Hubert Curien Laboratory

2024

yearbook

Université Jean Monnet Saint-Étienne

Institut d'Optique Graduate School ParisTech

Laboratoire Hubert Curien

UMR • CNRS • 5516 • Saint-Étienne

EDITO

It is a real pleasure to share with you the 2024 edition of the Hubert Curien Laboratory Yearbook - a look back at another year of scientific engagement, innovation, and teamwork.

Alongside an updated presentation of our laboratory, this year's edition features a selection of key projects and achievements that stood out over the year 2024. These examples reflect not only the diversity of our work, but also a defining strength in our lab: the strong connections between our different research areas and expertise. From international publications and innovation-driven advances to collaborative research and educational initiatives, the contributions of our teams, showcased throughout these pages, continue to make a mark at both national and international levels. As in previous editions, we have chosen to spotlight some of our academic partnerships, underlining the central role that education, research, and innovation play in shaping our mission. We are also proud to celebrate individual achievements, including the prestigious appointment of another of our members to the Institut Universitaire de France.

Our team continued to grow in 2024 with the arrival of five new researchers, each bringing valuable perspectives and ideas. This year also marked the official launch of the MALICE team, established in 2023 with Inria - to whom I am sincerely grateful for both their foundational role and continued support.

Whether you are a long-standing partner, a new collaborator, or simply interested in our work, we invite you to explore this Yearbook and hope you find it enjoyable and insightful.

I would like to extend my sincere thanks to our supervisory authorities - the University Jean Monnet, CNRS, and Institut d'Optique Graduate School - for their unwavering support, and gratefully acknowledge our institutional and industrial partners.

And of course, I warmly thank all members of the Hubert Curien Laboratory. Your commitment and expertise are at the heart of our accomplishments.

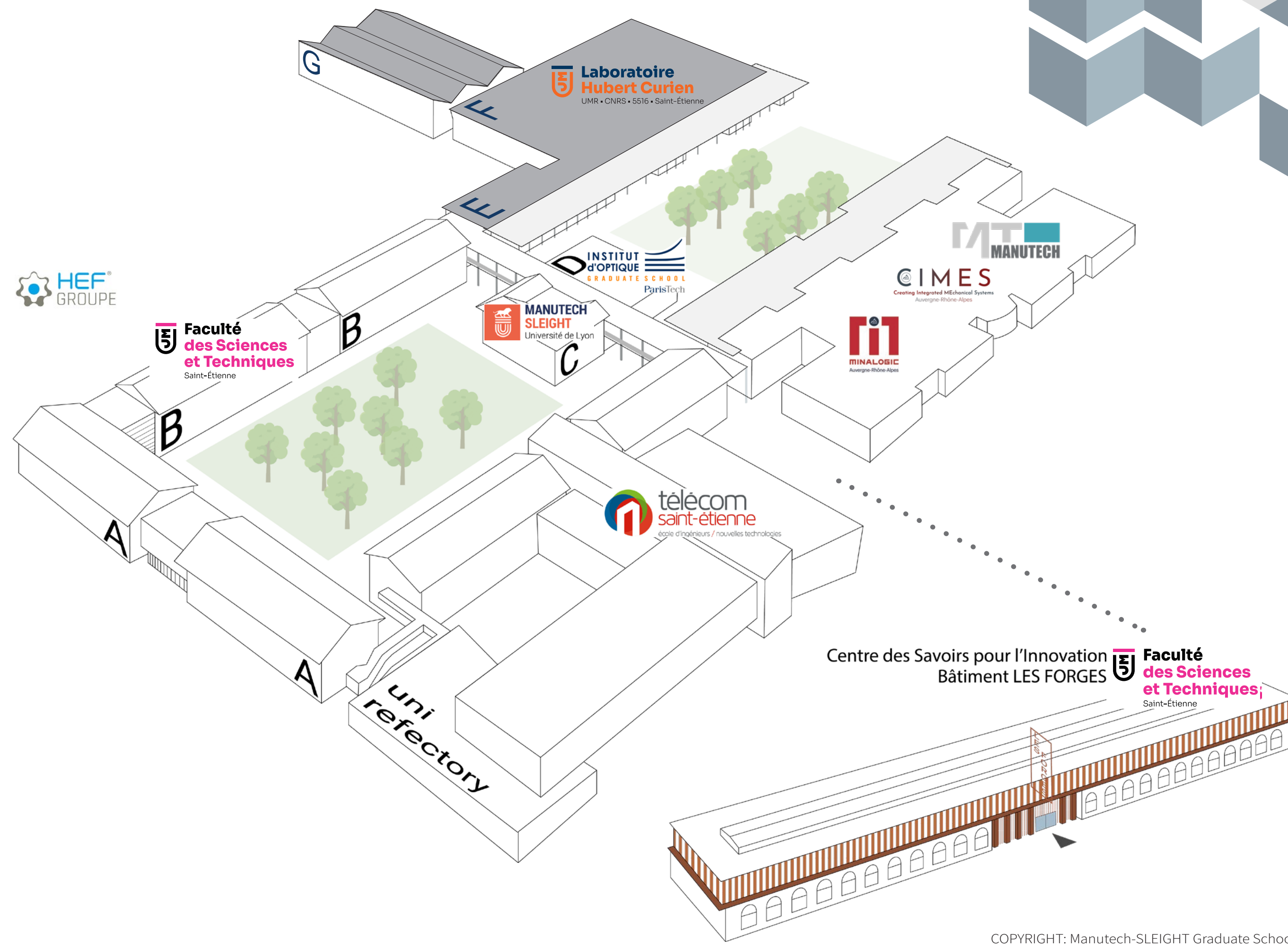
Florence Garrelie
Director of the Hubert Curien Laboratory

CONTENT

THE LAB

LOCATION

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



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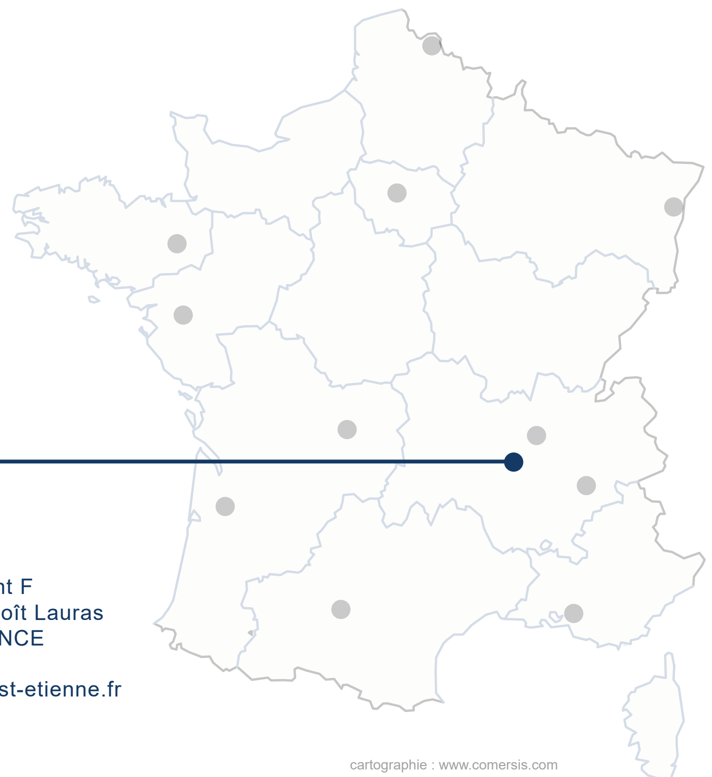

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Université Jean Monnet Saint-Etienne

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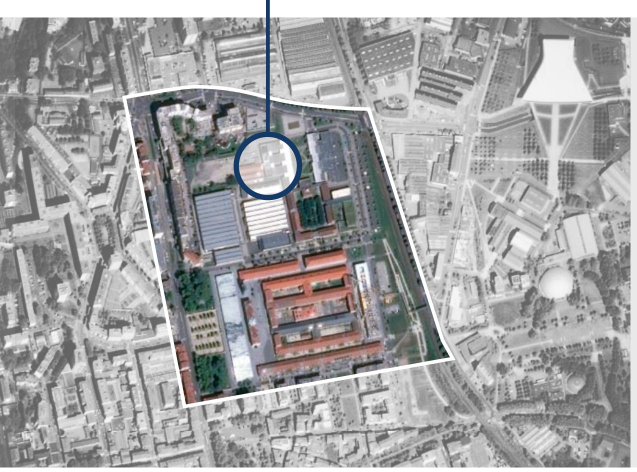
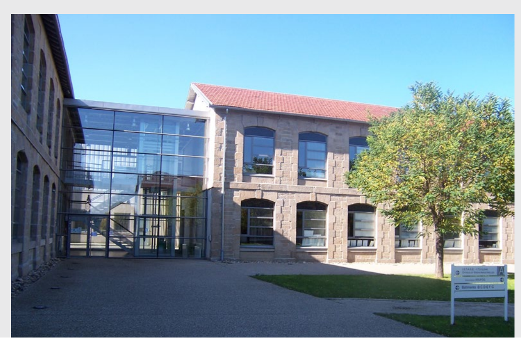
The Manufacture Campus houses the university's Faculty of Science & Technology, its Physics & Computer Science departments as well as its «Télécom Saint-Etienne» engineering school. In 2003, it was selected by the Institut Optique Graduate School to set up a branch outside Paris. Minalogic and Cimes, 2 local industrial «competivity clusters» occupy the site, together with the Economic Interest Group GIE Manutech USD. The company HEF R&D (surface engineering and micro/nanostructuring) has established its 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.

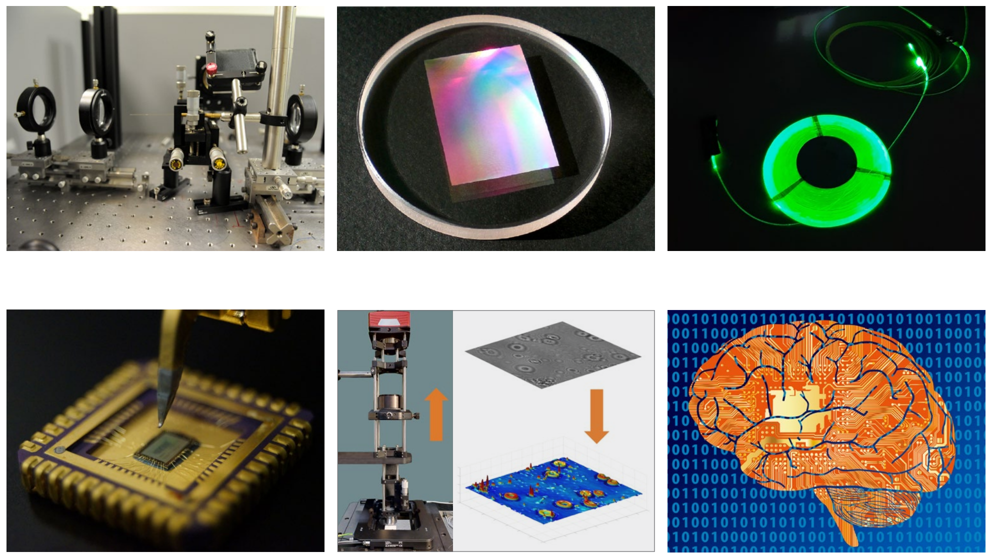


Manufacture Campus aerial view
(Imagery ©2023 CNES / Airbus, Maxar Technologies, Map data ©2023)

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, educational and research activities, as well as housing, sport and leisure facilities.

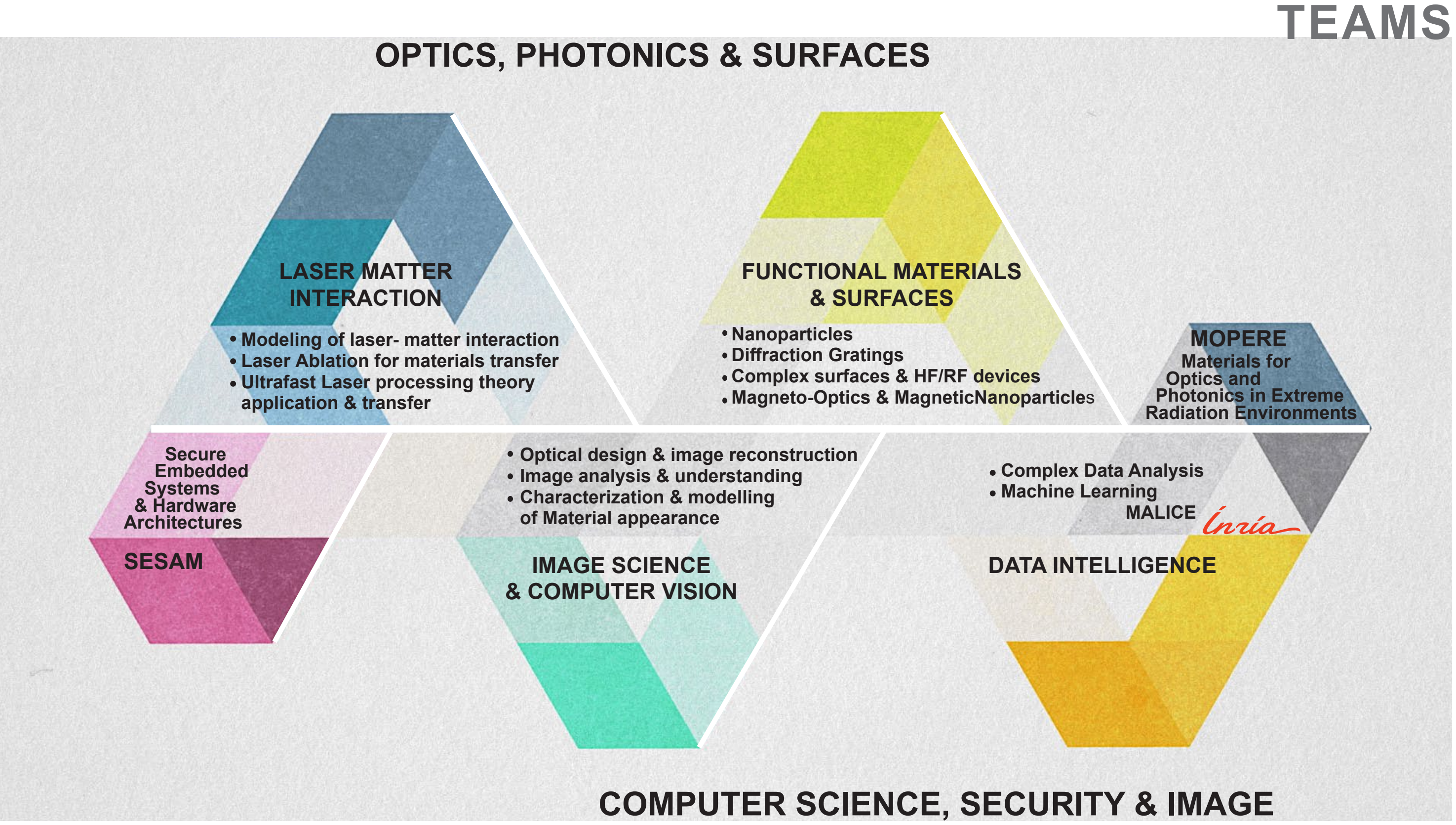


OUR ACTIVITIES
at a glance

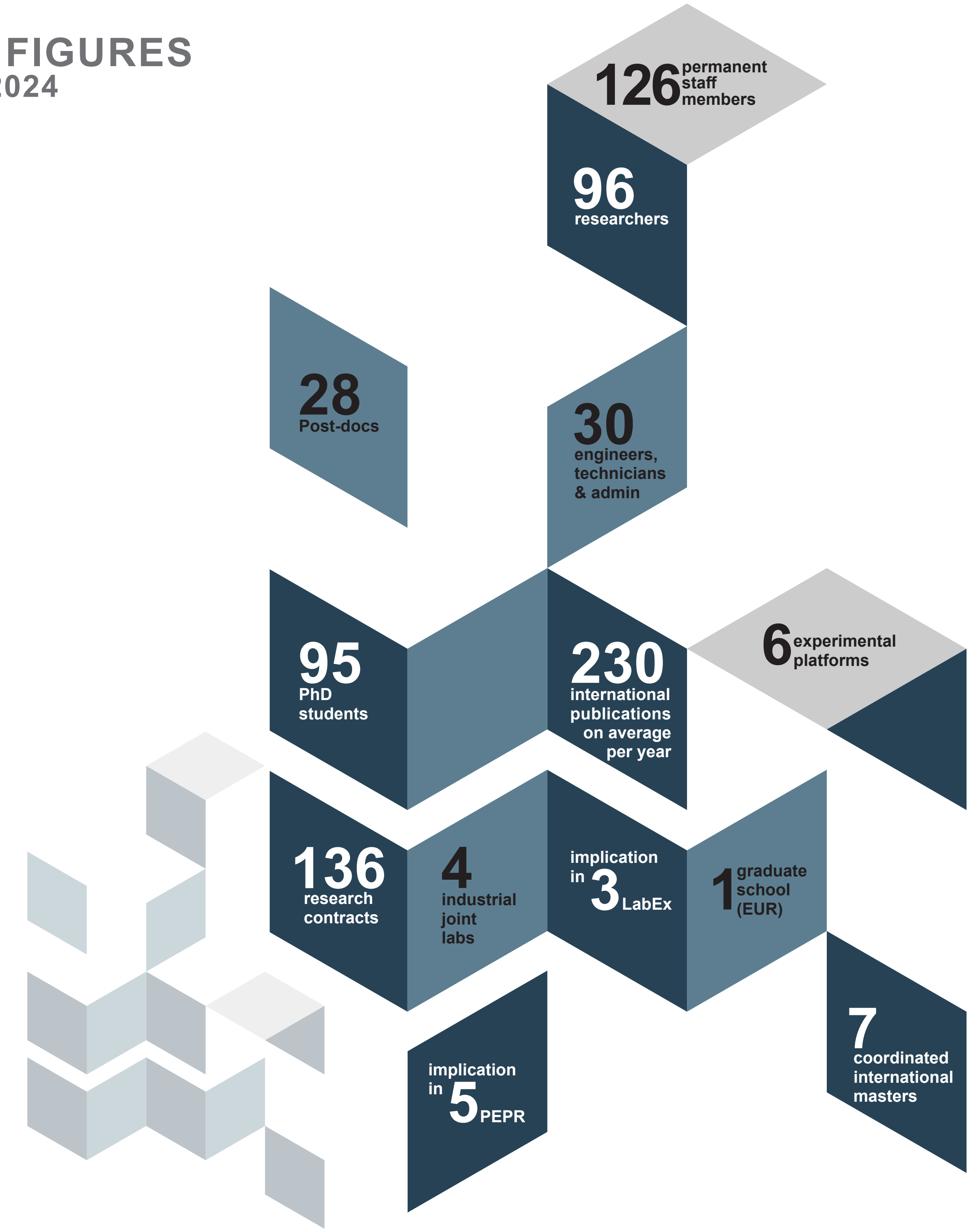


The lab covers a spectrum of research activities structured around 2 scientific departments: «Optics, Photonics & Surfaces» and «Computer Science, Security & Image». Our main expertise lies in Surface engineering, 2D & 3D materials' micro/nano structuring, Ultrafast laser processing, Electromagnetic 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 2024



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 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 - 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 - 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 - Surface Interface Science Engineering
Manutech SISE is a "Laboratoire d'Excellence" governed by the Université de Lyon and coordinated by our lab. It brings together the complementary skills of 6 academic laboratories (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 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.

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 CNRS Ingénierie, 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 - 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.

FIL - Fédération Informatique de Lyon
Supported by CNRS and Inria, the FIL gathers approximately 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.

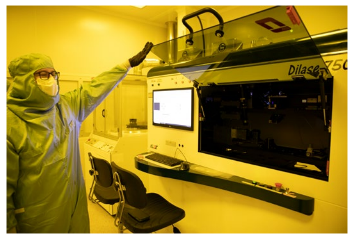
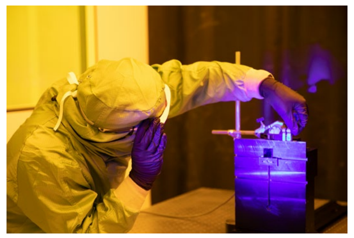
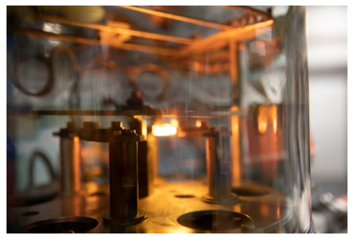
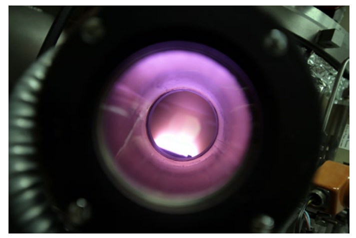
Institut Carnot TSN - Télécom et Société numérique
Our lab is a member of the Institut Carnot TSN through the Télécom Saint Etienne Engineering School. Carnot is a label of excellence awarded by the Ministry of Higher Education, Research & Innovation, encouraging research work by public labs in partnership with socio-economic stakeholders. It is organised around several Institutes working on the same topic. 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.

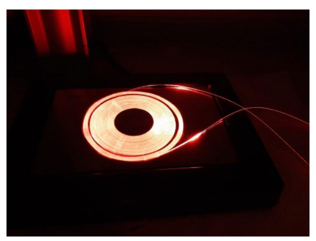
NanoSaintÉtienne

RENATECH+ cnrs NANO SAINT-ÉTIENNE LABORATOIRE HUBERT CURIEN UMR CNRS 5516

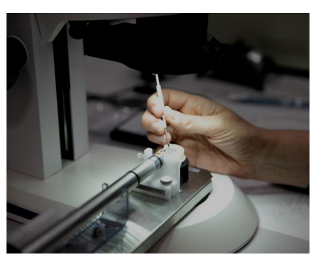
Our *Renatech+* affiliated NanoSaintÉtienne platform includes planar technology instruments dedicated to 5 main activities: gratings elaboration, thin film deposition, substrates processing, profile analysis and spectrometry. Managed by a team of 7 people, this micro-nano technological facility is **open to industrial and academic partners**.

PETRA - Radiation Testing




PETRA (Experimental Platform for Radiation Tests) brings together our lab's irradiation and radiation testing equipment. Built around 3 X-ray irradiation installations, it enables in-operando testing of materials, components and systems, across a wide temperature range (-120 to +400 °C) and under controlled atmospheric conditions. PETRA is **open to external users**.

Electron Microscopy



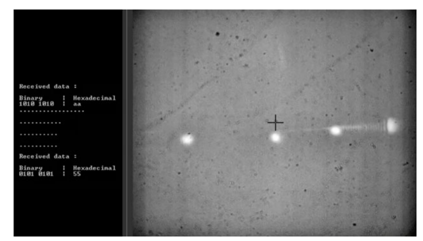
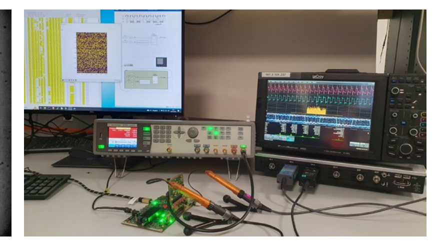
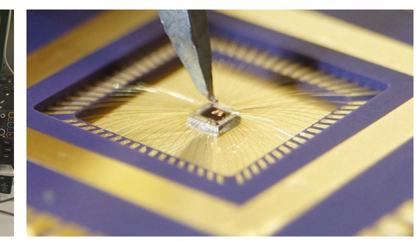
Our Electron Microscopy platform is dedicated to improve the knowledge of condensed matter structure from atomic to microscopic scale, in order to support the activities of our research teams. It is fitted with state-of-the-art equipment, including a CLYM affiliated JEOL NeoARM 200F Transmission Electron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

Femtosecond Laser




Our Femtosecond Laser platform features 6 ultrashort lasers with varying wavelengths, repetition rates and energy levels, covering all working environments. It supports devices such as OPAs for tunability, burst modes and variable frequencies, along with high-precision stages and scanners, spatial, temporal and polarization shaping of ultrashort laser pulses, or ultrafast spectroscopy systems. Primarily supporting the teams of our Optics, Photonics & Surfaces Department, the facility is **open to external partners**.

Electronics and Hardware Security

Originally founded to support the activities of our SESAM team, our Electronics and Hardware Security platform is available to all other teams within the laboratory. It includes various high-performance electronic instruments and acquisition systems, comprising both custom-developed solutions and commercial kits. Combined, these elements form specialized tools for analyzing embedded cryptography systems.

Access to IXR - Imaging and Extended Reality

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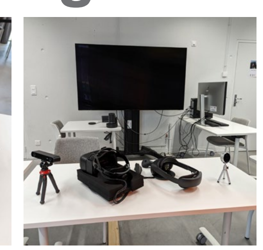
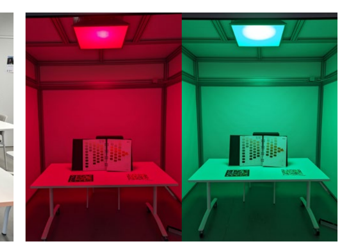
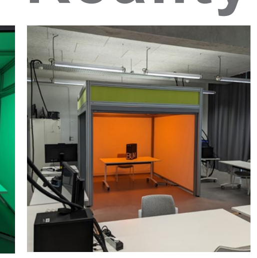

Managed by the Université Jean Monnet, the IXR platform is a modular space located within the Centre des Savoirs pour l'Innovation. It provides equipment dedicated to Imaging and eXtended Reality with AR/MR/VR devices, innovative screens, and a wide range of imaging sensors: color, stereo, LIDAR, multi- 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 or motion capture system.

2024
HIGHLIGHTS

Last year was once again marked by several significant events and projects for the Hubert Curien Laboratory. The following pages present five of the most important ones.

Exploring Baby Cries

A novel approach to neurodevelopmental prediction

Data intelligence team
Head: Rémi Emonet

As part of their national sponsorship program, which focuses on four areas (Solidarity, Environment, Territories, Health), the Mutuelles AXA have recently chosen to finance a project involving the ENES Bioacoustics Research Laboratory (Centre de Recherche en Neurosciences de Lyon, Université Jean Monnet Saint-Etienne, CNRS, Inserm), the Neonatal Unit of the Centre Hospitalier Universitaire de Saint-Etienne, and the Data Intelligence team at the Hubert Curien Laboratory. The BABY CRY project seeks to establish a reliable, non-invasive diagnostic tool based on the measurement of the acoustic characteristics of a baby's cries to assess its neurodevelopmental integrity.

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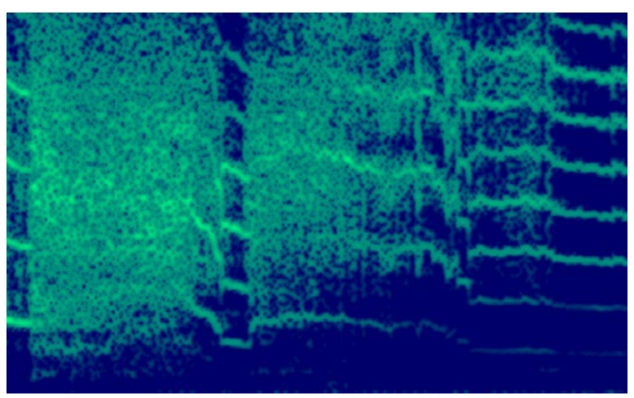
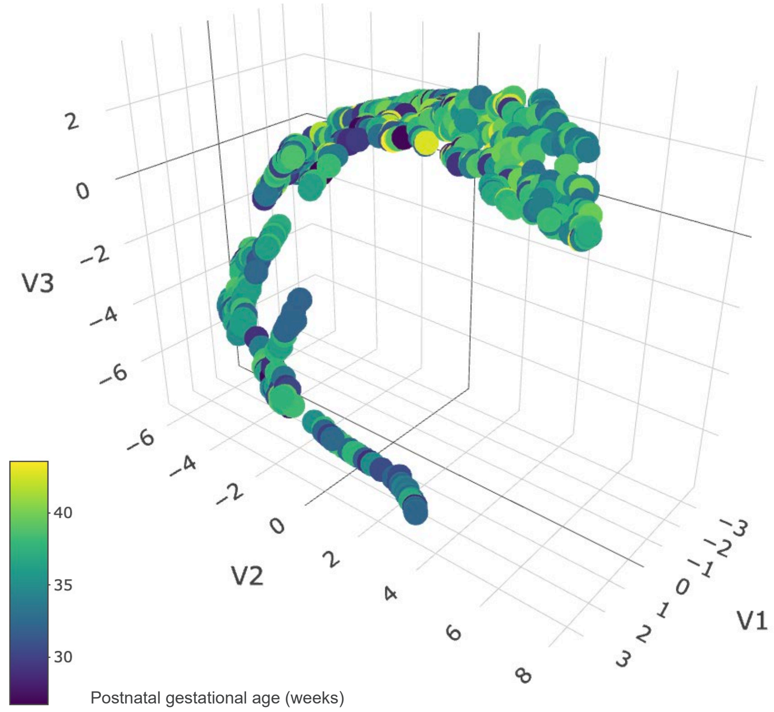


Baby cry spectrogram



The cry of a newborn is more than just a call for attention; it has been demonstrated to contain significant information. Since the vocal tract, respiratory system, and neurophysiological processes involved in sound production can be affected by certain pathologies, the cries of sick babies or those at developmental risk are likely to have unique characteristics that distinguish them from the cries of healthy babies.

The primary question driving this research is whether the individual vocal signature of baby cries can be used to diagnose and predict neurodevelopmental disorders. Previous studies on the relationship between this essential communication signal and the baby's brain structure and function have been limited by several factors (small sample sizes, inconsistent recording methods, lack of long-term neurodevelopmental follow-up), making the deciphering and interpreting of newborn cries extremely difficult for perinatal professionals. To overcome these limitations, the team will conduct an acoustic study of baby crying using innovative sound signal analysis tools coupled with AI algorithms trained on a large database of cries from full-term and premature babies, whose physiological and long-term neurodevelopmental data will be known.

The team has set four main objectives for the 2-year duration of the project. The initial phase, which is underway, consists of creating the largest bank of documented baby cry recordings to date. The second part of the project will aim to develop a method for automated cry analysis using Artificial Intelligence, with the ultimate goal of finalizing an application (BabyCryExplorer) that could be used by practitioners in a hospital setting as a new diagnostic tool for at-risk children. The application will be downloadable and installable on any computer and will also be available online, with all calculations performed directly from a browser. This will be followed by an investigation of the relationships between the acoustic properties of cries, the babies' characteristics at birth, and their neurodevelopmental outcomes at 2 and 5 years. Finally, the developed predictive tool will be tested on populations at high risk of neurodevelopmental disorders (extremely premature babies, peripartum anoxic-ischemic encephalopathy, neonatal seizures, known cortical or subcortical neurological impairments) to refine and validate its clinical relevance.

The project started in January 2024 with the recruitment of personnel, purchase of recording equipment and initial tests. Recordings began at the end of February 2024, and are expected to reach the target of 1,000 babies recorded by the end of 2025. The team has already gathered some preliminary data on cry detection (identifying when the baby is crying versus when there is no significant activity or excessive noise) and descriptive statistics on the amount of crying according to time, gender, etc. Our team at the Hubert Curien Lab will be involved in all four stages of the project, overseeing the organization of the recording bank, supervising the development of the BabyCryExplorer software, developing AI techniques, and creating the BabyCryExplorer user interface.

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This ambitious project combines the complementary skills of 3 expert teams. The ENES Lab, known for its work in bioacoustics and non-verbal human vocalizations, brings extensive experience in analyzing baby cries. The neonatal unit at CHU provides clinical expertise and access to infant subjects, while the Machine Learning group of our lab's Data Intelligence team contributes advanced AI methodologies for data analysis. These teams are already collaborating on the core themes of the current project: baby cries and the analysis of sound sequences by Artificial Intelligence.

By integrating three distinct fields (neonatology, bioacoustics, AI) to turn baby cries into a predictive diagnostic tool, this project represents a unique and innovative approach to neurodevelopmental studies. The creation of the first large, high-quality and well-documented database of baby cries will not only facilitate research but also benefit international teams working on automatic cry analysis.

With their project, the research team aims to enhance early detection and intervention strategies, ultimately improving the quality of life for thousands of children and adults.

The work has already led to the creation of a website dedicated to interpreting baby cries, and aimed at parents and healthcare professionals.

PEPR LUMA SUNRISE Project
How plasmonic interactions can revolutionize photochemical processes

Functional Materials & Surfaces team
Project Head: Nathalie Destouches

The Exploratory PEPR LUMA - Promoting Light-Matter Interactions - considers light as an omnipresent element in our natural and technological environment. It aims to study, understand, and develop this unique tool to explore and control physico-chemical and biological systems at the interfaces between physics, chemistry, engineering and life sciences, and between health and environmental / climate science.
The official inauguration of the PEPR LUMA took place in June 2024 at the University of Bordeaux, where Professors Dario Bassani and Nathalie Destouches presented the SUNRISE project, selected as part of the PEPR LUMA's Call for Expressions of Interest for Thematic Research. The SUNRISE project seeks to "Surpass Normal Resolution and Intrinsic Shortcomings of Excited States."

FRANCE 2030 PROGRAMME DE RECHERCHE INTERACTION LUMIÈRE MATIÈRE

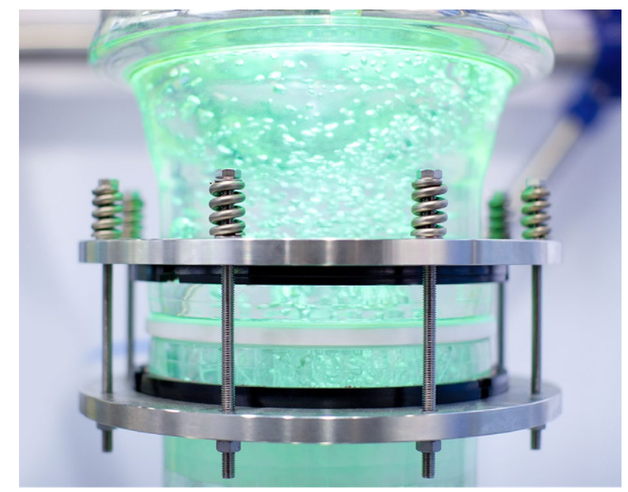
Photochemical reactions are ubiquitous in nature and play essential roles in processes such as photosynthesis in plants, vision in animals, or bioluminescence. However, light's potential for chemical activation remains largely untapped, despite a growing interest observed over the past decade due to advances made in the fields of sensing, photocatalysis, and super-resolution imaging. These advances have been driven by the interaction of organic chromophores with localized surface plasmons, which can significantly enhance their photoresponse. A broader application to various photoprocesses has been so far limited by a lack of fundamental understanding of the underlying mechanisms and interfering thermoplasmonic effects.
The SUNRISE project aims to address these limitations, which are constrained by the chromophores responsible for both light absorption and photochemical activity. By using plasmonic interactions, which create nanosources of light that can initiate photochemical reactions at spatial scales beyond the diffraction limits of conventional optics, the SUNRISE team intends to selectively modify how chromophores interact with light at the nanoscale, thereby enhancing both absorption and photoreactivity.

The project is structured into several Work Packages, all working towards 3 main objectives:
1. Enhance photoreactivity in solution using localized surface plasmon effects.
2. Achieve sub-diffraction resolution in photolithography. A novel aspect of this project is the incorporation of plasmonic nanoparticles to selectively direct the growth of nanofibers in specific areas, eventually producing patterns of nanoparticles.
3. Extend nanolithography to larger areas for applications in photochemical flow reactors.

Tackling such a long-standing challenge required an interdisciplinary team, which gathers 7 partners from leading French research institutions specializing in physics and/or chemistry. These include the Institut des Sciences Moléculaires (Université de Bordeaux), Laboratoire NIMBE (CEA), Laboratoire de Chimie (ENS Lyon), Laboratoire Hubert Curien (Université Jean Monnet), Laboratoire de Photophysique et Photochimie Supramoléculaires et Macromoléculaires (CNRS DR4), the Institut de la Vision (Sorbonne Université), and Institut de Sciences des Matériaux de Mulhouse (CNRS DR10). It is being co-led by Dario Bassani from the Université de Bordeaux, and Nathalie Destouches from our laboratory. The partners are bringing their complementary expertise to perform the necessary tasks in materials synthesis and characterization, optical subdiffractive fabrication and superresolved imaging, plasmon-enhanced photoreactivity and structuration, and the creation of photoinduced functional nanostructures over large surfaces.
Our Functional Materials & Surfaces team is leveraging its knowledge in the interaction of laser light with metallic nanoparticles. As part of this project, our team will carry out time-resolved characterization of nanoparticles-enhanced reactions, and will work on the photoinduced functionalization of large surfaces, ranging from millimeters to tens of square centimeters.

The SUNRISE project is expected to generate significant advancements in both fundamental and applied knowledge. At a fundamental level, it will investigate the mechanisms behind surface-localized plasmonic interactions to improve photochemical transformations such as photopolymerizations and out-of-equilibrium self-assemblies. At the applied level, the sub-diffractive nano-patterning of large areas will contribute to transformative solutions across various industrial sectors including gases, recycling, sustainable materials, urban mining, or energy materials (e.g. for converting or purifying harmful gases, degrading pollutants in waste, improving the efficiency of solar cells, extracting metals from industrial by-products, for hydrogen fuel production, etc.).

The project was officially launched in October 2024.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INSTITUT DE LA VISION PARIS — LABORATOIRE DE CHIMIE ENS DE LYON — IS2M Institut de Science des Matériaux de Mulhouse — Laboratoire de photophysique et photochimie supramoléculaires et macromoléculaires PPSM — nanosciences & innovation nimbe — Laboratoire Hubert Curien UMR • CNRS • 5516 • Saint-Étienne — ISM Institut des Sciences Moléculaires BORDEAUX

PEPR ORIGINS - From Planets to Life

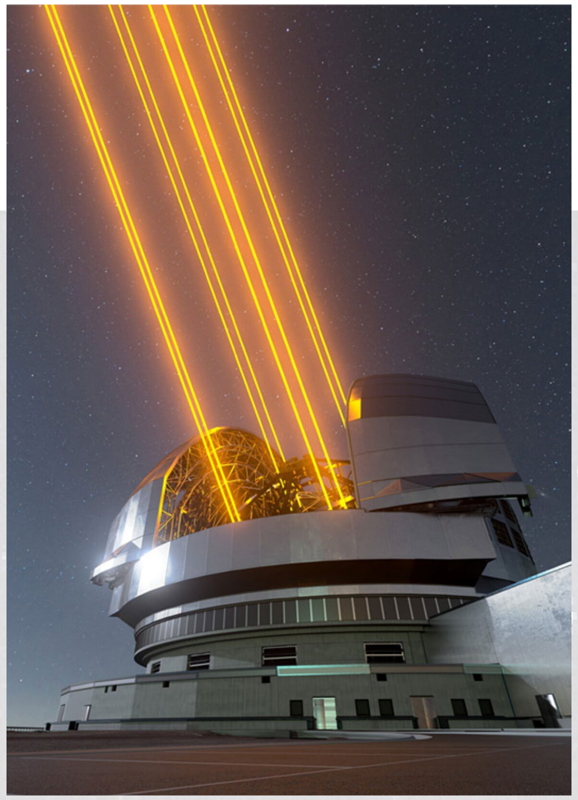
Two projects to unveil the secrets of exoplanets

Computer Science, Security & Image department
Project Head: Loic Denis

"Questions about the origin of our world and the existence of life elsewhere are as old as Humanity. Due to the lack of data, however, these questions have for centuries remained within the realm of philosophy, and even religion. Today, they are becoming genuine scientific questions to which we can hope to provide scientific answers". With these words, Alessandro Morbidelli, renowned astronomer, planetologist and Professor at the Collège de France, opened his keynote speech for the inauguration of the PEPR ORIGINS - From Planets to Life research program in September 2023, which he co-directs.
Funded under the France 2030 plan, this program aims to delve deep into the mysteries of planetary origins and the emergence of life, on the precept that advancements in this field hinge on the development of cutting-edge technology and innovative research instruments. The 17 PEPR ORIGINS instrumental projects initiated so far aim to address specific technological challenges identified to enable significant advances within 5 key areas of national research excellence:

- Detection and characterization of exoplanets through direct imaging,
- Analysis of space samples, with or without biological risks,
- Study of Earth in its entirety as a habitable planet,
- Laboratory experimentation in exobiology and bio-analysis of ancient Earth or Mars samples,
- Numerical modeling and data analysis.

This latter component of the program focuses on digital advancements, particularly in the fields of simulations and data analysis through intensive computing and Artificial Intelligence, to enhance our understanding of planet formation and exoplanet detection. Two of the projects included in this research axis involve members of our Computer Science, Security & Image Department, and have emerged as a result of our lab's longstanding collaboration with the Centre de Recherche Astrophysique de Lyon (CRAL).

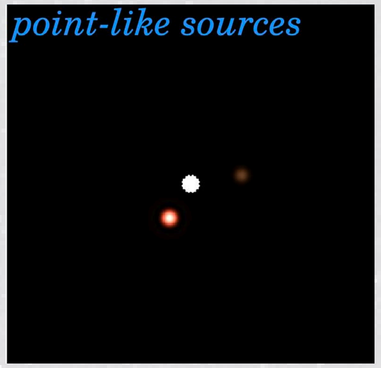


AO Unsupervised Predictive Control for Adaptive Optics
Project Lead: Eric Thiébaut (CRAL)

AO systems are crucial in fields such as astronomy, ophthalmology and optical telecommunications, for controlling wavefront shapes to improve image resolution and signal quality. These systems face significant challenges, including high computational demands, limitations in wavefront sensor capabilities, temporal delays, and rapidly changing observing conditions. Traditional AO systems often perform suboptimally under such variable conditions. The project aims to overcome these limitations by developing innovative control methods that approach theoretical optimum performance. It is structured around 3 main objectives:

- Real-Time Model Updates, with the development of dynamic models for wavefront sensors and deformable mirrors, using self-calibration to ensure these models accurately reflect current system behavior.
- Predictive and Optimal Control, with the implementation of predictive control to anticipate wavefront changes and mitigate temporal delays. Machine Learning will be used to continuously refine control parameters, enabling autonomous adaptation to varying conditions.
- Tests and validation of control algorithms on optical benches and telescopic systems, ensuring scalability from the Very Large Telescope (VLT) to the future European Extremely Large Telescope (ELT).

The expected advancements should significantly enhance astronomical observations, leading to clearer imaging and more precise exoplanet detection. They could also improve satellite communications by mitigating atmospheric disturbances and advance ophthalmic diagnostics with better corrective measures.



Opposite: Artist's visualisation of the ELT - Extremely Large Telescope under construction in Chile, with lasers used to create artificial stars for adaptive optics corrections.
©ESO
Above: AI reconstruction of the protoplanetary disk and two exoplanets around the star PDS 70.
© O. Flasseur, L. Denis, E. Thiébaut, M. Langlois.

AI Data Analysis
Project Lead: Loic Denis (Hubert Curien Lab)

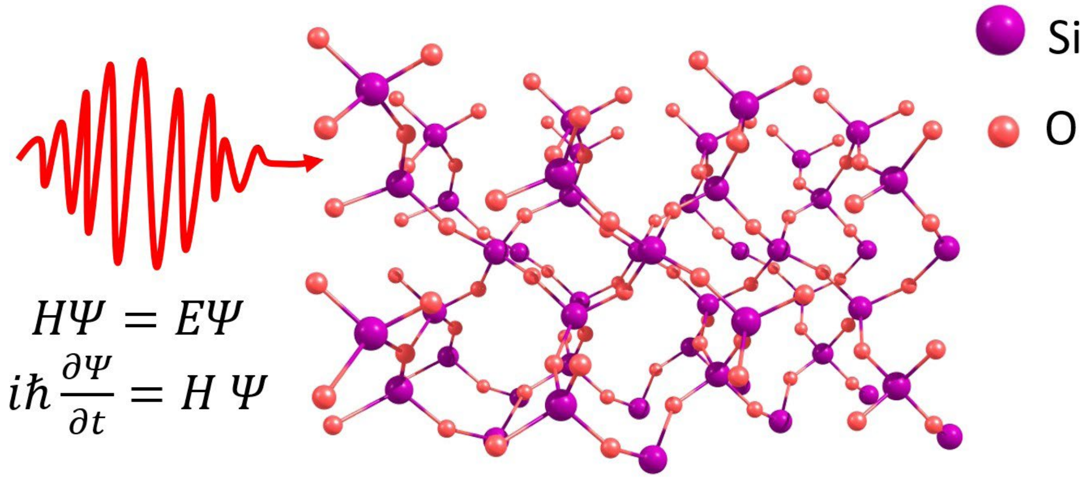
Given the technological challenge of detecting and analyzing the weak signatures from planets outside our solar system, powerful telescopes, extremely sensitive instruments, and AI-based image analysis are essential today to ensure optimal extraction of information from astronomical observations. This project aims to improve the detection and characterization of exoplanets by optimizing information extraction from noisy astronomical data. High-contrast imaging challenges, such as bright stellar speckles overshadowing faint signals of interest, require advanced AI-driven signal processing techniques. By using unsupervised machine-learning algorithms, the project seeks to enhance image contrast and reveal hidden bodies such as circumstellar discs or exoplanets. It focuses on developing new data processing methodologies, integrating physical and optical models, and performing multi-observation data analysis with statistical guarantees.
Structured around 4 main themes, the project addresses key issues in data science for astronomical observations:

- Development of self-supervised methods dedicated to the detection and characterization of exoplanets, as well as image reconstruction in high-contrast imaging;
- Signal processing for the detection and characterization of exoplanets by spectroscopy;
- Combination of multi-epoch observations and exploitation of archive data;
- Multi-instrument and multi-modality fusion of heterogeneous data.

The anticipated outcomes of this project include the development of open-source algorithms and software, with a particular effort made to simplify their usage and adoption by potential users, thereby enhancing the capabilities of current and future astronomical instruments. Beyond serving the scientific goal of better understanding our origins through the study of exoplanets, the detection and localization of objects with very weak signatures has direct applications in many domains, particularly in biomedical imaging, remote sensing, and defense. The general methodology of complementing physical models with a Machine Learning approach can benefit other fields of scientific imaging, from medicine to physics.

Computational Materials

Unraveling the electronic properties in SiO_2 under ultrafast laser irradiation



For many years, our Laser-Matter Interaction group has been exploring the way laser excitation alters material properties. For this article, we have asked Dr Elena Kachan to elaborate on the team's findings published in 2024 in the prestigious Computational Materials journal, by the Nature Publishing Group. For the first time, the team investigates the electronic properties of a transparent dielectric, a shift from earlier work that focused solely on metals, due to their simpler modeling requirements.

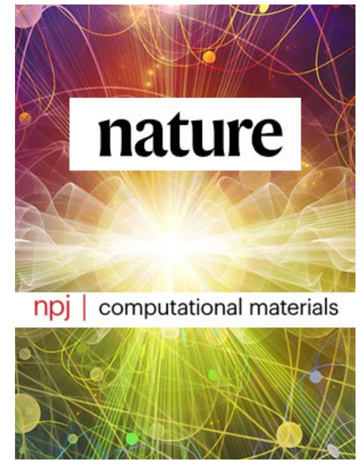
Dielectrics such as glass, quartz, or water are transparent at visible and infrared wavelengths. However, this property changes when they are exposed to ultrashort, highly intense laser pulses. Various interaction mechanisms lead to the appearance of transient nonlinear optical phenomena. These phenomena allow the optical properties of dielectrics to be controlled, ranging from transparent to metal-like states. Moreover, an electric current can appear for several femtoseconds in initially non-conducting materials, without causing damage. This ultrafast current switch can be used for petahertz signal processing - a significant leap from today's terahertz limit.

The ultrafast and ultra-localized energy input from laser pulses can also modify transparent materials at the nanoscale with atomic precision. For instance, laser-induced three-dimensional nanostructures inside glass can store data with very high density and unlimited lifetime. These highly-resolved nanostructures can also create three-dimensional optical circuits to transport and manipulate light in fiber-optic communication and optical quantum computing, contributing to faster and more efficient data communication technologies.

Electrons absorb ultrashort laser pulse energy in a highly nonlinear manner, leading to intense excitation that can completely transform the material behavior and its response to light and heat propagation. A transparent insulating dielectric becomes opaque and conducting, while laser-excited electrons affect atomic bond strength and vibrational properties.

Elena Kachan and Jean-Philippe Colombier perform advanced computations to model the properties of silica (SiO_2 glass or quartz) under ultrafast laser irradiation. Using quantum mechanics, they describe the behavior of laser-excited electrons. Their methods are based on an approximate solution of the Schrödinger equation for electron wavefunctions in the field of SiO_2 ionic cores and laser pulses. Various levels of approximation enable reasonable simulation times, though access to a French national supercomputer is required, where one simulation may take several days on 4,000 processors.

Figure above: Model, based on the Schrödinger equation, describing the excitation of electronic wave function by a laser pulse inside a SiO_2 crystalline structure.



Laser-Matter Interaction team

"Unraveling the electronic properties in SiO2 under ultrafast laser irradiation"
Arshak Tsaturyan, Elena Kachan, Razvan Stoian, Jean-Philippe Colombier
Computational Materials 10, 1 (2024)

The published paper provides an extensive set of electronic parameters obtained from quantum simulations. It demonstrates that electronic specific heat, electron pressure, and electron effective mass vary strongly with excitation intensity, dramatically changing electronic behavior. These effects primarily result from electron orbital distortions, leading to non-monotonic behavior of the band gap - which defines how easily electrons can initially be excited. The paper also explores the way electrons relax and transfer energy to atomic vibrations, showing that these processes strongly depend on the excitation level. For example, electron relaxation is twice as fast under strong excitation compared to weak excitation. This result was obtained using an improved method of electron-phonon coupling calculation, previously used only for metals in its approximated form.

These results will serve as a database for various electronic properties of SiO_2 under laser excitation, aiding laser-matter simulations and experimental estimations under various conditions. The work contributes to advancements in ultrafast-laser modifications of transparent materials, crucial for energy-efficient and fast data storage and communication.

The team's next step is to couple the obtained electronic properties with molecular dynamics simulations. This approach will describe atomic displacement resulting from energy transfer between electrons and atoms, thus reproducing laser-induced modifications of the crystalline structure using quantum methods.

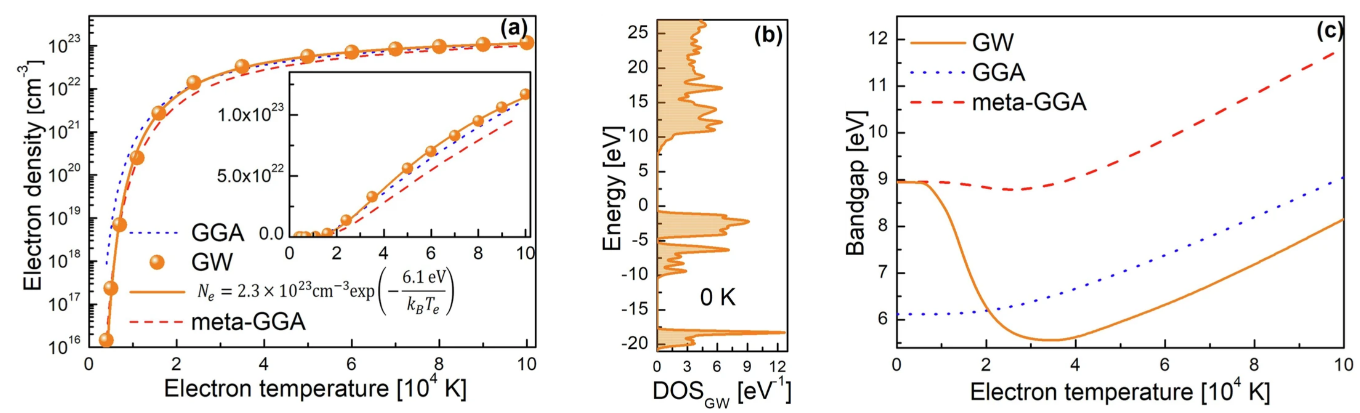


Figure above: Excited electron density and bandgap vs. electron temperature.

a. Electron density in conduction band as a function of T_e obtained with different approximation and a Boltzmann fit for *GW* results. Inset shows the same plot in a linear scale.
b. Electron DOS of quartz at $T_e = 0$ K. Energy is set to zero at the valence band edge.
c. Evolution of the bandgap as a function of T_e predicted by GGA (blue dotted curve), many-body GW (orange solid curve) and meta-GGA (red dashed curve) approximations.

PROOFS

Towards Better Security in True Random Number Generation

SESAM team
Project Head: Viktor Fischer

The 2024 conference on Cryptographic Hardware and Embedded Systems (CHES 2024) took place in Halifax, Canada, from 4th to 7th September 2024. As always, the conference was organized by the International Association for Cryptologic Research (IACR). The 2024 edition was particularly rewarding for our laboratory's SESAM team (Systèmes Embarqués Sécurisés et Architectures Matérielles), who successfully secured the publication of three full papers. Two of them, published in collaboration with STMicroelectronics Rousset et CEA Grenoble, respectively, focused on testing and modeling sources of randomness used to generate random numbers, while the third one, published with École des Mines de Saint-Etienne and CMP Gardanne, addressed attacks on powered-off data-security devices using lasers.

Recognized as one of the top experts in Random Number Generation for embedded devices, Viktor Fischer, Emeritus Professor at Jean Monnet University and 'founding father' of our lab's SESAM team, was invited to deliver a keynote speech at the 12th International Workshop on Security Proofs for Embedded Systems (PROOFS 2024), affiliated with CHES 2024. His talk, titled "Towards Better Security in True Random Number Generation", opened the workshop and underlined the importance of random number generators for the security of cryptographic systems. The presented material was based on joint work with Florent Bernard, Nathalie Bochard, and Maciej Skorski, all members of our SESAM team.

In his presentation, Viktor provided a comprehensive analysis of relatively rare sources of randomness available in logic devices and their security parameters - such as stability, robustness, non-manipulability - also examining the efficiency of various entropy extraction methods. He explained the principles and role of stochastic models, and stressed the significant role they play in entropy estimation, the process by which the unpredictability of generated numbers is measured, and their security therefore guaranteed.
Given that sources of randomness available in logic devices have statistical parameters - such as distribution and mutual (in)dependence of generated numbers - that are far from ideal, raw random numbers often require post-processing. The role of this operation is to enhance the statistical parameters of random numbers, at the cost of a reduced bit rate, and is typically done using a certain type of data compression method.
As statistical parameters of the source of randomness and of the entire generator can vary over time - e.g. due to underlying hardware aging or external attacks - security must be ensured through continuous monitoring of the randomness source, as well as dedicated statistical tests running continuously within the device. The proposal of a new, power-efficient and precise clock jitter measurement method - where jitter refers to the clock generated inside the device, which is the most commonly used source of randomness - was also the subject of one of SESAM's papers presented at CHES 2024.

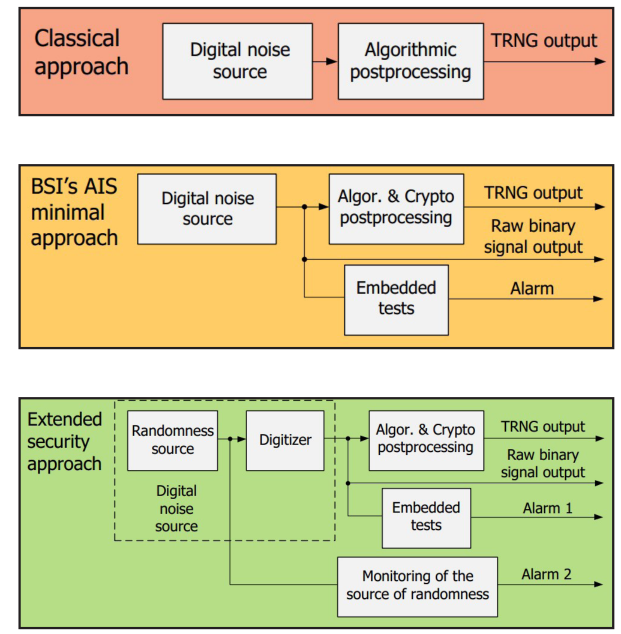
The evolution of security approaches in random number generation is illustrated on Figure 1, which includes the extended security method proposed by our SESAM team.

The graphic shows how the classical approach to achieving security of random numbers generators used to solely rely on verifying the statistical parameters of generated numbers.

This traditional approach has recently been replaced by the AIS 20/31 standard (published by the German - Bundesamt für Sicherheit in der Informationtechnik, BSI) which requires both stochastic models and dedicated embedded tests. This document has become a de facto European standard, having also been adopted by the French ANSSI (Agence Nationale de la Sécurité de Systèmes d'Information).

The SESAM's team approach enhances this standard by integrating continuous monitoring of the randomness source with embedded statistical tests.

Figure 1 below: Evolution of security approaches in random number generation



This methodology was successfully implemented in the design of a true random number generator developed within the framework of the Horizon 2020 research and innovation HECTOR project, funded by the European Union between 2015 and 2018. As illustrated on Figure 2, the Demonstrator 1 of the project included a couple of phase-locked loops (PLLs) that generated jittered clock signals used as sources of randomness.
In the latest version of the German AIS20/31 standard, published in September 2024, the PLL-based generator designed by the SESAM team is cited as one of three examples illustrating modern approaches to building secure true random number generators for cryptographic applications, reinforcing our team's position as a leading research group in the field.

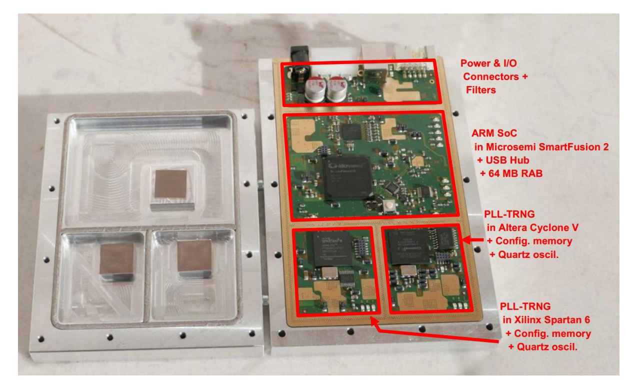


Figure 2 above:
Demonstrator 1 of the H2020-ICT-644052 HECTOR project

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 ongoing projects supported by the European Commission, the ANR, the Auvergne-Rhône-Alpes Region and by our industrial partners.

In 2024, our research teams were working on approximately 160 funded projects, including 9 European and 36 ANR contracts, as well as 8 Auvergne-Rhône-Alpes region-financed projects. Several of our doctoral students are working under CIFRE or other industrial contract theses.

ongoing 2024 ANR PROJECTS

Project acronym & *title*		Ref. no: ANR-	Team
HYPERSOL	*Interfaces management of Hybrid Perovskite based Solar cells*	18-CE05-0021	ISCV
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	LMI
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
MAGMA	*Machine learning to improve neonates' General Movements Assessment*	23-SSAI-0005	ISCV
CANDYCE	*Magnetic composites based on gold-functionalized YIG or Ce-YIG nanoparticles*	24-CE09-7888	FMS
MELISSA	*Methodological contributions in statistical learning inspired by surface engineering*	24-CE23-7140	DI
ULTRAVIBE	*Unravelling ultrafast heat transfer in glasses by direct MIR probing of anharmonic vibrations*	24-CE08-3983	LMI
ULTRAZO	*Ultimate laser-driven restructuring and defect formation dynamics in doped ZnO thin films*	24-CE08-7917	FMS
INSEPTION	*Investigation of nonlinear propagation of ultrafast infrared laser pulses inside narrow-bandgap semiconductors*	24-CE92-0007	LMI
GENIE	*Generative Network Intelligence and optimization Ecosystem*	24-IAS1-0005	DI
VO2Random	*Vanadium Dioxide-Based Films for Randomizing Integrated Circuits Photonic Emission and Absorption*	23-CE39-0004	LMI

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**

40 ongoing 2024 **INDUSTRIAL PROJECTS**
19 ongoing 2024 **CIFRE theses**

ongoing 2024 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
FAILURE ANALYSIS	*Key for reliable electronic devices in smart mobility and industrial production*	ISCV
PHOTONHUB	*Services to support your innovation in Photonics*	MOPERE
EURAD (MODATS)	*European Joint Programme on Radioactive Waste Management*	MOPERE
GREAT	*Grating Reflectors Enabled laser Applications and Training*	FMS
CIRCULIGHT	*Circulating light on any photonic platform*	FMS
RAVEN	*Revolutionary Accuracy in waVeguide- and photoacoustic-ENabled atmospheric sensors*	FMS
xDDIFF	*Multidimensional optical diffusion for the measurement of appearance*	ISCV

ongoing 2024 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
DIAGHOLO	*Microbiological Diagnosis by Holographic microscopy*	ISCV
SECURE-RISC-V	*Secure version of the Risc-V architecture*	SESAM
CAPTHY	*Optical Sensors for Hydrogen detection*	FMS
BOOSTER QABOT	*Question Answering & Chatbot*	DI
PAI 2024	*Micro Nano structuration de surface pour le photovoltaïque*	FMS

new 2024 ANR projects

In 2024, a total of 6 projects submitted by the Hubert Curien Laboratory were selected for an ANR AAP 2024 funding. The list of these projects reflects the variety and quality of the research carried out in our lab.

PRC PROJECT: CANDYCE
Partners: ICCF Clermont, Hubert Curien Lab
Project coordinator: PHENIX
Lab's PI: Damien Jamon
Functional Materials & Surfaces team

CANDYCE - "Magnetic composites based on functionalized YIG or Ce-YIG nanoparticles"
The Candyce project aims to overcome the challenging integration of efficient magneto-optical materials onto conventional photonic platforms through the liquid-phase synthesis of Ce-YIG (cerium-doped yttrium iron garnet) nanoparticles embedded in a sol-gel matrix. These nanoparticles may be coated with gold to highlight magneto-plasmonic effects. In addition to characterizations based on the determination of the suspensions' magnetic induced Mueller matrix, our lab will demonstrate the material integrability on a photonic platform based on microstructured optical fibers.

PRC PROJECT: MELISSA
Partners: ISIR (PSL), Inria MAGNET, Hubert Curien Lab
Project coordinator: Hubert Curien Lab
Coordinator: Marc Sebban
Data Intelligence team

MELISSA - "MEthodological contributions in statistical Learning InSpired by SurfAce engineering"
Physics-informed Machine Learning (PiML) has recently emerged as a promising way to solve Partial Differential Equations (PDEs). However, several open problems remain to be addressed: (i) Deriving generalization guarantees; (ii) Learning with a limited amount of data; (iii) Augmenting partially known physical laws; (v) Modeling uncertainty; (vi) Building foundation models for physics. The objective of MELISSA is to design the next generation of provably accurate PIML algorithms in the challenging context of laser-matter interaction, where data is scarce and the available physical laws only partially explain the observed dynamics.

TSIA PROJECT: GENIE
Partners: IMT Atlantique, Hubert Curien Lab, IRISA Rennes, Université de Côte d'Azur
Project coordinator: IMT Atlantique
Lab's PI: Kamal Singh
Data Intelligence team

GENIE - «GEnerative Network Intelligence and optimization Ecosystem»
This project aims to revolutionize network infrastructure management by proposing an approach combining the strengths of Large Language Models (LLMs) and network domain-specific expertise. It addresses the limitations of conventional techniques, enabling automated, adaptable and interpretable network management. The team aims to translate high-level intentions into network configurations and solutions, ensuring performance requirements and operational constraints. GENIE will design an LLM pipeline for network management and will investigate cooperative and evolutionary strategies. The project's potential impact lies in its ability to deliver significant advances in network infrastructure management and network automation.

PRCI PROJECT: INSEPTION
Partners and project coordinators:
Institute of Applied Physics Jena + Hubert Curien Lab
Coordinator: Elena Kachan
Laser-Matter Interaction team

INSEPTION - «Investigation of nonlinear propagation of ultrafast infrared laser pulses inside narrow-bandgap semiconductors»
The objective of this project is to realize highly-precise 3D modifications in the volume of narrow-gap semiconductors most commonly used in microelectronics, which is currently only possible for transparent wide-gap materials such as glass. The main challenge is to better control extreme nonlinear propagation effects taking place inside narrow-gap semiconductors, even for infrared radiation.
To address this issue, our lab will design an original computationally efficient quantum-mechanical model, validated using novel experimental techniques developed by the IAP in Jena, Germany.

JCJC PROJECT: ULTRAVIBE
Project coordinator: Hubert Curien Lab
Coordinator: Vincenzo De Michele
Laser-Matter Interaction team

ULTRAVIBE - "Unravelling ultrafast heat transfer in glasses by direct MIR probing of anharmonic vibrations"
Precise control of laser material structuring requires a comprehensive understanding of the light-matter interaction at the ultrafast timescale. This understanding includes the electronic processes governing the absorption of laser energy and the consequent relaxation, through electronic or vibrational pathways. ULTRAVIBE proposes a dynamic introspection into the fastest structural changes occurring in wide bandgap materials under strong field excitation, by directly interrogating the material matrix, i.e. by time-resolved monitoring of vibrational signatures on ultrafast scales using mid-infrared pump-probe spectroscopy. It aims to reveal a competition between electronically-induced and collisionally-activated vibration modes.

PRCE PROJECT: ULTRAZO
Partners: St Gobain (SVI Lab), Institut Fresnel, IPCMS, Hubert Curien Lab
Project coordinator: St Gobain (SVI Lab)
Lab's PI: Nathalie Destouches
Functional Materials & Surfaces team

ULTRAZO - "ULTimate laser driven Restructuring And defect formation dynamics in doped ZnO thin films"
Transparent Conductive Oxides (TCOs) thin films are largely used in photovoltaics, OLEDs, touch screens, and are essential materials for energy transition. The ULTRAZO project focuses on aluminum-doped zinc oxide (AZO), a non-toxic, abundant TCO compatible with energy-efficient deposition and baking processes. The main scientific goal is to understand and master local laser modification dynamics in out-of-equilibrium inorganic metal oxides. By using carefully selected laser beams to deliver precise amounts of energy, the project aims to control transformations with minimal energy input, to enhance understanding of crystallization, diffusion, activation and defect formation processes, as well as provide more sustainable TCOs.

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 Government. 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 its «Post-quantum padlock for web browser» project, our SESAM's team 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 benefits from part of the 39M€ of this PEPR dedicated to support the equipment of the CNRS RENATECH / RENATECH+ infrastructures.

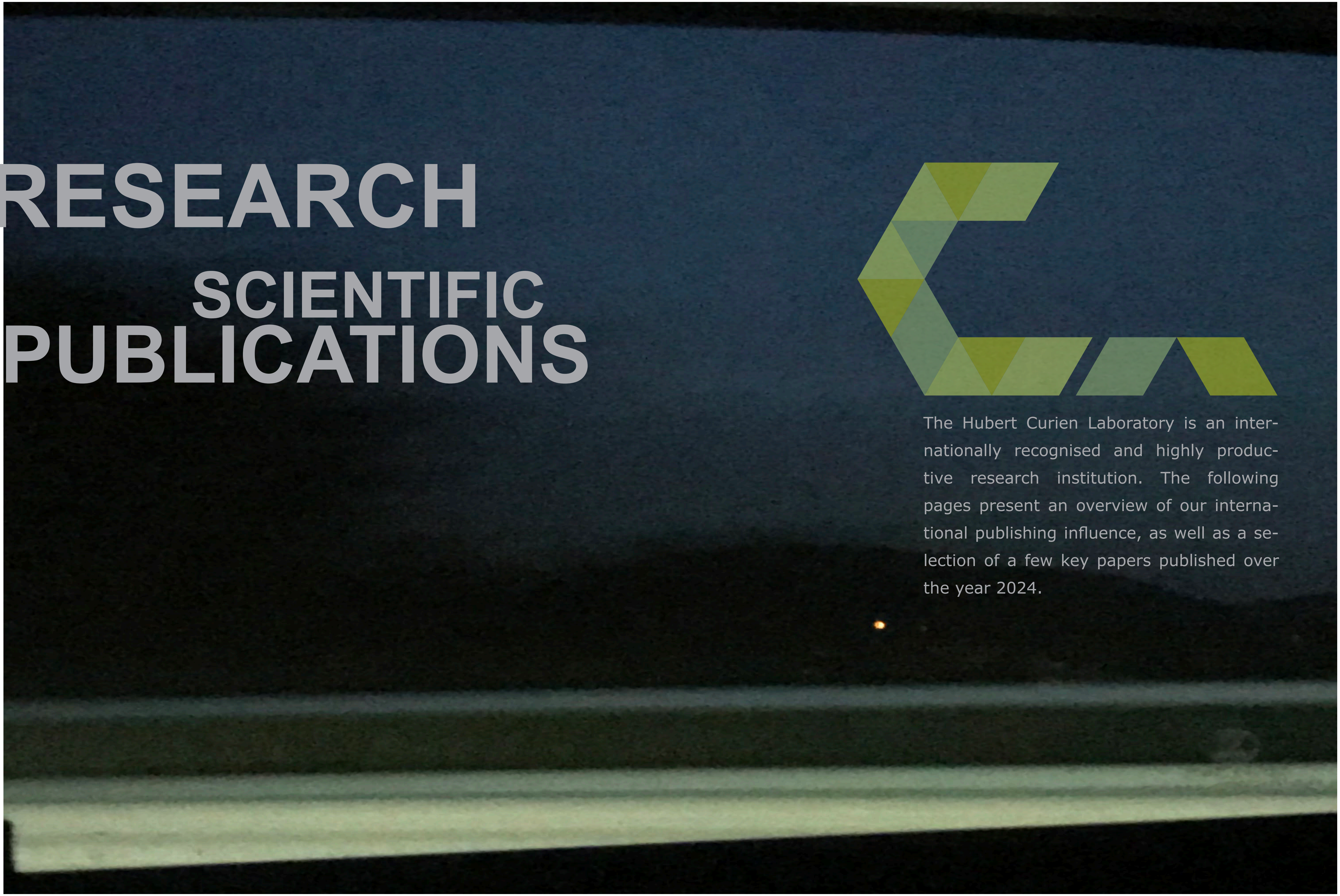
Our lab is also involved in the Artificial Intelligence PEPR and the TASE-Advanced Energy Systems Technologies PEPR.

Exploratory PEPRs
With these PEPRs, the State intends to support the exploration of emerging transformations' potentials. Projects should here follow a scientific policy aligning 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 20 and 21.

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". This PEPR also funds the access (50 days/year) to the lab's NanoSaintÉtienne and Ultrafast Laser 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.



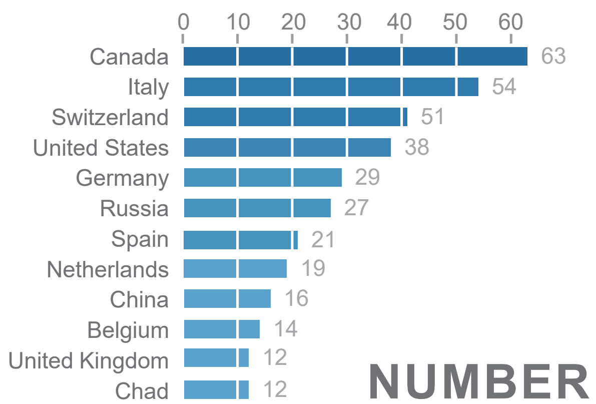
RESEARCH

SCIENTIFIC PUBLICATIONS

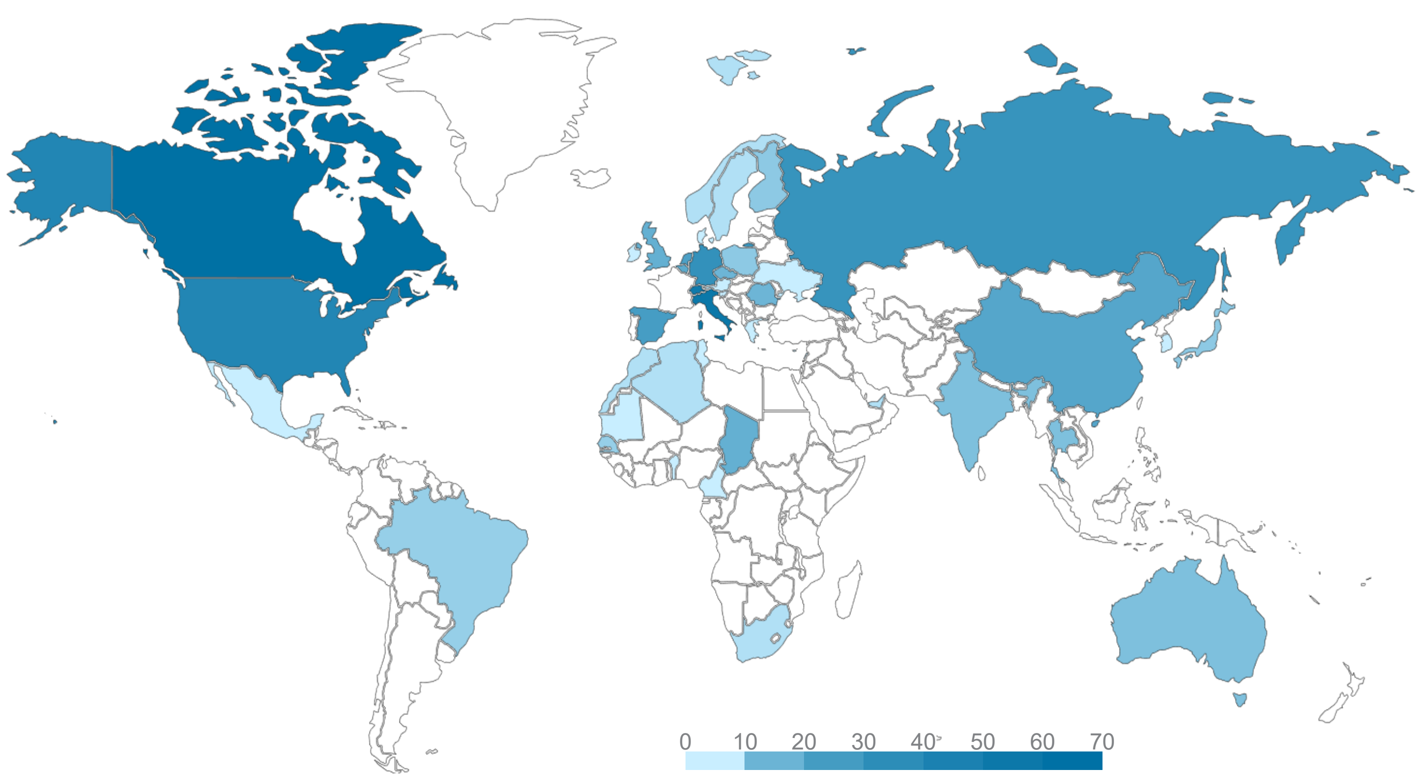
The Hubert Curien Laboratory is an internationally recognised and highly productive research institution. The following pages present an overview of our international publishing influence, as well as a selection of a few key papers published over the year 2024.

PUBLICATIONS
overview

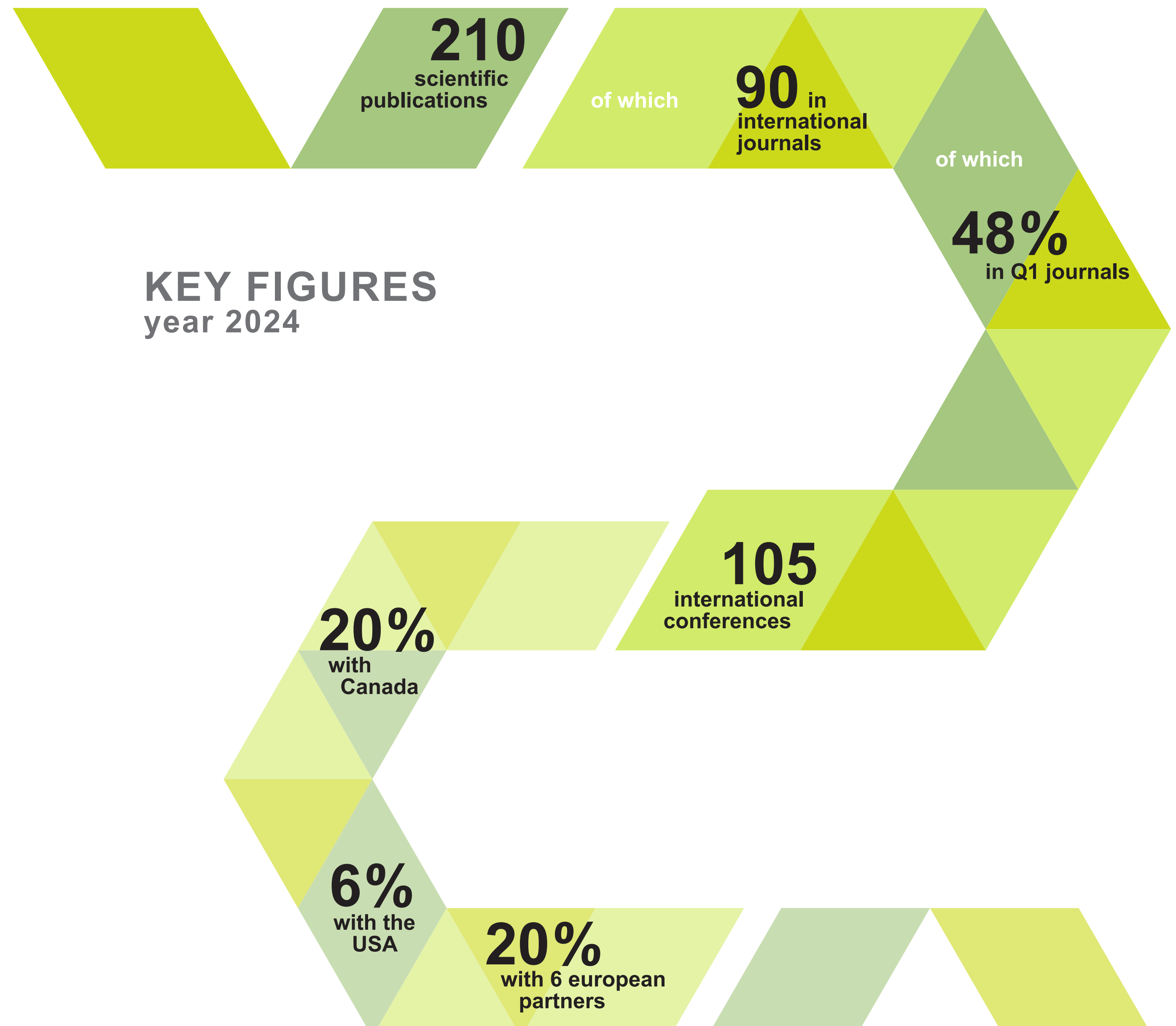
Our research collaborations are considerably spreading beyond the national stage to reach all continents.
Below are some graphics illustrating the geographical location of the institutions we have published with since 2020, also indicating the number of publications by individual country.



NUMBER of publications with an author from this country
last 5-year period - 2020 to 2024 (non-exhaustive list)



KEY FIGURES
year 2024



Scientific Reports

On thermal characterization method of integrated magnetic components

Bechir Mahamat Basma, David Piétroy, Mahamat Issa Boukhari, Zacharia Chahbi, Thomas Blanchet, Jean Pierre Chatelon, Stéphane Capraro and Jean Jacques Rousseau.

In February 2024, an article co-written by members of our Functional Materials & Surfaces team was published in Scientific Reports, a Nature journal dedicated to research from across all areas of the natural sciences, psychology, medicine and engineering. The paper focusses on the measuring of temperatures in integrated inductors for power electronics.

Nowadays' demand for portable technologies drives the general and increasing miniaturization of electronic components. This miniaturization leads to higher current densities and operating temperatures, particularly in power components such as integrated transformers and DC-DC converters, making thermal analysis crucial for ensuring reliability. High temperatures can alter electrical properties and cause mechanical strain, potentially resulting in component failure. Heat transfer occurs through conduction, convection and radiation, each influenced by material properties and component geometry. Smaller components face greater challenges in temperature management, especially in power electronic circuits with high currents and powers. Accurately measuring temperature in small components is difficult, and embedded temperature sensors have become a preferred solution.
This paper compares two methods for measuring temperature in integrated inductors for power electronics: a widely used method based on Integrated Resistive Sensors (IRS) and an innovative method based on Fiber Bragg Gratings sensors, which is less commonly used in the electronics industry. The study evaluates these methods through simulation and experimental results, highlighting their respective advantages and limitations. The goal is to determine the best approach for accurately measuring and managing the temperature in different electronic components, ensuring their reliability and performance.

Figure 1

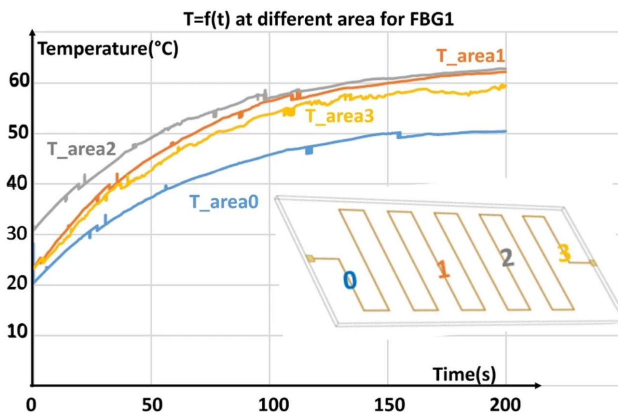


Figure 2

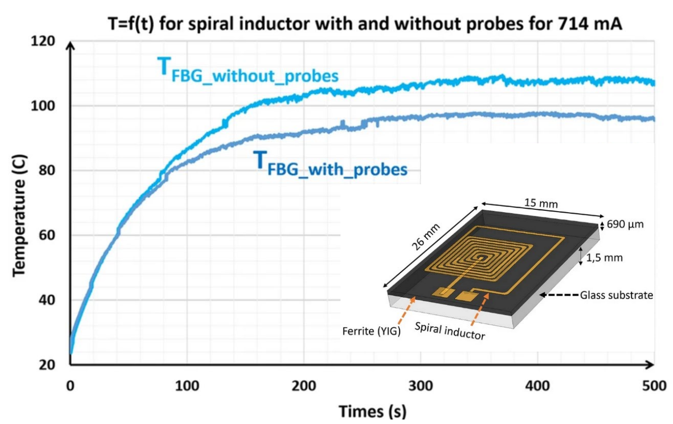


Figure 1:
Evolution of temperature along the central axis of the component.

Figure 2:
Evolution of the temperature of the spiral inductor with and without probes at current 714 mA, demonstrating the error induced by the impedancemeter-based measurement setup with IRS. Probes act like a heat leak while FBGS do not disturb the thermal behaviour of small components.

Scientific Reports, Vol.14 (2024), Article no. 4864

Applied Optics

Characterization of a perfect sinusoidal grating profile using an artificial neural network for plasmonic-based sensors

Moustapha Godi Tchéré, Stéphane Robert, Julie Dutems, Hugo Bruhier, Bernard Bayard, Yves Jourlin, and Damien Jamon.

Applied Optics publishes scientific articles focused on applications-centered research in optical technology, photonics, lasers, information processing, sensing and environmental optics. In May 2024, our Functional Materials & Surfaces team published a paper addressing the identification of a perfect sinusoidal grating profile from an ellipsometric signature using artificial neural networks.

The manufacturing process of gratings used as plasmonic sensors requires appropriate, fast, and reliable characterization techniques. Research has shown that a perfectly sinusoidal grating profile provides better coupling, allowing the plasmon to propagate at the metal-dielectric interface with high efficiency and minimal losses, mainly due to its smooth corrugation. Therefore, a perfectly sinusoidal grating is essential to ensure an optimal plasmonic effect.
The method put forward in this article allows the classification of the most optimal sinusoidal profiles of a grating structure produced by an interference lithography process before the etching process, using an optical signature.

Two types of multilayer perceptrons are implemented to classify ellipsometric measurements according to their corresponding geometrical profiles. The first perceptron, named TOR, aims to estimate the probability for each sample to belong to the targeted sinusoidal profile Ps (See Figure 1). The second perceptron, named Class4, is devoted to identifying manufacturing defects from the expected profile (See Figure 2).
The demonstration was performed on photoresist-based profiles, which are used as masters in the NanoImprint process to produce several conformal replicas. All results are validated by the corresponding AFM measurements.
The proposed method can then be efficiently implemented into a complete characterization process based on the inverse scatterometric problem. This technic typically relies on certain assumptions, such as prior knowledge of optical indexes or layers' thicknesses. In this context, the presented multilayer perceptrons can be used to provide additional information to certify, for example, the geometrical shape during the classical process (See Figure 3).

		Real class		Precision
		P_s	P_{fs}	
Predicted class	P_s	450	19	95.9%
	P_{fs}	0	431	100%
Sensitivity		100%	95.8%	97.9%

Figure 1: Confusion matrix of the TOR (20 hidden neurons) focused on the detection of a sinusoidal profile P_s. Class P_{fs} contains the other profiles considered as potential manufacturing defects.

		Real class				Precision
		P_s	P_g	P_{sd}	P_{st}	
Predicted class	P_s	450	13	9	0	95.3%
	P_g	0	414	15	1	96.3%
	P_{sd}	0	19	406	39	87.5%
	P_{st}	0	4	4	410	94.5%
Sensitivity		100%	92.0%	90.2%	91.1%	Accuracy: 93.3%

Figure 2: Confusion matrix of the Class4 focused to the classification among four geometrical profiles (the sinusoidal targeted shape P_s, the distorted sinusoidal profiles P_{sd} and the truncated sinusoidal profiles P_{st}) for a threshold of acceptability fixed at 50%.

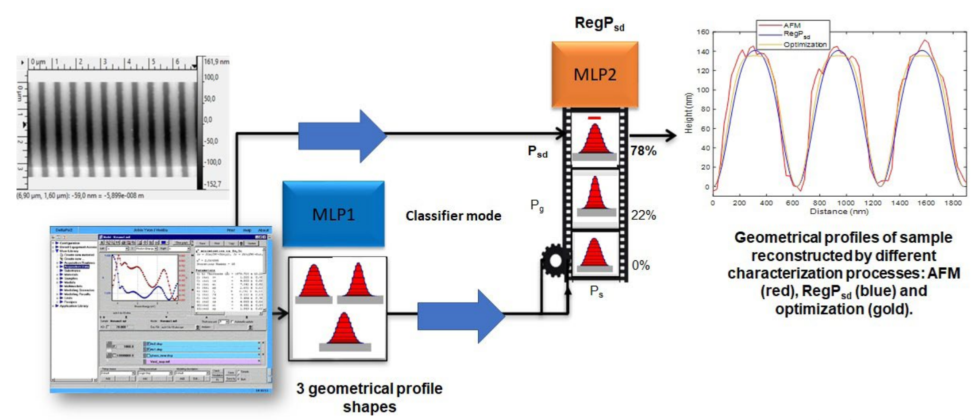


Figure 3: Geometrical profiles of sample reconstructed by different characterization processes: AFM (red), $RegP_{sd}$ (blue) and optimization (gold).

Applied Optics, Vol. 63, Issue 14 (2024), pp. 3876-3884

ACS Applied Optical Materials

Understanding and Exploiting the Optical Properties of Laser-Induced Quasi-Random Plasmonic Metasurfaces

Van Doan Le, Balint Eles, Nicolas Dalloz, Manuel A. Flores Figueroa, Francis Vocanson, Christophe Hubert, and Nathalie Destouches

ACS Applied Optical Materials is an international forum for original experimental and theoretical research in optical materials that can integrate knowledge in materials science, chemistry, physics, optical science and engineering. A paper by our Functional Materials & Surfaces team was selected to appear in the journal's March 2024 edition.

Structural color printing has gained significant attention as an eco-friendly method for producing vibrant, long-lasting colors and intriguing visual effects. Unlike traditional inks that rely on dye absorption, structural color technologies create colors through various optical phenomena such as scattering, absorption, diffraction, interference, and resonance mode coupling. This approach offers significant advantages and design flexibility for developing optical devices and applications, including data storage, information security, color filters, sensors, and display technologies. Numerous methods have been developed to produce metamaterials with structural colors, such as electron beam lithography, focused ion beam techniques, and chemical methods. Among these, laser-based technologies stand out in industrial processes due to their versatility, speed, cost-effectiveness, and scalability. Lasers can alter the physical properties of metamaterials, thus changing their colors. This includes resizing, reshaping, and organizing metallic particles to tune their localized surface plasmon resonances (LSPR) by adjusting geometric parameters. However, the random arrangement of nanoparticles (NPs) created by lasers hinders our understanding of the optical properties of the produced structural colors, limiting our confidence in their reproducibility. In their article, the team demonstrates how nanosecond lasers and random NP patterns can be used to control the diffraction of light and the production of colors.

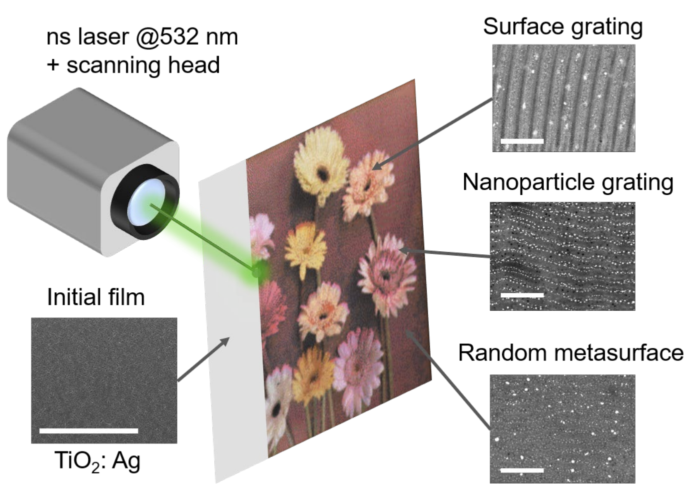


Figure left: Principle of the laser marking process illustrated with scanning electron microscopy images showing the varying colors of laser-induced metasurfaces.

ACS Applied Optical Materials, Vol. 2, Issue 3 (2024), pp. 373-385

Journal of the Optical Society of America A

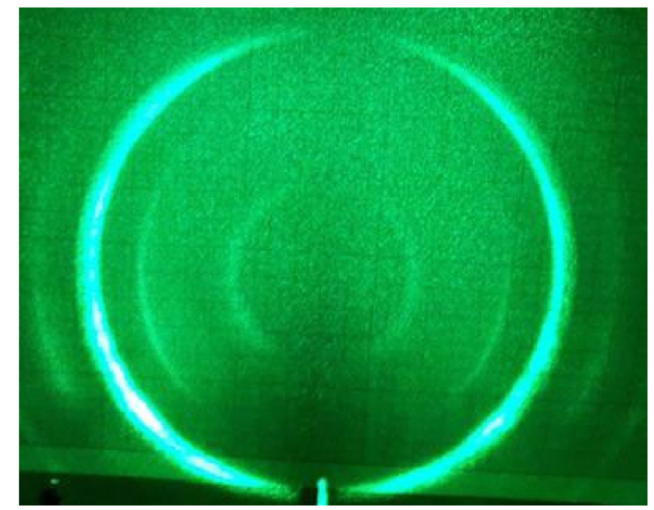
Optical diffraction properties of three superimposed self-organized nanostructures induced by a laser process

Van Doan Le and Nathalie Destouches

An article by our Functional Materials & Surfaces team was published in February 2024 in JOSA A, a journal publishing scientific research results related to developments in any field of classical optics, image science and vision.

Diffraction gratings are essential optical components that split and diffract light into specific directions. This occurs because gratings act as phase-modulating structures, creating periodic phase variations in the incoming electromagnetic waves. These structures are periodically spaced at the wavelength scale. Diffraction gratings have wide-ranging applications, including sensing, security, data storage, holography, surface plasmon resonance, beam splitting, and wave coupling. In recent decades, advances in laser-induced periodic structures (LIPSs) have enabled the customization of diffraction gratings for practical applications due to the simplicity and cost-effectiveness of the single-step process. LIPSs can be created on most materials, resulting from the interference of incident lasers with excited electromagnetic modes such as surface plasmon polaritons or guided waves. These structures hold significant potential in optical applications, biology, and other technical fields. Notably, the self-organization of Ag-based nanocomposites using lasers has shown promise for visual effects and security features due to the diffractive colors from nanoparticle arrays or surface gratings. For example, femtosecond lasers have been used to generate grating structures that reveal hidden images at specific observation angles by controlling the grating orientation.
In their article, Van Doan Le and Nathalie Destouches delve into the fascinating circular and asymmetric diffraction patterns created by superimposed grating structures or gratings with asymmetric geometry, using Rigorous Coupled Wave Analysis (RCWA) and diffraction equations written in cosine space.

Illustration below:
Circular diffraction patterns resulting from the combined effects of three superimposed laser-induced gratings.



Journal of the Optical Society of America A, Vol. 41, Issue 2 (2024), pp. 296-302

Nanophotonics

Magneto-plasmonic “switch” device for magnetic field detection

Laure Bsawmaii, Pascal Giraud, Gerges El Haber, Lukáš Halagačka, Jean-Pierre Chatelon, Damien Jamon, Yves Jourlin and François Royer

In June 2024, a paper co-authored by our Functional Materials & Surfaces team was published in Nanophotonics, a scientific journal dedicated to photon interactions with nano-structures. The research results from a collaboration with Lukáš Halagačka, from the Czech Technical University of Ostrava, who stayed in our lab as a visiting professor in 2023.

Building on a plasmonic «optical switch» device discussed in earlier newsletters, the team enhanced the system by adding a magnetic functionalization - a thin cobalt covering layer less than 15 nm thick (Fig. 1-a). One major challenge was implementing a simulation method that accounts for the off-diagonal terms of the permittivity tensor, a key feature of magneto-optical materials (Fig. 1-b-d). These devices, known for their high sensitivity to environmental changes, operate via differential measurement and were used to investigate the magnetic state of the cobalt layer, which is affected by its thickness (Fig. 2). Specifically, the magnetic anisotropy transitions from in-plane to out-of-plane as the layer's thickness decreases. This magnetic sensitivity arises from the non-reciprocal modification of the propagation constant of the plasmonic mode.

In the long term, these fully optical devices hold potential for detecting magnetic fields, leveraging the interplay between plasmonics and magneto-optical effects.

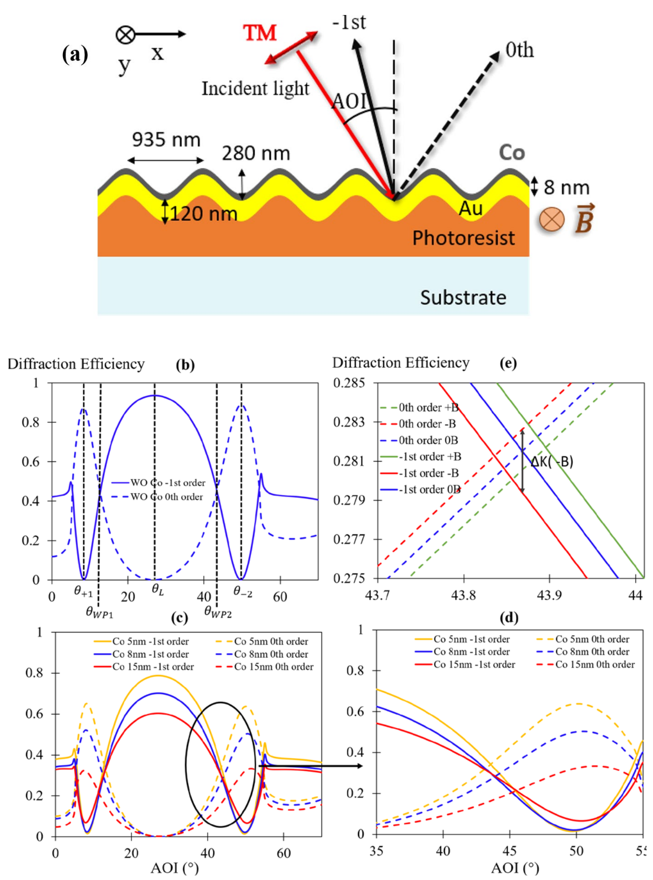


Figure 1, above: Numerical study of the magneto-plasmonic switch effect.
(a) Schematic illustration of the magneto-plasmonic structure with TM-polarized incident light.
Simulated angular spectra of diffraction efficiency for 0th and −1st diffraction orders for grating:
(b) without (WO) Co,
(c) and (d) with different Co thicknesses.
(e) Simulated angular spectra of diffraction efficiency for 0th and −1st diffraction orders for grating with 8 nm of C under an applied magnetic field.
Here, we are referring to a saturating B, inducing the full magnetic alignment of M of Co along the y direction.

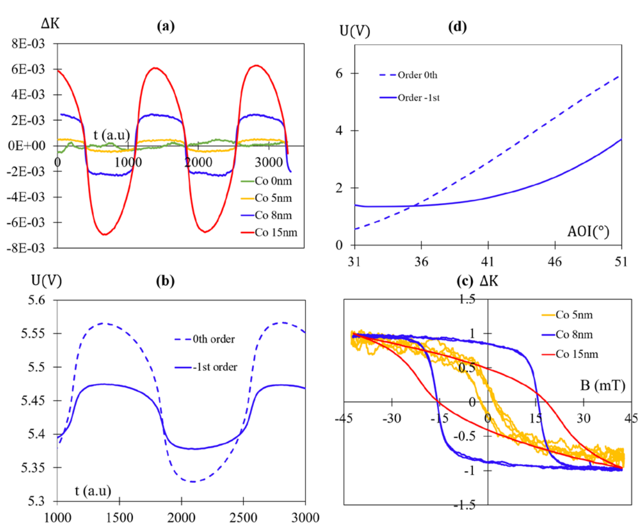


Figure 2, above: Effect of Co thickness.
(a) Normalized voltage difference (ΔK) for different Co thicknesses when a sinusoidal magnetic field is applied (F = 700 mHz) and at AOI corresponding to the second crossing point of each switch optical curve.
(b) Time evolution of the reflected voltage of the 0th and −1st diffracted orders of the structure with 15 nm of Co under the applied magnetic field and an AOI = 35.5°.
(c) Hysteresis loop of ΔK for different Co thicknesses.
(d) Measured optical switch, without magnetic field, for the structure with 15 nm of Co.

Nanophotonics, Vol. 13, Issue 19 (2024), pp. 3689-3698.

Scientific Reports

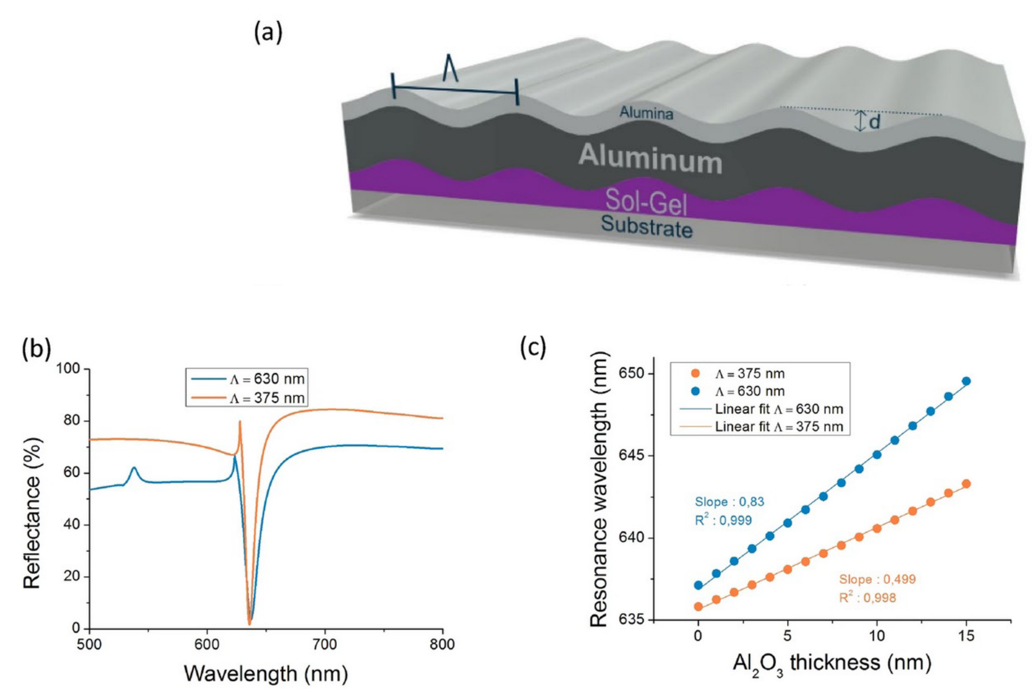
In situ monitoring of thin alumina passive film growth by surface plasmon resonance (SPR) during an electrochemical process

J. Dutems, N. Crespo-Monteiro, F. Faverjon, V. Gâté, D. Turover, S. Marcellin, B. Ter-Ovanessian, C. Héau, I. Verrier, B. Normand and Y. Jourlin

Scientific Reports is an open access journal that publishes original research spanning all areas of the natural sciences, psychology, medicine and engineering. In its June 2024 edition, our Functional Materials & Surfaces team co-authored an article presenting a novel optical method aimed at enhancing our understanding of passive film formation and characteristics.

Metals such as aluminium, its alloys, or stainless steel, are commonly used in various industries and high-technology sectors. These metals are often exposed to severe environments, making them susceptible to degradation, partly through corrosion. In order to limit this degradation, some metals have a defense mechanism that involves the formation of a passive film, a protective oxide layer only a few nanometers thick. This passive film is generally characterized using electrochemical methods, which allow to study its thickness, corrosion resistance depending on its environment, as well as its complexity. However, due to the films' extreme thinness and their evolution in different environments, their characterization remains challenging, and complementary measurements are necessary to validate the electrochemical models. The main objective of this article is to introduce surface plasmon resonance (SPR) as an optical method helping with the in situ characterization of passive films during electrochemical analysis.

Figure, below:
(a) Structure of the simulated diffraction grating with period Λ and the grating depth d.
(b) Reflectance response as a function of wavelength under the simulated configuration.
In orange, Λ=375 nm with grating depth d=36 nm. In blue, Λ=630 nm with grating depth d=54 nm.
(c) Simulation of the growth af an Al_2O_3 for both structures.



Scientific Reports, Vol. 14 (2024), Article number: 13804

ACS Applied Optical Materials

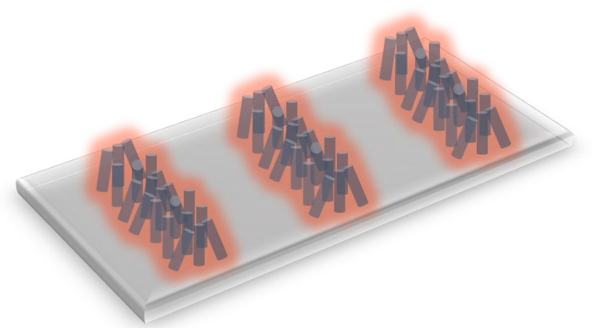
Enhanced Spontaneous Light Emission of ZnO Nanowire-Based Gratings

Emmanuel Centeno, Aubry Martin, Audrey Potdevin, François Réveret, Rafik Smaali, Jesukpego Anorld Capo Chichi, Victor Kalt, Elena Kachan, Yves Jourlin, Michel Langlet and Geneviève Chadeyron

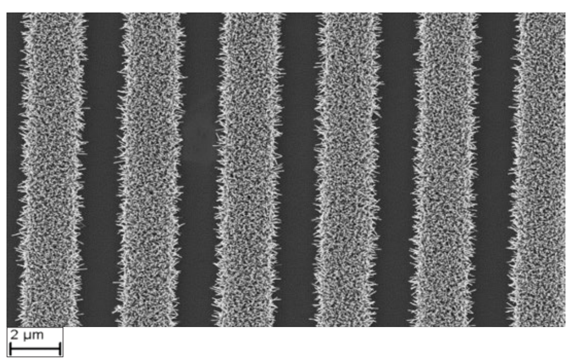
A paper co-authored by our Functional Materials & Surfaces team was published in 2024 in ACS Applied Optical Materials, a journal focused on experimental and theoretical research in optical materials integrating knowledge in materials science, chemistry, physics, optical science and engineering.

In this article, the authors present a novel light-emitting device (LED) that combines nano- and micro-structuring of photoluminescent material. Bands of ZnO nanowires - 40 nm in diameter and 500 nm in height - are arranged periodically on a quartz substrate, with a width of 2 µm and a period of 4 µm. This nanowire-based grating can enhance light extraction efficiency and color rendering index, resulting in more intense and whiter emitted light. Experiments and simulations demonstrate that this LED design benefits from both the light-guiding properties and high surface-to-volume ratio of nanowires, as well as the optical resonances of a micro-grating.

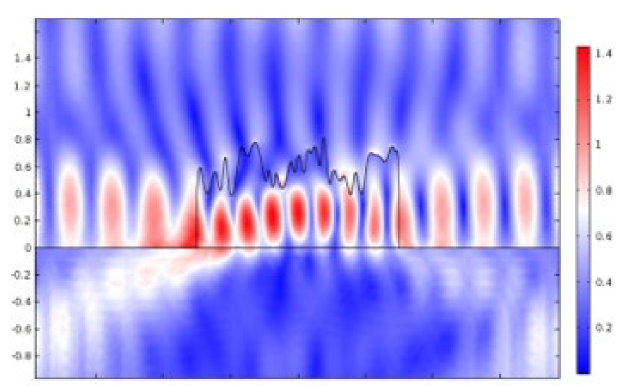
Figures, left:



a) Schematic of the nanowire-based grating.



b) Top-view scanning electron microscope image of the sample.



c) Simulated electric field amplitude distribution inside the sample. Note the enhancement of the field inside a nanowire band of the grating.

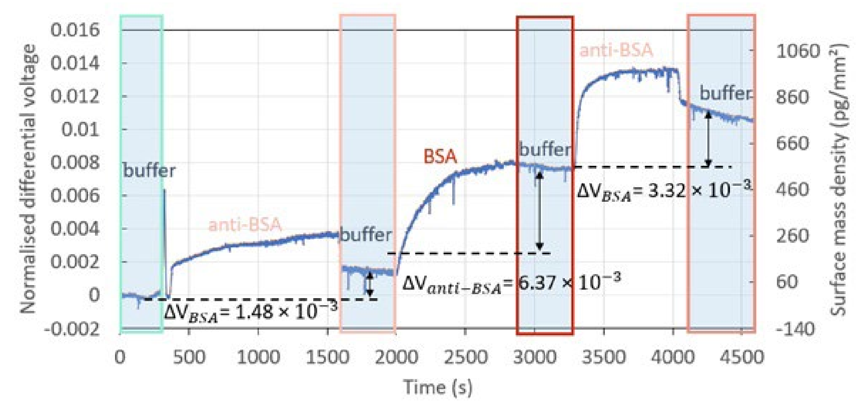
Sensing and Bio-Sensing Research

Biosensing in the optical switch configuration on strong plasmonic gratings enabling differential referenced detection

Emilie Laffont, Arnaud Valour, Nicolas Crespo-Monteiro, Pierre Berini and Yves Jourlin

Sensing and Bio-Sensing Research is a journal dedicated to the research, design development and application of all bio-sensing and sensing technologies. An article was published in its August 2024 edition, presenting the results of our Functional Materials & Surfaces team work, done in collaboration with the University of Ottawa.

Although widely used for disease detection, common tests such as Enzyme-Linked Immunosorbent Assays (ELISA) and Polymerase Chain Reaction (PCR) are time-consuming, expensive, and require complex sample preparation. To address these limitations, alternative rapid biosensors such as lateral flow assays (LFAs), electrochemical assays, and surface plasmon resonance (SPR) sensors have been developed. Among these, SPR sensors show particular promise due to their high sensitivity, ease of use, and suitability for point-of-care applications. Recent advancements include smartphone-based SPR platforms and portable devices that perform similarly to quantitative PCR. Additionally, a novel SPR configuration using an optical switch has been introduced, offering cost-effective, sensitive detection through a strong grating with a high depth-to-period ratio. This configuration improves accuracy by measuring two diffraction orders simultaneously, reducing noise and drift.
This paper focuses on implementing this optical switch configuration for biosensing, using immunoassays for bovine and human serum albumins and their corresponding antibodies. The results show promise for detecting infectious diseases, particularly by identifying infection stages through quantitative antibody concentration analysis.



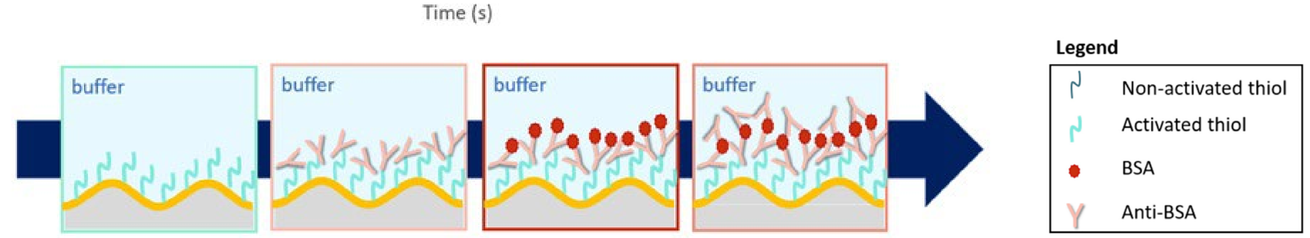


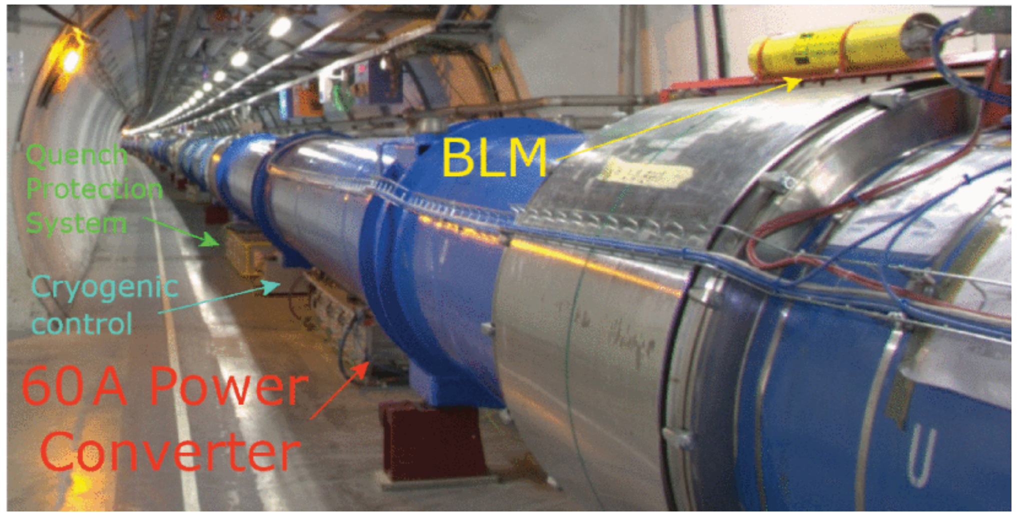
Figure:
Sensor's signal demonstrating a sandwich assay for the detection of BSA by a second injection of anti-BSA on a gold-coated sinusoidal grating.

IEEE Transactions on Nuclear Science

Radiation Environment in the Large Hadron Collider During the 2022 Restart and Related RHA Implications

Kacper Biłko, Rubén García Alía, Ygor Aguiar, Salvatore Danzeca , Diego Di Francesca , Simone Gilardoni, Sylvain Girard, Daniel Ricci, Marc Sebban and Slawosz Uznanski

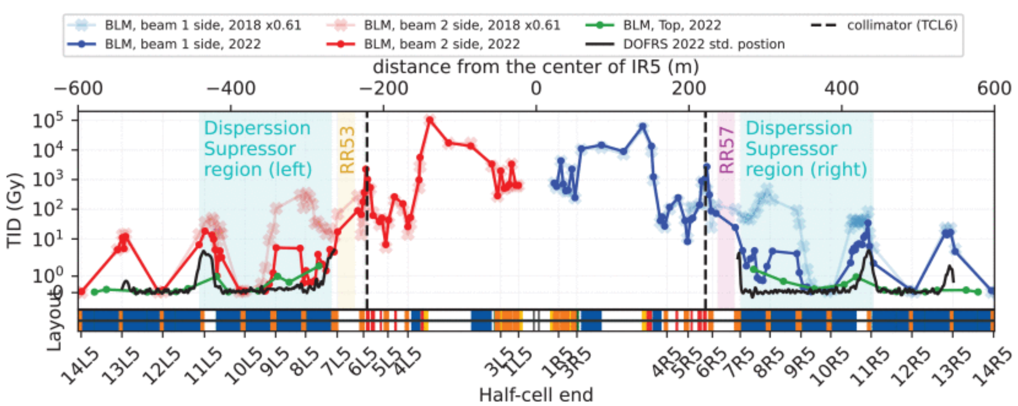
Illustration right: Example of the electronic systems for: quench protection system, cryogenic control, and 60-A power converters with the FGClite controller; installed under the LHC beamlines, in the 18th half-cell on the left side of IR3. On top of the interconnect of the main dipole magnets, a BLM is installed.



In April 2024, members of our MOPERE team contributed to a paper published by CERN in IEEE Transactions on Nuclear Science, a monthly publication of the NPSS Society covering the theory, technology and applications related to nuclear science and engineering.

This paper delves into the radiation levels around the Large Hadron Collider (LHC), the world's largest particle accelerator, which operates with two counter-circulating high-energy proton beams. The energy of each one can be likened to the velocity of a TGV train at 160km/h. The data collected during the beam collisions by four experiments led to multiple scientific breakthroughs, such as the discovery of the Higgs boson in 2012. However, alongside these triumphs lie challenges. The LHC's operation emits radiation that may compromise the performance of nearby electronic systems crucial to its functionality. This study comprehensively evaluates the impact of this radiation on electronic systems proximal to the accelerator, shedding light on the new challenges that might be encountered in operation after the last maintenance shutdown, which ended in 2021.

Figure right: TID levels in the IR5 (region of the CMS experiment, highlighted in Fig. 2), as measured in 2018 and 2022 by the BLMs. The smaller aperture of TCL6 collimators led to higher local losses (once normalized, increase in TID by a factor 20) and significant loss reduction in the half-cells of DSs (reduction in normalized TID over a factor 400). TID levels measured in 2018 were multiplied by a factor of 0.62 which is equal to the ratio of the integrated luminosities between 2022 and 2018.



IEEE Transactions on Nuclear Science, Vol.71, Issue 4 (2024), pp. 607-617

IEEE Journal of Lightwave Technology

Overview of the Infrared Radiation Responses of Telecom-grade Single Mode Optical Fibers

Alexis Dufour; Adriana Morana; Arnaud Meyer; Emmanuel Marin; Aziz Boukenter; Youcef Ouerdane and Sylvain Girard

The Journal of Lightwave Technology is a biweekly peer-reviewed scientific edition covering optical guided-wave science, technology, and engineering. A study of the radiation response of several singlemode optical fibers (SMF) was carried out by our MOPERE team and published in the Journal's April 2024 edition.

Given the widespread use of telecom-grade single mode fibers (SMFs) in harsh environments, such as space applications, it is of great interest to study their behaviour under ionizing radiation. The most predominant effect induced by radiation on optical fibers is their transmission degradation, known as radiation-induced attenuation (RIA). This is due to the generation of defects in the glass structure, mainly from various precursors. Consequently, the RIA depends on several parameters, linked to the harsh environment and the fiber itself, such as their core and cladding composition, or glass stoichiometry.
In this study, we investigated the RIA of ten different SMFs from three manufacturers, designated as A, B and C: these fibers have different specifications, such as the type of fiber (G.652, G.654, or G.657), cut-off wavelength, intrinsic loss level and composition.
As reported in Fig.1, these fibers can be divided into four categories, based on their radiation response:

- Germanosilicate fibers without P-codoping (A1, A2, A5, B2 and B3);
- P-codoped fibers (C1), which induced losses are higher compared to germanosilicate fibers;
- Ultra-sensitive fibers (A3, A4 et B1), which are ultra-low loss pure silica (ULL-PSC) fibers belonging to categories G.654 C and D. These fibers are characterized by a RIA higher than that of the P-doped fiber, under specific irradiation conditions;
- Fiber A6, an ULL-PSC fiber in the G.654.E category, which presents the lowest radiation sensitivity up to 100 kGy among the tested optical fibers, and an almost linear RIA increase with the dose, a behavior not previously reported in the literature. The nature of the defects involved in this new fiber type is still under investigation.

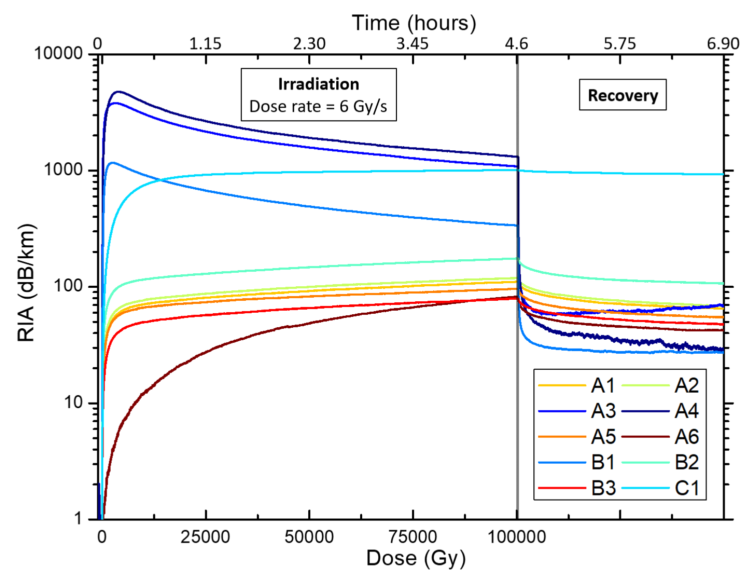


Figure 1:
RIA at 1535 nm for a dose rate of 6 Gy/s as a function of the dose up to 100 kGy, and an additional 2 hours of recovery for the 10 different commercial optical fibers from different manufacturers and with different specifications. These were divided in three categories (A, B and C) depending on their radiation response.

Journal of Lightwave Technology, Vol. 42, Issue 14 (2024), pp. 4987-4996

IEEE Sensors Journal

Distributed Optical Fiber-Based Dosimetry With Optical Frequency Domain Reflectometry

J. Perrot, A. Morana, E. Marin, A. Boukenter, Y. Ouerdane, J. Bertrand, H. Boiron and S. Girard

A paper by our MOPERE team appeared in the July 2024 issue of the IEEE Sensors Journal, a peer-reviewed publication that covers the theory, design, fabrication, manufacturing and applications of devices for sensing and transducing physical, chemical and biological phenomena, with an emphasis on the electronics and physics of sensors and integrated sensors-actuators.

Silica-based optical fibers are effective for monitoring various parameters in harsh environments, including temperature, strain, gas concentration, and radiation levels. However, in such environments, fiber degradation can occur due to factors such as Total Ionizing Dose (TID) and dose rates, making their evaluation essential.
This study introduces a real-time, high spatial resolution 2D mapping sensor for detecting X-rays ionizing radiation doses, proving more effective than traditional dosimetry methods. The sensor uses a phosphorus-doped, silica-based optical fiber combined with a Rayleigh-Optical Frequency Domain Reflectometry (R-OFDR) interrogator. It tracks radiation doses by measuring Radiation Induced Attenuation (RIA) around the 1550 nm wavelength.
The aim of the study is to assess the sensor's performance and its dose-mapping capabilities. The results highlight the value of distributed, time-resolved R-OFDR dosimetry for doses up to 2 kGy with high spatial resolution, as well as its ability to accurately sense radiation beam shapes. By offering significant advancements in optical fiber-based dosimetry, this technique holds promise for a range of applications, including beam shape sensing and monitoring dose distribution in the healthcare sector and nuclear industry.

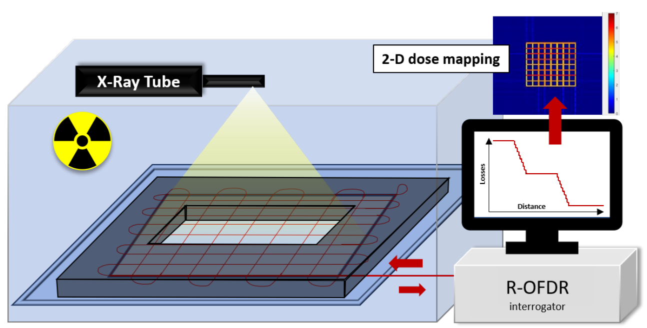


Figure 1 above:
The schematic dose mapping setup gathering the sample dimensions and the mapping principle using a R-OFDR interrogator and a radiation sensitive (P-doped) optical fiber installed for X-ray 2-D dose mapping.

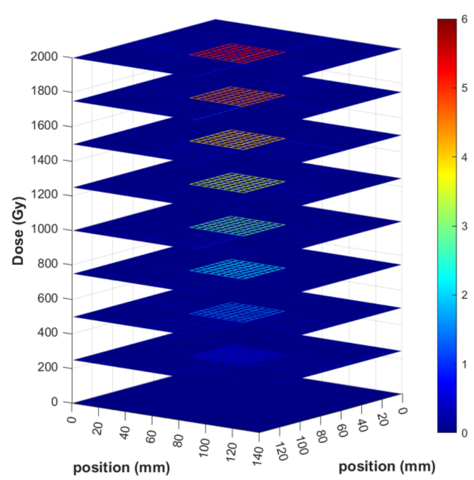


Figure 2, right:
2-D dosimetry mapping results for the sample grid after a cumulated dose up to 2 kGy with a 400 mGy/s dose-rate (X-Rays)

IEEE Sensors Journal, Vol. 24, Issue 13 (2024), pp. 20688-20695

Radiation Measurements

Online and offline Radiation-Induced Attenuation measurements on FD-7 radiophotoluminescence dosimeters irradiated at high X-ray doses

A. Hasan, Y. Aguiar, R. García Alía, C. Campanella, A. Morana, A.K. Alem, S. Girard, A. Raj Mandal and M. Ferrari

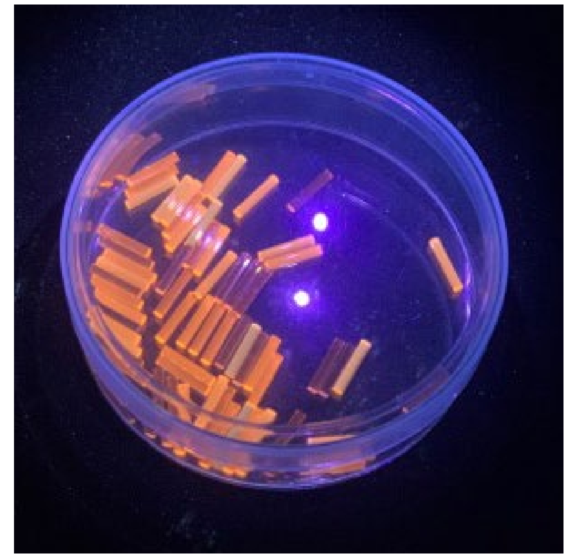


Figure 1, left:
Radiophotoluminescence of the studied glasses
(Acknowledgements: A. Raj, Y. Aguiar)

Radiation Measurements is a monthly peer-reviewed scientific journal that covers both fundamental and applied research in ionizing radiation detection and measurement. A paper by our MOPERE team was published in their September 2024 issue, presenting results obtained as part of the ongoing POEMIRA research project.

The paper presents a dosimetry technique based on the evolution of the optical properties of silver ion-doped phosphate glasses under radiation, taking advantage of phenomena such as radiophotoluminescence (RPL) (Figure 1) and glass darkening. The work focuses on one of the few techniques capable of measuring very high radiation doses - up to the MGy range - encountered in extreme environments such as particle accelerators and nuclear facilities. The paper describes a new setup developed in our laboratory (Figure 2) which enables real-time data collection and post-irradiation recovery measurements, to assess signal kinetics over time.
At CERN, thousands of these RPL dosimeters are deployed in specific locations within the accelerator complex, to passively monitor radiation doses and ensure the safety of both operators and equipment (Figure 3). Through a combination of optical measurements performed after irradiation, the sensitivity range is extended by approximately a factor of 10000.
This work was undertaken in collaboration with the High-Level Dosimetry team at CERN, led by Rubén García Alía (CERN) and Ygor Aguiar (UJM/CERN).

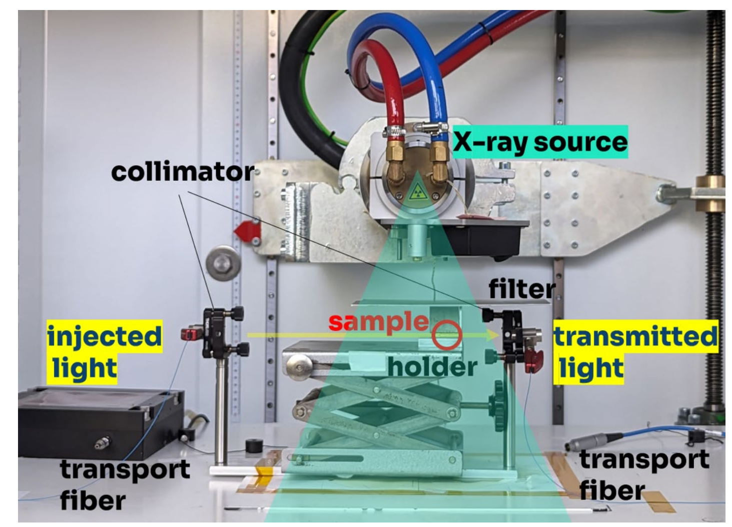


Figure 2, above:
The setup developed at the Hubert Curien Laboratory to study the evolution of optical properties in RPL glasses during irradiation

Radiation Measurements, Vol. 177 (2024), Article no. 107246

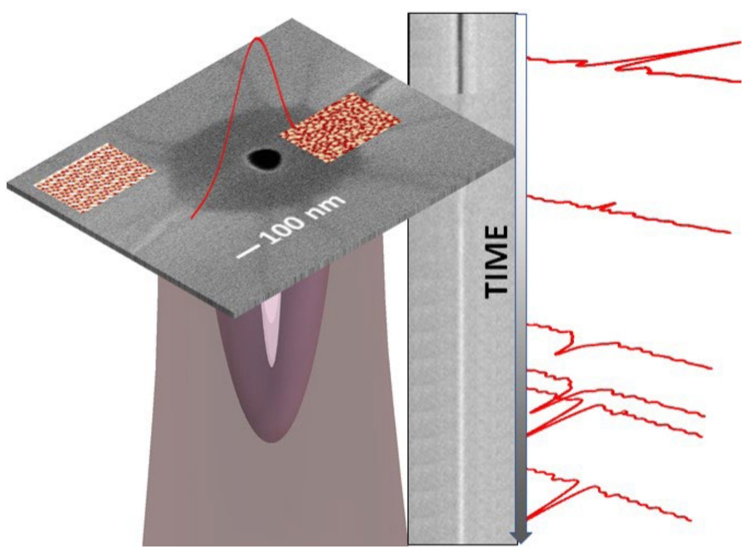
Ultrafast Science

Quantitative Mapping of Transient Thermodynamic States in Ultrafast Laser Nanostructuring of Quartz

H. Dat Nguyen, A. Tsaturyan, S. Sao Joao, R. Dwivedi, A. Melkonyan, C. D'Amico, E. Silaeva, J. P. Colombier, G. Kermouche and R. Stoian

Ultrafast Science is an open access platform for cutting-edge and emerging topics in ultrafast science. In 2024, the Laser-Matter Interaction group of the Hubert Curien Laboratory published a paper presenting a developed optical thermometer for ultrafast processes. The work was done in collaboration with the Ecole des Mines de Saint Etienne's Laboratoire George Friedel.

How light can produce effects on scales much smaller than the wavelength is a key issue in extreme laser manufacturing of technical materials. To this end, observing in real time the intermediate processes leading to nanostructuring under the action of a short and intense laser pulse can provide essential physical insights. Quantifying them in terms of structural and thermodynamic parameters would then become an important advance, permitting to reconstruct the trajectories of matter evolution. Quantitative optical methods can be developed to observe heat transport and structural transitions whenever the interaction region is confined in the bulk, almost as a nanoscale remote thermometer. In this article, the authors report combined time-resolved qualitative and quantitative phase imaging of ultrafast laser volume processing of quartz, to observe the sequence of events leading to volume phase transformation and structuring at the nanoscale.



Figure, above:
Volume nanostructuring of quartz in an amorphised surrounding.

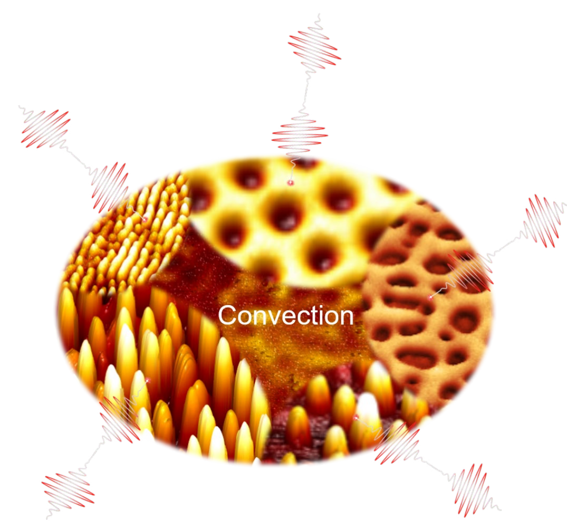
Ultrafast Science, Vol.4 (2024), Article no. 0056

Laser & Photonics Reviews

Beyond the Microscale: Advances in Surface Nanopatterning by Laser-Driven Self-Organization

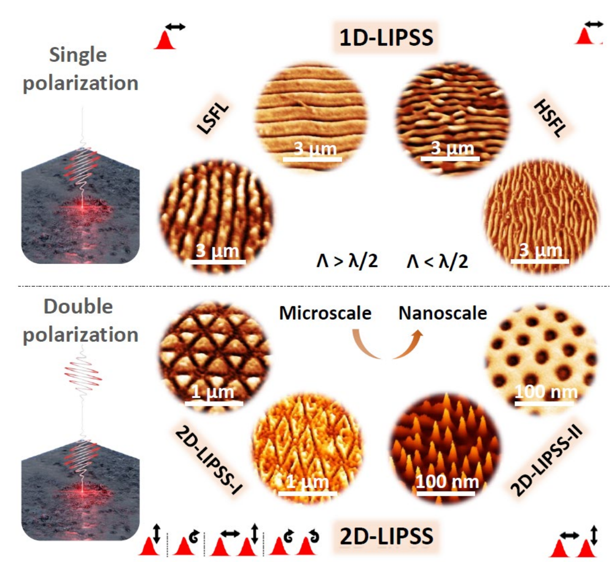
Anthony Nakhoul and Jean-Philippe Colombier

Laser & Photonics Reviews is an interdisciplinary journal at the interface of photonics and optics, publishing top-quality Reviews, original Research Articles, and Perspectives covering recent breakthrough research to specific developments and novel applications, both theoretical and experimental. A review article written by members of our Laser-Matter Interaction team was published in March 2024, presenting an overview of their recent research and experimental results on laser-induced bi-dimensional self-organisation.



Structuring on extreme scales is undergoing revolutionary progress, propelled by the emergence of tabletop ultrafast laser sources that exploit energy confinement and self-organization regimes. By surpassing current optical limits of laser processes, 2D self-organization driven by inhomogeneous light-surface coupling offers a direct pathway to nanoscale laser manufacturing. This strategy facilitates controlled manipulation of local matter through optical fields for laser processing targeting fluid or light transport and trapping.

This review delves into the complex transition from Laser-Induced Periodic Surface Structures (LIPSS) to two-dimensional LIPSS, seeking to comprehend their morphological evolution and shed light on the intriguing realm of 2D self-patterning. By synthesizing observations across multiple scales, this review presents an original compilation of recent results (mostly within the last five years) from international teams, illustrating their physical connection to a common primary mechanism. Categorizing them based on feature size, we uncover diverse configurations within 2D-LIPSS, all rooted in the initiation of fluid convection at different scales, demonstrating notable complexity. Our analysis dissects the nuances of generating fine-scale 2D-LIPSS, deciphering critical parameters governing symmetry breaking and morphological evolution. Moreover, this work offers unparalleled control in creating artificial media with nanofeatures that surpass those of naturally occurring surfaces, promising novel applications in biomedicine, nanocatalysis, and metaphotonics.



Figure, left:
Classification of LIPSS into distinct categories based on spatial period and scale. These categories include Low-Spatial Frequency LIPSS (LSFL), characterized by larger spatial periods, High-Spatial Frequency LIPSS (HSFL), featuring smaller periodicities, and the more intricate Two-Dimensional LIPSS (2DLIPSS) on both the micrometric (referred as 2D-LIPSSI) and nanometric (referred as 2D-LIPSS-II) scales. 1DLIPSS (One-Dimensional Laser-Induced Periodic Surface Structures) primarily employs a single polarization approach, while 2D-LIPSS are mainly generated using a double polarization strategy involving crossed or circular polarizations. This strategic use of double polarization leads to an isotropic response of the irradiated surface, enabling the formation of multifaceted structures.

Laser & Photonics Reviews, Vol. 18, Issue 5 (2024), Article no. 2300991

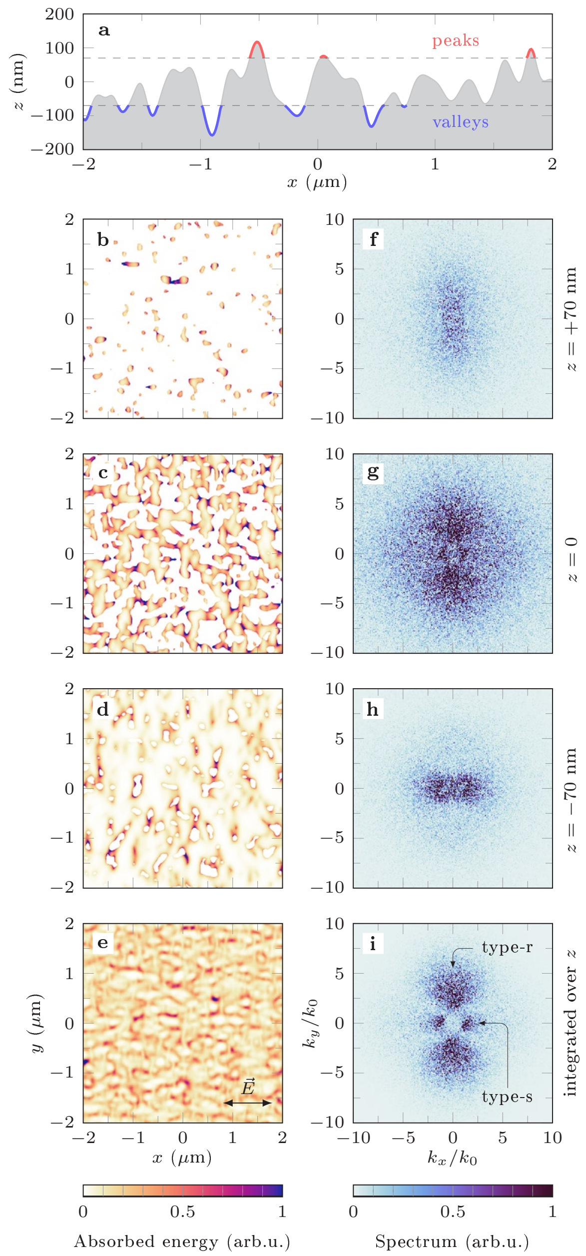
Physical Review B

Light-matter interaction at rough surfaces:
A morphological perspective on laser-induced periodic surface structures

Vladimir Yu Fedorov and Jean-Philippe Colombier

Published in the journal Physical Review B, this research delves into the light-matter interaction on rough surfaces, a fundamental phenomenon in the formation of laser-induced periodic surface structures (LIPSS). The article presents a study based on *ab initio* electromagnetic simulations using a statistical description of surface roughness to understand how incident laser energy is absorbed and how this initiates LIPSS formation.

The authors modeled surface roughness using continuous correlation functions, such as Gaussian and exponential functions, and investigated the influence of key statistical parameters like the root-mean-square (rms) height and correlation length. FDTD (finite-difference time-domain) simulations were employed to analyze the distribution of absorbed laser energy in different layers of the surface.
A significant finding is that high spatial frequency LIPSS (type-r) and low spatial frequency LIPSS (type-s) morphological features emerge in distinct surface layers: type-r features predominantly appear on the upper edge, while type-s features are mainly present on the lower edge. The study also reveals that increasing the correlation length of the roughness leads to a transition from laser polarization-aligned energy absorption to a speckle-like pattern. Furthermore, an increased rms height can suppress type-r LIPSS features.
The influence of laser polarization is also crucial: linear polarization induces LIPSS oriented parallel or perpendicular to the polarization, whereas circular polarization generates a radially symmetric absorbed energy distribution. Interestingly, the study demonstrates that circular polarization can be used to detect and measure asymmetries in surface roughness, as changes in the scale of surface inhomogeneities result in a proportional deformation of the absorbed energy spectrum. These results deepen our understanding of LIPSS formation mechanisms and offer insights for precision laser surface fabrication.



Figure, right:
Distribution of spatial and spectral energy absorbed on laser-irradiated rough surface. (a) A side view (at y = 0) of the rough surface, with dashed lines at z = ±70 nm. The surface has a Gaussian texture with a height variation (rms) of 50 nm and a correlation length of 100 nm.

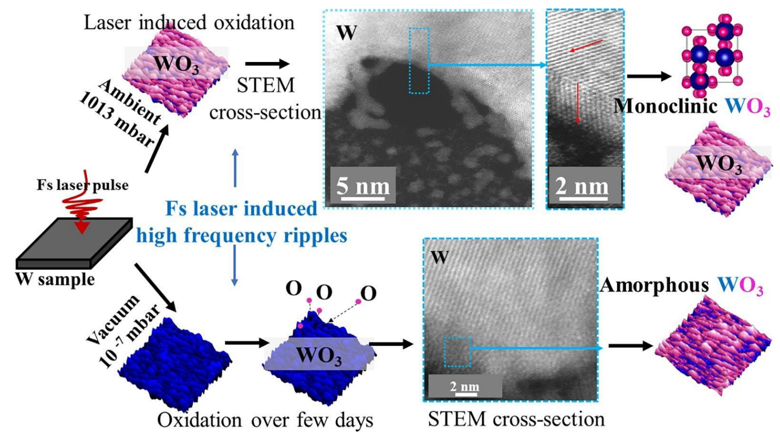
(b–d) Absorbed energy (Q) in three layers of the surface: at z = +70 nm, 0 nm, and −70 nm.
(e) Total absorbed energy (Qi) summed over all layers; the double arrow shows the laser's polarization direction.
(f–i) Power spectra of the energy distributions from (b–e). The arrows in (i) highlight distinct spectral features called type-r and type-s.

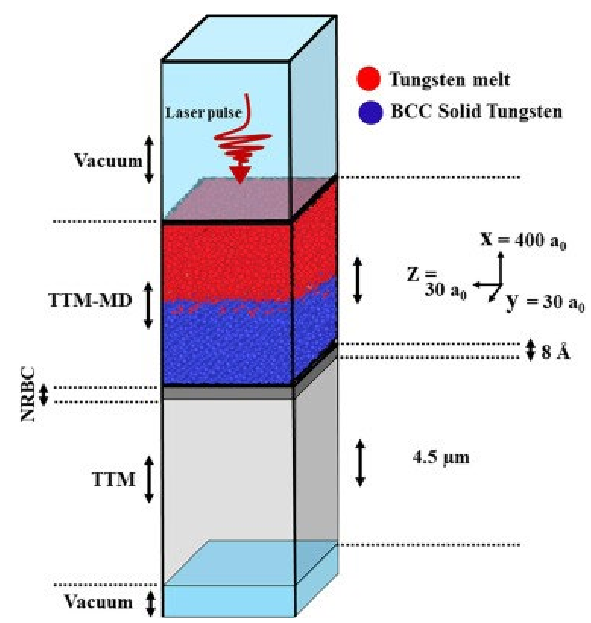
Physical Review B, Vol.110, Issue 11 (2024), Article no. 115438

Applied Surface Science

Unveiling nature and consequences of tungsten oxidation upon ultrafast laser irradiation

Priya Dominic, Djafar Iabbaden, Florent Bourquard, Stéphanie Reynaud, Anthony Nakhoul, Arnaud Weck,
Jean-Philippe Colombier and Florence Garrelie





Applied Surface Science covers topics contributing to a better understanding of surfaces, interfaces, nanostructures and their applications. In February 2024, an article by our Laser-Matter Interaction team was published in the journal, focusing on the chemical alterations induced by ultrafast laser-induced topography modification.

The aim of Priya Dominic's PhD was to understand the evolution of surface chemistry when irradiating materials with ultrashort laser pulses, particularly in the context of sub-wavelength nanostructure generation on metals. This article presents a comprehensive understanding of the generation and crystallization of tungsten oxides on samples irradiated in both air and vacuum environments, achieved by coupling molecular dynamics modeling and high-resolution transmission electron microscopy. Upon leaving the interaction chamber, an amorphous oxide layer appears on the vacuum-irradiated sample, as much higher temperatures are required for crystallization. Ultrafast irradiation in air creates a time window during which the temperature is sufficient to create monoclinic WO_3 while being short enough to control the number of oxygen molecules adsorbed on the sample's surface. This enables pulse-by-pulse control of the nanometric thickness of the oxide layer. In the case of tungsten, crystallized and amorphous WO_3 exhibit different wettability behaviors, highlighting the high applicative potential of ultrashort pulsed-laser nanotexturing under controlled environment.
The work was done in collaboration with the Department of Mechanical Engineering, University of Ottawa, Canada.

Illustrations, left:
Top: Article's graphical abstract.
Bottom: Initial setup geometry of the W sample used to model ultrafast laser interaction.
The extreme upper and bottom parts represent the surface vacuum part.
TTM-MD and TTM schemes are solved in the red-blue and gray colored regions respectively.
Tungsten atoms in the solid BCC and melted phase are colored in blue and red, respectively.

Applied Surface Science, Vol. 655 (2024), Article no. 159580

Nanoscale Advances

Understanding mono- and bi-metallic Au and Ni nanoparticle responses to fast heating

Tatiana E. Itina

Nanoscale Advances is an international gold open access journal that features high-quality research covering the fields of nanoscience and nanotechnology. An article written by member of our Laser-Matter Interaction team Tatiana E. Itina was published in its November 2024 edition.

Understanding how nanoparticles behave under rapid heating is crucial for advancing various technological applications, from catalysis to material science. This study explores the dynamics of gold (Au) and nickel (Ni) nanoparticles, both individually and in combination, when subjected to fast heating. By using molecular dynamics simulations, the research reveals how these particles undergo processes such as melting, alloying, and fragmentation. Such insights are vital for designing nanoparticles with tailored properties, enhancing their performance in applications like fuel cells and sensors. The study not only advances our fundamental understanding of nanoparticle behavior but also opens new avenues for developing innovative nanomaterials with improved functionalities.

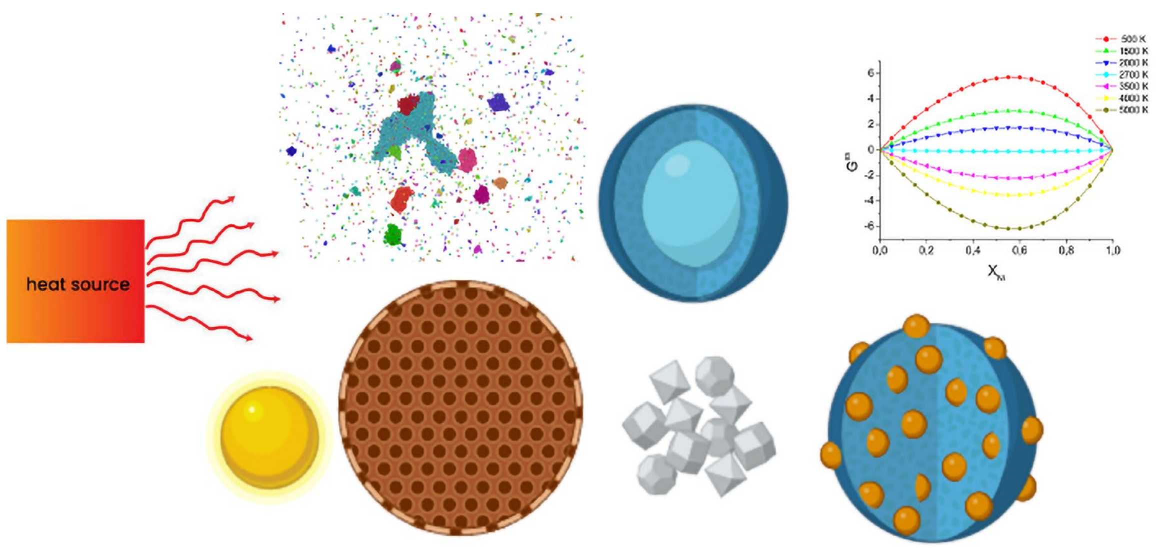


Figure above:
Graphical representation of the phase diagram relevant to Au-Ni nanoparticles evolution upon short pulsed heating.

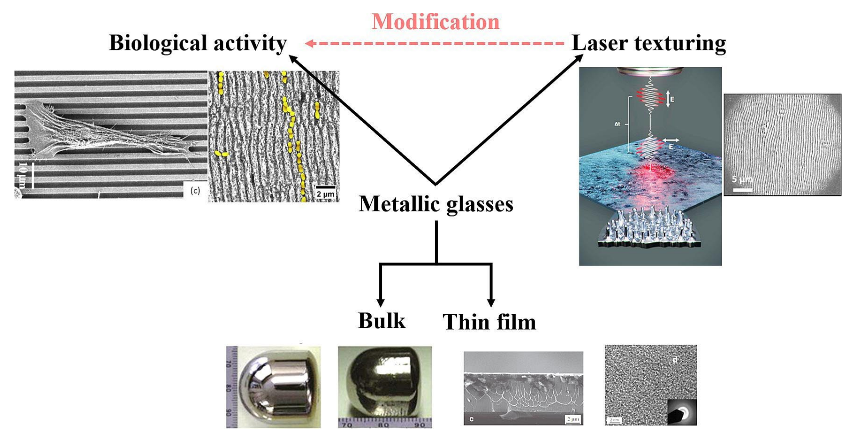
Applied Surface Science

Metallic glasses for biological applications and opportunities opened by laser surface texturing: A review

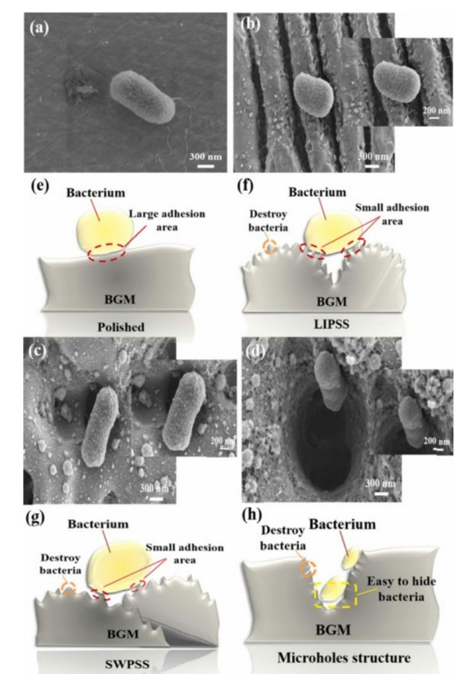
N. Lebrun, F. Dupla, H. Bruhier, M. Prudent, A. Borroto, C. Der Loughian, F. Bourquard, J.-M. Pelletier, M. Rousseau, J.-P. Colombier, J.-F. Pierson, F. Garrelie and P. Steyer

A review article co-authored by members of our Laser-Matter Interaction team was published in October 2024 in Applied Surface Science, a journal focused on advancing the understanding of surfaces, interfaces, nanostructures and their applications. The work was done in collaboration with MatéIS Lab, SAINBIOSE Research Centre and Institut Jean Lamour.

Metallic glasses are a class of material with excellent mechanical properties. They exhibit an amorphous atomic structure, and the absence of grain defects make them highly solid and chemically homogeneous. They can be produced in bulk form (up to the cubic centimetre scale) or as thin films on various substrates. This study aims to review recent findings in the literature on the effects of ultrashort laser texturing on the bio-properties of metallic glass surfaces for potential use in medical applications. The work shows that these modifications can influence the biocompatible and bactericidal behaviour of the materials, depending on the changes in surface topography and material chemistry at the extreme surface.



Above: Graphical abstract showing how laser texturing can modify the biological properties of metallic glass surfaces.



Right:
Illustration showing bacterial adhesion to various metallic glass surface textures, highlighting the differences in interaction according to surface topography (Source: H. Huang, P. Zhang, Z. Yu, X. Zhang, L. Shen, H. Shi, H. Yan, L. Wang, Y. Tian *Effects of periodic surface structures induced by femtosecond laser irradiation on the antibacterial properties of Zr-based amorphous material* Optik, 268 (2022), Article 169760, 10.1016/j.ijleo.2022.169760)

Materials & Design

Ultrafast laser-induced topochemistry on metallic glass surfaces

Mathilde Prudent, Alejandro Borroto, Florent Bourquard, Stéphanie Bruyère, Sylvie Migot, Florence Garrelie, Jean-François Pierson and Jean-Philippe Colombier

Materials & Design is an interdisciplinary journal emphasizing the correlations between structure, properties, and processing of both inorganic and organic materials, with a focus on innovative and proactive design. An article co-authored by our Laser-Matter Interaction team, the result of a collaboration with the Institut Jean Lamour, was published in their August 2024 edition.

The work focuses on the topochemical structuring of metallic surfaces using ultrashort lasers applied to thin films of metallic glasses, primarily amorphous zirconium-copper ($Zr_{50}Cu_{50}$) alloys. The laser irradiation induces chemical reactions with oxygen from the air, but only with one of the constituents, in this case, zirconium, which oxidizes to form an amorphous oxide matrix. During this process, copper separates and forms crystalline nanoparticles on the surface. This laser structuring method periodically modifies the surface on a nanometric scale, allowing the creation of surfaces with unique properties, such as crystalline phases on amorphous materials. These modifications offer potential applications in catalysis, antibacterial properties, and plasmonics, by increasing surface reactivity through the controlled formation of nanoparticles, which could be used in technical or medical environments.

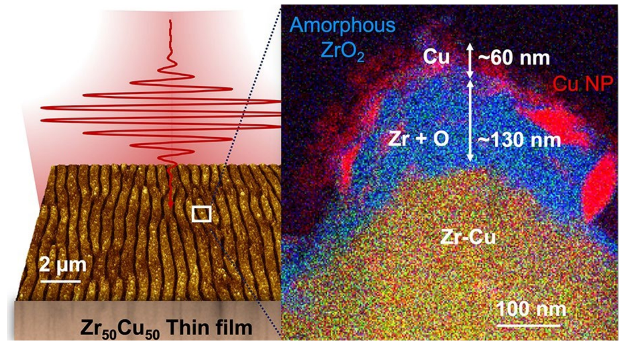


Figure 1, above:
Ultrafast laser irradiation in air significantly alters the surface chemistry of amorphous alloys, forming a superficial crystalline layer of 100 to 200 nm with pure metal nanoparticles on the surface.

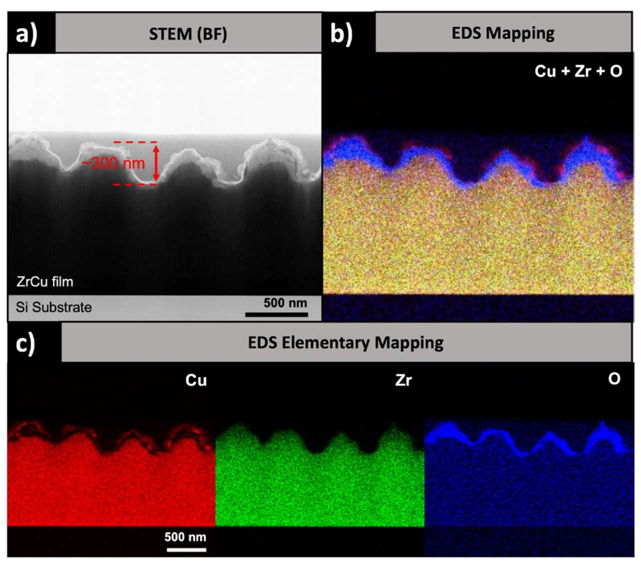


Figure 2, left:
a) Scanning transmission electron microscopy image acquired in Bright Field mode of the lamella extracted perpendicular to the LIPSS created by laser irradiation of the $Zr_{50}Cu_{50}$ thin film metallic glass.
b) Energy-dispersive X-ray spectroscopy mapping showing the superposition of the elements Cu, Zr, and O.
c) Energy-dispersive X-ray spectroscopy maps depicting the distribution of each element.

Materials & Design, Vol.244 (2024), Article no. 113164

ACS Applied Nano Materials

Atomistic Simulations of Wetting Dynamics of Water Nanodroplets on Nanotextured Titanium: Implications for Medical Implants

Ilemona S. Omeje, Djafar Iabbaden, Patrick Ganster, and Tatiana E. Itina

A study that could contribute to improving the effectiveness and longevity of medical implants was published in ACS Applied Nano Materials in October 2024 by our Laser-Matter Interaction team. This interdisciplinary journal publishes original research across engineering, chemistry, physics, and biology, with a focus on the applications of nanomaterials.

Titanium implants have revolutionized medical treatments, but their success heavily depends on surface properties. In this study, Ilemona Omeje and colleagues delve into the intricate world of nanotextured titanium surfaces and their interaction with water nanodroplets. Using advanced atomistic simulations, the researchers explore how different nanotexture patterns influence wetting dynamics, a crucial factor in implant integration and performance. Their findings shed light on the complex relationship between surface topography and water behavior at the nanoscale, offering valuable insights for optimizing titanium implant designs. This research not only advances our understanding of nanoscale wetting phenomena but also paves the way for developing more effective and longer-lasting medical implants, potentially revolutionizing fields such as orthopedics and dentistry.

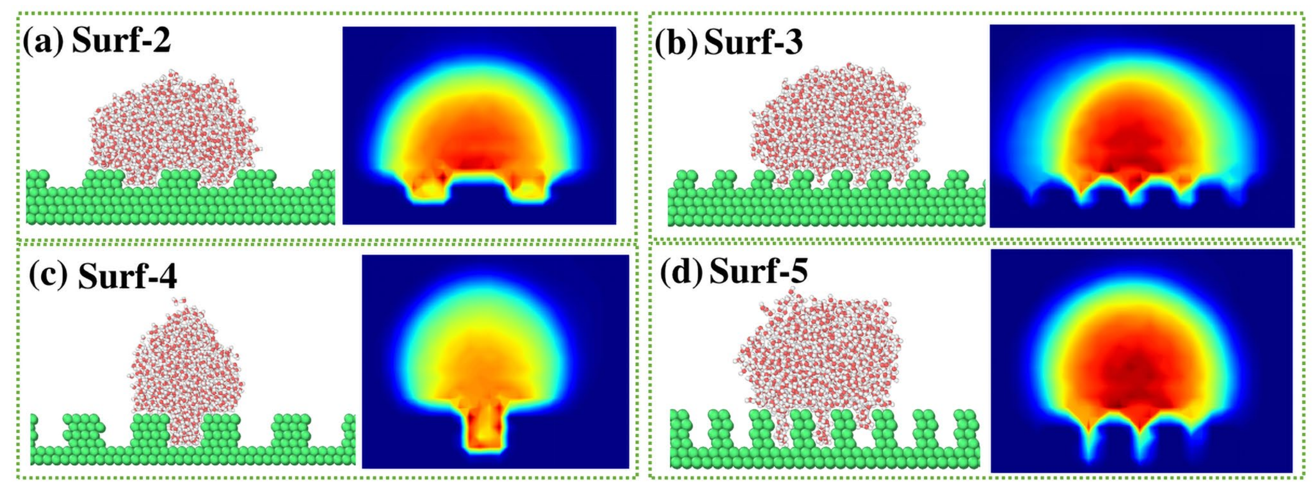


Figure 1, above:
Water nanodroplets interacting with different nanotexture patterns on titanium surfaces. It could show how droplets spread or remain more spherical depending on the surface topography, visually representing the key findings of the atomistic simulations conducted in the study.

ACS Applied Nano Materials, Vol.7, Issue 21 (2024), pp. 24426-24436

Neurocomputing

Introducing shape priors in Siamese networks for image classification

Hiba Alqasir, Damien Muselet and Christophe Ducottet

Neurocomputing is a journal covering research on artificial intelligence, machine learning, and neural computation. In February 2024, our Image Science & Computer Vision team published a paper putting forward a new approach to improve the learning and generalization properties of an image classification neural model.

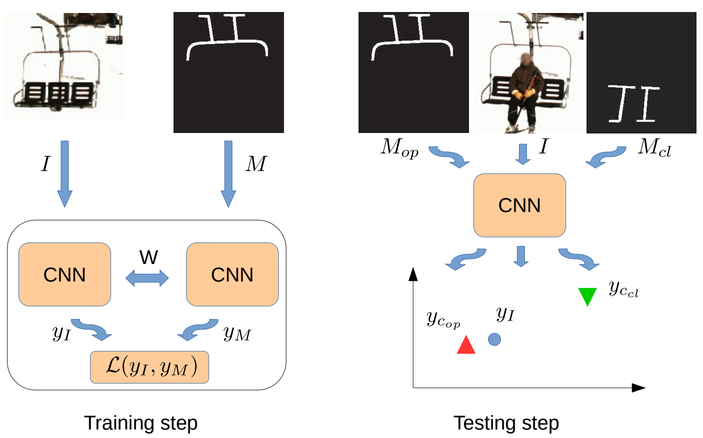
Illustrations below:

Figure 1, left: Examples of shapes priors i.e. binary masks representing prototypical classes.

Figure 2 right: We resort to a Siamese architecture that learns a mapping projecting images and masks into a feature embedding space. Euclidean distances are evaluated in the feature space at test time, to decide which class the input image belongs to.

Automatic image classification is the task of analyzing the visual content of an image to determine which class it belongs to among a given set of predetermined classes. An example of classification may be to determine whether an image contains a dog, a cat, or a mouse. This can be solved efficiently by a deep neural network, provided it is trained on a large set of images for which the class is known (annotated images). In practical applications, the main issue is to build an adequate set of annotated images corresponding to the problem at hand. In this paper, the team addresses a specific case where the classes to be learned can be represented by prototypical objects with discriminant shapes that are easily described by binary images. These are referred to as « shape priors » and can typically be drawn by humans using image processing software. This involves delineating the prototypical objects in selected training images that are characteristic of each class.

In many applications, this type of prior is easy to obtain as it corresponds to the general shape of the class. For example, in digit recognition, it is the basic shape of the digits. In sign language recognition, it is the prototype of each sign to be recognized. We also consider a real-world application in the field of video surveillance, where the goal is to determine whether people boarding a ski chairlift have properly set the safety bar. In this case, the mask corresponds to the shape of the safety bar in both open and closed positions. Figure 1 shows some examples of binary masks along their corresponding image instances. In their study, the authors put forward a Siamese based deep network that leverages shape priors to learn a model that generalizes well to new unseen images, even when trained with only few annotated images.



Neurocomputing, Vol.48 (2024), Article no. 127034

Code available on Github

Optics Express

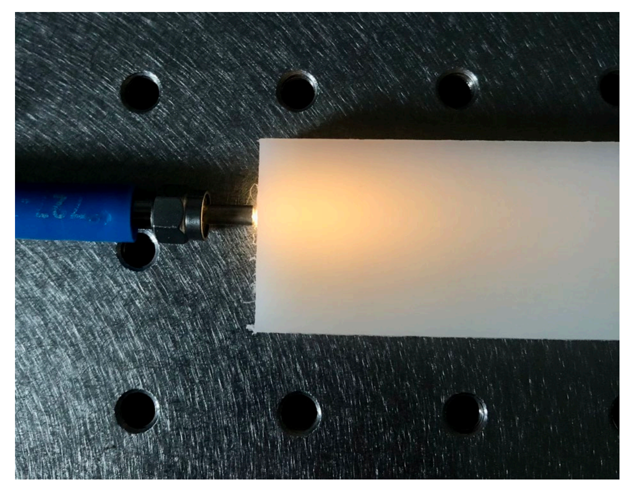
On the validity of two-flux and four-flux models for light scattering in translucent layers: angular distribution of internally reflected light at the interfaces

Arthur Gautheron, Raphaël Clerc, Vincent Duveiller, Lionel Simonot, Bruno Montcel, and Mathieu Hébert

In March 2024, an article co-authored by our Image Science and Computer Vision team was published in Optics Express, an open-access journal dedicated to scientific and technology innovations in all aspects of optics and photonics.

The research field of appearance has seen a significant surge in recent years, due to massive industrial demand driving rapid developments of digital technologies and optical solutions. The appearance of a material is strongly linked to the propagation of light within it, and today's research is particularly interested in materials referred to as "translucent", in which light penetrates deeply and diffuses while still retaining part of its directionality. These materials present challenges in both characterization by measurement and modeling, particularly when they are in the form of thin slices through which light can readily pass. Among the optical models that can be used to describe light propagation in these disordered materials - which are always based on highly simplifying assumptions regarding small-scale phenomena - those based on radiative transfer theory are particularly appropriate. Specifically, they enable to predict the angular distribution of light reflected or transmitted by a slice of translucent material. However, they can only do so provided the reflections occurring at the material-air interface are being considered. These reflections, known as "internal reflections", have indeed a significant effect. Other models - known as 2-flux or 4-flux models - widely used in application fields due to their simplicity, do take internal reflections into account, however their magnitude is very poorly estimated. Our study leads to a significant improvement of the reflections' magnitude estimation, therefore greatly enhancing the efficiency of the simplified models used for predicting the quantities of light reflected or transmitted by a translucent plate. These results pave the way for new approaches to better characterize the visual appearance of translucent materials, and ultimately achieve a more faithful reproduction of their appearance.

The work was done in collaboration with the CREATIS Laboratory in Lyon and funded by the LABEX PRIMES (ANR-11-LABX-0063), France Life Imaging (ANR-11-INBS-0006) and the Manutech SLEIGHT Graduate School (ANR-17-EURE-0026).



Illustration, left:
Example of a blade of translucent material illuminated by optical fiber.

Optics Express, Vol. 32, Issue 6 (2024), pp. 9042-9060

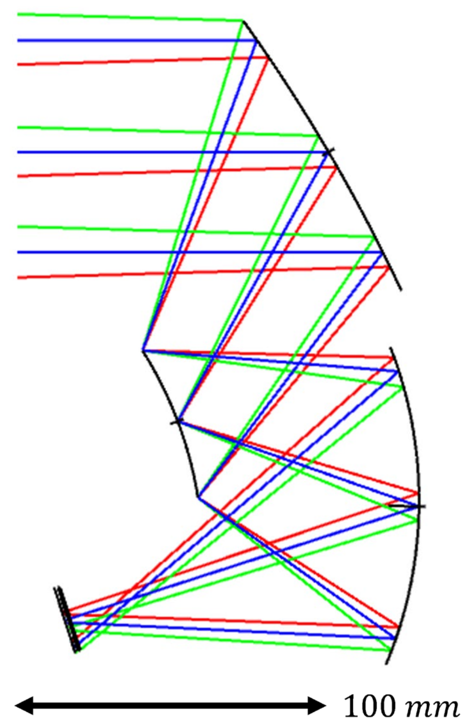
Photonics

Comparative Study on the Interest in Non-Uniform Rational B-Splines Representation versus Polynomial Surface Description in a Freeform Three-Mirror Anastigmat

Clément Freslier, Guillaume Druart, Alice Fontbonne, Thierry Lépine, Christophe Buisset, Tibor Agocs, Arnaud Heliere, Fanny Keller, Jean-Baptiste Volatier, Stéphane Beaussier and Paul Jougla

In September 2024, an article co-authored by the Hubert Curien Lab's Image Science & Computer Vision team was published in Photonics, a journal dedicated to publishing high impact theoretical and experimental research in optics and photonics.

Freeform surfaces have revolutionized the design of imaging systems, enabling the production of better aberration-corrected combinations with smaller volumes. These advantages are of particular interest to fields such as defense and space, as the volume and therefore the weight of the system significantly impact its cost.
Unfortunately, freeform surfaces introduce a large number of variables, making system optimization much more difficult than with classical spherical or aspherical surfaces.
Thus, much work focuses on the mathematical description of these surfaces. In the vast majority of cases, they are described by linear combinations of polynomials such as xy polynomials, Zernike polynomials, Legendre polynomials, Chebyshev polynomials, etc.
A few authors have taken a different path and focused on NURBS (Non-Uniform Rational B-Splines), which allows surfaces to be described locally. However, NURBS are not yet supported by commercial software such as Ansys-Zemax. The European Space Agency (ESA) recently funded a project to create a software that uses NURBS : the Formidable tool (Freeform Optics Raytracer with Manufacturable Imaging Design cApaBiLitiEs). We therefore used this new code by comparing it for the first time with Ansys-Zemax (with xy polynomials). The test case was the design of a three-mirror off-axis telescope, popular in the new space world.
The results of our study show that the Formidable tool provides slightly more better solutions than those provided by Ansys-Zemax. In particular, these solutions offer more consistent performance across the field of view. Hence, this study, funded by ESA and ONERA, confirms the interest of NURBS.



Illustration, above:
Layout of a three-mirror off-axis telescope

Frontiers in Pediatrics

AGMA-PESS: a deep learning-based infant pose estimator and sequence selector software for general movement assessment

Ameur Soualmi, Olivier Alata, Christophe Ducottet, Anne Petitjean-Robert, Aurélie Plat, Hugues Patural, and Antoine Giraud.

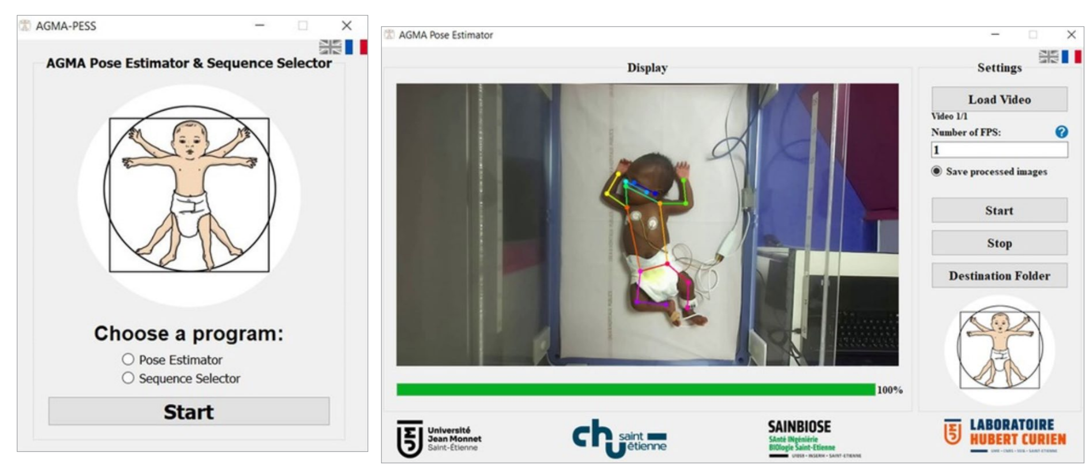
Frontiers in Pediatrics is a peer-reviewed, open-access journal that publishes research related to pediatric medicine. It covers a broad range of topics within child healthcare, including neonatology and developmental disorders. In 2024, our Image Science & Computer Vision team published a paper presenting an innovative software developed in collaboration with a team from the CHU Saint-Étienne Neonatal Unit and the SAINBIOSE laboratory.

The General Movement Assessment (GMA) is a functional evaluation of brain maturation based on the qualitative analysis of preterm infants' movement complexity, variability, and fluidity. It is essential to shaping early individual developmental trajectories, enabling the initiation of early developmental interventions. To perform the GMA, clinicians need to record preterm infants for 60 minutes before manually selecting at least three one-minute sequences. This time-consuming task impedes its implementation within the Neonatal Unit. Moreover, a handy and accurate pose estimation tool for preterm infants is essential to the development of the field of GMA automation.
The AGMA Pose Estimator and Sequence Selector (AGMA-PESS) software was developed to address these challenges. This deep-learning-based tool offers two main functionalities:

1. A Pose Estimator that automatically identifies key points on an infant's body, such as joints and limbs, to understand their posture and actions.
2. A Sequence Selector that automatically selects video sequences suitable for GMA, reducing the time-consuming task previously required by clinicians.

By integrating these functionalities, AGMA-PESS aims to promote the GMA method, making it more efficient and accessible within clinical settings. This automation holds the potential to enhance early detection of neurodevelopmental disorders in preterm infants, and facilitate timely interventions.

The software is shared with the scientific community and released as open source on Github:



Illustration, above:
AGMA-PESS user interface.
(A) Initialization window.
(B) AGMA Pose Estimator window.

International Conference on Document Analysis and Recognition - ICDAR 2024

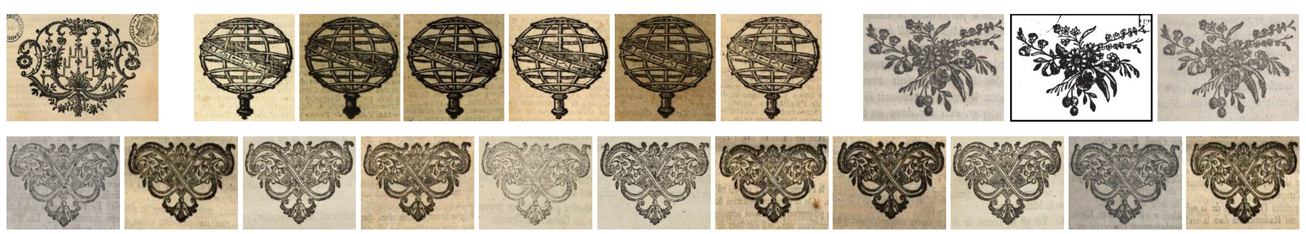
Historical Printed Ornaments: Dataset and Tasks

Sayan Kumar Chaki, Zeynep Sonat Baltaci, Elliot Vincent, Remi Emonet, Fabienne Vial-Bonacci, Christelle Bahier-Porte, Mathieu Aubry and Thierry Fournel

In September 2024, an article co-authored by our Image Science & Computer Vision and Data Intelligence teams was presented at ICDAR, a major international event dedicated to document analysis and recognition. The article stems from the team's research conducted as part of the ANR-funded ROIi project (ANR-20-CE38-0005).

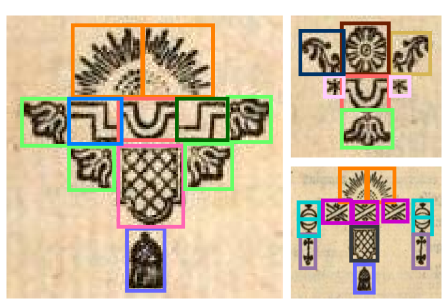
Typographical ornamentation plays a key role in the attribution of historical books to a specific printer, even to a publisher. Image analysis and unsupervised machine learning can help for this purpose whereas ornaments may represent well-contrasted but noisy data leading to new challenges: the automatic identification of woodblocks (older ornaments) and the capture of the composition style used in assembling typographical types, such as vignettes (more recent ornaments), during hand-press printing. The former corresponds to single handmade blocks, the latter to composites built from serial molded pieces, introducing both complexity and variability in the printing process. For any given set-up, ornaments are printed in a very limited number, especially in the context of deep learning, which results in very imbalanced data. To address these challenges, three complex tasks are identified: clustering blocks, discovering elements (vignettes) in composites, and unsupervised change localization.

Our evaluation focuses on ornaments extracted from a database dedicated to Marc-Michel Rey (1720-1780), the leading publisher of Enlightenment Philosophers. Collaborating with the Gaspard-Monge computer science lab (UMR 8049) and the Institute of History of Representations and Ideas in Modernities (UMR 5317), our team evaluated state-of-the-art models after benchmarking each of the task above. Printed during the censorship period, Rey ornaments are valuable due to their thorough documentation, including metadata about their position in the book and the geographical location of the volume. Thus, a part of blocks, composites and vignettes were extracted to form three sets, each annotated accordingly to its dedicated task.
Despite the apparent simplicity of the printed patterns, the performance of neural networks on the dataset appeared limited. For clustering blocks, the best state-of-the-art method (DTI-clustering) achieved less than 90% accuracy, with only a small margin of improvement over a simple k-means approach on imbalanced data. For element discovery in composites, the dataset's challenging statistics (such as rarity of many vignettes, and ornaments composed of numerous vignettes), the best obtained mean average precision (via AST-argmax, a state-of-the-art model in unsupervised object segmentation) was less than 30% after fine-tuning. In unsupervised change localization, a simple congealing approach led, on average, to a better segmentation of changes, compared with types of autoencoders recently proposed for anomaly detection. These findings highlight the value of the suggested dataset for evaluating and informing the design of new algorithms.

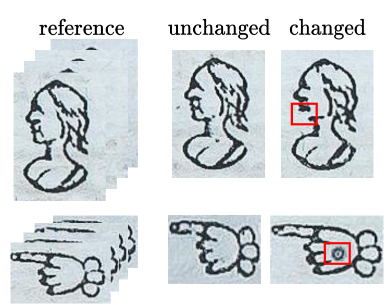


a) Clustering

Illustrations, above and right:
Annotated Rey's ornaments dataset and unsupervised tasks
(a) block ornaments clustered per woodcut template,
(b) compound ornaments formed with multiple vignettes to be discovered,
(c) vignettes without or with changes in shape to be localized.



(b) Element discovery



(c) Unsupervised change localization

International Conference on Document Analysis and Recognition (ICDAR), Sept. 2024, Athens, Greece.

European Signal Processing Conference - EUSIPCO 2024

Shrinkage MMSE Estimators of Covariances Beyond the Zero-Mean and Stationary Variance Assumptions

Olivier Flasseur, Éric Thiébaut, Loïc Denis and Maud Langlois

A paper co-authored by Loic Denis from our Image Science & Computer Vision team was presented at the 32nd European Signal Processing Conference (EUSIPCO), held in Lyon in August 2024. The article introduces new robust shrinkage estimators that can be applied to data with non-stationary variances and non-zero mean.

Covariance estimation is an essential step in learning models across diverse contexts such as economy (portfolio optimization), biology (gene expression analysis), or data science. Yet, the number of available samples is often too limited to obtain reliable estimates of large covariance matrices. To reduce the variance of the sample covariance estimator, shrinkage strategies are frequently used (see figure): the sample covariance is linearly combined with an estimate with much lower variance (such estimates assume a particular structure for the covariance matrix, generally a scaled identity matrix). Under a Gaussian assumption, formulas have been developed in the literature to achieve the optimal linear combination in an unsupervised fashion. Our paper extends these formulas to include non-centered Gaussian distributions and weighted samples in the more general case of shrinkage towards a diagonal matrix with non-constant diagonal values. These extensions, relying on rather technical mathematical developments, are very beneficial in practice since they can model non-stationary covariance matrices and are well-suited for robust estimation (thanks to the ability to weight samples and assign low weights to outliers). We applied this new estimator to the detection of exoplanets in high-contrast imaging.

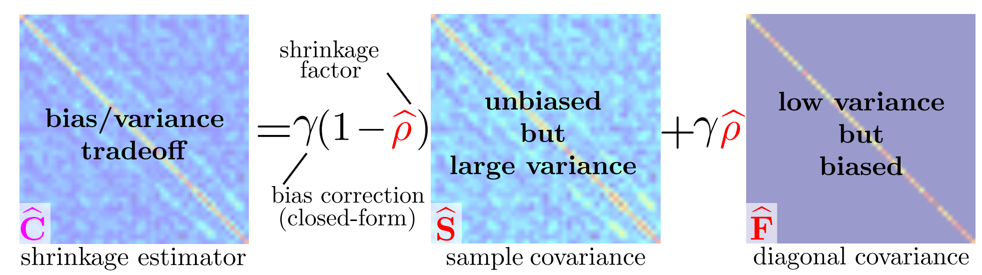


Figure above:
Covariance estimators can be improved through shrinkage, i.e., by linearly combining two estimators (which, as in this illustration, generally consists of bringing off-diagonal values closer to zero). We derived more general formulas to compute optimal weights for this combination, in the minimum mean square error sense.

European Signal Processing Conference (EUSIPCO), Aug. 2024, Lyon, France

Dental Materials

Comparative analysis of optical and numerical models for reflectance and color prediction of monolithic dental resin composites with varying thicknesses

Maria Tejada-Casado, Vincent Duveiller, Razvan Ghinea, Arthur Gautheron, Raphaël Clerc, Jean-Pierre Salomon, María del Mar Pérez, Mathieu Hébert and Luis Javier Herrera

In October 2024, an article co-authored by our lab's Image Science & Computer Vision team and the University of Granada was published in Dental Materials, a journal dedicated to fostering the exchange of clinical and laboratory research between academia, industry, and dental practitioners.

Research into dental materials is increasingly driven by the need for aesthetic appeal. On the one hand, it is needed to better characterize the optical properties of dental materials, such as absorption and scattering. On the other hand, it is necessary to predict the appearance of dental restorations made from specific materials or material mixtures. The challenge with these materials lies in their translucency, which makes optical measurement and modeling more complex compared to opaque materials.
To predict the spectral reflectance of dental materials, which is the signal carrying color, analytical models were developed at Hubert Curien, while machine learning approaches were developed at the University of Granada. Optical models have the advantage of enabling the extraction of a material's optical properties from a single sample, which can then be used to extrapolate the reflectance for different thicknesses. Machine learning approaches rely on the spectral measurements of several samples with similar thicknesses to interpolate reflectance for different thicknesses.
In this paper, both approaches show satisfying predictive performances, although each present distinct advantages and disadvantages, depending on the targeted application. Therefore, optical models are particularly suited for material manufacturers interested in extracting the optical properties of their materials, while machine learning approaches are better suited for embedded devices, due to their lower computational demands compared to optical models.

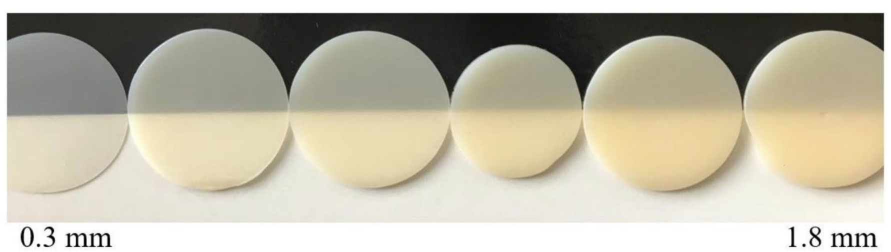


Illustration above: Samples of one dental material in different thicknesses from 0.3 mm to 1.8 mm, by steps of 0.3 mm. The black and white support highlights the gradient in color and translucency.

Dental Materials, Vol. 40, Issue 10 (2024), pp. 1677-1684

IEEE International Conference on Image Processing - ICIP 2024

Delving into the Explainability of Prototype-Based CNN for Biological Cell Analysis

Martin Blanchard, Olivier Delézay, Christophe Ducottet and Damien Muselet

In October 2024, our Image Science & Computer Vision team presented its findings on the explainability of prototype-based neural networks at the IEEE International Conference on Image Processing, a leading event focused on image and video processing, as well as computer vision.

Convolutional neural networks (CNNs) have become widely used for image analysis tasks. However, their adoption in biomedical and other high-stake fields remains limited, as their internal functioning is often considered a black-box. In this paper we investigate an explainable CNN architecture for classification: ProtoPNet [1].
We leverage ProtoPNet to analyze images from in-vitro cell cultures, with a reference population and a second population which was exposed to TNF-α, an inflammatory agent. The objective is for the network to classify cells as affected or healthy, and extract typical structures from each class, allowing to visualize the type of modifications TNF-α induces (see Figure).
The two main challenges are:
- A lack of prior knowledge of the affected cells structures
- Noisy labels due to some exposed cells resisting the treatment and staying healthy, or vice-versa.

ProtoPNet offers a solution to the first problem. It learns 'prototypes' in an unsupervised manner during training, which are typical representatives for each class. It then measures similarity between input images and these prototypes, to perform classification. The prototypes can be visualized to offer some insight into what the model considers typical.
Our article demonstrates how ProtoPNet can be adapted to the specific context of biomedical imaging.

[1] Chen, C., Li, O., Tao, D., Barnett, A., Rudin, C., & Su, J. K. (2019).
This looks like that: deep learning for interpretable image recognition.
Proceedings of the 33rd International Conference on
Neural Information Processing Systems
December 2019
Article No.: 801, Pages 8930 - 894

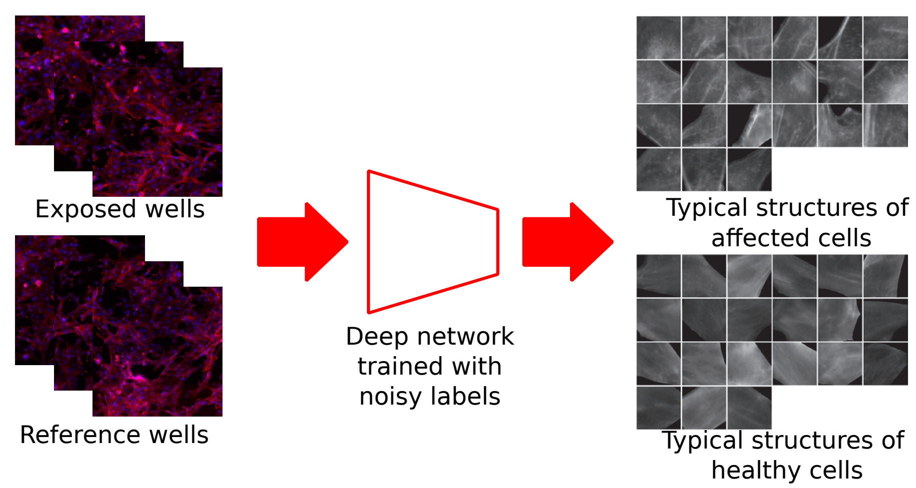


Illustration:

Overview of our approach: Without prior knowledge, extracting typical structures from affected and healthy classes, using a deep network trained with noisy labels caused by discrepancies between information from the culture well and the cell's final state (class).

IEEE International Conference on Image Processing (ICIP), Abu Dhabi, United Arab Emirates,(2024), pp. 2909-2915

International Conference on Artificial Intelligence and Statistics - AISTATS 2024

Length Independent PAC-Bayes Bounds for Simple RNNs

Volodimir Mitarchuk, Clara Lacroce, Rémi Eyraud, Rémi Emonet, Amaury Habrard and Guillaume Rabusseau

A paper was presented by our Data Intelligence team at the 2024 AISTATS conference, held in Valencia, Spain. The annual conference is an interdisciplinary gathering of researchers working at the interface of Computer Science, Artificial Intelligence, statistical Machine Learning and related areas. The work was done in collaboration with researchers from Mila, the Quebec Artificial Intelligence Institute.

Recurrent Neural Networks (RNNs) are a family of deep learning models designed for processing sequential data (such as music, text, etc.) where the order of the data is important and the sequence length varies. Similar to Neural Networks (NNs), RNNs are fundamentally based on artificial neurons, as illustrated in Figure 1. The main goal of machine learning (the scientific domain encompassing deep learning) is to learn from data to make predictions on new data. For example, if one has weather data and wants to extract the trend of a pattern in order to predict hailstorms, a machine learning model can be used to learn the pattern contained in the data, hoping that the model will be able to accurately predict a hailstorm based on new data. This illustrates the generalisation problem, and our article tackles an issue relative to RNNs within this problem. PAC-Bayes theory is a particularly well-suited mathematical framework for solving the generalisation problem in machine learning. Nevertheless, when applied to RNNs, a surge of unmanageable problems arises. One of the main issues is due to variable sequence lengths, which make PAC-Bayes tools ineffective. To circumvent this issue, researchers have previously suggested either imposing restrictions on RNN models, or considering bounded sequences. In addition to the development of several practical tools for the study of RNNs, this work theoretically proves the existence of a regime for RNNs in which the aforementioned restrictions are not necessary. To support their theoretical work, the authors empirically show that these regimes are observable in real-world applications.

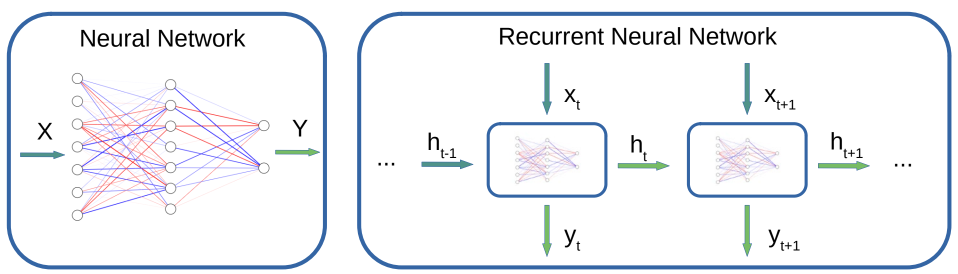


Figure 1 below: Illustration of RNNs.

International Conference on Artificial Intelligence and Statistics - AISTATS 2024

Leveraging PAC-Bayes Theory and Gibbs Distributions for Generalization Bounds with Complexity Measures

Paul Viallard, Rémi Emonet, Amaury Habrard, Emilie Morvant and Valentina Zantedeschi

Our Data Intelligence team presented a paper at the 2024 AISTATS conference, considering the problem of assessing the generalization capabilities of machine learning algorithms on new data unseen during training.

Assessing the generalization capabilities of machine learning algorithms on new data unseen during training is generally done by deriving probabilistic bounds over the expectation of errors committed by a learned model called the generalization error. These bounds usually involve a tradeoff between the empirical error estimated from a finite sample and a measure of complexity related to the family of models or the learning algorithm considered. However, the possible complexity measures are constrained by the existing theoretical frameworks such as the Vapnik-Chervonenkis dimension or the Rademacher complexity.

This paper makes what we believe to be a major contribution to the scientific community: the derivation of bounds that can incorporate any user-defined complexity measure. Our contribution leverages the PAC-Bayesian theory allowing to derive bounds in expectation over a posterior distribution of a family of hypotheses, given a prior distribution, with the objective to assign a higher probability to the best hypotheses. The user-defined complexity measure is included in the definition of the posterior distribution, under the form of a Gibbs distribution as illustrated in Figure 2, the bound being illustrated on Figure 1 and a practical illustration provided in Figure 3. This contribution paves the way for the development of novel theoretical results and new methodologies able to incorporate specific knowledge on the problem to solve via the complexity measure.

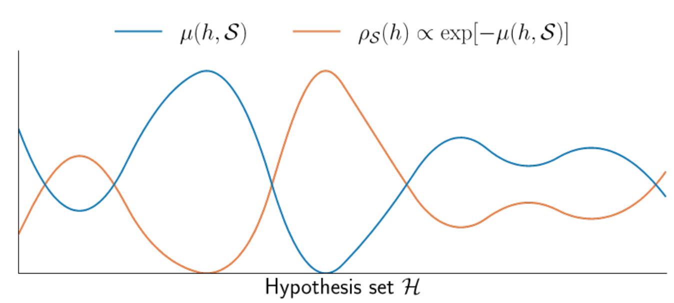
Our contribution: For any $\mathcal{D}$ on $\mathcal{X}\times\mathcal{Y}$, for any set $\mathcal{H}$, for any $\mu:\mathcal{H}\times(\mathcal{X}\times\mathcal{Y})^m\to\mathbb{R}$, for any $\omega:\mathcal{H}\to\mathbb{R}$, for any $\delta\in(0,1]$,
With probability at least $1-\delta$ over $\mathcal{S}\sim\mathcal{D}^m$, $h'\sim\pi$, $h\sim\rho_{\mathcal{S}}$ we have

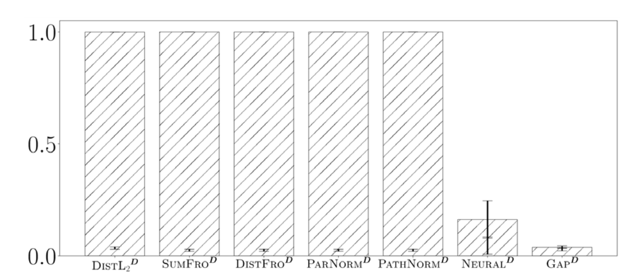
$$|\mathrm{R}_{\mathcal{D}}(h)-\mathrm{R}_{\mathcal{S}}(h)| \le \sqrt{\frac{1}{2m}\Big[[\mu(h',\mathcal{S})-\omega(h')] - [\mu(h,\mathcal{S})-\omega(h)] + \ln\frac{8\sqrt{m}}{\delta^2}\Big]_+},\quad \text{where } [a]_+ = \max(0,a).$$

Figure 1 above:
Illustration of the bound: R_D is the generalization error, R_S the empirical error, µ represents the complexity measure parameterized by an hypothesis h and an empirical sample S, ρ_S is the posterior,π the prior distribution and ω related to the prior distribution.

Figure 2 below:
Illustration of the posterior distribution ρS integrating the user-defined complexity measure µ, ρS gives a higher probability to hypothesis with a small complexity.

Figure 3 below:
Illustration of bounds obtained with different complexity measures on the MNIST dataset, the rightmost complexities lead to better bounds.





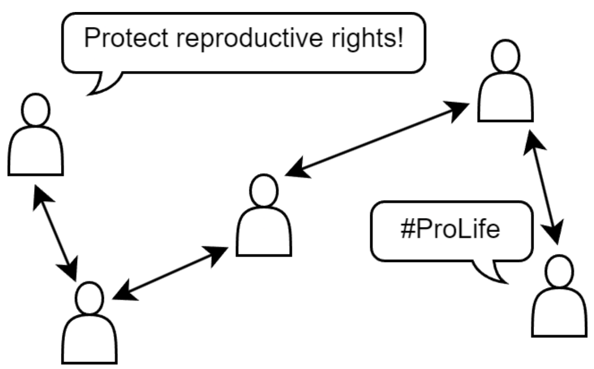
Conference of the European Chapter of the Association for Computational Linguistics EACL 2024 Proceedings

Unsupervised stance detection for social media discussions: A generic baseline

Maia Sutter, Antoine Gourru, Amine Trabelsi and Christine Largeron

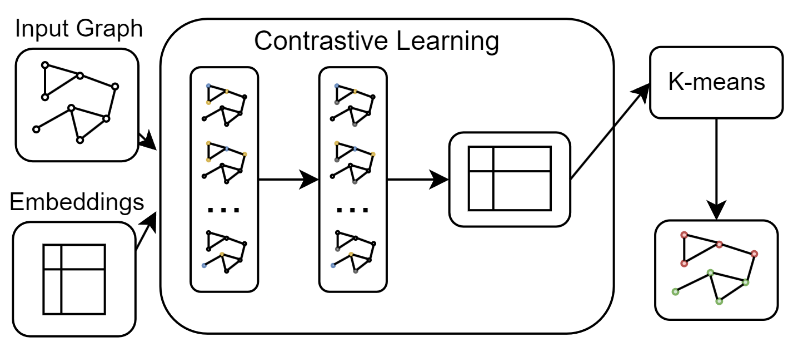
As the flagship European conference in the field of computational linguistics, EACL covers a broad spectrum of research areas related to computational approaches to natural language. Their 2024 event took place in Malta, where our Data Intelligence team presented a paper written in collaboration with the Université de Sherbrooke in Canada.

Social media platforms serve as major forums for individuals to express their opinions on various controversial topics. To automatically detect these opinions without relying on costly manual labeling, advanced machine learning techniques are necessary. In this study, we introduce a new method to improve automatic stance detection in an unsupervised setting, eliminating the need for annotated examples to train the model.
The challenge lies in that social networks come in two types: homophilic networks, where similar individuals are connected (e.g., X), and heterophilic networks, where people interact in a debating dynamic (e.g., CreateDebate). Existing models tend to work well with one type but not with both. In this work, we tested recent models on both types of networks and introduced a new approach that combines text information from social media posts with network structure using a graph neural network (GNN). This novel method demonstrates proficiency in handling both homophilic and heterophilic networks.



Illustration, left:
Example of Stance Detection:
the "Protect reproductive rights!" position expressed by one individual is labelled as "for" and the "#ProLife" position is labelled as "against", towards the "abortion" target.

Figure 2, below:
Overview of our proposed Generic Model for Unsupervised Stance Detection (GUSD).



Proceedings of the 18th Conf. of the European Chapter of the Association for Computational Linguistics, Vol. 1 (2024), pp. 1782–1792

Proceedings of the 2024 SIAM International Conference on Data Mining (SDM)

An Exemplars-Based Approach for Explainable Clustering: Complexity and Efficient Approximation Algorithms

Ian Davidson, Michael Livanos, Antoine Gourru, Peter Walker, Julien Velcin and S. S. Ravi

The SDM conference provides a venue for researchers specialized in Data Science to present their work addressing problems related to Data mining - the computational process for discovering valuable knowledge from data. During the 2024 edition of the conference, which took place in Houston, Texas, US, members of our Data Intelligence team presented a paper on Explainable AI for clustering.

Clustering methods allow to group sets of observations such that they are maximally similar within a cluster. This method is unsupervised and does not rely on any form of annotation. Consequently, the nature of the similarity remains uncertain, as the features used to determine that two observations are close are not given a priori. Explainable AI proposes tools to help understand the reasons behind the grouping of points by the clustering algorithm, often in a post-processing manner. In this work, we propose a novel clustering method that is explainable by design, using exemplars to provide an explanation of the cluster content and specificity. After a complexity analysis of the algorithm, we present experiments to demonstrate the effectiveness of the method on deep learning models for text and images.
This work was done in collaboration with Ian Davidson from UC Davis and Julien Velcin from the ERIC Lab (Université de Lyon 2).

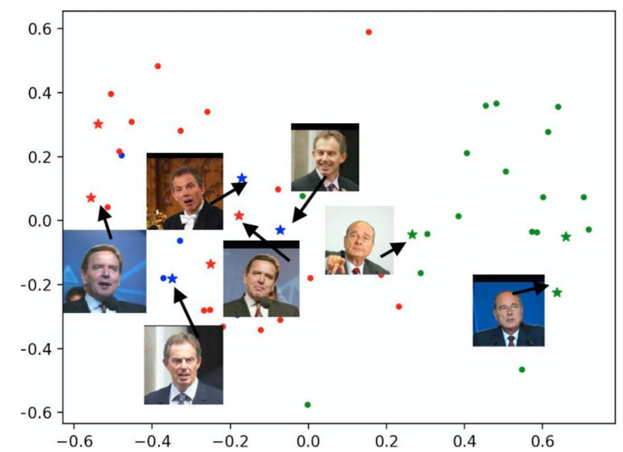
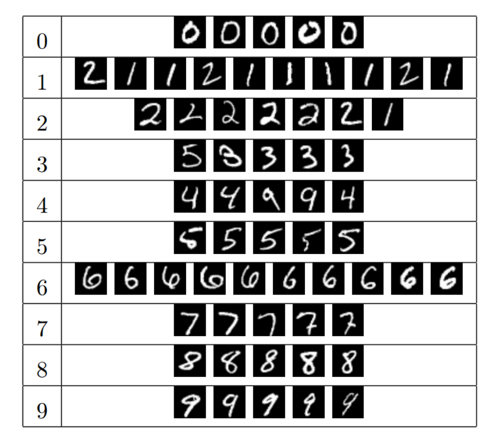


Figure 1, left:
An illustrative example of generating clusters (color) and selecting exemplars (stars).
The exemplars form a prototypical explanation of a cluster in that they cover all instances in the cluster.
Note the exemplars need not be (and rarely) are close to the centroids.

Table 1, right:
The clusters and exemplars found by our method on the MNIST data set.
Note that the exemplars provide a variety of ways that the digits are written.



Proceedings of the 2024 SIAM International Conference on Data Mining (2024), pp. 46-54

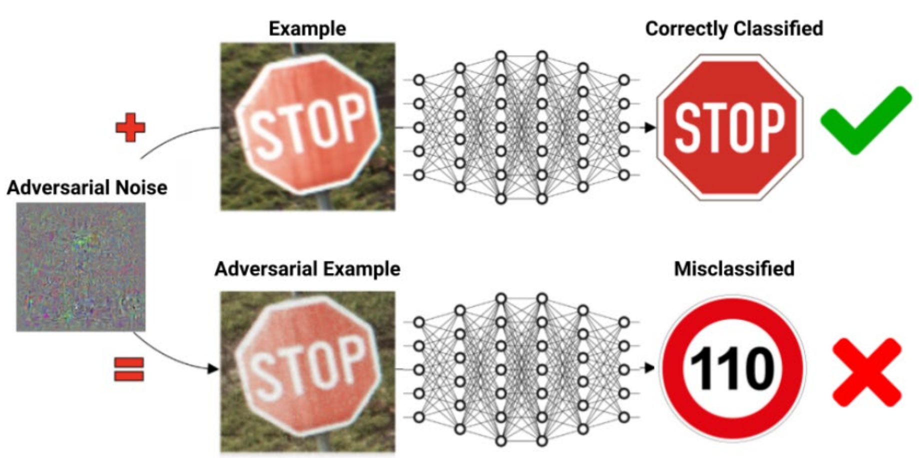
European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases - ECML PKDD 2024

A Theoretically Grounded Extension of Universal Attacks from the Attacker's Viewpoint

Jordan Patracone, Paul Viallard, Emilie Morvant, Gilles Gasso, Amaury Habrard and Stéphane Canu

ECML PKDD is a leading European conference on machine learning and data mining. Its 2024 edition was held in Vilnius, Lithuania, and was attended by several members of our Data Intelligence team. Among the research presented was the following paper, which contributes to advancing our understanding of adversarial attacks on machine learning models.

Adversarial attacks are techniques designed to fool machine learning models by subtly altering input data in ways that are imperceptible to humans, leading to misclassifications. Such attacks reveal vulnerabilities in models, particularly neural networks, and are used to test and improve model robustness. Understanding adversarial attacks is essential in fields such as security, autonomous systems, and any application that requires high model reliability. Adversarial attacks generally fall into two categories: specific attacks, which target individual inputs with custom noise, and universal attacks, which use a single perturbation to deceive the model across multiple inputs. In this work, we propose an extension of universal perturbations that bridges the gap between specific and universal perturbations by combining the best of both approaches. We also establish a bound on the effectiveness of the learned perturbation for fooling new examples, confirming its applicability for attacking models on data from the same task.



Figure, above: Principle of adversarial attacks

European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases, Sep 2024, Vilnius, Lithuania. pp.1-27

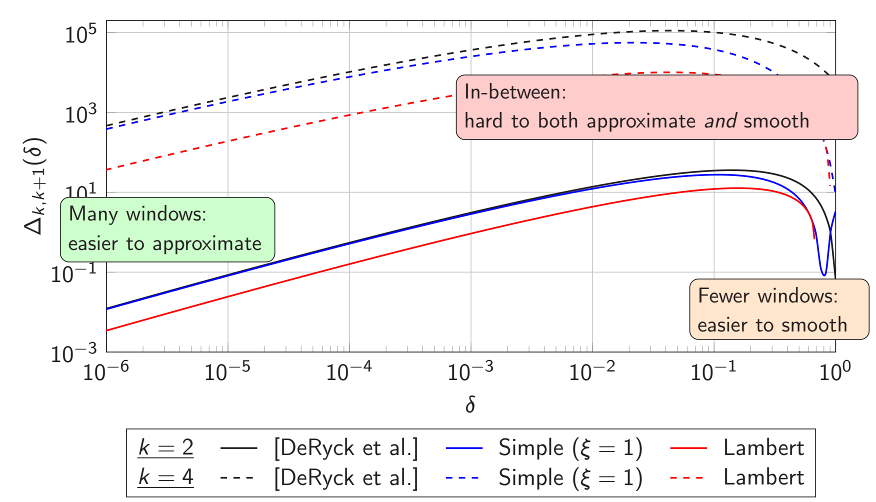
European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases - ECML PKDD 2024

Approximation Error of Sobolev Regular Functions with tanh Neural Networks: Theoretical Impact on PINNs

Benjamin Girault, Rémi Emonet, Amaury Habrard, Jordan Patracone and Marc Sebban

In another of their presentations at ECML PKDD 2024, our Data Intelligence team reported on their theoretical study of the approximation error in shallow neural networks within the context of Physics-Informed Machine Learning, and demonstrated how this error affects the performance of PINNs.

Physics-Informed Neural Networks (PINNs) were introduced in 2019 to offer an approximate surrogate solution to a Partial Differential Equation (PDE) using the neural network toolbox of machine learning. In this paper, we study approximation guarantees by addressing two key questions: Can we guarantee the existence of a PINN providing a solution to a PDE with arbitrarily small error? And how complex does such a PINN need to be? Through a novel analysis of the hyperbolic tangent (tanh) activation function used in PINNs, we are able to show that the approximation error of PINNs scales with the amplitude of the derivatives of the true solution, and that it decreases to zero as the complexity of the PINN increases. This results in lower complexity requirements for the design of PINNs that achieve a desired error.



The figure above shows how the complexity of the PINNs (with delta decreasing to 0) scales the approximation error. The proposed analysis (in red) outperforms the literature by at least one order of magnitude. Also shown on the figure is the larger error expected when the order of the PDE (k) increases. The case k=2 corresponds in particular to Navier-Stokes equation, while k=4 corresponds to Swift-Hohenberg equation. Interpretation of the various approximation regimes are given with respect to how the network is built to obtain the approximation error.

European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases, Sep 2024, Vilnius, Lithuania

European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases - ECML PKDD 2024

Reconstructing the Unseen: GRIOT for Attributed Graph Imputation with Optimal Transport

Richard Serrano, Charlotte Laclau, Baptiste Jeudy and Christine Largeron

A third paper presented by our Data Intelligence team at the ECML PKDD 2024 Conference introduces a novel approach for handling missing data in attributed graphs, leveraging Optimal Transport techniques to improve the accuracy of data imputation in complex graph structures.

In this article, we introduce GRIOT (GRaph Imputation with Optimal Transport), a new approach for handling missing data in attributed graphs. An example of attributed graph is a social network, where each person (node) carries specific information, such as interests or demographics. In real-world graphs, attributes are often partially missing. Missing data is represented by a mask, which can be generated from different mechanisms: it may be completely random or due to specific factors, making the data easier or harder to impute. Moreover, a key concept in graphs is homophily, which means that similar nodes are more likely to be connected. However, in real-world graphs, the level of homophily can be low, complicating the reconstruction process. To address this, GRIOT uses a new Optimal Transport (OT) loss function called MultiW (Multiview-Wasserstein) to optimize a Graph Neural Network. This loss function compares data from different subgraphs holding missing and known attributes, leveraging both the structure of the graph and the attributes, when filling in the gaps. This method is particularly useful for graphs with low homophily.

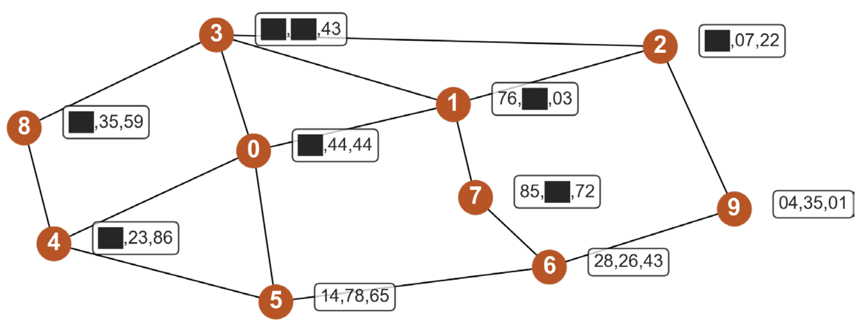


Figure 1, above: Example of an Attributed Graph with Missing Data
Each node has 3 numerical attributes, and some are hidden by the mask of missing data (black squares).
TASK: Reconstruct the missing attributes.

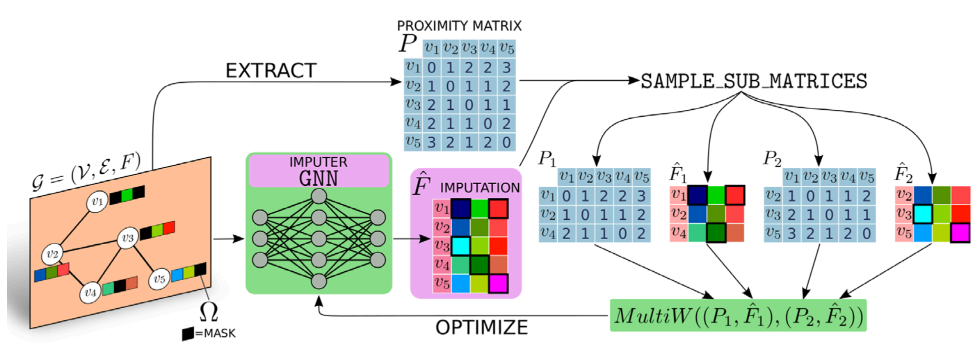


Figure 2, above: Representation of the GRIOT Framework Architecture
INPUT: The graph G: structure (V,E), attributes (F), and mask (Ω).
MAIN COMPONENTS: Imputer (GNN) and loss (MultiW).

Joint European Conference on Machine Learning and Knowledge Discovery in Databases, Sep 2024, Vilnius, Lithuania, pp.269-286.

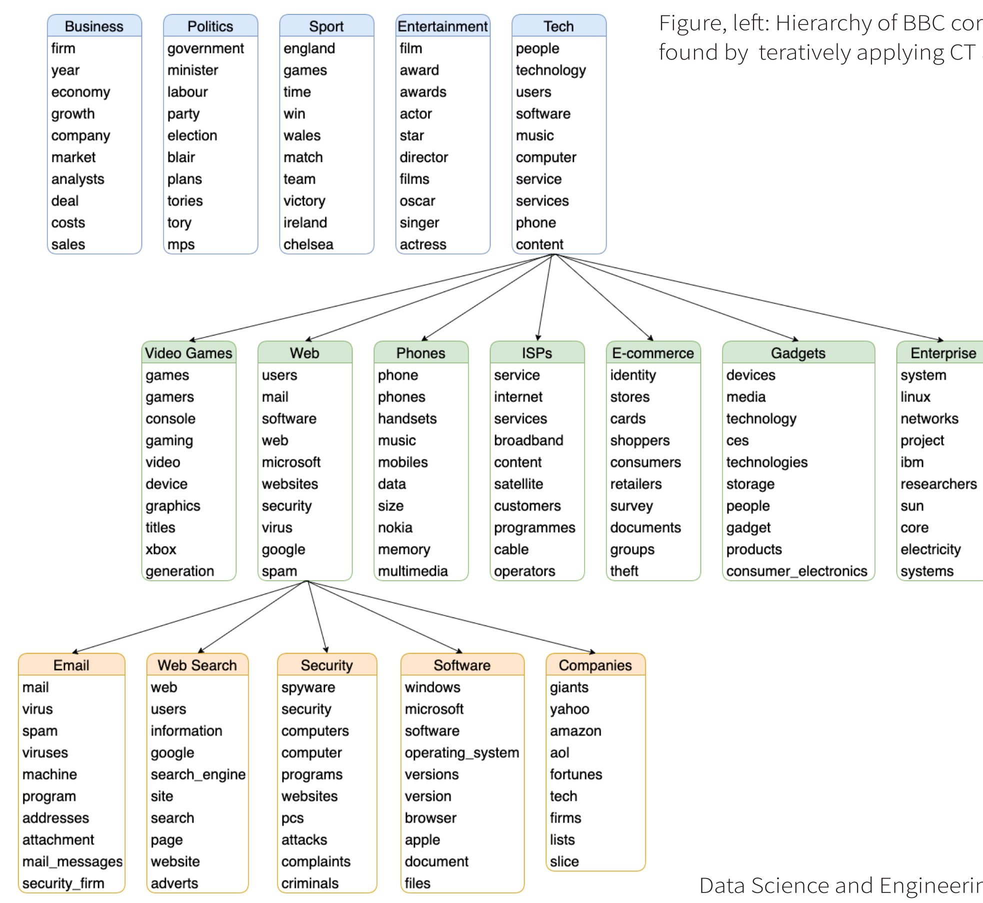
Data Science and Engineering

Uncovering Flat and Hierarchical Topics by Community Discovery on Word Co-occurrence Network

Eric Austin, Shraddha Makwana, Amine Trabelsi, Christine Largeron , Osmar Zaïane

Data Science and Engineering publishes research on data science, big data analytics, and related methodologies. This paper, co-authored by our Data Intelligence team and published in their March 2024 edition, introduces Community Topic (CT), a novel topic modeling algorithm designed to uncover both flat and hierarchical latent themes in text collections.

Topic modeling seeks to discover underlying themes in large text corpora, providing interpretable and coherent topics useful for various applications. The authors highlight the importance of identifying not only flat topics but also the hierarchical relationships between them, as topics naturally exist in a super-topic and sub-topic structure. Existing methods like Latent Dirichlet Allocation (LDA) lack the ability to produce topic hierarchies and suffer from other limitations such as the need to pre-specify the number of topics and inconsistencies across runs. To address these shortcomings, Community Topic (CT) leverages word co-occurrence networks and community detection algorithms to mine topics. The method constructs a network where words are vertices and edges represent their co-occurrence, weighted by frequency or Normalized Pointwise Mutual Information (NPMI). Topics are then identified as communities within this network using the Leiden algorithm, and the importance of terms within a topic is determined by their internal weighted degree. CT can discover flat topics and also generate a topic hierarchy by iteratively applying community detection to topic sub-graphs or by exploiting the iterative nature of the Leiden algorithm. The proposed CT algorithm was evaluated against several baselines, including LDA, Top2Vec, BERTopic, CorEx, Hierarchical LDA (HLDA), Pachinko Allocation Model (PAM), Hierarchical Pachinko Allocation (HPA), and nTSNTM, using datasets like 20Newsgroups, Reuters21578, BBC News, and EuroParl. Evaluation metrics included topic coherence (NPMI), diversity (PUW, PJD, IRBO), hierarchical topic specialization, and hierarchical affinity. The experimental results demonstrate that CT achieves comparable or superior coherence and significantly higher diversity compared to many baselines, while also being computationally efficient and producing more interpretable and well-structured topic hierarchies. Notably, CT is designed to be language-agnostic and showed consistent performance across English, Italian, French, German, and Spanish datasets. The authors conclude that CT offers a promising approach to topic modeling by effectively identifying both flat and hierarchical topics with good coherence, diversity, and efficiency.



Figure, left: Hierarchy of BBC corpus topics found by teratively applying CT algorithm.

Data Science and Engineering, Vol. 9, Issue 1 (2024), pp.41-61

Journal of Cryptology

Entropy Computation for Oscillator-based Physical Random Number Generators

David Lubicz and Viktor Fischer

The Journal of Cryptology provides a platform for presenting original findings in all facets of modern information security, encompassing both cryptography and cryptanalysis. Our SESAM team member Viktor Fischer collaborated with the Institut de Recherche Mathématiques de Rennes to publish an article introducing a novel RNG model aimed at addressing a prevalent issue encountered in entropy extraction and management.

Random numbers play a crucial role in modern cryptography, serving as confidential keys, initialization vectors, padding values, nonces (numbers used only once), and also as random masks in side-channel attack countermeasures. The random number generator (RNG) acts as an entropy source, guaranteeing the unpredictability of generated numbers even against an attacker with an unlimited computational power. Our paper deals with a general problem in designing an RNG for cryptography - entropy extraction from several low entropy sources and entropy management in the resulting combined bit stream. Moreover, we design and model a generator based on analog random physical phenomena, which are by principle reduced in logic devices that serve as a hardware support for cryptographic systems. Namely, we use a set of l independent freely running oscillators to generate clock signals featuring unstable clock period, i.e. the clock jitter (see Figure 1). We must wait for D reference clock periods to let the jitter accumulate before sampling outputs of oscillators and mixing the result in the entropy conditioner. To reduce the bit rate, D must be small. However, with a small D, the accumulated randomness is also dimished. Therefore, we have to increase number of oscillators (l). Our new model, based on Markov chains, helps find a compromise between the jitter accumulation time (D) and the number of oscillators (l) while maintaining security (output entropy rate).

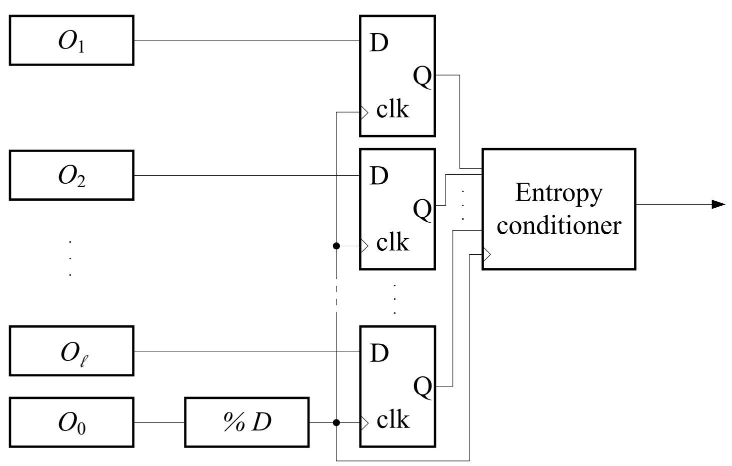


Figure 1:
Schematic diagram of a multi-oscillator-based TRNG.

Journal of Cryptology, Vol.37(2024), Article no.13

Journal of Cryptographic Engineering

Scoring the predictions: a way to improve profiling side-channel attacks

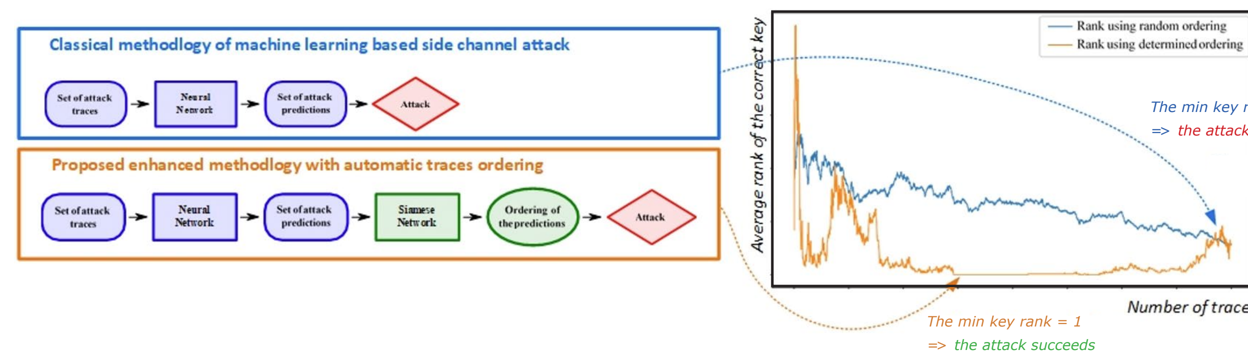
Damien Robissout, Lilian Bossuet and Amaury Habrard

The Journal of Cryptographic Engineering is dedicated to high-quality scientific research on architectures, algorithms, techniques, tools, implementations and applications in cryptographic engineering. In April 2024, our SESAM team published the findings of research conducted in collaboration with our Data Intelligence team, contributing to countermeasures against side-channel attacks.

In recent years, a number of research efforts, including joint work by the SESAM and Data Intelligence teams within our laboratory, have demonstrated the value of using machine learning algorithms to perform side-channel analysis attacks (e.g. power consumption or magnetic emanation). These attacks target the implementation of cryptographic algorithms in integrated circuits, most often aiming to uncover secret information, such as an encryption key, embedded in the circuit.

However, under certain conditions, particularly in the presence of high measurement noise and countermeasures causing measurement desynchronisation, a side-channel machine learning attack can fail. In such cases, the attack does not reveal the correct key and its rank is far from 1, which is the key rank of the answer given by the attack. If this attack fails with a number of traces (measurements) equal to N, the security evaluator (the one performing the attack) might conclude that the circuit is protected. However, as we demonstrate in this article, if a well-chosen and ordered subset of the N traces is used, the attack can succeed and lead to an overestimation of the circuit's security. In this paper, we propose a methodology based on Siamese networks to select this subset of traces, introducing a new loss function based on the learning to rank approach from machine learning.

The figure below illustrates how, with exactly the same information (same measurement traces and same number of traces), the classic attack approach fails, whereas the new proposed method, which includes an ordering of traces, succeeds.



Journal of Cryptographic Engineering, (2024)

IACR Transactions on Cryptographic Hardware and Embedded Systems (TCHES)

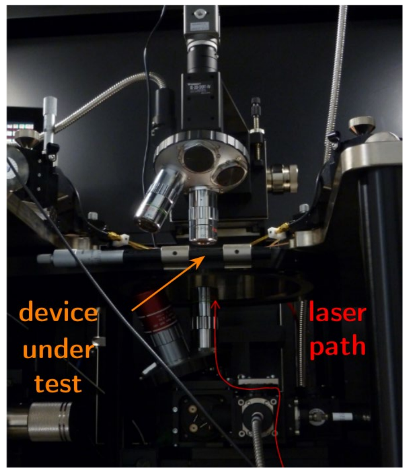
Switching Off your Device Does Not Protect Against Fault Attacks

Paul Grandamme, Pierre-Antoine Tissot, Lilian Bossuet, Jean-Max Dutertre, Brice Colombier and Vincent Grosso

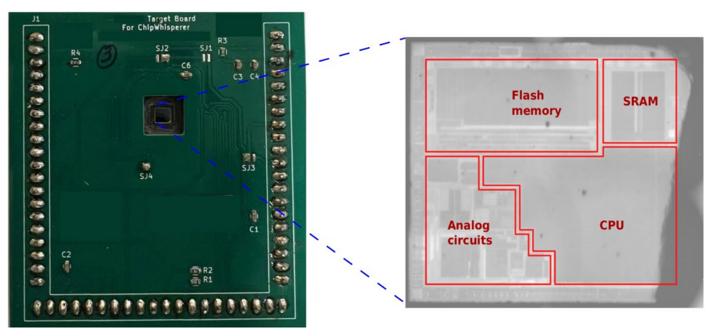
TCHES is a journal/conference hybrid publication model initiated by the Ruhr-University of Bochum, dedicated to new results in the design and analysis of cryptographic hardware and software implementations. A paper co-authored by our SESAM team was presented during the 2024 edition of the conference, exploring laser fault injection in unpowered devices.

For several decades, electronic devices have played a significant role in our lives, often containing large amounts of personal data or sensitive information. As a result, security has become an increasingly important factor in evaluating these devices. To assess their security, new methods of fault injection have been developed, with laser fault injection standing out as the most precise in terms of time and space. Most research in this field has focused on laser fault injection attacks on operational, and therefore powered, circuits. In this context, sensors are capable of detecting attacks, enabling the devices to respond accordingly. These sensors are considered «active» as they are only operational when switched on. This led us to investigate the potential of injecting laser faults into switched off devices. In electronic devices, permanent data (e.g. cryptographic keys, access rights) are stored in non-volatile memories such as Flash memories. In this paper, we describe how performing laser fault injection on switched off devices enabled us to successfully corrupt data stored in Flash memories. Additionally, we provide a detailed description of the fault model and a cryptographic application.

This research was supported by the French Agence Nationale de la Recherche, through the projects POP (ANR-21-CE39-0004) and PROPHY (ANR-22-CE39-0008).



Above: Picture of the laser bench



Above: Picture of the board (left)
and infrared image (right) of the hardware target.

IACR Transactions on Cryptographic Hardware and Embedded Systems, Vol. 2024 (4), pp. 425-450

IACR Transactions on Cryptographic Hardware and Embedded Systems (TCHES)

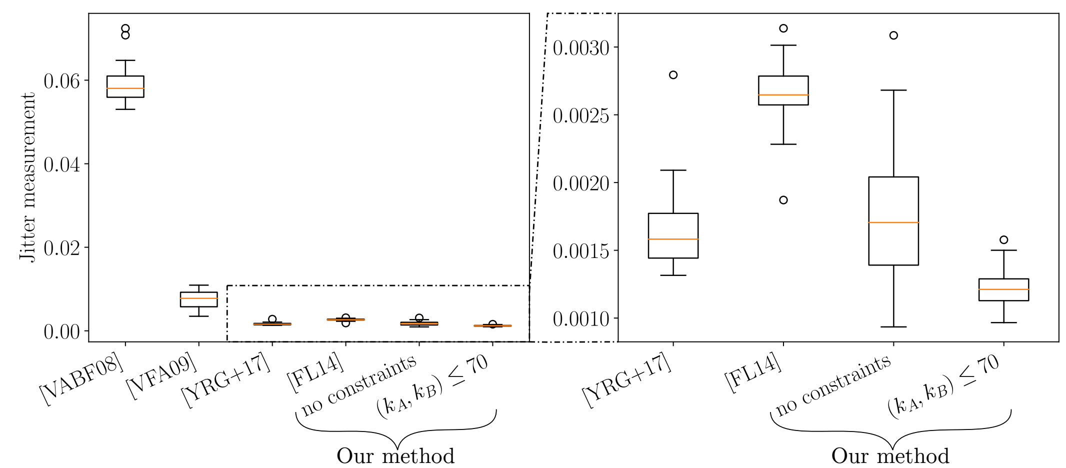
Low Cost and Precise Jitter Measurement Method for TRNG Entropy Assessment

Florent Bernard, Arturo Garay, Patrick Haddad, Nathalie Bochard and Viktor Fischer

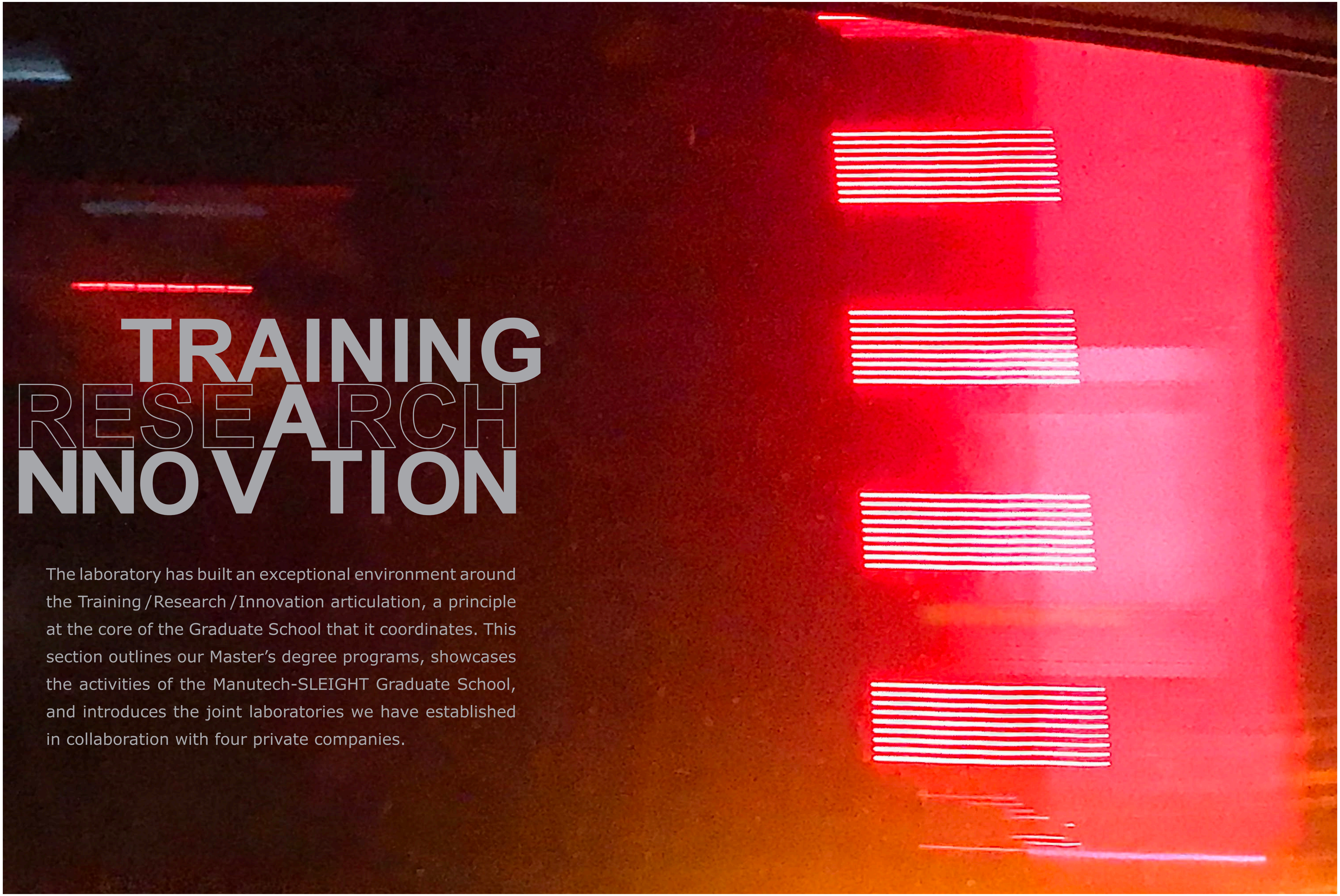
During the 2024 Conference on Cryptographic Hardware and Embedded Systems (CHES 2024), our SESAM team presented a proposed new jitter measurement method enhancing the reliability of True Random Number Generators.

The generation of true random numbers is a critical component of cryptographic systems, contributing to the security and integrity of our daily transactions and communications. True Random Number Generators (TRNGs) are tools that exploit the randomness of physical phenomena by using the random arrival time of oscillator edges, a phenomenon known as "clock jitter". Ring Oscillators (ROs) are commonly used for this purpose as they can be easily implemented in digital circuits and are prone to electronic noise, causing significant clock jitter. However, for reliable random generation, only thermal noise - which affects the initial oscillations of an RO - should be considered.
Any defect in a TRNG can compromise an entire cryptographic system. Therefore, continuous on-chip performance evaluation of these generators is crucial. Since most TRNGs rely on clock jitter, on-chip measurement of this jitter is necessary.
Although many on-chip jitter measurement methods have been proposed, none has proven to be at the same time precise, easy to embed, and capable of measuring jitter from the first few oscillations of ROs (mainly coming from thermal noise). We have here developed a new jitter measurement method that meets these stringent requirements, demonstrating its highest suitability compared to previously published methods.

Figure, below: Boxplots of 75 jitter measurements of the five compared methods.



IACR Transactions on Cryptographic Hardware and Embedded Systems, Vol. 2024 (1), pp. 207-228



TRAINING
RESEARCH
NNOV TION

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 four 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 (Hubert Curien Lab)

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 (EMJMD)
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: Damien Muselet (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

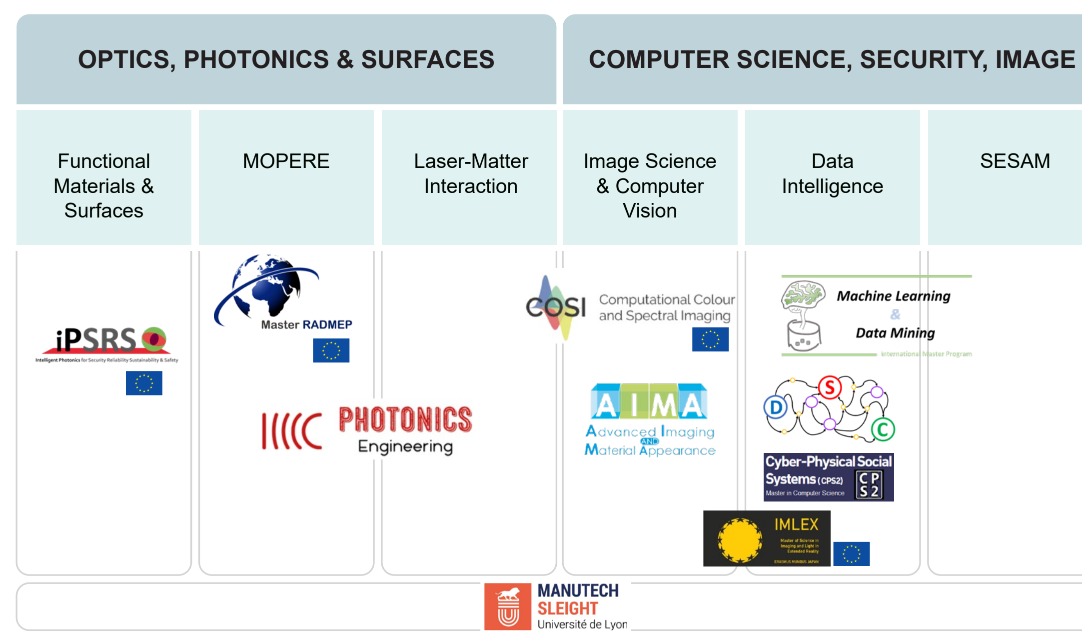
Master Degree in Computer science - Head: Amaury Habrard (Hubert Curien Lab)

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.

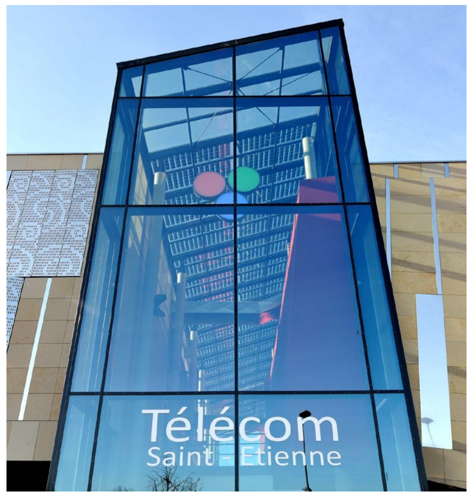
MLDM - Machine Learning Data Mining (International track)
Coordinators: Amaury Habrard & Marc Sebban (Hubert Curien Lab)
The MLDM master's degree is an attractive program focusing on machine learning, big data, pattern recognition, classification, modelling, knowledge extraction, and data mining.
These 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, 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, programming and project management.



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).

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 56 projects have been funded by Manutech-SLEIGHT so far, including 32 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.

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

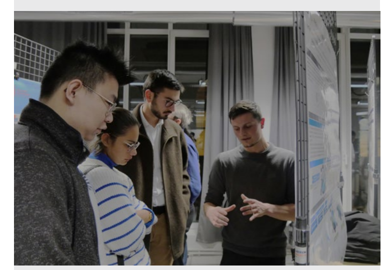
The Graduate School offers a unique environment for researchers who wish to undertake ambitious and transdisciplinary research projects, responding to major societal issues of the 21th century.

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

250 scientists
175 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.
28 Attractiveness scholarships awarded to international master 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.

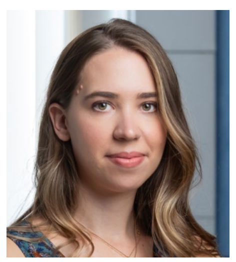
The Manutech-SLEIGHT Graduate School brings together a consortium of 12 public and private partners located in the Lyon/Saint-Étienne area, including 7 academic institutions (Universities, Engineering Schools), 2 national research organisations and 3 economic stakeholders, with the main goal to weave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

Manutech-SLEIGHT Science Event #11

8th to 12th January 2024

The Manutech SLEIGHT Graduate School held its 11th SSE in January 2024, gathering more than 200 participants for discussions covering the entire spectrum of topics included in the School's scientific program: Optics-Photonics, Machine Learning, Surface Engineering, Image Science, Artificial Intelligence and Bioengineering.





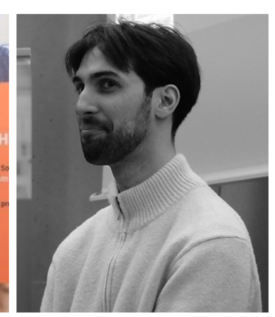

The event offered an opportunity for attendees to discover today's most advanced research on LIBS imaging and non-linear Raman microscopy, as well as the operation of free electron laser (FEL) facilities. Numerous PhD students and Post-doctoral fellows, as well as 5 special guests, presented their research during the workshops sessions.

The guest speakers of this 11th edition were:

- Vincent Motto-Ros
  (Institut Lumière-Matière, Lyon)
  LIBS imaging: a breakthrough in material and biomedical sciences?
- Albert Stolow
  (Canada Research Chair in Molecular Photonics, Canada)
  Coherent Nonlinear Raman Microscopy: Label-free chemical-specific imaging of materials.
- Marie-Emmanuelle Couprie
  (Synchrotron SOLEIL, France)
  Free Electron Laser, from its origin to recent developments.
- Elena Gofas
  (Institut de la Vision - UPMC, CNRS, Inserm)
  In vivo high-resolution imaging of the retina to study neurodegenerative diseases.
- Lourdes BASABE
  (Microfluidics Cluster UPV/EHU, Spain)
  The multiple uses of lab-on-a-chip technology and plasmonic nanosensors.

Several students' work, presentations and activities were awarded during the 5-day event: Lucas Rousseau and Sachin Joshi (Best Posters), Benjamin Lecoustre and Bruno Roca-Dhont (Best Pitches), Shubham Sharma (presentation award), Ariel Guerra Adames, Felipe Cortes Jaramillo, Bastian Schäfer and Franck Sirguey (collective work award), Vanina Amblas, Alexandre Bebon and Marie Traynar (for their involvement in the 11th SSE and the Graduate School's life).
On Wednesday 10th January 2024, former PhD student Rehan Jhuboo (Hubert Curien lab) successfully defended his thesis on a Machine Learning approach to the high resolution in bone microstructure CT imaging. His research project «MALBOT», result of a collaboration of the Hubert Curien, Sainbiose and CREATIS labs, was funded by the Manutech-SLEIGHT Graduate School.





Manutech-SLEIGHT Science Event #12

8th to 10th July 2024

The 12th edition of the Manutech-SLEIGHT Graduate School's Science Event took place in July 2024 on our campus, featuring a diverse program of lectures and equipment tours centered on the theme «**Imaging in Manutech-SLEIGHT**»






Six renowned scientists were invited to share their expertise on topics of interest to the Graduate School, including X-ray imaging, phase-contrast imaging in the X-ray domain, in situ electron microscopies, optogenetics, and high-resolution quantitative microscopy. The program also included guided visits to our onsite NEOARM Transmission Electron Microscope, as well as the Biomedical Imaging, Digital Histology, and Spatialomics facility.
Two students were rewarded as part of the Junior Scientist session: the best PhD Presentation prize went to Melis COBAN (BiiO lab), and the best Post-Doctoral Fellow Presentation prize was awarded to Anthony NAKHOUL (Hubert Curien Lab). Sofiane FRAINE, PhD student at the BiiO lab was also awarded for his involvement in many of the Graduate School's events and activities.

The guest speakers of this 12th edition were:

- **Ruth Sims** (Inserm, Institute of Vision, Paris),
  Parallel two-photon optogenetics and voltage imaging.
- **Olivier Haeberle** (UHA, Lab. IRIMAS, Mulhouse),
  Image formation in optical microscopy: from 2-D contrast only to 3-D quantitative imaging.
- **Renaud Podor** (CNRS, ICSM Marcoule, Bagnols-sur-Cèze),
  Advanced electron microscopy for a better understanding of in situ material dynamics. (Pt 1)
- **Philippe Steyer** (INSA Lyon, Lab. MatéIS, Lyon),
  Small scale characterization of advanced thin films by in situ eletron microscopies. (Pt 2)
- **Sorina Pop** (CNRS, Lab. CREATIS, Lyon), Computational reproductibility: an overview illustratedwith examples from the medical imaging research community.
- **Emmanuel Brun** (Inserm, Lab. Strobe, Grenoble), X-Ray wave imaging: principles and applications.



Upstream research for applied solutions

KEY FIGURES

32 granted patents between 2019 & 2024, including international term extensions

5 patent applications filed in 2024

5 startups created

Keranova
The QA Company
Dfinder
Newclin
Safehear

15 companies using and/or developing our work

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

4 joint labs

LabH6, with company Exail
https://www.exail.com/

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

COMETA, with HEF Group
https://hef.group

OPERA, with Orano Group
https://www.orano.group

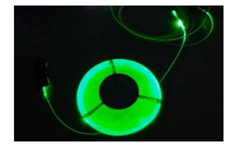
JOINT LABORATORIES

In order to further enhance the wide dissemination of its results to economic stakeholders and promote exchanges between research and society, the unit has established four joint laboratories with industrial partners since 2019.

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

labH6

since 2019



Photonics, Optic fibres, etc.
for the nuclear, space and health sectors, etc.
MOPERE team

+ exail
France | 1,800+ staff in 80 countries

This joint lab, focused on «Materials, Components, and Photonic Systems in Harsh Environments» develops breakthrough solutions for radiation environments, crucial to French and European sovereignty. Its radiation-hardened optical fibers are deployed in space, nuclear facilities, high-energy physics, and fusion installations. A key milestone was the deployment of «Made in France» fibers at the National Ignition Facility (NIF), USA. Its radiation-sensitive fibers are now the reference for dosimetry and are used at CERN. The MOPERE team contributes with 3 patents, 40+ joint publications, and a full-time Exail researcher seconded to the unit.

LAMCID

since 2022

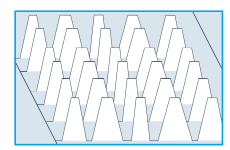
Identity documents security
Functional Materials & Surfaces team

+ HID
USA | 4,500+ staff in 100+ countries

This joint lab, focused on «Lasers, Materials, and Colors for Citizen Identity Documents» develops secure, innovative color marking technology, building on its collaboration with HID Global since 2016. HID Global, headquartered in Austin, USA, specializes in identity and access security. The lab advances image multiplexing through laser-based functionalization, and is recognized for its anti-counterfeiting potential. It involves our «Functional Materials & Surfaces» and «Image Science & Computer Vision» teams, with 3 patents and numerous joint publications.

COMETA

since 2024



Metasurfaces
Functional Materials & Surfaces
+ **Laser-Matter Interaction** teams

+ HEF GROUPE
France | 3,200+ staff in 20+ countries

The long-standing Hubert Curien Laboratory–HEF-IREIS collaboration has led to numerous joint projects, publications and patents, culminating in this joint lab on «Optical Components Based on Metasurfaces». It develops a unique platform for designing, modeling, and manufacturing optical metasurfaces, leveraging expertise in functional coatings, laser processes, and AI integration. The lab builds on joint patents with HEF-IREIS and involves its «Functional Materials & Surfaces» and «Laser-Matter Interaction» teams.

OPERA

since 2024

Photonics for nuclear applications
MOPERE + **Functional Materials & Surfaces**
+ **Laser-Matter Interaction** teams

+ orano
France | 17,000+ staff in 15+ countries

The lab's progress in fiber-optic dosimetry has driven multiple nuclear projects with ORANO (incl. *Plan de Relance Udd@Orano* project), leading to a joint strategy for innovative photonic solutions in the sector. A key achievement was developing drone-based embedded dosimetry, which won First Prize for Innovation (Nuclear Safety Category) at the World Nuclear Exhibition (WNE) 2023. OPERA involves the MOPERE team, with plans to expand to all teams within our "Optics, Photonics & Surfaces" Department.

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 2024.

Inauguration of the Inria MALICE project-team

26th March 2024

In March 2024, Inria, the University Jean Monnet Saint-Étienne and the CNRS inaugurated MALICE, a joint project-team for the development of new methodologies in machine learning to address major scientific and technological challenges in surface engineering. MALICE, which stands for ***MAchine Learning with Integration of surfaCe Engineering knowledge: Theory and Algorithm***, is hosted in our lab as part of the Data Intelligence team. As highlighted by our lab's director Florence Garrelie, the Inria MALICE team defines a new ambition anchored in the Hubert Curien laboratory's strategy.

While embedding physics knowledge into Machine Learning to enhance a Neural Network's predictive capabilities is a prevalent trend in contemporary scientific research, MALICE distinguishes itself by tackling physics laws that are not yet fully mastered. Specifically, the team addresses the complex mechanisms governing self-organizing phenomena that emerge from the interaction between laser light and matter, a technique pivotal in Surface Engineering applications. Our lab's distinctive combination of expertise in both statistical learning and surface engineering has been the catalyst for such new venture, with collaborative work dating a few years back.

Marc Sebban, head of MALICE, emphasizes the potential mutual benefits of the research for both domains. The main challenges of the team indeed consists in anwering the following 3 questions: Can we learn from (few) data and (partial) physical knowledge? Can we transfer knowledge from one material to another? Can we discover or complete the knowledge in surface engineering?

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

Université Jean Monnet Saint-Étienne

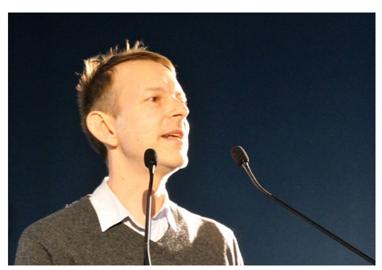
Above:
Bruno Sportisse, CEO of Inria;
Florent Pigeon, President of the University Jean Monnet Saint-Étienne;
Gabriele Fioni, Deputy Rector for Higher Education, Research & Innovation of the Auvergne Rhône-Alpes Academic Region;
Marc Sebban, Head of the Malice team;
Florence Garrelie, Director of the Hubert Curien Laboratory;
Stéphane Ubéda, Director of the Inria Lyon Centre.

The establishment of MALICE marks the addition of a 16th project-team to the Inria Lyon Centre, the first to be located in the Saint-Etienne area. The project aligns with the Centre's objective to foster new interdisciplinary research initiatives, particularly in the fields of digital and engineering. As pointed out by Bruno Sportisse (CEO of Inria) during the inaugural event, "*The creation of this new interdisciplinary team concretely illustrates Inria's commitment to supporting scientific risk-taking and the pursuit of greater impact, with its academic and university partners, in a promising field where the challenges are significant.*" The project is also in line with the University Jean Monnet's scientific strategy, which revolves around four distinct structural axes, including the Photonics-Surface-AI domain. Florent Pigeon (President of the University Jean Monnet) commented: "*Benefiting from complementary expertise in machine learning and surface engineering, developed within the Hubert Curien Laboratory and recognized at the highest international level, this team, unique in its kind, illustrates the scientific excellence of the activities carried out within this unit. This new collaboration with Inria fully aligns with Jean Monnet University's strategy to develop leading interdisciplinary activities with very high economic and societal potential in the strategic axis of 'Photonics-Surfaces-AI' of the institution.*"

Above:
Bruno Sportisse and **Florent Pigeon**, with members of the MALICE project-team:
Jordan Frecon Patracone,
Amaury Habrard,
Farah Cherfaoui,
Benjamin Girault,
Marc Sebban,
Rémi Eyraud,
Rémi Emonet,
Fayad Ali Banna,
Eduardo Brandao.

Institut d'Optique Graduate School:
20 Years in Saint-Etienne...and a Nobel Prize visit !

The Institut d'Optique Graduate School (IOGS) achieved a significant milestone in January 2024 by celebrating its 20th anniversary on the site of Saint-Étienne. The event brought together over 80 guests, including representatives from the State, Region, and Saint-Étienne Métropole, all demonstrating their support for this renoned institution, to which our lab has been affiliated for many years. The celebration started with speeches from Rémi Carminati, CEO of IOGS, and Florent Pigeon, President of the UJM. Both highlighted key moments in the development of the IOGS branch, achieved in close partnership with the university, and outlined future challenges. Our Director Florence Garrelie emphasized the successful outcomes of our collaboration with IOGS, our lab's secondary institutional affiliation since 2016, demonstrated by the recent emergence of the 'Appearance of materials' as a new research theme pioneered by Mathieu Hébert, Professor at IOGS and member of our Image Science & Computer Vision team. Mathieu further illustrated this synergy between teaching and research by presenting his work in metrology and surface appearance control. A special tribute was paid to Pierre Chavel, associate Director of IOGS in charge of the Saint-Etienne site, for his pivotal role in the branch's development over the last two decades. The day was animated by further high-level scientific and technical presentations, complemented by IOGS alumni and current students sharing their experiences, testifying to the high-quality educational environment offered by our city and the Graduate School.

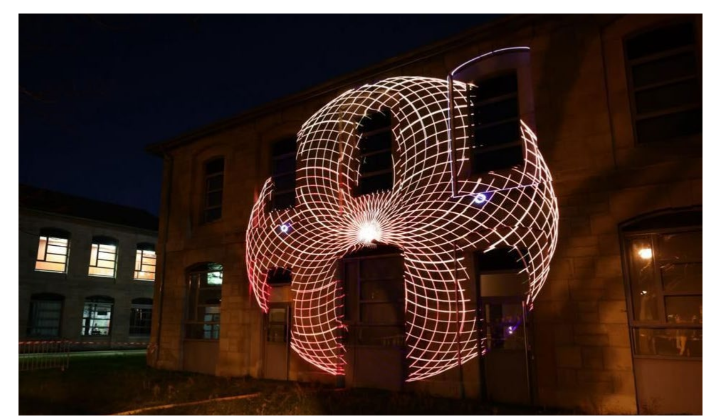


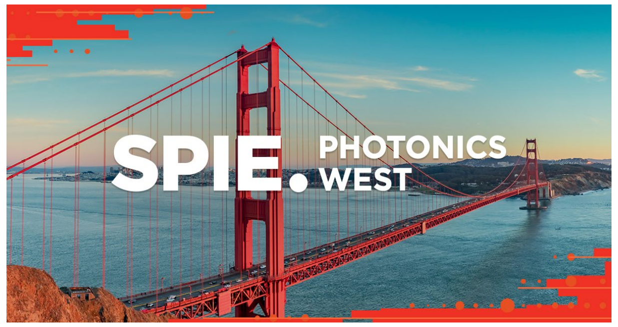
Right, top to bottom:
Rémi Carminati, Florent Pigeon, Florence Garrelie, Mathieu Hébert, and Pierre Chavel.

Left: Alain Aspect, co-laureate of the 2022 Nobel Prize in Physics

The highlight of the event was a lecture by Alain Aspect, a researcher at IOGS and the 2022 Nobel Prize co-laureate in Physics. His engaging presentation on quantum entanglement captivated a full auditorium of over 300 attendees! Prior to his lecture, Florence Garrelie and Aziz Boukenter had the opportunity to give Alain Aspect a tour of our lab's premises and laser research installations, after hosting Gérard Mourou in 2019. The day concluded with a spectacular laser mapping show by LaserWave, a student association from IOGS that creates performances using professional lasers. The successful event underscored the Institut d'Optique Graduate School's commitment to excellence in education, research and innovation, celebrating two decades of significant contributions to the optics and photonics community in Saint-Etienne and beyond.

We congratulate the IOGS on 20 years inSaint-Etienne and wish for many more years of successful collaborative work and achievements to come !





SPIE Photonics West Conference

27th January to 1st February 2024

SPIE Photonics West is the world's largest photonics technologies event gathering scientists, researchers and companies to present the most cutting-edge research in lasers, biomedical optics, biophotonics, quantum mechanics and optoelectronics. In 2024, the meeting was held in San Francisco, California, USA. Our Laser-Matter Interaction team researchers Tatiana E. Itina and Razvan Stoian were part of the Program Committee for two of the planned conferences, while other members of our lab made the following contributions:

Session 1: "Laser processing and modification of nanoscale and quantum materials"
Co-chair: Tatiana E. Itina. (Laser-Matter Interaction team).

- "Mechanisms of laser-based synthesis and modifications of nanomaterials";
  Invited paper presented by Tatiana E. Itina (Laser-Matter Interaction team).

Session 5: "Photonic ink and sensors"

- "Eco-friendly soft nanoimprinting of TiO_2 nanostructures with a large range of pattern heights";
  Paper presented by Huiru Ren (Institut des Nanotechnologies de Lyon), co-authored by Nicolas Crespo-Monteiro and Arnaud Valour (Functional Materials & Surfaces team).

Session 8: "AI and Machine Learning based processing"

- "Laser-induced surface organization on the nanoscale guided by machine learning";
  Invited paper presented by Jean-Philippe Colombier (Laser-Matter Interaction team).

Session 9: "Additive manufacturing and bonding"
Chair: Jean-Philippe Colombier (Laser-Matter Interaction team).

Session 17: "Nano-Photonics III"

- "Magneto-optical functionalized surfaces for sensing applications";
  Invited paper presented by Laure Bsawmaii (Functional Materials & Surfaces team).

POPILS 2024

16th February 2024

The «Journée Parcimonie, Optimisation et Problèmes Inverses Lyon Saint-Etienne» aims to bring together students and researchers from Lyon and Saint-Étienne who are interested in the fields of optimization, inverse problem solving, and sparsity. It seeks to create a dynamic of regional collaboration by encouraging interdisciplinary exchanges and identifying opportunities for cooperation.

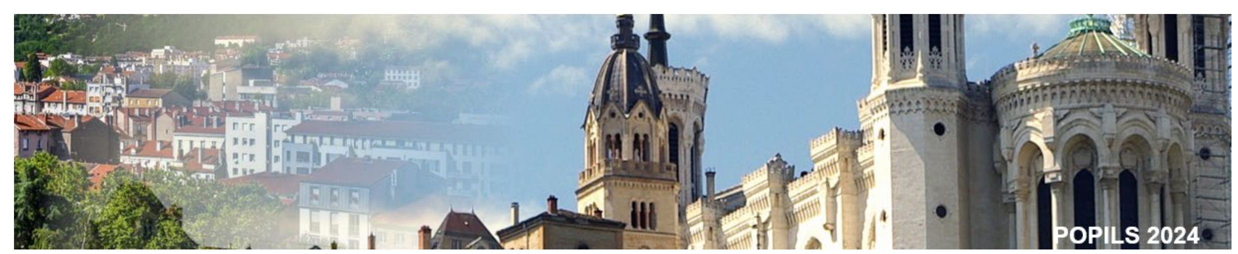
This first edition of POPILS was held in Febrary 2024 at the Bibliothèque Marie Curie on the site of INSA Lyon.
Jordan Patracone Frecon, from our lab's Data Intelligence group, was a member of the event's organising team,
while the following presentations were made by other members of our lab:

- "Parcimonie, optimisation et problèmes inverses en observation de la Terre et de l'Univers";
  Talk by Loïc Denis (Image Science & Computer Vision team).

- "Reconstruction auto-étalonnée par approche problème inverse pour la microscopie tomographique diffractive";
  Poster presented by lecturer Fabien Momey (Image Science & Computer Vision team).

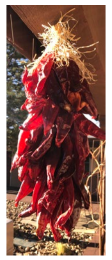
- "Sparse by Design Neural Operators";
  Poster presented by doctoral student Abdel-Rahim Mezidi (Data Intelligence team).

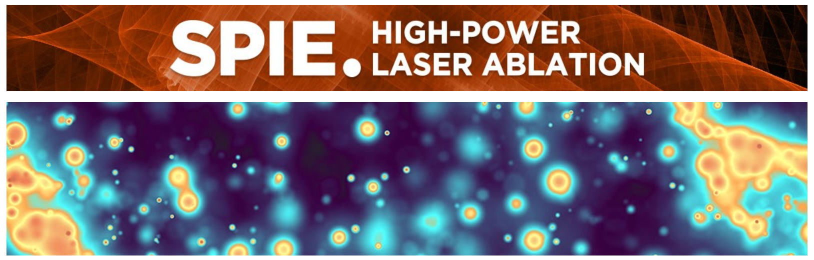
- "Problèmes inverses pour la reconstruction quantitative de phase appliqués à la microscopie holographique";
  Poster presented by post-doctoral fellow Dylan Brault (Image Science & Computer Vision team).



SPIE High-Power Laser Ablation Symposium

26th February to 1st March 2024





The International HPLA Symposium provides a unique forum for exchange of ideas on the physics and application of high-power laser-materials interaction, including advances in relevant high-power laser sources and problems of beam propagation and detection. The event was held in 2024 in Santa Fe, New Mexico, USA. Our Laser-Matter Interaction team member Tatiana E. Itina was part of the program committee, whilst several members of our lab made the following presentations:

Session 20: "Biological Applications of Lasers"
Scientific Committee and organisation: Tatiana E. Itina;
Introduction: X. Sedao.

- "Ultrafast laser micro and nanoprocessing for biomedical applications"; Invited talk by X. Sedao.
- "Numerical analysis of the mechanisms involved in integrated THz imaging with a NIR femtosecond laser illumination"; Paper by Tatiana E. Itina and X. Sedao; presented by X. Sedao.
- "Advanced femtosecond laser structuration for functionalization of optical components"; Poster presented by X. Sedao.
- "The quest for resolution: a dynamic view on ultrafast laser extreme volume nanostructuring"; Keynote lecture by Razvan Stoian.

Session 17: "Fundamentals of Ultrashort Laser-Materials Interactions: Theory and Simulations"

"Excited-state bandgap dynamics in silica from first principles"; Invited talk by Elena Kachan.

JSGAuRA15

28th March 2024

The 15th edition of the «Journée Sol-Gel et Chimie Liquide Auvergne Rhône-Alpes» took place in March 2024 on our Manufacture Campus. This biennial event, focusing on sol-gel technology and liquid-phase chemistry (such as solvothermal processes, co-precipitation, and emulsions), brings together academics and industry professionals in the field. Emphasizing a friendly and collaborative atmosphere, it provides a platform for students and young researchers to present their work on various application areas and share their perspectives.

This event was once again co-organised by Prof. Francis Vocanson from our Functional Materials & Surfaces team, together with colleagues from Grenoble (Laboratoire des Matériaux et du Génie Physique LMGP) and Clermont Ferrand (ICCF/SIGMA-Clermont).
The following presentations were made by members of our lab:

- “Procédé sol-gel pour la fabrication d’un marquage anti-contrefaçon avec un réseau résonant enterré sous un revêtement luminescent”; Paper presented by Marie Traynar.
- “Inscription par laser d’images en couleur dans des cartes en polycarbonate”; Paper presented by Manuel Flores.
- “Films sol-gel de TiO2 micro-nanostructurés par nano impression pour la génération photocatalytique d’hydrogène”; Paper presented by Léa Marichez.
- “Micro-nanostructuration et nitruration de films minces de sol-gel de ZrO2 photo-gravable pour obtenir du ZrN micro-nanostructuré”; Paper presented by Victor Allejo-Otero.

SPIE Optical Systems Design Symposium

7th to 11th April 2024

The SPIE Optical Systems Design Symposium aims to provide an interdisciplinary forum for technicians, engineers, researchers, and managers involved in instrumental optics at all levels: specifications, design, manufacturing, and testing. The 2024 edition was held in Strasbourg, France.

Thierry Lépine, Associate Professor at the Institut d'Optique Graduate School and member of our Image Science & Computer Vision team, served as symposium chair for this event while being also part of the technical committee. The following papers involving members of our lab were presented during the symposium.

CONFERENCES

«Optical Design and Engineering IX»
Chair: Thierry Lépine (Image Science & Computer Vision team).

- "Design of a freeform, wide field of view, high angular resolution four-mirrors system working in the visible and near-infrared spectrum";
  Paper presented by François Riguet (Safran Reosc), co-authored by Agnès Vinoy (Hubert Curien Lab/ONERA/ESA), Thierry Lépine (Image Science & Computer Vision team).

- "Optimization of a freeform TMA with a differential ray tracer with NURBS capabilities";
  Invited paper presented by Clément Freslier (Hubert Curien Lab/ONERA/ESA), co-authored by Thierry Lépine (Image Science & Computer Vision team).

«Optical Instrument Science, Technology, and Applications III»

- "OpenMIC: a DIY twelve slides scanner microscope with evolutive and multimodal capabilities";
  Paper presented by Anthony Ain (Lab. BIIO), co-authored by Thierry Lépine (Image Science & Computer Vision team).

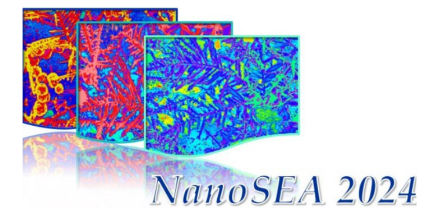
«Advances in Optical Thin Films VIII»

- "Micro-nanostructuring by optical-lithography and nitriding of photo-patternable ZrO_2 sol-gel to obtain micro-nanostructured ZrN";
  Paper presented by Victor Vallejo Otero (Functional Materials & Surfaces team).

- "2D nanopillars patterning of complex shape using multiple colloidal lithography illumination on photo-patternable TiO2 and ZrO2 based sol-gel layers";
  Paper presented by Rosa Olloghe Mandoukou, co-authored by Victor Vallejo Otero, Arnaud Valour, Marie Traynar, Maxime Royon, Isabelle Verrier, Nicolas N. Crespo-Monteiro, Yves Jourlin (Functional Materials & Surfaces team).

NanoSEA

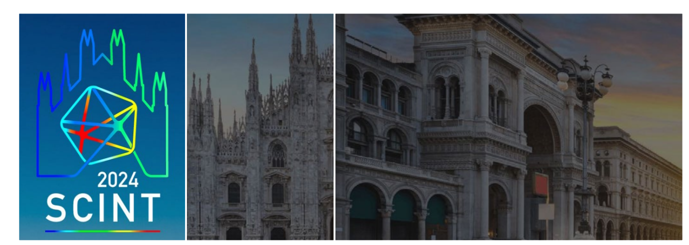
16th to 19th July 2024



For the 8th International Conference on Nanostructures and Nanomaterials Self-Assembly, held in Marseille in July 2024, member of our Functional Materials & Surfaces team Nathalie Destouches was invited to deliver a talk on "Laser-Induced Self-Organization of Nanocomposite Films." Organised every two years, either at French or Italian seaside locations, the event provides an opportunity for all researchers involved in nanostructured materials, 2D materials, and self-assembly to meet and discuss the inherant progress of the nanoscience.

SCINT

8th to 12th July 2024



The 17th International Conference on Scintillating Materials and their Applications was held at the University of Milano-Bicocca, Italy, in July 2024. Our MOPERE team PhD student Aditya Raj Mandal presented a paper titled "Online Radiation Induced Attenuation measurements of Radioluminescence Dosimeters irradiated with X-rays: Dose rate dependence at high doses".

GreenAI Project

On 13th November 2024, members of our Image Science & Computer Vision joined the companies Asygn and Dracula Technologies in Grenoble to present GreenAI, a groundbreaking European industrial platform dedicated to the development of energy-autonomous and intelligent connected devices. This project, co-financed by the French government within the framework of the France 2030 program, the Auvergne-Rhône-Alpes Region, and Grenoble Alpes Metropole, addresses critical challenges in the Internet of Things (IoT) and artificial intelligence (AI).

With 18 billion connected devices worldwide in 2024, the need for innovative approaches to data processing and energy efficiency is more pressing than ever. Most connected devices currently depend on cloud servers, which create challenges like bandwidth limitations, high energy consumption, and data privacy concerns.
GreenAI offers a transformative solution by embedding AI directly within devices. This enables real-time data processing, reduces reliance on cloud servers, lowers bandwidth costs, and enhances data security by minimizing unnecessary data transmission.

GreenAI unites three regional technology innovators:
- Dracula Technologies specializes in organic photovoltaic cells. As part of GreenAI, it is developing a new generation of innovative cells designed to harness ambient light within a room, making IoT devices sustainable and environmentally friendly.
- The Hubert Curien Laboratory concentrates on energy-efficient AI tailored to computer vision. Supported by two scientific theses, our lab's team is optimizing neural network architectures for deployment on resource-efficient electronic chips. Its research focuses on: 1) Developing open-source optimization software for CNN-based architectures.; 2) Exploring physics-informed neural networks to enhance AI efficiency.
- Asygn coordinator of the project, focuses on low-power electronic chips. It is developing an ultra-low-power hardware accelerator to support the artificial intelligence created by the Hubert Curien Laboratory. This chip equips IoT devices with computer vision capabilities, enabling efficient, localized data processing.

By 2026, GreenAI aims to deliver two demonstrators showcasing its technology:
- Smart Building/Home Automation: Transforming how we monitor air quality in buildings while enhancing energy efficiency and automation.
- Traffic Monitoring: Improving safety and traffic flow in low-light conditions, such as tunnels.

The intelligent IoT devices developed through GreenAI collect data from integrated sensors. This data is processed and analyzed autonomously using artificial intelligence. By combining AI, low energy consumption, and renewable energy sources, GreenAI's solutions address industry demands for smart, sustainable, and scalable devices. These easy-to-deploy technologies aim to revolutionize not only road safety and indoor environments, but could also find applications in nature conservation and crowd management.

The event was attended by Catherine Staron, Vice-President of the Auvergne-Rhône-Alpes Region, and Florent Cholat, Metropolitan Advisor of Grenoble-Alpes Métropole.

ICLPR-ST Conference 2024

16th to 21st June 2024

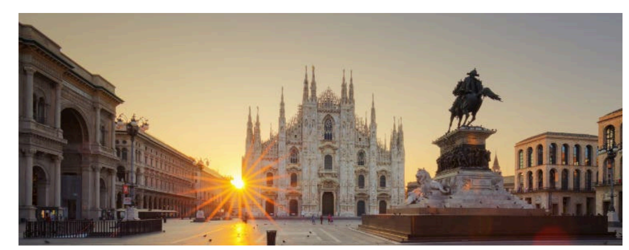
The second edition of the International Conference on Laser, Plasma and Radiation - Science and Technology took place in June 2024 in Romania. The event provides an interdisciplinary environment for sharing and discussing the latest scientific and technological developments in the fields of lasers, plasma and radiation physics.

Razvan Stoian, head of the Laser-Matter Interaction group at the Hubert Curien Lab, was a member of the conference's scientific committee. He was also invited to give a talk at the summer school held prior to the conference. His presentation, titled 'Ultrafast Non-Diffractive Beams with Tunable Dispersion: Opportunities for Smart Laser Material Processing,' explored advanced beam shaping techniques and their applications in laser material processing.»

ECCV

29th September to 4th October 2024

As part of the 18th European Conference on Computer Vision (ECCV) - a biennial, premier research event in Computer Vision and Machine Learning - a workshop titled "The Dark Side of Generative AIs and Beyond" was organized. The workshop focused on examining some challenging aspects of generative AIs, including ethical concerns, the spread of disinformation, legal ramifications, and the risks of model collapse. Within this context, Quentin Bertrand, a member of our Data Intelligence team, delivered a keynote talk on "Challenges in Retraining Generative Models Using Their Own Data."



NSREC

22nd to 26th July 2024

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. The latest NSREC edition was held in July 2024 in Ottawa, Canada. The members of the conference committee were hard to miss this year, as each sported a custom-made Canadian-style hockey jersey! See if you can spot our very own Sylvain Girard in the group photo below, who served as Awards Chairman for this NSREC 2024 edition.

The conference was preceded by a one-day short course titled "Radiation Effects on Electronic and Photonic Technologies: From Basic Concepts to Advanced Mechanisms" for which a Notebook will be published, as is done every year.
While the first three sections of the course focused on the main radiation effects in electronics, a special fourth section explored the effects on photonic technologies. During this session, Sylvain Girard delivered a lecture on "Radiation Effects on Silica-based Optical Fibers and Bulk Glasses", discussing the advantages and limitations of implementing these technologies in various harsh environments, their potential applications, as well as the parameters governing their macroscopic radiation responses.

The following studies by members of our MOPERE team were also presented:

CONFERENCES:

- "Temperature Dependence of the Radiation Response of Ultra-low Loss Optical Fibers: Role of Self-Trapped Holes";
  M. Roche, A. Morana, V. De Michele, C. Campanella, E. Marin, A. Boukenter, Y. Oeurdane, J. Mekki, S. Girard.

- "Sensitivity Enhancement of Tapered Cerium-Doped Optical Fibers for Dosimetry Applications";
  F. Fricano, R. Vallifuoco, D. Lambert, A. Morana, P. Paillet, H. El Hamzaoui, B. Capoen, M. Bouazaoui, E. Marin, E. Catalano, A. Minardo, Y. Oeurdane, A. Boukenter, S. Girard.

POSTER:

- "14 MeV and Atmospheric Neutron Monitoring Through Optical Fiber Dosimeters";
  M. Roche, D. Lambert, L. Weninger, N. Kerboub, C. Bélanger-Champagne, A. Colangeli, C. Hoehr, M. Trinczek, E. Marin, Y. Ouerdane, P. Paillet, J. Mekki, T. Robin, S. Girard.

ECML PKDD

9th to 13th September 2024

ECML PKDD, a leading European conference on machine learning and data mining, held its latest edition in September 2024 in Vilnius, Lithuania.
Our Data Intelligence team was well-represented, with contributions that included the following papers:

Adversarial Machine Learning Session

- «A Theoretically Grounded Extension of Universal Attacks from the Attacker's Viewpoint»; Jordan Patracone, Paul Viallard, Emilie Morvant, Gilles Gasso, Amaury Habrard, Stéphane Canu. (See page 70 for details)

- «Linear Modeling of the Adversarial Noise Space»; Jordan Patracone, Lucas Anquetil, Yuan Liu, Gilles Gasso, Stéphane Canu.

Deep Learning Theory Session

- «Approximation Error of Sobolev Regular Functions with Tanh Neural Networks»: Theoretical Impact on PINNs»; Benjamin Girault, Rémi Emonet, Jordan Patracone, Amaury Habrard, Marc Sebban. (See page 71 for details)

Missing Data Session

- «Reconstructing the Unseen: GRIOT for Attributed Graph Imputation with Optimal Transport»; Richard Serrano, Charlotte Laclau, Baptiste Jeudy, Christine Largeron. (See page 72 for details)

RADECS

16th to 20th September 2024

The RADiation Effects on Components and Systems (RADECS) Conference is an annual international scientific and industrial forum on radiation and its effect on electronics and photonics materials, devices and systems. Co-sponsored by IEEE-NPSS, the RADECS 2024 edition was organized by the National Institute of Aerospace Technology (INTA), the European Space Agency (ESA) and the European Organization for Nuclear Research (CERN), on behalf of the RADECS Association. It was held in Maspalomas, Canary Islands, Spain, where the following research results were presented by several members of our MOPERE team:

CONFERENCE:
Session C - Photonics, Optoelectronics & Sensors

- «Influence of Manufacturing Parameters on the Steady State Radiation Response of Radiation Sensitive Optical Fibers»;
  R. Pecorella, A. Dufour, A. Morana, A. Boukenter, Y. Ouerdane, M. Cannas, S. Girard.

POSTERS:
Session C - Photonics, Optoelectronics & Sensors

- «Radiation Effects on Graded Index Germanosilicate Multimode Optical Fibers»;
  R. Pecorella, A. Morana, E. Marin, A. Boukenter, M. Cannas, Y. Ouerdane, S. Girard.
- «Investigation of the Radiation Response of a Dual-Stage Optical Amplifier»;
  A. Facchini, A. Morana, L. Mescia, T. Robin, A. Boukenter, E. Marin, Y. Ouerdane, S. Girard.
- "External Quantum Efficiency Evolution of Light-Emitting Diodes under γ-rays, Electrons, Neutrons and Protons";
  L. Weninger, A. Morana, M. Ferrari, A. Boukenter, Y. Ouerdane, E. Marin, P. Paillet, M. Gaillardin, O. Duhamel, C. Hoehr, C. Bélanger-Champagne, M. Trinczek, S. Girard.
- "Radiation and Temperature Effects on Carbon- and Aluminum-Coated Optical Fibers";
  J. Perrot, A. Morana, E. Marin, A. Boukenter, Y. Oeurdane, J. Bertrand, M. Burger, B. Morgan, I. Jovanovic, S. Girard.
- "Photobleaching Effects on the Radiation-Induced Attenuation of Germanosilicate Optical Fibers at Low Temperature";
  A. Morana, A. Facchini, M. Roche, H. Boiron, E. Marin, A. Boukenter, Y. Oeurdane, S. Girard.

Session H - Basic Mechanisms of Radiation Effects:

- "Impact of gate metallization for Total Ionizing Dose Testing of MOS capacitors";
  V. Girones, J. Boch, D. Lambert, F. Saigné, T. Maraine, F. Wrobel, S. Girard, A. Carapelle, A. Chapon, R. Garcia.

Session G - Dosimetry & Facilities:

- "Characterization of heavy-ion beams with silicon solid-state detectors through transient analysis";
  K. Bilko, S. Girard, R. Garcia, A. Coronetti.
- "Silicon Solid-state Detector for Characterization of Thermal Neutrons in the Accelerator Radiation Environment";
  K. Bilko, R. Garcia, M. Sacristan Barbero, I. Slipukhin, S. Girard.
- "Analysis of the Thermal Annealing Regeneration Process of RPL Dosimeters for High Dose Levels";
  Y. Aguiar, R. Garcia, M. Ferrari, A. Hasan, J. Perrot, A. Raj Mandal, S. Girard.
- "Dose rate effects in Ag-doped metaphosphate glass RPL dosimeters up to MGy range";
  Y. Aguiar, R. Garcia, M. Kranjcevic, M. Ferrari, D. Soderstrom, A. Raj Mandal, J. Gascon, J. Trummer, H. Vincke, A. Alessi, O. Cavani, A. Costantino, G. Lerner, S. Girard.

COLA

29th September to 4th October 2024

The 17th International Conference on Laser Ablation (COLA) was held in Greece in September 2024, and gathered an international community of laser scientists, end-users, students and industry professionals to discuss the latest advancements in laser ablation and its applications. Our lab actively contributed to the event, showcasing a number of presentations co-authored with several members of our Laser-Matter Interaction team:

CONFERENCE

- "Deciphering the complexity behind laser-induced self-organized nanopatterns";
  Jean-Philippe Colombier.
- "Multiscale characterization of the wettability of fs-laser textured thin film metallic glasses surfaces";
  Hugo Bruhier.

POSTERS

- "Oxidation of metals during topographic functionalization upon ultrafast laser irradiation";
  Jean-Philippe Colombier.
- "Time resolved mid-infrared absorption in silica: ultrafast heat transfer observed by direct probing of anharmonic vibrations"; Vincenzo De Michele.
- "Ultrafast laser induced anisotropic carrier transport dynamics in smooth and surface pre-structured crystal semiconductors, detected by terahertz pulses"; Ciro D'Amico.
- "Densification of amorphous silica obtained from different polymorphs"; Aram Melkonyan.

Biomim - Santé
Thematic school, GdR CNRS BIOMIM
6th to 11th October 2024

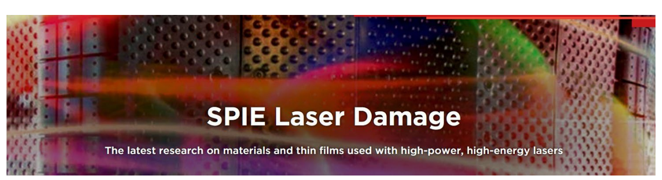
Established in 2020 by the CNRS Institute of Chemistry, the research consortium GDR 2088 "BIOMIM" aims to connect France's researchers and doctoral students from diverse scientific backgrounds and specializations, who are experts in biomimicry and bioinspiration, to tackle key scientific and societal challenges through nature-inspired solutions.
Through our Laser-Matter Interaction team, the Hubert Curien Laboratory is an active member of GDR 2088. Our research engineer X Sedao was a member of the committee that organized the consortium's latest thematic school, held on Île d'Oléron in October 2024. X Sedao also delivered a talk on «Biomimetic Surfaces and Interfaces: Surface Functionalization with Ultrafast Lasers – Inspiration, Applications, and Pathways to Industrialization.»

NuMat
14th to 17th October 2024

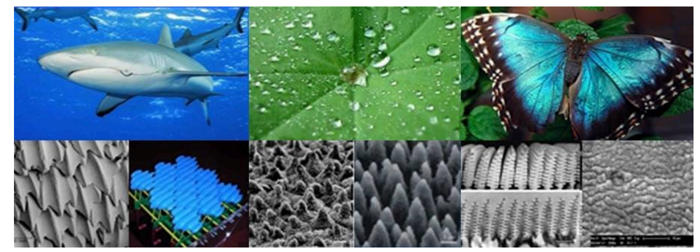
The Nuclear Materials Conference (NuMat) is a biennial event organised by Elsevier in cooperation with the International Atomic Energy Agency (IAEA). Since 2012, the conference has been dedicated to nuclear materials science related to fission and fusion reactors, and the overall nuclear fuel cycle. Its 8th edition was held in October 2024 in Singapore.
As part of the conference track on Radiation Effects in Functional Materials, the head of our MOPERE team, Sylvain Girard, was invited to deliver a talk titled «Understanding radiation effects on silica-based optical fibers: from radiation-hardening studies to fiber dosimetry». The paper was co-authored with group members Adriana Morana, Aziz Boukenter, Emmanuel Marin and Youcef Ouerdane.

SPIE Laser Damage
7th to 10th October 2024

The 2024 edition of the SPIE Laser Damage conference, a specialized meeting on materials and thin films for high-power, high-energy lasers, took place in San Ramon, CA, USA. Our colleague Jean-Philippe Colombier, a member of the lab's Laser-Matter Interaction team, attended as an invited speaker, presenting a paper titled "Ultrafast Laser-Irradiated Silica: From Excited-State Dynamics to Nanostructuring".



Labex Manutech-SISE workshop
16th to 18th October 2024



LABEX MANUTECH-SISE
UNIVERSITÉ DE LYON

Science & Engineering of Surfaces and Interfaces Workshop

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.

Researchers and professionals from laboratories and companies affiliated with the Labex Manutech-SISE gathered in Écully, near Lyon, in October 2024 to share the outcomes of their work with the broader academic and industrial communities involved in surface science and engineering. The event welcomed 65 participants who attended project presentations aligned with the Labex's core themes. Additionally, contributions from industry leaders emphasised the critical challenges and opportunities in surface and interface engineering.

European Cyber Week
18th to 21st November 2024

The European Cyber Week congress held its ninth edition in November 2024, bringing together experts from the French and European cyber defense and AI ecosystem in Rennes. Members of our SESAM team participated in this event, presenting the following work:

Poster Session

- "Beyond Total Locking: Demonstrating and Measuring Mutual Influence on a RO-Based True Random Number Generator on an FPGA"; Eloïse Delolme.

Randomness generation Worshop

- "Low cost and precise jitter measurement method: application to ERO and PLL-based TRNGs"; Florent Bernard.
- "On jitter transfer in ring oscillators"; Maciej Skorski.

Journées Nationales sur les Technologies Emergentes en Micro-Nanofabrication

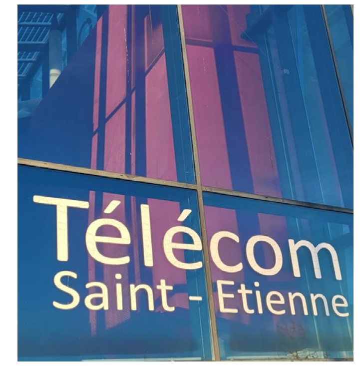
27th to 29th November 2024

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

The 2024 edition of the *Journées Nationales sur les Technologies Émergentes en micro-nanofabrication* (National Days on Emerging Technologies in Micro-Nanofabrication) was organized by Maxime Darnon from our lab, and took place on our Manufacture Campus at Télécom Saint-Etienne. The event brought together members of the scientific community engaged in micro-nanotechnologies to exchange results and ideas, foster continuity of expertise from fundamental research to applied innovation, and strengthen interactions between key stakeholders and researchers.

With over 120 participants from France and beyond, it showcased cutting-edge advancements in micro/nano fabrication methods, tools, and characterization techniques, highlighting contributions from members of the industrial and academic community.
The rich program of seminars, poster presentations and site visits was focusing on several topics including:

- Processes and methods for shaping matter at the micro/nano scale;
- Functionalities enabled by micro/nano structuring and their characterization;
- Integration methods for incorporating micro/nano technologies into complex systems;
- Applications of micro/nano technologies to address societal needs.

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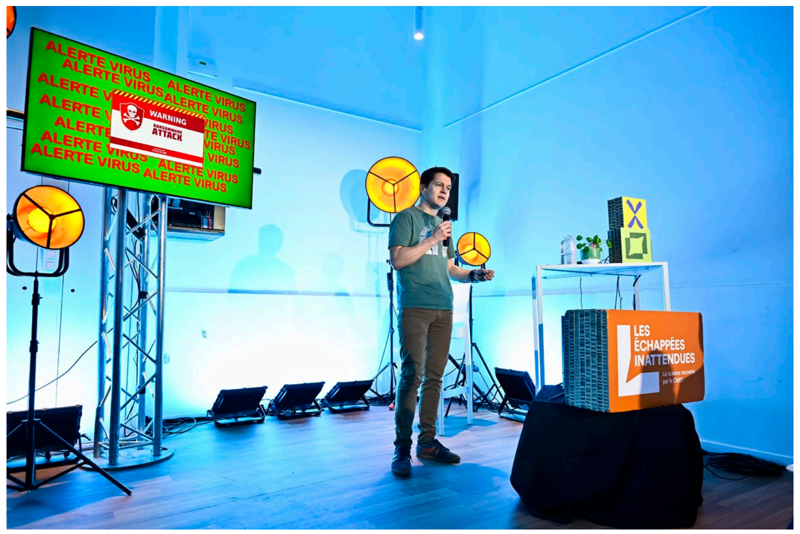
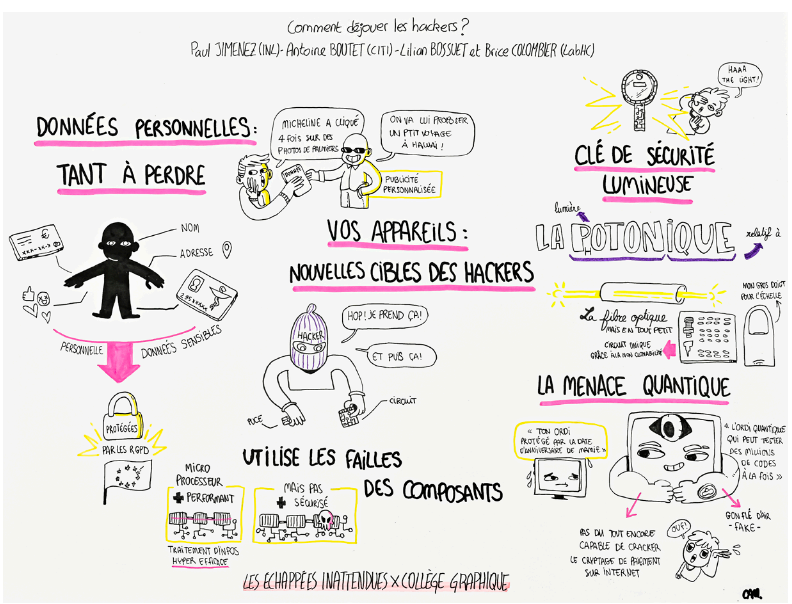
Échappées inattendues x Collège Graphique

15th to 17th November 2024

Les Échappées Inattendues is the name given by the CNRS to its extensive science dissemination program aimed at a broad audience. This initiative takes place annually throughout the year and across the country, featuring exhibitions, conferences, debates, educational workshops, and other activities. The Rhône-Alpes delegation of the CNRS organized a variety of events over three days in November 2024 at Truffaut College, a creative hub dedicated to comics located on the Pentes de la Croix-Rousse in Lyon. Members of our SESAM team Lilian Bossuet and Brice Colombier each delivered a talk as part of a micro-conference titled: «How to outsmart hackers?». During the talks, an illustrator created a series of live drawings inspired by the content being presented (see board below).



"Your Devices: A New Target for Hackers" by Lilian Bossuet.
When discussing cyberattacks, people often think of viruses infiltrating the code of our software. However, hackers don't just hack digital systems; they also target electronic components, such as the chip in your bank card or the circuits in your smartphone. Scientists are working on developing security solutions akin to barrier gestures, aimed at countering these new forms of attacks.



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Watch the micro-conference on the CNRS' Youtube channel:

"The Quantum Threat", by Brice Colombier.
As quantum computers increase in capacity, post-quantum cryptography becomes crucial for protecting our data. Current methods, based on the difficulty of factoring large numbers, are vulnerable to these new technologies. To counter these threats, scientists are developing cryptographic systems resistant to the capabilities of quantum computers, including solutions integrated into physical devices and techniques to identify and eliminate new vulnerabilities.

Fête de la Science 2024 - *Nuit de la Recherche*

4th October 2024

The "Nuit de la Recherche" is part of the French national "Fête de la Science" program. Since 2019, it has been coordinated by La Rotonde-Mines Saint-Étienne for the Auvergne-Rhône-Alpes region. In collaboration with Jean Monnet University, Saint-Étienne Metropole, and many higher education institutions in the area, a rich program of events was organised in October 2024, involving more than 80 researchers and offering the general public an opportunity to discover the world of research in an entertaining and surprising way.

In 2024, our lab took part in the event, with contributions from students and researchers Selyan Acid, Fiammetta Fricano, Corinne Fournier, Hugo Bruhier, Martin Roche, Marie Traynar and Victor Vallejo-Otero.

Pint of Science 2024

14th May 2024

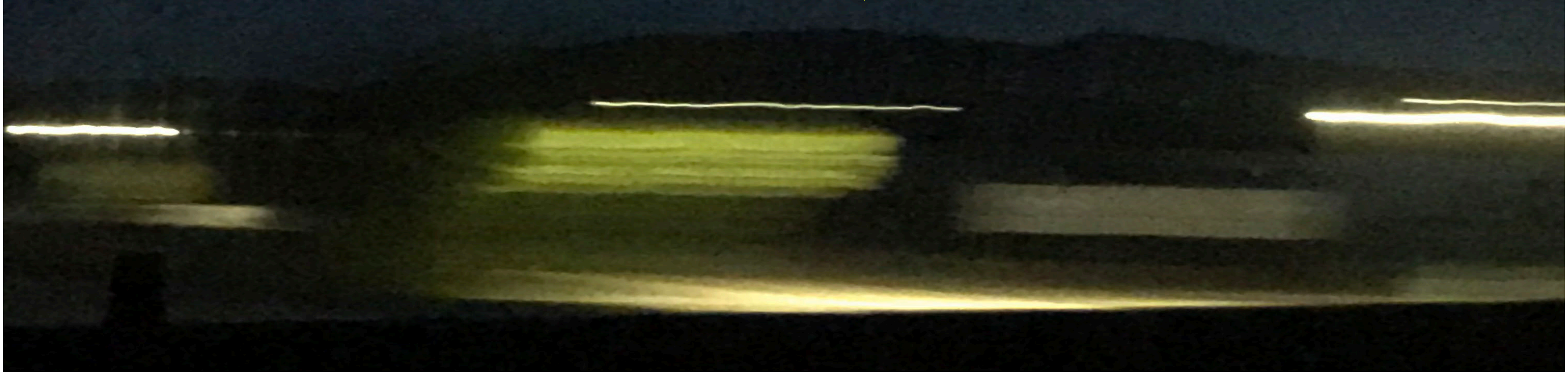
Bringing science to the people

In 2024, our lab once again participated in the Pint of Science Festival, a worldwide event that brings researchers to local pubs, cafés, and other public spaces to share their scientific discoveries. Talks were given at Café Le Méliès and Six Nations Bar in Saint-Etienne by various members of the Ecole des Mines and Université Jean Monnet. Prof. Cédric Killian from our SESAM team presented his research on Artificial Intelligence and Electronic Security.

Abstract: «From autonomous vehicles to the medical revolution, and through innovative entertainment, this technology remarkably improves our lives. However, behind this advancement lie crucial challenges related to electronic security. The electronic components, which are the true brains housing artificial intelligence, can be targeted by malicious individuals. But what can they concretely do by attacking these electronic components? Throughout this presentation, let's explore these potential threats and their implications for our security.»

AWARDS & DISTINCTIONS

Researchers are rarely motivated by the pursuit of distinctions, but they are certainly never disappointed to receive recognition from their peers! Congratulations to all our lab's recipients of prizes and accolades, whether they are doctoral students or experienced scientists.



Martin Roche & Fiammetta Fricano

IEEE NPSS Paul Phelps 2024 awards

The IEEE Nuclear and Plasma Sciences Society (NPSS) is the premier professional association for the advancement of the nuclear and plasma sciences, sponsoring seven technical conferences and three peer-reviewed journals. Now former PhD students Martin Roche and Fiammetta Fricano were recipients of the association's 2024 Paul Phelps Awards, recognizing "exceptional promise as a student, postdoc or research associate in any of the fields of NPSS, or exceptional work in those fields".

In 2021, after obtaining a double master's degree from Jean Monnet University and the Telecom Saint-Etienne engineering school, Martin Roche completed his final-year internship at Airbus Defence and Space, in partnership with our MOPERE team at the Hubert Curien Laboratory. During these few months, he discovered and worked on optical fibers and their behaviour in space environments, focusing particularly on telecommunication challenges. Highly interested in this topic, he continued his studies with a PhD thesis at CNES (Centre National d'Études Spatiales), co-funded by the company Exail and still in partnership with the MOPERE team. Martin was studying the influence of space radiation on optical fibers under the supervision of Sylvain Girard and Emmanuel Marin (Hubert Curien Lab), as well as Nicolas Balcon (iXblue), until his viva in December 2024. Martin has actively participated in the LUMINA project, an optical fiber-based dosimeter that was sent to the International Space Station in 2021 during the ESA Alpha mission.

Fiammetta graduated from the University of Palermo in 2020. She completed her master's internship in Spring 2021 with our lab's MOPERE group, working on radiation effects on optical fiber-based dosimetry, and continued with the same team for her doctoral studies under the supervision of Aziz Boukenter. Her PhD research, completed in March 2025, was focusing on the luminescence induced by radiation on several types of optical fibers, for the development of a radiation sensor for medical applications. Her doctoral research was funded by the ANR project FIDELIO, led by the Université Jean Monnet in collaboration with the Université de Côte d'Azur, Université de Lille and the company Exail.

Martin and Fiammetta received their award at the 2024 NSREC Conference in Ottawa, Canada, in July 2024. With this new recognition from the IEEE NPSS community, they are following in the footsteps of Adriana Morana, who received the Paul Phelps Award in 2017, Imene Reghouia in 2018, Marine Aubry in 2021, and Cosimo Campanella in 2022.

Nathalie Destouches

new senior member of the IUF

Nathalie Destouches is our latest researcher to be appointed as a member of the Institut Universitaire de France (IUF). She was awarded an Innovation Chair as part of the 2024 Senior IUF promotion, for a period of 5 years. The Institut Universitaire de France is a service of the French Ministry of Higher Education that each year distinguishes a small number of faculty members for their research excellence, as evidenced by their international recognition. It 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-funded research project.

Graduated in 1998 with an engineering degree in optics from the Ecole Nationale Supérieure de Physique de Marseille, followed by a PhD from the Fresnel Institute and the University of Aix-Marseille III in 2001 and a postdoctoral fellowship at the Laboratory of Glasses in Montpellier, Nathalie joined the Hubert Curien Laboratory (then named «LTSI») and the University Jean Monnet in 2002. While her initial research focused on the design, fabrication, and characterization of resonant gratings for filtering applications, she now focuses on laser-induced nanostructuring of plasmonic materials, as part of the Functional Materials & Surfaces team's «Nanoparticles» group that she has been leading since 2006. Nathalie has also been actively working on developing applications of her fundamental research with industrial partners, activities which have gained her an «Innovation» position at the IUF. Nathalie also coordinates the UJM master's degree program in Optics, Image, Vision, Multimedia (OIVM), as well as its EMJMD IPSRS (Intelligent Photonics for Security Reliability Sustainability and Safety) specialization track.

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE
Liberté Égalité Fraternité

Ouvrir la science !

Lucas Potin

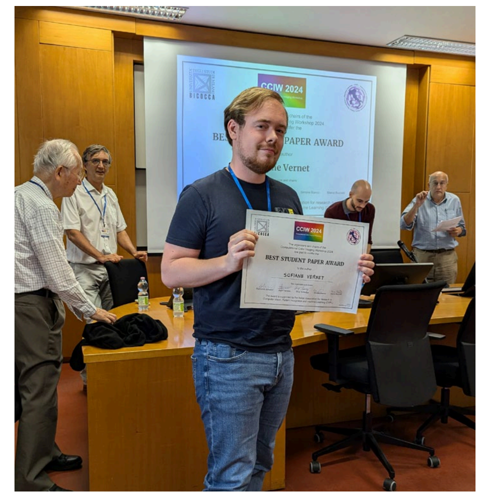
2024 Open Science Research Data Awards

In November 2024 and for the third time, the French Ministry of Higher Education and Research presented the Open Science Research Data Awards. This initiative, part of the Second National Plan for Open Science, recognized researchers, projects, and research teams dedicated to data management and dissemination. Some of these initiatives also leveraged the reuse of existing datasets to advance scientific research. The awards were presented during the National Conference on Research Data, held at the Mucem museum in Marseille.
For this edition, the awards were divided into three categories:

- Creating a Missing Dataset Award - Recognizing four outstanding projects that developed new datasets to address specific scientific needs.
- Creating the Conditions for Reuse Award - Honoring two teams for exemplary research data management, ensuring their accessibility and reusability.
- Special Jury Mention - Awarded to a project that made a significant contribution to data availability and enrichment.

Lucas Potin, computer science PhD student under the supervision of Christine Largeron from our Data Intelligence team, shared the "Creating a Missing Dataset" category award with doctoral student in Economics Adrien Deschamps, for their "Extended, Enhanced, and Unified Public Procurement Announcement Database - BeauAMP" dataset. The project introduces a large-scale dataset on public procurement allocations in France (2015–2023). It consolidates and structures textual data from the Official Bulletin of Public Procurement Announcements, cross-referencing it with INSEE data on businesses and public buyers. Given the complexity and fragmentation of these datasets, AI algorithms were used to refine and establish the most accurate alignments with economic agents (SIRET identifiers) present in other databases.
The BeauAMP dataset was developed by both students from the University of Avignon, as part of the ANR funded DeCoMaP project (ANR-19-CE38-0004). The work follows up the "FOPPA Open Database of French Public Procurement Award Notices From 2010–2020", co-created and published in 2023 by our lab with the LIA - Laboratoire Informatique d'Avignon and the LBNC - Laboratoire Biens, Normes et Contrats.

Picture above: Winners of the 2024 Open Science Research Data Awards, with Lucas Potin at far right.
(Credits: DIRCOM, Aix-Marseille University)



Sofiane Vernet

CCIW 2024 Best Student Paper Award

The Computational Color Imaging Workshop (CCIW) has been at the forefront of color imaging research and innovation for the past 15 years. Its 2024 edition was held in Milan, Italy, and focused on research demonstrating the integration of cutting-edge AI algorithms and deep learning models to advance the field of color imaging.

During the event, a best student prize was awarded to member of our Image Science & Computer Vision Sofiane Vernet, who presented a paper titled "Stabilization of the spectral power distribution of a tunable multichannel LED lighting system", co-authored with Rei Nakayama, Éric Dinet, Alain Trémeau and Philippe Colantoni.

Eduardo Brandão

CSS/France 2024 Thesis Prize

COMPLEX SYSTEMS SOCIETY

Pictured above: Eduardo Brandão (right) alongside the other laureates of the 2024 CSS/France Thesis Prize.

Established in 2004, the Complex Systems Society (CSS) brings together an international community of researchers to advance the science of complex systems and its applications. The Society's objectives include promoting pure and applied research in complex systems, providing guidance on education in the field, addressing the societal implications of complexity science, fostering international collaboration, cultivating a sense of identity among complexity scientists, and representing the community at an international level.

To recognize outstanding contributions to the science of complex systems, the Society has established several awards, including a thesis prize designed to honor the work of exceptionally promising young researchers. In September 2024, an open scientific event in Lyon provided a platform for 18 nominees for the 2024 CSS/France Thesis Prize to present their work to a jury of field experts.
Among the six nominees awarded a prize by the jury for the quality of their research and presentations was Eduardo Brandão, a member of our Data Intelligence team. Eduardo's research focuses on Complexity Methods in Physics-Guided Machine Learning.

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

Rémi Emonet

In February 2024, Associate Professor Rémi Emonet successfully defended his accreditation to lead research (HDR). Rémi joined the University Jean Monnet in 2013 after completing a PhD in software architectures for intelligent environments at Inria and a postdoctoral fellowship at the Idiap Research Institute (EPFL) in Switzerland. In his HDR presentation, Rémi provided an overview of his research work as part of our Data Intelligence team, offering a selection of studies centered around anomaly detection and transfer learning - two pivotal subdomains within machine learning with extensive practical implications. Anomaly detection can be seen either in a supervised or unsupervised context. In supervised scenarios, the main challenge lies in addressing class imbalances: one must compensate for the low number of anomaly examples. In unsupervised settings, anomaly detection essentially consists in modeling the distribution of (normal) data, in order to detect future points that deviate from it. Transfer learning aims to leverage a model learned from one dataset to help learning from a new dataset or a new task. Some transfer approaches use formulations based on the optimal transport problem, which involves deciding how to best allocate resources, or, for example, align two datasets.
Rémi was appointed junior member of the Institut Universitaire de France in October 2023.

Ciro D'Amico

Ciro d'Amico, a member of our Laser-Matter Interaction team, has recently received accreditation to lead research (HDR). After completing his undergraduate studies in his native Italy, Ciro obtained a doctorate in Physics at the École Polytechnique of Palaiseau in 2007, where he studied femtosecond filamentation in passive and amplifying transparent media, as well as filamentation as a source of secondary electromagnetic radiation. Several consecutive post-doctoral positions led Ciro to Jean Monnet University, where he became an Associate Professor in 2013. His research activities in our lab can be divided into two main areas. The first aspect, which has a more applicative focus, involves mastering the irradiation process through the spatial and temporal shaping of the ultrafast laser pulse to transform the material and control its optical, mechanical, and chemical properties. The second area, with a more fundamental focus, involves using the irradiation process to study the response of the material (spectroscopy, pump-probe experiments) and generate secondary sources (plasma photoluminescence, THz radiation, etc.) that can be used to analyze and understand the interaction mechanisms and thus optimize the structuring process. Ciro's HDR presentation focused on the «Structuring and Functionalization of Materials by Ultrashort Laser: From the Fundamental Response to the Application.»

Promotion

Maxine Darnon

Maxime Darnon, CNRS research fellow who joined our laboratory through a transfer from the IRL LN2-Laboratoire Nanotechnologies Nanosystèmes at the University of Sherbrooke in Canada, has been recently promoted to Director of Research by the CoNRS (Section 08).
Maxime 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 moved to the IRL LN2 in 2015, focusing on photovoltaic applications. Since November 2023, Maxime has been developing activities in surface nanopatterning (as part of our Functional Materials & Surfaces team) and optoelectronic devices in severe environments (as part of our MOPERE team).

Our new doctors

Rehan Jhuboo
Data Intelligence
Janvier 10th, 2024

Super-Resolution for Bone Microstructure CT Imaging

Thesis supervisors

Marc Sebban
Hubert Curien Lab, Supervisor

Alain Guignandon
Sainbiose, Co-Supervisor

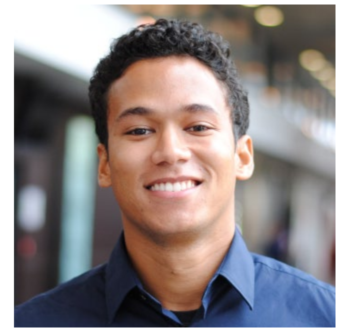
Françoise Peyrin
Creatis, Co-Supervisor

Ilemona Sunday Omeje
Laser-Matter Interaction
February 12th, 2024

Numerical study of the wettability of femtosecond laser-treated and textured surfaces

Thesis supervisor

Tatiana E. Itina
Hubert Curien Lab, Supervisor



Mateus Simões
SESAM
June 14th, 2024

Characterization of Masking Schemes Against Side-Channel Attacks in the Presence of Glitches

Thesis supervisors

Lilian Bossuet
Hubert Curien Lab, Supervisor

Nicolas Bruneau
STMicroelectronics, Rousset, Supervisor

Vincent Grosso
Hubert Curien Lab, Co-supervisor

Patrick Haddad
STMicroelectronics, Rousset, Co-Supervisor

Daiwei ZHANG
Laser-Matter Interaction
February 13th, 2024

Ultrafast laser-induced anisotropic charge transport dynamics in laser structured materials, probed by terahertz pulses

Thesis supervisors

Razvan Stoian
Hubert Curien Lab, Supervisor

Ciro D'Amico
Hubert Curien Lab, Co-supervisor

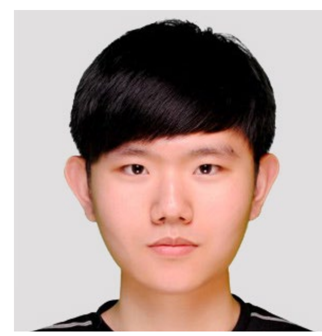
Marion Agoyan
MOPERE
March 28th, 2024

Chromatic confocal measurement: study of influencing parameters and extension of operation to extreme conditions

Thesis supervisors

Aziz Boukenter
Hubert Curien Lab, Supervisor

Guy Cheymol
CEA, Paris, Co-Supervisor



Kunpeng Guo
Data Intelligence
November 22nd, 2024

Improving Neural Language Models for Question Answering: Fine-Tuning Techniques and Applications in Knowledge Graph Completion and Web Search

Thesis supervisors

Christophe Gravier
Hubert Curien Lab, Supervisor

Antoine Gourru
Hubert Curien Lab, Co-supervisor

Dennis Diefenbach
The QA Company, Co-supervisor

Arturo Mollinedo Garay
SESAM
November 25th, 2024

On-board characterization and measurement of clock jitter used as source of randomness by TRNGs

Thesis supervisors

Viktor Fischer
Hubert Curien Lab, Supervisor

Florent Bernard
Hubert Curien Lab, Co-supervisor

Patrick Haddad
STMicrelectronics, Co-supervisor

Ugo Mureddu
STMicrelectronics, Co-supervisor

Our new doctors

Bastien Giles
Data Intelligence
November 25th, 2024

Detecting Health Care Frauds In Attributed Graphs Using Explainable Methods

Thesis supervisors

Christine Largeron
Hubert Curien Lab, Supervisor

Baptiste Jeudy
Hubert Curien Lab, Co-supervisor

Sachin Joshi
Image Science & Computer Vision
November 28th, 2024

Digital in-line holographic microscopy: improvement and analysis of geometrical aberrations calibration and preliminary study of unstained biological samples

Thesis supervisors

Corinne Fournier
Hubert Curien Lab, Supervisor

Thomas Olivier
Hubert Curien Lab, Co-supervisor

Clément Freslier
Image Science & Computer Vision
December 5th, 2024

Study of freeform catoptric systems with an accessible exit pupil in coplanar and non-coplanar arrangements for nanosatellites

Thesis supervisors

Thierry Lépine
Hubert Curien Lab, Supervisor

Guillaume Druart
ONERA, Palaiseau, Co-supervisor

Raphaële Milan
SESAM
December 9th, 2024

TrustSoC: a heterogeneous secure-by-design SoC architecture

Thesis supervisors

Lilian Bossuet
Hubert Curien Lab, Supervisor

Loïc Lagadec
ENSTA-Bretagne, Supervisor

Tristan Cladière
Image Science & Computer Vision
December 9th, 2024

Context-aware emotion recognition: exploring compact architectures for social robotics

Thesis supervisors

Olivier Alata
Hubert Curien Lab, Supervisor

Christophe Ducottet
Hubert Curien Lab, Co-supervisor

Hubert Konik
Hubert Curien Lab, Co-supervisor

Anne-Claire Legrand
Hubert Curien Lab, Co-supervisor

Martin Roche
MOPERE
December 13th, 2024

Towards Advanced Architectures of Fiber Dosimeters for Space Applications

Thesis supervisors

Sylvain Girard
Hubert Curien Lab, Supervisor

Emmanuel Marin
Hubert Curien Lab, Co-supervisor

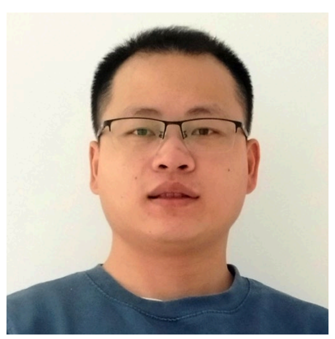
New recruits

Yuliya DADOENKOVA

Yuliya is a newly appointed Associate Professor at the Université Jean Monnet and member of our Functional Materials & Surfaces team. She began her professional career in 2008 at the Donetsk Institute for Physics and Engineering in Ukraine, and subsequently held research positions at Ulyanovsk State University and Novgorod State University in Russia. Prior to her arrival in Saint-Etienne, Yuliya was part of the Lab-STICC Laboratory at the École nationale d'ingénieurs de Brest (ENIB). Her expertise lies in photonics, plasmonics, and magnonics, with her current research focusing on functional nanocomposite magnetic metasurfaces for non-reciprocal photonic applications, as well as spin waves in anisotropic thin films.

Victor KALT

Victor joined the Université Jean Monnet in September 2024 as an Assistant Professor and research member of our Functional Materials & Surfaces team. In 2023, he completed a PhD at the University of Rouen Normandie on the numerical simulation of superfluids, followed by a postdoc at the Institut Pascal in Clermont-Ferrand, focusing on the numerical modeling of structures that combine resonant waveguide gratings with photoluminescent materials. His primary areas of research are the modeling, numerical simulation, and optimization of metasurfaces. In particular, Victor is interested in understanding the impact of imperfections on resonant structures and how to use this knowledge for the design of photonic structures.



Haifei ZHANG

Haifei completed his Ph.D. at the Université de Technologie de Compiègne in November 2023 with a thesis titled «Explainable Cautious Classifiers.» Following his doctoral studies, he held a Temporary Teaching and Research Position (ATER) at the same institution until August 2024. Haifei joined our lab in September 2024 as a member of the Data Intelligence team, while also teaching at Télécom Saint-Etienne School. His research interests include explainability in machine learning, uncertainty modeling, graph-based learning, and the analysis of complex data.

Quentin BERTRAND

Quentin completed his Ph. D. at Inria Paris-Saclay (in the Parietal Team) under the supervision of Joseph Salmon and Alexandre Gramfort. His thesis work was focusing on the optimization and statistical aspects of high dimensional sparse linear regression applied to brain signal reconstruction, with an emphasis on efficient large-scale optimization solvers. From November 2021 to June 2024, Quentin was a post-doctoral researcher at Mila-Quebec, collaborating with Gauthier Gidel and Simon Lacoste-Julien, primarily working on representation learning and generative models. Since July 2024, Quentin is an Inria researcher and member of our MALICE team, focusing on leveraging synthetic data from generative models in low-data regime, as in physics.

Jean-Philippe BANON

Jean-Philippe earned a PhD in Physics from the Norwegian University of Science and Technology in 2018. He then held postdoctoral positions at Saint-Gobain Recherche, Institut Langevin (Paris), Laboratoire de Physique de la Matière Condensée (École Polytechnique, Palaiseau), and Laboratoire Charles Fabry (Institut d'Optique, Palaiseau), before joining our University as Assistant Professor on a fixed-term contract. As part of our lab's Laser-Matter Interaction team, Jean-Philippe studies the interplay between surface roughness properties and laser pulse characteristics in energy deposition, complex surface structure formation and methods to control them. Specializing in wave behavior (light, electrons, atoms) in disordered environments, he also collaborates with our Functional Materials & Surfaces team.

Naïma Chalais-Traoré

Naïma joined our lab on 1st February 2024 as a new administrative staff member working in our research support unit. She 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. Naïma also participates in the organisation of events such as conferences, important scientific meetings, thesis defenses, HDR defenses, etc. As an Inria Research Team Assistant (AER Inria), part of her working time is dedicated to the administrative support of the lab's new Inria project-team MALICE.

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