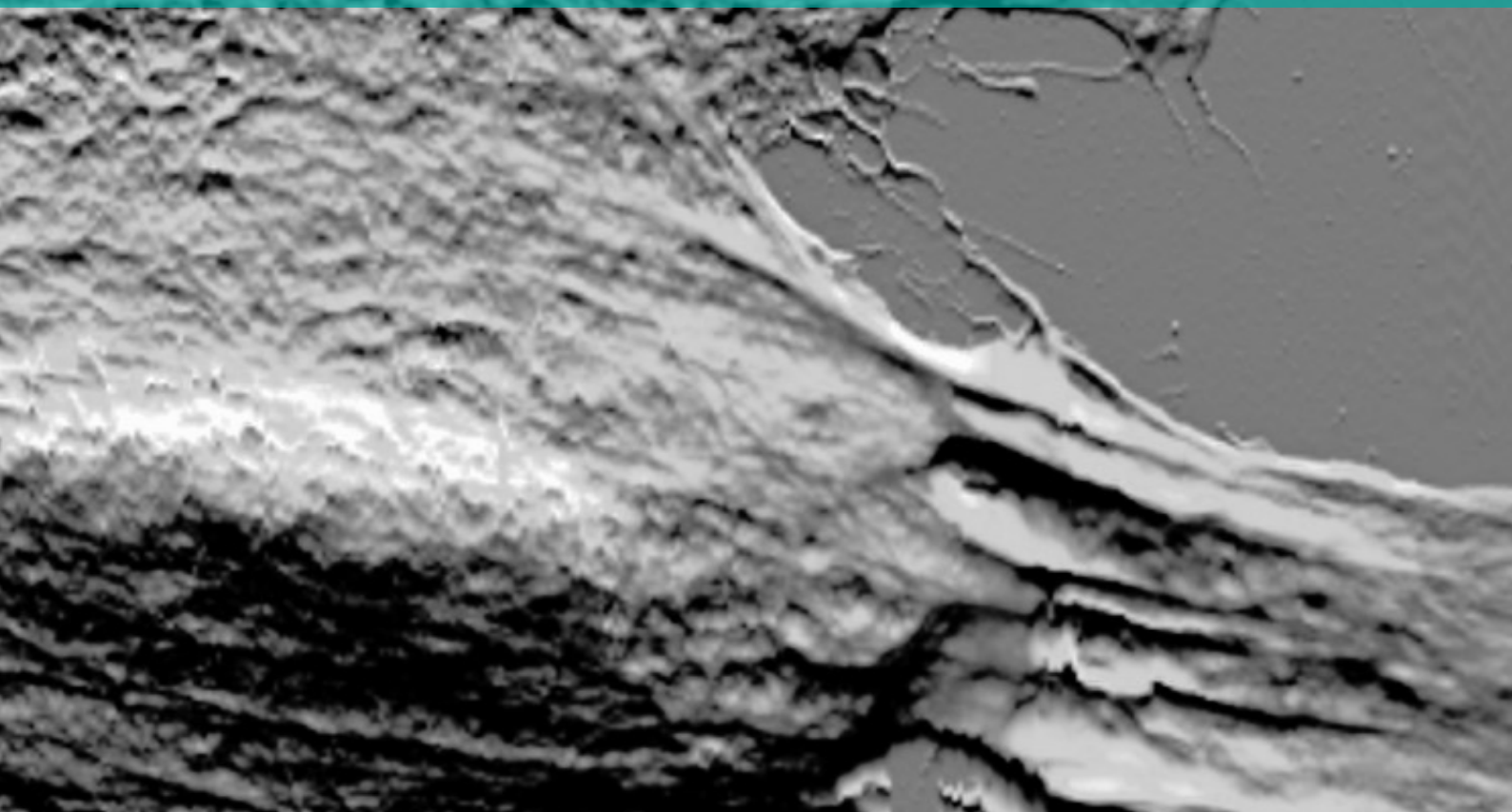
femto-st
SCIENCES &
TECHNOLOGIES

2022
ANNUAL REPORT



The FEMTO-ST institute is the largest public research laboratory in the Bourgogne-Franche-Comté region, located in eastern France, next to Switzerland and Germany. It comprises 7 scientific departments with approximately 750 staff members (PhD students, postdoctoral fellows, technicians, engineers, administrative staff, researchers and professors).

FEMTO-ST members are essentially employed by five different French public research organizations and higher education and research (HER) institutions: SupMicroTech-ENSMM (an engineering HER institution in microtechnology and mechanics), University of Technology Belfort-Montbéliard in Energy (HER in mobility, networks and industry 4.0), the University of Franche-Comté (a broad spectrum traditional university, which will celebrate in 2023 its 600th anniversary), the National Centre for Scientific Research (CNRS) and the University Bourgogne-Franche-Comté (UBFC, the federal HER institution in the region).

FOREWORD

Exploring Science and Innovation, from basic research to industries and spin-offs, from theory to experiments through high technology facilities, developing micro and nanotechnology, increasing the density of functions and integrating intelligence for the engineering of components and systems with optimized performances, contributing to the future of a knowledge-based improved society.

2022 was a particularly brilliant academic year for FEMTO-ST and its members. We experienced for example both successful closing of very high socio-economic impact projects funded by the European Regional Development Fund (e.g. microtechnology for innovative biotherapies; extremely compact silicium engines for connected watches with hands), as well as starting very exciting projects such as an ERC on 3D integrated neuromorphic processors, or plutonium-based power systems for far space exploration, among many others.

Our institute scientific strategy also progressed with big steps ahead, through great achievements of more and more highly relevant research projects with respect to EU priority activity sectors, such fuel cell systems, deeptech systems and technologies for the future of information and communications (programmable matter, space quantum cryptography, high performance integrated clocks, novel materials and structures for integrated energy harvesters, test benches for automated detection infectious and cardiac diseases, etc.). Conference and school organizations finally recovered a more usual activity level, and FEMTO-ST members contributed to this very important knowledge sharing practice in science, not only as contributors, but also as very active organizers.

The reader will be able to discover all those activities performed in 2022, and even more. I wish you to enjoy the reading, discovering our projects, results and achievements, and maybe find reasons to start new collaborations with us.

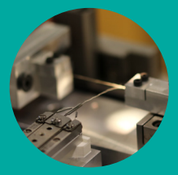
Laurent Larger
Head of FEMTO-ST Institute

A BROAD RANGE OF MASTERED SCIENTIFIC EXPERTISE

FEMTO-ST INSTITUTE constists of 7 research departments and two transverse axes RECITS and BIOM'@X, which make collaborative efforts to organize multidisciplinary research activities. We also encourage multidisciplinary research activities in collaboration between departments.

APPLIED MECHANICS

- Materials, surfaces, processes, structures
- Micromechanics, microfabrication
- Fonctionalisation, smart structures
- Sustainability, reliability, biocompatibility



ROBOTICS & AUTOMATION (AS2M)

- Microrobotics, mechatronics
- Automation
- Prognostic & Health Management (PHM)

TIME & FREQUENCY (TF)

- Oscillators/ resonators
- Time & frequency metrology
- Microwave systems and sensors

COMPUTER SCIENCE (DISC)

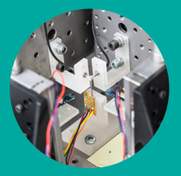
- Parallel and distributed computing
- Formal methods for software engineering
- High performance computing
- Distributed smart microsystems

MICRO-NANOSCIENCES & SYSTEMS (MN2S)

- Opto-electro-mechanical microsystems
- Phononics and microscopy
- Nanosciences and nanostructured materials
- Biomicrosystems

OPTICS

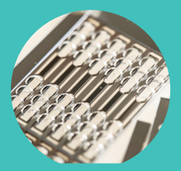
- Nonlinear photonics
- Quantum photonics
- Nano-photonics
- Complex optoelectronic systems & AI



ENERGY

- Hydrogen-energy
- Electromagnetic converters
- Thermal machines
- Metrology and energy management

TRANSVERSE AXES



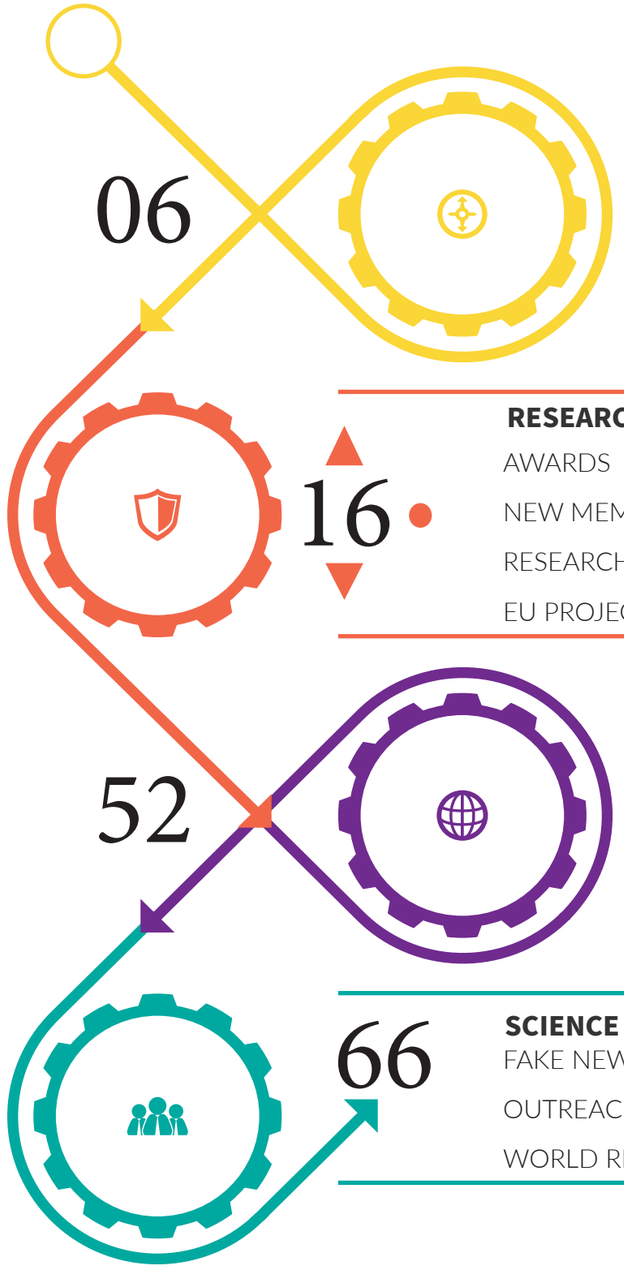
Biom'@x

- Towards technological translational medicine

RECITS

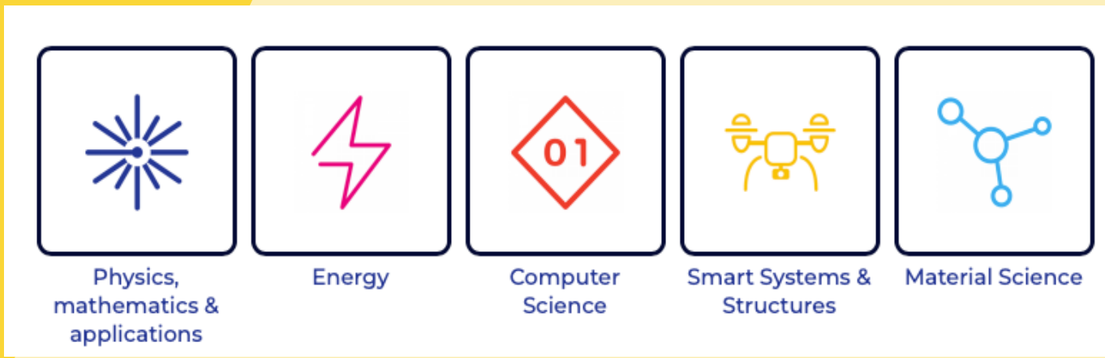
- Research and study of industrial, technological and societal evolution

CONTENTS



EDUCATION

MASTER/PHD STUDIES IN FIVE RESEARCH AREAS



GRADUATE SCHOOL EIPHI

EIPHI graduate school

at University Bourgogne Franche-Comté
- 5 outstanding research areas
- Worldclass research labs
- Close connection with industry
- Broad mobility opportunities
- Tutoring and mentoring
- Scholarships

Coordinated by:
Hervé Maillotte (FEMTO-ST)
Gerard Colas des Francs (ICB)

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http://gradschool.eiphi.ubfc.fr/

In terms of training, EIPHI offers 16 Master tracks: 15 since the 2021-22 academic year, as the arrival of the four new laboratories has been accompanied by 5 new Master degree programmes (CompuPhys, Advanced Mathematics, T2MC, VIBOT, MaIA – an ERASMUS MUNDUS), and a 16th with the opening of QuanTeem, a second ERASMUS MUNDUS Master degree in the 2022-2023 academic year. Fifteen Master programmes are now taught entirely in English (8 in 2020, 13 in 2021) and there are 301 registered Master students, of which 191 international ones (52%), including 27 double-diploma students, 15 engineering students, and 534 PhD students (further 26% international students are not coming from our Master studies).

EIPHI Strategic Advisory Board

The year 2022 got off to a flying start with the organization of the first face-to-face EIPHI Strategic Advisory Board (SAB, composed of alumni and leading researchers from academia or industry) meeting of two days in Besançon. The 5 research and training areas of the Graduate School were presented by the heads of the Master programmes and doctoral schools and by Master/PhD students and researchers. This event was also an opportunity to present the 4 new laboratories (ICMUB, ImViA, UTINAM, LmB) which joined in 2021 the 3 founding laboratories (FEMTO-ST, ICB, IMB) and which increased the EIPHI community from 450 to more than 600 permanent researchers and professors. The SAB underlined the quality and richness of the presentations and wrote a report highlighting the strengths and weaknesses of EIPHI activities. Thus, the year 2022 was thus an opportunity to correct the trajectory with the organization of several events and actions in line with the SAB recommendations.

2022 EIPHI Welcome Day: Presentation of the Open Badges to the EIPHI student award laureates (Best Oral Master or PhD Presentations in each of the five training-research areas of the Graduate School).

Training-Research Link

The transformation of the training offer to match international standards has been pursued. The project-based learning approach has become widespread, promoting the training-research link through projects and internships, in deep immersion in the laboratories and accompanied by tutoring and mentoring, although the latter are still too limited. This project-based approach extends beyond the formal training, as demonstrated by the participation of 22 Master students and 18 PhD students from the four EIPHI campuses in Hacking Health Besançon, both committed for organizing the event, participating in the challenges, and managing the health innovation projects. This contributes to shared actions on both levels of training (Master and PhD) and to reinforce the training-research link.

"French & Sciences" Program

The involvement of PhD students in training is also done through interdisciplinary courses that they have deeply prepared and then deliver in the "French + Sciences" program in collaboration with the Besançon Center for Applied Linguistics (CLA) and Campus France, intended for foreign bachelor students to learn French language and discover the applied sciences too. These activities also contribute to professionalizing the doctoral students, since they are not only trained to conduct high-level research, but also to supervise, to manage, to work in a team and to communicate. Recognition of the commitment of Master and PhD students in such skill development is an issue that the implementation of Open Badges aims to address. These badges recognize and value tutoring, dissemination, networking and communication skills. More than 300 Open Badges have been issued to date to over 150 Master and PhD students, and 12 milestone badges have been awarded to PhD students completing their training. The work of EIPHI and the doctoral schools has become more coordinated thanks to the recognition of these additional activities requested by EIPHI in the individual training program of the PhD students.

This year, 11 PhD students gave interdisciplinary courses from January to mid-May for 10 Indonesian students (as part of an exchange agreement with Sepuluh Nopember Institute of Technology - ITS), but also for an international group of 11 bachelor students in June (from United States, Singapore, Syria, Northern Macedonia) who came to participate in a summer school "French + Sciences" in partnership with the CLA Besançon and Campus France.

EIPHI Events

Finally, for the first time, a common welcome day for all EIPHI masters was organized at the begining of the 2022-23 academic year. The Graduate School overall activity and the UBFC Alumni network were presented, as well as testimonials from EIPHI doctoral students on their motivations and experience in research. Interdisciplinary courses for Master students were also organized over four days at the beginning of November, including a Climate Fresco and a training on the “safe and just space for humanity” concept realized by groups to raise awareness of sustainable development and social responsibility. The groups were made up of students from the different EIPHI Master programs so that they could interact each other among the five training-research areas and thus better understand the contours of EIPHI and reinforce the feeling of belonging to a Graduate School.

GRADUATE SCHOOL EIPHI

2022 scientific production

216 peer-review papers with a strong improvement in quality:

- 55% papers in the 1st quartile (44% in 2021),
- 74 with IF>5,
- 15 with IF>10 (8 in 2021),
- 4 WoS Highly Cited Papers.

Internal Call for Research Projects

The 2022 internal Call for Research Projects (CFP) cofinanced with the Bourgogne-Franche-Comté region, which was consolidated prior to the COS meeting, ended with a funding of **€3.6 million for 24 projects**. These projects tend to adress societal and environmental challenges (green production and solid storage of H_2, sensors for health and energy, low-energy buildings, biomechanical analysis of perineal tissues, spectroscopy of space/atmospheric molecules), industrial issues (additive manufacturing by arc wire, cascade plasma burners, smart thermal spraying, oil-free lubrication, electrochemical texturing), the emergence of new technologies requiring scientific advanced information and quantum control theory, helical lasers, ultra-dense hybrid photonic integration) and the development of innovative technologies (robotic gripper with controlled adhesion, inelastic diffusion microscopy, mechanical microcharacterization by X-ray tomography, AI for multimodal industrial imaging, high-stability optical micro-clocks, self-reconfigurable structures for vibration control). In 2021, two new Graduate Schools in the environmental and health sciences were created at UBFC. Two inter-GS projects, implying EIPHI and new GS, have also emerged (nanoparticle-based theranostic for glioblastoma treatment, chemical assessment of lipids in wine fermentation). Right after the finalization of the 2022 research CFP, the scientific animation has started so as to set up the 2023 CFP and the latter is already demonstrating a significant increase of inter-GS projects (up to 17 projects are currently assessed).

EIPHI 2022 interdisciplinary days: Realization by the Master students of the Climate Fresco and the training on the "safe and just space for humanity" concept.

Le "Trophée Hydrogénies"

CMI H3E has been awarded the "Hydrogenies trophée" in the category "Awareness, Education and Training Award"

The CMI H3E stands for Master of Engineering in Hydrogen Energy and Energy Efficiency. It is a selective 5-years program in Hydrogen Energy at the University of Franche-Comté (uFC/UFR STGI) teaching from the Bachelor degree to the Master degree courses in energy in general with the main focus on hydrogen energy.

The CMI H3E, based on two major tracks in Electrical and Thermal Energy, offers additional courses in hydrogen and soft skills modules allowing students to have a more global expertise.

Students' enrolment in international internships and their numerous activities in research laboratories or in industry as part of projects, internships and work-study programs confront students with field issues during their training.

The CMI H3E is led by Nadia Yousfi Steiner, full professor at the University of Franche-Comté and researcher at the FEMTO-ST Institute.

"This award is a very good recognition of our commitment within the University of Franche-Comté, to consolidate the link between Research, Training and Innovation in the field of Energy in general and hydrogen more specifically. With our support laboratories, FEMTO-ST and UAR FCLAB, our training is open to the world of research and innovation for a new generation of experts who will be a real support to a fast-growing hydrogen energy sector. Our students are both ambassadors of their training and active actors of communication and awareness among young people and wide public.

"This prestigious award is a great honour for us at the UFC, but also a huge responsibility to keep offering our students the education of excellence that will give them the keys to the sustainable world of tomorrow", says Nadia Yousfi Steiner, Director of CMI H3E.

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EDUCATION

PHOTO CONTEST, organized by FEMTO-ST Student Chapter in May 2022

Supercontinuum light and surface plasmons in a suitcase

G. Fanjoux ; J. Salvi ; J.C. Beugnot ; T. Sylvestre

OPTICS

The supercontinuum light triggers the curiosity and the admiration of the general public thanks to its simple appearance and its visual aesthetic. This paper presents a compact and transportable optical setup illustrating the generation of supercontinuum in an optical fiber followed by the excitation of a surface plasmon on a gold film. Put in the form of an educational suitcase, this assembly is used since 2015 (International Year of Light) as a support during laboratory visits or exhibitions to the general public. Thanks to its multiple facets and its scientific richness, it allows the illustration and explanation in an efficient and exciting way the phenomena of nonlinear optics and the physics of plasmons. It allows the description of non-linear optical phenomena at different levels of society (general public, high school students, postgraduate students). The suitcase was built in the form of complementary modules to make it evolve and allow the addition of other illustrative experiments such as second harmonic generation, absorption spectroscopy or white light interferometry. This educational kit was financed by the Region Bourgogne Franche-Comté and the labex ACTION.

G. Fanjoux et al., Lumière supercontinuum et plasmons de surface dans une valise!. Photoniques, 112, 22-25 (2022). https://doi.org/10.1051/photon/202211222

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WIMS exercise platform at UBFC

M. Lenczner (local coordinator)

TIME & FREQUENCY

WIMS is an online and free learning platform allowing each student to create his own exercises. These exercises all incorporate random data allowing the student to practise on exercises with similar data. They can combine calls to software or APIs that return different types of data: mathematical formulas, numerical results, images, audio, etc. WIMS can be integrated with Moodle. It is supported by an active community of users and developers and has a large database of exercises. The WIMS BFC group has been a winner of three RITM BFC calls for projects. This support has enabled the development of a community of users and developers made up of secondary and higher education teachers, the organization of two regional workshops, the national WIMS 2022 conference at UTBM (supported in particular by EIPHI) and the installation of a WIMS server at UTBM accessible to all. The working group meets every fortnight and will be integrated into the IREM group from 2023.

WWW Interactive Multipurpose Server
Free access @ https://wims.univ-bfc.fr/wims/

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RESEARCH SCHOOLS

Leading to System Development

Series of lectures (18 hours)

March-May 2022, Online

Organizers: STMicroelectronics and FEMTO-ST (S. Margueron)

70 participants

Virtual-FCS

International summer school

June 7-10, 2022, Belfort

Organizers: FEMTO-ST
(D. Chrenko, N. Steiner, E. Pahon)

30 participants (7 countries)

https://virtualfcs-summerschool.utbm.fr/

9th Colloquium WIMS

June 13-15, 2022, Sevenans

Local organizers: F. Bazzaro, A. Cara, A. Dalet, A. Flesch,C. Godey, F. Holweck, T. Jeannin, M. Lenczner, S. Margueron, K. Mauffrey, M. Rougnant, N.-C. Sthal, J. Tessé

80 participants

https://wims-2022.utbm.fr

Algebra, Arthmetics & Applications

A CIMPA Research School

June 13-24, 2022, Bénin

Organizers: FEMTO-ST (C. Maire) & Univ. d'Abomey-Calavi

40 participants

European Frequency and Time Seminar

July 4-8, 2022, Besançon

Organizers: FEMTO-ST (E. Rubiola)

35 participants

http://efts.eu

SEL2022

8th International School of Sound and Light

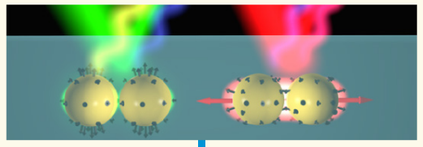
September 12-23, 2022,

Saint-Pierre d'Oléron

Organizers: FEMTO-ST (J.C. Beugnot), Univ. Lyon 1, Univ. Sorbonne Paris Nord

100 participants

http://sel2022.univ-lyon1.fr/en



Port Hamiltonian Systems: modelling, numerics and control

2nd meeting of the French-Dutch-German doctoral college

November 7-9, 2022, Besançon

Organizers: FEMTO-ST (Y. Le Gorrec, Y. Wu)

38 participants

https://events.femto-st.fr/doctoral-college-phs/

Micro/Nano-Technology School

November 28-29, 2022,

Besançon

Organizers: FEMTO-ST (A. Bartasyte, D. Belharet, G. Jutzi, G. Ulliac, L. Robert, L. Arapan, M. Ouhabaz, S. Margueron, S. Queste, S. Bargiel, X. Vacheret)

30 participants

https://2022jnte.sciencesconf.org

RESEARCH

THE SCIENTIFIC AXES OF FEMTO-ST INSTITUTE

Waves, complex matter and media of propagation

microacoustics, phononics and integrated photonics, nonlinear photonics and dynamics of optical pulses, laser beam shaping and fs laser-matter interactions, spatial or temporal manipulation of quantum states, atomic spectroscopy, vibro-acoustics

Microsystems, micromechatronics

microrobotics, miniature microwave and optical atomic clocks, biochips, microfluidic circuits for health applications, integrated sensors, energy transducers, MEMS

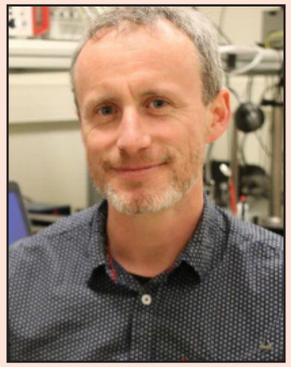
Complex systems and information

fuel cell systems, thermal systems, systems and time-frequency metrology, health management prognosis, programmable matter, security and software testing, neuromorphic optical computing, embedded systems, distributed systems, artificial intelligence

Advanced materials and processes

micro-/nano-fabrication, heterogeneous integration, metamaterials, electroactive materials ($LiNbO_3$), thin film growth, tribology, surfaces, molecular grafting on the surface, 3D-4D structuring, fs laser machining, composites and architectural materials, bio- and eco-materials, precision machining, micromechanics

AWARDS



DANIEL BRUNNER

Researcher

CNRS

OPTICS

His interests include novel computing using quantum or nonlinear substrates with a focus on photonic neural networks. He has received the IOP's 2010 Roys prize, the IOP Journal Of Physics: Photonics emerging leader 2021 prize as well as the CNRS Bronze medal in 2022. He edited one book and two special issues, has presented his results 45+ times upon the invitation, has published 50+ scientific articles and has been awarded a prestigious ERC Consolidator grant.

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CNRS Bronze Medal

The Bronze Medal rewards the initial works of permanent CNRS researchers. This distinction represents encouragement from the CNRS to pursue research that is already well underway and fruitful.

Daniel Brunner, received the CNRS Bronze medal in 2022 for his exploration of a new generation of photonic architectures for information processing. The objective are neuromorphic photonic devices inspired by the human brain, whose architecture enables substantially faster and more efficient artificial intelligence (AI) technology. The principal idea is to create 3D integrated photonic circuits to implement neural networks that communicate via optical rather electronic signals. Such 3D integration, fabricated via 3D printing, enables substantially better scaling behaviour compared to classical 2D chips. This is crucial for enabling the large physical networks for AI computing required in the future.

Léon-Nicolas Brillouin Award

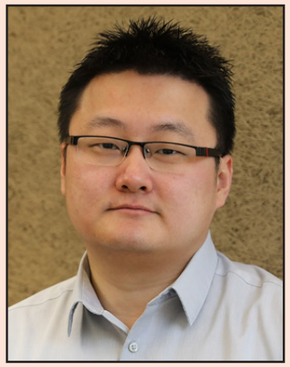
By French "Société de l'Electricité, de l'Electronique et des TIC" (SEE) and IEEE France section.

Sustainable Future Visionary Award

By Typhoon HIL inc. for a remarkable educational and scientific contribution to a better and greener energy landscape, through propagating model-based technologies that scale.

Fei Gao received these awards for his innovative research work on ultrafast real-time models (nanosecond scale on FPGA processors) for power electronics and hydrogen fuel cells, which have been valued by the company for many years in the global digital twin market. Fei and his team developed and successfully demonstrated a novel nonlinear multiphysics real time modelling framework, resulted in 5 times faster computational performance compared to state-of-art commercial products.

FEI GAO



Full Professor

UTBM

ENERGY

Prof. Fei Gao is the Deputy Director of FEMTO-ST institute. He received from UTBM the PhD degree in renewable energy with distinguished Youth Doctor Award in 2010. His main research fields include fuel cell technology and real time digital twins for power systems. He is a Fellow of IET, the Editor-in-Chief of IEEE Industrial Electronics Technology News and the Deputy Editor-in-Chief of IEEE Transactions on Transportation Electrification. He currently serves as the Chair of Strategic Planning Committee of IEEE Transportation Electrification Community, and the Vice-Chair of the Technical Committee on Electrified Transportation Systems of IEEE Power Electronics Society.

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IUF Senior Member (Innovation Chair)

By the Institut Universitaire de France (IUF, Academic Institute of France) is a service of the French Ministry of Higher Education that distinguishes each year a small number of university professors for their research excellence & their international recognition.

IEEE Fellow

IEEE Fellow is a distinction reserved for select IEEE members whose extraordinary accomplishments in any of the IEEE fields of interest are deemed fitting of this prestigious grade elevation.

His main research activities are concerning hydrogen-energy systems dedicated to automotive and stationary applications, modelling, nonlinear control, energy optimization and state-of-health estimation of these systems. He was appointed as Fellow of IEEE in 2021, and appointed as a Senior Member of the IUF in 2022, for his exceptional research work on hydrogen-energy systems that has led to groundbreaking innovation in his technological field.

DANIEL HISSEL

Full Professor

UFC

ENERGY

Since 2012, Prof. Daniel Hissel is the Head of the "Hydrogen-energy systems, electric actuators, control, production, storage and conversion of electricity" in FEMTO-ST (CNRS) Institute. Since 2020, he is the Deputy Director of the French national hydrogen research federation (CNRS), gathering about 300 researchers on hydrogen technologies in France. He has published more than 500 scientific papers in peer-reviewed international journals and/or international conferences. He has been awarded by the Blondel Medal in 2017, by the Innovation Medal of the CNRS in 2020.

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AUSRINE BARTASYTE

Full Professor

UFC

TIME & FREQUENCY

Prof. Ausrine Bartasyte is the scientific Deputy Director of FEMTO-ST institute. Her research is focused on advanced engineering of $LiNb(Ta)O_3$ thin films/single crystals for acoustics, energy harvesting, and optical applications. She presented 23 invited presentations & 10 invited seminars and is a co-author of > 70 scientific articles and 7 patents. She is a coordinator of several French national projects, H2020 ITN- ENHANCE and several industrial projects (TDK-EPCOS, Annealsys, WIKA, IXBlue). At present, she supervises 5 PhD students (10 supervised PhD thesis defended). She was a vice- president and a member of the French ANR and Swedish project selection committees, respectively. She is a member of the advisory board for IUS & conference MCARE, ENRIS, and CIMTEC.

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IUF Junior Member (Innovation Chair)

By the Institut Universitaire de France (IUF, Academic Institute of France) is a service of the French Ministry of Higher Education that distinguishes each year a small number of university professors for their research excellence & their international recognition.

Her research activity concerns thin films and advanced material architectures, lead-free piezoelectric materials, alkaline niobates and electro-active MEMS and nano-/microtechnology. She was appointed as a Junior Member and an Innovation Chair of the IUF in 2022 for bringing the $LiNbO_3$ thin film growth towards the industrialization, for $LiNbO_3$ film integration with the structures of high-frequency SAW and BAW devices for 5G-6G telecommunications, and for the lead-free piezoelectric material solution with a figure of merit similar to that of PZT for vibrational energy harvesting in harsh environments.

AWARDS

AUDE BOLOPION

Researcher
CNRS
AS2M

CNRS researcher since 2011 at the FEMTO-ST Institute. She received a PhD degree in robotics in 2010 from the University of Pierre et Marie Curie, Paris, and the HDR diploma from UBFC in 2020. In 2019, she received the CNRS bronze medal for her work on microrobotics using remotely induced actuation. She collaborates actively with international groups in EPFL (Switzerland), Max Planck Institute (Germany), ULB (Belgium) and CTU (Czech Republic), and national groups including ISIR and EFS.

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https://www.femto-st.fr/fr/personnel-femto/audebolopion

Big-on-Small Award 2022

This Award is intended to recognize the 'Microroboticist of the Year'. It is presented annually at MARSS conference, the International Conference on Manipulation, Automation and Robotics at Small Scales, which is the reference in the domain of micromanipulation and microrobotic. It promotes upcoming talents in these research communities and targets young professionals with excellent performance and international visibility.

At micrometer scale, the classical approach consists in using tips or microgrippers to manipulate objects. However, it necessitates a physical link to power and control the tools. Aude Bolopion's work focuses on an original approach using remotely induced force fields to control microscopic objects from a distance. She with the PhD students, post-docs, engineers, and internship students of her team have developed methodologies for the modelling, design and control of these systems. As an example, she proposed the first microrobotic system for the manipulation of micrometer size components at air/liquid interface based on convection flows induced by thermocapillary effects.

ACerS Honorary Member

JOHN M. DUDLEY
Full Professor
UFC
OPTICS

In recognition of exceptional contributions to optical physics; inspirational leadership and encouragement leading to a United Nations International Year of Light and International Year of Glass; and dedication to international friendship, peace, and cultural understanding.

John Dudley was elected an Honorary Member of the American Ceramic Society (ACerS, including academia and industry from over 70 countries) in 2022, based on John Dudley's many contributions to optical physics and nonlinear optics in glass optical fibre, as well as his work promoting international outreach with United Nations organizations. Specifically, he worked with the ACerS to advise them in approaching the United Nations to proclaim the year 2022 as the International Year of Glass, which has seen events around the world celebrate the many ways that glass and related materials impact science and culture.

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3rd prize for the best business plan at the HEC Challenge+

The HEC Challenge + programme helps creators of innovative projects with high growth potential to draw up their business plan and supports them in their development. Its pedagogical formula combines training, advice, and personalized follow-up. At the end of the 9-month programme, HEC organizes a pitch competition.

RÉMY TRIBHOUT, JULIEN BOURGEOIS
DISC

The Phigi startup project was awarded the 3rd prize for the best business plan for 2022.

Phigi is a startup from the OMNI team of the DISC at FEMTO-ST. It develops an interactive clay that facilitates collaboration between teams around the design of industrial products. This material is composed of thousands of microballs that assemble to form a physical model according to its digital 3D representation on the computer. It is therefore a phygital design tool that adapts to your collaborators' preferences. Whether you modify one of the models by hand or with the mouse, the other will be updated in real time, even if you work remotely.

This transfer is made possible thanks to the success of the research on Programmable Matter conducted under a research contract between FEMTO-ST and the University of Michigan since 2017. This award from HEC validates the commercial potential and the coherence of the project to valorize the research results obtained and in progress.

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phigi.io

Outstanding Editor of "Light: Science & Applications"

HERVÉ MAILLOTTE
CNRS Research Director
OPTICS

Since 2012, Hervé Maillotte is Associate Editor of "Light: Science & Applications", which ranks 3rd among about 100 optics-photonics journals (IF2021=20.26). As a reward for his great and constant contribution to the editorial process (> 130 articles to date), the journal has recognized him, for the sixth time, as "Outstanding Editor" for the year 2021.

Hervé Maillotte is a CNRS research director with recognized expertise in nonlinear photonics. He has co-authored > 270 papers and international conferences, co-directed 21 PhDs, and has been coordinating about 30 academic or industrial research contracts and national or international cooperation programmes (including three H2020 projects). He has been locally committed in several management responsibilities, both academic (current director of the interdisciplinary Graduate School EIPHI) and related to innovation and technology transfer (e.g. vice-president of FC'Innov Foundation). At national and international levels, he has served on various conference committees, scientific networks and carried out numerous expert assessments and evaluation activities, notably chairing a Belgian FNRS evaluation committee in 2016- 2019.

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https://www.nature.com/lsa/editorial-board

AWARDS

CHRISTOPHE GORECKI

Retired Research Director
CNRS
MN2S

Christophe GORECKI, born in Warsaw in 1952, obtained a PhD degree in 1983 at the P.M. Duffieux Optics Laboratory (Besançon). He was CNRS researcher from 1984 and worked on heterodyne interferometry and pattern recognition until 1995. Then, until 1998 he moved to Tokyo where his research turned to micro-optical systems on silicon. Back in Besançon, he became a recognized specialist, coordinator of international projects, holder of the EOS award in 2012, the board member of SPIE in 2013. He retired in 2019 and became scientific director of the ICTER Institute in Warsaw.

cgorecki@orange.fr

SFMC Honorary Diploma

The honorary diploma of the French Society of Microtechniques and Chronometry (SFMC) is awarded to people who have made a significant contribution to progress in the field of Microtechniques or Chronometry.

Christophe Gorecki received the honorary diploma of the SFMC especially for his contribution to the French MOEMS sector. In this field, he worked on micro-optical sensors, and on the French micro-atomic clock from the beginning of 2004 to its transfer to industry in 2013. Since 2012, he worked on ultra-miniature endoscopic imaging microsystems using the principle of OCT, for early cancer detection. He has been a member of the European optical manufacturing networks since the NEMO network in 2004, co-director of the French-Swiss SMYLE partnership and scientific leader of the FEMTO-ST cleanroom. He authored more than 300 publications, cited 3000 times.

SFMC Award 2022

Award for the contributions to microengineering fields especially for the development of mechanical watches industry .

Sébastien Thibaud received this award for his contribution in the field of micromanufacturing processes and microengineering technologies in particular for the development of French watches industry and luxury goods. It contributes to highlighting development in hybrid micromanufacturing processes to develop high value microparts (coupling MEMS Technologies and Micromechanical manufacturing approaches). He contributes to developing knowledge in the field of mechanical micromanufacturing processes (micro-EDM, microforming, microturning, micromilling) from design to prototype (numerical simulations, material characterisation, experimental methods, metrology). His contributions have direct applications to industry and especially in plane industry, luxury goods, micromanufacturing processes.

SÉBASTIEN THIBAUD

Full Professor
SUPMICROTECH -ENSMM
APPLIED MECHANICS

He is a head of the MICRO (Intelligent MICROengineering) team dedicated to develop micro-products (mechanisms, sensors, actuators) by coupling MEMS and micromechanical technologies. He has supervised more than 15 PhD thesis and he is a member of Micronora organization (office member) and the Société Française de Métallurgie et de Matériaux (office member of TOMMI Commission).

www.femto-st.fr/fr/personnel-femto/sebastienthibaud

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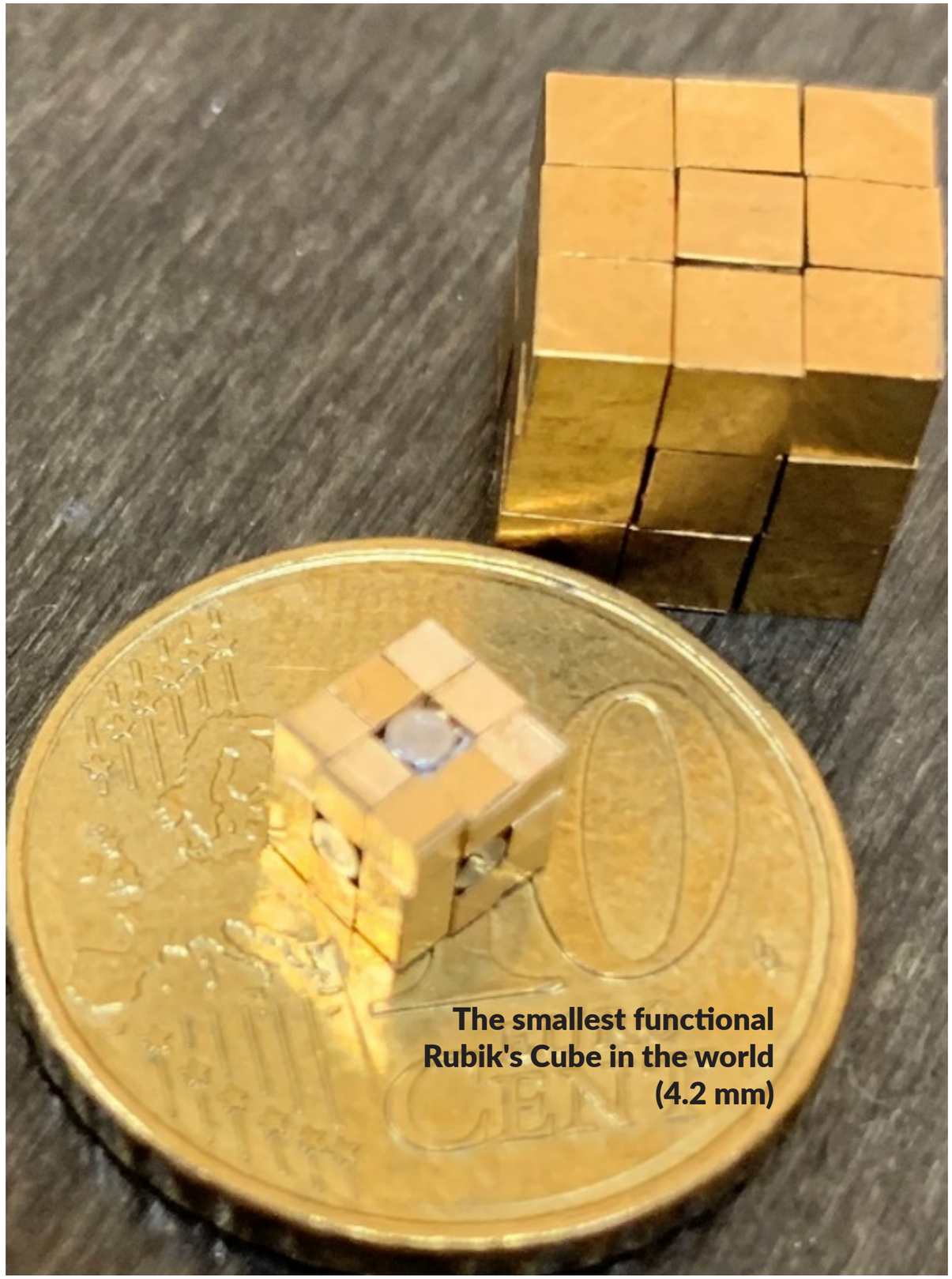

The smallest functional Rubik's Cube in the world (4.2 mm)

STUDENT AWARDS

First Place in the Roger Kelly Award - Rising stars

SLIMS 2022 - 7th Venice International School on Lasers in Materials Science

(Poster Competition for 3rd year PhDs & Postdocs)

VALERIA BELONNI
PhD student

OPTICS

Bessel beams are quasi-nondiffracting beams that find numerous applications in high-aspect ratio laser material processing, optical trapping, and nonlinear photonics. A high-angle Bessel beam allows increasing the local intensity and to reduce the diameter of the nanostructures. She reported a new Bessel beam shaper that reaches a half-cone angle of 42 degrees, i.e. approximately twice higher than the state of the art. The single-shot machining of a sapphire sample with a radially polarized Bessel beam with a high angle of 36 degrees is reported. For some combinations of energy and pulse duration, it is possible to obtain micropillars.

Belloni, Valeria V., et al. "Extremely high angle Bessel beam shaper." Laser Resonators, Microresonators, and Beam Control XXIV. SPIE, 2022.

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Best Student Paper Award

International Frequency Control Symposium-European Frequency Time Forum Joint Meeting 2022 (Paris)

CLÉMENT CARLÉ
PhD student

TIME & FREQUENCY

The PhD thesis of C. Carlé is at the interface between Time-Frequency and MN2S departments and it aims to develop a miniaturized microwave microcell-based atomic clock. These clocks exhibit unrivalled size, weight and power stability budget and find multiple applications. In this domain, C. Carlé has demonstrated the implementation of advanced pulsed interrogation protocols, which permit reducing by two orders of magnitude the sensitivity of the clock frequency to laser power and frequency variations. These approaches might pave the way for the development of next-generation pulsed CSACs with improved long-term frequency stability.

M. Abdel Hafiz et al. Appl. Phys. Lett. 120, 064101 (2022). https://doi.org/10.1063/5.0082156

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Best Paper Award

International Conference on Technologies and Materials for Renewable Energy, Environment & Sustainability

RUSBER OCTAVIO RODRIGUEZ VELASQUEZ
PhD student

ENERGY

A hydrogen-based backup system for modern buildings could supply loads in a multi-day blackout; however, the backup system should be sized appropriately to ensure the survival of essential loads and low cost. In this sense, this work proposes a sizing of fuel cell backup systems for low-voltage buildings using the history of power outages. The proposed sizing is applied to a university building with a photovoltaic generation system as a case study. Results show that the sizing of an FC-battery backup system for the installation is cheaper than a battery-only system under studied outage scenarios. It ensures a 99% probability of supplying essential load during power outages. It evidences the pertinence of an FC backup system to attend to outages of long duration and the integration of batteries to support the abrupt load variations. The proposed sizing is generalizable and scalable for other buildings and allows quantifying the reliability of the backup system tending to the resilience of electrical systems.

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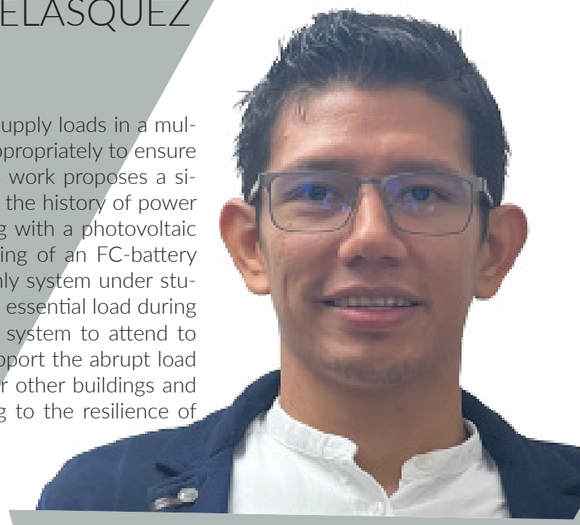


Prix AFM Paul Germain

Association Française de Mécanique (AFM) at the “Congrès Français de Mécanique”

(PhD thesis Award given by AFM every two years)

SVENJA HERMANN
PhD student

APPLIED MECHANICS

The PhD thesis focuses on a magneto-active elastomer (MAE) composite material. Experimental studies concerning the manufacturing of MAEs and the characterization of their mechanical, magnetic and coupled properties are presented. A multi-scale model is developed using a continuum approach at the microstructural scale. The effective properties are determined with classic homogenization techniques on statistically homogeneous composites by numerical simulations. The behaviour law is modelled with a piezomagnetic approach. In two proofs of concept, the MAE composites are applied in membrane actuators and for passive vibration damping. The concepts provide promising results for future applications of MAE in mechatronic devices.

S. Hermann et al. (2020). Smart Materials and Structures, 29(10), 105009 (2020). https://doi.org/10.1016/j.jsv.2022.117000.
S. Hermann, J. Sound and Vibration, 117000 (2022). https://doi.org/10.1016/j.jsv.2022.117000.

svenja.hermann@tu-dortmund.de

NEW MEMBERS

RAFAEL DE OLIVERA TELOLI

AssociateProfessor
SUPMICROTECH-ENSMM

APPLIED MECHANICS

Artificial intelligence algorithms for applications in structural dynamics, identification of data-driven models for nonlinear systems, decision making in the structural health monitoring

rafael.teloli@femto-st.fr

He received BSc (2016) and PhD. (2021) degrees in Mechanical Engineering, at UNESP - Engineering School of Ilha Solteira. During his PhD (FAPESP Direct scholar) he carried out a research internship at the FEMTO-ST Institute (UFC). In 2021, he returned to UFC for a post-doctoral stay. His research concerns the identification, verification and validation of models for engineering structures.

FLORIAN BOUTENEL

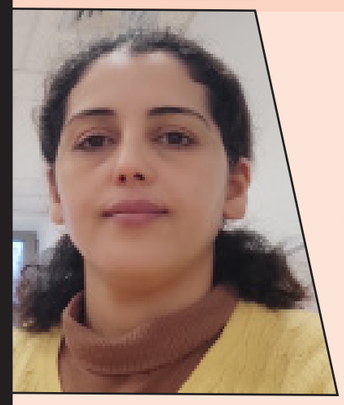
Associate Professor
SUPMICROTECH-ENSMM

APPLIED MECHANICS

Micro-scale modelling of the behaviour of biosourced composite materials, the relationships between the physico-chemical properties and mechanical behaviour

florian.boutenel@femto-st.fr

Florian Boutenel received his PhD degree in 2020 from IMT Mines Albi. His thesis focused on the behaviour of an alumina-silica matrix during the processing of oxide/oxide ceramic matrix composites. He then worked on the development of a ceramic additive manufacturing process for investment casting as a postdoctoral researcher at Institute of Research for Ceramics (IRCER, Limoges).



NOURA DRIDI

Associate Professor
SUPMICROTECH-ENSMM

AS2M

Data sciences, statistical signal processing, probabilistic models, deep learning for physic with combined models and data-based approaches, uncertainty evaluation for neural networks algorithms, with applications for renewable energy.

noura.dridi@ens2m.fr

She received her PhD from Telecom-Sud Paris jointly with the University of Lille 1. In 2012, she joined the laboratory of Material and System Integration, at the University of Bordeaux, as a post-doctoral researcher. She worked as an assistant professor at the National Engineering School of Gabes in Tunisia (2012-2019). In 2019, she joined as a postdoctoral researcher the Lab-STICC laboratory at IMT Atlantique in Brest.

HUGO DAGUERRE

Associate Professor
UFC

AS2M

Microrobotics, remote actuation and perception at the microscale, improvement of the mobility of microrobots and their sensing capabilities for various applications including bioengineering & healthcare

hugo.daguerre@femto-st.fr

Hugo Daguerre is an engineering graduate from INSA Lyon. He did his PhD thesis at FEMTO-ST Institute, UBFC (2018-2021) and was involved in multiple international projects with researchers from EPFL (Switzerland) and Max Planck Institute (Germany). He was a postdoctoral researcher at the Surgical Robotics Laboratory of the University of Twente (Netherlands).

JONATHAN GILLOT

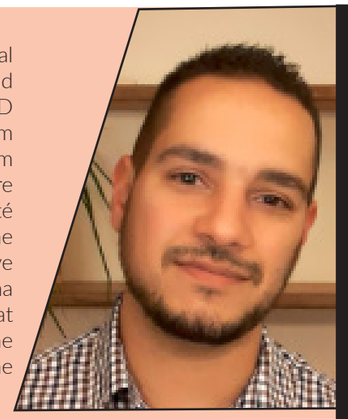
Junior Professor Chair
SUPMICROTECH-ENSMM

TIME & FREQUENCY

Ultra-stable laser stabilized on a silicon cryogenic cavity, local high-performance frequency reference

jonathan.gillot@femto-st.fr

He has a background in experimental physics for metrology and fundamental physics. He did his PhD on the measurement of two quantum geometrical phase shifts by atom interferometry at the Laboratoire Collisions, Agrégats, Réactivité (Toulouse). He did a postdoc at the Institut d'Optique on the Matter-wave Interferometric Gravitation Antenna (MIGA) project and second one at SYRTE-Observatoire de Paris on the development of a molecular-iodine stabilized laser.



ZHONGLIANG LI

Junior Professor Chair
UFC

ENERGY

Degradation mitigation control of PEM water electrolyser, ageing models, diagnosis, prognosis, and health-aware control tools

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Zhongliang Li received BSc and Master degrees in electrical engineering from Tsinghua University, Beijing, China. He received PhD degree in automation from Aix-Marseille University in 2014. He was a postdoc with labs FEMTO-ST/FCLAB (2014-2016) and an associate professor at Aix-Marseille University with Laboratory of Information and Systems (2016-2022). He is leading an ANR young researcher (JCJC) project dealing with fuel cell durability improvement.

DJAFFAR BELHARET

Research Engineer
CNRS

CLEAN ROOM

Responsible for the plasma etching area at clean room, development & coordination of etching processes of different materials for M(O) EMS, PiezoMEMS applications

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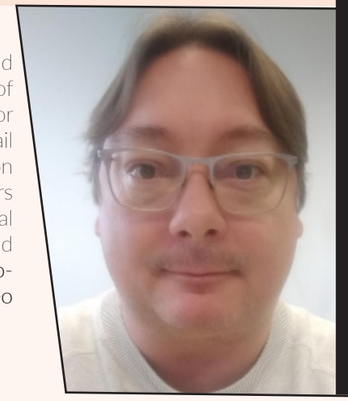
In 2009, he obtained a PhD degree in microelectronics (thesis topic: advanced process control of the STI module of 135 nm and 90 nm MOS technologies) at Ecole des Mines de Saint-Etiene in collaboration with ST-Microelectronics. He joined CNRS-LAAS as a research engineer in plasma etching projects for photonic applications, MOS, MEMS, tec. (2008-2012). He joined the FEMTO-ST institute in 2013.



KEVIN VAN KEULEN

Assistant Engineer
UFC

IT SERVICE, DISC

Systems and network administrator

kevin.vankeulen@femto-st.fr

Prevention assistant in health and safety at DISC; management of fixed and portable workstations for students and staff; FEMTO-ST mail server administration; administration of education server and clusters of LINUX and Windows virtual machines; support for students and teachers; management of audio-visual equipment: touch panels, video projectors, touch tablets.

RESEARCH HIGHLIGHTS

The Fastest Pick-and-Place Robot in the World

M. Leveziel, W. Haouas, G.J. Laurent, M. Gauthier and R. Dahmouche

AS2M

SA research team has developed a miniature robot capable of manipulating micrometric objects at unprecedented speeds. This work has been published in the prestigious American journal "Science Robotics".

Speed and precision are two major issues in robotics and in Industry of the Future (also known as Industry 4.0). Within this framework, RoMoCo research team of AS2M department at FEMTO-ST Institute has developed a unique robot.

MiGriBot is a miniature robot able to perform pick-and-place operations of submillimetre objects at unprecedented speeds. These performances are made possible thanks to its original and unique architecture that allows it to grip and manipulate micro-objects barely visible to the naked eye (from 40 micrometres to several hundred micrometres). In fact, where other microrobots have a rigid end effector, MiGriBot is based on a new principle with an articulated end. This articulated end allows driving a microgripper without any wire or embedded actuator!

The second advantage of this robot is that all its degrees of mobility, including the ones from the microgripper on the articulated end, are operated from the base of the robot, making its mobile parts very lightweight. Finally, its robotic structure occupies a surface of only 20 x 20 mm^2. This level of compactness is achieved by using silicon for the rigid elements, a polymer (polydimethylsiloxane - PDMS) as flexible joints and piezoelectric actuators equipped with position sensors. MiGriBot is therefore lighter, more compact and faster than existing robotic micro-manipulators.

M. Leveziel et al., Science Robotics, 7(69), 2022. DOI: 10.1126/scirobotics.abn4292

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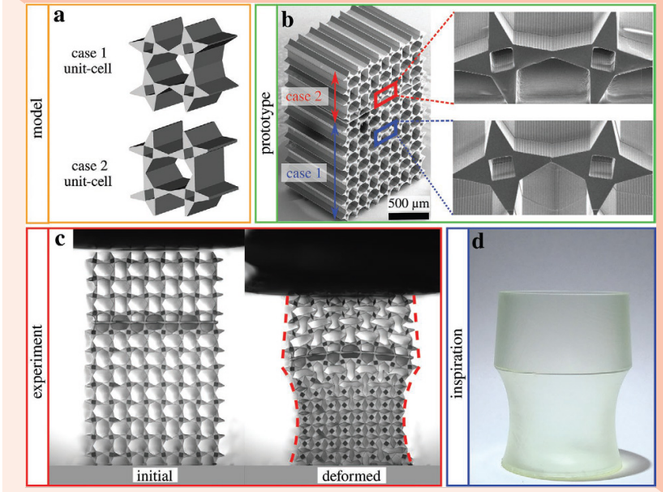
Micro-Scale Auxetic Hierarchical Mechanical Metamaterials for Shape Morphing

K.K. Dudek, J.A. Iglesias Martínez, G. Ulliac, and M. Kadic

MN2S



Shape morphing of the considered hierarchical mechanical metamaterials aimed toward the possibility of replicating the shape of the reference object.

Shape morphing and the possibility of having control over mechanical properties via designed deformations have attracted a lot of attention in the materials community and led to a variety of applications with an emphasis on the space industry. However, current materials normally do not allow to have full control over the deformation pattern and often fail to replicate such behaviour at low scales which is essential in flexible electronics. Thus, in this paper, novel 2D and 3D microscopic hierarchical mechanical metamaterials using mutually competing substructures within the system that are capable of exhibiting a broad range of the highly unusual auxetic behaviour are proposed. Using experiments (3D microprinted polymers) supported by computer simulations, it is shown that such ability can be controlled through geometric design parameters. Finally, it is demonstrated that the considered structure can form a composite capable of shape morphing allowing it to deform to a predefined shape.

K. K. Dudek et al., Adv.Mater. 34, 2110115 (2022). DOI: 10.1002/adma.202110115

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High accuracy positioning for microrobotics

A. André, J. Govilas, H. Bettahar, G. Laurent, H. Saadana, P. Sandoz, V. Gauthier, A. Lefevre, A.|Bolopion, J. Agnus, V. Placet, N. Courjal, C. Clevy, P. Lutz

AS2M, APPLIED MECHANICS, OPTICS

The AS2M department, in close collaboration with DMA and optics departments, has proposed several approaches to guarantee high accuracy positioning of microrobotics systems. Reaching high accuracy on several degrees of freedom remains an open challenge at small scale, due to the inaccuracies of the commercial actuators, and to the limited visual feedback. It is, however, of utmost importance to propose assembly stations to fabricate complex micromachines, and to characterize microobjects. After proper calibration of the intrinsic and extrinsic parameters based on 1-D Fabry-Perot interferometric measurements, high accuracy in 6 DoF positioning has been demonstrated. A positioning accuracy estimate of 50 nm and 0.004◦ has notably been obtained for the full pose of the robot (position and orientation respectively) and can be held during several hours after the measurements. Alternatively, High-Precision (HP) fiducial markers have enabled a demonstration of ultra-high resolution i.e. 2 nm and 5 µrad along X; Y -axes and theta angle, respectively. These HP codes are used to automatically assemble two micro-fluidic chips through visual servoing with a completed positioning accuracy below 50 nm. They are also integrated into a compliant structure enabling simultaneous micro-force and displacement sensing capabilities, which is applied to the micromechanical characterization of single fibres.

A. André et al. IEEE Trans. Autom. Sci. and Eng. 1, 1 - 14 (2022)
H. Bettahar et al. IEEE Trans. Autom. Sci. and Eng. 1, 348-359 (2020)

https://www.femto-st.fr/en/Research-departments/AS2M/Research-groups/ROBIMSS

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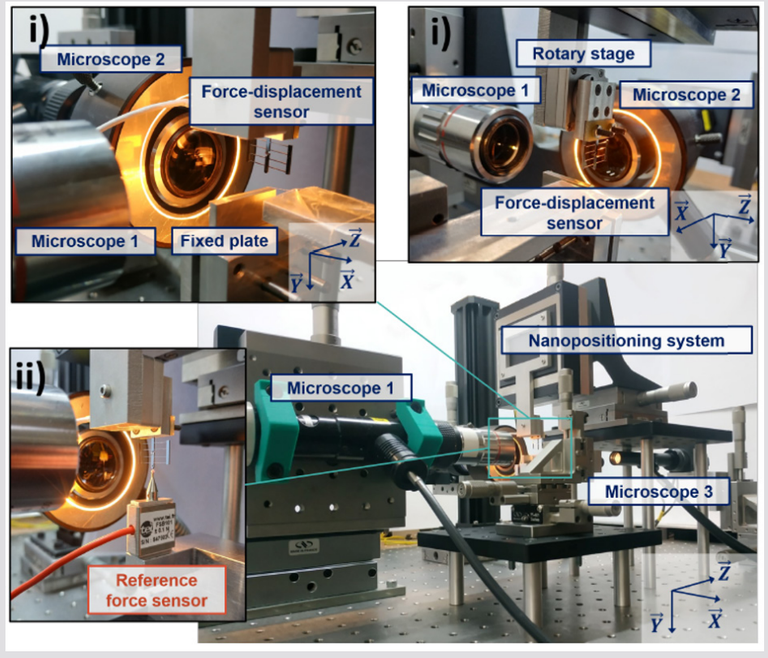

Set up dedicated to the characterization of natural fibres. High positioning accuracy is obtained by using High-Precision fiducial markers.

RESEARCH HIGHLIGHTS

Advances in characterization and modelling of ultrafast instabilities

M. Mabed, F. Meng, J. M. Dudley

The study of instabilities in optical fibre systems is of importance both to understand the fundamental properties of nonlinear systems, as well as to develop optimized laser sources. Work in 2022 has developed on both numerical and experimental fronts. From a numerical perspective, we have applied machine learning to study the noise-like pulse fibre laser, a highly unstable system producing hundreds of chaotic femtosecond solitons underneath a picosecond envelope. We have shown how it is possible to train a neural network to accurately correlate spectral intensity with time-domain peaks, and to reproduce the associated long-tailed probability distributions. These results are significant in extending machine learning to the understanding of spectro-temporal correlations in highly unstable lasers. A key experimental technique used to study such instabilities has been pioneered at FEMTO-ST since 2012, based on capturing shot-to-shot fluctuations in spectra emitted from lasers, or developing from nonlinear propagation in fibre. This technique has led to major results including the observation of rogue wave structures in fibre, and novel dynamics in dissipative soliton lasers. With researchers from France, Germany, the United Kingdom, Australia, Canada, and Finland, we prepared a significant review article on this subject, summarizing landmark results obtained in many different systems.

M. Mabed et al., Optics Express 30, 15060-15072 (2022)

T. Godin et al,, Advances in Physics: X, 7, 2067487 (2022)

https://www.femto-st.fr/en/Research-departments/OPTICS/Research-groups/Optoelectronics

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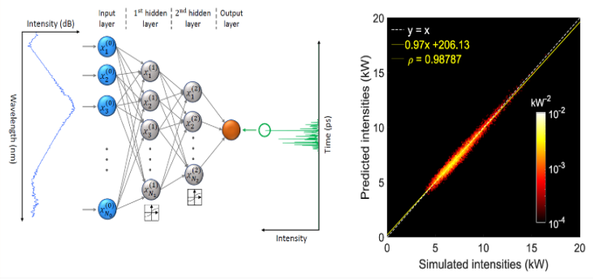

Applying a neural network to correlate laser spectra with temporal intensity peaks. The figure shows a network schematic and the excellent regression results after training.

"Opto-magnets": light-induced magnetization of non-magnetic plasmonic nanostructures

V. Karakhanyan, C. Eustache, Y. Lefier, T. Grosjean

Light is known to possess polarization and spatial degrees of freedom, manifested by its linear momentum as well as spin and orbital angular momenta (SAM and OAM, respectively). Remarkably, the SAM of light can be transferred to electrons in matter, a phenomenon which refers to as the inverse Faraday effect (IFE).

By exploring resonant IFE in plasmonic nanostructures, a research team of FEMTO-ST Institute has introduced the concept of an "optomagnet", i.e., a non-magnetic nanoantenna capable of generating a stationary magnetic field from an impinging light. Upon illumination with femtosecond light pulses, resonant plasmonic nanoantennas [1] and nano-apertures [2] have been shown to produce highly confined stationary magnetic fields on the order of one Tesla (see figure). The resulting magnetization is controllable by the helicity of light. In addition, the researchers have predicted the existence of an IFE driven by the OAM of light [3]. The OAM of light thus provides an additional degree of freedom in the control of the IFE, which has been so far solely attributed to the optical SAM.

These results open the prospect of an ultrafast optoinduced magnetism which overcomes current temporal limitation of ferromagnets, with direct applications in a vast domain including all-optical magnetization switching and spin-wave excitation.

[1] V. Karakhanyan et al., Opt. Lett., 46, 613 (2021)

[2] V. Karakhanyan et al., OSA Continuum, 4 (2021)

[3] V. Karakhanyan et al., Phys. Rev. B 105, 045406 (2022)

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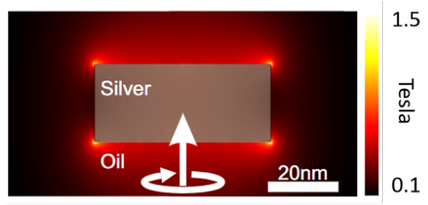

Optomagnetic field generated by a silver nanocylinder upon illumination with a circularly polarized Gaussian beam of maximum intensity of 5 1011 W.cm-2 (Excitation wavelength: 800 nm).

Modelling of the interaction between ultrafast laser pulses and nano-plasma

K. Ardaneh, B. Morel, P.-J. Charpin, R. Giust, F. Courvoisier

Ultrafast laser pulses are ideal tools to structure transparent materials a high speed and sub-micron scales. This is because the high intensity reached during the pulse allows ionization and the formation of a plasma of electron and holes. A crucial aspect is that the dynamics of the laser pulse propagation and the one of the ionization are highly interdependent. We discovered strong discrepancies between predictions by state-of-the-art models and experimental results in the generation of nano-plasma with high density. Unfortunately, this is precisely the interesting regime where the formation of plasma leads to ablation.

FEMTO-ST has developed during the past years, within the framework of the ERC PULSAR project, a complete set of complementary physical and numerical models to simulate the laser-plasma interaction within dielectrics. The models capture the transport of electrons and holes and the formation of plasma waves. This has also involved in the development of electromagnetic field injectors and stable algorithms. This work has enabled the understanding of the exceptional results obtained using Bessel-beam shaped femtosecond pulses and identification of new physical mechanisms.

B. Morel et al., Physical Review B, 106, 035207 (2022). https://link.aps.org/doi/10.1103/PhysRevB.106.035207

K. Ardaneh et al., Physics of Plasmas 29, 072716 (2022) https://doi.org/10.1063/5.0090270 & 072715 (2022) https://doi.org/10.1063/5.0086708

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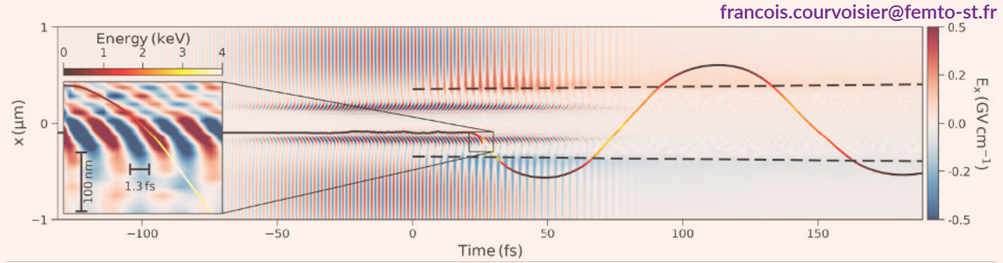

Electron acceleration within the resonance field created by the interaction of the laser pulse onto an over-critical density plasma.

Brillouin light amplification in silica nanofibre gas cell

J.-C. Beugnot, A. Godet, J. Chrétien

Brillouin scattering in optical waveguides draws attention since it has been widely exploited for various important applications, such as microwave photonics, highly coherent fibre laser, and distributed fibre sensors.

EPFL scientists, in collaboration with FEMTO-ST Institute, have achieved a huge amplification of light over a few centimetres with tapered silica optical fibre surrounding by gas. The much stronger Brillouin gain in the evanescent field as well as more tunability such as changing the gas pressure and the gas type, makes the integrated Brillouin amplifier very distinct compared to its solid material counterpart. We demonstrate a 79-times higher Brillouin gain coefficient in the nanofibre gas cell with 57 Bar of CO_2 compared to that of a standard telecommunications fibre.

With the evanescent property, this platform can be used for sensing and spectroscopy of the outside medium directly. Instead of measuring the change of Brillouin spectrum in the solid material due to the temperature change or acoustic impedance change, the measurement of the type of gas and gas pressure can be obtained by measuring the Brillouin spectrum of the outside medium. Therefore, this work can be used to develop a bridge between Brillouin scattering in waveguides, Brillouin spectroscopy and microscopy.

Fan Yang et al., Nat. Comm. 13, 1432 (2022). https://doi.org/10.1038/s41467-022-29051-8

https://www.femto-st.fr/en/Research-departments/OPTICS/Research-groups/Non-Linear-Optics

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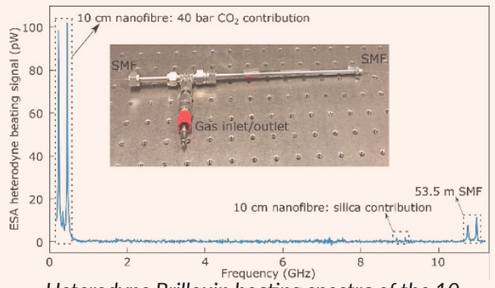

Heterodyne Brillouin beating spectra of the 10 cm nanofibre gas cell with 57 Bar of CO_2 and the appended 53.5 m SMF

RESEARCH HIGHLIGHTS

Nonlinear modulational dynamics of spectrally stable Lugiato–Lefever periodic waves

M. Haragus

OPTICS

This is the latest publication from a series of articles devoted to the mathematical analysis of the Lugiato-Lefever equation (LLE). Originally derived by Lugiato and Lefever in 1987, this nonlinear partial differential equation is used, for instance, as a model for optical Kerr frequency combs in whispering gallery modes resonators. The topic was initiated at FEMTO-ST from a physics and nonlinear dynamical systems viewpoint by Yanne Chembo in 2012 (ERC Starting Grant, NextPhase). This work also triggered a rich cross-disciplinary research with mathematicians, in an unexplored way. While extensively studied in Physics, there are relatively few mathematical studies of this model, most of them being very recent. Mathematically, frequency combs are stationary periodic solutions of the LLE. Previous works showed the existence of such solutions and studied their modulational linear dynamics. The aim of this article is to investigate their modulational nonlinear dynamics. Being a particularly challenging mathematical problem, it has recently received much attention. Despite efforts, there are no answers so far for many nonlinear equations, including the popular nonlinear Schrödinger equation. This article proposes a new methodology representing a step forward in the understanding of this mathematical question and of LLE dynamics.

M. Haragus et al.,. Ann. Inst. H. Poincaré C, Anal. Non Linéaire (2022), DOI 10.4171/AIHPC/65

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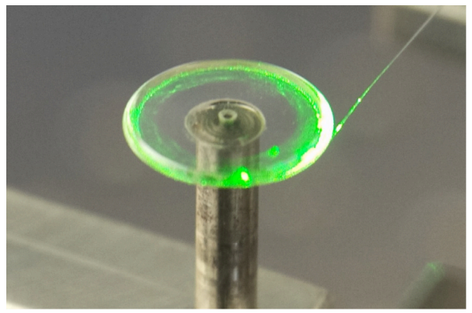

A home-made whispering gallery modes resonator at FEMTO-ST (Y. Chembo, R. Henriet, A. Coillet)

Digital control of residual amplitude modulation at the 10^{-7} level for ultra-stable lasers

J. Gillot, S. Falzon Tetsing-Talla, S. Denis, G. Goavec-Merou, J. Millo, C. Lacroûte, Y. Kersalé

TIME & FREQUENCY

Stabilization of lasers is of crucial importance in time-frequency metrology for the development of optical atomic clocks. To date, lasers with best frequency stability consist on stabilizing the frequency of a laser frequency onto an ultra-stable Fabry-Perot optical cavity through the Pound-Drever-Hall (PDH) technique [1].

The improvement of such lasers faces several technical challenges such as mechanical vibrations of the cavity, laser power fluctuations, or thermal noise. In this domain, residual amplitude modulation (RAM), arising from light polarization mismatch with the extraordinary axis of the electro-optic modulator (EOM) crystal used in the locking setup, etalon effects along the optical path, or spatial inhomogeneity of the laser beam, are responsible for an uncontrolled offset on the servo error signal that deteriorates the laser frequency stability.

We implemented a digitally controlled triple servo loop, implying laser power and EOM crystal temperature stabilization, and active RAM compensation through the EOM DC port. With a cavity of finesse of 2.5 × 10^5, a RAM level of 10^{-7}, one order of magnitude better state-of-the-art results [2], was achieved [3]. This RAM level contributes to the laser fractional frequency instability at the level of 5 × 10^{-19}, well below the thermal noise limit of a few 10^{-17}.

[1] R. W. P. Drever et al., Appl. Phys. B 31, 97–105 (1983).

[2] W. Zhang et al., Opt. Lett. 39(7), 1980–1983 (2014). www.doi.org/10.1364/OL.39.001980

[3] J. Gillot et al., Opt. Exp. 30, 20, 35179 (2022). https://doi.org/10.1364/OE.465597

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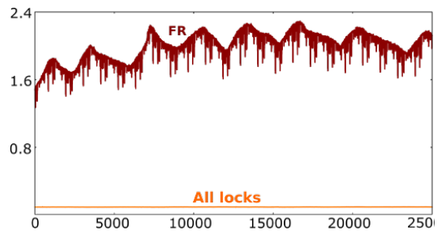

Mitigation of the residual amplitude modulation (RAM) demonstrated in [3], in comparison with the free-running (FR) case. The x-axis is time in seconds.

High Performance Space Lubrication of MoS_2 with Tantalum

G. Colas

APPLIED MECHANICS

Molybdenum disulphide coatings have been employed as lubricants for spacecraft since the 1950s but continue to face major engineering challenges including performance in both terrestrial air and deep space vacuum environments and service lifetimes on the order of decades without maintenance. Co-deposition of MoS_2 with additive compounds provides enhancements in some circumstances but a lubricant which can perform in all space-facing environments with long lifetimes remains an ongoing problem. Herein, it is demonstrated the multi-environment adaptable performance of a novel MoS_2 + tantalum lubricant coating, which excels as a lubricant in both terrestrial and space environments while the benchmark space-qualified commercial MoS_2 lubricants do not. It is noted that the 10% tantalum additive exhibits preferential oxidation in air to preserve the lubricating ability of MoS_2 while forming phases of TaS_2, which aid in the exceptional lubrication of MoS_2 in ultra-high vacuum. Additionally, completely different tribofilms of small particles and compact sheets are noted for air and vacuum environments, respectively, which allows for adaptable lubricating mechanisms from a single coating depending on the environment. This novel coating sets the benchmark as the first demonstrated instance of a fully versatile space lubricant which offers high-performance in both terrestrial and deep space environments.

P Serles et al., Advanced Functional Materials (2022). https://doi.org/10.1002/adfm.202110429

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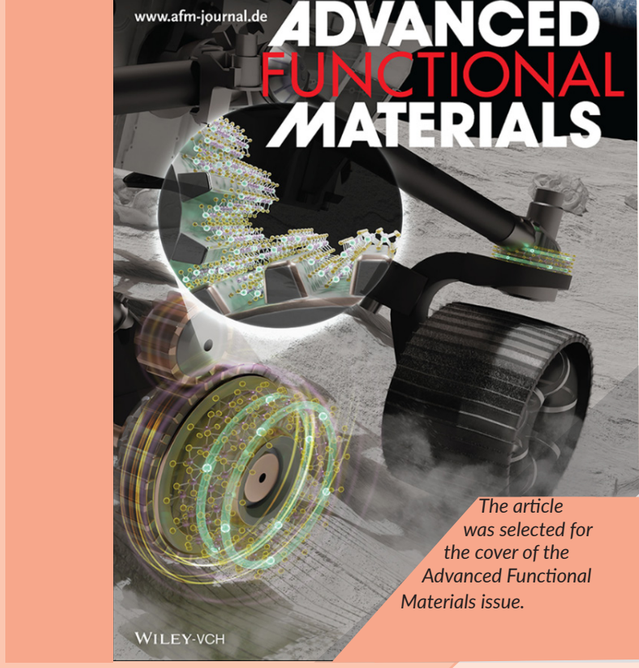

The article was selected for the cover of the Advanced Functional Materials issue.

Wafer-level vapour cells filled with laser-actuated hermetic seals for integrated atomic devices

C. Carlé, S. Keshavarzi, S. Queste, L. Gauthier-Manuel, J.-M. Cote, R. Vicarini, M. Abdel Hafiz, R. Boudot, and N. Passilly

MN2S, TIME & FREQUENCY

Miniature atomic devices such as atomic clocks and optically pumped magnetometers rely on the interrogation of atoms contained in a millimetric cell whose inner content has to meet high standards of purity and accuracy. Whereas glassblowing techniques have been optimized for decades to achieve such standards in macroscopic vapour cells, many shortcomings remain for millimetre-scale vapour cells built by microfabrication techniques. The new approach, inspired by the century-old approach of glass-blowing, aims to structure, fill and seal microfabricated vapour cells, through opening and closing single-use zero-leak microfabricated valves. These valves are actuated exclusively by laser, and operate in the same way as the “make-seals” and “break-seals” found in the filling apparatus of traditional cells. The make-seal structure consists of a glass membrane that can be locally heated and deflected to seal a microchannel. The break-seal is obtained by breaching a silicon wall between cavities, where one can be employed as a gas reservoir. This new approach is a reliable solution for filling miniature cells collectively with alkali vapour and well-controlled gas mixtures, at the wafer-level. It can also be adapted to the development of other atomic sensors and instruments made by microfabrication.

V. Maurice, et al. Nature Microsystems & Nanoengineering 8, 129 (2022). https://doi.org/10.1038/s41378-022-00468-x

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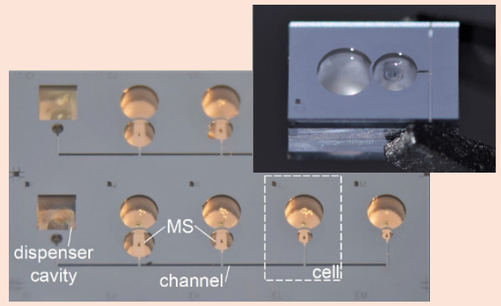

“Make-seal” wafer with 4-cell clusters, all connected to an alkali dispenser cavity (left). Individual cell released by saw-dicing, the glass membrane has been locally heated by laser to deflect it towards the channel mouth and seal it (right).

RESEARCH HIGHLIGHTS

Multiphysical and multidimensional modelling of Parallel-Plate active magnetic regenerator

A. Ismail, M. Perrin, S. Giurgea, Y. Bailly, J.C. Roy, T. Barriere

ENERGY, APPLIED MECHANICS

Active Magnetic Refrigeration (AMR) is a complex multiphysical process that requires optimization. A revised description of the analytical formulations is proposed, starting from the essentials of the magnetocaloric effect. Each physical aspect has been extensively investigated, including the actual magnetic field inside the ferromagnetic domain. An AMR test bench was modelled using a 3D magnetostatic finite-element model, thermofluidic finite-volume models (2D and 3D), and a 1.5D semi-analytical model. Different boundary conditions were simulated to understand the operation of the AMR system. Based on the temperature histories, an agreement was found between the models and the experimental results. In addition to its flexibility and simplicity, the 1.5D model had the lowest computation time of approximately 1.2 s cycle-1. This makes it an excellent tool for the optimal design of an active magnetocaloric device.

A.Ismail et al., Applied Energy 314, 118963 (2022). DOI: 10.1016/j.apenergy.2022.118963

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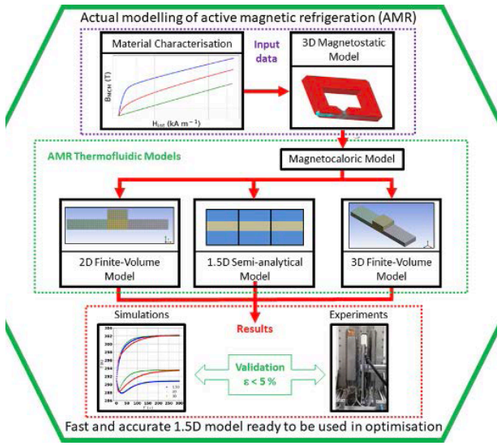

Multiple-Fuel Cell Module Architecture Investigation: A Key to High Efficiency in Heavy-Duty Electric Transportation

H. Wang, A. Gaillard, Z. Li, R. Roche, D. Hissel

ENERGY

This article is on the subject of the multiple-fuel cell (MFC) power module system in heavy-duty (HD) electric transportation. The MFC system is promising for increasing the system power level, redundancy, and lifetime and to reduce costs. In particular, the number of FC modules can affect fluidic system and electrical architectures significantly. Furthermore, system complexity and performance can also be influenced. Different MFC system electric architectures can lead to system global efficiency varying a lot, which is closely related to fuel economy. Meanwhile, an optimization strategy can also be used to help assign power demand among FC modules more efficiently, then help reduce power loss and hydrogen consumption. Hence, this article aims to make an investigation of MFC system architecture development in HD electric transportation and find the most suitable architecture from the view of efficiency and fuel economy based on quantitative analysis.

H. Wang et al., IEEE Vehicular Technology Magazine 17 (3), 2022. DOI: 10.1109/MVT.2022.3179801 13.6

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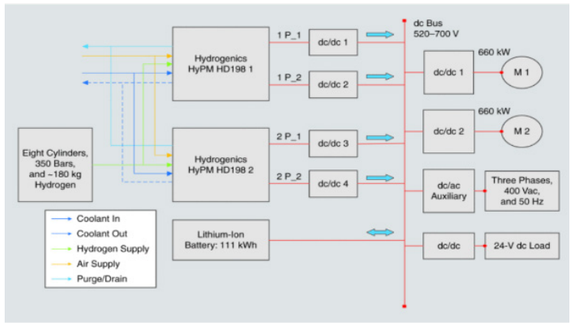
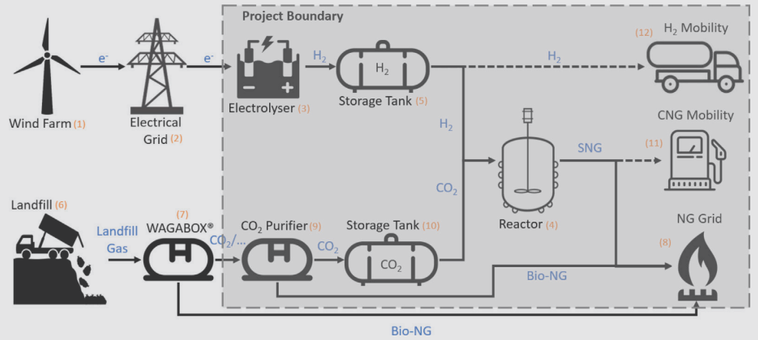


Techno-economical modelling of a power-to-gas system for plant configuration evaluation in a local context

C. Duncan, R. Roche, S. Jemei, M.C. Pera

ENERGY

Decarbonisation of the European energy networks is critical to meet Commission targets in the coming decades. The presented study aims to contribute to this by analysing one of the proposed solutions: power-to-gas. A techno-economic model is created for the purposes of evaluating specific projects on their feasibility in terms of local constraints and opportunities, using a current project as a template for model generation and analysing different possible configurations in 8 operational scenarios. Five metrics were used for scenario analysis: levelized cost of methane, minimum selling price, operational hours, hydrogen tank size and capital cost. The results from the analysis indicate that, in terms of the stated project, synthetic natural gas production and grid injection along with on-site mobility applications provide the best economical result. However, selling prices of obtained synthetic natural gas are one magnitude higher than current natural gas prices, indicating that government support is required for further development. Future projections of electrolyser efficiency and equipment capital costs will greatly reduce production costs, giving promise for feasible business cases in the coming years.



C. Duncan et al., Applied Energy 315, 118930 (2022). DOI: 10.1016/j.apenergy.2022.118963

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Plant schematic and process flow

Ensuring the Compatibility of Autonomous Electric Vehicles Components Through a Formal Approach Based on Interaction Protocols

S. Chouali and A. Mostefaoui

DISC

In the context of automotive applications, complex tasks such as automatic driving of electric vehicles are handled through the composition of several components, each offering a different service. Such component composition is not straightforward and is often subject to bugs that might stem mainly from the incompatibility of services. In other words, in this context, which includes critical services and in which people's life is at stake, detecting and eliminating bugs early in the design stage is crucial and even mandatory. To remedy this issue, we propose in this paper a formal approach for modelling and verifying the reliability of electric self-driving vehicles that are continuously communicating with off-road infrastructure. First, for the modelling phase, SysML language is used to model the system architecture and to specify the connections between its embedded components. Second, we present a formal verification approach based on the extended interface automaton formalism to verify the compatibility between the interacting components. Results in this paper show, on one hand, that SysML and extended interface automaton formalism are relevant to model and capture component features in the context of automotive systems, on the other hand, that our methodology allows developing autonomous electric vehicle systems correct-by-design, regarding component compatibility.

S. Chouali et al., IEEE Transactions on Vehicular Technology, 2022 doi: 10.1109/TVT.2022.3209339

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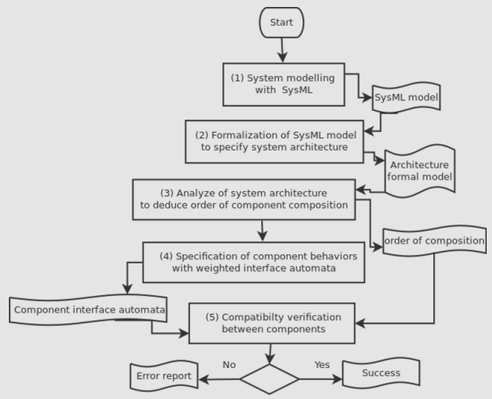

RESEARCH HIGHLIGHTS

A Single Pass and One Round Message Authentication-Encryption for Limited IoT Devices

H. Noura and R. Couturier

DISC

In this work, we propose three efficient variants of a Message Authentication Encryption (MAE) algorithm, which is based on the dynamic key-dependent concept and dynamic operation mode to reach a high level of security. These variants consist of a single pass and a single round, in addition to using common operations for the encryption and authentication processes to reduce the required execution time and resources. Accordingly, the proposed scheme outperforms the existing solutions that are based on the static approach with multiple rounds. Furthermore, to reduce the overhead associated with the regeneration of the dynamic key and the corresponding cryptographic primitives, we propose a simple, yet effective update process. In addition, different cryptographic primitives are used for each input message, which guards against the existing cryptanalysis techniques. The experimental results show that the proposed MAE variants are more efficient than the Counter with Cipher block Chaining Message authentication code (CCM), Galois Message Authentication Code (GMAC), Offset Codebook Mode (OCB), and the Chacha20-poly1305. The best performance is achieved with the third MAE variant that presents a high throughput with an enhancement of at least 373% compared to CCM, 90% compared to GCM, 23% compared to OCB, and 22% compared to Chacha20-poly1305.

H. Nouraet al., IEEE Internet of Things Journal (2022). https://ieeexplore.ieee.org/document/9739669

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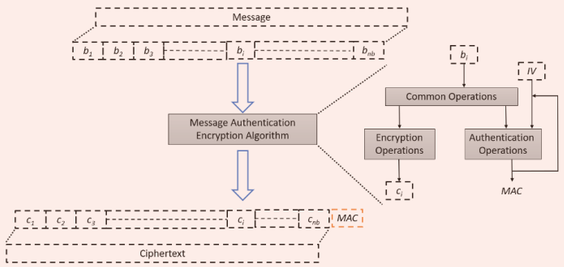
raphael.couturier@univ-fcomte.fr



The proposed general scheme of Dynamic Key dependent Message Authentication Encryption variants.

Multi-qubit doilies: Enumeration for all ranks and classification for ranks four and five

A.Muller, A. Giorgetti

DISC

The doily is the unique triangle-free self-dual finite geometry composed of 15 points and 15 lines, with three points on a line and, dually, three lines through a point. This work is about doilies labelled with N-qubit observables, to be called N-qubit doilies or multi-qubit doilies, that are related to Kochen-Specker operator-based proofs of quantum contextuality. We first bring forth several formulae giving the number of both linear and quadratic doilies for any N > 2. Then we present an effective algorithm for the generation of all N-qubit doilies. Using this algorithm for N=4 and N=5, we provide a classification of N-qubit doilies in terms of types of observables they feature and number of negative lines they are endowed with. We also list several distinguished findings about N-qubit doilies that are absent in the three-qubit case, point out a couple of specific features exhibited by linear doilies and outline some prospective extensions of our approach.

A. Muller et al.,. J. Computational Sci. 64, 101853 (2022). https://doi.org/10.1016/j.jocs.2022.101853

https://quantcert.github.io/doilies/

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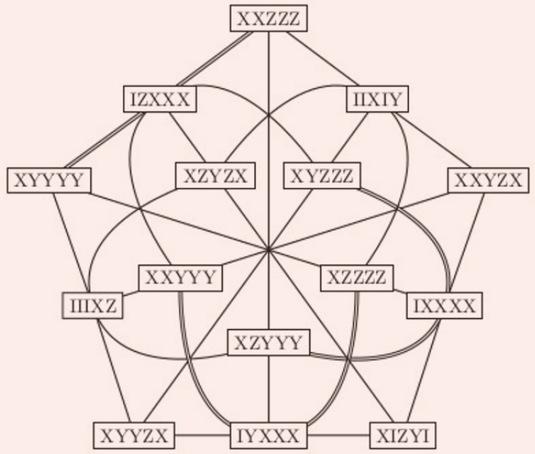
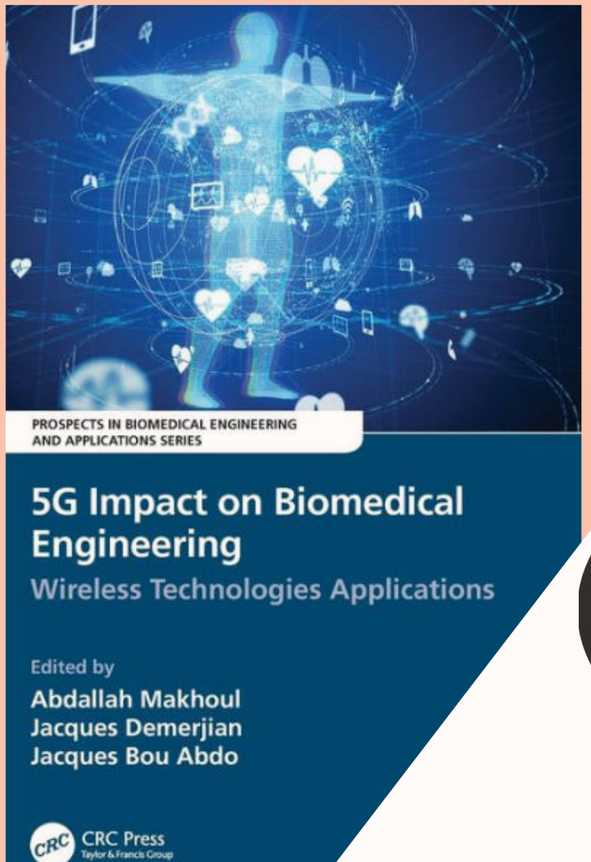


Example of 5-qubit doily



DISC

Taylor&Francis group
https://doi.org/10.1201/9781003058434

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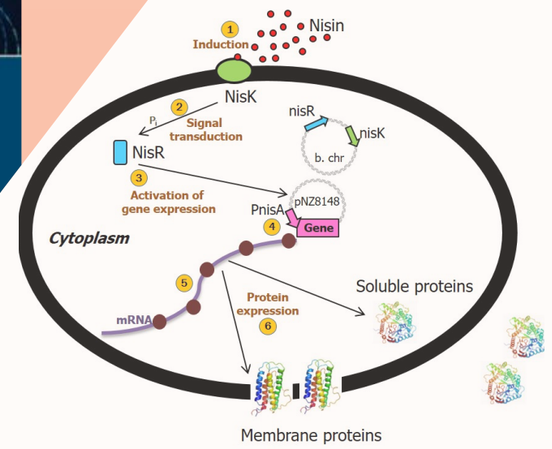

The NICE (Nisin controlled gene expression) system for soluble (cytoplasmic and excreted) and membrane protein expression in Lactococcus lactis

Lactococcus lactis, an Attractive Cell Factory for the Expression of Functional Membrane Proteins

A. Frelet-Barrand

MN2S

Membrane proteins play crucial roles in most key cellular processes, ranging from cell-to-cell communication to signalling processes. Despite recent improvements, the expression of functionally folded membrane proteins in sufficient amounts for functional and structural characterization remains a challenge. Indeed, it is difficult to predict whether a protein can be overproduced in a functional state in some expression system(s). Prokaryotic expression systems present several advantages over eukaryotic ones. Among them, Lactococcus lactis (L. lactis) has emerged in the last two decades as a good alternative expression system to the historical and famous Escherichia coli. This review in the special issue “Advances in Membrane Proteins” describes the bacterial cell factory Lactococcus lactis and how it can be useful for membrane protein expression to facilitate their functional and structural characterizations. In the last 20 years, the inducible NICE system allowed functional expression of almost 113 membrane proteins from various topologies, origins, sizes, and functions of which thirty within the last 7 years and 20 MPs for which 3D structures could be obtained.

A. Frelet-Barrand, Biomolecules 12(2):180 (2022) https://doi.org/10.3390/biom12020180

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RESEARCH HIGHLIGHTS

Questioning the history of corporate communication

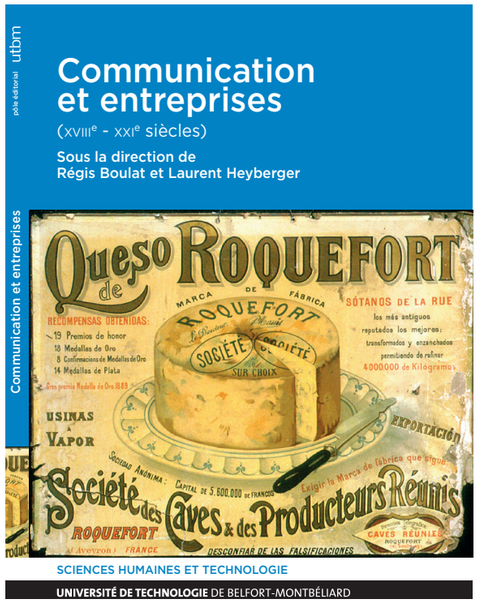
L. Heyberger

RECITS

Since the appearance of textile fashions during early industrialization, corporate communication has developed and perfected its tools, objectives and strategies as consumption grew and markets became saturated. From everyday consumer products to luxury Swiss watches, the case studies gathered here help to identify the temporal depth and multiform character of corporate communication.

The articulation of trademark legislation to the expansion of markets, the role of middlemen in the marketing chain, the temporalities of communication, the circulation of "models", or the "values" promoted by "global" strategies and increasingly sophisticated communication tools, paradoxically calling upon tradition and heritage, are all examined.

The notion of imitation in turn raises the question of "fair competition", of the "genuine" product; just as communication on "values" raises the question of what makes a link and of identification in an increasingly individualistic society, with increasingly strong ethical and ecological demands, to which companies' true "societal" and environmental commitment or greenwashing respond.



R. Boulat, L. Heyerger (ed.), Communication et entreprises (XVIIIe-XXIe siècles), Belfort, UTBM (col. « sciences humaines et technologie »), 2022.

laurent.heyberger@utbm.fr

S. Ammouche, A. Blanchet, B.-O. Dozo, M. Triclot (Eds.), Lire les magazines de jeux vidéo. Couverture(s) de la presse spécialisée française, Presses Universitaires de Liège, 2022

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The first collective work dedicated to the study of the video game press in France

M. Triclot

RECITS

French-speaking research on video games has regularly used the French specialized press as a source. But this press has never been studied in itself. This press, which developed from the 1980s to the 2000s, nevertheless has large print runs, federates a large, rather young and male readership, introduces a new technical and critical vocabulary into the French language, and participates in the construction of a new gaming culture.

"Lire les magazines de jeux vidéo" is the first collective work dedicated to the study of the French-speaking video game press. This corpus sheds new light on existing works on the Anglo-Saxon press and the formation of gaming cultures. Its originality lies in the multiplication of approaches regarding a press that has mainly been mobilized for the study of video games: this work thus proposes a new exploration of its contents, from the perspective of game sciences, but also of press studies, cultural and Japanese studies, digital humanities, critical writing, and the philosophy of technology... Drawing on the sections of the magazines of the great era - from the editorial to the preview, including tests, trade show covers and readers' letters, not forgetting the place of advertisements - the contents of this volume aim precisely to reflect this diversity of approaches and objects.

Milestones for a collaborative construction of the concept of territorial revitalization

M. Gasnier, N. Kroichvili, N. Winckel

RECITS

Although the expression "revitalization" appears more frequently in the field of public policy, particularly in France since the mid-1990s, it remains unexplored by researchers. Often linked to territorial issues, revitalization is a fuzzy concept. Characterizing this process to discriminate it from other territorial dynamics is, however, a real academic and practical challenge to better support public policies. Building on experiments carried out in several fields of territorial policies in the region of Bourgogne-Franche-Comté (France), an interdisciplinary group of researchers from MSHE involving FEMTO-ST/RECITS members has therefore set out to conceptualize the "territorial revitalization". This paper thus initiates a collective intelligence approach aiming at the co-construction of an evolving concept, based on revitalization experiences, with other researchers and actors taking part in such processes. Based on a synthesis of the knowledge, resulting from a cognitive analysis of the discourse on a specially prepared corpus, and complementary theoretical frameworks combined through a series of keys for reading the territory as a complex system, the collective work resulted in a concept of territorial revitalization, based on five principles. It is illustrated and tested through a case study on the deployment of the Techn'hom project in Belfort, from the 2000s to the present day.

M. Gasnier et al., « Jalons pour une construction collaborative du concept de revitalisation territoriale », Cybergeo, European Journal of Geography (Online), Space, Society, Territory, Document 1007 (2022)

In collaboration with MSHE Claude Nicolas Ledoux

https://doi.org/10.4000/cybergeo.38404

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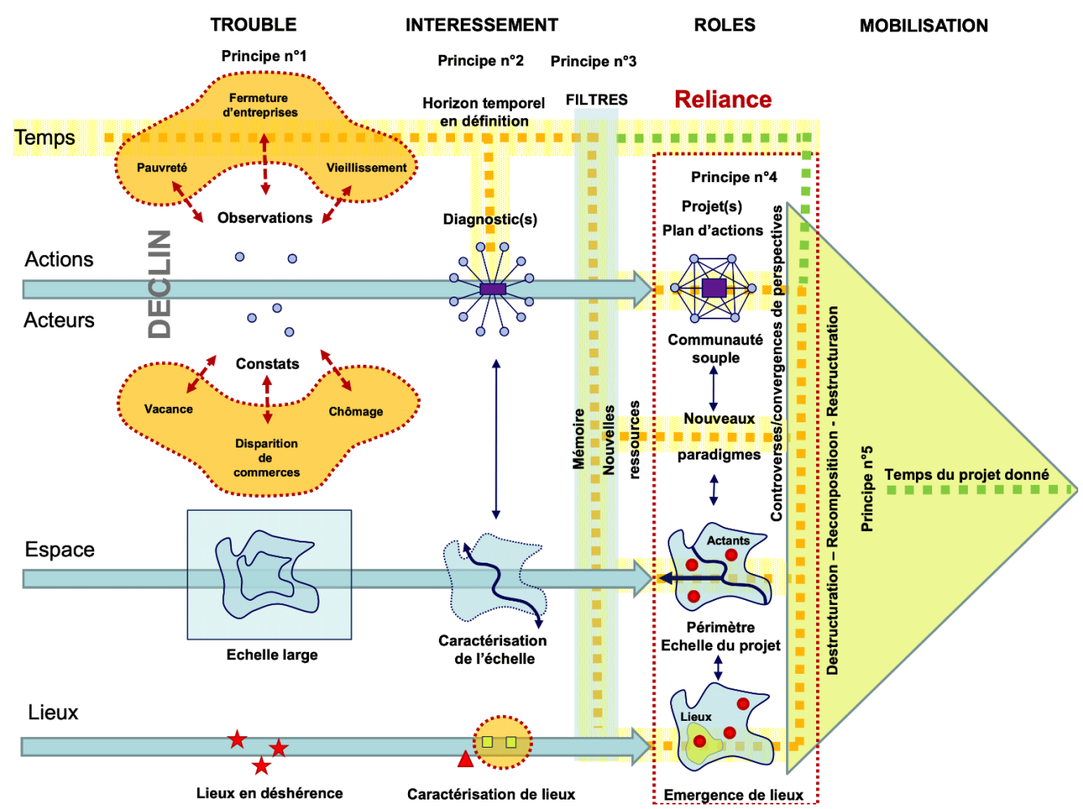

Principles of revitalization

CONFERENCES & WORKSHOPS

2022

30th Days of Manufacturing
French Annual Seminar, May 11-13, Besançon
Organizers: FEMTO-ST (M. Fontaine, L. Chaabani, N. Charpentier, N.F. Niang)
52 participants
https://events.femto-st.fr/manufacturing21-besancon

Optical Microwaves
Day of Club, June 13, Besançon
Organizers: FEMTO-ST (R. Boudot, J. M. Friedt, F. Cornu, S. Ricochet, T. Ducret)
55 participants
https://jcom2022.sciencesconf.org/

iceai
3rd International Conference on Energy and AI July 11-12, Belfort
Organizers: FEMTO-ST (F. Gao)
102 participants
http://www.energy-ai.org/

Workshop on Capillary Micromanipulation
November 22, Online
Organizers: FEMTO-ST (A. Barbot, B. Ahmad, H. F. Ortiz Villasuso
30 participants (7 countries)
https://events.femto-st.fr/wcm/en

DARS2022
The 16th International Symposium on Distributed Autonomous Robotic Systems
November 28-30, Montbéliard
Organizers: FEMTO-ST (J. Bourgeois (genera,B. Piranda, A. Makhoul)
97 participants
https://dars2022.org/#/

Geometric and Arithmetic Methods in Number Theory
April, Besançon
Organizers: FEMTO-ST (C. Maire)
20 participants

Industrial heritage and old materials with regard to the ecological transition
European colloquium, June 16-17, Belfort
Organizers: FEMTO-ST (M. Gasnier) & LMC-IRIMAT
20 participants
https://utbm.fr/colloque-pi-2022/

Hydrogen and Human and Social Sciences
National conference, June 30, Belfort
Organizers: FEMTO-ST (N. Kroichvili, N. Simoncini, O. Dembinski)
50 participants

ETOPIM12
12th International Conference on Elastic, Electrical, Transport, and Optical Properties of Inhomogeneous Media
July 4-8, Besançon
Organizers: FEMTO-ST (M. Kadic, V. Laude, F. I. Baida, J.-C. Beugnot, N. Courjal, K. Dudek, M. Haragus, M. Lenczner, M. Ouisse, J.-Y. Rauch, F. Miller, S. Quarroz, B. Ungureanu)
XX participants
https://etopim12.sciencesconf.org/

Industrial Rivers
9th French Days of Industrial History
November 24-25, Rouen
Organizers: FEMTO-ST (Y. Bouvier, R. Boulat, L. Heyberger), GRHis, CRESAT
50 participants

JNTE2022
French Symposium on Emerging Technologies for Micro-Nanofabrication
November 30 -December 2, Besançon
Organizers: FEMTO-ST (A. Bartasyte, D. Belharet, F. Chollet, G. Jutzi, G. Ulliac, L. Arapan, S. Margueron, S. Queste, S. Bargiel, X. Vacheret)
130 participants (5 countries)
https://2022jnte.sciencesconf.org/

EUROPEAN PROJECTS

H2020-EU.3.4. - SOCIETAL CHALLENGES -
Smart, Green And Integrated Transport

SALUTE (2018-2022)- Smart Acoustic Lining for UHBR Technologies Engines

M. Ouisse, E. Foltête, E. Sadoulet-Reboul, G. Chevallier

APPLIED MECHANICS

SALUTE (Smart Acoustic Lining for UHBR Technologies Engines) is a research project funded by the European Union's Horizon 2020 research and innovation programme Clean Sky 2 Joint Undertaking. It aims at developing and improve the Technology-Readiness Level (TRL) of innovative acoustic treatments for aircraft engine nacelles to reduce noise pollution of future aircraft, based on metasurfaces with a regular lattice of 5 cm diameter electrodynamic loudspeakers, each comprising 1/8-inch electret microphones on the 4 corners of the square unit cells, and an individual electronic control. Contrary to classical active noise control strategies that generate opposite waves to the incoming sound signals, the cells are designed to synthesize acoustic impedances able to absorb acoustic waves, which is much more efficient in terms of energy consumption. The project covers an upgrade of the electroacoustic components (loudspeakers, microphones, electronic hardware) wrt environmental specifications (weight, dimensions, operating temperature, etc.), the improvement of performance in the presence of flow (Mach number over 0.15), and the validation of the concept in EQUIPEX PHARE testbench (1/3rd scale aircraft engine with flow in anechoic room for liners characterization).

FEMTO-ST was in charge of the development of the acoustic control cards, assembly and acoustic tests of individual cells, panels and final prototype. Individual cells have been tested in many situations in terms of frequency and acoustic levels (up to 140 dB), showing their ability to synthesize target acoustic impedances over large frequency ranges. A 39-cellspanel was then developed and validated at NLR facilities in the Netherlands, with performance up to 20 dB reduction of tones, while the frequency of the maximum absorption of the device can be tuned in real time to track a given objective. For the target applications, this provides the ability of the system to follow the rotation speed of aircraft engines. The final prototype of the project was specifically designed to operate in the 1/3rd scale aircraft engine of PHARE Equipex at Ecole Centrale de Lyon, with a controlled rotating speed covering aeronautics requirements. The active liner could successfully be tuned to target different frequency ranges between 300 Hz and 2000 Hz according to the rotational speed, reaching additional attenuation of the tones (wrt the passive liner) between 4 dB and 8 dB depending on the configuration. This was obtained with only 2 cells in the longitudinal direction of the engine (28 on the periphery), opening the path to the next generation of devices for acoustic control of aircraft.

Consortium:
ECL-LTDS (FR, coordinator), UBFC-FEMTO-ST (FR), EPFL (CH). U Le Mans (FR)

Total funding: 2 M€
FEMTO-ST funding: 377 k€

https://salute-h2020.epfl.ch
https://vimeo.com/780741219/be4e698783

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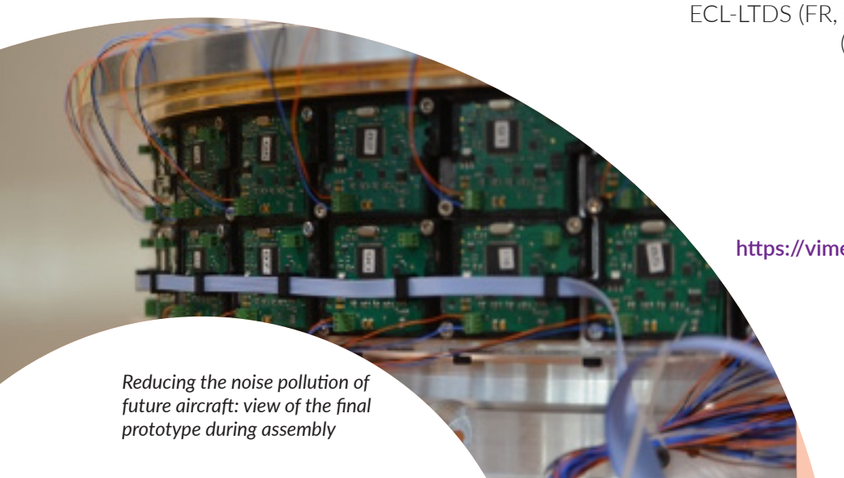

Reducing the noise pollution of future aircraft: view of the final prototype during assembly

NEW EUROPEAN PROJECTS

HORIZON-EURATOM-2021-NRT-01

PULSAR - PU-238-Coupled Dynamic Power System for Space Exploration and beyond

F. Lanzetta, S. Bégot and E. Gavignet

ENERGY

For space missions both Photovoltaic (PV) cells and Radioisotope Thermoelectrical Generators (RTG), fuelled by Plutonium 238 (Pu-238) are used to produce electricity to power missions. From a European point of view, this has several drawbacks, as neither Pu-238 nor any RTGs are produced in Europe and RTGs are very power inefficient, with a yield often of 5% of the fuel potential. This means that large amounts of fuel, and large RTGs, are needed to power missions, which increases the payloads. PULSAR is the first step on a European path to resolve these issues and take a world leading role in powering space exploration based on Stirling technology.

Consortium: SCK CEN (BE), Tractebel Engineering (BE), CEA (FR), Airbus Defence and Space (FR), UFC/UBFC (partner organization), Incotec (ES), ARTTIC (FR)

Total funding: 1.4 M€, FEMTO-ST funding: 320 k€

https://www.linkedin.com/company/pulsar-euratom/
https://twitter.com/PULSAR_Euratom

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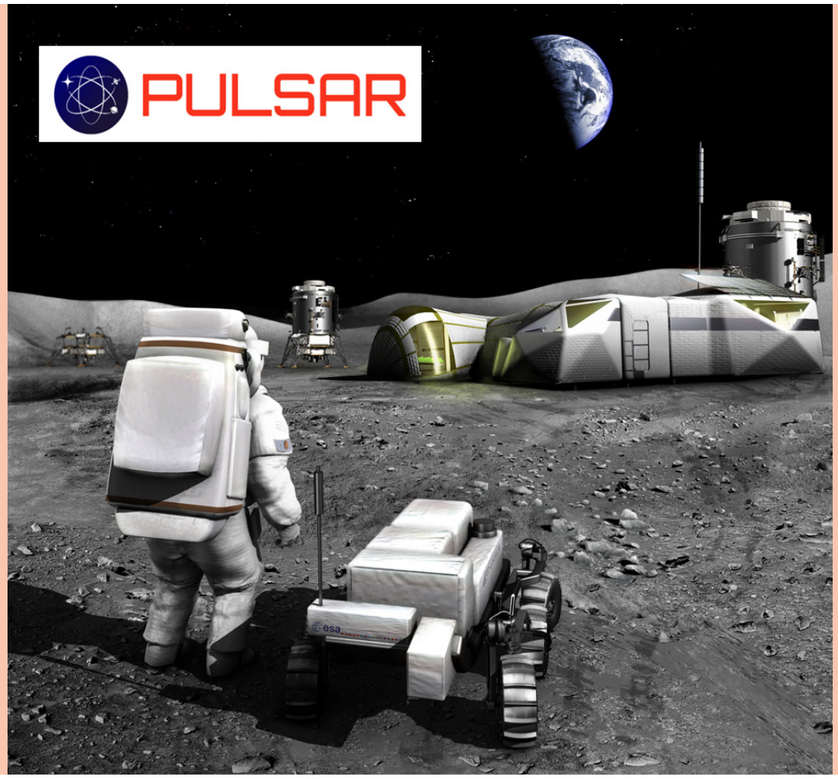

PULSAR will use a Stirling engine to design a European dynamic Radioisotope Power Systems, a key enabling technology for exploration of deep space.

NEW EUROPEAN PROJECTS

HORIZON-MSCA-2021-SE-01

UBIGIoT - Ultra-Low Design-Effort, Energy-Efficient and Battery-Indifferent Sensor Node for the Green Internet of Things

S. Margueron, A. Bartasyte

TIME & FREQUENCY

The rapid technological improvement in the semiconductor industry has enabled smaller and smaller devices to pervade our everyday lives. The real challenge in reducing the size to facilitate a ubiquitous integration of smart functions in any “thing” is drastically reducing the power consumption that constrains the volume to the presence of bulky batteries. An electronic device that dramatically reduces its power consumption can be powered by an alternative "green" source of energy such as light or vibration enabling the vision of the “Internet of Things”. In this scenario, the proposed research activity is intended to substantially enhance the energy efficiency of an IoT sensor node by a synergetic approach targeting both multisource harvesters and the System-on-Chip (SoC) design.

Consortium: Univ. Degli Studi Di Genova (Coord., IT), Tyndall National Institute (IE), STMICROELECTRONICS (IT), Univ. Degli Studi Di Catania (IT), Univ. Putra(MY), UBFC (Partner) Nat.Univ. Singapore, LeQuyDon Tech.Univ., Vietnam Nat. Univ.

Total funding: 980 k€

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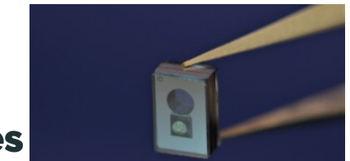
EDF-2021-DIS-RDIS

ADEQUADE - Advanced, Disruptive and Emerging Quantum Technologies for Defence



Alkali vapour micro-fabricated cell, Photo: N. Passilly

R. Boudot, N. Passilly

TIME & FREQUENCY, MN2S

The ADEQUADE project is a wide collaborative European project funded by the European Defence Fund (EDF). It aims at providing a breakthrough in different quantum sensing domains which will develop capabilities with significant technological, operational and strategic advantages over existing defence technology products. In this project, FEMTO-ST will be involved in the development of micro-fabricated cells for ultra-precise miniaturized atomic clocks or magnetometry applications. This project started to the end of 2022 for duration of 36 months.

31 industrial and academic partners:

- **France:** Thales (Coord.), CNRS, ENS Paris-Saclay, iXblue, ONERA, SAFRAN Electronics&Defense, Sorbonne Univ.
- **Italy:** Consiglio Nazionale delle Ricerche,Flysight SRL, Elettronica SRL, Ellettronica SPA , INRIM,Leonardo, MBDA Italia, Politechnico di Milano,Telespazio SPA, Univ. degli Studi di Bari Aldo Moro
- **Netherlands:** Chilas BV,Nederlandse Organisatatie Voor Toegepast Natuurwetenschappelijk Onderzoek TNO, Quix Quantum BV
- **Germany:** Diehl Defence GMBH, ,Fraunhoffer Gesellschaft zur Foerderung der Angewandten Forschung E.V, Rheinmetall Electronics GMBH, Univ. Stuttgart, Supracon AG
- **Spain:** ICFO, G.E.M. Indra Sytemas SA,Sener Aerospacial Sociedad Anonima
- Laser centre/Univ. of **Latvia** Tech. Univ. of **Denmark**, Univ. Palachého v Olomouci (**CZ**).

Total funding: 27.4 M€, FEMTO-ST funding: 695 k€

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EPSRC

INMAQS - International Network for Micro-fabricated Atomic Quantum Sensors

Consortium: Univ. Strathclyde (UK), Univ. Glasgow (UK), Univ. Sussex (UK), NIST Gaithersburg (USA), NIST Boulder (USA), Stanford (USA), CSEM (Switzerland), Univ. Neuchâtel (CH), Univ. Adelaide (Australia), ICFO (ES), Johannes Gutenberg Univ. Mainz (DE), Hebrew Univ. Jerusalem (Israel), FEMTO-ST (FR), Univ. Lille (FR).

Total funding: 500 k£

https://www.inmaqs.ac.uk/

R. Boudot, N. Passilly

TIME & FREQUENCY, MN2S

FEMTO-ST is a partner of the INMAQS, International Network for Microfabrication of Atomic Quantum Sensors. This network is coordinated by Dr. James McGilligan et Dr. Erling Riis (University of Strathclyde, Scotland). The kick-off meeting of the INMAQS network was done virtually on March 10, 2022. The INMAQS network aims to bring together international expertise on quantum physics and micro-engineering to oversee the development of the next generation miniaturized quantum sensors, specifically atomic clocks and magnetometers. The INMAQS network will target the development and integration of diverse technologies, for the demonstration of miniaturized quantum sensors and their individual components for advanced quantum capabilities. The INMAQS network will contribute to the demonstration of advanced quantum platforms that will help to facilitate the deployment and integration of a wider range of quantum sensors for electric fields, thermometry, or wavelength referencing.

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FACILITY HIGHLIGHTS

FEMTO-ST key facilities are grouped into centres in order to make them accessible not only to FEMTO-ST members, but also to teaching activities and to regional, national and international industrial and academic partners for their research and/or development projects:

AMETISTE

Mechanical characterization of materials, surfaces and structures in a wide range of dimensions and frequencies

MIFHYSTO

Micromanufacturing, mechanics, micromachining, powder injection molding, metal additive manufacturing, surface

CLIPP

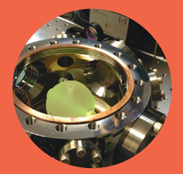
Clinical innovation proteomic facility, know-how in (bio) chemistry, physico-chemistry, nano- and micro-engineering, biostatistics and bioinformatics

MIMENTO

Microfabrication for Mechanics, Nanosciences, Thermal Science and Optics

CMNR

Robotics centre offering services in micro/nanocomponents, characterization, manipulation and micro-assembly



OSCILLATOR IMP

Oscillator instability measurements, frequency references (from RF to optics) and state-of-the-art comparative measuring instruments

FLUIDIX

Facility for fluidic and thermal characterization of complex flows

SMARTLIGHT

Formation-Research-Innovation in the field of photonics and optoelectronics

FRANCHE-COMTE MESOCENTRE

Numerical simulation, high-performance computing

SURFACE

Development and characterization of thin-film materials

HYDROGEN ENERGY (FCLAB)

Hydrogen-energy and testing of fuel cell systems, durability of energy sources for electric and hybrid vehicles and for stationary applications.

https://www.femto-st.fr/fr/Plateformes-technologiques/Mimento-presentation

https://www.femto-st.fr/fr/Plateformes-technologiques/autres-plateformes

New Advances in Micro-Assembly

Y. Lei, J.-Y. Rauch, C. Clévy

Centre of Micro and Nano Robotics (CMNR)

In 2022, the centre has continued its development with the acquisition of three new equipments: a thermal camera FLUKE TV46L-TL-O 60HZ dedicated to the thermography of small objects, a haptic device FORCE DIMENSION OMEGA 7 and a generator of magnetic fields MAGNEBOTIX OCTOMAG.

These new devices and the previous ones can be booked via the internal reservation system Booked since the beginning of 2023. A ticket management system hosted by the GPLI application has also been implemented as part of a quality plan.

New advances in micro-assembly in vacuum have enabled the functionalization of an articulated mechanism of 30x30x20 µm. The structure is made by folding silica in the µROBOTEX station of the CMNR. The assembly is made of a silica membrane of less than 1 µm thickness, on which an aluminium/silica bimetal is welded. The bimetal, heated by the light, deforms under the effect of the differential expansion between the aluminium and the silica. Beyond this demonstration on a small gripper, the new process opens the way to the realization of poly-articulated microrobots actuated by light through an optic fibre. This result has been awarded by a "Micron d'or" award at MICRONORA trade fair 2022.

https://platforms.femto-st.fr/cmnr/fr

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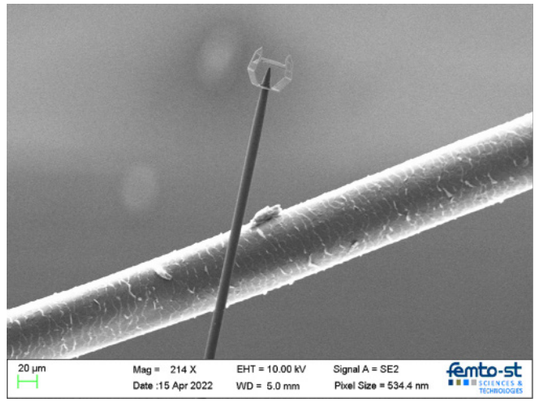

Thermally actuated microgripper

Two-Way Satellite Time and Frequency Transfer

J.-M. Friedt, G. Goavec-Merou

OSCILLATOR IMP

Two-Way Satellite Time and Frequency (TWSTFT) is used to define Coordinated Universal Time (UTC) by comparing clocks between European and North American time and frequency metrology laboratories. The current implementation of TWSTFT relies on proprietary hardware developed in the 1990s. A portable open source, open hardware implementation using Software Defined Radio (SDR) of the communication schemes implementing TWSTFT by pseudo-random binary sequence spectrum spreading is proposed at https://github.com/oscimp/amaranth_twstft to prototype various radio frequency link parameters including pseudo-random code sequence and length, or modulation schemes aimed at optimizing spectral efficiency. The framework aims at opening to scrutiny by the community the link parameters and their impact on the TWSTFT accuracy and stability. The current implementation running on a broad variety of Field Programmable Gate Array (FPGA) platforms and SDR dual-channel receivers have demonstrated performances similar to the proprietary hardware, opening the path towards improvement and addressing some of the artefacts observed in the current setup.

Furthermore, this development is an opportunity to assess the performance of a high-level representation of hardware description benefiting from the flexibility of the Python language by using Amaranth, hence easing prototyping and code maintenance over classical Hardware Description Languages and removing the vendor-locked synthesis tool dependency.

http://oscillator-imp.com

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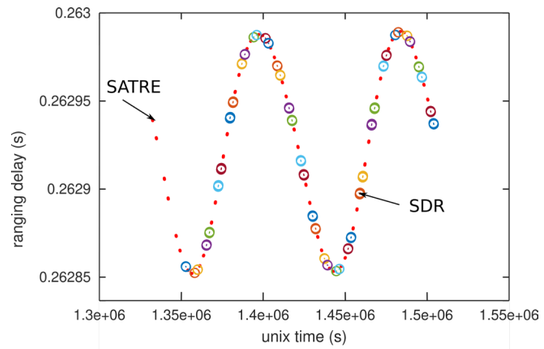

Ranging between LNE-LTFB in Besançon and the Telstar11 geostationary satellite using SDR-based TWSTFT.

FACILITY HIGHLIGHTS

Nano-Micro-X-ray Tomography
(Computational Tomography Scan)

X. Gabrion, S. Thibaud, V. Placet

MIFHySTO

The MIFHySTO platform has been equipped with a micro-nano X-ray tomography machine since 2017. It is dedicated to control and analyse components nor assemblies in volume by X-ray and image processing technologies. Depending on the analysed samples (dimensions, materials), volume resolutions of 4 µm (micro-tomography) and 400 nm (nano-tomography) are available. The study concerns the ability of hemp shives as adsorbents for the removal of copper present in aqueous solutions [1–3]. The results showed remarkable different mechanisms for copper adsorption onto the SHI-C and SHI-BTCA hemp shives. For the first one, Physisorption mechanism operates for copper adsorption while for the second one, the mechanism is governed by chemisorption mechanism.

Since December 2022, the MIFHySTO facility has been equipped with a µCMM (Bruker Alicona) machine for metrology measurement. This optical machine is used to measure extremely tight tolerances in high accuracy. This machine can measure dimensions, position, shape and roughness of components. The resolution is 10 nm for a minimal measurable roughness (Ra) of 30 nm.

[1] C. Mongioví et al., Chem. Eng. J. Adv. 10 (2022) 100282. https://doi.org/10.1016/j.ceja.2022.100282.

[2] C. Mongioví et al. Molecules. 26 (2021) 4574. https://doi.org/10.3390/molecules26154574.

[3] C. Mongioví et al., Arab. J. Chem. 15 (2022) 103742. https://doi.org/10.1016/j.arabjc.2022.103742.

µCMM machine.

https://www.femto-st.fr/fr/Plateformes-technologiques/autres-plateformes

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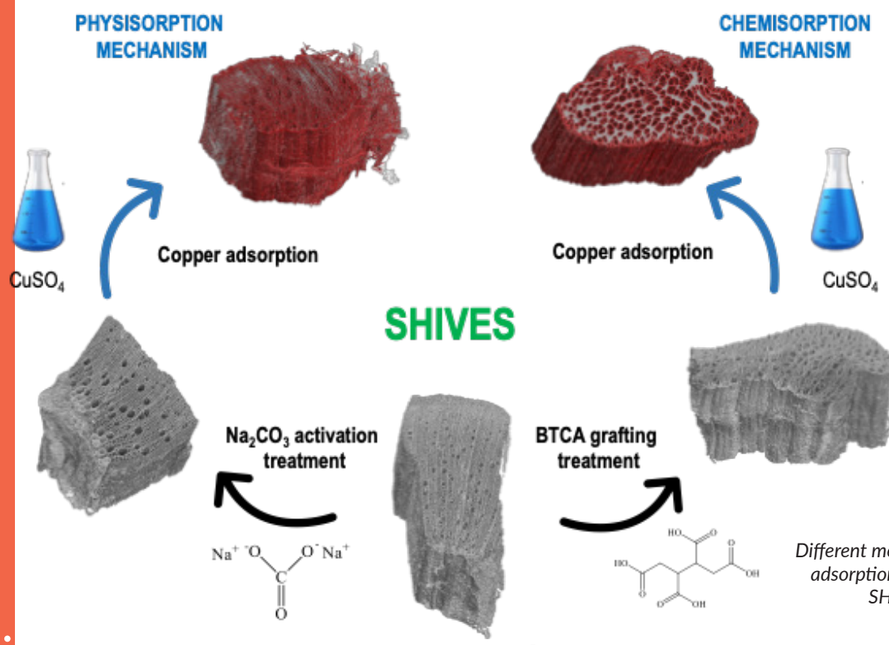

Different mechanisms for copper adsorption onto the SHI-C and SHI-BTCA hemp shives.

In-situ Temperature Measurements during Cutting

M. Fontaine, A. Gilbin, G. Michel

MIFHySTO

The MIFHySTO proposes the measurements of cutting forces in order to study the cutting process and machinability of materials. A novel equipment was purchased to measure in-situ temperature during cutting thanks to the Actarus© device and prepared tool-holders and cutting inserts. A thermocouple is inserted close to the cutting edge in a position depending on the need. It allows us to validate models and simulations developed for cutting and micro-cutting analysis and optimization. The measure can be conducted simultaneously with other ones, as cutting forces or accelerations. Information about local temperature is critical to simulate the cutting process, to develop constitutive or friction laws adapted to such processes or friction laws, to develop new tools or to enhance surface integrity of produced parts.

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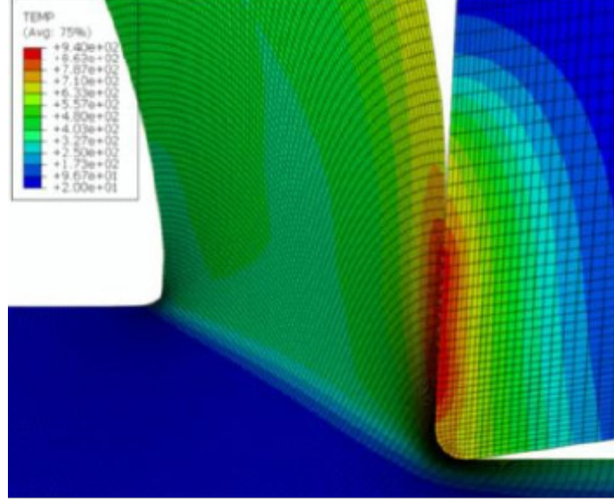

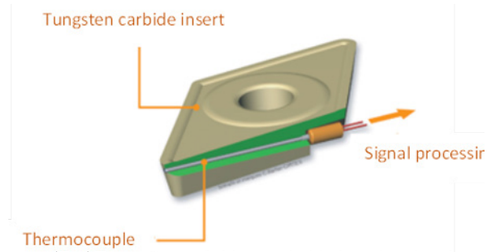

(Top) Temperature field at tool-chip interface in micro-cutting (FEM). (Bottom) Cutting tool insert equipped by Actarus© for temperature measuring during machining.

Ultrafast Oscilloscope & an Arbitrary Wave Form Generator

J.M. Merolla, M. Jacquot

SMARTLIGHT

The SMARTLIGHT research platform aims to centralize state-of-the-art equipment needed to develop the next-generation of self-adaptive and reconfigurable light sources, sensors, and photonic systems. A key focus is to be able to image to the nanometre scale, to detect the faintest amounts of light, to detect light over broad spectral ranges, and with the ability to process spatiotemporal signals and control/structure matter on ultrafast timescales. SMARTLIGHT encompasses both the development of “thinking” technologies such as the hardware implementation of photonic neural networks, as well as the application of algorithmic machine learning techniques in nonlinear optics, quantum information, ultrafast photonic sciences and nanophotonics. In December 2022, SMARTLIGHT acquired two of its flagship instruments, a Keysight ultrafast oscilloscope and an arbitrary wave form generator with the world’s highest sample rates and the widest bandwidths, enabling the capacity to record, process and generate large amounts of data in real time. The equipment consists of

- A 4-channel oscilloscope with a 100 GHz bandwidth enabling data acquisition at 240 GSa/s.
- An arbitrary waveform generator operating at 120GSa/s

High-speed optoelectronics devices are, of course, already available, but existing 50 GHz bandwidth limitations are now acting as a major research bottleneck. The new Keysight equipment represents a huge step forward in our characterization capability. This equipment will be shared between SMARTLIGHT users, and hosted at FEMTO-ST.

https://www.ubfc.fr/recherche/projets-de-recherche/pia/plateforme-smartlight/

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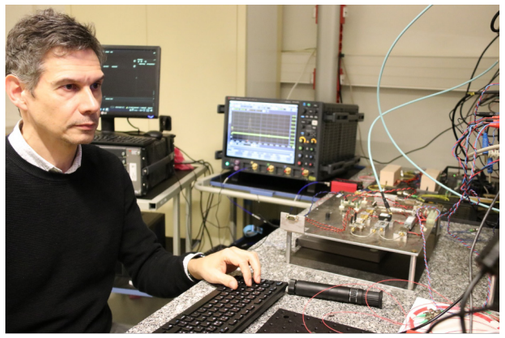

J.-M. Merolla (CNRS) is operating first experiments with SMARTLIGHT ultrafast oscilloscope in the framework of Aurea Technology shared laboratory with FEMTO-ST Institute.

FACILITY HIGHLIGHTS

Hydrogen Energy

FCLAB

Open Day

The UAR FCLAB organized its Open Day on Saturday, October 15, 2022, at the Hydrogen-Energy platform of the UTBM in Belfort. The UAR welcomed more than 150 people during that day. Researchers, PhD students from FEMTO-ST, CMI H3E students from UFR STGI in Belfort as well as staff from the central services animated this day around the theme of hydrogen and ecology. The day revolved around 3 axes: education for all ages with 7 stands, research axes with 7 stands too and scientific questions with 3 sessions of speed searching, lasting 45 minutes. Two exhibitions, created by the members of the FCLAB also accompanied this day. Visitors enjoyed their visit with some wishing to come back again next year.

10th Anniversary

Monday, November 7, 2022, the evening before the Hydrogen Business for Climate Forum in Montbéliard, FCLAB celebrated its 10th anniversary surrounded by more than 40 personalities including representatives of the UAR supervisory bodies, industrial partners who expressed their confidence in FCLAB and representatives of the local councils. These personalities showed their support during the opening ceremony and the round table. The anniversary evening continued with the visit of the laboratory where doctoral students presented their thesis in 3 minutes. Finally, the guests and the organizing committee gathered around a cocktail reception. Each of the guests expressed their satisfaction while bringing back a small souvenir of this evening.

www.fclab.fr

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Surface Plasmon Resonance Technology & Atomic Force Microscopy for Extracellular Vesicles Analysis in Human Plasma

G. Raizada, C. Elie-Caille, A. Rouleau, W. Boireau

CLIPP

Open Day

Multiple myeloma (MM), a haematological malignancy, is associated with the highest risk of thrombosis, particularly when treated with immunomodulatory drugs. In the frame of METRO study [1], CHU hospital (Dr Emilie Chalayer, PhD student Mr Sébastien Charles) and CLIPP team are carried out an investigation of circulating extracellular vesicles (EVs) which are involved in physiological functions notably coagulation. CLIPP provides its NBA platform [2] based on a combination of biophysical instrumentations (Surface Plasmon Resonance and Atomic Force Microscopy) to assess and describe all types of EVs (small, medium and large, cell origin) in blood of MM patients and particularly endothelium-derived microvesicles. Immunosensor chip coupled to SPRi enabled to selectively catch and detect biological elements (among them, EVs) whereas on-chip AFM investigations allowed the nanometrological characterization of these elements (membrane deformation and morphomechanics). CLIPP has provided a training program for the PhD student in 2022 and is accompanying this project. The results allow a first phenotypical view of the EVs contained in plasma of patients: an increase in CD138+ EVs (as expected), CD41a+ and CD14+ in MM plasma at diagnosis. The AFM analysis was consistent with their EV nature. These promising results have been recently awarded [3] and paved the way for further investigations with plasma samples after patient treatments.

[1] Chalayer, et al. Research and Practice in Thrombosis and Haemostasis 3, 89-90, 2018

[2] Obeid, et al. Biosensors and Bioelectronics 93, 250-259, 2017

[3] S. Charles et al., Extracellular vesicles circulating in blood of multiple myeloma patients: an innovative detection. Poster, SLEIGHT Science Event'2023, France.

https://manutech-sleight.com/manutech-sleight-graduate-school/

www.clipproteomic.fr

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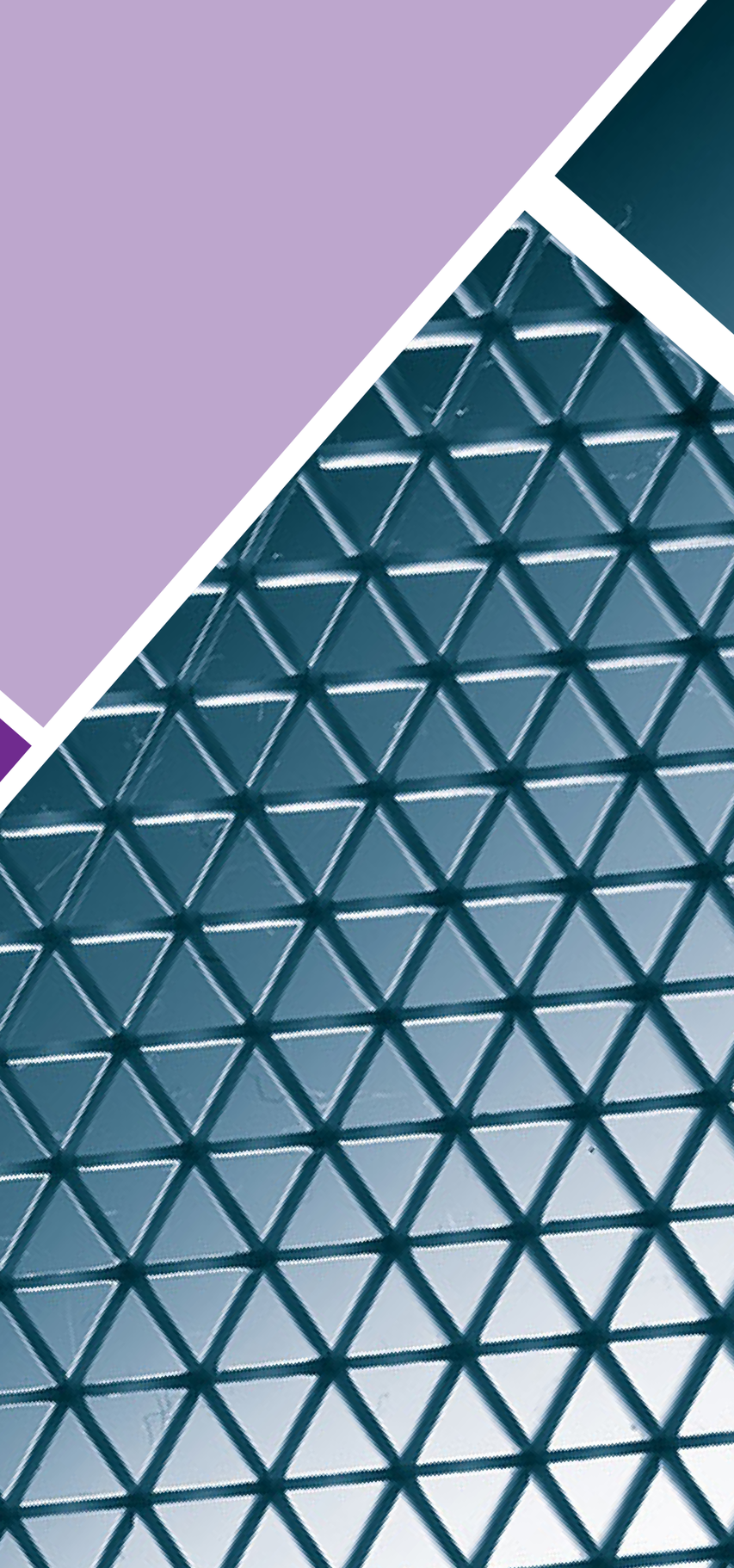
Sébastien CHARLES, PhD student at the SAINBIOSE lab, was awarded the Best Poster prize for the biophysical investigation of EVs from patients of Multiple Myeloma performed inside CLIPP facilities. SLEIGHT Science Event'2023.

INNOVATION



FEMTO Engineering

The Engineering Centre of the FEMTO-ST Institute offers to industry high-level engineering developments, based on research conducted at FEMTO-ST. FEMTO Engineering has sixteen employees and cooperates directly with the research groups within the FEMTO-ST Institute.

FEMTO Engineering contributed to the development of technologies from the laboratory (called proprietary technologies) and concluded contracts both with local companies and large international groups.

Technological fields:

- **Energy**
- **Optics, photonics and laser machining**
- **Electronics and hyperfrequencies**
- **Micro-technologies for cleanrooms**
- **Robotics**
- **Artificial intelligence**
- **Mechanical characterization**

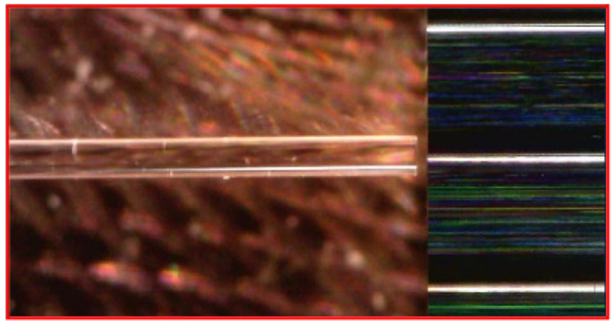
FACILITIES:
MIMENTO, CMNR,
OSCILLATOR-IMP, AMETISTE

www.femto-engineering.fr
contact@femto-engineering.fr

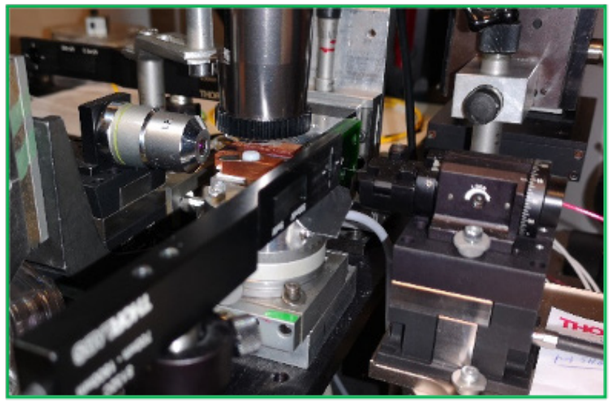
Design and manufacture of an optical frequency converter From TRL4 up to TRL6

Based on the research work carried out in the Optics department of FEMTO-ST, FEMTO Engineering has designed and manufactured a packaged frequency conversion components:

- Manufacturing of PPLN (Periodically Poled Lithium Niobate) structures
- Dicing of PPLN ridge waveguide
- Development of a characterization and pigtailing bench
- Packaging



Injection of light into a waveguide



Characterization and pigtailing bench

FEMTO Engineering is labelled Carnot for the quality of its engineering partnerships with industrial companies.

FEMTO Engineering is a partner of Carnot Telecom & digital society.

FEDER Intelligent Specialisation Program (RIS3)

Next Watch
Revolutionary Motors for Watches

2018-2022

J.C. Jeannot, D. Belharet, S. Queste

MIMENTO clean room

Partners: Silmach

The objective of Next Watch industrial research and collaborative experimental development project was the design, development and industrialization of a silicon-based disruptive technology for the motorization of quartz watches and integration of clock hands with smart/connected watches. The challenge was to create a new driving element based on silicon in order to eliminate the kinematic chain of current stepper motors. This project was a part of the "Microtechnologies and luxury markets such as watchmaking and jewellery" sector. On the scientific level, FEMTO-ST carried out the electromechanical modelling, design and development of manufacturing processes in clean room. At the end of the project, it was to set up microfabrication processes for the production of hybrid motors for watches based on bulk micromachining technology with silicon deep plasma etching technique.

With the industrial partner Silmach, MIMENTO facility and staff contributed to the development of MEMS actuator production on 6-inch wafers for watchmaking applications. A microfabrication process flowchart was proposed, validated and reproduced over several runs on several SOI wafers. The fabrication process combined electrode deposition operations, lithography to define the comb-drive actuator with 6 µm width fingers. Plasma etching was the most critical operation because it needed to satisfy normally irreconcilable objectives: on one hand, obtain a high anisotropy of the etching profile as it affects the operation of the final device, and on the other hand, reach high smoothness of the sidewalls. After etching the front and the backside of the SOI wafer, the structure of the actuator was released by etching the sacrificial SiO_2 layer. A specific hydrofluoric vapour process was developed to optimize process time and etched depth to eliminate spurious adhesion issues. These results allowed fabrication of an electrostatic MEMS motor that was embedded in a working prototype of a watch.

Total FEDER funding: 5.36 M€

D. Belharet & al, Manufacturing optimization of hybrid watch MEMS Micromotors on 6 inch wafer, JNTE (2022).

https://www.silmach.com/

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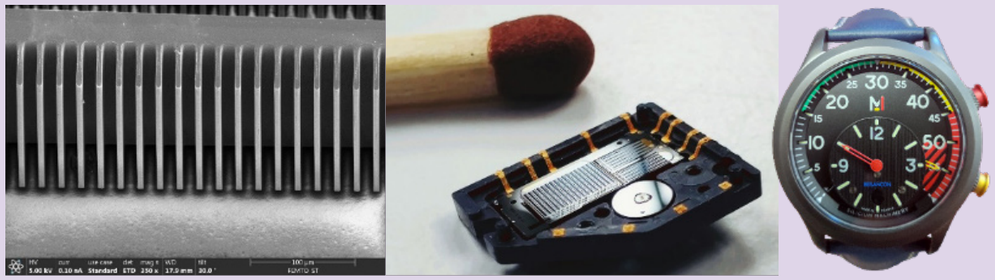


SEM image of etched structures - comb drive actuator (left), MEMS electrostatic motor (middle), new generation watch (right)

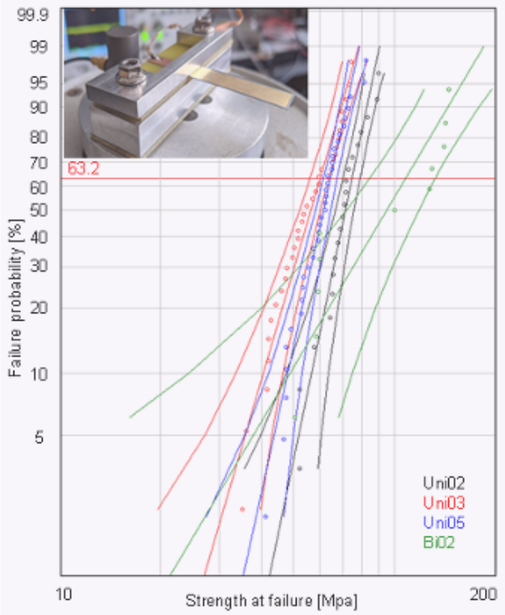
Maturation project HARVEY

LiNbO3 Vibrational Energy Harvesters

S. Margueron, G. Clementi, M. Ouhabaz,
G. Giuffrida, A. Bartasyte

TIME & FREQUENCY

The HARVEY project aims to develop self-powered and communicating sensors thanks to a vibrational energy harvesting module present in the immediate environment. This module is made of materials that comply with RoHS and REACH regulations. The generated power density by our device, based on thick Y128°-$LiNbO_3$ films on metal substrates fabricated by bonding/polishing technique is among the highest reported values compared to both Pb- and Pb-free vibrational harvesting devices (patented process, in collaboration with FEMTO Engineering). $LiNbO_3$ thick layers offer a low-cost solution of lead-free materials ($LiNbO_3$ crystals are available at the industrial level at a price of 25 $ / wafer 6 ") for micro-energy harvesting and micro-actuators. The targeted markets are miniaturized industrial sensors for applications in the industry of the future, transport, IoTs and IoHs. The current phase of development is to offer a robust and packaged final micro-energy source for the market.



Reliability test of energy harvester based on metal/$LiNbO_3$

Bartasyte et al. Patent EP20 203952,
International extension PCT/EP2021/078543

samuel.margueron@femto-st.fr

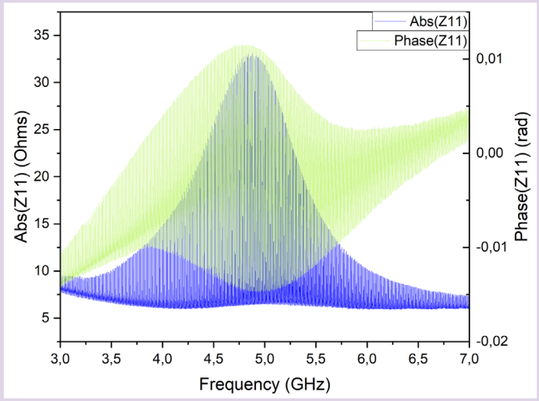
Maturation project EPILIFILM

LiNbO3 Films for 5G Acoustic Filters

A. Bartasyte, S. Boujnah, L. Arapan, M. Ivan,
S. Margueron

TIME & FREQUENCY

The demands of the RF filter market are pushing for the development of new piezoelectric materials for bulk acoustic wave (BAW) devices to meet the challenges of modern telecommunications in terms of high operational frequencies and performances. RF filter technology requires integration of $LiNbO_3$ layers with BAW heterostructures to replace devices based on standard sputtered AlN layers limited in electromechanical coupling, K^2, (= narrow bandwidth) at high frequency for 5G telecommunications. In the literature, $LiNbO_3$ layers, grown along the c-axis, offering a K^2 equivalent to AlN, have been obtained in BAW structures. Therefore, top-down methods (ion slicing or wafer bonding-polishing techniques) are considered for this purpose although the precision control of thickness (definition of frequency) and its homogeneity remains a challenge. We have demonstrated a direct textured growth of 33°Y-$LiNbO_3$ on BAW structures using a patented buffer layer. The K^2 of the longitudinal mode of 33°Y-$LiNbO_3$ is almost four times higher than that of the standard AlN layer. The HBAR resonators based on deposited 33°Y-$LiNbO_3$ films were fabricated up to frequencies of 7.5 GHz.



HBAR resonator based on deposited 33°Y-$LiNbO_3$ films, operating at ~ 5GHz.

Bartasyte et al. Patent EP3920416,
International extension WO2021244978

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FEDER -Intelligent Specialisation Program (RIS3)

MiMédi - Microtechnologies for Innovative Medicines

2017-2022

O. Lehmann, A. Bolopion, A. Frelet-Barrand

AS2M, MN2S, FEMTO Engineering

Partners: UMR RIGHT, EFS BFC, Institute FEMTO-ST, FEMTO Engineering, CHU Besançon and its clinical investigation centre (CIC 1431) and companies : Ilsa, AUREA Technology, Diaclone, Med'Inn Pharma, Smaltis.

OATMPs are new drugs for people in therapeutic deadlock or failure. Their production requires complex technologies in a controlled clean room environment and is costly due to numerous manual steps. Started in December 2017, the FEDER project MiMedI for "Microtechnologies for ATMPs" is part of the intelligent specialization programme (RIS3). With a total cost of €15 million (€11,283,209.47 financed by the European Regional Development Fund and €584,000 - by the BPI via the Regional Innovation Assistance Fund). This programme with duration of 5 years allowed to establish a close collaboration between the 9 partners of Grand Besançon. The objectives were to limit/reduce manufacturing costs and to be as close as possible to the patient-personalized medicine. This large-scale project aimed to develop innovative production methods, in particular a modular bioreactor integrating different modules representing the different steps of biosimilar production. Numerous developments have been realized, notably:

- The simplification of the production thanks to the technological contributions in micro-fluidics, micro-fabrication, acoustics, vision, automation, microtechnologies, and optics;
- The optimization of ATMP manufacturing through the contribution of microtechnologies to reduce manufacturing costs and increase their number and their transfer to the evaluation phases in humans.

The closing meeting took place on October 7th in the presence of the different project partners and local politics (president of UFC, director of EFS, regional vice-president in charge of higher education, research, equality, and laicity, etc.). The different developments and achievements of MiMédi project were demosntrated, which were also summarized within the promotional video (QR code).

https://projects.femto-st.fr/mimedi/

olivier.lehmann@femto-st.fr

Closure meeting on October 7, 2022

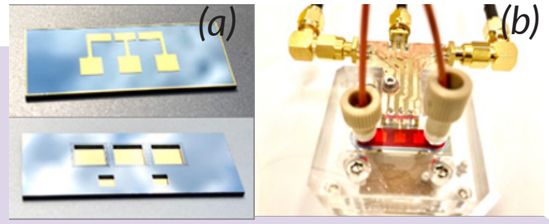
Maturation project

Acoustic Bioassay

T. Leblois, F. Chollet

MN2S

This project results from the GHOST ANR project (Microfluidic device for the Global assessment of primary HaemOSTasis with flowing whole blood) managed by FEMTO-ST Institute. The objective of the GHOST project was to develop an integrated analysis system in whole blood and in flow coupling (i) a microfluidic cell mimicking the rheological conditions of a blood vessel, covered with collagen analogues immobilized on the surface and (ii) a device allowing the detection and quantification of surface-platelet interactions. In this context, a microfabrication technology has been developed and patented for the development of an acoustic biosensor for the detection of biological phenomena occurring during the primary haemostasis phase. This technology being innovative and relevant for the design of biomarker detection devices, it was decided to develop a new portable analytical platform that allows multiplex detection/quantification of specific biological elements such as biomarkers of cardiac or infectious diseases via a maturation project with SATT Sayens (Société d'Accélération du Transfert de Technologie). The core of the innovation is the development of a biosensor array based on a multiplexed label-free acoustic transduction. This device addresses needs that are currently not covered by the market.



Fabricated bioassay chips with three multiplexed sensing units (a) Acoustic biosensor for in vitro diagnostic of primary haemostasis (b)

A. Oseev and T. Leblois, Patent EP 20306611.3-1020 extended at international No. PCT/EP2021/078820

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Joint Technological Unit UMT CAPPLAI

Sensors for Dairy Process Optimization

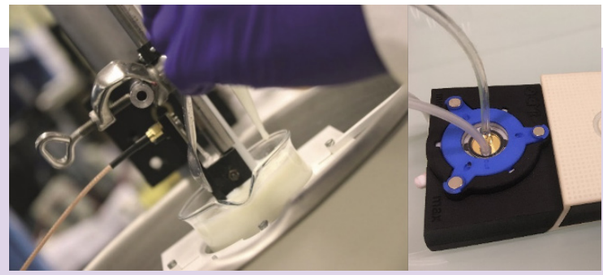
T. Leblois, J.F. Manceau, V. Humblot

MN2S

Partners: ACTALIA, INRAE Poligny, ISBA (ÉNIL de Poligny et Mamirolle), UMR STLO (INRAE, AGRO Rennes-Angers)

In the food industry, innovation in the milk and dairy products sector has more often benefited the products than manufacturing processes. FEMTO-ST researchers with the partners are actively involved within the Joint Technological Unit UMT CAPPLAI, which aims at improving the performance of the manufacturing processes of cheeses, yoghurts and other dairy products to control their quality.

One of the projects developed in this framework concerns the online monitoring of the milk coagulation process. An acoustic sensor is designed to be adapted to industrial conditions placed directly in the vat of milk, to monitor the viscoelasticity of the product, relay the information remotely and thus assist the cheesemaker in his work. Another project aims to optimize the processes for detecting Salmonella, Listeria or any other pathogenic bacteria in milk. The current detection method is time-consuming, requiring up to three days of processing and bacteriological analysis. The solution we are working on would cut this time in half.



Acoustic sensor in milk for coagulation monitoring (left), Bacteria detection (right)

FEMTO-ST Institute has the opportunity to put the know-how and skills of its researchers for new applications to help the agri-food sector take the turn towards the industry of the future.

https://www.femto-st.fr/fr/L-institut/actualite/femto-st-partenaire-de-lunite-mixte-technologique-capplai

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Joint Laboratory

LabCom SADIAND

C. Guyeux

DISC

Partners: SAD Marketing & SDIS25

For the past three years, through the Project Prédictops (a tool for the prediction of firefighters' interventions, with CIFRE thesis supported by SDIS), work has been carried out to examine the extent to which artificial intelligence could help the departmental fire and rescue services (SDIS) in their operations. More precisely, the aim is to predict the number of interventions (according to the type of intervention, the geographical area and the time horizon of prediction) as well as the number of calls to the 18. These predictions allow a certain number of operational optimizations, such as sizing the call reception room according to the expected number of calls. The state-of-the-art algorithms proved to be efficient and the predictions of good quality.

An ergonomic interface has been deployed and this tool is now used on a daily basis within the SDIS of Doubs, and two other departments will be equipped at the beginning of 2023.

Moreover this partnership has led to the creation of the LabCom SADIAND in 2022 (transport SAnitaire D'urgence optimisé par Intelligence Artificielle, traitement automatique des laNgues naturelles et Deep learning), with SDIS, team AND of FEMTO-ST/DISC, and the society SAD Marketing.

C. Guyeux et al., Proceedings of IntelliSys 2022, Intelligent Systems Conference. Amsterdam (Netherlands), 1-2, 2023. Vol. 542 (1), pp. 558-572.

C. Guyeux. France. Proceedings of IS'2022, 11th IEEE International Conference on Intelligent Systems. Warsaw (Poland), October 12-14, 2022.

R. Mallouhy et al., Proceedings of IWCMC 2022, International Wireless Communications and Mobile Computing Conference. Dubrovnik (Croatia), May/June 30-3, 2022. (Rank B (Core)).

cguyeux@femto-st.fr

The use of PredictOps at SDIS25

European Digital Innovation Hubs (EDIHs)

C. Guyeux, T. Barrière

APPLIED MECHANICS, DISC

A EDIH (European Digital Innovation Hubs) is a grouping of actors whose purpose is to constitute a one-stop shop, physical or virtual, aiming to connect businesses in their territories to the resources and ecosystems they need to succeed in their digitaWI transformation. EDIHs provide services such as pre-investment testing, training and skills development, assistance in finding investments, networking and access to innovation ecosystems.

In June 2022, two EDIHs were obtained (DEDIHCATED and POLYTRONICS) in which the DISC and DMA are associated. They are two of the 10 French EDIHs selected and funded by the European Commission as part of the "Digital Europe" programme. This programme aims to strengthen the adoption of digital technologies by companies and to build an ethical and sustainable European vision of the deployment of digital solutions for businesses (Artificial Intelligence (AI), cybersecurity and high-performance computing).

POLYTRONICS

POLYTRONICS is the winner of the EDIH to support the digitalization of polymer materials companies. The idea of the Polytronics Hub is to allow companies in the plastics, composites and polymer materials industries with a digital transformation project to benefit from a complete and grouped service offer, through the Polytronics partners.

POLYTRONICS project is led by Polymeris, a competitiveness cluster for rubber, plastics and composites, specialized in supporting innovative start-ups and SMEs, and complemented by Techtera, competitiveness cluster, the textile materials cluster. Accompanied by the consortium composed of IPC, IFTH, Université d'Orléans, FEMTO-ST, CRESITT Industrie, SWARM, MAYFAIR VILLAGE, INNOVALLYS, GEMTEX (ENSAIT), Université Lyon 1 Claude Bernard, ALTAIR Engineering France, FABLAB Orléanais, Université Dijon Bourgogne, S2P, INSA Lyon, the project is supported by the regions Auvergne-Rhône-Alpes, Bourgogne-Franche Comté et Centre-Val de Loire.

https://polytronics.eu/projets/

DEDIHCATED

Dedihcated BFC is the European digital innovation cluster that is being deployed in the region, led by the Véhicule du Futur cluster. It brings together 14 partners: Nuclear Valley, le Pôle des Microtechniques, Vitagora, BFC Numérique, Numerica BFC, l'Usinerie, Amvalor (Ensam), l'université de Bourgogne, l'université de Franche-Comté, l'université de Technologie de Belfort-Montbéliard, le Cetim, Cap'tronic et la CCI Bourgogne Franche-Comté.

Two thematic courses have already been designed according to the identified regional industrial needs: the first one, called "From data to AI for company management", aims at developing a range of services around data management to make the associated technologies and methodologies accessible and to allow the company to gain maturity in the long term. The second, entitled "Digitalization of business and production processes towards the digital twin", offers a range of industrial services accessible to PMEs to support their digital transformation through the integration of new technologies and digital skills.

https://digital-strategy.ec.europa.eu/en/activities/edihs

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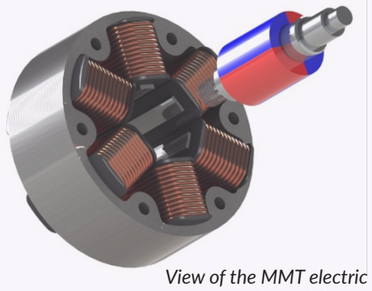
Unique Inter-Ministerial Fund (FUI)

E-Silence - Silent design of electrical machines, uncertainties and optimization

2018-2022



View of the MMT electric motor optimized during the E-Silence project .

E. Sadoulet-Reboul, M. Ouisse, K. Jaboviste, B. Auzanneau, R. Teloli

APPLIED MECHANICS

Electric drivelines emit noises of electromagnetic origin known as “siren” noises, with high-pitched tonal components that are very detrimental in terms of sound perception. This type of noise is taking an increasing part in all industrial sectors. The E-Silence project contributes to different objectives: 1. Development of tools allowing electrotechnical engineers to quickly estimate the impact of electromagnetic design on vibrations and radiated noise at the pre-sizing stage. 2. Development of methods for optimizing the topology of electrical machines (shapes of teeth, rotors, magnets, etc.) with the aim of reducing electromagnetic excitations "at the source" while preserving machine performance and taking account of manufacturing tolerances. 3. Development of techniques for reducing electromagnetic and dynamic models of structures, to reduce calculation times and allow rapid optimization loops and the consideration of uncertainties in simulations. 4. Demonstration of the benefits of providing resin coating with an “acoustic” function, by optimizing the mechanical properties of the resin.

FEMTO-ST main contributions to the project were twofold. First, design methods for noise estimation during the design stage were developed. These techniques are based on ROM (Reduced-Order Modelling) to guarantee fast and accurate estimation of the acoustic power radiated by electric motors. The electromagnetic sources obtained from electromagnetic ROMs were provided by L2EP. The vibroacoustic reduced models are built from structural finite elements to handle the complexity of the system (anisotropic, layered materials, presence of viscoelastic resins), but also the uncertainties, which can be related either to the unknow design parameters or to the manufacturing uncertainties. These models can deal with geometry uncertainties and frequency dependency of material properties, which are two things that cannot be handled with classical ROMs. The second main contribution was related to the optimization of coating resins: additionally to their positioning and thermal effects, strong improvement of the vibroacoustic behaviour can be obtained by properly tuning the viscoelastic properties of the coating resins. All the contributions were implemented and validated during the electric machines developments that have been performed during the project, in close collaborations with the industrial partners.

French consortium:

Vibratec, UFC-FEMTO-ST, U. Lille-L2EP, MMT Altair

Total funding: 951 k€

FEMTO-ST funding: 201 k€

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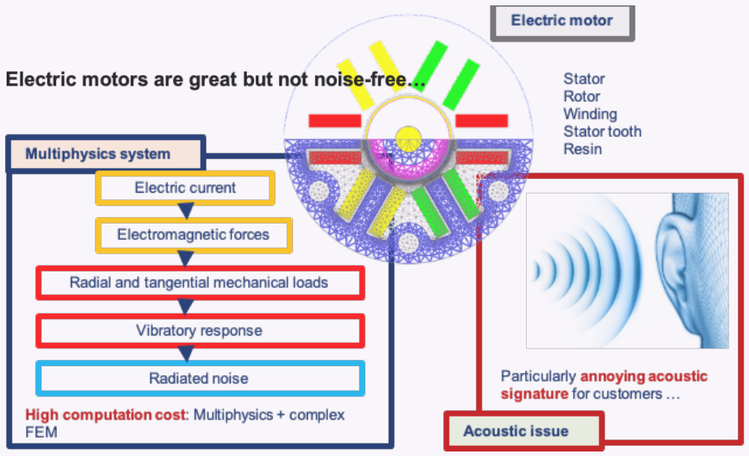

Patent

Programmable Modular 3D structures

R. Tribhout, J. Bourgeois, B. Piranda

DISC

Partners: University of Michigan

Patent application for Programmable micro-robot and assembly of such micro-robots forming a modular three-dimensional structure

Within the framework of the contract between the University of Franche-Comté and the University of Michigan, the OMNI team of DISC has filed a joint patent application reference FR2205640 on June 11, 2022, covering the technological bricks composing its interactive clay technology: a polyhedral box, a flexible electrode PCB, and its control unit.

Y. Peng et al., IEEE Symposium on VLSI Technology and Circuits (2022). www.doi.org/10.1109/VLSITechnologyandCir46769.2022.9830205

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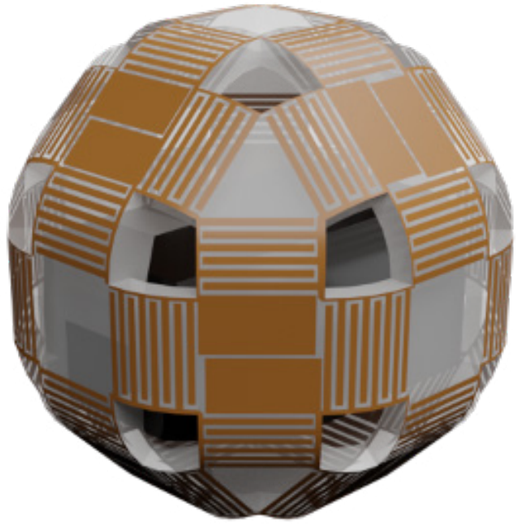

Render of a micro-robot of 3.6 mm diameter.

DGA Project CHRONOS

New Generation Atomic Clocks

R. Boudot, M. Abdel Hafiz

TIME & FREQUENCY

Partners:Thales, Syrlinks, SYRTE

The CHRONOS project, supported by DGA (Direction Générale de l’Armement) and combining the expertise of Thales (Coordinator), Syrlinks, SYRTE and FEMTO-ST, aims to the development of new-generation compact and high-performance industrial atomic clocks. These quantum clocks aim to offer excellent stability (error lower than 1 ns in tens of thousands of years) and will find various applications such as 5G network synchronization, transport or GNSS-denied navigation systems.

https://www.thalesgroup.com/en/worldwide/group/press_release/quantum-technologies-thales-and-syrlinks-develop-next-generation

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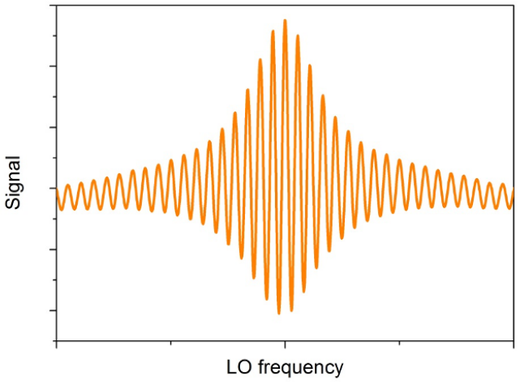


Clock resonance signal.

TRANSFER SUCCESS STORIES

IQUPHOS: High-Performance Entangled Photon Source

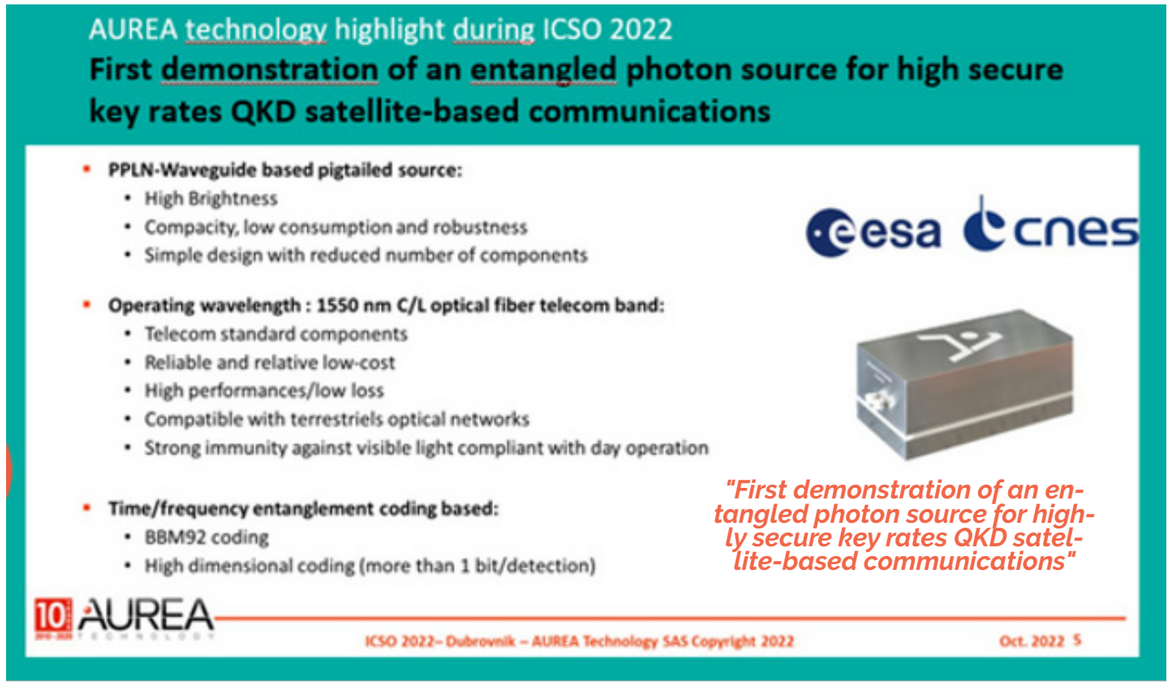
J.-M.. Merolla

OPTICS

AUREA technology and FEMTO-ST has a long-term interaction since 2012. This strong interaction is the result of a knowledge transfer strategy to develop compact and efficient single photon counting detectors. Since 2017, FEMTO-ST and Aurea Technology have strengthened their interaction to develop new building blocks dedicated to Quantum Information Network. The aim of the project IQUPHOS is to provide space components for future Euro Quantum Communication Infrastructure (Euro-QCI). In particular the project is focused on the implementation of high performances (compact, high brightness >1Gpairs/s) entangled photon sources (EPS) used for space to ground quantum key distribution (QKD). In addition a demonstration of a quantum key distribution on a distance compliant with Low Earth Orbit (60 dB of attenuation) and Geostationary Earth Orbit (70 dB) satellite will be realized. This activity is related to the Secure And cryptoGrAphic (SAGA) project under ARTES 4.0 programme (ESA's programme of Advanced Research in Telecommunications Systems - https://artes.esa.int/. The different partners involved are AUREA Technologie (Coordinator), Airbus Defense and Space ADS (France-Subcontractor) and FEMTO-ST (France).

www.aurea.com

jm.merolla@femto-st.fr



Amarob® company: Winner of the i-Lab 2022 National Competition

AS2M

Amarob®, a CNRS spin-off from the AS2M department of the FEMTO-ST institute, opens the way to a new generation of medical devices for a more precise, faster and less expensive intracorporeal laser surgery. 3 patents protect the innovations that Amarob can exclusively exploit. The founders are Professor Nicolas Andreff, professor in the AS2M department, Sergio Lescano - Amarob's CEO - who had done his thesis work in the same laboratory, and Tristan Davaille, a financial engineer. Amarob has been selected as a winner of the i-Lab 2022 national competition for innovative companies in the Deeptech sector. This award comes with a large financing that will allow accelerating the marketing of Amarob's flagship product, a revolutionary surgical laser scalpel. Amarob, which is already generating revenues, is developing at Temis-Innovation with a team of 6 people in strong growth.

https://amarob.com/

sergio.lescano@amarob.com

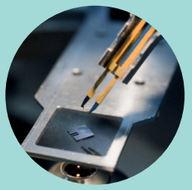
i-Lab Award Ceremony: Sylvie Retailleau (left) - Mrs Minister of Higher Education and Research (MESR) and Sergio Lescano (right) - CEO of AMAROB Technologies.

SCIENCE FOR SOCIETY

FEMTO-ST INSTITUTE FOSTERS RESEARCH AND INNOVATION TO ADDRESS THE SOCIETAL CHALLENGES

HEALTH AND WELL-BEING

- Therapy
- Diagnosis, screening and biological qualification
- Ethics and acceptability



CLEAN, SAFE & EFFICIENT ENERGY

- Hydrogen energy
- Energy harvesting
- Energy efficiency of systems

ENVIRONMENT

- Environmental sensors
- Geodesy
- Water and air treatment
- Vibration and noise protection
- Preservation of resources

INDUSTRY OF THE FUTURE

- New materials and processing
- Sensors and actuators
- Factory 4.0

INTELLIGENT SYSTEMS

- Artificial intelligence: distributed systems, diagnosis and prognosis
- Smart objects & complex systems
- Ethics

COMMUNICATION AND INFORMATION

- Ultra-localized optics
- Quantum technologies
- Telecommunication systems and materials

DEFENCE - SECURITY

- Network and software security
- Intelligent systems for defence

Fake News & the Infodemic

John M. Dudley

OPTICS/ UFC

On January 20, 2022, as part of the mission of the International Relations, Art, Culture and Scientific Communication Pole of the University of Franche-Comté, a conference was held at FEMTO-ST focusing on the theme of misinformation and fake news and the challenges they pose to society. Indeed, the COVID-19 health crisis as well as political events of the last few years have seen an explosion in the dissemination of fake news of all kinds, and this conference aimed to stimulate discussions on how the university and research communities can work to tackle this problem. In addition to talks by specialists who addressed diverse areas of current research in the field, a round table discussion considered the importance of science communication, and the need for clear guidelines aimed at the public so that they can combat fake news in their daily lives.

Email: john.dudley@femto-st.fr

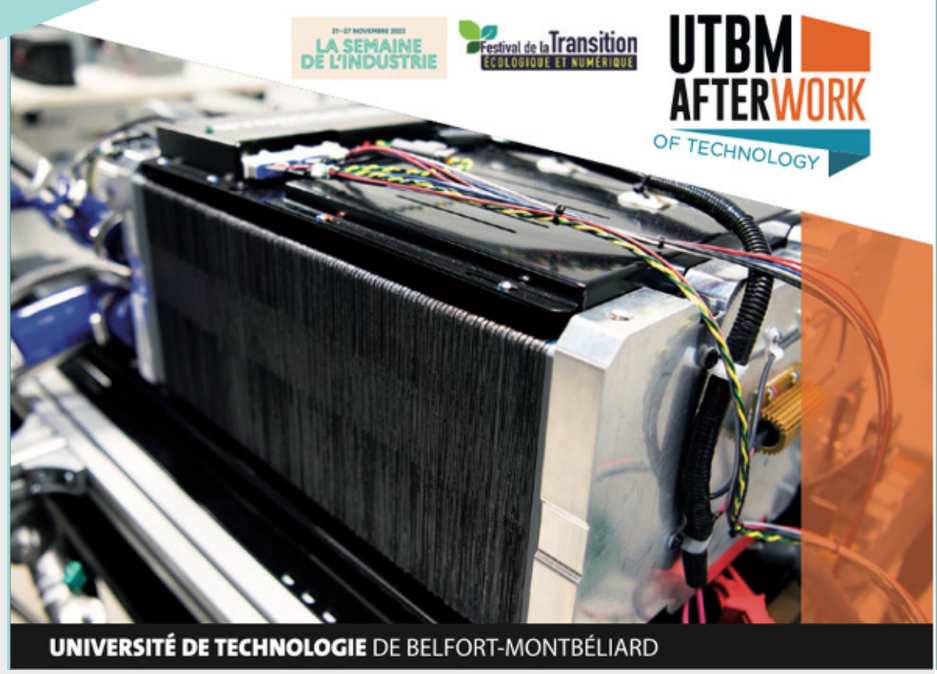
Website: https://events.femto-st.fr/Conference_Infodemie/fr

Students of Collège Gueux in teaching cleanroom at SupMicrotech-ENSMM
https://www.estrepublicain.fr/education/2022/05/30/

Visit of FEMTO-ST by middle school students

1 day stay including visits of experimental optical or biological benches spectacular holograms, lasers, bioengineering benches and first experiences in the clean room in order to promote scientific disciplines: chemistry, physics, biology and micro & nanotechnology.

HYDROGEN ENERGY



AFTERWORK: A history of fuel cells in France as part of Industry Week and the Festival of ecological and digital transitions

FCLAB & FEMTO-ST Open Doors Day

15 October 2022
150 visitors

CNRS year of BIOLOGY

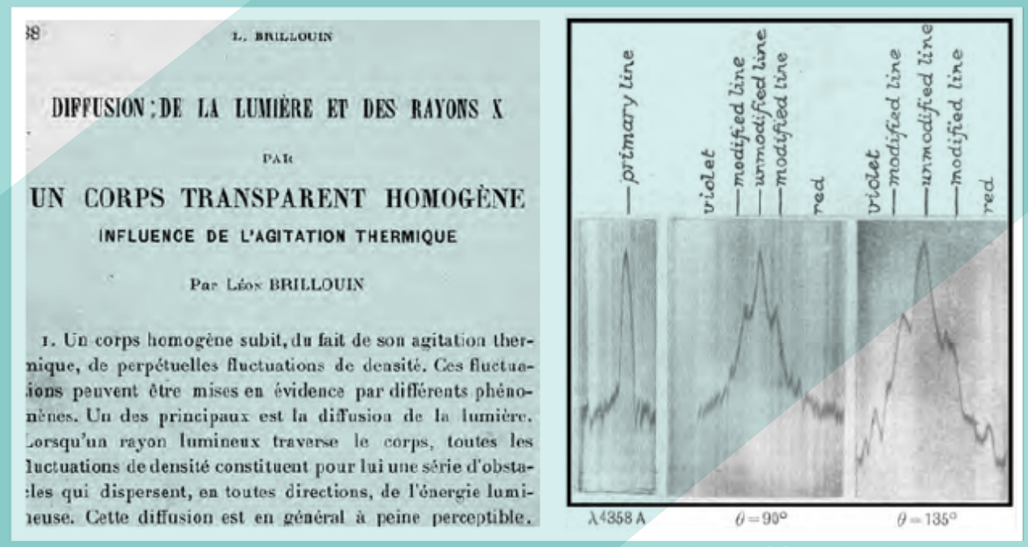
https://anneedelabiologie.cnrs.fr2021-2022 (cnrs.fr)

Annie Frelet Barrand, Wilfrid Boireau

MN2S / EFS Bioinnovation / Chrono-environnement

The Year of Biology brings together worlds of education and research to highlight major advances and challenges in biology research. In this context, we welcomed 35 teachers from secondary and high schools and BTS from the academy of Besançon at the institute. In the morning, they attended presentations on the themes of “Cognitive sciences” (Jean-Pierre Thibaut, UB), "When biology combines with engineering sciences for a better understanding of biological phenomena" (Annie FRELET-BARRAND) and "Impact of essential oils on antibiotic resistance" by Catherine LLANES, lecturer at Chrono-Environnement. The afternoon was devoted to visits of laboratories of bioengineering/bioproduction involved in the MiMédI project (MN2S department and EFS Bioinnovation) and in Chrono-Environment.

Email: annie.frelet-barrand@femto-st.fr



L. BRILLOUIN

DIFFUSION DE LA LUMIÈRE ET DES RAYONS X

PAR

UN CORPS TRANSPARENT HOMOGÈNE

INFLUENCE DE L'AGITATION THERMIQUE

Par Léon BRILLOUIN

1. Un corps homogène subit, du fait de son agitation thermique, de perpétuelles fluctuations de densité. Ces fluctuations peuvent être mises en évidence par différents phénomènes. Un des principaux est la diffusion de la lumière. Lorsqu'un rayon lumineux traverse le corps, toutes les fluctuations de densité constituent pour lui une série d'obstacles qui dispersent, en toutes directions, de l'énergie lumineuse. Cette diffusion est en général à peine perceptible.

On the left, a copy of the first page of the article published by Leon Brillouin in 1922 [1]. On the right, experimental verification of Brillouin scattering in benzene by E. Gross in 1930. Source [2], with permission ©Nature.

Focus on the centenary of the discovery of the Brillouin effect

Jean-Charles Beugnot

OPTICS

In 1922, Léon Brillouin published alone and in French, in the "Comptes Rendus de Physique" a paper on the scattering of light by acoustic waves coming from thermal fluctuations. He theoretically demonstrates that these acoustic waves induce a shift in frequency of the backscattered light. In sixties, the invention of lasers made this scattering very efficient and allowed many technological and industrial developments in materials spectroscopy, medical microscopy, lasers and distributed fiber optic sensors.

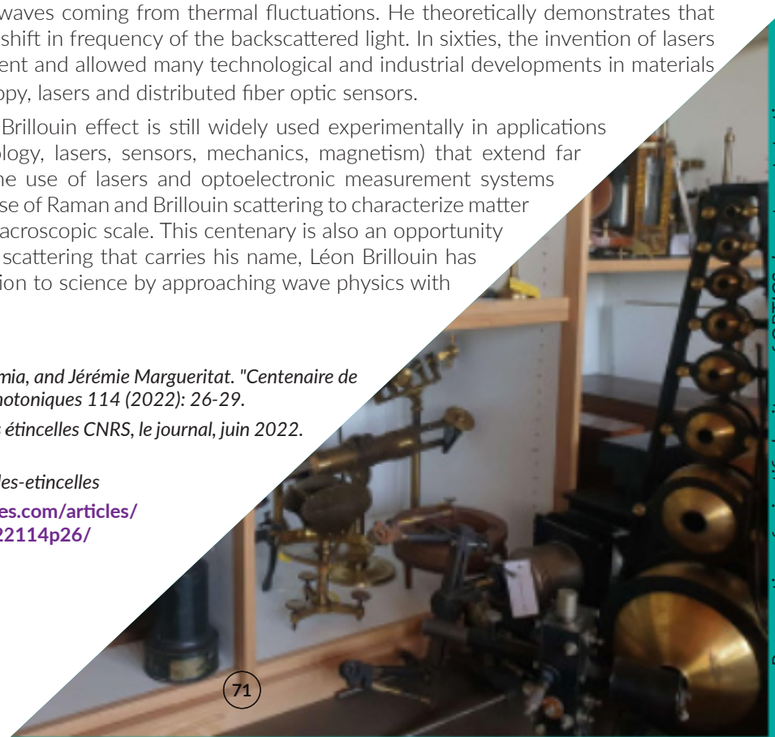
After one hundred years, the Brillouin effect is still widely used experimentally in applications spectroscopy, microscopy, biology, lasers, sensors, mechanics, magnetism) that extend far beyond condensed matter. The use of lasers and optoelectronic measurement systems allows today to consider joint use of Raman and Brillouin scattering to characterize matter from the microscopic to the macroscopic scale. This centenary is also an opportunity to remember that beyond the scattering that carries his name, Léon Brillouin has made an exceptional contribution to science by approaching wave physics with relevance and originality.

Jean-Charles Beugnot, Philippe Djemia, and Jérémie Margueritat. "Centenaire de la découverte de l'effet Brillouin." Photoniques 114 (2022): 26-29.

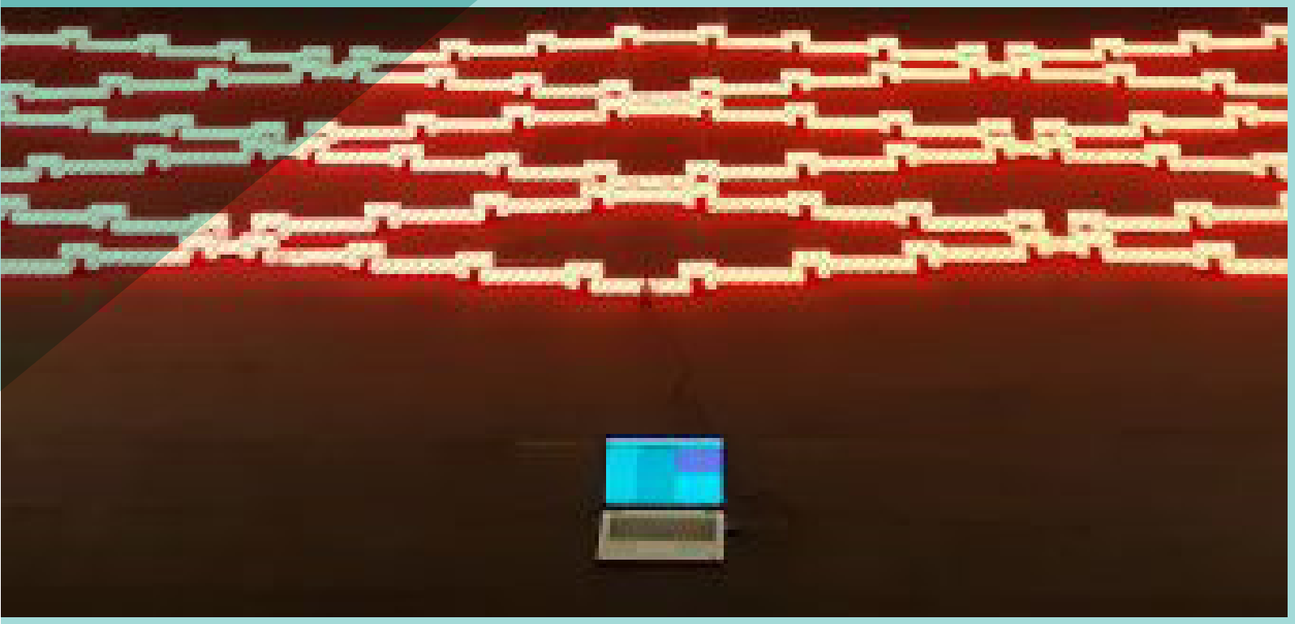
Quand le verre et la lumière font des étincelles CNRS, le journal, juin 2022.

https://lejournal.cnrs.fr/articles/quand-le-verre-et-la-lumiere-font-des-etincelles

Website: https://www.photoniques.com/articles/photon/abs/2022/03/photon2022114p26/photon2022114p26.html



Preservation of scientific heritage of OPTICS department starting from pioneering works of P.M. Duffieux
https://projects.femto-st.fr/patrimoine-scientifique/



PROGRAMMABLE MATTER

Guinness World Record : the largest number of autonomous light blocks assembled in a structure

Remy Tribhout

DISC

In 2022, FEMTO-ST research team got the record for the largest number of autonomous light blocks assembled in a structure approved by the "Guinness World Record". For more than 10 years, the Department of Computer Science and Complex Systems of the FEMTO-ST Institute (CNRS - UBFC - UFC - ENSMM - UTBM) in Montbéliard, has been working on the themes of distributed programming for modular systems. On August 27, 2021, the team of professors and researchers behind the modular robots "Blinky Blocks" will attempt to set the record for the largest number of autonomous light blocks assembled in a structure, i.e. 1824 modules in the category of the largest object in size.The communication between hundreds of independent modules highlights the progress made in the field of distributed programming for modular robotics, with the future goal of creating programmable matter. This record attempt is part of the art and science partnership between the artist couple Scenocosme, which is realizing the interactive structure in Blinky Blocks, the FEMTO-ST laboratory, and the theatre “MA scène nationale”, which is hosting the event in its digital stage on the campus in Montbéliard. To validate the record, Simon Hauser, PhD in modular robotics, graduated from EPFL, counted the quantity of individual blocks composing the structure, which light up autonomously, after receiving an external stimulation (finger tapping, sound, message from its neighbours). The dimensions of the structure are then recorded by Jean-Baptiste Rollin, an expert surveyor in Belfort, using a digital scanner. The whole process took place under the watchful eye of Samuel Gomes, mayor of Badevel. The Blinky Blocks are manufactured by the Tech Power Electronics group for the FEMTO-ST Institute. A block is made of two Lego-shaped plastic shells, screwed together. It contains magnets, a microcontroller, a microphone, a speaker, LEDs and pin connectors. The microcontroller is programmed by the Department of Computer Science and Complex Systems of the FEMTO-ST Institute.

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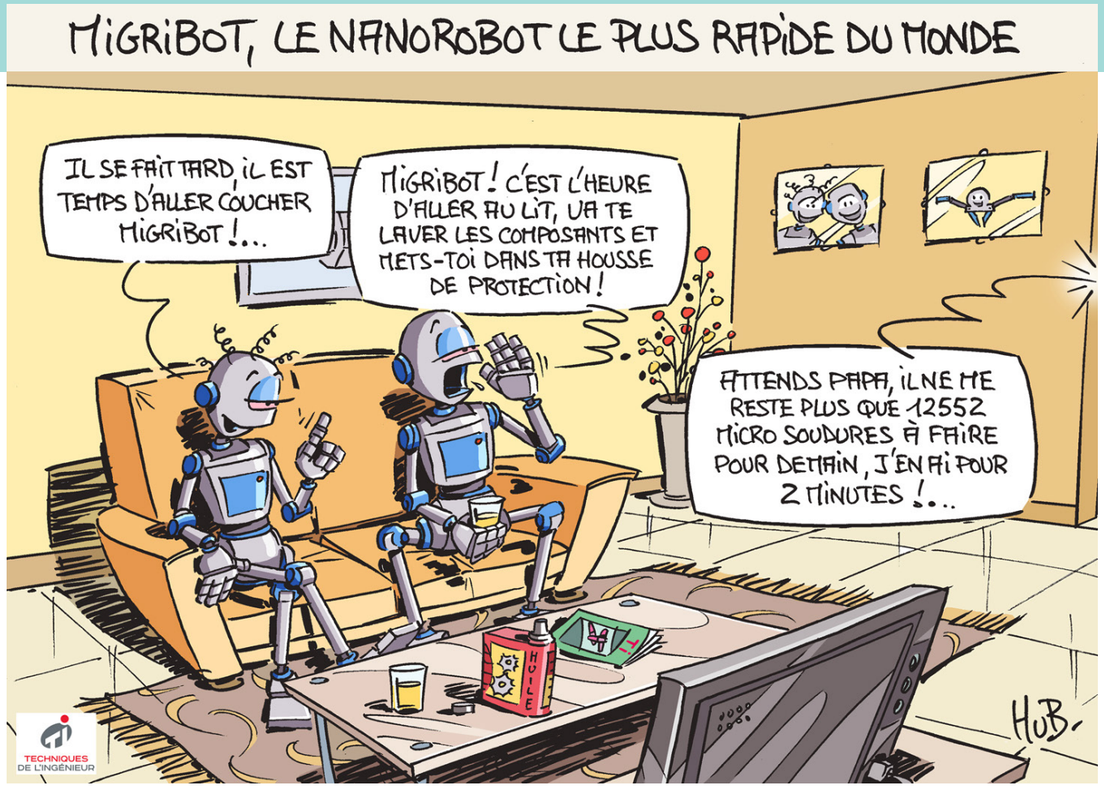
Migribot, the fastest nanorobot in the world

Maxence Leveziel, Wissem Haouas, Guillaume J. Laurent, Michaël Gauthier and Redwan Dahmouche

AS2M

The MiGriBot (Miniaturized Gripper Robot) nanorobot broke the world speed record in manipulating micro-objects although he initial objective of the French team behind this performance was miniaturization! These news were broadly communicated by national media:

- Journal of CNRS
- BFM TV BUSINESS
- France Culture on nanorobotics (1h)
- Innovations sectorielles, Techniques de l'ingénieur
- Another press and media services



By Hubert Blatz in Innovations sectorielles, Techniques de l'ingénieur

https://www.techniques-ingenieur.fr/actualite/articles/en-image-migribot-le-nanorobot-le-plus-rapide-du-monde-114047/

FEMTO-ST

IN FIGURES

760

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- 245 Professors & Associate Professors
- 36 CNRS Researchers
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- 48 Postdocs
- 70 Engineers/technicians

MORE THAN

100

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1 MICRO-NANO TECHNOLOGY CENTRE (CLEAN ROOM MIMENTO)

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ANNUAL BUDGET

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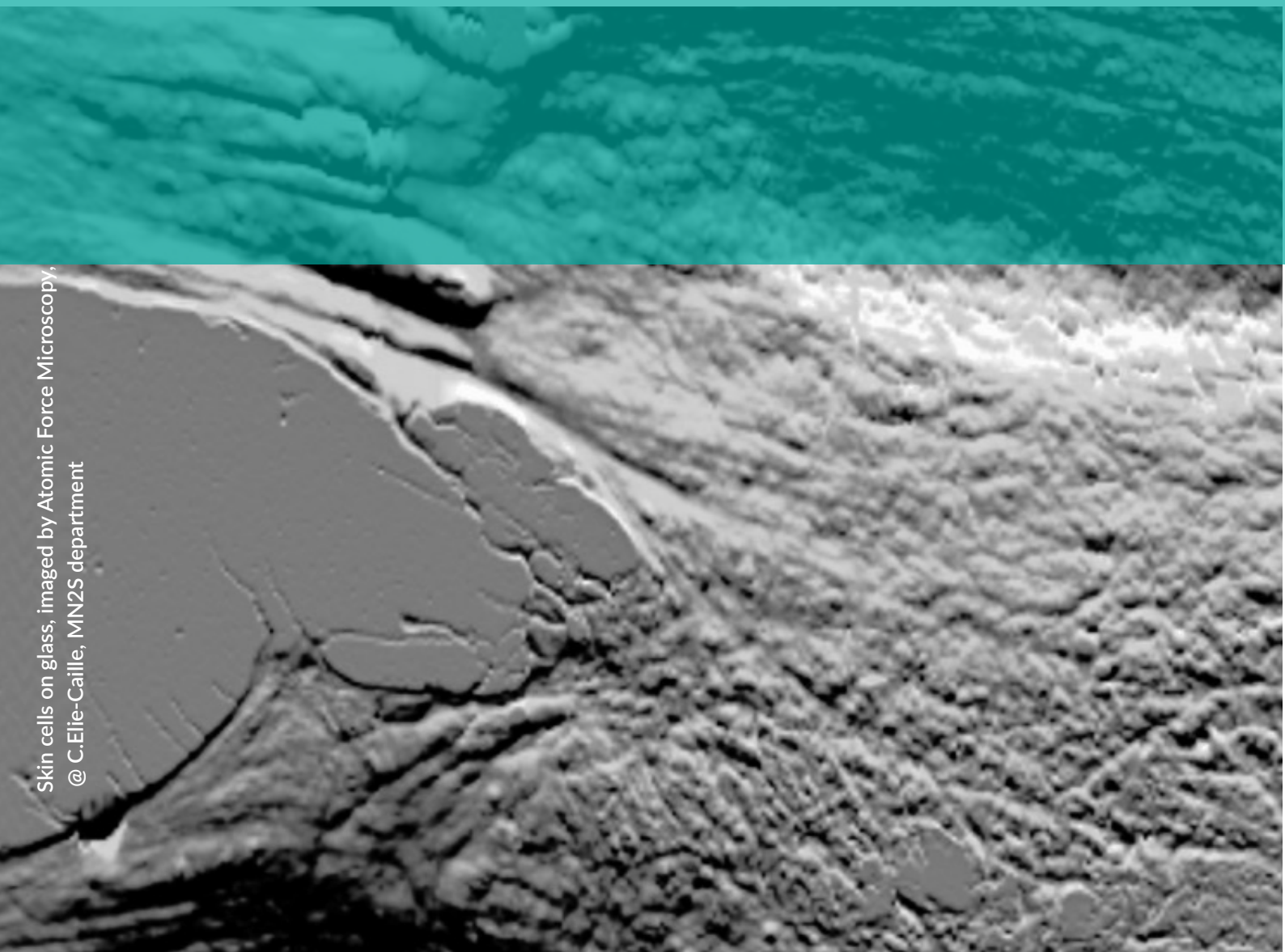

Skin cells on glass, imaged by Atomic Force Microscopy,
@ C.Elie-Caille, MN2S department