FEMTO-ST 2020 ANNUAL REPORT

femto-st SCIENCES & TECHNOLOGIES

FEMTO-ST, a joint Research Institute from :

FOREWORD

Exploring Science and Innovation, from basic research to industries and spin-offs, from theory to experiments through high technology facilities, developing micro and nanotechnologies, 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.

We hope that you will discover and enjoy some selected highlights from 2020 in this report. Despite the severe conditions we had had to face because of the pandemic we are proud to have maintained high quality, diversity and an intense level of research. I would like to dedicate this Annual Report to all our members who adapted to the conditions so that our academic achievements were sustained at a high level, making strong contributions to science, education and society.

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 approxomately 750 staff members (PhD students, postdoctoral fellows, technicians, engineers, administrative staff, researchers and professors). FEMTO-ST members are essentially employed by four different French public research and higher education institutions: the National Centre for Scientific Research (CNRS), the University of Franche-Comté, the National Engineering Institute of Mechanics and Microtechnology and the University of Technology Belfort-Montbéliard. The last three higher education institutions are brought together under the common banner of a unique federal regional university, University Bourgogne-Franche-Comté (UBFC).

I hope you will enjoy the 2020 annual Report, whether keeping up to date with our latest results and achievements, or discovering the wide range of our activities. You are welcome to join us in building fruitful future collaborative projects from fundamental research to industrial and social breakthroughs.

Laurent LARGER
Director of FEMTO-ST Institute
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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 organise 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, bio-compatibility

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

ENERGY

Hydrogen-energy

Electromagnetic converters

Thermal machines

Metrology and energy management

OPTICS

Nonlinear photonics

Complex optoelectronic systems

Nano-photonics

MICRO-NANOSCIENCES & SYSTEMS (MN2S)

MICRO- OPTO- ELECTRO-MECHANICAL SYSTEMS

Phononic and microscopy

Nanosciences and nano-structured materials

Bio-microsystems

RECITS

Research and Study on Industrial,

Technological and Societal evolutions

BIOM'@X

Science and technology:

Towards a technological translational medicine

CONTENTS

EDUCATION

GRADUATE SCHOOLS UBFC INTEGRATE

CREATION OF A JOINT UNIVERSITY RESEARCH SCHOOL, FOR GREATER CONTINUITY BETWEEN THE MASTER AND DOCTORAL PROGRAMS

Budget : 12 M€ over 7 years

University Bourgogne Franche-Comté (UBFC) offers integrated international master's-doctorate program supported by world-renowned laboratories and research teams and their partners. UBFC thus creates a highly competitive, state-of-the-art environment for PhD and Master students in science from around the world.

Joining the UBFC Graduate School ensures that Master students will be:

- integrated into a research team from the very first day of the first year of the Master program;
- involved in a curriculum that is compatible with other international programs, that promotes interdisciplinarity and that integrates project-oriented teaching practices, while relying on open labs and facilities;
- in direct contact with research teams, including doctoral students via tutoring;
- individually monitored (mentoring) to develop their professional network;
- supported for their international mobility project (internship, double degree, etc.);
- ambassadors for their training: tutors for undergraduate students in their field of study;
- trained in societal-economic issues through cross-disciplinary courses.

It ensures that doctoral students will:

- play an active role in a doctoral training program that is both enhanced and internationally oriented;
- be followed individually (mentoring) to develop their professional network;
- be supported for their international mobility project (European label, networking, etc.).

https://www.ubfc.fr/en/formations/ubfc-integrate-graduate-schools/

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UBFC Integrate includes 3 graduate schools:

EIPHI Graduate School
Physics, Mathematics, Applications / Intelligent Systems and Structures / Energy / Materials Science / Computer Science

TRANSBIO Graduate School
Social-ecological transition / Sustainable territories, complexity and transition processes / "Livelisystem" and environmental transformation processes, agro-ecology / Innovation within integrated food chains, production and behaviour

INTHERAPI Graduate School
Individualized and integrated care / Health / Innovative intelligent systems technologies / Cognitive sciences / Humanities and social sciences

Engineering and Innovation through Physical Sciences, High-technologies, and crossdIsciplinary research

EIPHI graduate school

University Bourgogne Franche-Comté - France

- 5 outstanding Research Areas
- Worldclass Research labs
- Close connection with industry
- Broad mobility opportunities
- Tutoring and mentoring
- Scholarships

Coordinated by:
Hervé Maillotte (FEMTO-ST) - Stéphane Guerin (ICB)

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Master/PhD in 5 Research Areas

- PHYSICS, MATHEMATICS and APPLICATIONS
- ENERGY
- COMPUTER SCIENCE
- SMART SYSTEMS & STRUCTURES
- MATERIAL SCIENCE

FRENCH + SCIENCE

Shakiba Dowlati, Marc Prudhomme, Yakini Tchouka, Sudnya Vaidya, Martina. Daniel Brunner

APPLIED MECHANICS, MN2S, OPTICS, DISC, ENERGY, TIME&FREQUENCY

The UBFC Graduate School EIPHI and the Center for Applied Linguistics (CLA) of the University of Franche-Comté in Besançon has collaborated to provide a program of French + Sciences in Besançon, Dijon and Belfort. The program will be offering language, cultural and scientific immersion focus on micro and nanotechnology for industrial applications. Designed for English-speaking students, the program includes classes in French as foreign language from A1 to B2 level, meetings with researchers, visit to the research institutes FEMTO-ST, ICB and IMB organized by PhD students as part of their science popularization mission and a wide range of excursions and cultural activities.

The scientific topics covered for the 2021 edition are Smart & Green Mechanics, Challenges of Micro & Nano systems, Nano-optics: from chameleon colors to quantum technologies, Non linear Fiber Optics, Neural Networks & Quantum Computing, Artificial Intelligence & Complex Systems, Green Energy for Mobility, New Material for a Green Planet, Quantum Physics & Technologies, Mathematics for Applied Physics : An application in Health Science, Innovative Drugs & Nano-technologies and Time-Frequency Metrology & Quantum Physics.

https://gradschool.eiphi.ubfc.fr/?page_id=3100

CHALLENGE M³

Emmanuel Piat, Nadine Piat, Gaël Chevallier, Yong Xin Wu

APPLIED MECHANICS, AS2M

The UBFC Graduate School EIPHI this year supports the challenge M³ (Mechanics, Mechatronics, Microtechnology) proposed by three start-ups in its different fields of expertise:

- the development of an electromagnet to recover catalytic nanoparticles (https://www.linkedin.com/company/son-sas/),
- the study of a mechanism generating power from environmental vibrations for ST Microelectronics (https://www.linkedin.com/company/stmicroelectronics/),
- the optimization of a driving system for a motorized wheelchair (https://www.linkedin.com/company/unimotion/).

5 Master students will work for 6 months an will bring the expertise of FEMTO-ST, ICB, and IMB laboratories to the industry.

The objectives of the M³ challenge is to promote the mechatronic and the microsystems in Bourgogne-Franche-Comté as well as to support the innovation in that domain. For that EIPHI finances Master 2 internships for start-ups, researchers or even students having an innovative project.

This challenge lasts over an academic year. During the first semester, students are initiated to the topic and interact with the project leader. The second semester they start to work full time in a team during their Master 2 internship.

https://gradschool.eiphi.ubfc.fr/?page_id=2575

EDUCATION HIGHLIGHTS

VIPER DOCTORIALS - FINAL DEFENCES OF THE PHD CANDIDATES

Morvan Ouisse, Noureddine Bouhaddi, Emeline Sadoulet-Reboul, Emmanuel Foltête, Abdelkrim Khelif

APPLIED MECHANICS

VIPER was a European Joint Doctorate on Vibroacoustics (H2020-MSCA-ITN-EJD EU Project 675441, 2016-2020). It aimed at consolidating academic research dealing with VIbroacoustics of PERiodic media and train future researchers in the topic.

Scientifically speaking, the main goal was to develop and to validate tools for the design of global vibroacoustic treatments based on periodic patterns allowing passive control of vibration and acoustic paths in layered concepts. This was achieved by addressing in-depth structural periodicity and stiffness as well as absorption attributes. The proposed concepts have ensured a significant improvement of vibroacoustic performance in a wide frequency range. Questions about uncertainty, due to the lack of perfect periodicity whether desired or not, were also investigated this being quite an important issue in view of the manufacturing aspects of engineering applications of periodic media.

In this training network grants have been made for 11 Early-Stage Researchers, all jointly advised by 2 of the 5 Universities in the project (Ecole Centrale de Lyon – FR, University of Bristol – UK, KU Leuven – BE, Univ. Bourgogne Franche-Comté – FR, Università di Napoli Federico II – IT). Among the significant training activities organized in the projects, 5 thematic schools have been open to all attendants, and a closing event, untitled VIPER Doctorials, was organized so that eight of the PhD VIPER defences could take place in Napoli on 20th February 2020.

Four of them were co-advised by members of FEMTO-ST:

Marc-Antoine Campana - Periodic inserts in auxetic media for a vibroacoustic control (with University of Bristol)

Dario Magliacano - Vibroacoustics of Porous Media with Periodic Inclusions (with Università di Napoli Federico II)

Simone Del Broccolo - Sandwich panel periodic cell topology effects (with University of Bristol)

Safiullah Timorian - Investigation for the Analysis of the Vibrations of Quasi-periodic Structures (with Università di Napoli Federico II)

http://viper.ec-lyon.fr

Reference

S. De Rosa et al., Mech. Systems Signal Process. 142, 106870 (2020).

VIPER doctorials: 8 PhD defenses took place in Napoli on Feb. 20th, 2020

ARCLAB PILOT PROJECT: JOBS 4.0 IN THE FRENCH-SWISS JURA ARC

Nathalie Kroichvili

RECITS

The ArcLab project (Analysis and Prospects for territorial innovation in the cross-border Swiss-French Jura Arc) originated in a more general INTERREG project named the Community of Knowledge, aiming at structuring a French-Swiss network of seven graduate and postgraduate schools and their research laboratories in the Jura Arc (www.communautedusavoir.org).

Together with a research partner in Switzerland (Institut de Sociologie-GRET-Université de Neuchâtel), RECITS was in charge of the implementation of a pilot project related to employment in an era of increasing digitalisation in the Jura Arc region. It consisted in designing an innovative method so that teachers and researchers belonging to several scientific fields from the Community of Knowledge as well as economic, public and social actors from the Jura Arc, can interact on the issue. Together they proposed relevant jobs 4.0 for the region and identified drivers and obstacles to their emergence. Two motion designs (one for the method, one for results) were produced and are available on the website of the Community of Knowledge. The method and results can further be used and developed for students' training and citizens' participation in public life.

www.communautedusavoir.org

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OPEN MATLAB PLATFORMS FOR STRUCTURAL DYNAMICS TEACHING

Betty Auzaneau, Morvan Ouisse, Emmanuel Foltête, Gaël Chevallier

APPLIED MECHANICS

Two software tools for teaching structural dynamics have been developed and provided for training with students. The first one, intended for the 3rd year Bachelor students and the 1st year Master students, is dedicated to numerical analysis of vibrations of lumped systems: eigenmode calculations, animation of real and complex eigenvectors, computation of time and frequency responses, graphic representation of solutions. This tool, used as a support during applications carried out during teaching sessions, allows students to overcome calculation difficulties and to concentrate on understanding and interpreting physical phenomena.

The second one, intended for 2nd year Master level students, enables acquisition and processing of vibration (and acoustic) measurement signals, based on NI modular systems, that can be adapted to each structure to be characterized. These tools can be used at different levels, from a basic approach for the students new to the topic, thanks to ergonomic graphical interfaces, up to advanced uses thanks to the availability of source codes giving an understanding of the underlying methods and implementing changes or new methods in the open code. Students from ENSMM, UFC, and EIPHI Graduate school are now using these tools.

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Presentation of the ArcLab pilot project at the UTBM Innovation Crunch Time May 2018 (intermediary results)

NATIONAL SCHOOL ANF MINAPHOTON « MICRO- AND NANO-FABRICATION OF PHOTONIC DEVICES"

Ausrine Bartasyte, Samuel Margueron

TIME & FREQUENCY/MIMENTO

National school ANF MiNaPhoton , supported by CNRS, national CMDO+ network (http://cmdo.cnrs.fr), and the Graduate School EIPHI (https://gradschool.eiphi.ubfc.fr), was held November 30-December 2, 2020 at FEMTO-ST Institute in Besançon. The aims of this school were:

- to share our knowledge in chemistry, materials science, microfabrication and physics in order to support multidisciplinary approaches in photonic device development;

- to present and to practice different methods of microfabrication and heterogeneous integration.

The school program consisted of 9 hours of lectures and 7 practicals of 3 hours in small groups of 2-4 persons (each participant could choose 3 different practicals, in total practicals were given for 16 groups), given by engineers and scientists from SOITEC company, FEMTO-ST, C2N, and LAAS Institutes. Most of the practicals took place in the MIMENTO cleanroom, belonging to the French Renatech Network. Due to sanitary conditions the participation in person was limited to 12 people and the possibility of following lectures online was given for 45 participants by using Microsoft Teams platform. The participants were from all over France (Paris, Marseille, Nice, Grenoble, Dijon, Nancy, Rennes, Troyes, Strasbourg, etc.). The MiNaPhoton school was a great success and we hope to get a financial support for future events.

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TRAINING SCHOOL "KNOWLEDGE TRANSFER, PATENTING & COMMERCIALISATION"

Ausrine Bartasyte (FEMTO-ST), Simon Yarwood (Knowledge Transfer Network, UK)

TIME & FREQUENCY

In the frame of european ITN ENHANCE Project, the training school "Knowledge Transfer, Patenting & Commercialisation" was organized in collaboration between FEMTO-ST Institute and Knowledge Transfer Network (KTN, UK). This event, dedicated to PhD students and early stage researchers (70 participants from different European countries) was held online by using Zoom and streamed via webcast across two mornings to look at how research ideas can be turned into business opportunities. There were a number of talks including funding innovation in industry, protecting your IP and the case study of an Energy Harvesting company that has been along that route themselves.

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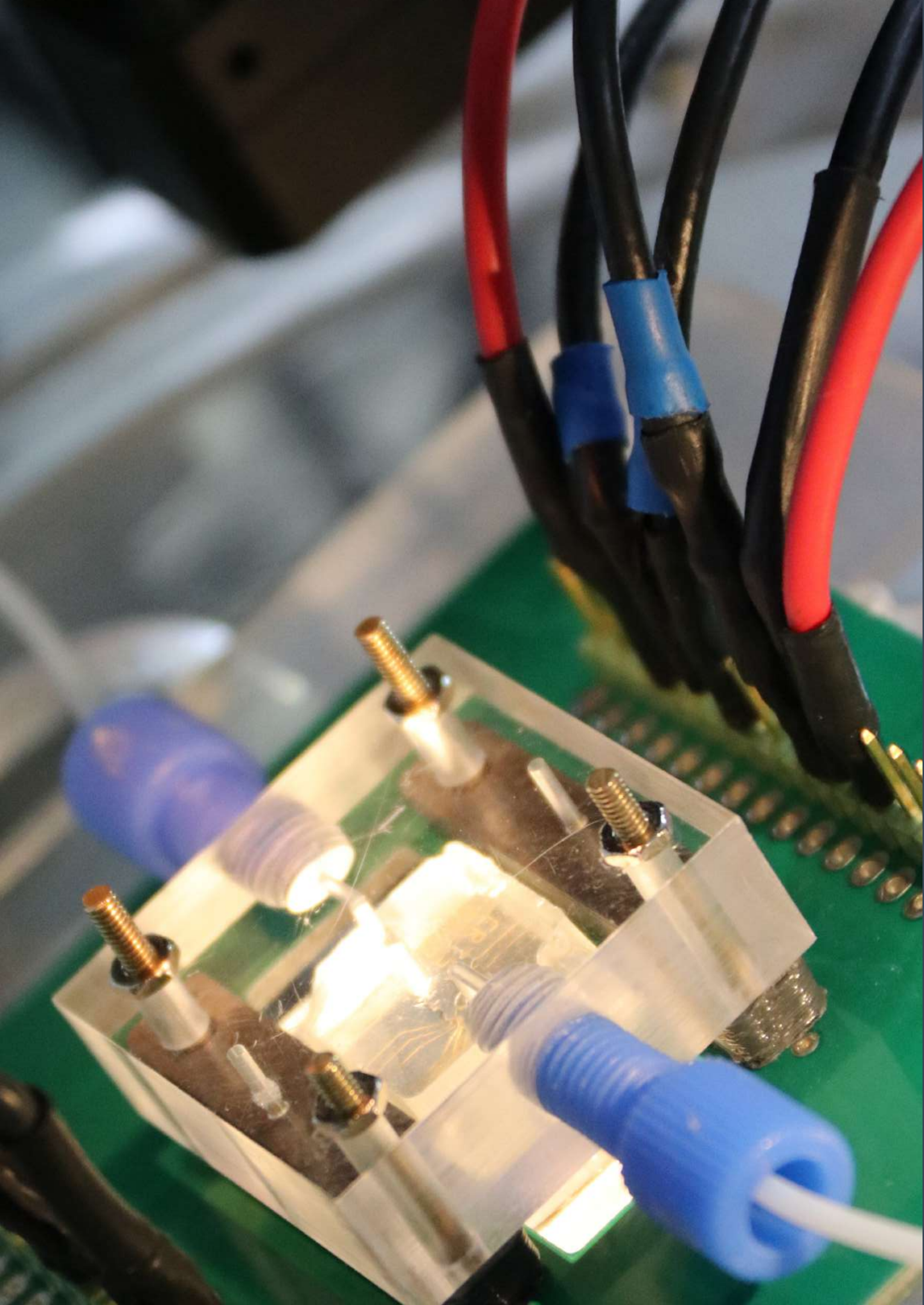

RESEARCH

DANIEL HISSEL

CNRS INNOVATION MEDAL

ENERGY

The CNRS medal of innovation honors exceptional research that led to striking technological, therapeutic, or social innovation, thereby enhancing French scientific research. The jury awards between one and five medals each year. The winning researchers or engineers can be CNRS members, but can also come from other research organizations, universities, higher-education institutions, and companies involved in research.

Prof. Daniel Hissel obtained a PhD from the Institut National Polytechnique de Toulouse, France, in 1998. He is a Full Professor at the University of Franche-Comté. He is the Head of the "Electric Actuators, Hybrid & Fuel Cell Systems" research team in FEMTO-ST. His main research activities are concerning hydrogen-based systems dedicated to automotive and stationary applications. Between 2012 and 2019, he has been the founding Director of the FCLAB Research Federation (CNRS). Since 2020, he is the Deputy Director of the French national hydrogen research federation (CNRS). He has been awarded by the Blondel Medal in 2017 for his work towards industrialisation of fuel cell systems.

Daniel Hissel was among the first researchers conducting research, at system level, on real-time diagnosis of fuel cell systems. In particular, he successfully combines his expertise in artificial intelligence and knowledge in fuel cell systems behaviour to develop robust models, new approaches for diagnosis and prognostic of fuel cell systems under actual operating conditions, and efficient real-time control laws for hybrid hydrogen-based devices devoted to transport and stationary applications. This work has led to major academic and industrial partnerships and also to the establishment of a spin-off company, H2SYS, devoted to the development of hydrogen-based hybrid power gensets.

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LAURENT LARGER

2021 DOUBLE OSA & IEEE FELLOW ELEVATION

OPTICS

Laurent Larger was independently elevated to Fellow member by two societies: In the field of Optics (OSA: "for pioneering studies of nonlinear dynamics in optoelectronics, and the development of novel architectures for photonic artificial intelligence") and in the field of Engineering Sciences (IEEE, Photonic Society: "for contributions to optoelectronic delay oscillators and neuromorphic processing applications").

Laurent Larger received his PhD degree at University of Franche-Comté (UFC) in 1997, after having studied in Strasbourg and Paris and worked as an R&D engineer in the Black Forest Region, Germany. In 1997 he was a Physics lecturer at the University of Nîmes, and became assistant professor at UFC in 1998. From 1998 to 2005 he was involved in Metz in a joint US-French laboratory, which he was heading from 2002 to 2005 as a joint faculty of GeorgiaTech Atlanta. He received his accreditation to supervise research (habilitation) degree in 2002 from UFC, where he became Associate Professor in 2005 and full Professor in 2009. He has been the director of FEMTO-ST since April 2016.

As an experimental physicist in photonics, Laurent Larger has always been fascinated by both the fundamental and applied aspects of a particular class of dynamical systems modelled by nonlinear delay differential equations. Most of his research has been using an experimental test-bench known as the optoelectronic delay oscillator. He explored many of its numerous complex solutions and instability issues, developing at the same time with the same setup, advanced signal processing and generation techniques, such as optical cryptography using chaos, ultra-high spectral purity microwaves for radar applications, and nonlinear transients in an infinite dimensional phase space serving as a brain-inspired processor.

References

L. Larger et al., IEEE J. Quantum Electronics 34 (4), 594 (1998).

A. Argyris et al., Nature 438, 343 (2005).

L. Larger et al., Physical Review X 7, 011015 (2017).

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JOHN DUDLEY

2020 OSA R.W. WOOD PRIZE

OPTICS

The Optical Society of America (OSA) honoured John Dudley with its R.W. Wood Prize in recognition of his fundamental contributions to the physics of supercontinuum generation, which has opened the way to practical high-power broadband light sources and their numerous applications.

The R.W. Wood Prize recognizes an outstanding discovery or invention in the field of optics, as measured chiefly by its impact in opening new areas of research. Dudley's work on supercontinuum generation began as the result of a fortuitous experimental discovery made in 2001, a year after his appointment at the Université de Franche-Comté, and rapidly developed into a major theme of research internationally. In addition to its direct applications in nonlinear optics, supercontinuum generation has found applications in areas of frequency measurement, biomedical imaging, and in interdisciplinary studies of extreme events and rogue waves. His studies on supercontinuum generation has also motivated parallel research at FEMTO-ST developing new measurement techniques to characterize complex pulse propagation in nonlinear fiber optics.

As well as the R. W. Wood Prize, 2020 also saw two other international distinctions for John Dudley. He was elevated as a Fellow of the International Society for Optics and Photonics SPIE, and elected as an Honorary Fellow of the Royal Society of New Zealand. These Fellowships were awarded to recognize both Dudley's research achievements, as well as his many years of service promoting international educational initiatives and public engagement with science.

https://www.osa.org
https://www.spie.org
https://www.royalsociety.org.nz
https://members.femto-st.fr/john-dudley/en

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BRUNO WACOGNE

BEST PAPER AT BIODEVICES 2020

MN2S

Best Paper Award in the international congress BIODEVICES 2020 has nominated B. Wacogne for the program co-chair of the 2021 edition.

Bruno Wacogne is a CNRS Research Director at the FEMTO-ST Institute. In 2010, he applied and has been awarded a Translational Research Fellow position from the National AVIESAN Alliance. This supplementary position allows him to be at the interface between the health activities at the FEMTO-ST Institute and the Clinical Investigation Center at Besançon University Hospital where he is the technological supervisor of the institution and the head of "Microsystems and biological qualification" unit. His research interests concern translational research, science and technology for health and more precisely immuno-combined medical devices, biological qualification devices and biomedical optics.

Fabrication of ATMPs (Advanced Therapy Medicinal Products) takes place in clean and sterile environment and is extremely expensive. Quality controls are performed throughout the process to monitor cell growth and to detect contaminations. Drawbacks are a delayed result and an added risk of contaminations while sampling. He with collaborators have reported a real time optical spectroscopy method used to monitor the cell growth and rapidly alert users in case of contamination. This allows stopping the fabrication as soon as a problem arises leading to several tens of thousand dollars savings. Many more patients will then benefit from the use of ATMPs.

References

B. Wacogne et al., BIOSTEC, 64 (2020).

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AWARDS

FEI GAO

IEEE J. DAVID IRWIN EARLY CAREER AWARD

ENERGY

To recognize a young researcher who has made significant contributions to the advancement of the field of industrial electronics, the award is selected based on the technical importance of the contribution, subject matter, originality, and prospects for future success.

Fei Gao is a Full Professor at the University of Technology of Belfort-Montbeliard (UTBM) and the Deputy Director of FEMTO-ST institute. He received from UTBM the PhD degree in renewable energy with the distinguished Youth Doctor Award in 2010. His main research fields include fuel cells and their applications in transportation, multi-physical modeling and real time simulation systems. He is a Fellow of IET, the Editor-in-Chief of IEEE Industrial Electronics Technology News, the Assistant Deputy Editor-in-Chief of IEEE Transactions on Transportation Electrification, and an Associate Editor of 4 other IEEE Transactions journals. He currently serves as Conferences Committee Chair of the IEEE Transportation Electrification Community, and Vice-Chair of the Technical Committee on Vehicle and Transportation Systems of IEEE Power Electronics Society.

One distinctive contribution of Prof. Gao is the development of a novel modeling approach of power converters and energy sources for nanosecond time-step real-time simulation using FPGA technology. Prof. Gao has pioneered a new hardware design structure of FPGA and has achieved a 5 nanoseconds real-time waveform resolution for a fuel cell vehicle boost-inverter DC-AC powertrain model, which is a ground-breaking record in the literature world-wide. Another distinctive contribution of Prof. Gao is in the development of a new fault-tolerant fuel cell powertrain topology with an online diagnostic model, which allows power redundancy for increased safety, while keeping cost down.

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NICOLAS SIMONCINI:

2020 TURRIANO ICOHTEC PRIZE

RECITS

The Turriano ICOHTEC Prize is an Early Career Prize for Books on the history of technology, sponsored by the Juanelo Turriano Foundation and the ICOHTEC (International Committee for the History of Technology).

Associate professor in Science and Technology Studies at the UTBM (University of Technology of Belfort-Montbéliard), Nicolas Simoncini is part of the transversal axis FEMTO-ST/RECITS and of SHARPAC group (Energy Department at FEMTO-ST). His work focuses on the history and sociology of fuel cells and hydrogen, as well as on the intervention of Human and Social Sciences in design and technological research.

Nicolas Simoncini received the Turriano Prize for his doctoral thesis which analyses the techno-scientific, economic and political context of the production and implementation of fuel cells in France from the 1960s to the 1980s.

References

N. Simoncini "History of Fuel Cell Research in France from the 1960s to the 1980s", PhD Thesis, University of Technology of Belfort- Montbéliard (2018).

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SCOTT COGAN

D.J. DEMICHELE AWARD, SOCIETY OF EXPERIMENTAL MECHANICS

APPLIED MECHANICS

This award, established in 1990 in honor of Dominick J. DeMichele (1916-2000), recognizes an individual who has demonstrated "exemplary service and support of promoting the science and educational aspects of modal analysis technology" (see https://sem.org/awardsdemichele). This award is presented annually at the International Modal Analysis Conference.

Scott Cogan received his Bachelor's and Master's degrees in Mechanical Engineering from the University of Michigan in 1984 and 1985. He went on to obtain his PhD in 1990 from the University of Franche-Comté in Besançon, France under the direction of Professor Gérard Lallement. Scott Cogan has been a research fellow with the French National Center for Scientific Research (CNRS) since 1991 and is currently director of the Model Validation and Uncertainty Quantification group at the Department of Applied Mechanics of the FEMTO-ST Institute, University Bourgogne Franche-Comté.

Scott's research interests focus on model validation and robust decision-making under a lack of knowledge. He has co-advised 35 PhDs and has participated in over 40 national and international research projects with academic (Technion-Israel, Los Alamos National Laboratories-USA, University of Liege-Belgium, University of Liverpool-UK, Clemson University-USA) and industrial partners (PSA, Renault, EDF, SAFRAN, ARIANE GROUP, ALSTOM, CNES, and the Paris Philharmonic). Scott has coauthored 40 articles in peer-reviewed journals and over 200 technical articles and reports. He also develops dedicated MATLAB-based software tools to facilitate the transfer of promising research developments to an industrial environment for real-world applications.

References

https://www.femto-st.fr/fr/Departements-de-recherche/MECANIQUE-APPLIQUEE/Themes-de-recherche/V3MQI

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AUDE BOLOPION

NOMINATION TO THE BIG-ON-SMALL AWARD 2022

AS2M

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 microrobotics. It promotes upcoming talents in these research communities and targets young professionals with excellent performance and international visibility. Due to the pandemic crisis, the final decision of selecting the award recipient among the five nominees will be made public in the next MARSS conference, to be held in 2022.

CNRS researcher since 2011 at the FEMTO-ST Institute she received a Ph.D. degree in robotics in 2010 from the University Pierre et Marie Curie, Paris, and the 'Habilitation à Diriger des Recherches' diploma from University Bourgogne Franche-Comté 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), ULB (Belgium) and CTU (Czech Republic), and national groups including ISIR (Paris) and EFS (Besançon).

At the micrometer scale, the classical approach consists in using tips or microgrippers to manipulate objects. However, it necessitates a physical link to the power and to control the tools. Her work focuses on an original approach using remotely induced force fields to control microscopic objects from a distance. With the phD students, post-doc, engineers and internship students of her team she 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 the air/liquid interface based on convection flows induced by thermocapillary effects.

References

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

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AWARDS

MENGJIA WANG

CHINESE GOVERNMENT AWARD 2020

OPTICS / MN2S

As a PhD student of the Optics Department of FEMTO-ST, Mengjia Wang has been recognized by the Chinese Government for his outstanding work in the field of nanophotonics and plasmonics.

This prize, established by the China Scholarship Council in 2003, is intended to reward outstanding graduate students studying outside China. The government yearly chooses 500 recipients based on a record of significant accomplishments in any discipline. This award is the highest award the government gives to graduate students studying outside China. The number of Chinese students leaving China to study abroad is more than half a million each year, making this award highly competitive.

In his PhD, Mengjia Wang demonstrated optical spin-orbit interaction for steering Bloch surface waves with the magnetic field of light [1] (CNRS release: https://insis.cnrs.fr/en/node/1020) and for reaching new degrees of freedom in light polarization control by twisting surface plasmons in individual and coupled plasmonic helical nanoantennas [2,3] (CNRS release: https://www.insis.cnrs.fr/fr/cnrsinfo/polariser-la-lumiere-tres-petite-echelle-grace-aux-vortex-plasmoniques).

References

[1] M. Wang et al., Light: Sci. Appl. 7, 24 (2018).

[2] M. Wang et al., Light: Sci. Appl. 8, 76 (2019).

[3] M. Wang et al., Opt. Lett. 44, 19 (2019).

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MAYA GEAGEA

2019 I-PHD INNOVATION AWARD

MN2S

To meet the great challenge of doubling the number of "Deep tech" start-ups companies in France, the Ministry of Higher Education, Research and Innovation, in partnership with Bpifrance, has launched the i-PhD Innovation Award in 2019. This award honors young scientists that have been leading entrepreneurial research projects relying on disruptive technological innovation.

Maya Geagea holds an MSc degree in Nanotechnology from the Université de Bourgogne and received a PhD degree in Material Science from MINES Paris-Tech in 2017. Her PhD work was mainly dedicated to investigating the impact of the exchange surfaces on the overall performance of solid oxide fuel cells. She joined FEMTO-ST in 2018, where she put her expertise into use in the context of the ANIOPAC innovation project, funded by the SATT SAYENS, under the guidance of Bernard Gauthier-Manuel, CNRS research scientist at FEMTO-ST.

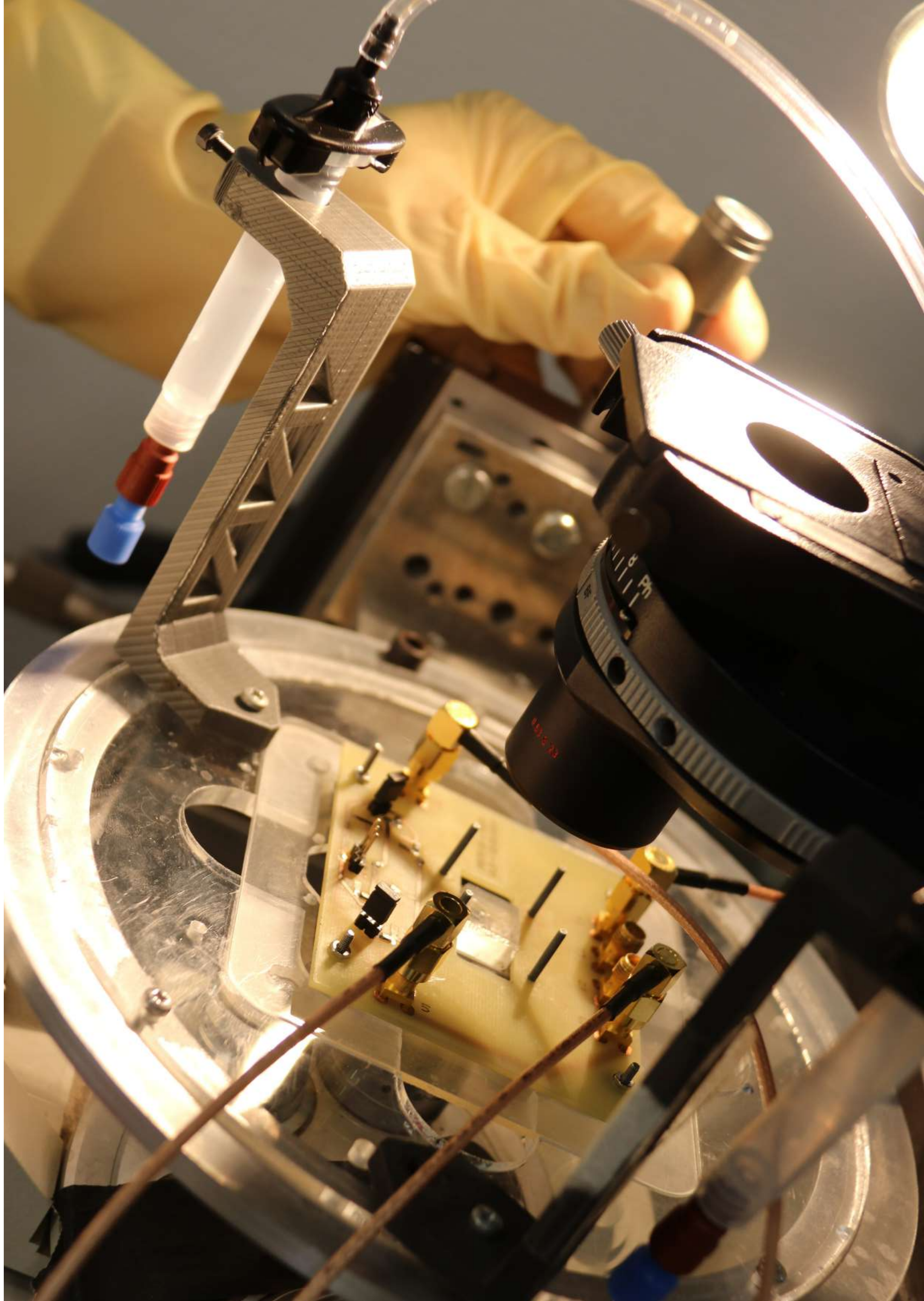
The ANIOPAC project aimed at the development of a new hydrogen fuel cell technology powered by its own integrated hydrogen production system. The fuel cell operates in anionic mode and allows to replacement of platinum, a rare metal used as catalyst, by nickel, hence preserving the natural resources of our planet. This small size energy source is intended to power nomadic wireless devices (laptops, smart cards, sensors, etc.). The miniature fuel cells developed are made from silicon and machined using micro-manufacturing processes that are easily transposable and low cost. The project led to fuel cell prototypes successfully achieving TRL 4.

References

https://www.enseignementsup-recherche.gouv.fr

Facility: MIMENTO

maya_geagea@hotmail.com, bernard.gauthier@femto-st.fr



NEW MEMBERS

JEAN-JULIEN AUCOUTURIER

Research Director CNRS

AS2M

JJ Aucouturier is Directeur de recherche CNRS in cognitive science, working on the application of system-science methods to the study of auditory cognition and neurosciences, with a focus on clinical applications in neurology and psychiatry. He holds a PhD in Artificial Intelligence from University Paris 6 (2006), and has held several postdoctoral positions in cognitive neuroscience, incl. in University of Tokyo (Japan), RIKEN Brain Science Institute (Japan) and Université de Bourgogne (Dijon). From 2012-2020, JJA. lead the music neuroscience team at STMS UMR9912 (IRCAM/CNRS/Sorbonne Université, Paris) and was the PI of ERC Starting Grant project CREAM (http://cream.ircam.fr). His work received the Prix d'Excellence Scientifique 2018 of the Fondation pour l'Audition. JJA joined the FEMTO-ST institute in Jan. 2021.

JJA's recent work is concerned with application of system identification methods (e.g. reverse-correlation) to the study of vocal cognition; for instance, how do listeners identify, upon hearing a single word such as the word "hello", that a speaker is trustworthy or dominant (https://lejournal.cnrs.fr/videos/dis-moi-bonjour-et-je-te-dirai-qui-tu-es); and how to use these techniques in clinical contexts, such as the diagnosis of speech deficits in brain stroke patients or the detection of consciousness in coma patients.

https://scholar.google.com/citations?user=jnST06UAAAAJ

jean.aucouturier@femto-st.fr

ANTOINE BARBOT

CNRS researcher

AS2M

Antoine Barbot received a Ph.D in 2016 for his work focusing on mobile magnetic microrobots inside microfluidic chip performed in C2N-CNRS. He then started a postdoctoral position in Imperial College London where he focused on microrobotics applied to non-invasive surgery. He particularly developed a floating magnetic microrobot for flexible microelectronic assembly as well as micropneumatic and microfluidic actuators embedded at a capillary tip.

Antoine Barbot focuses on the use of capillary forces toward the development of compact micromechanism. He is especially interested in the design, model and control of a fluid joint. This surface tension based joint would connect micro-element with a liquid drop allowing several degrees of freedoms in a compact design.

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antoine.barbot@femto-st.fr

WISSEM HAOUAS

Associate professor

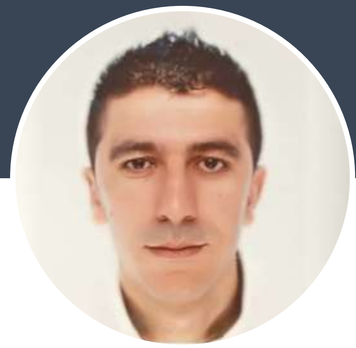
AS2M

Wissem Haouas is an associate professor in automatic and micro-robotics, at the Bourgogne-Franche-Comté University (UBFC), focusing on the design and development of micro-manipulators. He was a Postdoctoral Researcher in Robotics at the School of Mechanical Engineering, University of Leeds. Where he was working on the design of robotic systems for deployment by drones in structures and the development of a 3D asphalt-printing drone that autonomously detects and repair cracks. He holds a PhD (2018) in automation from the UBFC where he developed novel robotic structures for dexterous micromanipulation applications.

His research topic consists in developing a miniature and soft robotic hand ensuring high dexterity and capable of generating active adhesion forces to manipulate fragile and complex objects.

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

wissem.haouas@femto-st.fr



DJAFAR CHABANE

Associate Professor

ENERGY

Djafar Chabane received the electrical engineering degree and M.S degree in electrical engineering from the University of TIZI-OUZOU, Algeria, in 2011. He then obtained the M.S degree in physics and engineering of energy from École Normale Supérieure de Cachan, France, in 2013, and the Ph.D. degree in engineering sciences from Université Bourgogne Franche-Comté, France, in 2017.

Since September 2020, he is an Associate Professor with UBFC and UTBM, with the FEMTO-ST Institute, and also with the FCLAB Research Center.

His current research focuses on fuel cell and hydrogen storage in solid form. He develops energy management strategies and smart control approaches for transportation and stationary applications.

djafar.chabane@femto-st.fr

NICOLAS SIMONCINI

Associate Professor

RECITS AND ENERGY

Associate professor in Science and Technology Studies at the UTBM, Nicolas Simoncini is part of the transversal axis FEMTO-ST/RECITS and of SHARPAC (Energy Department). He received his PhD degree in 2018 from Université de Technologie de Belfort-Montbélliard. He received Turriano ICOHTEC prize in 2020 for his PhD work on analysis of technoscientific, economic and political context of production and implementation of fuel cells in France from the 1960s to the 1980s

His work focuses on the history and sociology of fuel cells and hydrogen, as well as on the intervention of Human and Social Sciences in design and technological research.

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MOUSTAFA ABDEL HAFIZ

Associate Professor

TIME-FREQUENCY

Moustafa Abdel Hafiz received his Ph.D. degree in 2017 from Université Bourgogne-Franche-Comté, Besançon, France. His Ph.D. thesis work, led at FEMTO-ST, was focused on the development of a high-performance Cs vapor cell atomic clock. From March 2018 to end 2019, M. Abdel Hafiz worked as a post-doctoral researcher at PTB, Braunschweig, Germany, on the development of a transportable Yb+ ion optical clock. Since January 2020, M. Abdel Hafiz is associate professor at ENSMM, with his research activities based at FEMTO-ST.

Moustafa has joined the OHMS Group, in the Time-Frequency Department. His research activities are mainly focused on the development of single Yb+ trapped-ion optical clock, with additional contributions to the study and development of new-generation miniaturized vapor cell atomic clocks.

moustafa.abdel@femto-st.fr

NEW PROJECTS

PHOTONHUB EUROPE: PHOTONICS BOOSTS MULTI-SECTOR INDUSTRIAL INNOVATION AT THE EUROPEAN SCALE

OPTICS, MN2S, AS2M, TIME & FREQUENCY

Nadège Courjal (Head of the MOEMS & Hybrid Photonic Systems technology branch of PhotonHub Europe and member of its Project Evaluation Team), Hervé Maillotte (French academic coordinator and representative for CNRS), Jean-Charles Beugnot, Luc Froehly, Francois Courvoisier, Sylwester Bargiel, Nicolas Passilly, Franck Chollet, Jean-Yves Rauch, Cédric Clévy, Kanty Rabenorosoa, Philippe Lutz, Marion Delehaye, Ausrine Bartasyte

It is now recognized that Photonics is a key-enabling and key-digital technology for increasing Europe's industrial competitiveness and powering its digital transformation, but also contributing to green methods and sustainable development in a range of sectors like Health, Digital Infrastructure, Manufacturing and Industry 4.0, Safety, Security, Space & Defence, Agro-Food, Mobility & Energy…

Built on a successful 17-years history of networks of excellence and collaborative projects in which FEMTO-ST has been participating from the outset, PhotonHub Europe, submitted to the ICT H2020 calls for Digital Innovation Hubs. This is the only project that has been selected in October in the "Photonics Innovation Hubs" category and awarded a € 19 million EU investment.

PhotonHub's goal is to establish a single pan-EU Innovation Hub that integrates the best photonic technologies, facilities, expertise and experience of 54 partners from 18 EU member states, including Research & Technology Organizations (RTOs), EU manufacturing pilot lines, business & innovation accelerators, and local photonic hubs, and representing a task force of >500 experts. Organized as a one-stop-shop solution, PhotonHub will provide European companies willing to include photonics in their innovation developments, in particular non-photonics SMEs and early adopters of photonics, with open access and guided orientation to a comprehensive range of key support services:

- on-line and on-site training and upskilling for both technology- and application-specific learning in photonics,

- subsidized technology support from a PhotonHub partner to a company, aimed at TRL acceleration from prototyping (TRL3-4) to upscaling (TRL5-6) to manufacturing through pilot lines (TRL7-8). This support relies on 8 technology branches (Free-Space Optics, Polymer-based Optics, Specialty Fibers, MOEMS & Hybrid Photonic Systems, silicon-, silicon nitride-, indium phosphide-photonics, laser-based manufacturing) that all form a breadth of RTOs and facilities with the capacity of supporting a full supply-chain from design, modelling, prototyping, integration, characterization, measurement, packaging to demonstration,

- targeted business and intellectual property coaching to the companies, to further boost the market-readiness levels of their innovation activities,

- support to find investment (guidance, orientation, investment-readiness coaching and investor match-making) from suitable finance sources, especially for start-ups and scale-ups, in order to successfully bring new products to market,

- PhotonHub will simultaneously work closely with the local photonic hubs to develop and roll out best practices for regional financial support of SME innovation activities and to support the creation of new local innovation hubs across Europe.

Starting from January 2021 for a 52-month duration and deployed with a fine business plan to become sustainable, PhotonHub Europe will thus accelerate the uptake and deployment of photonics, thereby helping European SMEs and mid-caps to become highly competitive digital businesses through faster and smarter deployment of photonics-based technologies, and directly creating over 1.000 new high-tech EU jobs and nearly €1 billion in new revenues and venture capital by 2025.

This new pan-EU photonics innovation hub is coordinated by Vrije University at Brussels. On the French side, CNRS is the sole academic partner with FEMTO-ST being the national scientific and technical coordinator, bringing together over 70 experts from 11 other research units and their 28 platforms, including 9 micro-nanofabrication big facilities from RENATECH/RENATECH+ and 10 Equipex: LabHC (St Etienne), Fresnel, LP3 and LAM (Marseille), C2N and LCF (Palaiseau), CRISMAT (Caen), L2N (Troyes), IEMN and PhLAM (Lille), LAAS (Toulouse).

References

https://www.photonhub.eu

https://www.femto-st.fr

Facilities: MIMENTO, FRI-LIGHT, Micro Robotex, Oscillator-IMP, FLUIDIX

nadege.courjal@femto-st.fr
herve.maillotte@femto-st.fr

30 MILLION CORE HOURS FOR MASSIVELY PARALLEL COMPUTING AWARDED BY PRACE TO ONE OF OUR TEAMS

Kazem Ardaneh, Francois Courvoisier

OPTICS

Within the development of the ERC project PULSAR, the team led by Francois Courvoisier at FEMTO-ST develops research on laser-plasma interaction within transparent solids. Their research aims at discovering the specific mechanisms yielding microexplosions within the bulk of materials when they are illuminated by femtosecond laser pulses in certain conditions. The core of the research is to decipher the high intensity laser interaction with nano-plasmas.

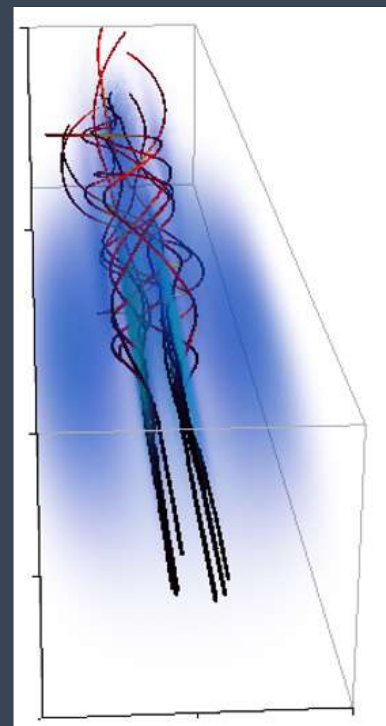
The movement of electrons induced by the intense laser field reshapes the plasma at the nanometric scale, which in turn, reshapes the local electromagnetic field strength. Solving both the evolution of the electromagnetic fields and trajectory of electrons is performed by the team using a so-called "Particle-In-Cell" code. But this requires massively parallel computing. A typical simulation runs for 24 hours using 1024 cores! The team applied for competitive European funding, PRACE (Partnership for Advanced Computing in Europe), and was awarded 30 million core-hours on a supercomputer in 2020. This was key for the team to understanding how laser pulse energy can be absorbed within an extremely confined volume, which generates Warm Dense Matter, a thermodynamical state of the interior of stars and planets. This will allow the development of novel laser materials processing strategies.

https://prace-ri.eu/

francois.courvoisier@femto-st.fr

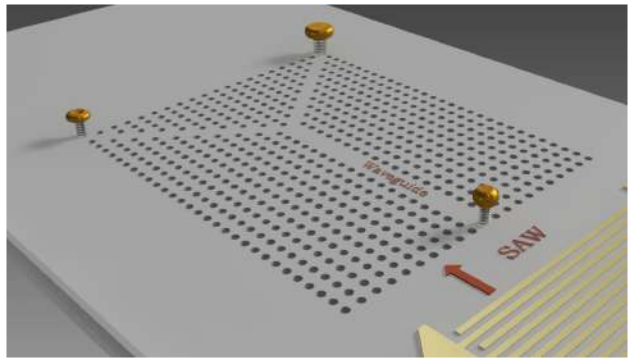
References

J. Del Hoyo et al., Nanophotonics 10(3), 1089 (2021)



Trajectories of electrons (red) heated by the intense laser pulse (blue).

NEW PROJECTS



Schematic view of the quantum electro-acousto-mechanical platform proposed within uNIQUE. Mechanical qubits are combined with surface acoustic waves for information transport and phononic crystals for wave propagation management.

uNIQUE

NANOPHONONICS FOR QUANTUM INFORMATION PROCESSING

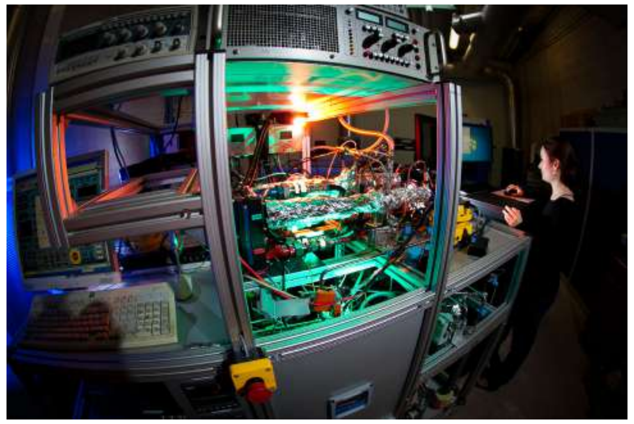
EU call: ERC-2019-COG (1.99 M€)

MN2S: SARAH BENCHABANE (COORDINATOR, FEMTO-ST)

The uNIQUE project aims at the development of an all-electro-acousto-mechanical quantum information platform exploiting the potential presented by surface acoustic waves at the single-phonon level. The project will adopt a yet unexplored approach at the crossing of phononics, nanomechanics and quantum acoustics to yield a fully coherent mechanical playground that can be used at the interface with other solid-state or photon qubits or as an independent quantum signal processing system.

https://teams.femto-st.fr/MOSAIC/

sarah.benchabane@femto-st.fr


Characterisation and modelling of the stack and the blowout preventer components at FEMTO-ST

VIRTUAL-FCS: VIRTUAL & PHYSICAL PLATFORM FOR FUEL CELL SYSTEM DEVELOPMENT

EU Call: H2020-EU.3.4.6.1.(1.9 M€)

ENERGY: NADIA YOUSFI STEINER (PI FOR UBFC)

Consortium: Coord. SINTEF (Norway), UBFC (France), BALLARD (Denmark), WESTCON (Norway), BANKE (Denmark), VIVARAIL (UK), SOLARIS (Poland)

VIRTUAL-FCS tends to reduce the production cost of fuel cell systems to be used in transportation applications, while increasing their lifetime to levels which can compete with conventional technologies (Topic: FCH-01-3-2019 - Cyber-physical platform for hybrid Fuel Cell Systems).

www.virtual-fcs.eu

nadia.steiner@univ-fcomte.fr - Kyrre.sundseth@sintef.no


Backup system form Ballard tested by FEMTO-ST. Diagnostic and prognostic algorithms developed on Machine Learning basis are implemented and their impact on durability is evaluated.

RUBY: ROBUST AND RELIABLE GENERAL MANAGEMENT TOOL FOR PERFORMANCE AND DURABILITY IMPROVEMENT OF FUEL CELL STATIONARY UNITS

EU Call: H2020 – H2020-JTI-FCH-2019-1 (FCH2-RIA, 3,08 M€)

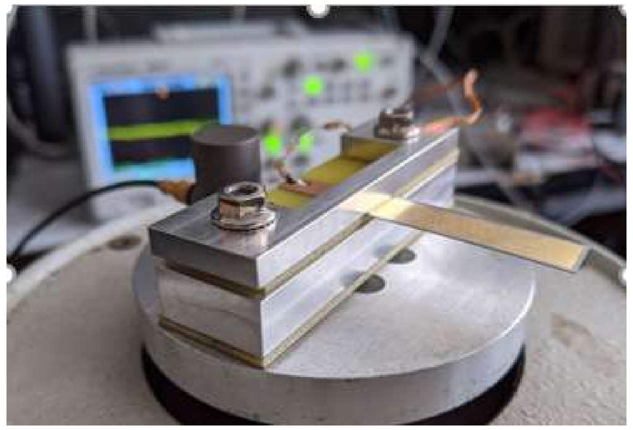
ENERGY: MARIE-CÉCILE PÉRA (PI FOR UBFC), DIDIER CHAMAGNE, NADIA YOUSFI STEINER

Consortium: Coord. Universita degli studi di Salerno (Italy), CEA (France), Solidpower SPA (Italy), Ballard Power systems Europe AS (Denmark), Bitron SPA (Italy), Institut Jozef Stefan (Slovenia), VTT Oy (Finland), EIFER (Germany), UBFC (France), EPFL (Switzerland), Fondazione Bruno Kessler (Italy).

RUBY develops a specific instrument for monitoring and control of fuel cell stationaries (FCS) and completes the work by integrating hardware, stack diagnosis, control algorithms and fault detection algorithms for a blowout preventer. The project's goal is to evaluate the lifetime of FCS components for reliable and accurate monitoring.

https://www.rubyproject.eu/

marie-cecile.pera@univ-fcomte.fr


Design, modeling and characterisation of vibrational energy harvesting systems based on lead-free LiNbO3 at FEMTO-ST.

REACTIVE TOO: RELIABLE ELECTRONICS FOR TOMORROW'S ACTIVE SYSTEMS

EU Call: H2020-MSCA-RISE-2019 (791 k€)

TIME & FREQUENCY: SAMUEL MARGUERON (PI FOR UBFC), AUSRINE BARTASYTE

Consortium: Coord. University of Wolverhampton (UK), Liverpool University (UK), Tampere University (Finland), Satakunta University (Finland), UBFC (France), APTIV-Delphi Electronics (Poland), Sensor City (UK), Junet (Finland), Sataedu (Finland), Annealsys (France), Cedrat Technologies (France), Chanzhou Univ. (China).

ReACTIVE Too will carry out research into designing for the reliability for electronics-based systems and will include the introduction of an agile hardware development cycle with virtual techniques to uniquely address reliability and physical validation in active safety systems.

https://reactivetoo.org/

samuel.margueron@femto-st.fr

PIA 3 - 3RD NATIONAL PROGRAM OF THE INVESTMENTS FOR THE FUTURE

TERRITOIRE D'INNOVATION: TRANSFORMATION OF AN INDUSTRIAL TERRITORY IN THE NORTH FRANCHE-COMTÉ REGION

Julien Bourgeois, Nathalie Kroichvili, Aurore Niechajowicz

DISC / RECITS / FEMTO ENGINEERING

This project was developed through the AMI-TIGA (2018-2019) and the PIA3-TI (2020-2027) French national programs.

It is leaded by the local community Pôle métropolitain de Belfort-Montbéliard and brings together local authorities, local subsidiaries of large companies as well as other economic actors, professional networks such as the Competitiveness Pole "Véhicule du Futur" and "La Vallée de l'Energie", the science association "Pavillon des Sciences", several graduate and postgraduate schools and their research laboratories within UBFC (UTBM and UFC), cultural actors and the civil society (CODEV).

This project aims at supporting the evolution of the North Franche-Comté's industrial territory and the structuration of an innovative ecosystem around industry 4.0 and hydrogen-energy.

In this project, together with FEMTO Engineering, DISC will help local companies to embed more techniques from artificial intelligence (AI) into the production process. To do so, an innovative production line embedding new sensors and AI technologies will be built with UIMM. RECITS is responsible for the definition and the implementation of a methodology for the whole project evaluation as well as for the assessment of the territory structural evolutions that are expected to result from such a project.

https://www.banquedesterritoires.fr/24-laureats-de-signes-pour-lappel-projets-territoires-dinnovation

https://www.dailymotion.com/video/x7rxr32

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nathalie.kroichvili@utbm.fr

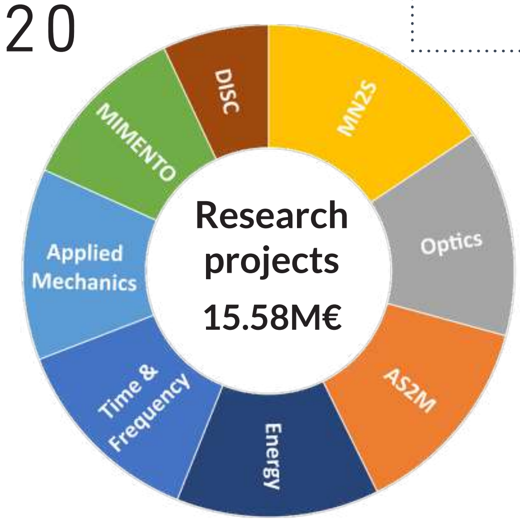
Deep learning algorithms can help detecting low quality welding

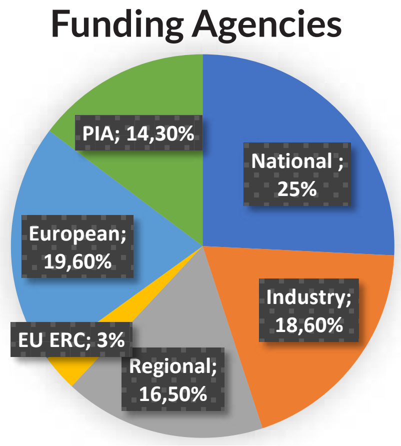
Call ESR/EQUIPEX+ 2020/PIA 3

FEMTO-ST Institute is the winner of the 6 projects:
T-REFIMEVE, TIRREX, SMART-LIGHT, NANOFUTUR, DurabilitHy, CALHIPSO

Total funding of ~11M€ (2021-2028)

IN 2020





HIGHLIGHTS ON INTERNATIONAL COLLABORATIONS

SMYLE COLLEGIUM: FRENCH-SWISS PARTNERSHIP BETWEEN FEMTO-ST AND EPFL

COORDINATORS:

MICHAËL GAUTHIER (FRANCE)
YVES BELLOUARD (SWITZERLAND)

FEMTO-ST Institute and EPFL develop common research and education projects in the framework of the French-Swiss SMYLE Partnership. Three major topics " Photonics, Microsystems, GreenTech" of common interest to the two institutions are currently supported by the SMYLE Collegium. The Collegium SMYLE aims to support the construction of common research projects to be funded by binational (ANR/FNS) and European (INTERREG, H2020/Horizon Europe) funding agencies. In order to promote further French-Swiss interaction, the Collegium activities are complemented by training through and for research and by exchanges with the industry. Two examples of the fruitful research collaboration between EPFL and FEMTO-ST are given below.

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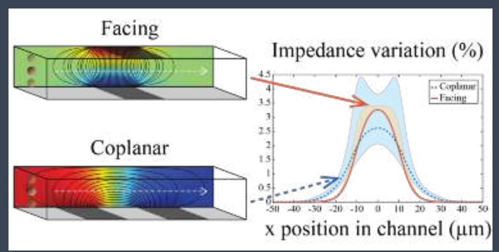

Positional dependence of particles and cells in micro-fluidic electrical impedance flow cytometry

POSITIONAL DEPENDENCE OF PARTICLE ELECTRICAL IMPEDANCE IN LAB-ON-CHIP

EPFL (PHILIPPE RENAUD)

AS2M (HUGO DAGUERRE, MICHAËL GAUTHIER, AUDE BOLOPION)

The ANR/FNS CodiCell project in which Aude Bolopion (FEMTO-ST), Prof. Philippe Renaud (EPFL) and also Prof. Borg (French Blood Agency -EFS-) are developing common microfluidic devices using particle electrical impedance measurements for highly selective cell sorting. In this framework, they have provided a common review paper published in the Lab-on-Chip journal providing an overview of the positional dependence of impedance measurements in microfluidic systems.

This review deals with the microfluidic electrical impedance flow cytometry, a well-known and established method for single-cell analysis. One of its major limitations is the variation of the impedance signal with the position of the cell in the sensing area. The positional dependence can be considered as a challenge for the accuracy of microfluidic impedance cytometers. It has also recently been regarded by several groups as an opportunity to estimate the position of particles in the microchannel and thus take a further step in the logic of integrating sensors in "Lab-on-a-chip" devices.

Facilities: ROBOTEX, MIMENTO

H.Daguerre et al., Lab on Chip, 20 (20), 3665(2020)

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NEXT GENERATION 3D PHOTONIC CHIPS FOR AI

EPFL (DEMETRI PSALTIS)

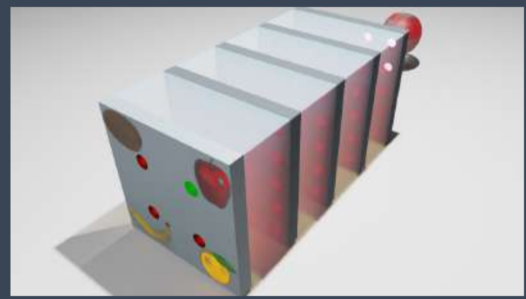
OPTICS (DANIEL BRUNNER)

Artificial Intelligence (AI) techniques are among the most important technological and scientific breakthroughs. Neural network (NNs) are the driving force of this AI revolution, and their computational power originates from connecting large numbers (potentially millions) of neurons to a network topology that is determined via learning.

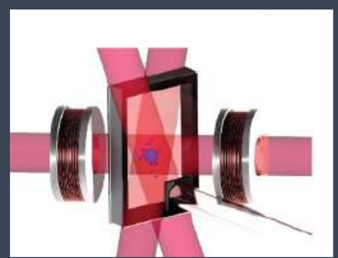
This imitates aspects of the human brain, and it is likely that NNs will immensely benefit from more neuro-inspired processor architectures. A principle aspect of brain-topology is that neural connections are three dimensional – otherwise the brain would not fit inside our skull. Combining their efforts, Daniel Brunner (FEMTO-ST) and Demetri Psaltis (EPFL) are therefore exploring photonic integration based on 3D printing for next generation NN processors.

daniel.brunner@femto-st.fr

U. Dinc et al., Photoniques 104, 34 (2020).



3D-printed optical neural networks are a promising technology for neuro-inspired next generation AI processors.



Laser cooling in a chip-scale platform

CHIP-SCALE ATOMIC DEVICES AND COLD ATOMS

NATIONAL INST. OF STANDARDS AND TECHNOLOGY, USA (J. KITCHING)

UNIVERSITY OF STRATHCLYDE, UK (E. RIIS/ MCGILLIGAN)

TIME & FREQUENCY (RODOLPHE BOUDOT, 16 MONTHS STAY AT NIST)

Demonstrations: (i) laser cooling of ^{85}Rb atoms in a glass-silicon-glass ultra-high vacuum microfabricated cell using a 6-beam magneto-optical trap connected to an external ion pump; (ii) cooling light using a single incident laser beam with the help of a planar microfabricated grating-chip, (iii) passively pumped vacuum package sustaining cold atoms for several days.]

J. P. McGilligan et al., Appl. Phys. Lett. 117, 054001 (2020).

R. Boudot et al., Sci. Rep. 10, 16590 (2020).

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REGENERATIVE STIRLING MACHINE

BAHIR DAR UNIVERSITY
(MULUKEN ZEGEYE GETIE)FRENCH AMBASSY ETHIOPIA

ENERGY (FRANÇOIS LANZETTA
SYLVIE BEGOT)

The development and the optimization of a regenerative Stirling machine for moderate refrigeration that uses air as refrigerant and that presents high efficiency and ecological cleanliness.

2 articles, 6 proceedings, article nominated for the scientific Biot-Fourier award (29th SFT conference, Belfort, June, 1-3, 2021).

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PHONONIC CRYSTALS AND ACOUSTIC METAMATERIALS.

TIANJIN UNIVERSITY, CHINA
(YUE-SHENG WANG)

MN2S (VINCENT LAUDE)

In 2020, the collaboration focused on reconfigurable phononic crystal waveguides and resulted in the successful defense of a joint PhD student and the publication of 6 joint articles.

T.-T. Wang et al., Phys. Rev. Appl. 13, 014022 (2020).

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IMPLEMENTATION OF SIMULTANEOUS SENSING AND ACTUATING TOOLS FOR DIELECTROPHORESIS-ON-A-CHIP APPLICATION

MICROENGINEERING & NANOELECTRONICS, UNIV. KEBANGSAAN, MALAYSIA (YEOP MAJLIS)

MN2S (CELINE ELIE-CAILLE)

The project aims to lay the scientific and technological bases for sorting extracellular vesicles in complex fluids, and resulted already to 2 joint articles, and the obtention of an "invited professor" EUR EIPHI call to welcome thebcollaborator Dr Muhamad Ramdzan Buyong during 1 month in FEMTO-ST.

M.R. Buyong et al., Microelectronics Int. 37(4) 215 (2020)

celine.elie@femto-st.fr

TRANSMISSION OF GENERAL ROUTING PROTOCOLS

VICTORIA UNIVERSITY OF WELLINGTON, NEW ZEALAND (WINSTON SEAH)

DISC (EUGEN DEDU)

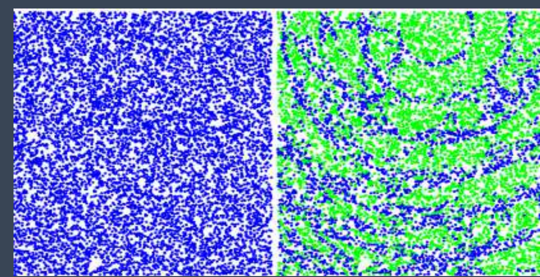
The Improvement of the transmission of general routing protocols, either by unicast or flooding (broadcast) in multi-hop networks, through a careful selection of nodes which forward the packets to the destination(s).

Co-supervised PhD thesis.

https://homepages.ecs.vuw.ac.nz/~winston/

F. Hoteit, et al., IFIP Networking, (2021)

ededu@femto-st.fr



A pure flooding on the left size, and a careful selection of forwarders on the right, achieving the same result (flooding) but with much fewer forwarders.

RESEARCH HIGHLIGHTS

ACCURATE ROBOTIC NANOPOSITIONING FOR ORIGINAL NANOPHOTONIC ARCHITECTURES

Morris Mwangi, Nadège Courjal, Miguel Suarez, Olivier Lehman, Adrien Godet, Houari Bettahar, Ludovic Gauthier-Manuel, Philippe Lutz, Cédric Clévy

AS2M/OPTICS

The AS2M and Optics departments of the FEMTO-ST institute study 3D heterogeneous nanophotonic architectures using robotic nanopositioning and assembly. An original photo-robotic approach has especially been proposed to synergize the optical signal (active alignment approach) and the internal sensory feedback of the nanopositioning robot. This approach enables, for the first time, to identification of extrinsic parameters (typ. the relative position between a photonic component and the robot) but also intrinsic ones (typ. imperfections in the robot structure). Experimental investigations notably demonstrated an unprecedented positioning accuracy of 50 nm and 0.004° (positions and orientations respectively). A collaboration between FEMTO-ST and ISIR also conducts research to control algorithms that enable the detection of contacts happening between two photonic components in a very delicate way preventing damage and giving key information about their relative position. These new capabilities open the way to several original nanophotonic architectures such as an optical disk resonator vertically positioned to its waveguide for enhanced performances.

References

H. Bettahar et al., IEEE Trans. Automation Science and Eng.(2020).

https://teams.femto-st.fr/micro-and-nano-robotics/

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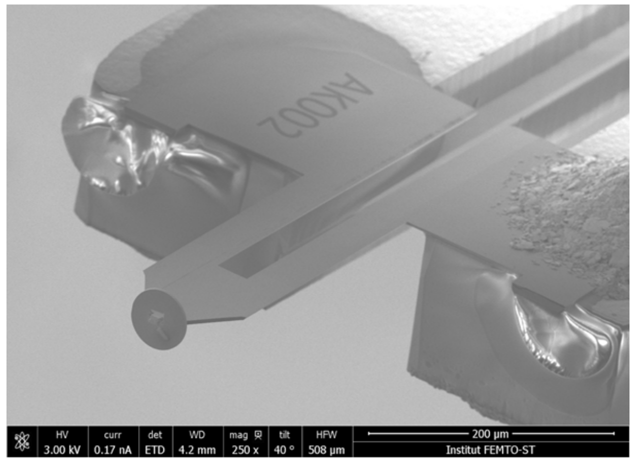

Optical disk resonator at the instrumented tip of a nanopositioning robot (collaboration FEMTO-ST/ISIR).

A REVIEW ON DEVICE-LEVEL REAL-TIME SIMULATION OF POWER ELECTRONIC CONVERTERS

Hao Bai, Chen Liu, Elena Breaz, Fei Gao

ENERGY

The device-level description of power switches is an emerging topic that enhances the real-time simulation (RTS) accuracy of power electronic converters. However, device-level RTS (DLRTS) is challenging due to contradictions between the additional computing amounts introduced by nonlinear switch models and the nanosecond-level simulation time step required by fast switching transients. Therefore, much research has sought a trade-off between accuracy and speed in DLRTSs. In the article published in IEEE Industrial Electronics Magazine (Impact Factor 13.593), the authors from FEMTO-ST institute review state-of-the-art DLRTS technologies, in particular for device-level switch models and efficient network solvers. Moreover, the authors summarize different applications of DLRTSs and compare their performances. The article also gives some indication of future research. It not only provides a comprehensive overview of DLRTSs for general audiences but also provides a technical reference for practitioners.

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H. Bai et al., IEEE Industrial Electronics Magazine 15(1), 12 (2021).

https://www.typhoon-hil.com/

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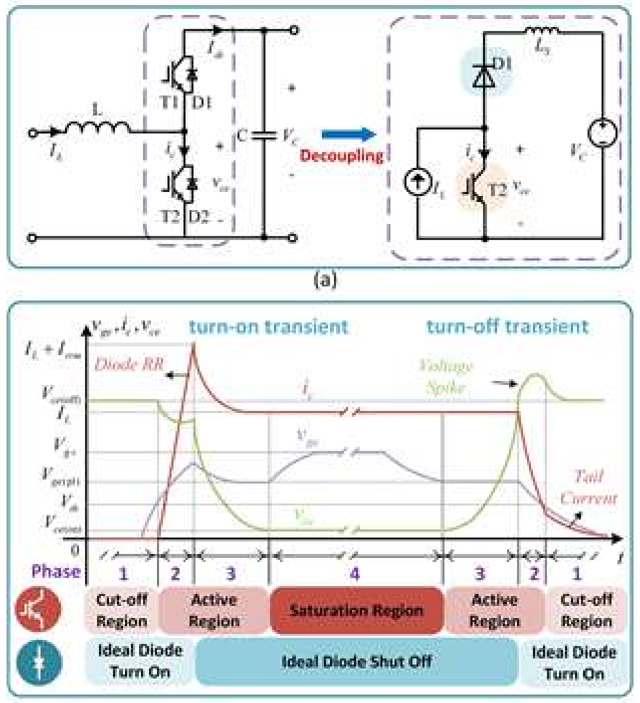

Basic modeling concepts of a device-level transient modeling approach for the FPGA-based real-time simulation of power converters

GNSS SIGNAL ANTISPOOFING AND ANTIJAMMING IN A SOFTWARE DEFINED RADIO RECEIVER FOR SECURE TIME TRANSFER

David Rabus, Gwenhael Goavec Merou, François Meyer, Jean-Michel Friedt

TIME&FREQUENCY

Global Navigation Satellite Systems (GNSS) have become ubiquitous to most daily activities, from time synchronization of mobile phone networks to smart grid energy production to trading and obviously positioning, with an economic impact estimated at up to 1 billion pounds/day of disrupted service in the UK (2017). With satellites located 20000 km away, jamming (loss of service) or spoofing (generating erroneous information) from the ground has become trivial using Software Defined Radio. This signal processing strategy aims at removing as many hardware components as possible to focus on software Digital Signal Processing. Hence, this signal processing approach also brings the antidote by giving access to the raw physical properties of the incoming electromagnetic wave for Direction of Arrival (DoA) measurement allowing for the identification and cancelling of spoofing and jamming sources. The free, opensource gnss-sdr multi-constellation GNSS decoding framework has been complemented with DoA analysis and 1-PPS timing generation capability. Performances equivalent to those found in hardware were demonstrated.

FEMTO-ST researchers in collaboration with Weike Feng (Xidian University, China) have achieved the GNSS receivers (relative time stability of 10-8) with the flexibility of the software approach and computational load requirements compatible with embedded single board computer capabilities. Current investigations aim at extending the narrowband L1 C/A GPS BPSK signal processing techniques to more complex L5/E5 bands with BOC modulation.

References

W. Feng et al., IEEE Aerospace and Electronic Systems Magazine 36 (3), 36 (2020).

https://github.com/oscimp/gnss-sdr

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IMAGING SPATIOTEMPORAL HONG-OU-MANDEL INTERFERENCE OF BIPHOTON STATES OF EXTREMELY HIGH SCHMIDT NUMBER

Fabrice Devaux , Alexis Mosset, Eric Lantz

OPTICS

In a crystal, the photons can be split into pairs of entangled photons of lower frequencies forming a single quantum object. Therefore, if they are sent to a beam splitter, they exit randomly, but both exit at the same output port. This is the famous Hong-Ou-Mandel (HOM) two-photon interference.

HOM interference is used in new communication protocols, such as quantum teleportation and quantum information processing, but so far without spatial resolution, using point detectors. However, entanglement concerns all properties of the twin photons, including their position in space and time, and here HOM interference is obtained for thousands of space-time modes.

In our HOM interferometer, the spatial coincidences between the 2 output ports are imaged on two cameras. As we control temporally, spatially, in polarization and wavelength the indistinguishability between the photons of a pair, we have observed and quantified spatially and temporally the HOM interference at the quantum level. Given the essential role played by two-photon HOM interference in most of the systems developed for quantum information processing, demonstrating that HOM interference can be obtained by manipulating quantum states of giant dimension opens the way to the development of very high-dimensional quantum information protocols.

References

F. Devaux et al., Phys. Rev. X 10, 031031 (2020).

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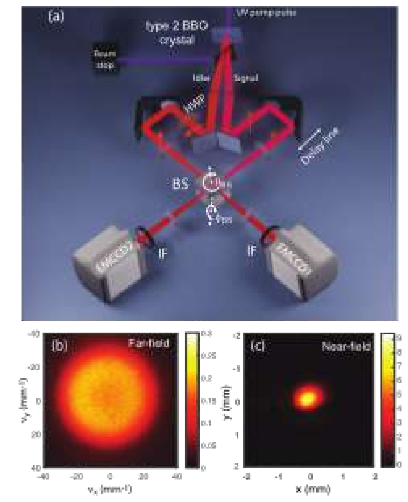
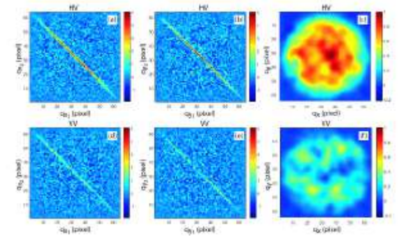


Diagram of the 2-camera HOM interferometer, images of the photon distribution in far-field (b) and near-field (c) images.



1D and 2D mapping of the covariances of the spatial coincidences between 500 pairs of twin images when the photons of a pair are discernible (HV) or indistinguishable (VV).

RESEARCH HIGHLIGHTS

MECHANICAL METAMATERIALS AT THE MICROSCALE

Vincent Laude, Muamer Kadic, Xueyan Chen, Johnny Moughames

MN2S

Metamaterials are designed structures whose effective properties can go beyond those of natural materials. Very often, they are constructed by repeating a basic unit cell, the dimensions of which are smaller than those characterizing the applied stimulus. The metamaterial shown in figure a was designed to absorb a large amount of mechanical energy and withstand large deformations, resulting for instance from a shock, while at the same time having a light weight. In the future such metamaterials could enter the composition of helmets or bulletproof wearables. The metamaterial shown in figure b has a quite different functionality, though still being based on a cubic unit cell: it will not expand laterally whatever direction you press on it. Mechanically, it possesses an isotropic zero Poisson's ratio, a property that even natural cork can't match.

The first metamaterial was 3D-printed using standard additive manufacturing, but the second was fabricated at a very small scale, thanks to two-photon lithography performed in FEMTO-ST's clean room facility, MIMENTO. This research was performed in the frame of the doctoral work of Xueyan Chen, a joint PhD student with Harbin University of Technology in China.

References

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X. Chen et al. Extreme Mechanics Letters 41, 101048 (2020).

https://teams.femto-st.fr//phononics-microscopy/en

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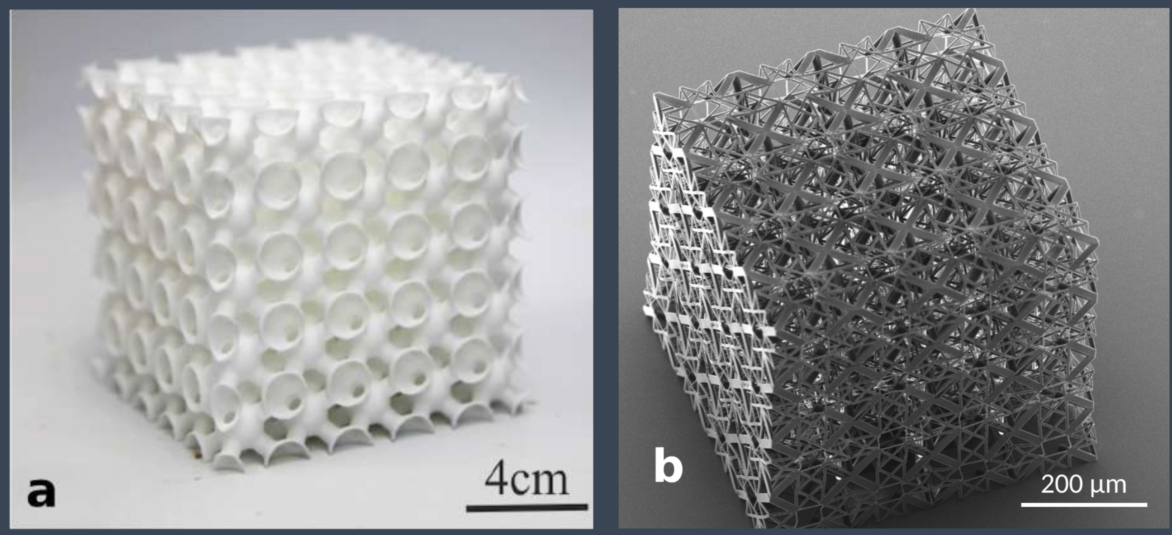

(a) A light-weight shell-lattice metamaterial for mechanical shock absorption; (b) an isotropic and reusable cork-like metamaterial with isotropic Poisson's ratio close to zero.

SURVEY PAPERS WITH HIGH IMPACT FACTOR

Mickael Hilairet

ENERGY

IEEE Industrial Electronics Magazine (IEM) publishes peer-reviewed articles with impact factor of 13.59 that present a survey of emerging trends in the industrial electronics society. In this context, two papers have been co-published in 2021 with foreign colleagues.

The 1st one focuses on a cross disciplinary view of industrial electronics, including electronic systems on chip, standards, resilience and security matters, human factors and educational aspects, while the 2nd one looks into System-on-Chip (SoC) Field Programmable Gate Arrays (FPGA) for controlling complex electrical energy systems and details the practical experience of FEMTO-ST researchers for the control and prognosis of a hybrid fuel cell system with soft-core processors.

References

O. Lucía et al., ``Emerging trends in industrial electronics: A cross disciplinary view,'' IEEE Industrial Electronics Magazine 15 (1), 127 (2021)

E. Monmasson et al., "System-on- Chip FPGA Devices for Complex Electrical Energy Systems Control," IEEE Industrial Electronics Magazine, Forthcoming in 2021.

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MINIMAL INFORMATION FOR STUDIES OF EXTRACELLULAR VESICLES 2018 (MISEV2018): A POSITION STATEMENT OF THE INTERNATIONAL SOCIETY FOR EXTRACELLULAR VESICLES AND UPDATE OF THE MISEV2014 GUIDELINES

Wilfrid Boireau, Céline Elie-Caille, Annie Frelet-Barrand

MN2S

W. Boireau, C. Elie-Caille, A. Frelet-Barrand have contributed as coauthors of this position paper which has been cited 1204 times, as a reference paper giving guidelines on how to prepare, characterize and study extracellular vesicles (EVs) samples. This makes this article a "hot paper" since it was published in the past two years and received enough citations in July/August 2020 to place it in the top 0.1% of papers in the academic field of Biology & Biochemistry. As of July/August 2020, this JEV paper also received also enough citations to place it in the top 1% of the academic field of Biology & Biochemistry based on a highly cited threshold for the field and publication year, it is also considered as a "highly cited paper". The nanobioanalytical (NBA) platform, developed by the MN2S/BMD team, constitutes one of the characterization approaches claimed in this reference JEV article, for EVs subsets characterization in crude biological sample of interest.

References

C. Thery et al, Journal of Extracellular Vesicles 7 (1), 1535750 (2018).

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CRISPRBUILDER-TB: "CRISPR-BUILDER FOR TUBERCULOSIS".

EXHAUSTIVE RECONSTRUCTION OF THE CRISPR LOCUS IN MYCOBACTERIUM TUBERCULOSIS COMPLEX USING SRA

Christophe Guyeux

DISC

Mycobacterium tuberculosis CRISPR locus diversity has long been studied solely investigating the presence of a known set of spacers. Unveiling the genetic mechanisms of its evolution requires a more exhaustive reconstruction in a large amount of representative strains. In this article, we point out and resolve the problem of CRISPR reconstruction based directly on short read sequences in M. tuberculosis. We show that the process we set up allows an efficient reconstruction of simulated or real CRISPRs, even when including complex evolutionary steps like the insertions of mobile elements. Compared to more generalist tools, the whole process is much more precise and robust, and requires only minimal manual investigation. Second, we show that more than 1/3 of the currently complete genomes available for this complex in the public databases contain largely erroneous CRISPR loci. Third, we highlight how both the classical experimental in vitro approach and the basic in silico spoligotyping provided by existing analytic tools miss a whole diversity of this locus in MTC, by not capturing duplications, spacer and direct repeats variants, and IS6110 insertion. This work opens perspectives for an in-depth exploration of M. tuberculosis CRISPR loci diversity and of mechanisms involved in its evolution and its functionality, as well as its adaptation to other CRISPR locus-harboring bacterial species.

References

C. Guyeux et al., PLOS Computational Biology. Accepted article (2021).

https://github.com/cguyeux/CRISPRbuilder-TB

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RESEARCH HIGHLIGHTS

LABEL-FREE MICRO-ACOUSTIC ASSAY PLATFORM FOR PRIMARY HAEMOSTASIS ASSESSMENT.

Aleksandr Oseev, Thérèse Leblois, Céline Elie-Caille, Franck Chollet, Wilfrid Boireau, Alain Rouleau, Jean-François Manceau

MN2S

Primary haemostasis is a dynamic physiological process, which involves complex in-flow interactions between blood platelets and sub-endothelial matrix at the area of the damaged vessel wall. The quantitative integrative assessment of primary haemostasis is still challenging, particularly for mild but clinically significant disorders of platelet function and vWF (von Willebrand factor). Real-time monitoring of platelet plug formation with direct sensing methods is foreseen to reach the assessment level beyond the present state of the art but it is still the Holy Grail.

To address the challenge we have developed an integrated label-free micro-acoustic bioassay platform for the real-time evaluation of in-flow interaction of circulating blood platelets with a collagen bio-interface. The assay chip relies on novel quartz-on-silicon microfabrication technology developed at FEMTO-ST within the ANR GHOST project (2017-2020). It combines advantages of monocrystalline piezoelectric substrates and flexibility of silicon micromachining to design and realize an integrated micro-acoustic assay (patent registration in progress). Single chip integrated micro-acoustic sensing units enable multiplexed measurement of the platelet deposits up to micrometer thickness, with Q factor in-liquid above 1000.

The developed micro-acoustic bioassay has been tested successfully with whole blood from healthy volunteers in collaboration with the French Blood Agency in Besançon and has shown great potential for bio-medical studies as an advanced on-a-chip integrated analytical platform.

This project is conducted within the framework of ANR GHOST with medical partners specialized in haemostasis from Geneva University and HUG, EFS and Dijon University Hospital and a private company, NVH Medicinal. (T. Lecompte, G. Mourey, E. de Maistre, D. Vandroux)

References

A. Oseev et al., IEEE Trans. Biomed. Eng., 1 (2020).

A. Oseev et al., Nanomaterials, 10, 2079 (2020).

https://teams.femto-st.fr/BioMicroDevices/en

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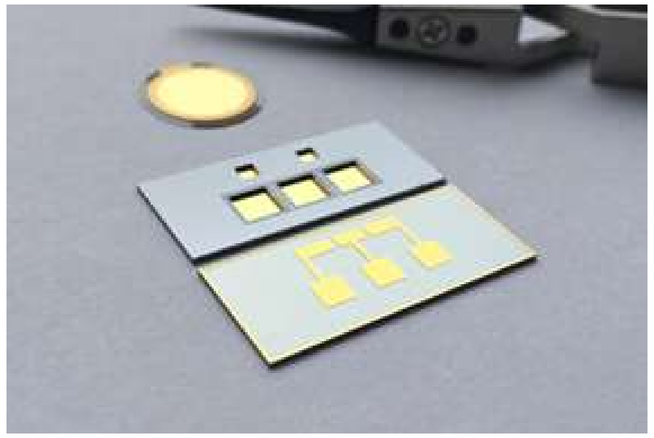

Primary haemostasis assay chip comprising three integrated micro-acoustic sensors and a three-channel custom GHOST-X3 measurement device.

GAPCOD: A GENERIC ASSEMBLY PLANNER BY CONSTRAINED DISASSEMBLY

Benoît Piranda, Julien Bourgeois

DISC

Programmable matter is made of connected micro-robots. The construction of an object made of programmable matter implies assembling all the robots that compose it. However, the order of assembly is constrained by internal or global physical rules. For example, the mechanical balance of the assembly: at each step, the object does not fall or break under the effect of its weight. A major hurdle in the assembly is the lack of generic of existing algorithms.

GAPCoD is an algorithm that generates a precedence graph for the construction of objects by successive assemblies of modular robots whatever the type of robot. This method is generic and can be adapted to all types of constraints and robots. In this approach, we consider two very different constraints: the geometrical insertion of the 3D Catoms and the mechanical stability of the Blinky Blocks. In the first case, we aim to build a structure using 3D Catoms: quasi-spherical robots developed within the OMNI team of DISC). For the mechanical constraint on the Blinky Blocks, an element will be added in the graph only if it allows a stable overall structure.

References

F. Pescher et al., 19th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2020), New Zealand, May 9-13, 2020. (Rank A*, AR 186/808=23%).

YouTube video of an experiment: https://youtu.be/s_-LyYyVnCU

https://www.programmable-matter.com/

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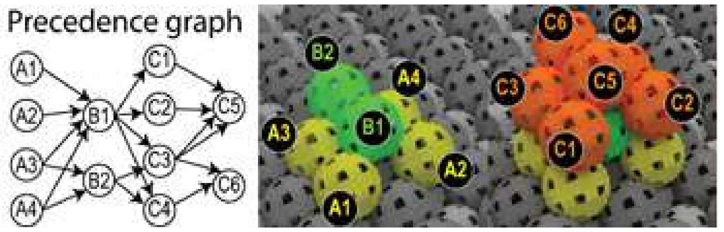

Precedence graph (on the left) for a 3D Catoms configuration (on the right, presented here in two images to better show the 3 layers of Catoms).

FEMTO-ST BRINGS PHOTONICS TO AI AND AI TO PHOTONICS

Daniel Brunner, John M. Dudley

OPTICS

The union between Artificial Intelligence (AI) and photonics is among the most exciting current developments in optics. Celebrating its 60th anniversary this year, the laser is considered one of the defining inventions of the 20th century. However, techniques to design and operate ultrafast lasers have changed little in the past, which resulted in performance limitations. Combining the latest advances in ultrafast photonics with the powerful tools of AI makes it possible to overcome these bottlenecks, but although AI is now ubiquitous in many areas, its uptake in ultrafast photonics remains limited. Written by an international group of scientists and members of FEMTO-ST, a review article in Nature Photonics [1] provides a comprehensive overview of how AI and associated methods can be applied to both improve next-generation laser sources, and revolutionize related applications.

Equally exciting are the possibilities photonics offers for AI. Computing architectures utilizing photonic technology have the potential for ultra-high performance AI hardware that overcomes the limitations of classical electronic computers. Processors for AI application using 3D printed photonic integrated circuits [2] promise size-scalable solutions for AI hardware for the first time. Crucially, similar 3D integration strategies in electronics face fundamental challenges, and integrated photonics could prove essential for next generation computing. Neural network will be fully implemented in physical hardware [3] and inefficient emulation in classical processors is avoided.

References

[1] G. Genty et al., Nature Photonics 15, 91 (2020).

[2] J. Moughames et al., Optics Materials Express 10 (11) (2020).

[3] D. Pierangeli et al., Nanophotonics 9 (13) (2020).

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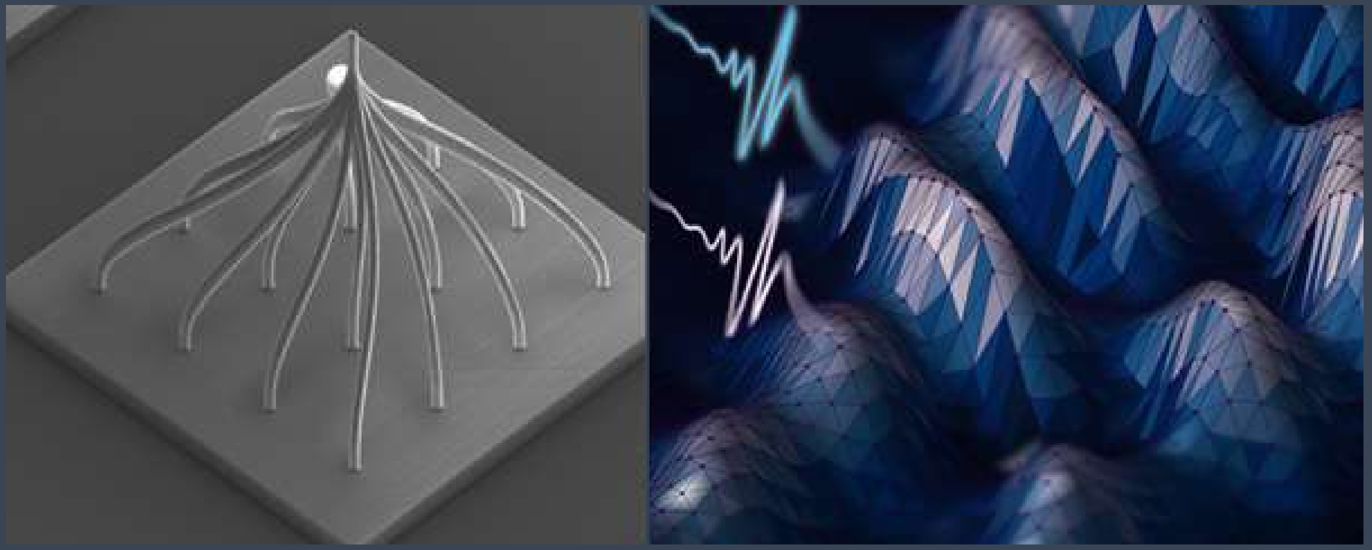

3D-printed optical connections allow for ultra-fast next generation photonic AI processors, and AI concepts promise breakthroughs for ultra-fast lasers and applications.

RESEARCH HIGHLIGHTS

2D OPTICS WITH LIGHT SURFACE WAVES

Maria-Pilar Bernal, Fadi Baida, Miguel Suarez, Mathieu Chauvet, Thierry Grosjean

OPTICS

Surface wave excitation can be seen as a high Q-factor resonance accompanied by a strong electromagnetic field confinement. The latter is the key point to enhance linear and nonlinear phenomena such as SERS (surface-enhanced Raman scattering), SHG (Second harmonic generation), fluorescence or Kerr effect. In this context, both theoretical and experimental studies are carried out at FEMTO-ST.

A double analytical/numerical formalism describing the properties of surface plasmon and BSW (Bloch surface waves) (propagation length and lateral displacement) has been developed to predict their optical behaviour in order to optimize their interaction with matter.

The combination of a Kerr medium and plasmonic waves offers an appealing configuration to control the self-confinement of low power beams with an ultrafast response. In this work, a strongly enhanced self-focusing effect undergone by a beam propagating in a plasmonic structure is reported for the first time (Figure below). Efficient reshaping of the observed beam takes place over distances as small as 100 microns, opening new perspectives for the development of integrated photonic devices.

An ultrathin optic based on Bloch Surface Waves has been demonstrated to generate optical vortices of tunable topological charge. BSWs have been used to impart orbital angular momentum to light owing to Spin-Orbit Interaction. As an extension of this concept, chiral diffractive structures for BSWs can be employed in combination with surface cavities hosting light sources therein.:

References

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T. Kuriakose et al., ACS Photonics 7 (9), 2562 (2020).

U. Stella et al., ACS Photonics, 7, 774 (2020).

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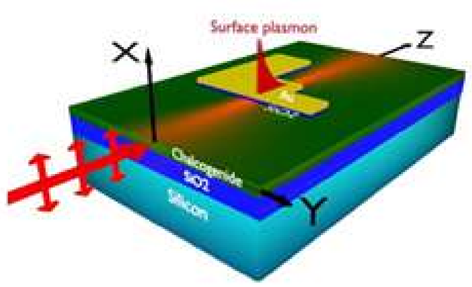

Schematic diagram showing the configuration of a nonlinear self-confined plasmonic wave.

ARTEFACTS AND ERRORS IN CROSS-SPECTRUM PHASE NOISE MEASUREMENTS

Yannick Gruson, Enrico Rubiola

TIME&FREQUENCY

Once upon a time in the countryside close to Bucharest, a radio amateur named Adrian observed that the white phase-noise floor of an oscillator became lower after inserting an attenuator between oscillator and noise analyzer. Taken literally, this means that energy dissipation increases the signal-to-noise ratio!

Asked to find the "obvious mistake," we realized that the experiment is so easy to reproduce, and that the plague affects numerous oscillators and most noise analyzers. We gathered a team here, with collaboration from the Rohde & Schwarz R&D center in München and of a company manufacturing oscillators in the New York area, and of course Adrian.

The explanation is a rather intricate combination of simple science and deep understanding of high tech. First, people do not realize how low the phase noise can be, compared to the thermal energy. Second, all instruments use the cross spectrum, which is a form of covariance and takes either sign. Third, the signal splitter at the instrument input contributes a negative term equal to its own thermal energy, which is obviously higher than in the lab room. Fourth, RF/microwave equipment suffer from leakage (crosstalk), which results in systematic error (bias) of either sign. Finally, all instruments take the absolute value before converting into dB, without warning about nonsensical, negative values. We ended up with the theory and an experimental method that corrects the bias. Checking on the theory, the two companies had to hack their own products without delivering factory secrets. All this is published on Metrologia, the official journal of the BIPM.

References

Y. Gruson et al., Metrologia 57 (5), 055010 (2020).

Facility: LNE-LTFB Oscillator IMP

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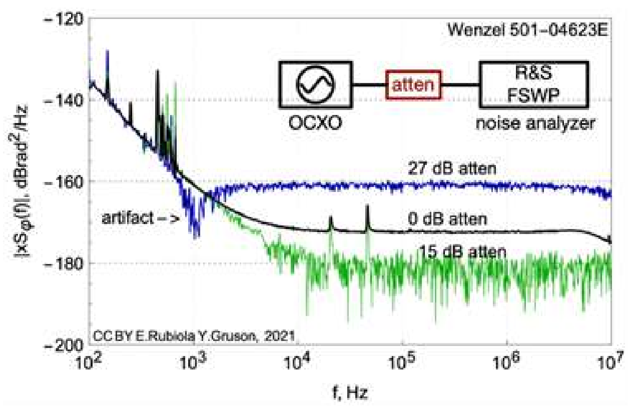
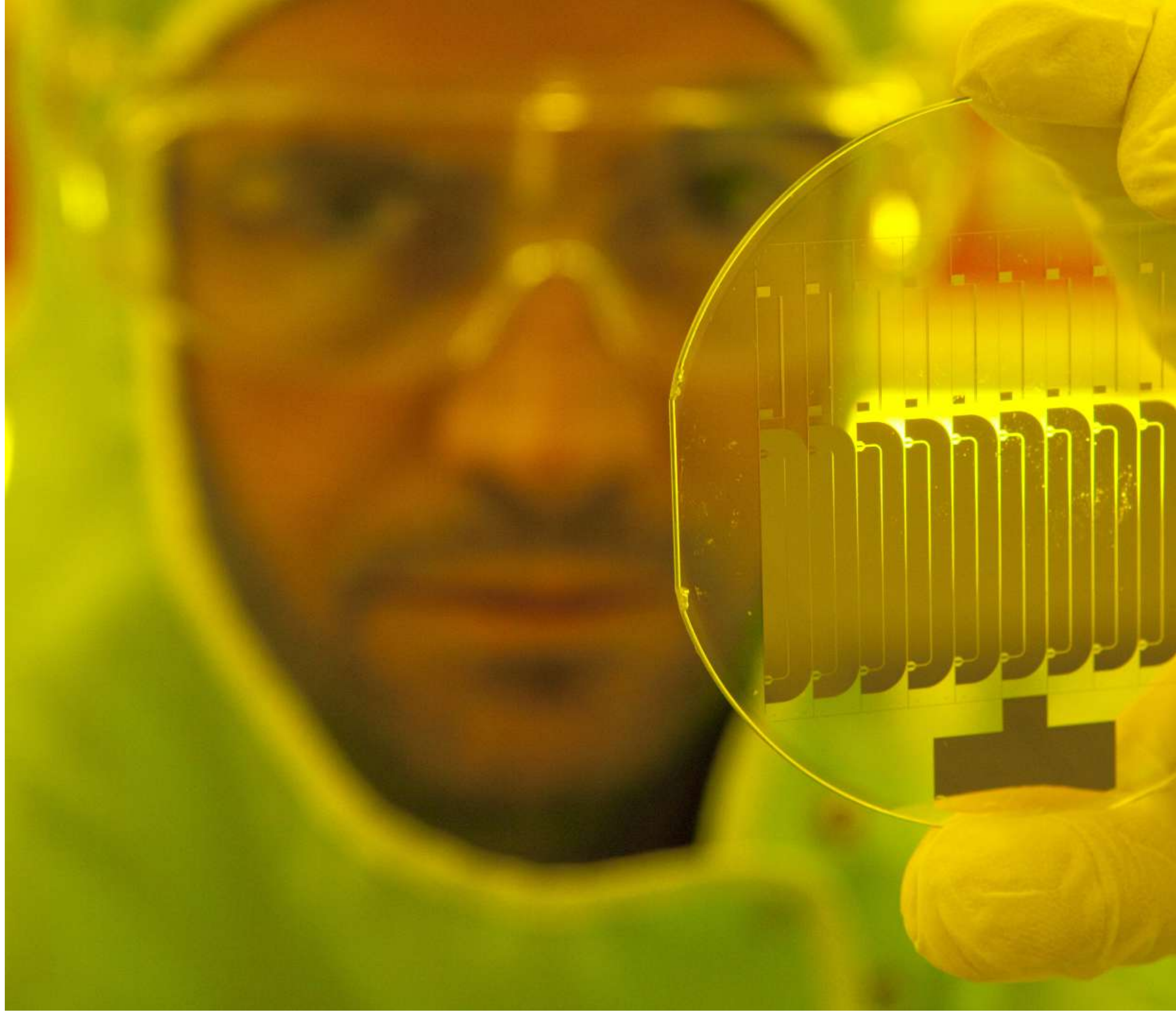


Phase noise of a Wenzel 100 MHz oscillator. Introducing a 15-dB attenuator in the signal path, the white noise displayed by the instrument gets lower. A pathology like this is rather common with the best oscillators manufactured in the last 20-30 years. Take away 3 dB to convert into dBc/Hz.



DATABASE

EMIDEC: AUTOMATIC EVALUATION OF MYOCARDIAL INFARCTION FROM DELAYED-ENHANCEMENT CARDIAC MRI

Raphaël Couturier, Michel Salomon, Gilles Perrot, Zhihao Chen

DISC

The EMIDEC challenge has been designed by partners of the ADVANCES ISITE UBFC project. The team leader is Alain Lalande from ImVIA laboratory of University of Burgundy. The context of this challenge concerns the evaluation of the state of the heart after myocardial infarction (MI) and the viability of the myocardial segment. MRI are performed several minutes after the injection of a contrast agent (delayed enhancement-MRI or DE-MRI) . There are two main objectives. First, the goal is to classify normal and pathological cases from the clinical information with or without DE-MRI. The second goal is to automatically detect the different relevant areas (the myocardial contours, the infarcted area and the permanent microvascular obstruction area (no-reflow area)) from a series of short-axis DE-MRI covering the left ventricle. Thirteen teams took part in the challenge, two did both contests, 7 only the segmentation contest and 4 only the classification contest. Data are freely available in order to let other researchers try to improve the prediction and classification results.

Reference

www.emidec.com

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BOOKS

RECITS

Laurent Heyberger

The latest issue of the Cahiers de Recits: technological training and gender, the Great war in the Europeans and US movies, battle of memories. Collectif Cahiers de RECITS n°11

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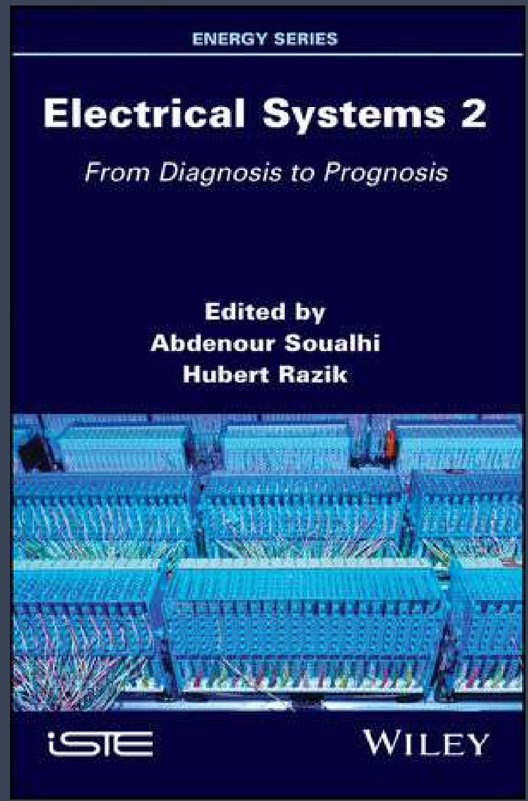

ENERGIE / SHARPAC

Zhongliang Li,
Zhixue Zheng,
Fei Gao

Chapter 5 "Diagnosis and Prognosis of Proton Exchange Membrane Fuel Cells" of "Electrical Systems 2: From Diagnosis to Prognosis"

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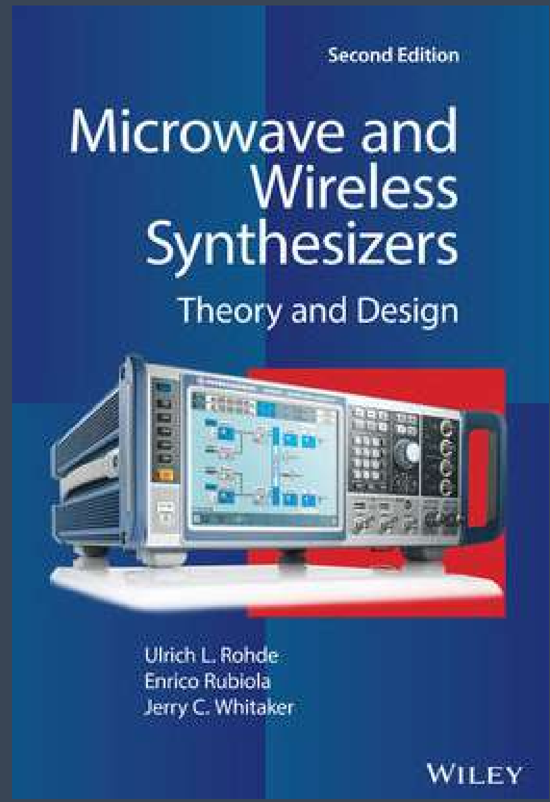

TIME & FREQUENCY/OHMS

U. Rohde, E. Rubiola and J. C. Whitaker

Microwave and Wireless Synthesizers

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EVENTS

ICRA CONFERENCE 2020

WORKSHOP ON THE APPLICATIONS OF MICRO-NANOROBOTICS IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION

Aude Bolopion, Cédric Clévy

AS2M

The FEMTO-ST Institute/AS2M department is proud to have initiated a workshop on the hot topic "Applications of robotic systems dedicated to micro (sub mm)/nano (sub micrometer) scales", held in the IEEE ICRA 2020 conference, the largest conference on robotics. In spite of the pandemic context, this on-line event gathered more than 300 attendees from all the major universities in the field – an unprecedented audience! For almost five hours, and despite the time difference, 14 speakers from three continents presented the most recent results in the field, offering a space for researchers to discuss despite strong measures were unfortunately preventing in-person interactions

https://teams.femto-st.fr//micro-and-nano-robotics/workshop-applications-micro-nanorobotics

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ICEREGA 2020

INTERNATIONAL CONFERENCE ON EMERGING AND RENEWABLE ENERGY: GENERATION AND AUTOMATION

Mohamed Becherif, Mickael Hilairet, Daniel Hissel, Amel Benmouna, Mehroze Iqbal

ENERGY

Partners: ITU (Turkey), University of Mohamed Khider (Algeria), University of Djibouti (Djibouti)

ICEREGA2020 is an international conference related to renewable energies: generation and automation. The previous meetings were in Belfort, (France), Sousse, (Tunisia) and Istanbul, (Turkey). ICEREGA 2020 was organised online as a webinar due to the COVID-19 and lockdown situation. 18 papers were published.

Partner journals: Computer and Electrical Engineering Journal (Elsevier), European Journal of Technique (EJT), balkan Journal of Electrical & Computer Engineering, The Journal of Cognitive Systems

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28E CONGRÈS FRANÇAIS DE THERMIQUE

François Lanzetta, Valérie Lepiller, Sylvie Begot, Philippe Baucour

ENERGY

Every year, the French Thermal Society (SFT) organizes its annual conference with an international audience. This conference, which concerns about 250 French-speaking and international researchers, is organized by a laboratory whose research is recognized internationally. The conference has been cancelled and postponed due to Covid-19 pandemic but the reviewing process was carried out and 110 articles were finally published.

https://www.sft.asso.fr/DOIeditions/CFT2020/TableofContents.html

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14E JOURNÉE MICRO ET MINI COGÉNÉRATIONS

François Lanzetta, Sylvie Begot

ENERGY

Partners: CNAM, SATIE, LEMTA, ATEE, GRDF (France)

Since 2006, the Energy department organizes this technical conference with an industrial and academic audience. This conference concerns the development of the cogeneration technologies in France and Europe. Each year, around 10 to 15 people present activities and results concerning academic and industrial European and French programs. In 2020, 120 participants attended this technical conference.

https://events.femto-st.fr/Journees-Cogeneration/journee-2020

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PHM BESANCON 2020

PROGNOSTIC AND SYSTEM HEALTH MANAGEMENT CONFERENCE

Jean-Marc Nicod, Noureddine Zehrouni, Zeina Al Masry, Rafael Gouriveau, Christophe Varnier, Omar Bougacha

AS2M

The PHM conference is an international conference organized every year since 2010. It was held mainly in China and for the second time in France. It is an opportunity for researchers and industry professionals in the field to discuss key issues, challenges and advancements in PHM. Two keynote speeches were proposed during the last edition. 62 articles were published.

https://ieeexplore.ieee.org/xpl/conhome/9108980/proceeding

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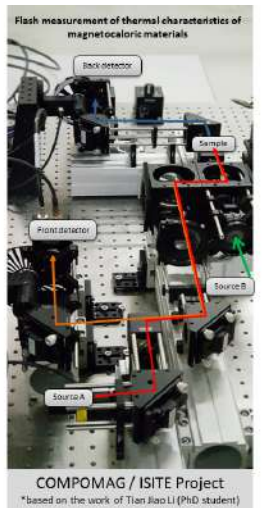
FLUIDIX

FluidiX research facility provides access to thermofluidic parameters: Development of photothermal detection methods to simultaneously obtain thermal diffusivity and effusivity of samples of magneto-caloric materials

Tianjiao Li, Yannick Bailly, Jean-Claude Roy, David Ramel, Laurent Girardot, Thierry de Larochelambert, Stefan Giurgea, Raynal Glises, Frédéric Dubas, Thierry Barrière, Antony Plait, Michaël Perrin, Ali Ismaïl.

The development of magneto-caloric machines (heat pumps/refrigeration systems) is highly dependent on the available materials. The ISITE / Compomag project demonstrated the advantage of using materials with different transition temperatures to increase both net thermal power and machine efficiency. However, magnetocaloric materials are not readily available in nature and offer few different transition temperatures. To increase the material resource and create a transition temperature continuum, the solution lies in the manufacturing of new materials combining magnetocaloric materials powders and polymers. Moreover, an important challenge is to have a practical tool to determine the thermophysical characteristics. Nextpac, one of the industrial partners of the project, and the Energy department have defined research work in this direction, entrusted to PhD student (Tianjiao Li). The FluidiX platform makes possible the development of this new innovative measurement method. A photothermal detection method allows one to simultaneously obtain the thermal diffusivity and the effusivity of materials in temperature driven conditions. The front side of a magnetocaloric sample is illuminated by a light beam of very low intensity. Two detectors collect the thermal response occurring simultaneously on the front and rear faces, then the thermal properties of the magnetocaloric materials are determined.



Flash measurement of thermal characteristics of magnetocaloric materials

Reference

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CLIPP

Nanobioanalytical solution developed at CLIPP for the characterization of potential therapeutic products.

Geetika Raizada, Céline Elie-Caille, Wilfrid Boireau

SPRi Chip: Rabah Zeggari

Research Partnership with the Vetbiobank company

CLIPP provides to the scientific community an original and powerful nanobioanalytical solution (NBA) for the deep characterization of extracellular vesicles (EVs) in complex biological media. The NBA utilizes Surface Plasmon Resonance imaging (SPRi) for real-time detection and characterization of EVs according to their phenotype, which were then further deeply characterized by Atomic Force Microscopy (AFM) to a precise size distribution and distinguish captured EVs from other biological materials.

Vetbiobank (VBB) is a biotech company specialised in developing cell therapies, as alternatives to chemical-based drugs, focused on veterinary chronic inflammatory diseases. Mesenchymal stromal cells (MSCs) are of particular interest because of their validated safety profile and tremendous biological properties. MSCs secrete various paracrine factors, including EVs, that support the healing process by managing inflammatory conditions.

In this project, launched in 2020, CLIPP has designed a biochip devoted to the cell secretome, especially EVs produced by MSCs. Working on different bioproduction products, specific immunocapture of EVs have led to singular and differential biochemical signatures of EVs populations. For its part, VBB investigates, by in vitro and in vivo models, the functional activities of EVs samples in order to distinguish the most promising culture conditions and their potential use for therapeutic treatments.

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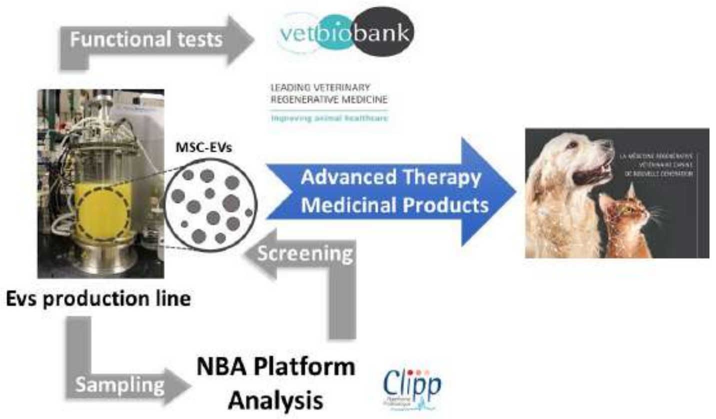

Off-line EVs investigations with NBA platform

MÉSOCENTRE

Myocardial Infarction Segmentation From Late Gadolinium Enhancement MRI By Neural Networks and Prior Information

Zhihao Chen, Michel Salomon, Gilles Perrot, Raphaël Couturier

In this work, we propose an automatic myocardial infarction segmentation framework from Delayed Enhancement cardiac MRI (DE-MRI) using a convolutional neural network (CNN) and prior information-based post-treatments. 195 cases of DE-MRI examinations constitute this dataset, including on average 7 images per case with manually drawn contours by an expert. The objective is to automatically segment myocardial infarctions on both healthy and pathological images in the dataset. In the proposed framework, a downsampling-upsampling segmentation CNN firstly generates high recall segmentations of myocardial infarction from left ventricle DE-MR images, then the proposed prior information-based post-processing method identifies and removes false-positive segmentations from the CNN's prediction. To obtain a high recall prediction, two U-NET like semantic segmentation networks are investigated. Combining the high recall networks and prior postprocessing information, we achieve segmentation results comparable to those produced by human experts.

Note that training such a network requires the use of a machine with efficient GPUs. The ADVANCES ISITE project provided the funds to buy a DGX machine equipped with 4 V100 GPUs. This machine is now hosted and managed by in the Mésocentre and shared with other users.

References

http://emidec.com/

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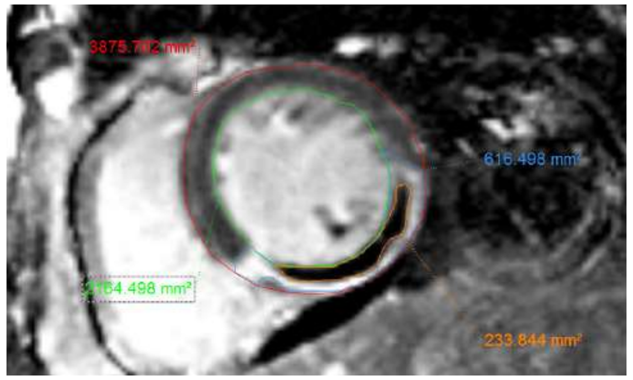

An example of segmentation of the myocardium and calculation of some parameters

FRILIGHT

Maxime Jacquot, Alexis Mosset

The FRILIGHT platform was the winner of the EQUIPEX+ call with the SMARTLIGHT project, coordinated by Benoit Cluzel (ICB), and gathering ICB laboratory (PICASSO Platform) and FEMTO-ST institute. The new proposed research platform will provide key facilities to drive the next generation of Smart Photonic technologies. This project lies at the crossroads between The French National Strategy on Artificial Intelligence and the European Commission's new Industrial Strategy for Europe to 2030. In this context, our ambition in SMARLIGHT is to position the UBFC as an international leader in smart photonics and to federate the French and international community in this field around an open research platform. To this end, SMARTLIGHT will implement a disruptive equipment aimed at feeding scientific facilities to support the development of active control and optimization of optical systems, structured around four interdependent scientific and technological blocks that address specific challenges: optoelectronic high-bandwidth devices for real-time monitoring; ultrafast laser lines; a multimodal optical microscopy platform, and a 3D printer of photonic wires. This highly ambitious project is closely related to ISITE-APPEAR BFC project and EIPHI Graduate School.

References

https://teams.femto-st.fr//FRI-LIGHT/en

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Illustration of the SMARTLIGHT concept for the next generation of optical and photonic technologies based on machine learning and the techniques of data science. Light shaping as a transverse axis will enable the development of new approaches for the implementation of smart optical sensors connected to optical neural networks with help of 3D optical elements.

FACILITY HIGHLIGHTS

µROBOTEX

µROBOTEX expands and becomes the Centre for Micro and Nano-Robotics (CMNR)

Guillaume Laurent

For a few years, the µROBOTEX facility of FEMTO-ST has offered new possibilities to manipulate, assemble and characterize objects and systems at very small scales (typical dimensions less than 100µm). Some of its results, such as the assembly of the smallest "house" in 2018, have reached an international audience. Initially focused on manipulation under scanning electron microscopy, the platform is now broadening its technical and thematic offer. Mature setups developed by the AS2M department as well as new acquisitions are made available to laboratories and companies. The objective is to provide state-of-the-art instruments for research at small scale in engineering sciences but also in the biomedical field such as individual cell handling or medical microrobotics. This new perimeter translates into an evolution of µROBOTEX into the Centre for Micro and Nano-Robotics (CMNR). The centre is part of the national network of experimental robotics platforms ROBOTEX (Equipex). The centre is installed in 80 m² of class 1000 clean rooms newly created by ENSMM in 2020 which offer optimal conditions for the characterization of micro-objects and cells as well as for the assembly of microrobots.

Reference

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

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New clean rooms of the Centre for Micro and Nano-Robotics (CMNR)

HYDROGÈNE ENERGIE

Marie-Cécile Péra, David Bouquain.

The platform is dedicated to the test of Hydrogen components and systems. These facilities are unique in Europe : PEM fuel cell stacks from 500 W to 120 kW, PEM FC systems up to 160 kW, SOFC stacks up to 1 kW. Very long duration tests can be carried out, 24h a day and 7 days a week, for few thousands of hours. Real life environmental operating conditions can be reproduced indoor with a climatic chamber and a vibrating test bench that can be coupled. Prototyping can be accelerated through the Power Hardware In the Loop devices, able to emulate a complete power train for transportation applications as well as power conversion for connected or off-grid applications. Our 8 rooms and 600 m² of ATEX surface are accessible to academic and industrial partners, as well as our test benches and the expertise of our staff. The platform has received its ISO 9001 certificate in November 2020. It is operated by the Center for Service and Research FCLAB to ensure up-to-date test benches and expertise acquired during the last 2 decades through research activities of FEMTO-ST and the 5 other partner laboratories. We won the EQUIPEX + DurabilitHy which will further emphasize our equipment.

References

Petrone R. et al., Fuel Cells (jun. 2018).

www.fclab.org

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Test room – 10kW test bench and the control room

MIFHYSTO

Nano-Micro-X-Ray tomography (Computational Tomography Scan)

Xavier Gabrion, Sébastien Thibaud, Pierrick Malécot

The MIFHySTO platform has been equipped with a micro-nano X-Ray tomography machine since 2017. It is dedicated to control and analyse components or assemblies in volume by X-Ray and image processing technologies. Depending on the samples analyzed (dimensions, materials), volume resolutions of 4 µm (micro-tomography) and 400 nm (nano-tomography) are available. The study concerns in-situ micromechanical tensile test of a plain weave Flax epoxy specimen under X-Ray radiation. Tensile tests at different force level lead to specimen fracture. The stress/strain evolution is correlated to defect evolution by computational Tomography reconstruction. The porosities are thus calculated in relation to the evolution of the defects and cracks initiated. The next developments of this work consist in developing new characterization tests (bending, shear, tension/compression) on very small samples (less than one millimeter) of various materials (metals, composites, polymers, glass, ceramics, wood, ...) and under variable conditions (temperature, humidity, liquid/gas).

References

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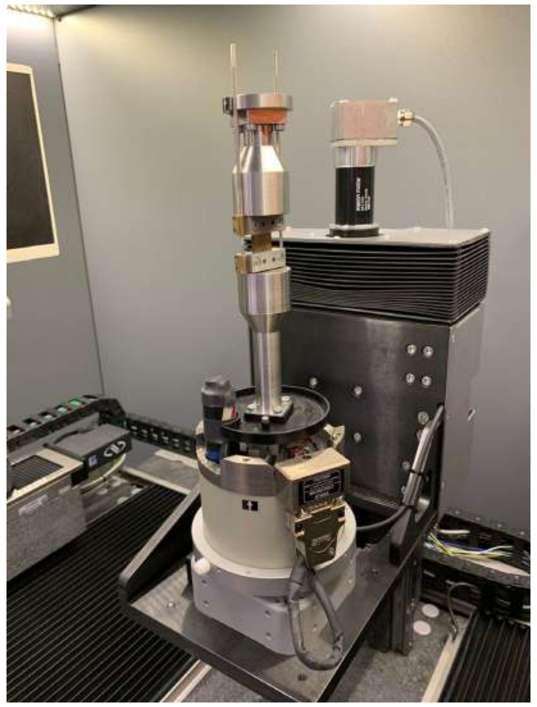

Tensile test of a plain weave Flax epoxy specimen under X-Ray radiation for different applied force levels.

MIMENTO

Mimento will extend its 3D direct micro-manufacturing capacity with the Equipex+ project.

In collaboration with the Renatech+ network of French technological facilities and the CNRS, the MIMENTO platform has obtained two new projects for more than 2M€ in the Equipex+ call from the 3rd round of the Investment for the Future Program (PIA3).

For this project MIMENTO wanted to further its 3D micro-manufacturing capabilities, which currently use a Nanoscribetool for polymers, a FEMTO-Print tool for glass and a standard FIB for other materials (mostly ablation processes).

In this context, we have proposed two innovating tools for both additive and substractive 3D structuring of complex materials. First, we will procure a new multi-source (Au, Si, Ga...) focused ion beam (FIB) tool specially configured for manufacturing on a large area. It will be used, for example, in photonics for its ion implantation capabilities to create a 3D array of nano-sources for new light control schemes. Then, in collaboration with a CVD manufacturer, we propose to develop a new femtosecond laser assisted chemical vapor deposition (Femto-CVD) tool. The new capacity to trigger CVD deposition at the focal point of the laser will open up the possibility to form complex 3D structures with multifunctional, including piezoelectric materials. One of the goals is to produce dexterous microrobots for biomedical applications with severe space constraints, going beyond endoscopic systems.

https://platforms.femto-st.fr/centrale-technologie-mimento/

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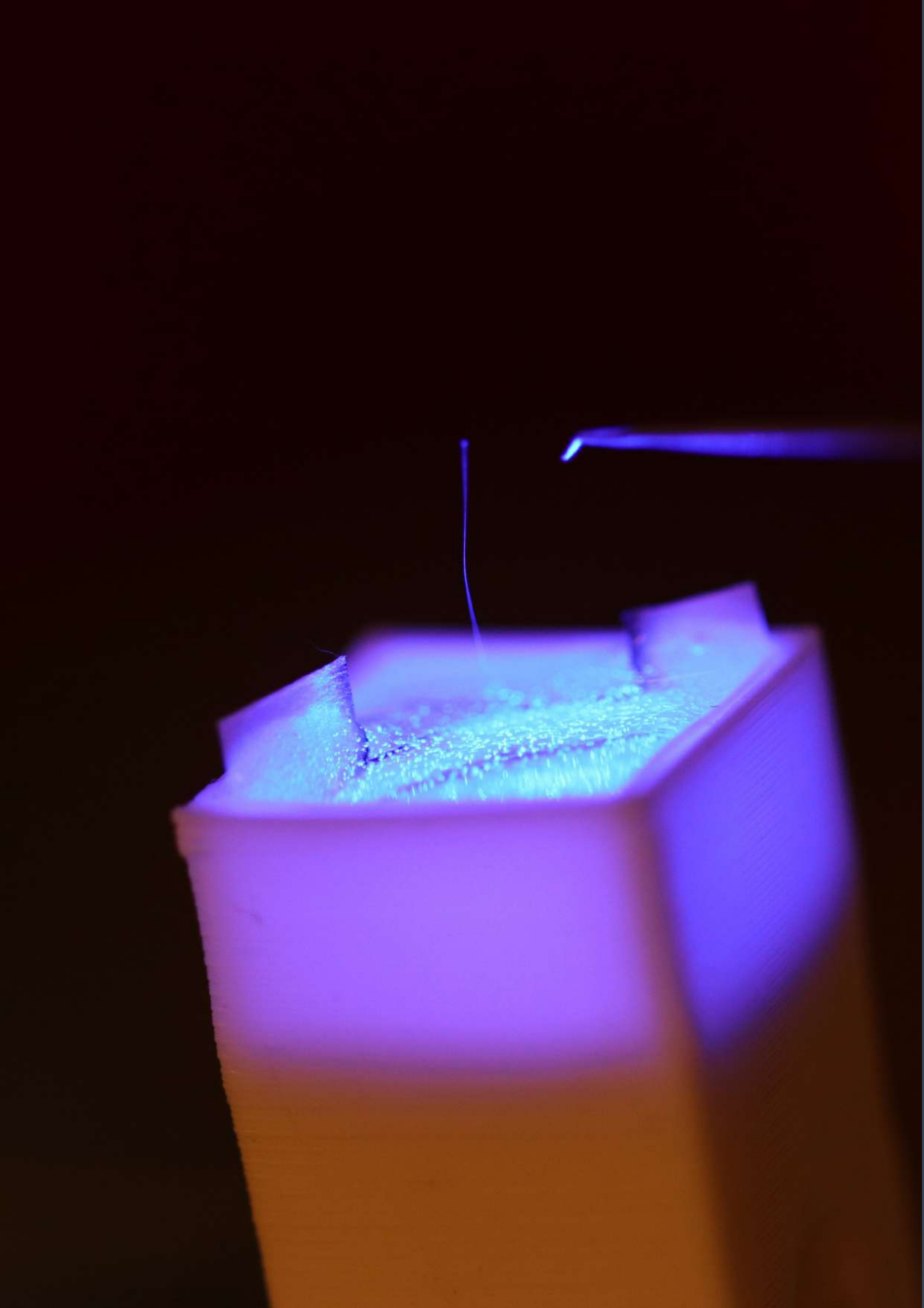
Large scale multi-source focused ion beam tool



INNOVATION

FEMTO ENGINEERING

The engineering Centre of the FEMTO-ST Institute offers industrial companies high level engineering developments based on the research conducted at FEMTO-ST. FEMTO Engineering has fifteen employees and cooperates directly with the research groups within the FEMTO-ST Institute. Technological fields of concern:

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

Facilities: MIMENTO, µrobotex, OSCILLATOR-IMP, AMETISTE

TECHNOLOGICAL PROGRESS ON THE CUTTING OF THICK GLASS WITH LASERS

FROM TRL3 UP TO TRL6

This project, which is part of FEMTO Engineering's mission to mature innovative technologies issued from FEMTO-ST academic research, is based on the work of François Courvoisier's group (CNRS research director). In 2019 he demonstrated the possibility for fs-laser to efficiently cut thick glass from 3 mm to 10 mm thanks to a new original optical architecture based on Bessel beam shaping [1].

FEMTO Engineering has made the following developments in this project:

- Assembly of a compact optical system allowing generation of a length-tunable Bessel beam, followed by first integration tests into a 5-axis laser machining station.
- Development of a laser process to cut glass from 2 to 5 mm thickness, in a multi-pass approach.
- Development of a new laser cutting process capable of cutting glass up to 2mm in thickness with an inclination up to 30 ° between the Bessel beam and the glass plate surface.

FEMTO Engineering is already dealing with industrial companies about this innovative method for thick glass cutting using femtosecond laser.

This innovation project is supported by the Bourgogne-Franche-Comte Region.

References

R. Meyer et al., Applied Physics Letters 114, 201105 (2019).

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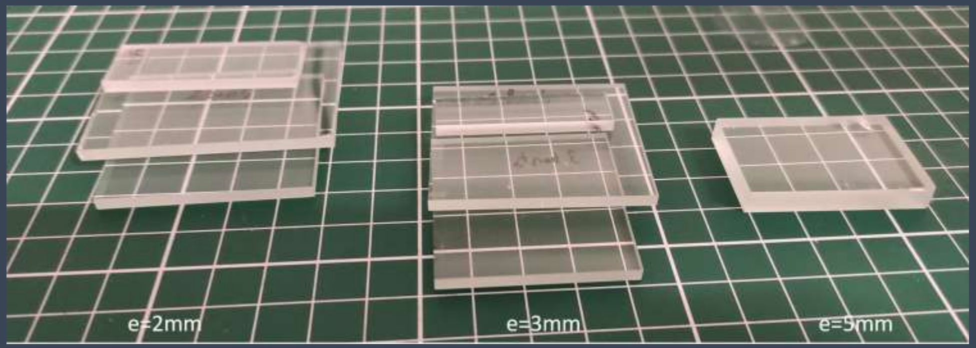
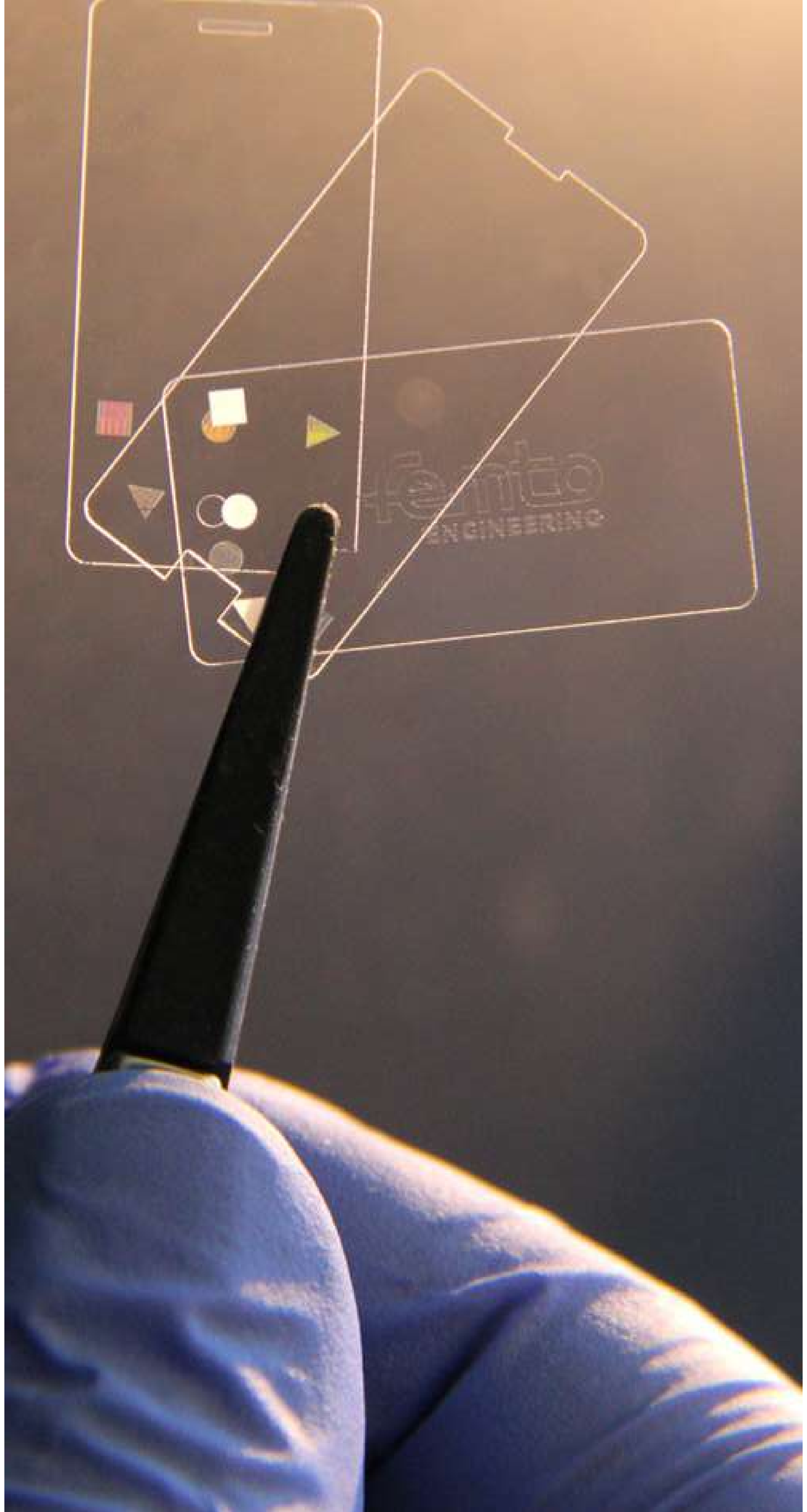


Several glass samples cut using the new Bessel beam shaping of different thickness, 2, 3 and 5mm.



HIGHLIGHTS ON INDUSTRIAL COLLABORATIONS

STELLANTIS

Programmable matter made from mm-scale autonomous robots

Julien Bourgeois

DISC

The collaboration with Stellantis (former PSA Groupe) is a long-term effort around the concept of programmable matter made from mm-scale autonomous robots. Stellantis has brought its knowledge of advanced materials and developed an application. The idea is to develop an interactive computer-aided design (CAD) tool for fast prototyping and moulding of new parts. Design of a new automotive part can begin with CAD software and then be transferred into an ensemble of robots that take the same shape as in the CAD representation. The designers can then modify the object, mold it with a shape-memory polymer to obtain a smooth surface while the new shape is directly modified in the CAD software which can perform mechanical resistance simulation for example. This work has been funded by a ANR (ANR-16-CE33-0022-02) and a ISITE-BFC project.

Reference

https://www.stellantis.com

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Dual CO/CO_2 sensors based on the surface acoustic wave

Virginie Blondeau-Patissier, William Daniau, Valérie Soumann, Thomas Baron, Gilles Martin, Meddy Vanotti, Sacha Poisson

TIME&FREQUENCY

Odorless and colorless CO gas is formed during the incomplete combustion of organic matter. On a daily basis, we are exposed to numerous atmospheric pollutants emitted in particular by urban car traffic. CO is responsible for>350 deaths per year in France. The aim of CO_2DECIN is to design mixed carbon monoxide (CO) and carbon dioxide (CO_2) sensors based on the selective adsorption properties of these gases by active and porous molecular materials with a view of developing new marketable sensors. The current CO sensors are limited by either a low differentiation from other gases or a low sensitivity.

The consortium, composed of FEMTO-ST, ICMuB, Stellantis and ETHERA proposes to develop a new family of dual CO/CO_2 sensors based on the surface acoustic wave (SAW) technology, known for their high sensitivity to surface phenomena associated with a specific molecular material functionalization (COF based on cobalt corroles or MOF based on triazacyclononanes). Quantification is based on the slowing down of the propagation speed of the waves due to the mass deposited on the device's surface. The use of Love waves can gain a factor of 10 in sensitivity compared to a conventional quartz microbalance. A reference element is subjected to the same conditions as the test body in order to subtract the background noise. This technology has already achieved a detection limit for CO below 80 ppb.

References

M. Vanotti et al. Sensors and Actuators, online (2021)

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ALSTOM

TOOLS FOR THE DESIGN OF BOGIES PANTOGRAPHS AND CATENARIES

David Renault, Betty Auzanneau, Justine Larivière, Scott Cogan, Morvan Ouisse, Emmanuel Foltête

APPLIED MECHANICS

The development of analysis or simulation tools on demand is part of the interdepartmental cooperation in the Institute. A collaboration with Alstom has led to the development of two software programs which are now used on a daily basis for the design of rail transport systems. One of these tools is dedicated to the transfer of virtual prototyping and certification methods for the train industry. Currently implemented approaches include a robust tolerance strategy to help engineers make design decisions under manufacturing uncertainties, as well as a range of modules to facilitate cost-intensive design and certification calculations (stability, comfort, resistance to derailment, etc). The second tool makes it possible to simulate the dynamic behavior of the interactions between the catenary and the pantograph during the movement of trains. Taking into account the complexity of these interactions, the finite element calculations make it possible to design the catenary and pantographs in order to guarantee contact conditions for proper transfer of the electric current to the train motors for all catenary arrangements.

Reference

https://www.alstom.com

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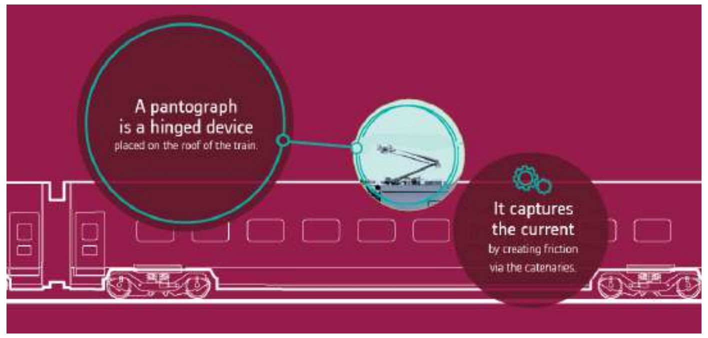

credit: ALSTOM

SYRAH-LAB : A NEW JOINT LABORATORY BETWEEN FEMTO-ST AND KAPTEOS

Nadège Courjal, Maria-Pilar Bernal, Fadi I. Baida, Miguel Suarez, Florent Behague, Antoine Coste, Adrien Godet

OPTICS

Since september 2021, the FEMTO-ST institute and the Kapteos company have joined their research activities within the SYRAH-lab joint laboratory. The acronym - Sondes intégrées hYperfréquences pour la mesure de RAyonnement électromagnétique à Haute sensibilité - means in English: "Integrated hYperfrequency probes for the measurement of electromagnetic radiation with high sensitivity". The measurement of hyperfrequency electric-field (E-field) exposure is an ever-evolving subject that has recently led the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to change its recommendations. From wireless telecommunications to intense radiofrequency treatments, daily exposure to hyperfrequency electric fields is diverse and ubiquitous, requiring adequate E-field sensors to evaluate and prevent the correlated risks. In this context, SYRAH-lab aims at developing broadband E-field sensors with micrometric spatial resolution and high sensitivity (< 100 $\mu V \cdot m^{-1} \cdot Hz^{-1/2}$).

SYRAH-lab combines the expertise of Kapteos and FEMTO-ST:

- Kapteos is an SME company leader in the measurement of E-fields in severe environments (cold plasmas, MRI, high voltage) thanks to its fully dielectric fibre optic probes.

- through its optics department, and with the MIMENTO platform facilities, FEMTO-ST contributes it expertise in the design/manufacture/characterization of electro-optic photonic circuits.

This new joint lab paves the way for a new generation of miniature E-field sensors meeting the ever-demanding requirements of 5G, ultra-high-field Resonance Magnetic Imaging (RMI), plasmas, or hyperthermia treatments.

The SYRAH-lab will be opened officially in March 2021.

References :

F. Behague et al., "Minimally-invasive optical sensors for micro-wave-electric-field exposure measurements", Journal of Optical Microsystems, Review #20020V, to be published (2021)

Facility: MIMENTO

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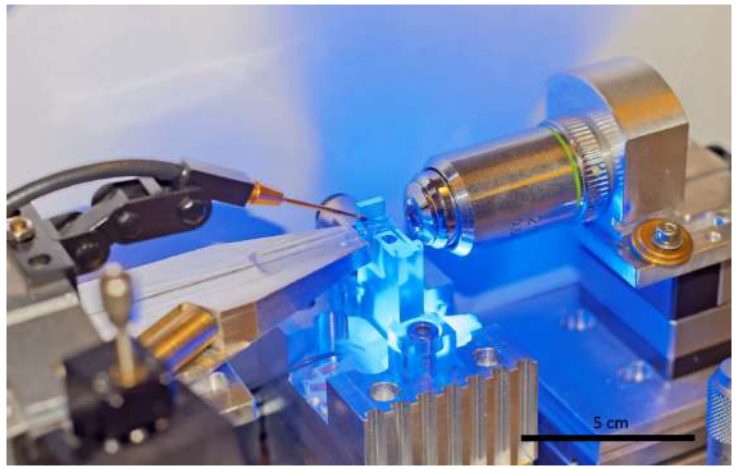

Picture of the characterization setup bench

COLRUYT

Prediction and study of the behavior of customers

Raphaël Couturier, Olivier Bonnet, Bernard Agbemadon

DISC

Colruyt is a supermarket chain with stores mainly in the east of France. Colruyt collects a very large amount of data on a daily basis about the products purchased by their custumers. This data is not always sufficiently exploited, especially from a behavioural and predictive point of view. This work which started at the beginning of 2020 is done through a CIFRE PhD thesis. The aim of this work is to predict and study the behaviour of customers. For that two lines of enquiery will be followed, the first is to understand, as far as possible, the factors that lead to changes in customer behavour. The second consists of improving the customers shopping experience and to deduce the patterns of shopping behaviour pattern. The PhD student is working on these subjects with the company and the experience of FEMTO-ST/DISC in time series prediction with gradient boosting algorithms and deep learning algorithms.

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TYPHOON HIL, INC.

Real-time Hardware-in-the-Loop modeling libraries developed by FEMTO-ST researchers are now available in Typhoon HIL commercial software worldwide

Elena Breaz, Fei Gao

ENERGY

As one of the privileged academic partners, FEMTO-ST institute has maintained a close collaboration with the R&D team from Typhoon HIL company in the past few years in the field of real-time simulation technology and energy source modeling for Hardware-in-the-Loop applications. Since 2018, researchers from FEMTO-ST Energy department have worked with engineers at Typhoon HIL to develop together a fuel cell real time modeling library for their commercial HIL software. This 2-year long collaboration has given an extremely satisfying result in 2020: the real-time fuel cell models developed by FEMTO-ST researchers have been successfully integrated and deployed in 2020 commercial release of "Typhoon HIL Control Center Toolchain" and have become one of the standard energy sources libraries in the software. Typhoon HIL Inc. is the market and technology leader in the rapidly-growing field of ultra-high-fidelity controller-Hardware-in-the-Loop (C-HIL) simulation for power electronics, microgrids, and distribution networks. The company provides industry-proven, vertically integrated test solutions along with highest-quality customer support. The company was founded in 2008 and since then has been creating products distinguished by the ultimate ease of use, unrivaled performance, leading-edge technology, and affordability.

Reference

https://www.typhoon-hil.com/

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HIGHLIGHTS ON PATENTS

TAPERED OPTICAL FIBER PLATFORM

Jacques Chrétien, Emmanuel Dordor, Kien Phan Huy, Gil Fanjoux, Thibaut Sylvestre, Alexandra Monnin, Alexandre Matic, Simon Colombel, Adrien Godet, Jean-Charles Beugnot

OPTICS, FEMTO-ENGINEERING

Tapered optical fibres (TOF) are hairlike slivers of silica glass. The fabricaion process by the tapering of standard telecom optical fibres, enables enhanced optical confinement and generates a very large optical evanescent field. The platform was initially designed and created during Adrien Godet's PhD thesis (2015-2018) and funded by the Bourgogne-Franche-Comté region.

We manage all aspects of design. We have developed a homemade spectroscopy method to measure diameter and homogeneity of TOF with a prevision of 1%.

This platform is dedicated to applied research mostly for studiying light/sound interactions at the nanoscale and to develop relevant technology. As the main industrial limitations of these TOF include high loss after packaging and the difficulty of handling such fragile items which are easily contaminated by dust and humidity, we design and developed homemade packaging in collaboration with our mechanical design and fabrication service to overcome all these limitations.

Industrial partners and new products are identified and collaboration with SATT Sayens, Prematuration CNRS is in progess. We have just filed a patent for all-optical delay lines based on TOF, showing one of the direct applications of these promising new optical components.

Wider range experiments and applications are envisaged in a near future to develop both light mater interaction and industrial applications from sensing to laser component.

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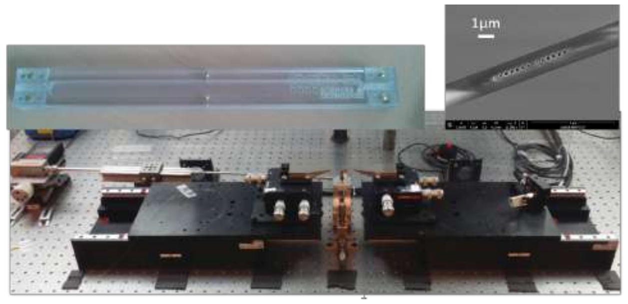

Up left, tapered optical fiber packaging develop at FEMTO-ST. Up right, MEB image of functionaliazed nanofiber. The Bench of the fiber tapering system.

AUTONOMOUS SENSOR BASED ON LEAD-FREE VIBRATIONAL ENERGY HARVESTING

Giacomo Clementi, Merieme Ouhabaz, Bernard Dulmet, Mario Costanza, Ausrine Bartasyte, Florent Bassignot, Ludovic Gauthier-Manuel, Samuel Margueron

TIME&FREQUENCY

Industry 4.0, the Internet of Things (IoT) and especially the new generation autonomous vehicles need monitoring and communication systems. With the multiplication of sensors, it becomes necessary to simplify energy supply. We are developing, within the framework of the European project ITN "ENHANCE" (2017-2021), prototypes of vibrational energy harvesters based on lead-free materials.

With our technology of LiNbO3 (LN), we implemented high-quality piezoelectric single crystalline films onto flexible host materials and composite structures. Typically, the developed prototypes are capable of attaining output power levels similar to standard lead-based ceramics (such as PZT). The important aspect of our technology is that it provides toxic-free, ultra-compact and cheap materials that can be designed for all situations. Our technology is fully cleanroom compatible, and it can be upscaled for massive production of electroactive flexible devices with complex geometry and high integration.

These devices can be designed and optimized based on user's specifications and in terms of their environmental application conditions. Moreover, thanks to the integration of a Bluetooth Low-Energy module developed in collaboration with STMicroelectronics, we demonstrated that our system can be used as a self-powered wireless sensor capable of transmitting data to a smartphone positioned more than 20 meters away.

These devices respecting REACH and RoHS regulations, open a new era for autonomous sensor based on vibrational energy harvesting, and as a follow-up of this work, Giacomo Clementi obtained a post-doc Itineraire Chercheur Entrepreneur BFC (2020-2021) to create a start-up based on this technology.

References

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https://www.itn-enhance.com/

Facility: MIMENTO, MIFHySTO

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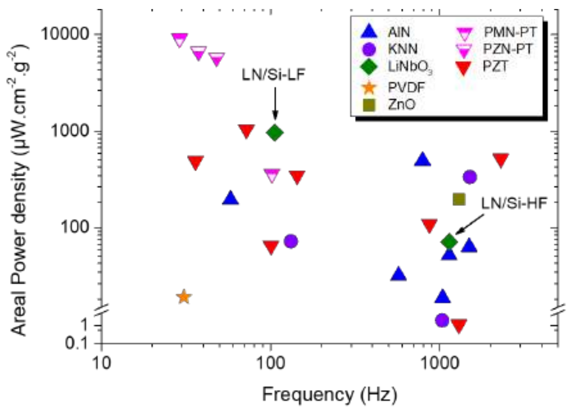

Comparison of vibrational energy harvesting performance of different piezoelectric materials

TEMPERATURE-CONTROLLED RADIOFREQUENCY RESONATOR AND CORRESPONDING RADIOFREQUENCY OSCILLATOR

Thomas Baron, Gilles Martin, Valérie Soumann, Yannick Gruson

TIME&FREQUENCY

A patent relating to the innovative reduction of power supply connections of a radio frequency resonator and of an oscillator was obtained in June 2019 (patent FR1906710). This technological optimization gives an oscillator with reduced thermal losses which has direct consequences for energy consumption and start-up time. A first experimental set-up proves that the phase noise is still interesting for oscillator applications. A market study, initiated by SATT SAYENS, demonstrates the potential of the idea and highlights the need to quantify all the chacteristics of a commercial system using this patent. A development project was initiated in 2020 with SATT SAYENS.

The objective of this development project is to demonstrate the advantages offered by the invention and to quantify the characteristics of an OCXO (Oven Controlled X-tal (Crystal) Oscillator) marketed after the integration of the invention. Development will take place in two phases. The first involves the development of an advanced laboratory mock-up while the second aims to integrate the invention into an industrial OCXO component. This second phase can only be done, after a go-no-go, by means of collaborative development with an industrial partner. By the end of the maturation project, the technology will have reached a TRL 7.

Reference

Patent FR1906710

Facilities: MIMENTO, OSC-IMP

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Experimental setup for the proof of concept

STIRLING MACHINES OPTIMIZATION

Steve Djetel-Gothe, Mathieu Doubs, Mohamed Said Kahaleras, François Lanzetta, Guillaume Layes, Sylvie Begot, Hakeem Khirzada, , Philippe Nika

ENERGY

Interest in Stirling engines has grown recently because they can work with many heat sources including combustion of biofuels, solar sources or waste heat. Recovering waste heat at low temperature can lead to design miniaturized Stirling engines, therefore changing fabrication technology and move to 3D printing or clean room fabrication. The great interest is that a same Stirling machine can operate as engine or refrigerator or heat pump.

The efficiency of a Stirling machine depends on several factors such as heat losses between the different volumes and fluid losses in the exchangers and regenerator in particular.

Concerning the heat losses, we developed a solution [1] to reduce heat exchanges by conduction between the hot and cold volumes of the Stirling machine, reduce the dead volumes of the Stirling machine, reduce the pressure losses during the circulation of the working gas in the Stirling machine, and improve cooling in the friction zones of the Stirling machine.

Whatever the machine size, the regenerator in Stirling engine is a key element because the engine efficiency is strongly dependent on its thermal and fluidic performances. The regenerator is a porous medium subjected to reciprocating flows between the hot source and the cold sink. Therefore, fluidic performances in reciprocating flows have to be known to design efficient Stirling machines, although most of the published correlation concerns unidirectional steady flows. Our patent [2] concerns a regenerator whose porosity does not vary with successive gas passages, whose hydraulic diameter does not vary with the successive passages of the gases, a regenerator with low pressure drops compared to the pressure drops of state-of-the-art regenerators, and with limited heat conduction losses in the direction of gas flow.

References

[1] Patent FR 3 090 840/ WO2019EP85696 20191217

[2] Patent FR 3 090 749/ WO2019EP85691 20191217

https://www.inpi.fr

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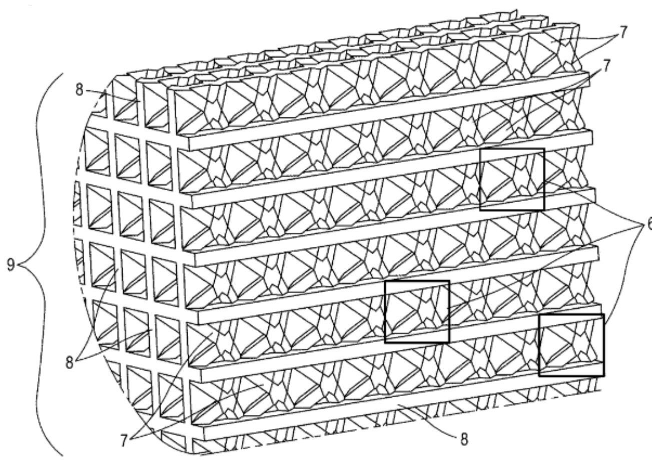

Regenerator with controlled porosity

SOFTWARES

VISIBLESIM: A BEHAVIORAL MODULAR ROBOTIC SIMULATION FRAMEWORK

Dominique Dhoutaut, Benoit Piranda, Julien Bourgeois

DISC

VisibleSim is a framework for creating behavioral simulators for distributed lattice-based modular robotic systems in a regular 3D environment. Physics simulation is not the purpose of VisibleSim, instead, its aim is to provide the tools for studying the behavior of such systems, through the simulation of the interactions between the robotic modules and their environment (neighbor detection, motions within the lattice, user interactions, etc.), or between the modules themselves (communication between modules through message passing).

Each module in the system is assigned a unique identifier, and executes the same controller as all other modules, generating communication or environmental events that are handled deterministically by VisibleSim's discrete-event scheduler. This allows for accurate simulations of complex algorithms on robotic ensembles up to millions of modules in size on a single computer. VisibleSim is powered by discreet-event simulation, which means that it relies on a scheduler that executes a sequence of discrete actions over time scheduled at fixed dates. Each event represents an action on the simulated world and potentially causes new events to be scheduled at a later date.

References

B. Piranda et al., IEEE 24th Euromicro International Conference on Parallel, Distributed, and Network-Based Processing (PDP), 1–9. IEEE (2016).

A. Naz et al., IROS 2018, IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (Spain), 4825 (2018).

P. Thalamy et al., Robotics and Autonomous Systems 120, 103242 (2019).

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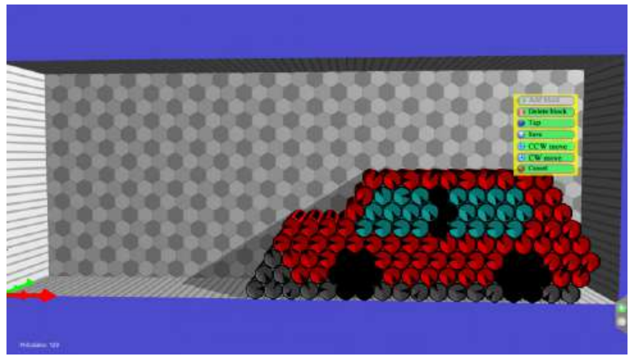


An overview of the VisibleSim interface

BITSIMULATOR, A DENSE NANONETWORK SIMULATOR

Dominique Dhoutaut, Eugen Dedu, Farah Hoteit, Ali Medlej

DISC

BitSimulator is a simulator of electromagnetic nanonetworks. Nanonetworks are networks of nanomachines, defined as machines of nanometric size (less than one micrometer). Due to their very small size, they have limited resources (CPU, memory, communication) which call for completely different methods.

BitSimulator allows us to validate (test) the communication protocols we conceive for these novel networks. It implements several protocols at various levels. It features in six published articles and two others in preparation. It also comes with a visualisation tool (VisualTracer) which reads the huge logs (of the order of GB) generated by the simulator and shows the map of nodes and various information about transmitters, receivers, and packet collisions, among others.

Due to the small size of nanomachines, nanonetworks can potentially be very dense. We usually test networks of 10000 nodes, where each node has hundreds of nodes in its vicinity (in its communication range). We believe that networks will, in future, be ultra dense numerous machines in close proximity and communicating directly.

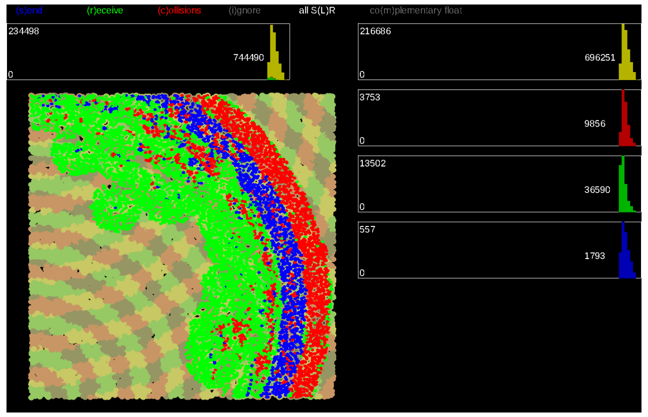
BitSimulator is focused on nanonetworks and very fast at execution. We usually execute it on our own laptops, and sometimes on a 48-core machine with 128 GB of memory.

References

D. Dhoutaut et al., 5th ACM/IEEE International Conference on Nanoscale Computing and Communication (NanoCom), Iceland, 1 (2018).

http://eugen.dedu.free.fr/bitsimulator/

eugen.dedu@univ-fcomte.fr



A packet broadcasted in a network of 20000 nodes, as shown by BitSimulator and VisualTracer (nodes in blue are sending packets, in green are receiving packets, and in red are experiencing packet collisions during a given time frame).

FPMAS: A MULTI-AGENT SIMULATION PLATFORM FOR PARALLEL AND DISTRIBUTED MEMORY ARCHITECTURES

Paul Breugnot, Laurent Philippe, Bénédicte Herrmann, Christophe Lang

DISC

FPMAS is a C++ Multi-Agent Systems simulation platform designed to run on parallel and distributed memory architectures, such as computing clusters. Use of such resources allows the simulation of large scale Multi-Agent systems, that can involve millions of Agents, which would be impossible on a single machine because of time and memory requirements. Multi-Agent Systems are notably used in a wide range of fields to model economical, biological, epidemiological or social problems. However, modelers are not expected to be High performance computing experts, which strongly limits distributed computing usage in Multi-Agent simulations, even if their results could be improved by simulating large numbers of Agents with faster execution times.

Existing platforms, such as Repast HPC, still require the user to deal with distribution problems to implement their model, limiting interactions between Agents that are not simulated on the same processors, which can have a significant impact on model results.

The purpose of FPMAS is to reduce, as far as possible, issues related specifically to distributed computing for the final modeler, who can then focus on the implementation of its Multi-Agent Model, while allowing him to run it on High Performance Computing resources without any impact on simulation results.

Reference

https://github.com/FPMAS/FPMAS

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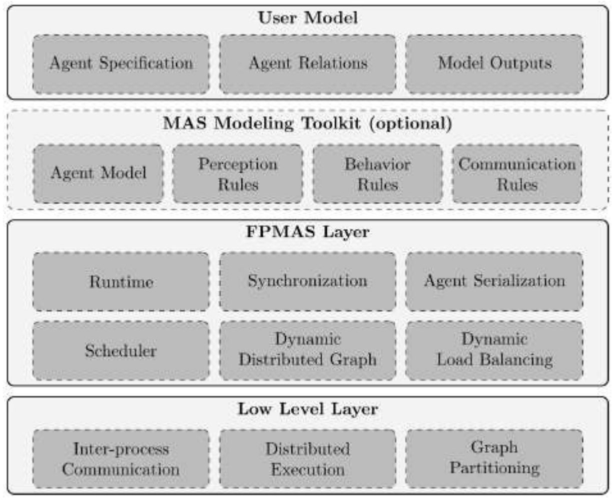

FPMAS Software Stack

SOFTI : SOFT TISSUE MECHANICAL PARAMETER IDENTIFICATION

Aflah Elouneg, Emmanuelle Jacquet, Jérôme Chambert, Arnaud Lejeune, Danas Sutula

APPLIED MECHANICS

SofTI (Soft Tissue Identification) is mainly devoted to characterization of the mechanical parameters of skin from in-vivo eperiments. It is based on open-source components for Digital Image Correlation, Finite Element simulation and inverse identification, such as FEniCS project library. It allows determination of mechanical parameters for healthy skin or tumored skin made of two materials: healthy and keloid skin. Several hyperelastic constitutive laws could be easily implemented to model soft tissue, using their respective strain energy density formulas. The 2D meshed geometrical model generated from Gmsh framework is extracted from a 3D scan approach applied on a patient. In post-treatment, sensitivity analysis may be conducted on the identified material parameters in order to study their influence on the mechanical response.

The user can configure on his own the nonlinear forward and the inverse solver methods, i.e., optimization algorithm type (Gauss-Newton or Gradient), sensitivity computation method (adjoint or direct) and their respective parameters.

References

D.Sutula et al.,J. Mechanical Behavior of Biomedical Materials,112 (2020).

A. Elouneg et al., Congrès Français de Mécanique, France (2019).

https://hal.archives-ouvertes.fr/hal-02376993

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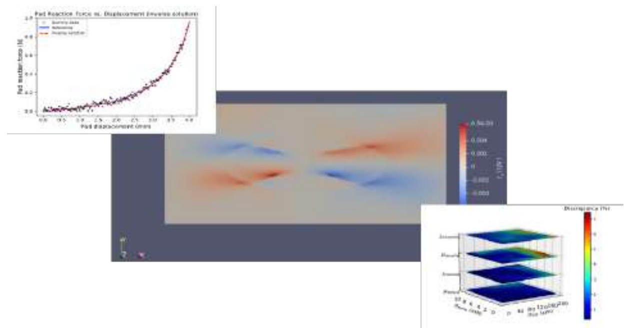

Shear stress field obtain from inverse identification of a tumored skin modelled with 2 Gent hyperelastic laws

FEMTO-ST SPIN OFF: EVERY SECOND, 3 MICRO-ASSEMBLIES ARE PERFORMED BY PERCIPIO ROBOTICS MACHINES IN THE WORLD.

Michaël Gauthier, Philippe Lutz, Cédric Clevy, Dominique Gendreau

AS2M / MIMENTO / ROBOTEX

The story stated in February 2011 when the start-up Percipio Robotics was launched. Based on the FEMTO-ST know-how in microrobotics and especially the design of piezoelectric microgrippers and the control of automated micro-assembly platforms developed since 1995. David Heriban, research engineer at FEMTO-ST , decided to found an innovative company, Three patents and two software licences were transferred from FEMTO-ST (CNRS, UFC, ENSMM) to the start-up.

Ten years later, Percipio Robotics is a total success: The company is selling, in Europe, innovative production machines enabling highly precise and complex robotic micro-assemblies. Percipio Robotics is now a world-known company, leader in highly complex robotic micro-assembly with 26 employees and a turn over of 6 million in 2020. Every second, three automatic micro-assemblies are performed by a Percipio Robotics machines in the world.

FEMTO-ST supports this development in several ways. Several R&D projects have been developed between Percipio Robotics and FEMTO-ST in order to improve performance and innovation of the production machinery. Percipio Robotics is also using the FEMTO-ST technological facilities such as the clean room for micro-nano-fabrication (MIMENTO) and the MicroNanoRobotics Center (ROBOTEX) for their own productions and R&D activities.

Reference

www.percipio-robotics.com

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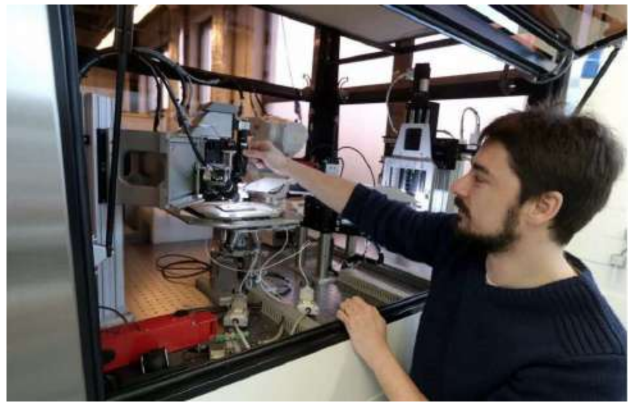


David Hériban, CEO of Percipio Robotics in front of a full autonomous micro-assembly machine dedicated to microelectronics industry.

METABSORBER, THE DEEP TECH START-UP THAT TRANSFORMS THE QUALITY OF OUR SOUND ENVIRONMENT

Mahmoud Addouche

MN2S

A strong challenge lies ahead in the years to come. There is a need between people.to recreate social bonds in increasingly divers urban environments, and acoustics can make a significant contribution to strengthening the bonds and attachments that people share.

To do this , METABSORBER, a start-up from the FEMTO-ST institute, cofounded by Aliyasin El Ayouch & Mahmoud Addouche, has developed strong expertise in the field of acoustic metamaterials, and we tend to be a catalyst between this expertise and the building an industrial players.

This is why METABSORBER signed strategic agreements, in 2020, with SATT SAYENS for an exclusive license to exploit these two patents. METABSORBER has also concluded commercial agreements with industrial manufacturers to deploy these new techniques, for example with Les Etablissements de La Boisserolle, who manufacture and distribute decorative wood panels, with whom we will be offering a new line of products under the brand name SonikMTB incorporating absorbent acoustic metamaterials, and which will give architects new tools, particularly in terms of acoustic design.

References

Mahmoud Addouche, Aliyasin El Ayouch et Abdelkrim Khelif, « Metabsorber, une start-up deeptech qui transforme nos objets du quotidien en métamatériaux absorbants », Acoustique & Techniques n°94-95 (2020).

Reference

www.metabsorber.com

aliyasin.elayouch@metabsorber.com

SonikMTB, a 40mm thick absorbent metamaterial that does not contain any common foam or mineral wool.

VIBISCUS: A NEW START-UP DEVELOPING THE CONCEPT OF PROGRAMMABLE ACOUSTIC MATERIALS.

Gaël Matten, Morvan Ouisse

APPLIED MECHANICS

The start-up Vibiscus develops compact materials with a programmable acoustic behavior. Similar to a screen made of pixels, the product is made of a set of small 5cm wide cubes called « acoustic pixels » that can absorb specific or wide band noises. Vibiscus intends to reduce noise in open spaces and in air vents.

Based on a noise reduction technology developed at FEMTO-ST with a patent pending by Manuel Collet, Morvan Ouisse and Gaël Matten, it is quite unique. Unlike active control systems, it does not produce a counter noise to mask the noise. The technology synthesizes an acoustic impedance that makes the material absorbant, like a passive foam. And unlike passive materials, it is very efficient in the low frequencies.

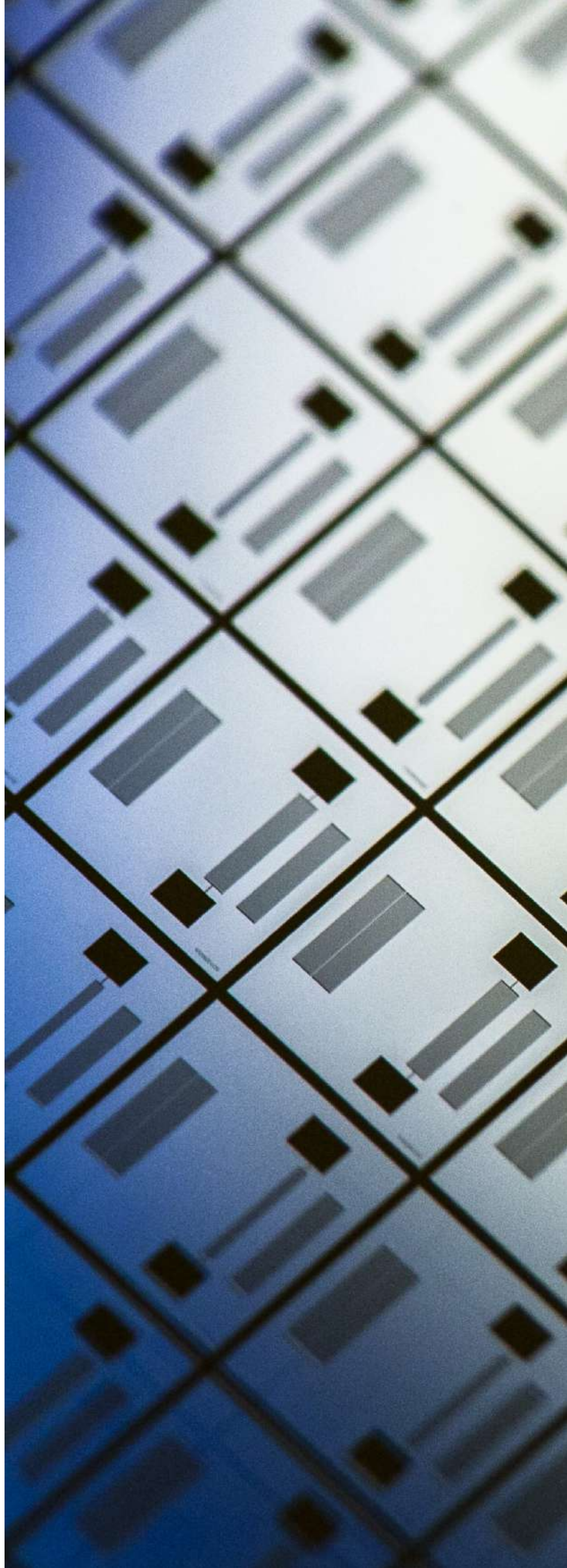
The start-up is led by Gaël Matten, a former PhD student and post-doc of the Institute and is supported by the public incubator DECA-BFC. It is part of « RISE », the start-up program of CNRS Innovation and it has received several prizes: « i-PhD », « Docteur Entrepreneur Challenge » and « PEPITE ».

Reference

http://www.vibiscus.com

gael.matten@vibiscus.com

Gaël Matten and the acoustic control system hidden behind a porous layer



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

INTELLIGENT SYSTEMS

- Artificial Intelligence: distributed systems, diagnosis and prognosis
- Smart Objects & Complex Systems
- Ethics

COMMUNICATION AND INFORMATION

- Ultra-localized optics
- Quantum technologies
- Telecommunication sys-tems and materials

INDUSTRY OF THE FUTURE

- New Materials and Processing
- Sensors and actuators
- Factory 4.0

DEFENSE - SECURITY

- Network and software security
- Intelligent Systems for Defense

SCIENCE & SOCIETY

HYDROGEN ECOSYSTEM IN NORTH FRANCHE-COMTE

SHARPAC team

ENERGY

The development of hydrogen in North Franche-Comté began at the turn of the 2000s, within the framework of laboratories today integrated within the FEMTO-ST Institute and partners of the FCLAB research support unit. At the same time there was already strong political support which made it possible to initiate this dynamic, focused on the integration of hydrogen in systems for transport or stationary applications. In 2004, the UTBM fuel cell platform made it possible to support the first academic, industrial, national and European projects, in their experimental dimension.

The platform was extended in 2014 to respond to the strong growth in activity in this domain. Also, in 2014, anticipating the need for qualified engineers in the field, the University of Franche-Comté launched a CMI (Master's Degree in Engineering) in the field of hydrogen energy and energy efficiency. From a purely academic configuration at the beginning, this ecosystem has enabled start-ups to emerge (H2SYS in Belfort and Mahytec in Dole are two emblematic examples) and to interest regional industrial groups (ALSTOM, FAURECIA, GAUSSIN in particular).

The constant political support of the State, of the Bourgogne-Franche-Comté Region, of Grand Belfort and more broadly of the local authorities, coupled with the strategic interests of these companies to get closer to the actors of training and research, continues today, with the arrival in the territory of other players in the sector (ROUGEOT Energie, Xydrogen, Avions Mauboussin, etc.). The labeling of the Territoire d'Innovation (TI) project in 2019 enabled new projects to emerge: around the supply of social housing by hydrogen vector with Territoire Habitat 90, of datacenters with the HyDATA project, or around the development of EcoCampus project in its hydrogen dimension, all projects in which FEMTO-ST is strongly involved.

Recently, the MobiCampus CMQ, labeled as Campus of Excellence in 2020, is a new step forward in these developments. All the economic, industrial, political, research and training players, the competitiveness cluster, have therefore been able to work together in order to develop, over the years, a unique hydrogen ecosystem, now also considered as a great opportunity for the renewal of a long industrial history

Reference

https://www.femto-st.fr/en/Research-departments/ENERGY/Research-groups/SHARPAC

https://hydrogeneurope.eu/

Facility: Hydrogène-Energie

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Hydrogen ecosystem

THE HIDDEN FACE OF SUSTAINABLE DEVELOPMENT: MINING

Nathalie Kroichvili

RECITS

Digital technologies (the Industry 4.0 revolution) as well as renewable energies are full of promise in order to support the energy and environment transition. However they contribute to an increasing demand of mineral resources whose extraction and exploitation have severe impacts that are barely addressed from the environmental, human, social, geopolitical point of view. This also raises economic and industrial issues as the largest and easily minable deposits are being depleted, which results in higher supply risks.

During the conference on October 22, 2020, Aurore Stephant, who is a geological and mining engineer, specialising in environmental and sanitary risks in this field and who is nowadays employed by the SystExt Association, proposed a comprehensive overview of the present situation of mining on the basis of thorough surveys she realized. Then she reminded us that new and more sustainable mining technologies do exist but are barely used due to their costs and a lack of constraining regulations. Her presentation highlighted that the energy and environment transition requires that we adopt a systemic point of view and deal with challenges that are not only technological but also of a political, regulatory and social nature.

References

Recording of the conference:
https://www.youtube.com/watch?v=a_8SN3FTDfU

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FORECASTING THE TURNAROUND OF FIREMEN AMBULANCES IN HOSPITALS

Selene Cerna, Héber H. Arcolezi, Christophe Guyeux.

DISC

This is a study on the impact of the current COVID-19 pandemic on the firefighter ambulances' turnaround time (time between arriving at the hospital and being available to other interventions again) on hospitals in the region of Doubs, France.

A significant increase in the average turnaround time per day has been identified in 2020 as soon as the number of official and suspected cases of the disease began to rise. Additionally, in comparison with previous years, this increment is not normal, which strengthens the claim that the average turnaround time per day increased due to the COVID-19 pandemic.

A direct and negative chain-like effect is the increment of breakdowns on the firefighters' service in 2020 due to the lack of ambulances in the centers of Departmental Fire and Rescue of Doubs. Therefore, the study develops a data-driven system to forecast the turnaround time that an ambulance will have in a given hospital. This prediction could be made at the moment when the personnel report that they will go to the hospital. This would help fire brigades, and in a global context, emergency medical services to activate proactive decision-making with the available resources in order to allow saving more lives.

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THE INTERNATIONAL DAY OF LIGHT 2020

John Dudley

OPTICS

The International Day of Light is an annual United Nations celebration that highlights how light science and technology impacts society. It has special relevance for scientists, because it is celebrated on May 16, the anniversary of the first operation of the laser. Since its first proclamation in 2018, the International Day of Light has operated a Secretariat Node at FEMTO-ST and the Université de Franche-Comté, where John Dudley from the Optics Department chairs the International Steering Committee. International Day of Light Activities have now reached millions of children and members of the general public worldwide, through events including conferences, hands-on activities, and light shows.

In 2020, although plans were affected significantly by the pandemic, organizers rapidly adapted to move activities online. Over 300 events in 69 countries reached a global audience of over 750,000. In addition, a number of special conferences and articles focussed on the 60th anniversary of the very first laser operation in 1960. Significantly, the events of 2020 also dramatically highlighted the key role of photonics research in society, which underpins key technologies that we have all made use of, from diagnostic tools such as infrared thermometers, to video conferencing to support online education.

References

J. M. Dudley, Light, Lasers, and the Nobel Prize, Advanced Photonics 2, 050501 (2020)

lightday.org

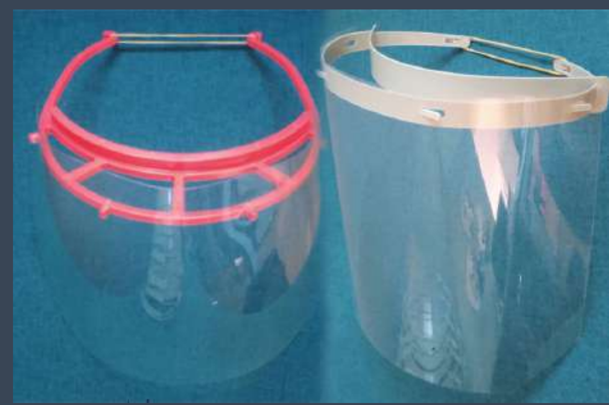
john.dudley@univ-fcomte.fr

MASS PRODUCTION OF FACE SHIELDS IN THE CONTEXT OF THE COVID-19 PANDEMIC

With contribution of Grand Besançon Métropole, ENSMM, University of Franche-Comté, UIMM Franche-Comté training center, Plastiform, S.MART cluster, and IUT GMP

2400 hard face shields were manufactured in less than a week by plastic injection and cutting. These shields were offered to caregivers, staff from medical and social centers, staff ensuring public order or solidarity with isolated or fragile people.

The flexible face shields were produced by laser cutting of polypropylene sheets at a rate of up to 1,000 copies per day and were given to the Senior Housings.



Special thanks to:

Sébastien Thibaut, Laurent Guyout, Gérard Michel, Xavier Wallerand, Sophie Krajewski, Christophe Bertillon, Christelle Tisserand, Elise Cardot, Romain Jamault, Emmanuel Rosetti, Gilles Martin, Patrick Rougeot, Emmanuel Foltête, Isabelle Maillotte, Pierre Roux, Mohamed Haouchine, Patrick Humbert.

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FEMTO-ST IN FIGURES

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including

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- 148 ASSOCIATE PROFESSORS
- 35 CNRS RESEARCHERS
- 232 PHD STUDENTS
- 85 ENGINEERS/TECHNICIANS

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1 INNOVATION TRANSFER UNIT (FEMTO ENGINEERING)

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7 RESEARCH DEPARTMENTS

11 start-up in 10 years

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