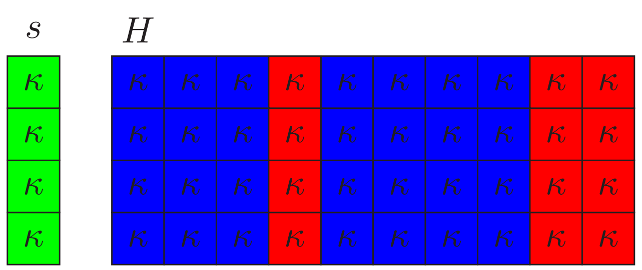


Figure left:
By analyzing the behavior of the device, we found that the distributions of the intermediate results varied depending on the secret value (zero and different from zero).
We needed a rule to select non-zero values, as the final result is not affected by a secret value of zero.

Figure below:
The selection of blocks of columns that have an impact on the final result allows us to reduce the problem by puncturing, and thus reduce the size of the matrices.



14th International Workshop on Constructive Side-Channel Analysis and Secure Design, Cosade 2023, April 3 - 4, 2023, Munich, Germany

IACR Transactions on Cryptographic Hardware and Embedded Systems (TCHES)

Enhancing Quality and Security of the PLL-TRNG

Viktor Fischer, Florent Bernard, Nathalie Bochard, Quentin Dallison and Maciej Skórski.

The Laboratoire Hubert Curien's SESAM team has released an article in TCHES, a journal/conference hybrid publication model highlighting new results in the design and analysis of cryptographic hardware and software implementations. The journal is published by the Ruhr-University of Bochum.

Cryptographic systems rely on the generation of true random numbers for many use cases, such as keys, masks or single-use numbers (nonces). As the building block of cryptographic security, true random number generators (TRNG) must provide a high-quality and secure randomness. A typical TRNG consists of an entropy source (analog noises such as thermal noise in electronic devices) and a digitization mechanism of this source, aimed at producing true random bits.

In order to assess the quality of the generator, observing the random sequence produced by the TRNG and using some battery of black-box statistical tests is insufficient. Modern certification schemes such as the BSI AIS-31 in Europe require a deeper understanding of both the entropy source and the digitization mechanism, and ask for a stochastic model of the TRNG.

In this paper, published in the most relevant conference in our domain (CHES: Cryptographic Hardware and Embedded Systems), we study the use of phase-locked loops (PLL) in FPGA as a source of randomness, and present an improved design of a PLL-based TRNG. We significantly improve the theoretical model of the TRNG, by thoroughly validating the model assumptions and by conducting an unprecedented study of the sampling correlations. We also add new embedded security tests that rely on a multi-bit resolution. These tests and their thresholds are based on the improved stochastic model and can be embedded in the device to analyze the source of randomness in real-time, with higher reliability and faster detection time of any loss of entropy. This study meets the requirements of the new and demanding AIS31 certification scheme. The BSI will include this work as a reference in the future AIS-31 evaluation guideline. Furthermore, because we value reproducibility in experimental science, we have shared all our raw data as well as all necessary scripts for data processing, figure generation and model computations on a public GitHub. Reviewers have commended this effort and have been able to explore the model further. We have also received recognition from the conference committee through their «Best Artifact» award.

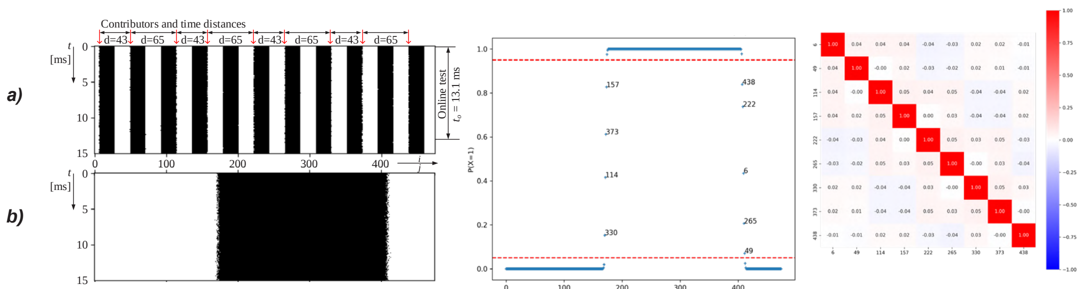
Illustrations below

Evolution of KD samples
a) before and b) after reordering to obtain the image of period T1 during 15 ms, black pixels are bits equal to one, white pixels are bits equal to zero

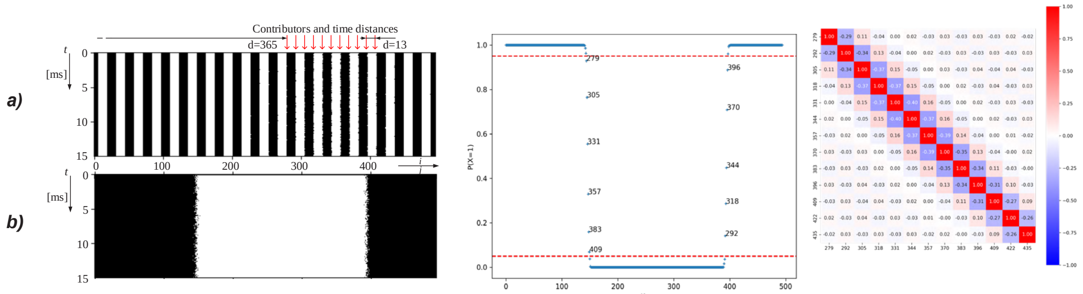
Reconstruction of period T1 with indices i of random bits in the period TP within the Spartan 6 device, for each configuration

Correlations between random bits within the pattern period, in the Spartan 6 device S6_1

1) Configuration B: a "good" spread of random bits reduces correlation



2) Configuration C: a "bad" spread of random bits with high correlation



IACR Transactions on Cryptographic Hardware and Embedded Systems, Vol. 2023, Issue 4 (2023), pp. 211-237.

IEEE International Conference on Physical Assurance and Inspection of Electronics (PAINE 2023)

X-Ray Fault Injection in non-volatile memories on Power OFF devices

Paul Grandamme, Lilian Bossuet and Jean-Max Dutertre.

Since 2018, the International Conferences on Physical Assurance and Inspection of Electronics (PAINE) gather researchers and practitioners in the field of Hardware Security and Trust to share ideas and solutions to make electronics devices and systems safe and secure. An article by members of our SESAM team was presented by doctoral student Paul Grandamme during the 2023 edition of the conference that took place in Huntsville, Alabama, USA.

In embedded electronic circuits, all permanent data are stored in non-volatile memories such as Flash or EEPROM. Data can be firmware, cryptographic algorithms or keys, access rights, etc. Their security is therefore very important. Such memories are known to be sensitive to fault injection attacks. For many years now, new means of fault injections have been developed (laser or electromagnetic injections, clock or voltage glitches, etc.). The aim of these attacks is to obtain sensitive information or twist the component from its nominal operation. Almost all of the attacks in the state of the art were carried out on power ON devices.

In this paper, we flip bits stored in non-volatile memories of power OFF devices by X-Ray exposure. We enhance an exponential dependency between the Total Ionizing Dose and the number of errors injected in the memories. An explanation of the physical phenomenon according to the fault model is also proposed. This attack could be an original attack vector in hardware security.

The experiments were carried out with the kind collaboration of Sylvain Girard and Adriana Morana of our MOPERE team. The work is funded by the Agence Nationale de la Recherche within the framework of the ANR POP project (ANR-21-CE39-0004).

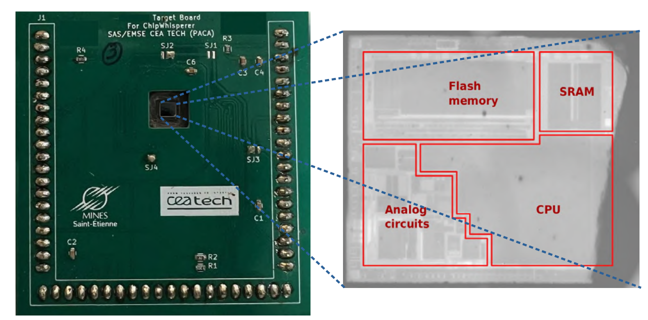


Figure 1 above:
Left: 32-bit microcontroller target mounted on a custom board and prepared for backside access.
Right: Infrared image of the DUT.

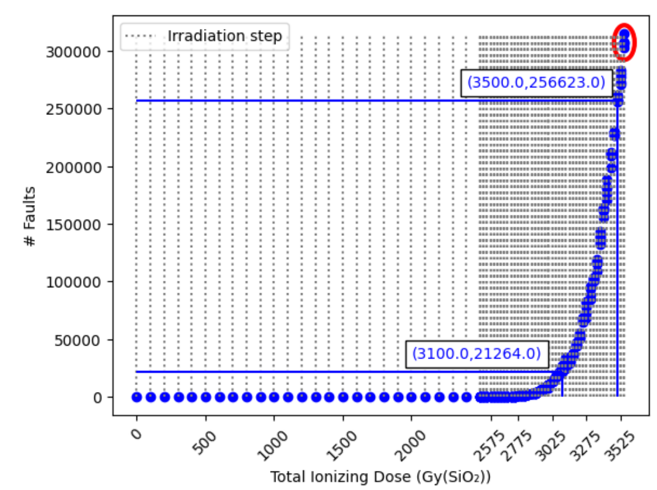


Figure 2 above:
Evolution of the number of faults in the Flash memory during X-Ray irradiations. Each blue dot corresponds to a Flash memory acquisition.

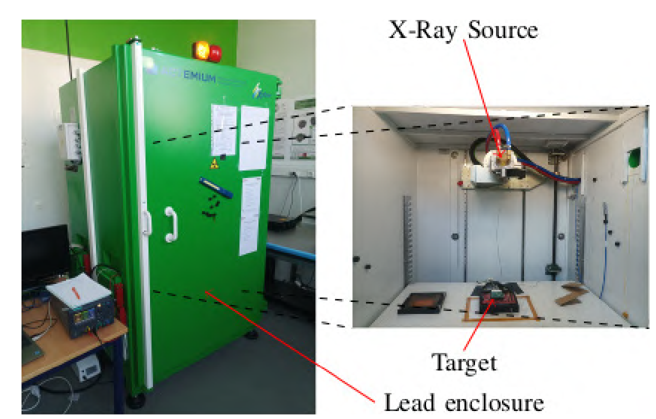
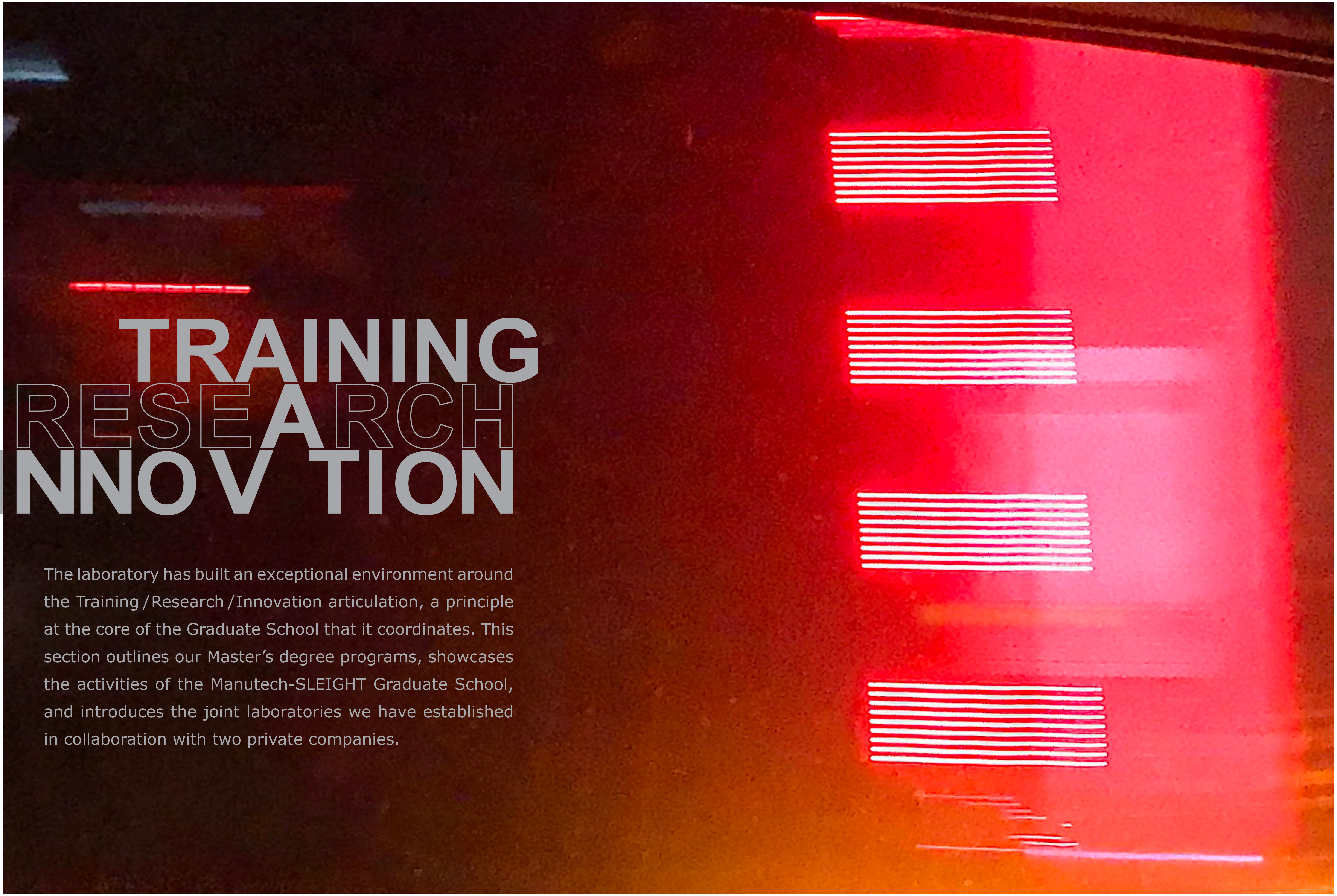


Figure 3 above:
Picture of the irradiator

PAINE, IEEE International Conference on Physical Assurance and Inspection of Electronics, Huntsville, AL, USA, 2023



TRAINING
RESEARCH
INNOVATION

The laboratory has built an exceptional environment around the Training / Research / Innovation articulation, a principle at the core of the Graduate School that it coordinates. This section outlines our Master’s degree programs, showcases the activities of the Manutech-SLEIGHT Graduate School, and introduces the joint laboratories we have established in collaboration with two private companies.

Our related Master's Degrees

Our lab's researchers manage 9 master tracks as part of 2 master degrees of the University Jean Monnet (Faculté des Sciences et Techniques), including 4 Erasmus+ and several international courses. The programs developed as part of these degrees cover all scientific thematics of the lab's research activities. Our local partners include the Manutech-SLEIGHT Graduate School, the Institut d'Optique Graduate School, the Ecole Centrale de Lyon, the Université de Lyon and the Ecole des Mines de Saint-Etienne.

Master Degree in Optics, Image, Vision, Multimedia (OIVM) - Head: Nathalie Destouches

The MSc in Optics, Image, Vision, Multimedia (OIVM) is a unique master program offering 6 specialisation tracks including 4 Erasmus Mundus Joint Master Degrees - EMJMD. This master program seeks to shape the future of industrial and academic experts in optics, photonics, surface engineering, image, material appearance, imaging technologies, spectral imaging, security, reliability, safety and radiation effects. All courses are taught in English.

IPSRS - Intelligent Photonics for Security Reliability Sustainability and Safety
(applying for the 2024 EMJM call) - **Coordinator: Nathalie Destouches (Hubert Curien Lab)**
iPSRS is an innovative program at the intersection of Artificial Intelligence and Photonics. It focuses on Security, Reliability, Sustainability, and Safety across various sectors including Healthcare, Electronics, Communication, Defense, Aeronautics, Agri-food, Space, Transport, Mobility, AR/VR, Civil Engineering and Photovoltaic. This leading-edge master program provides future leaders in intelligent photonics with the knowledge, skills and experience needed to thrive in this dynamic and innovative field.

RADMEP - Radiation and its Effects on Micro Electronics and Photonics Technologies (EMJMD)
Coordinator: Sylvain Girard (Hubert Curien Lab)
The multidisciplinary and innovative RADMEP's program covers the interactions between Radiation & MicroElectronics and Photonics, two Key Enabling Technologies for the future of Europe.
RADMEP's objective is to educate students in those advanced technologies, providing methodologies and introducing practical applications for their implementation in a variety of natural or man-made radiation-rich environments.

COSI - Computational Colour and Spectral Imaging (EMJMD)
Local coordinator: Alain Trémeau (Hubert Curien Lab)
This master course aims at training the next generation of highly-skilled industrial experts in applied colour science, in various cutting-edge industries (photonics, optics, spectral imaging, multimedia technologies, computer graphics and vision) and in a diverse range of sectors (including multimedia, healthcare, cosmetic, automotive, agri-food). The two areas of focus are spectral technologies and applied colour imaging.

IMLEX - Imaging and Light in Extended Reality (EMJMD)
Local coordinator: Philippe Colantoni (Hubert Curien Lab)
This multidisciplinary program combines the topics of image conversion, lighting and computer science. Its objective is to train future experts who, in addition to acquiring a solid theoretical understanding of virtual reality, will also develop strong practical skills for virtual reality applications. IMLEX students benefit from a combined European and Japanese expertise in research related to virtual reality and robotics.

AIMA - Advanced Imaging and Materials Appearance: Metrology and modelling (International track)
Coordinator: Mathieu Hébert (Hubert Curien Lab)
The Advanced Imaging and Material Appearance: Metrology & Modelling - AIMA track focuses on imaging. It encompasses physical principles of image formation, imaging technologies, image analysis, digital image processing and image reproduction by printing. It also includes the appearance of materials and other specific imaging applications such as document security. The aim of the program is to provide sufficient knowledge and skills to start a career as an engineer or a researcher in these fields.

PE - Photonics Engineering (International track)
Coordinator: Emmanuel Marin (Hubert Curien Lab)
The Photonics Engineering's program is based on fundamental, practical and in-depth courses at the interface between optics, photonics and computer science. It provides a progressive specialisation training enabling future professionals to develop a research-engineering activity in the sectors related to applied physics, optics, photonics, fiber optic sensors, surface structuring by laser at micro & nanometric scales, modelling & optical, physical & mathematical characterisation of surfaces, structured interfaces, etc.

Faculté des Sciences et Techniques
Saint-Étienne

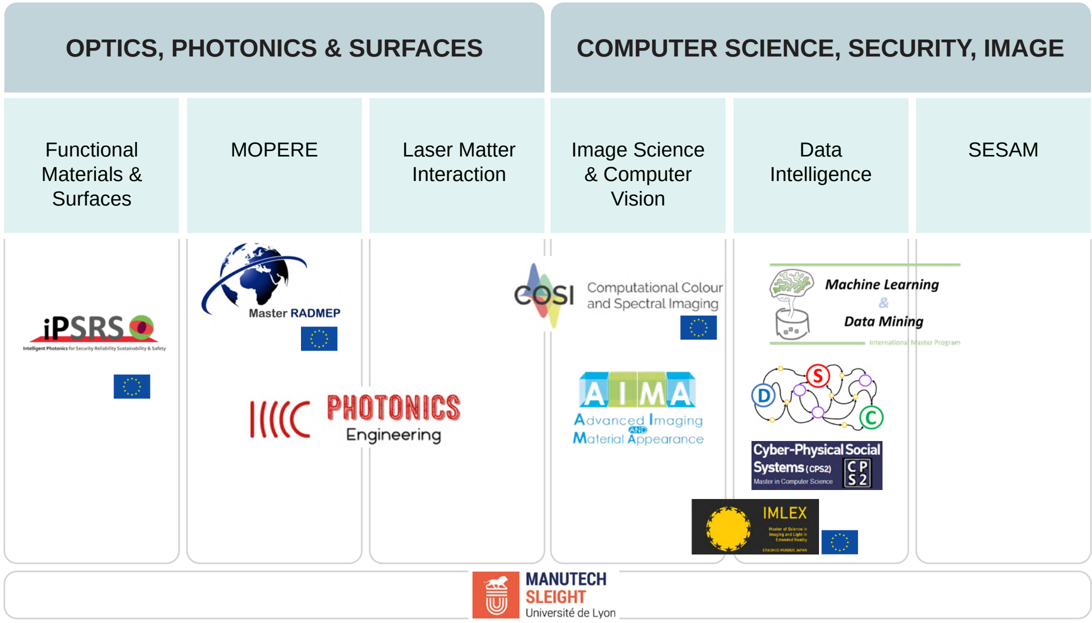
Master Degree in Computer science - Head: Amaury Habrard (Hubert Curien Lab)

The MSc in Computer Science offers 3 specialisation tracks mainly taught in English. The programs are designed to train students specialised in Artificial Intelligence (AI) and Information Technology (IT), and prepare them for careers in both academic research and R&D for private companies.

MLDM - Machine Learning Data Mining (International track)
Coordinators: Amaury Habrard & Marc Sebban (Hubert Curien Lab)
The MLDM master's degree holds a unique scientific position in Europe concerning issues related to machine learning, big data, pattern recognition, classification, modelling, knowledge extraction, and data mining. These topics offer strong employability potential for students trained in data science, prediction, data analysis, decision support, as well as in areas such as the Web, image and video processing, health informatics, fraud and anomaly detection, etc.

CPS2 - Cyber-Physical Social Systems (International track)
Coordinators: Pierre Maret (Hubert Curien Lab), Maxime Lefrançois (Ecole des Mines de Saint Etienne)
The aim of this program is to provide students with a triple expertise on technologies and methods to design and integrate intelligent cyber-physical systems at the interface of the physical, social and digital dimensions of our environments (Technological, Functional, Scientific). Topics taught in CPS2 are related to the Internet of Things, Web and mobile applications, Artificial Intelligence, Cloud and Edge Infrastructures, Digital Twins, Cyber-security, Scientific Writing.
Application domains include Industry 4.0, Smart Cities, Smart Buildings, Intelligent Transport Systems.

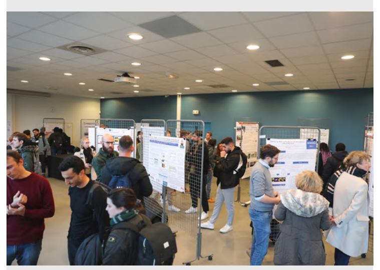
DCS - Data and Connected Systems (national track 50% French 50% English)
Coordinators: 1st year: François Jacquenet (Hubert Curien Lab), 2nd year: Baptiste Jeudy (Hubert Curien Lab) & Antoine Zimmerman (Ecole des Mines de Saint Etienne)
The objective of the DSC track is to train specialists capable of responding to the problems of data massification and the interconnection of computer systems and communicating objects linked to the current digital metamorphosis (Web, Internet of Things, big data) by mastering the processing chain from raw data to its analysis, as well as its use in interconnected intelligent systems. Mainly aiming to train computer scientists, part of the teaching offers advanced courses in algorithms, programing and project management.



The Manutech-SLEIGHT Graduate School

MANUTECH SLEIGHT Université de Lyon

The Manutech-SLEIGHT Graduate School provides an attractive research-integrated program, offering a unique environment for training and for cross-disciplinary research in the domain of Surfaces Light EngIneerinG Health and socieTy (SLEIGHT). The School is coordinated by the Université de Lyon and managed by our lab. A total of 44 projects have been funded by Manutech-SLEIGHT so far, including 25 Ph.D. theses, focusing on the interface of surface science (material physics, mechanics, surface engineering), light (optics-photonics, laser engineering), image and data sciences (machine learning, data mining, AI), biology, and medicine.



© Jean Monnet University

Scientific excellence

The ambitious program is structured around 3 scientific objectives:

- Predict and experiment light-induced surface modification processes
- Extract full information and meaning from surface imaging through an integrated chain of skills
- Foster a decisive technological leap in engineering and control of light-induced or light-monitored surface modification effects

The Graduate School offers a unique environment for researchers who wish to undertake ambitious and transdisciplinary research projects, responding to major societal issues of the 21th century.

Top-level training

Manutech-SLEIGHT offers graduate programs promoting interdisciplinary cross fertilisation (international master programs, engineering schools and Ph.D. programs) within a very pleasant learning environment.

3 MASTER'S DEGREES / 9 MASTER TRACKS
2 ENGINEERING SCHOOLS' RESEARCH TRACKS
2 DOCTORAL SCHOOLS

«Science, Engineering, Health» Doctoral School (ED 488 SIS)
«Mechanics, Energetics, Civil engineering, Acoustics» Doctoral School (ED 162 MEGA)

TOPICS
Surface Engineering, Optics-Photonics, Material physics & Mechanics, Image & data Science, Bio-engineering

190 scientists
100 Ph.D. students involved

A multidisciplinary consortium of 8 research labs working on Light - Surfaces Engineering

Over 300 students involved in graduate programs including 50% of international students

3 Master programs with 9 tracks including 4 Erasmus Mundus Joint Master Degrees
"Research tracks" of 2 Engineering schools
2 Ph.D. Schools

A DYNAMIC ECOSYSTEM
The innovation clusters Minalogic, CIMES & Novéka
The FrenchTech ONE LYON ST ETIENNE
PULSALYS (Technology Transfer Office)

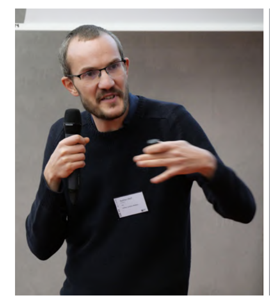
Twice a year, the School organises the «SLEIGHT Science Events» (SSE). During these, scientists and students can meet, interact, discuss their progress as well as their ambitions. The events include lectures from international guests, workshops, pitch and poster presentations, Ph.D. and post-doc sessions, thesis defenses and social events.

The Manutech-SLEIGHT Graduate School brings together a consortium of 12 public and private partners located in the Lyon/Saint-Étienne area, including 7 academic institutions (Universities, Engineering Schools), 2 national research organisations and 3 economic stakeholders, with the main goal to weave links between education and research.

Manutech-SLEIGHT Science Event #9

9th to 13th January 2023

The Manutech-SLEIGHT Graduate School held its 9th scientific event at the begining of January 2023, gathering more than 200 participants around the topic of light-surface engineering.
This winter edition allowed students, young scientists, academic and private researchers from the Graduate School's consortium to discover the state of research in physics, optics-photonics, laser engineering, materials science, image science, data science, mechanics and bioengineering. The 5-day event included lectures by 4 renowned international guest speakers. As usual, specific sessions were dedicated to presentations by Master and Ph.D. students, Post-doctoral fellows (Pitch and Junior Scientists sessions), and by all members of the SLEIGHT community (Poster session).
Thomas Labardens, then a Ph.D. student at the LNE-CNAM (supervisor: G. Obein) and the Hubert Curien Laboratory (Supervisors: M. Hebert and P. Chavel), successfully defended his thesis on the subject of «Appearance metrology: effect of speckle on high angular resolution BRDF measurements».



The guest speakers of this 9th edition were:

- Aurélien CRUT (Institut Lumière-Matière (UCBL, CNRS) - Lyon)
  Vibrational and cooling dynamics of metal nanoparticles: experimental investigations and modeling
- Florence TUPIN (LTCI, Télécom Paris, Institut Polytechnique de Paris)
  SAR (Synthetic Aperture Radar) imaging: principle, applications, and a focus on deep learning approaches for speckle reduction
- Olivier MARTIN (EPFL – Suisse)
  Plasmonic nanostructures: fabrication and applications (Parts 1 and 2)
- Alessandro RIZZI (Dipartimento di Informatica - Università degli Studi di Milano - Italy)
  Why vision is spatial and why we cannot measure color or spectrum if our device has a lens

The «Pitch session awards» went to Vanina Amblas and Alexandre Bebon (IOGS and OIVM-AIMA master track students) for their presentation on «Exploring the optical properties of the stained-glass windows in Conques Abbey by Pierre Soulages», and by Marie Traynar (OIVM-Photonics Engineering master track student) for her presentation on «Colloidal photolithography for the fabrication of metasurfaces».
The «Best Poster awards» were attributed to Ana Florencia Juarez Saborio, doctoral student in our lab and at the Institut Lumière Matière of Lyon for her presentation on «Deterministic Graphene folds through Ultrafast Laser Nanotexturization», and to Sébastien Charles, Ph.D. student at the SAINBIOSE lab, for his presentation on «Extracellular vesicles circulating in blood of multiple myeloma patients: an innovative detection».

The Manutech SLEIGHT Graduate School

Manutech-SLEIGHT Science Event #10

3rd to 6th July 2023

The Manutech-SLEIGHT Graduate School's 10th Science Event was held in July 2023, under the topic of Sustainable Surface Engineering. Scientists and industry experts in development of surfaces for solar technologies and hydrogen mobility presented the progress of their research during this four-day event.

Talks by 5 guest speakers addressed the subjects of surface topology, coating structures, surfaces architecture optimization, fabrication and characterization, as well as their tribologic properties in relation to energy dissipation. A specific session, chaired by Franck Simon of the CIMES Hub (Creation of Integrated MEchanical Systems), welcomed industry experts Bertand Nicolet from HEF Group and Jacques Pourcher from Sofiplast who presented case studies related to the event's main topic. Yoan Di Maio, R&D Engineer at the GIE Manutech USD, shared his experience on the sustainable benefits of femtosecond laser processing for industrial and scientific applications. An entire day dedicated to surface development for hydrogen mobility was organised in partnership with AFM-AUM (Association Française de Mécanique - Association Universitaire de Mécanique), and the doctoral schools MEGA and MATÉRIAUX (University of Lyon).

Former Hubert Curien lab's Ph.D. student Julie Dutems successfully defended her thesis on the subject of «Thin passive film characterization by surface plasmon resonance». Her research project «COUPLES» was funded by the Manutech-SLEIGHT Graduate School.

Pascal Giraud, also PhD student in our lab, was awarded a prize for his presentation on "Plasmonic optical switch for hydrogen detection for very low concentration", as part of the Young Scientists Session.

The guest speakers of this 10th edition were:

- Audrey Soum-Glaudes (PROMES Laboratory, CNRS)
  Solar thermal technologies: engineering optically efficient and durable surfaces
- Philippe Voarino (INES Institute - CEA, Université Savoie Mont-Blanc)
  Is concentrator photovoltaics (CPV) a solution to make photovoltaic energy even more sustainable?
- Alain Fave (INL – INSA Lyon, CNRS)
  Photovoltaic solar cells: present and future.
- Döme Tanguy (ILM – UCBL, CNRS)
  Hydrogen in metals : influence on mechanical properties.
- Jean-Jacques Greffet (Laboratoire Charles Fabry - Institut d'Optique Graduate School, CNRS, Université Paris-Saclay)
  Controlling light emission and absorption with metasurfaces.

Télécom Saint-Etienne
The Jean Monnet University's Engineering School

Télécom Saint-Etienne is a public engineering school specializing in digital technology. In its 2024 ranking of engineering schools, «L'Etudiant» website positioned the school as the top French school in Optical and Photonics Engineering, and the 3rd among public engineering schools of the Auvergne Rhône-Alpes region in the field of computer science. Educating each year over 725 students, it is part of the Jean Monnet University and is affiliated with the Mines Telecom Institute. The majority of its students come from its integrated CITISE preparatory class (conducted in partnership with the Faculty of Science & Technology and the IUT of Saint-Etienne), as well as from preparatory classes to the "grandes écoles" (French higher education schools outside the university system), recruited through the Mines-Télécom competition. Teaching and research staff at the school come from its 3 supporting laboratories: Hubert Curien, Elico and the Camille Jordan Institute. Télécom Saint-Etienne and the Hubert Curien Laboratory are part of the local Télécom and Digital Society Carnot Institute, for their high-quality training in innovation and partnership-based research in engineering. The school also manages the Jean Monnet University's Use'In incubator, located at the Centre des Savoirs pour l'Innovation on the Manufacture campus.

The "Engineering training under student status" program

Télécom Saint-Etienne trains engineers in the field of digital technology, particularly in the scientific and technological areas of photonics, electronics, networks & telecommunications, imaging, and computer science.
After a common core year, the 360 students of this program are offered training in at least 2 of these domains (mono-thematic paths do not exist). Nearly 160 different companies interact annually with engineering students through internships, projects, conferences, and events organized at the school.

INSTITUT CARNOT
Télécom & Société numérique

The «Engineering training under apprentice status» program

Télécom Saint-Etienne offers 2 apprenticeship engineering programs over the course of a student's three years of training:

- The «Image & Photonics, Smart-Industry» apprenticeship engineering program, which has been training engineers in photonics and imaging for industrial applications for over 20 years (approximately 60 apprentices each year).
- The «Data Engineering» program, which meets the growing needs of industry in the data processing field, from capture to visualization, including software architectures, connected objects, and artificial intelligence (approximately 75 apprentices each year).

Upstream research for applied solutions

KEY FIGURES

24 **granted patents** between 2019 & 2023, including:
18 international term extensions

3 **patent applications filed** in 2023

10 international term extensions granted in 2023 alone

3 **startups created**

Keranova (incl. granted patent)
The QA Company
Dfinder

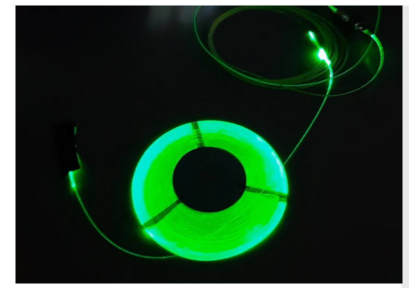
15 **companies using and/or developping our work**

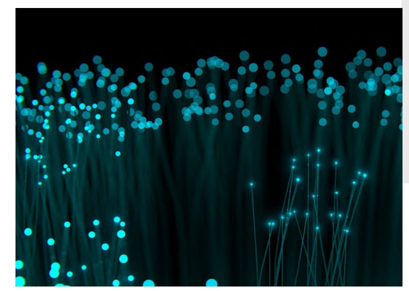
Keranova (incl. granted patent)
The QA Company (incl. granted patent)
Dfinder (incl. granted patent)
Newclin (incl. granted patent)
Aitenders
Kejako
Safehear
HEF Groupe (incl. granted patent)
Quantel (incl. granted patent)
bioMérieux
Michelin
Renault
Thales (incl. granted patent)
HID Global
Exail

2 **joint labs**

LabH6, with company Exail (ex-iXblue)
https://www.exail.com/

LAMCID, with company HID Global
https://www.hidglobal.com/



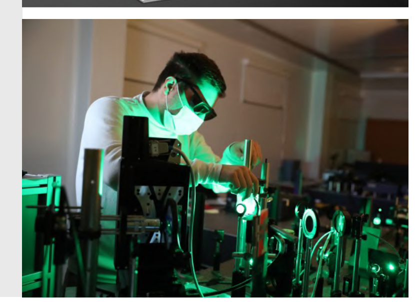


Our Materials for Optics and Photonics in Extreme Radiation Environments (MOPERE) team and the company Exail (formely IxBlue), designer and manufacturer of photonic devices, had been collaborating for many years before launching «LabH6», their joint research laboratory, in 2018. The objective was for this new framework to enable the industrial valorization of the research conducted by both parties. Owing to a strong complementarity of skills, the team has made significant progress on the study of special optic fibres in harsh environments with potential applications in the nuclear, space and health sectors. The successful collaboration has so far resulted in no less than 45 joint publications in international journals and 1 granted patent since 2018. LabH6 notably participated in the «Lumina project», developed under the CNES leadership and in partnership with the CERN Laboratory, which has led to the development of a fiber optic dosimeter that was sent in 2021 on board the International Space Station, as part of the European Space Agency (ESA) ALPHA mission.

exail labH6

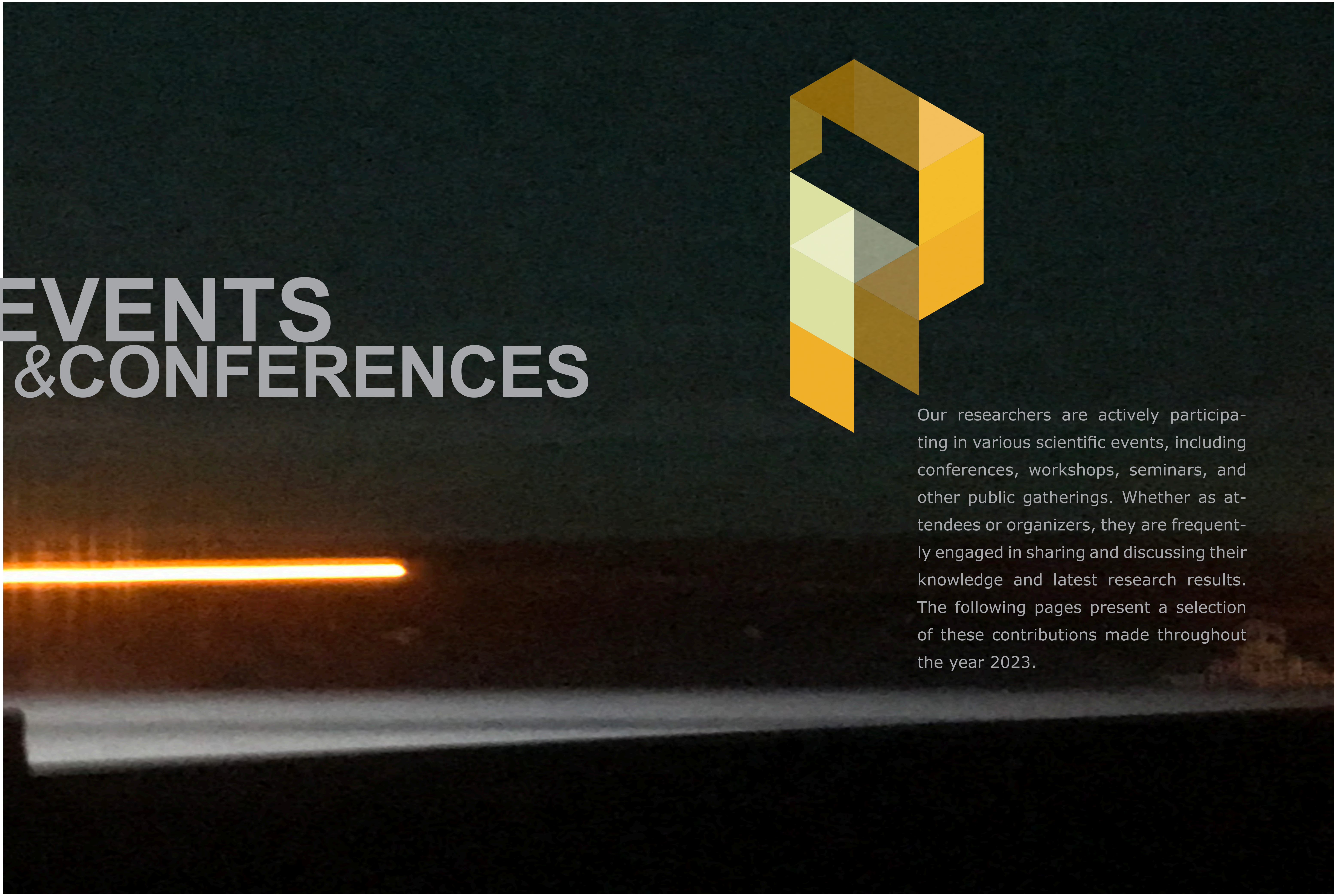
Laboratoire Hubert Curien
UMR • CNRS • 5516 • Saint-Étienne

LAMCID HID



The creation of the LAMCID joint lab in 2022 came to seal a long-term collaboration between our Functional Materials & Surfaces team and HID Global CID, a company specialised in the development and manufacture of ID documents. The partnership involves combining the Hubert Curien Lab's knowledge and expertise in various disciplines (laser- matter interaction, plasmonics, sol-gel, materials' appearance, science of colour, secure images, machine learning, laser micronanostructuring) with HID's industrial expertise in ID documents manufacturing, in order to secure their authenticity. The team is looking to further develop techniques for laser inscription of images on and inside polycarbonate substrates, exploring the implementation of multiplexed images printing as well as the non-multiplexed inscription of color images to create special visual effects.

Our LabH6 and LAMCID joint labs illustrate the way structured partnerships between academia and industry can drive innovation and advance technology.



EVENTS &CONFERENCES

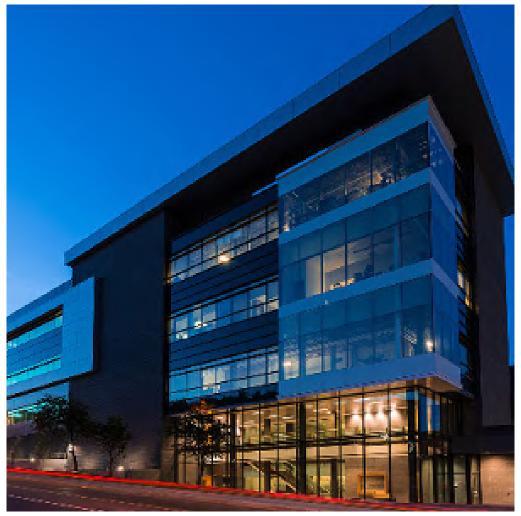
Our researchers are actively participating in various scientific events, including conferences, workshops, seminars, and other public gatherings. Whether as attendees or organizers, they are frequently engaged in sharing and discussing their knowledge and latest research results. The following pages present a selection of these contributions made throughout the year 2023.

CNRS IRP POLARIS inauguration

20th April 2023

In April 2023, the Hubert Curien Laboratory and the Photonics Research Centre of the University of Ottawa have inaugurated their CNRS International Research Project (IRP) POLARIS. The event took place at the Advanced Research Complex of the University of Ottawa, and was attended by our lab's Director Florence Garrelie and Jean-Philippe Colombier, coordinator of the IRP and member of our Laser-Matter Interaction team.

The new IRP aims to pursue cutting-edge fundamental research in photonics for surface and materials engineering, with potential applications in the fields of sensors, energy and security.
The project is structured around 4 axes, involving 3 different teams within our lab (Laser Matter Interaction, Functional Materials & Surfaces, MOPERE), each working on a specific subject but all seeking scientific and societal results. “Through these four axes, light will be exploited as a manufacturing process, a means of ultrarapid diagnosis, of biological detection and for communication purposes” explains Jean-Philippe Colombier. These are “topics where fundamental research is feeding into applications that will potentially be of strategic industrial interest in France and Canada” emphasises Pierre Berini.
POLARIS extends five years of productive scientific collaboration between the two laboratories. “Since 2018, several joint scientific development areas have been identified, based on the recognised expertise of the two labs in surface engineering, the ultrafast dynamics of ultrashort laser processes, the modelling of laser-matter interaction, plasmonics, sensors for harsh environments and 3D optical systems” says Florence Garrelie.
The CNRS IRP status of the project will facilitate student mobility between the two laboratories, extend the jointly supervised Ph.D. program that has already been initiated, and lead to several scientific publications in international conferences and journals.



Centre for Research in Photonics uOttawa

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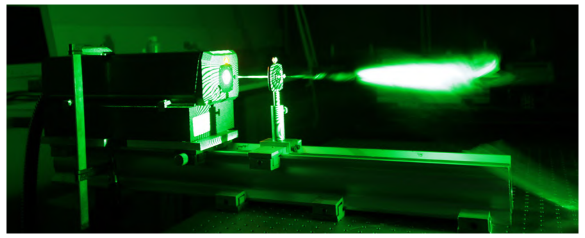
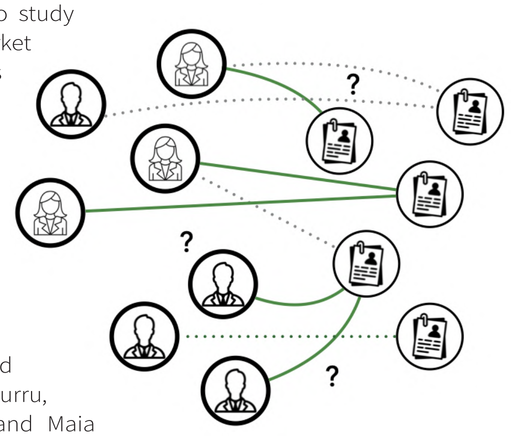


AI 4 HR & PES 2023

9th to 10th February 2023

The second AI 4 HR & PES - AI for HR and Public Employment workshop was held in February 2023 at Ghent University, Belgium. It gathered academics industry leaders and public employment agencies for discussions around the use of Artificial Intelligencel in their operations.

The AI 4 HR & PES workshop aims to study the way the contemporary job market and HR management's challenges can be addressed by means of data-driven solutions, enabling job seekers, employers, HR agencies, policy makers, training facilities or government agencies to achieve their goals.



Member of our Data Intelligence team Christine Largeron was part of the workshop's organising comittee and participated, together with Antoine Gourru, Charlotte Laclau, Manvi Choudhary and Maia Sutter in the the following seminars:

B. Audeh (InsaSoft), M. Sutter, C. Largeron:
- Unsupervised keyword extraction for job recommendation

M. Choudhary, A. Gourru, C. Laclau and C. Largeron:
- LEAVE: an End-to-End Variational Model for Fair Edge Prediction

CryptArchi 2023 Workshop

11th to 14th June 2023

The Hubert Curien Lab's SESAM team has organised a 19th CryptArchi Workshop, an event that took place at the University of Cantabria's International Center for Mathematical Meetings (CIEM) in Castro-Urdiales, Spain, in June 2023. The main topic of this workshop was related to cryptographic architectures embedded in logic devices, and security aspects of the use of modern logic devices in cryptography. The use of deep learning techniques to break cryptographic implementations was also addressed.

The objectives of the event were:
1. for participants to present their research activities's progress.
2. to discuss issues related to embedding cryptographic functions into modern logic devices (control and security aspects, architectural aspects, protocol-related aspects, key generation and key management aspects, attacks against implementations and countermeasures against attacks, neural networks and deep learning approach applied to DPA).
3. to put forward a structure for future logic devices or systems aimed at cryptographic applications.
4. to discuss problems related to the development of secure embedded cryptographic systems based on future logic devices.

ANIMMA 2023

12th to 16th June 2023

The 8th edition of the International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications took place in June 2023 at the Real Collegio in Lucca, Italy. The annual event brings together scientifics, academics and industrials involved in R&D related to nuclear instrumentation and measurement methods.

The head of our MOPERE team Sylvain Girard was part of the Scientific Committee, whilst numerous contributions were made by several of our researchers. Adriana Morana was appointed Associate Editor of the upcoming IEEE Transactions on Nuclear Science Journal's special issue, dedicated to the ANIMMA conference.

POSTER SESSION
Education, Training and Outreach

- «EMJMD RADMEP: Master on Radiation and Its Effects on Microelectronics and Photonics Technologies»; by Sylvain Girard.

POSTER SESSION
Research Reactors and Particle Accelerators

- «Confocal chromatic sensor prototype hardened at 400°C for future application in nuclear reactor»; by Marion Agoyan.

CONFERENCE SESSION
Fusion Diagnostics and Technology
Session chaired by Sylvain Girard.

CONFERENCE SESSION
Current Trends in Development of Radiation Detectors

- «Embedded Fiber-based Dosimeter For Drone Inspection in Radiation Environments»; by Sylvain Girard.
- «Potential of Germanophosphosilicate Single Mode Optical Fiber for Dosimetry»; by Cosimo Campanella.
- «Beam Profile Monitoring based on Radioluminescent Ce^{3+}-doped Silica-based Optical Fiber Material»; by Jeoffray Vidalot.

CONFERENCE SESSION
Decommissioning, Dismantling and Remote Handling

- «Single-Ended Mirror-Assisted Fiber Optic Dosimeter for Dismantling Applications»; by Adriana Morana

CONFERENCE SESSION
Research Reactors and Particle Accelerators

- «Online optical glass refractive index change measurement under irradiation»; by Marion Agoyan.

CONFERENCE SESSION
Severe Accident Monitoring

- «Study of Combined Radiation and Temperature Effects on Fs-void Fiber Bragg Gratings»; presented by Thomas Blanchet (CEA, Univ. Paris-Saclay); co-authors incl. Adriana Morana, Aziz Boukenter, Emmanuel Marin, Sylvain Girard and Youcef Ouerdane.

SiO_2 2023

12th to 14th June 2023

The 14th international symposium on Advanced Dielectrics and related Devices (SiO_2) took place last year at the Palazzo Chiaramonte-Steri in Palermo, Italy. The biennial event covers various topics, including Optical and electronic properties, Defect generation and transformation, Radiation effects, Dosimetry/sensors/radiation hardening, Micro-/nano-structuring, Fiber optics and fiber-based devices, Nanomaterials and nanocomposites for applications in electronics, photonics and optoelectronics.

Aziz Boukenter, Sylvain Girard and Youcef Ouerdane were once again part of the Scientific Committee, whilst several papers were presented by members of our MOPERE team:

CONFERENCE SESSION
Modeling
Session chaired by Youcef Ouerdane.

CONFERENCE SESSION
Dosimetry, sensors, radiation hardening

- «Optical fibres - some applications in radiative environments: sensors, dosimetry»; invited talk by Youcef Ouerdane.
- «Impact of a pre-irradiation on the radioluminescence performance of a Nitrogen-doped silica-based optical fiber»; by Fiammetta Fricano.
- «Thermoluminescence and Radioluminescence Processes in Sol-Gel Gd^{3+}doped silica glasses»; by Ismael Zghari (collaboration with our MOPERE team).

CONFERENCE SESSION
Radiation effects (including laser processing and harsh environments) I

- «Femtosecond tunable excitation pump in transparent materials: a new method to reveal the photocycle of point defects»; invited talk by Vincenzo De Michele.
- «X-ray radiation-induced changes on the infrared lifetimes of Er^{3+} ions»; by Alberto Facchini.
- «Photoluminescence of Germanosilicate Optical Fibers as a function of γ-ray Dose and Dopant Concentration»; by Roberto Pecorella.

The next SiO_2 symposium will take place in Saint-Etienne in 2025. The event will be organized by our MOPERE team.

EMRS 2023 Spring Meeting

29th May to 2nd June 2023

With its 20 to 25 topical symposia and about 2,500 attendees, the annual Spring Meeting organised by the European Materials Research Society (E-MRS) is widely recognized as the most important of its kind in Europe.

Last year, the meeting was held in Strasbourg, France, from 29th May to 2nd June. Several contributions were made by members of our laboratory, whilst a «Making light matter: lasers in material sciences and photonics» Symposium was co-organised by the head of our Laser- Matter Interaction team Razvan Stoian.

SESSION: Ultra-short and Ultra-high Power Laser Interaction with Matter - I

- «Time resolved mid-infrared absorption in silica: a new approach to study the electron-phonon coupling in glassy dielectric materials «; by Vincenzo De Michele.
- «Analysis of ultrashort laser-induced plasma anisotropy in Zinc Telluride, by using terahertz probe pulses»; by Daiwei Zhang.

SESSION: Laser Surface Texturing Applications Session chaired by Razvan Stoian.

- «Ultra-fast Laser texturing : A New Approach for Deterministic Graphene Folds»; by Ana Florencia Juarez Saborio.
- «Ultrashort laser-treated PVD ZrCu-based thin film metallic glasses, or how to switch the biological behaviour of surfaces from biocide to biocompatible?»; by Hugo Bruhier.

SESSION: Laser Additive Manufacturing - II

- «Pulsed laser deposited BN/VO_2/BN architectured films with thermochromic properties at low transition temperature»; by Florent Bourquard.

SESSION: Laser Surface Processing - I

- «Femtosecond Laser Induced Oxidation Mechanism on Tungsten Surfaces»; by Florence Garrelie.

LPM 2023

13th to 16th June 2023

The 24th International Symposium on Laser Precision Microfabrication was held last year in Hirosaki-city, Japan. The aim of this event is to provide a forum for discussions around fundamental aspects of laser-matter interaction and the state of the art in laser materials processing. Members of our Laser-Matter Interaction team attented the meeting, and presented their work as part of the symposium sessions.

SESSION: Fundamental aspects

- «Transient thermodynamic pathways in ultrafast volume laser nanostructuring; by Razvan Stoian.

SESSION: Modeling and Simulation

- «Dynamics of Cu-Zr metallic glass devitrification under ultrafast laser excitation revealed by atomistic modeling»; by Djafar Iabbaden.

SESSION: Micropatterning structuring and modification

- «Ultrafast laser induced chemical modification on Tungsten Surface»; by Priya Dominic.
- «On the Insignificant Role of the Oxidation Process on Ultrafast High-Spatial- Frequency LIPSS Formation on Tungsten»; by Priya Dominic.

NSREC 2023 Conference

24th to 28th July 2023

The Nuclear & Space Radiation Effects Conference is an IEEE annual event dedicated to radiation effects on electronic and photonic materials, devices, circuits, sensors and systems, as well as semiconductor processing technology and design techniques for producing radiation-tolerant (hardened) devices and integrated circuits.

Last year, the meeting was held in Kansas City, Missouri USA, where several members of our MOPERE team made the following contributions:

PAPERS:

- "Temperature Cycling Effects on Infrared Radiation-Induced Attenuation of Silica-based Optical ";
  incl. Martin Roche, Adriana Morana, Emmanuel Marin, Aziz Boukenter, Youcef Ouerdane, Sylvain Girard.
- "Influence of Hydrogen on the Radiation-Induced Attenuation of Ge-doped Optical Fiber";
  incl. Adriana Morana, Martin Roche, Emmanuel Marin, Aziz Boukenter, Youcef Ouerdane, Sylvain Girard.
- "Ultra-Large Silicon Solid-State Detector for Characterizing Low- Intensity Radiation Environments "; incl. Kacper Bilko.
- "Radiation Environment in the Large Hadron Collider During the 2022 Restart and Related RHA Implications";
  incl. Kacper Bilko, Sylvain Girard, Marc Sebban.

POSTER:

- "Mixed-Field Radiation Monitoring and Beam Characterization Through Silicon Solid-State Detectors"; incl. Kacper Bilko.

ECML-PKDD 2023 Conference
18th to 22nd September 2023

The European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases was held last year in Torini, Italy. This top machine learning and data mining event was attended by members of our Data Intelligence team, who made the following contributions:

- «Is my Neural Net driven by the MDL Principle?»
  incl. Eduardo Brandao, Rémi Emonet, Amaury Habrard, François Jacquenet, Marc Sebban.

- «Pattern Mining for Anomaly Detection in Graphs: Application to Fraud in Public Procurement»
  incl. Christine Largeron.

- «A General Framework for the Practical Disintegration of PAC-Bayesian Bounds»
  incl. Paul Viallard, Amaury Habrard, Emilie Morvant.

  As part of the conference, an AI 4 HR & PES -
  AI for Human Resources and Public Employment Services workshop was co-organised by Christine Largeron, with 5 presentations addressing the challenges of the contemporary job market and human resources management by means of data-driven solutions.

MNO 2023 Conference
19th to 21st September 2023

The Metallic Nano-Objects MNO conferences aim to provide an overview of recent advances and challenges in the development of metallic nano-objects and their applications. Last year, their International Workshop was held at the University of Technology of Troyes (UTT), France, from 19th to 21st September.

The MNO2023 workshop covered the topics of Ultrafast and nonlinear plasmonics, Enhanced light-matter interactions at the nanoscale, Metasurfaces and nanophotonics, Novel materials and technologies for plasmonics, Theoretical and numerical studies, Sensors and bioplasmonics, Plasmonic colors and Plasmonic devices. Members of our Functional Materials & Surfaces team Nathalie Destouches and Christophe Hubert were part of the workshop's scientific comittee, with Nathalie chairing the "Novel materials, synthesis and technologies for Plasmonics" session.

ICPEPA 12 Conference
18th to 22nd September 2023

With topics ranging from fundamental laser-material interactions, theory and modeling to applications with nanoparticles and nanophotonics as well as photoexcitations, the biennial International Conference on Photo-Excited Processes and Applications was held in September 2023 in Suzhou, China.

For this 12th edition, the head of our Laser-Matter Interaction team, Razvan Stoian, was invited to discuss the topic of "Micro and nanoscale dynamics of ultrafast laser refractive index engineering for 3D optical design", whilst our researcher Tatiana Itina also gave an invited talk on the subject of "Modeling of laser-induced modifications of nano-objects and nanocomposite materials".

RADECS 2023 Conference

25th to 29th September 2023

The RADiation and its Effects on Components and Systems Conference (RADECS) is the annual European scientific and industrial forum on radiation and its effects on electronics and photonic materials, devices, circuits, sensors and systems. This annual event took place this year in Toulouse from 25th to 29th September.

Sylvain Girard acted as Technical Program Chair for the conference, whilst various other members of our MOPERE research team made the following contributions:

CONFERENCE SESSION

- «Very High Dose Rate Proton Dosimetry with Radioluminescent Silica-based Optical Fibers»; incl. F. Fricano, A. Morana, C. Campanella, A. Boukenter, E. Marin, Y. Ouerdane and S. Girard.

POSTER SESSIONS

- "Radiation Detection with Radiosensitive Pure-Silica Core Ultra-Low Loss Optical Fiber"; incl. L. Weninger, A. Morana, C. Campanella, J. Vidalot, E. Marin, Y. Ouerdane, A. Boukenter and S. Girard.
- "Radiation Responses of Pure-Silica Core Multimode Optical Fibers in the UV to near-IR Domains at MGy Dose Levels"; incl. C. Campanella, A. Morana, E. Marin, Y. Ouerdane, A. Boukenter and S. Girard.
- "Temperature Effect on the Radioluminescence of Differently doped Silica-based Optical Fibres"; incl. N. Kerboub, A. Morana, Y. Ouerdane, A. Boukenter, E. Marin and S. Girard.
- "Simulation-assisted Methodology for the Conception of Fiber-based Dosimeters for a Variety of Radiation Environments"; incl. S. Girard, A. Morana, A. Meyer and J. Vidalot (presented by D. Lambert - CEA DAM)
- "Solar Particle Event Detection with the LUMINA Optical Fiber Dosimeter aboard the International Space Station"; incl. M. Roche, A. Morana, E. Marin and S. Girard.
- "CHARM High-energy Ions for Micro Electronics Reliability Assurance (CHIMERA)"; incl. K. Bilko, S. Girard and M. Sebban.
- "High-Energy Heavy Ion Beam Dosimetry using Solid State Detectors for Electronics Testing"; incl. K. Bilko (presented by A. Waets - CERN/Univ. of Zurich)
- "Characterization of Radio-Photo-Luminescence dosimeters under X-ray irradiation"; incl. M. Ferrari, A. Hasan, A. K. Alem and S. Girard (presented by S. Girard and Y.Q. Aguiar - CERN)

SSD20 Conference

17th to 22nd September 2023

Since 1995 the International Solid State Dosimetry Organization, ISSDO, promotes and assists in the organization of the triennial Solid State Dosimetry Conferences. Its 2023 edition was held in September in Viareggio, Italy.

Our MOPERE team member Matteo Ferrari attended the event and presented some of his recent research work related to Radio-Photoluminescence dosimeters, done in collaboration with CERN.

CONFERENCE SESSION
Monitoring & Detection II

- "On-line attenuation measurements of RPL dosimeters irradiated with X-Ray sources for high-dose applications."; by Matteo Ferrari.

RADOPT 2023 Workshop

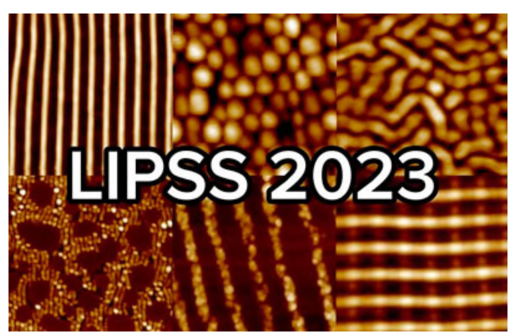
29th & 30th November 2023

The main objective of the Radiation effects on Optoelectronics and Photonics Technologies Workshop is to provide a forum for the presentation and discussion of recent developments regarding the use of optoelectronics and photonics technologies in radiation-rich environments. The second edition of this event took place at ISAE Supaéro in Toulouse last November, and was co-organised by Sylvain Girard, head of our MOPERE team. Opposite is a list of all contributions that were made by members of our lab.

- "Effects of 6 MeV Electron Radiation on Multi-colored Commercial LEDs"; and:
- "Spatially Distributed Radiation Detection based on a Radiosensitive Ultra-Low Loss Optical Fiber"; by Luca Weninger.
- "Overview of the Infrared Radiation Responses of Telecom-grade Single Mode Optical Fibers"; by Alexis Dufour.
- "Recent studies on Radio PhotoLuminescent (RPL) dosimeters"; by Matteo Ferrari.
- "Solar Particle Event Detection with the LUMINA Optical Fiber Dosimeter aboard the International Space Station"; by Martin Roche.

LIPSS 2023 Workshop

27th to 29th September 2023



The annual LIPSS Workshops are dedicated to the most recent advances and studies on Laser Induced Periodical Surface Structures formation mechanisms, considering a wide range of materials, and using various laser sources.

The 11th edition of this international event was held in Madrid in September 2023 with Florence Garrelie, Jean-Philippe Colombier, Xxx Sedao and Tatiana Itina as members of the workshop's scientific board committee. Three of our Laser-Matter Interaction team members also made the following presentations:

- "Key topographic parameters on surface adhesion of biological organisms"; by Xxx Sedao.
- "Understanding oxide formation on HSFL: the case of Tungsten"; by Florent Bourquard.
- "Changes in the wettability of femtosecond laser-textured Zr–Cu thin-film metallic glasses"; by Hugo Bruhier.

Labex Manutech-SISE seminar

12th and 13th October 2023

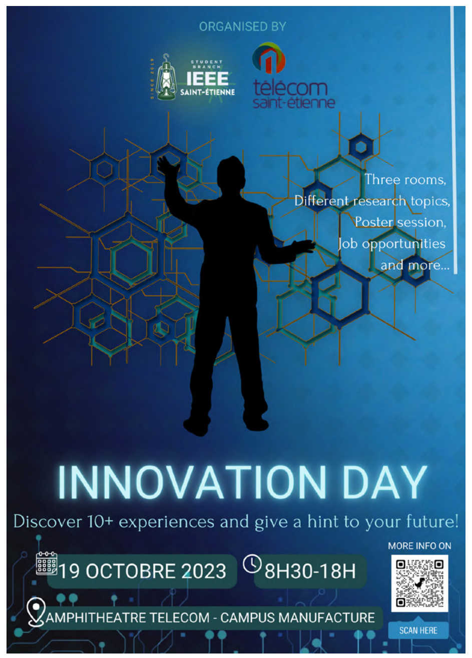
LABEX MANUTECH-SISE
UNIVERSITÉ DE LYON

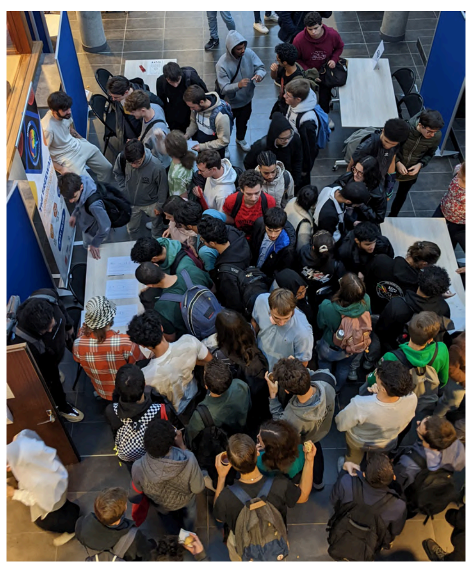
The Labex Manutech-SISE is a "Laboratoire d'Excellence" governed by the University of Lyon and coordinated by the Hubert Curien Laboratory. It constitutes a national and international reference in the science and engineering of surfaces and interfaces. The Labex is managed by Yves Jourlin, head of our Functional Materials & Surfaces team.

Every two years, Manutech-SISE organizes a seminar presenting the current state and ongoing projects of the Labex. The seminar provides the Labex community with an opportunity to meet and discuss research and training related to its current working themes, namely Design and Elaboration of Surfaces, Characterization of Surfaces and Interfaces, Multifunctional Surfaces, and Innovative Integrated Processes. The Labex's 2023 seminar took place on Thursday 13th and Friday 14th October, once again at the Château de Goutelas (Marcoux, Loire).
Several presentations were made by members of our lab, including Razvan Stoian, Vladimir Fedorov, Jean-Philippe Colombier, Huu Dat Nguyen, Daiwei Zhang, Ciro D'amico, Ninfa Del Carmen Lozano Rincon, Cyril Mauclair, François Royer, Gerges El Haber, François Goutaland, Christophe Donnet, Alexis Dufour, Damien Jamon, Emilie Laffont, Yves Jourlin, Léa Marichez, Francis Vocanson, Ilemona Sunday Omeje, Tatiana Itina, Emilie Gamet and Maxime Royon.
As with previous seminars, this edition has been rich in exchanges and the Labex is committed to renewing the experience!

The Saint-Etienne IEEE Student Branch Innovation Day

19th October 2023



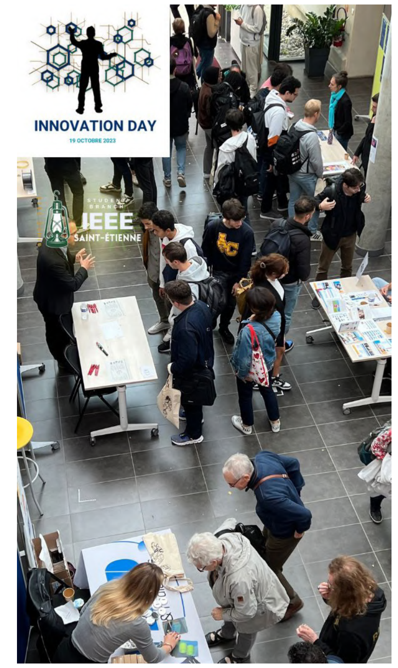


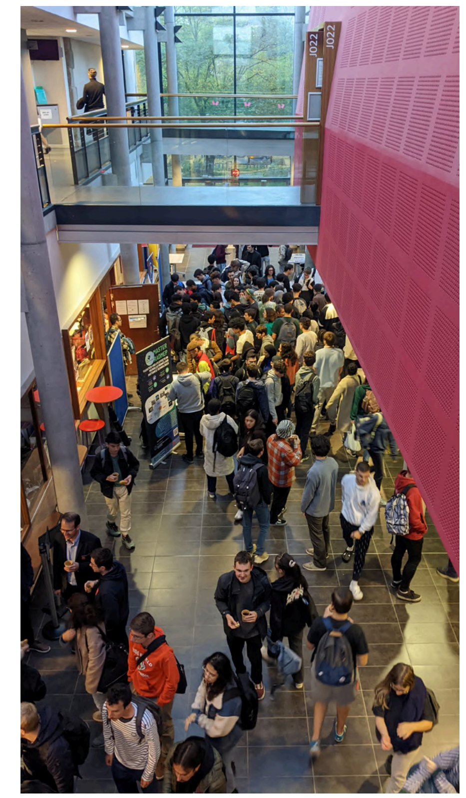
The Institute of Electrical and Electronics Engineers (IEEE) is a professional association for electronics engineering, electrical engineering and other related disciplines. With over 427,000 members in more than 190 countries, it is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity. In addition to publishing approximately 200 journals and more than 1,200 conference proceedings every year, the IEEE supports the establishment and operation of IEEE Student Branches worldwide. The activities of these branches may include organizing social events, planning speakers, conducting field trips, providing tutorials, and publishing newsletters.

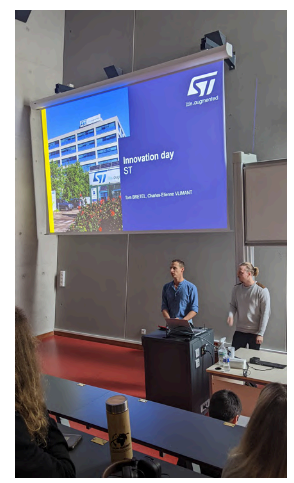
The Saint-Etienne IEEE Student Branch was founded in 2021 by Marine Aubry, former PhD student in our lab and now research engineer for TRAD-Tests & Radiations. Their most recent event, which was attended by over 300 engineering, doctoral, and Master's students, focused on the theme of Innovation and Research. The objectives were to raise an awareness of R&D among these students, introduce them to scientific conferences, and connect them with Innovation stakeholders (incl. companies and researchers).

The "Innovation Day" event took place within Télécom-Saint-Etienne School's facilities on our Manufacture Campus, and was divided into two parts. The day started with a general presentation by representatives of the companies BIOmerieux, CNES and ORANO of their respective research areas, as well as their contributions to innovation. The afternoon was dedicated to lectures by young doctors and doctoral students, as well as scientists from French research labs and companies (incl. CEA, BIOmerieux, Orano, Exail, STMicroelectronics, Avnir Energy, TRAD). The topics covered were extensive: photonics, optics, electronics, image, and computer science applied to the fields of space/nuclear/ medicine. The day concluded with a poster session prepared by young researchers, whilst several companies were available to discuss career-related subjects with students. A special presentation was made by students from the European Master RADMEP (Radiation and its Effects on MicroElectronics and Photonics Technologies) on their personal journey and international experiences.

The event was organised by Martin Roche and Fiammetta Fricano, students from our MOPERE team, with the help and support of lab members Sylvain Girard, Youcef Ouerdane, Aziz Boukenter, Matteo Ferrari, Emmanuel Marin, Adriana Morana, and specifically Corinne Fournier. Considering the success and interest the event received, it has already been suggested to renew it in the future.







AWARDS & DISTINCTIONS

Researchers are rarely motivated by the pursuit of distinctions, but they are certainly never disappointed to earn marks of recognition from their peers! Once again this year, many members of our laboratory received various prizes and accolades. We congratulate all our laureates, may they be doctoral students or already experienced scientists.

ORANEF & dosiX

2023 World Nuclear Exhibition (WNE) Innovation Award

The WNE is a prestigious and international event dedicated to civil nuclear power, where industry leaders gather to shape the future of the field. During its 2023 edition, the traditional Innovation Awards ceremony was held and recognised the work of Orano's team with two prizes, including one for *Oranef*, a foldable drone developed within the framework of the *udd@Orano* project.
This year, nearly 130 innovative projects (including 23 from Orano), competed in five categories: «Social and Environmental Responsibility», «Nuclear Safety», «Knowledge and Skills Management», «Operational Excellence» and «Products and Services». Winner of the «Nuclear Safety» category, *Oranef* is a foldable drone can be inserted into a 100 mm diameter endoscope hole to access sensitive areas during inspection operations in nuclear facilities. Combined with DosiX, a miniaturized optical fiber sensor, this device allows for a better control of radiological risks and for the safety of operators.
Oranef was developed within the framework of the «*udd@Orano - Usines De Demain sur les sites industriels d'Orano*», a project that aims at accelerating the deployment of the «factory of the future» at the heart of the group's nuclear industrial sites, and in which our MOPERE team is actively involved. The objective is to leverage the expertise of the project's partners to develop and implement new technological solutions aimed at enhancing performance, optimizing production, improving factory competitiveness, and ensuring operators' safety. Innovative solutions are under development, such as miniaturized sensors for more efficient radiological measurements, new algorithms based on Artificial Intelligence to facilitate decision-making and anticipation of actions, mixed reality platforms based on 3D digital models and dematerialization of flows to assist operators in their missions, new robots for remote complex operations and automation of simple tasks. These new solutions will not only be applicable to Orano's industrial sites, but also to the nuclear industry and the French industry as a whole.

Congratulations to the team!

IUF - Institut Universitaire de France

new appointments

Sylvain Girard and Rémi Emonet have recently been appointed senior and junior members of the Institut Universitaire de France, respectively. This took effect as of 1st October 2023, and for a period of 5 years.
The IUF's mission is to promote the development of high-level research in public education establishments under the responsibility of the Ministry of Higher Education. It also aims at strengthening interdisciplinarity by encouraging excellence in fundamental research, innovation, and scientific mediation. During their five-year delegation, members of the IUF are relieved from part of their teaching duties, which allows them to focus on their IUF research project.

Sylvain Girard

new senior member

After obtaining his Ph.D. in 2003, Sylvain Girard joined the Centre d'Energie Atomique - CEA - as an Engineer. He started his teaching and research career at the Jean Monnet University in 2012, as part of the Physics Department and member of the Hubert Curien Lab. His expertise lies in the development of optical materials, photonics and optoelectronics technologies for operations in radiation-rich environments. Whilst heading our MOPERE team, he coordinates the Erasmus Mundus Joint Master Degree - EMJMD RADMEP, and is the local coordinator of the SWISSMODICS, MODATS, PHOTONHUB and RADNEXT collaborative European projects. Sylvain has authored or co-authored over 280 articles in peer-reviewed journals, and has filed 6 patents. He is the recipient of the 2021 iXcore-iXlife-iXblue Foundation Research Award, recognising the exceptional quality of his scientific work.

Rémi Emonet

new junior member

As member of our Data Intelligence team, Rémi is conducting research related to Machine Learning and Computer Vision, with a particular emphasis on temporal aspects. He joined the University Jean Monnet in 2013 as an Associate Professor, after completing a Ph.D. in software architectures for intelligent environments at Inria, and a postdoctoral fellowship at the Idiap Research Institute (EPFL) in Switzerland. Rémi is actively involved in teaching, both within our university and outside as a volunteer. His IUF project, titled «Optimal Transport for Structured Data, with Guarantees» focuses on the topics of optimal transport for transfer learning, with connections to diffusion models and their application in the field of laser-matter interaction physics.

Jean-Philippe Colombier

2023 Paul Langevin Award

Professor Jean-Philippe Colombier, a member of our Laser-Matter Interaction team, is the latest recipient of the prestigious Société Française de Physique's Paul Langevin Award. Since 1957, this prize has been annually awarded to mid-career researchers who have achieved exceptional work in theoretical physics. The 2023 prize covered the domains of atomic and molecular physics, optics, plasmas, physical and nonlinear chemistry.
Jean-Philippe Colombier develops a theoretical activity of modeling and simulation of the ultrafast laser-matter interaction, supporting experimental developments of surface structuring, as well as observation of ultrafast excitation and relaxation in irradiated matter. His research field combines fundamental topics related to this ultrafast and non-equilibrium dynamics of photoexcited materials, with applicative strategies of surface functionalization by direct structuring and induced self-organization. By bridging nanophotonics and materials nanoscience, these highly relevant scientific themes are opening many promising avenues for surface engineering, paving the way for structuring by complexity, a field that remains largely unexplored at the nanoscale.
Jean-Philippe's work is conducted within the framework of our Laser-Matter Interaction team, a group focusing on laser irradiation effects in condensed matter which are pertinent for material processing, functionalization, and fabrication. The primary objective is to spatially and temporally investigate laser-induced phenomena at ultimate scales, and explore their potential practical applications, facilitating their transfer to industrial environments. His activities are also integrated into the Graduate School Manutech-SLEIGHT, which provides an international MSc/PhD program focused on surface engineering by ultrafast laser / light. As stated by the SFP, "[Jean-Philippe Colombier's] research work feeds into a teaching activity that positions Saint-Etienne as a reference in the field of surface engineering through the use of light as a functionalization tool."
We extend our deepest congratulations to Jean-Philippe for receiving this prestigious honor from the physics community. This recognition not only highlights his exceptional achievements as a scientist but also reflects the dedication and excellence of our research teams.

Thierry Lépine

new Senior Member of the Optica Society

Associate professor at the Institut d'Optique Graduate School and researcher in our lab as part of our Image Science & Computer Vision team, Thierry Lépine was named last year senior member of Optica (formerly OSA). The Advancing Optics and Photonics Worldwide is a society dedicated to promoting the generation, application, archiving and dissemination of knowledge in the field of optics and photonics.
Having worked for 10 years in the field of ultrafast lasers and nonlinear optics, Thierry's carrer took a turn in 1999, when the opportunity arose to join Alain Léger's team at the Institut d'Astrophysique Spatiale in France. There, Thierry participated in the ESA Darwin space mission, marking the start of a new activity in the field of optical instrumentation. More specifically, Thierry Lépine's research interests lie in the design, simulation and analysis of imagery optical systems for applications in astronomy, space and ophthalmology.
Optica Senior Memberships are awarded to individuals as a recognition of their experience, professional accomplishments and service within the field, as well as their active involvement with Optica.

Mateus Simões

HOST 2023 Best Student Paper award

Final year Ph.D. student Mateus Simões has received a Best Student Paper award during the 2023 IEEE International Symposium on Hardware Oriented Security and Trust. The prize was awarded for his publication titled «Low-Latency Masking with Arbitrary Protection Order Based on Click- Elements».
After studying electrical engineering in Brazil, Mateus was granted a scholarship that allowed him to join the Ecole des Mines Saint-Etienne (EMSE) for a Master's Degree in Microelectronics and Computer Science. Following a 6-month internship and a 6-month contract as a full-time engineer for the company STMicroelectronics, Mateus joined our lab to start a CIFRE thesis titled «Modeling and characterization of masking schemes resistant to side-channel attacks in the presence of glitches». The work, done as part of our SESAM team and under the supervision of Lilian Bossuet, focuses on the design of secure and efficient microchips, offering cryptographic solutions to protect electronic devices against third parties.

Nicolas Dalloz

C'Nano Ph.D. thesis award

The CNRS French national competency Cluster in Nanoscience, C'Nano, is a support and research unit serving the French scientific community in nanoscience. For the fifth year in March 2023, it organized its interdisciplinary «Nanoscience Congress» during which the best doctoral works in Nanoscience and Nanotechnologies carried out at a French University or «Grande Ecole» were awarded.
Nicolas Dalloz was the recipient of this prize in the applied research category. His thesis, conducted under the supervision of Nathalie Destouches from our Functional Materials & Surfaces team and Mathieu Hébert from our Image Science & Computer Vision team, focused on «Printed image multiplexing by laser processing and its application to security and identity documents». Nicolas' work has led to the setup of the LAMCID joint lab between the company HID Citizen Identity and the Hubert Curien Laboratory, which was inaugurated in 2022. Nicolas is also co-inventor of three patents and co-author of several articles in top journals dedicated to material and color science. Since obtaining his PhD, he has been working at HID alongside Nipun Sharma, another former member of our laboratory.

Fondation de l'Université Jean Monnet

FONDATION
UNIVERSITÉ JEAN MONNET
SAINT-ÉTIENNE

Excellence Awards evening *18th October 2023*

On Wednesday 18th October 2023, the Fondation de l'Université Jean Monnet hosted an evening of conferences and debates centered around the topic of Artificial Intelligence. The event featured contributions from experts from our lab, Amaury Habrard and Christine Largeron. Additionally, the evening served as an opportunity for the Foundation to recognize the recipients of its Bachelor's, Master's, and Engineer's Excellence Awards for the academic year. These awards are given to graduates of the Université Jean Monnet who have demonstrated excellence in their academic studies, as well as notable professional integration within the region or with partner organizations affiliated with the University.

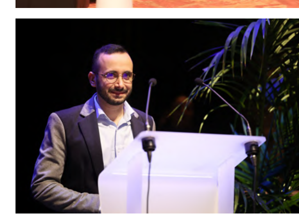
Marie Traynar, a former student of the OIVM Master's program in Photonics Engineering, was among the 14 prize recipients of the evening. Her excellent performance as a master's student, coupled with an enriching internship at CERN and her pursuit of a Ph.D. in our lab, positioned her as a prime contender for the prize. During her 6-month internship in Switzerland, Marie focused on research involving fiber optic sensors at cryogenic temperatures. She has since started her Ph.D. within our Functional Materials & Surfaces team, where she is investigating 'Safety components based on optical resonance and luminescence effects,' under the supervision of Yves Jourlin.

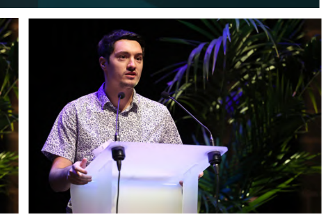
Research evening *28th November 2023*

At the end of November 2023, the Fondation held a second major event, celebrating the winners of their 2024 Funds for research projects. Recent Ph.D. recipients were also awarded special prizes during the evening, in recognition of the excellence of their doctoral work and support for the dissemination of their research.

No less than 6 doctors having completed their Ph.D. within our lab during the academic period of 2022/2023 were laureates for the young researcher awards:

- Hugo Bruhier - Functional Materials & Surfaces team
- Nicolas Dalloz - Functional Materials & Surfaces team
- Cosimo Campanella - MOPERE team
- Anthony Nahkoul - Laser-Matter Interaction team
- Dylan Brault - Image Science & Computer Vision team
- Paul Viallard - Data Intelligence team





MEMBERS NEWS

As with any other academic institution, we are proud to see each year our students graduate and our permanent members advance in their careers. In this section, we have listed out our new doctors and HDRs, as well as all personnel who joined our lab in the past year.

Our new HDRs

Nicolas Crespo-Monteiro

Associate Professor Nicolas Crespo-Monteiro successfully completed his HDR (Accreditation to Supervise Research) in 2023. Following a Ph.D. in our lab, dedicated to studying the photochromic behavior of mesoporous films containing silver for the development of active photonic components, Nicolas joined the Institut Charles Sadron in Strasbourg as a post-doctoral fellow. During this time, he focused on determining the nature of electronic transitions in organic materials containing metallic nanoparticles. Over the past decade, Nicolas has actively contributed to teaching at Télécom Saint-Etienne, where he currently serves as the head of the school's program for optics and photonics. His HDR research concentrated on the development of a process for micro-nanostructuring metal nitride through nitriding under infrared annealing of micro-nanostructured metal oxide sol-gel coatings.

Adriana Morana

In December 2023, Associate Professor Adriana Morana achieve Accreditation to Supervise Research (HDR) with a presentation on 'Integration of optical fiber sensors in extreme radiation environments.' Adriana became a member of our MOPERE team in 2010, at the start of a Ph.D. focused on the effects of Gamma-Rays and Neutrons on Optical Fibers and Bragg Gratings for Temperature Sensors. Over the years, she has actively participated in numerous research projects within our lab, concurrently contributing to teaching activities at the IUT and the FST of the Jean Monnet University. Adriana plays a crucial role in the UJM-coordinated Erasmus Mundus Joint Master Degree RADMEP, a multidisciplinary and innovative program covering interactions between radiation, microelectronics, and photonics.

Damien Muselet

Associate Professor Damien Muselet successfully defended his HDR (Accreditation to Supervise Research) in July 2023. After a Ph.D. at the University of Lille and a post-doctoral fellowship at the University of British Columbia in Vancouver, Damien joined the University Jean Monnet and our Image Science & Computer Vision team in 2006 to work on color invariance in the context of object recognition. More recently, Damien has established strong collaborations with our lab's researchers specialised in Material Appearance and in Machine Learning, to offer unique solutions to vision problems by leveraging the knowledge of physical models of colour formation as well as deep learning approaches. His HDR work was focussing on «Models and data for the extraction of physical, invariant or discriminative information from color images».

Our new doctors

Moustapha Godi Tchéré
Functional Materials & Surfaces
January 20th, 2023

Detection and inspection by neural network in the context of ellipsometric scatterometry

Thesis supervisors

Bernard Bayard
Hubert Curien Lab, Supervisor

Stéphane Robert
Hubert Curien Lab, Co-Supervisor

Djafar Iabbaden
Laser Matter interaction
January 27th, 2023

Atomistic Simulations of Ultrafast Laser-induced Devitrification of Metallic Glasses

Thesis supervisors

Jean-Philippe Colombier
Hubert Curien Lab, Supervisor

Florence Garrelie
Hubert Curien Lab, Co-Supervisor

Léa Marichez
Functional Materials & Surfaces
April 6th, 2023

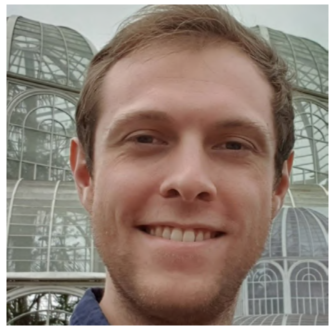
Microstructurating of luminescent coatings for anticounterfeiting and traceability

Thesis supervisors

Yves Jourlin
Hubert Curien Lab, Supervisor

Geneviève Chadeyron
Institut de Chimie de Clermont-Ferrand, Co-Supervisor

Daniel Zambon
Institut de Chimie de Clermont-Ferrand, Co-Supervisor



Samuel Thé
CRAL / Hubert Curien Lab
ED PHAST Université de Lyon
Image Science & Computer Vision
March 7th, 2023

Methods for unmixing and deconvolving objects in images. Applications in high-contrast astronomical imaging

Thesis supervisors

Maud Langlois
Centre de Recherche Astrophysique de Lyon, Supervisor

Eric Thiébaut
Centre de Recherche Astrophysique de Lyon, Co-Supervisor

Loic Denis
Hubert Curien Lab, Co-Supervisor

Quentin Bouniot
CEA LIST Paris Saclay / Hubert Curien Lab
ED SIS Université de Lyon
Data Intelligence
March 29th, 2023

Towards Few-Annotation Learning in Computer Vision: Application to Image Classification and Object Detection tasks

Thesis supervisors

Amaury Habrard
Hubert Curien Lab, Supervisor

Hugo Boiron
MOPERE
May 17th, 2023

Thermomechanical analysis of optical fibre coils by studying their Rayleigh backscattering

Thesis supervisors

Emmanuel Marin
Hubert Curien Lab, Supervisor

Adriana Morana
Hubert Curien Lab, Co-supervisor

Maxime Rattier
Exail, Co-supervisor

Hervé C. Lefèvre
Exail, Co-supervisor

Hugo Bruhier
Functional Materials & Surfaces
June 6th, 2023

Development of a plasmonic sensor for air quality control

Thesis supervisors

Isabelle Verrier
Hubert Curien Lab, Supervisor

Jérôme Brunet
Laboratoire IP, Université Clermont-Ferrand, Co-Supervisor

Yves Jourlin
Hubert Curien Lab, Co-Supervisor

Our new doctors

Julie Dutems
Functional Materials & Surfaces
July 6th, 2023

Thin passive film characterization by surface plasmon resonance (COUPLES)

Thesis supervisors

Yves Jourlin
Hubert Curien Lab, Supervisor

Nicolas Crespo-Monteiro
Hubert Curien Lab, Advisor

Manuel Flores
Functional Materials & Surfaces
September 4th, 2023

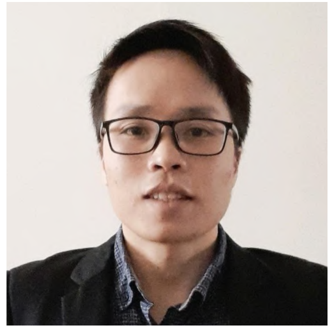
Materials and nanostructuring processes on flexible supports for personalized security features

Thesis supervisors

Nathalie Destouches
Hubert Curien Lab, Supervisor

Francis Vocanson
Hubert Curien Lab, Co-Supervisor

David Grosso
University Aix Marseille, Co-Supervisor



Van Doan Le
Functional Materials & Surfaces
September 22nd, 2023

Study on the optical properties of metal-dielectric nanocomposite materials induced by laser

Thesis supervisors

Nathalie Destouches
Hubert Curien Lab, Supervisor

Myriam Zerrad
Institut Fresnel, Co-Supervisor

Nourdine Kerboub
MOPERE
October 4th, 2023

Optical fiber dosimetry for space research and high-energy physics

Thesis supervisors

Sylvain Girard
Hubert Curien Lab, Supervisor

Julien Mekki
CNES, Co-Supervisor

Diego Di Francesca
CERN, Co-Supervisor

Emilie Laffont
Functional Materials & Surfaces
October 10th, 2023

Development of a new plasmonic transducer for the detection of biological species

Thesis supervisors

Yves Jourlin
Hubert Curien Lab, Supervisor

Pierre Berini
CRPu Ottawa, Supervisor

Nicolas Crespo-Monteiro
Hubert Curien Lab, Co-Supervisor

Fanny Dailliez
LGP2 / Hubert Curien Lab
ED IMEP2
Université Grenoble Alpes
Image Science & Computer Vision
October 12th, 2023

Multiscale impact of the addition of a coating layer on the color of halftone prints

Thesis supervisors

Anne Blayo
LGP2 Lab, Supervisor

Lionel Chagas
LGP2 Lab, Co-Supervisor

Mathieu Hébert
Hubert Curien Lab, Co-Supervisor

Thierry Fournel
Hubert Curien Lab, Co-Supervisor

Vincent Duveiller
Image Science & Computer Vision
October 26th, 2023

Optical models for predicting the color of dental composite resins

Thesis supervisors

Mathieu Hébert
Hubert Curien Lab, Supervisor

Raphaël Clerc
Hubert Curien Lab / IOGS, Co-Supervisor

Our new doctors

Wanajaroen Weerapot
Image Science & Computer Vision
November 3rd, 2023

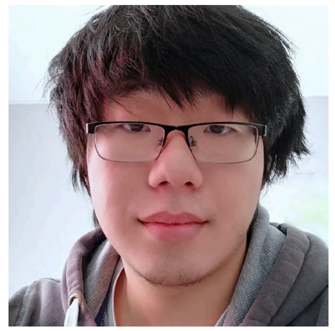
Design and performance estimation of a compact Hyperspectral Imager for an Earth observation satellite

Thesis supervisors

Thierry Lépine
Hubert Curien Lab / IOGS, Supervisor

Suwicha Wannawichian
University of Chiang Mai (Thailand), Co-supervisor

Siramas Komonjinda
University of Chiang Mai (Thailand), Co-supervisor



Cyril Li
Image Science & Computer Vision
November 29th, 2023

Semi-supervised interactive deep learning for volume segmentation in electron tomography

Thesis supervisors

Sylvain Desroziers
Michelin, Supervisor

Christophe Ducottet
Hubert Curien Lab, Supervisor

Maxime Moreaud
IFP Energies Nouvelles, Co-Supervisor

Priya Dominic
Laser-Matter Interaction
December 13th, 2023

Ultrafast laser interaction for chemical and topological functionalization of metallic surfaces

Thesis supervisors

Florence Garrelie
Hubert Curien Lab, Supervisor

Florent Bourquard
Hubert Curien Lab, Co-supervisor

Arnaud Weck
University of Ottawa, Co-Supervisor

Arnaud Meyer
MOPERE
December 8th, 2023

Optical-fiber-based distributed dosimetry for space applications

Thesis supervisor

Aziz Boukenter
Hubert Curien Lab, Supervisor

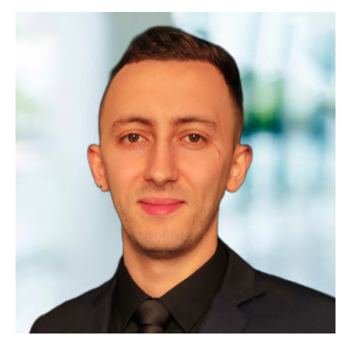
Pierre-Antoine Tissot
SESAM
December 11th, 2023

Protection of symmetric encryption devices against multiple fault injections

Thesis supervisors

Lilian Bossuet
Hubert Curien Lab, Supervisor

Vincent Grosso
Hubert Curien Lab, Co-supervisor



Ameur Soualmi
Image Science & Computer Vision
December 15th, 2023

Early developmental evaluation of premature infants with quantitative general movements assessment using deep learning based 3D pose estimation

Thesis supervisors

Hugues Patural
Sainbiose Lab, Supervisor

Olivier Alata
Hubert Curien Lab, Supervisor

Antoine Giraud
Sainbiose Lab, Co-Supervisor

Eduardo Brandão
Data Intelligence
December 20th, 2023

Complexity methods in physics-guided Machine Learning

Thesis supervisors

François Jacquenet
Hubert Curien Lab, Supervisor

Rémi Emonet
Hubert Curien Lab, Co-Supervisor

New recruits

Farah Cherfaoui

After a thesis in machine learning and an ATER position at Aix-Marseille University, Farah joined the University Jean Monnet Saint-Étienne in 2023 as an Assistant Professor and member of our Data Intelligence team, within our new Inria MALICE project-team. She works on statistical learning, with a particular focus on accelerating kernel-based methods by developing approximation algorithms. Her research aims to provide theoretical guarantees on the prediction quality of these approximations. Farah is also interested in using kernel methods to build tools for comparing discrete probability distributions.

Maxime Darnon

Maxime Darnon, Ph.D., earned his degree in micro-nano electronics from the Université de Grenoble in 2007. Following roles as a process engineer at IMEC (Leuven, Belgium) and a Research Staff Member at IBM Research (Yorktown Heights, NY, USA), he joined the CNRS at the Laboratoire des Technologies de la Microélectonique (Grenoble, France). Specializing in plasma/surface interactions for semiconductor industry plasma etching, he transitioned to the Laboratoire Nanotechnologies Nanosystèmes (Sherbrooke, Qc, Canada) in 2015, focusing on photovoltaic applications. In November 2023, Maxime joined our lab to develop activities in surface nanopatterning (Functional Materials & Surfaces team) and optoelectronic devices in severe environments (MOPERE team).

Benjamin Girault

Benjamin obtained his Ph.D. in Computer Science at the ENS of Lyon in 2015, focusing on Graph Signal Processing (GSP) and introducing the study of random graph signals using graph signal stationarity. He then continued his work on GSP as a postdoctoral fellow at the University of Southern California, Los Angeles (USA). This work led to the introduction of a new generalization to the Fourier transform on graph signals, and various contributions to machine learning applied to understanding human behavior. In 2020, he worked at ENSAI (France) as Assistant Professor, leveraging his contributions to propose a novel method for performing graph learning. Benjamin is now a full-time researcher at Inria and has recently joined our new Inria MALICE project-team, working on the connections between GSP and machine learning.

Cédric Killian

Cédric obtained his Ph.D. in electronic systems at the University of Lorraine in 2012 and has been an Associate Professor at the University of Rennes since 2013. His research within the Taran project team, common to IRISA and Inria, focused on on-chip interconnections, silicon photonics, fault tolerance and energy efficiency. Since September 2023, he serves as a Full Professor of the University Jean Monnet and researcher in our lab's Secure Embedded Systems and Hardware Architectures (SESAM) team. His research currently concentrates on securing hardware implementations of neural networks, as well as addressing security issues related to the use of emerging technologies in system-on-chip designs.

Malika Otmani

A new administrative support service for research was recently created in our lab, with the objective to work at the interface between our researchers/teacher-researchers and our accounting team. Malika was recruited in October 2023 as a support and monitoring officer for large-scale scientific projects. She assists in writing, financial planning, and monitoring the progress (reporting/finances) of these projects, in collaboration with the Université Jean Monnet's Research and Valorization Department (DRV), and the CNRS's Project Monitoring Service (SPV).

Stéphane Criedlich

Stéphane joined our lab in September 2023 as an administrative assistant attached to our newly created research support unit. He is responsible for assisting in the organisation of missions, acting as an interface between scientists and our travel agency, as well as handling expense reports. Stéphane also participates in the organisation of events such as conferences, important scientific meetings, thesis or HDR defenses.

Anthony Cazier

Following his success in the external competition for Engineers in Experimental Techniques, our colleague and long-term lab member Anthony Cazier has officially joined our "Femtosecond Laser" technical platform team, on a full-time basis. After a Master's degree in Physics and a CAPES in Physical Sciences, Anthony started his career teaching in high schools in the Haute-Loire region of the Clermont-Ferrand Academy. Seeking a career change, he prepared and successfully passed the external competition for the ITRF BAP C Technician, allowing him to join the University Jean Monnet in December 2008. Anthony was then dividing his activities between the IOGS and the Hubert Curien Laboratory. Within our lab's NanoSaintEtienne technical platform, he was managing the mutualization of opto-mechanical equipment and laboratory instrumentation, providing scientific and technical support to research teams, and collaborating in the development of experimental devices. Over the years, Anthony also became co-responsible for developing submicrometer network fabrication processes by interferential lithography, and took charge of the platform's exposure systems. Anthony's new responsibilities as part of our Femtosecond Laser platform include the development and operation of experimental devices related to ultra-short laser sources, technical assistance to platform users while ensuring the maintenance of the platform's installations.

Emeritus appointment

Viktor Fischer

Following his official retirement in October 2023, member of our SESAM team Viktor Fischer was granted an Emeritus Professorship, allowing him to continue his research work on hardware security.
Viktor pursued his higher education studies at the Kosice University in Slovakia, where he conducted a thesis on «Fast Methods of Digital Image Segmentation». He joined our lab as a temporary part-time researcher in 1992, also providing teaching at ISTASE (Institut Supérieur des Techniques Avancées de Saint-Etienne) and then at Télécom Saint-Etienne for the University Jean Monnet. He successfully defended his HDR (Accreditation to Supervise Research) in 2002 and achieved a Full Professorship in 2006. Viktor notably founded our laboratory's SESAM team. This group was initially conducting research in Image Processing Architectures whilst providing electronic development support for the lab's Image Science team. Under his influence, the group gradually became entirely focused on hardware security, becoming one of the largest teams at the national level in this field. Viktor is recognized as one of the world's leading experts in the field of Random Number Generation in embedded devices. Throughout his career, he has authored over 100 publications in top journals and conferences in his field, and has supervised more than 15 doctoral theses at the Université Jean Monnet.
Viktor received the «NATO Science Partnership Prize» in 2018, together with Otokar Grosek (Slovak University of Technology in Bratislava), Eran Tromer (Tel Aviv University) and Reiner Steinwandt (Florida Atlantic University), for their exceptional contribution to science and the excellence of their cooperation within the framework of the «Secure Implementation of Post-Quantum Cryptography», a project, funded by NATO under its «Science for Peace and Security 2013» program in the field of cybersecurity.

Retirement

Jean-Claude Pommier

A member of our laboratory for nearly 40 years, Jean-Claude Pommier earned his retirement on 1st October 2023.
After completing his degree in Mechanical Engineering Technology at Lyon 1 University, followed by a specialized degree in Science Research with a focus on Physics at the University Jean Monnet, Jean-Claude joined our lab (then known as the «TSI Lab») in 1983 as a materials development technician. Over the years, his career evolved, until he was promoted Assistant Engineer in 1986, Study Engineer in 1992, and Research Engineer in 2003. In addition to his role as technical manager of our lab, Jean-Claude was responsible for overseeing the NanoSaintEtienne platform. As a Prevention Officer for many years, he also played an essential role in the laboratory's Health & Safety issues. He was an elected member of the College C section 08 of the CoNRS and, in 2013, officer for «Training» missions for the INSIS Institute.
In recognition of this milestone, he was presented with a Medal of Honor by the CNRS, his employer for 40 years. The CNRS medal is awarded to employees who have been with the institution for at least 15 years and have made significant contributions to its activities.
We extend our gratitude to Jean-Claude for his many years of dedicated service in our laboratory and wish him a happy retirement !

STAY CONNECTED

Laboratoire Hubert Curien
UMR CNRS 5516, Bâtiment F
18 Rue du Professeur Benoît Lauras
42000 Saint-Etienne, FRANCE
Tel : +33 (0)4 77 91 57 80
email : lab.h.curien@univ-st-etienne.fr

https://twitter.com/LabHubertCurien

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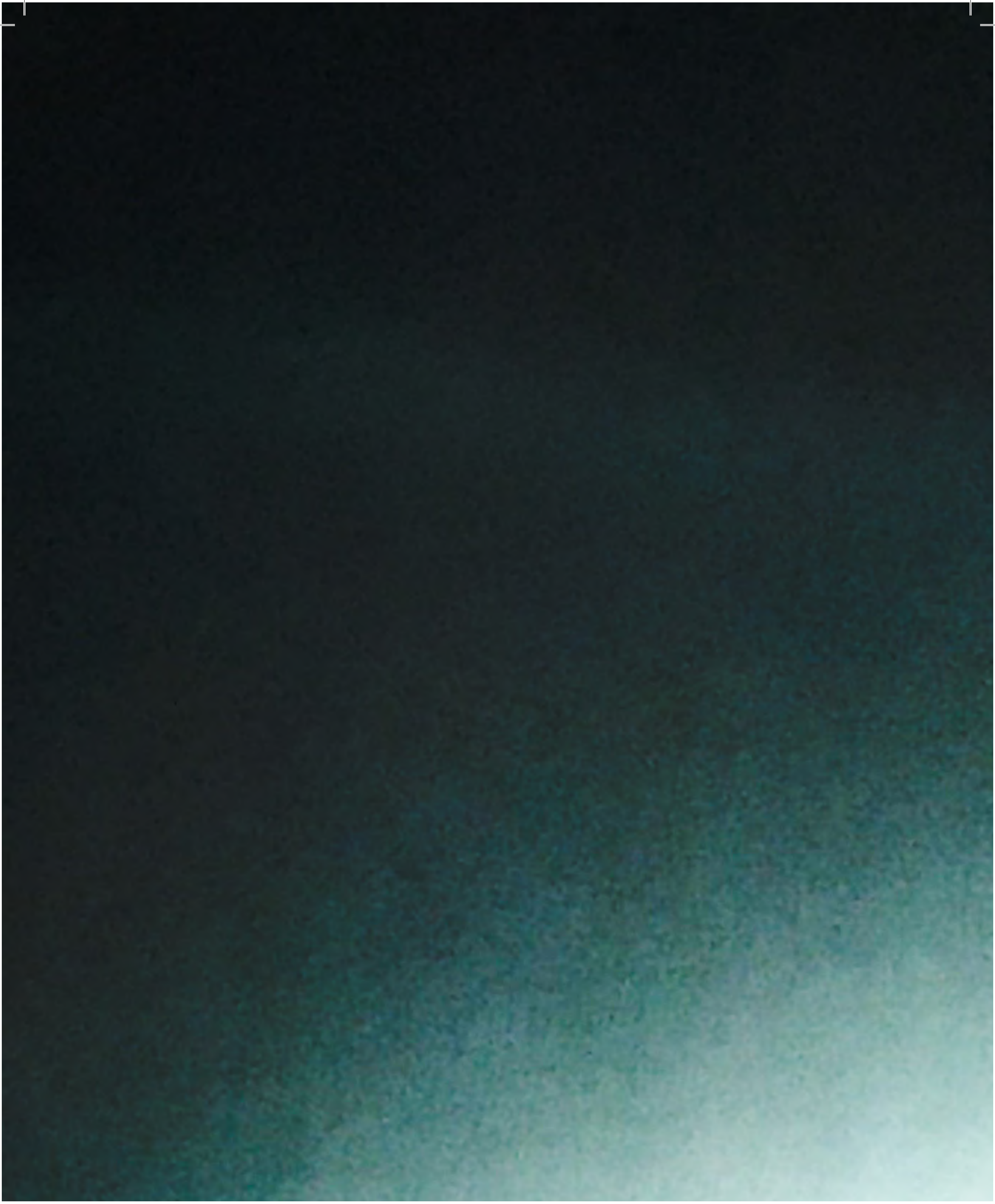

Laboratoire Hubert Curien
UMR CNRS 5516
Bâtiment F
18 Rue du Professeur Benoît Lauras
42000 Saint-Etienne, FRANCE

Tel : +33 (0)4 77 91 57 80
email : lab.h.curien@univ-st-etienne.fr

WEBSITE