FEMTO-ST
2019
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.

« This Annual Report presents samples of the activities deployed at the FEMTO-ST research institute during last year. Throughout this report, we wish you can discover and enjoy a few selected highlights of 2019. We have tried to illustrate the diversity, the richness, and the broad range of topics and actions which were brilliantly performed by FEMTO-ST members. For those who already know us, you will have an update of our research results and strategic actions. For those who only heard about us, or even don't know our institute, we hope you will learn about activities that can be of interest for you. In the latter case, we wish the interested reader can find opportunities to interact with us on the many different areas we are involved in: Setting-up a new collaborative academic project with our talented researchers; Joining us for a Master or PhD program of our Graduate School EIPHI, and becoming member of FEMTO-ST; Starting a Research & Development project for industrial innovation based on some of our very specific know-how and technological facilities; Or also contributing with us to enthusiastic dissemination actions, making Science, Arts, & Society more entangled. It will be a pleasure to share with you our passion and dedication for science, in an open mind spirit, on a very fertile ground for creativity and knowledge discovery.

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, gathering about 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 now brought together under the common banner of a unique federal regional university, University Bourgogne-Franche-Comté (UBFC). Our activities obviously cover many different themes within the broad disciplines of engineering sciences, from fundamentals to applications. Each research department dedicates concentrated efforts to obtain world class scientific results in its own area. Beyond this internationally recognized & focused expertise, we are also firmly dedicated to cross-disciplinary interactions whenever it appears relevant and with highly innovative scientific and technological breakthrough potentials.

I would like to thank all members of FEMTO-ST for their continued commitment, their passionate and professional contributions to our many scientific and technological successes. I wish the reader will enjoy going through this 2019 Annual Report. »

Laurent LARGER
Director of FEMTO-ST Institute
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A BROAD RANGE OF MASTERED SCIENTIFIC EXPERTISE

FEMTO-ST INSTITUTE CONSISTS OF 7 RESEARCH DEPARTMENTS, 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)

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

MICRO-NANOSCIENCES & SYSTEMS (MN2S)

MICRO- OPTO- ELECTRO-MECHANICAL SYSTEMS

PHONONIC AND MICROSCOPY

NANOSCIENCES AND NANO-STRUCTURED MATERIALS

BIO-MICROSYSTEMS

OPTICS

NONLINEAR PHOTONICS

COMPLEX OPTOELECTRONIC SYSTEMS

NANO-PHOTONICS

TIME & FREQUENCY (TF)

OSCILLATORS/ RESONATORS

TIME & FREQUENCY METROLOGY

MICROWAVE SYSTEMS AND SENSORS

CONTENTS

EDUCATION

EIPHI-BFC

GRADUATE SCHOOL
CROSS DISCIPLINARY SCIENCE
AND TECHNOLOGY

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

APPLY ONLINE

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

Master/PhD in 5 Research Areas

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

UBFC
UNIVERSITÉ
BOURGOGNE FRANCHE-COMTÉ

EIPHI graduate school
Engineering and Innovation through Physical Sciences, High-technologies, and cross-dIsciplinary research

EIPHI proposes 10 Master Degrees covering 5 research areas with a strong interdisciplinay content. Outstanding students will acquire a solid knowledge in various topics, ranging from fundamental to applied sciences, allowing them to build a successful career in R&D sectors.

PHYSICS, MATHEMATICS and APPLICATIONS

Master degrees in theoretical and experimental physics or mathematics for physics, providing knowledge and lab expertise in photonics, non-linear physics, time & frequency metrology, micro/nano- and quantum technologies.

> 3 Masters: -Physics, Photonics, and Nanotechnology (PPN)

- Photonics, Micronanotechnology, Time-Frequency Metrology, and Complex Systems (PICS)

-Mathematics for Physics (Math4Phys)

> Career Sectors:
Photonics, nano-technology, time & frequency metrology, aeronautics, space industry, Industrial consulting, numerical analysis for industrial applications, big data analysis

COMPUTER SCIENCE

Research aspects of network applications (web, distributed, mobile, the Internet of Things) and quality assurance (verification and validation) of complex digital systems

> Master : Computer Science, Internet of Things (IoT)

> Career Sectors:
Software development, web, network, embedded software in mechatronic system, assurance quality, Tests

SMART SYSTEMS & STRUCTURES

Master Degrees in mechanics, electronics and control for applications in smart systems and tomorrow's structures (vibro-acoustic, control, composites, microtechnology and embedded electronics...)

> 3 Masters: GREEM, SMART MECHANICS, MIR

> Career Sectors:
Aeronautics and space industry, ground transportations, energy, luxury watches, micro-technology, time & frequency instrumentation, robotics, control, classical manufacturing, R&D in automotive industry, large machines design & development

ENERGY

Optimization and Integration of thermal, electrical and hydrogen-based systems in stationary and transportation applications for a sustainable development.

> Master : ELECTRICAL ENERGY, THERMAL ENERGY

> Career Sectors:
Energy, Energy, renewable energies, hydrogen energy, electrical vehicles, eco-systems

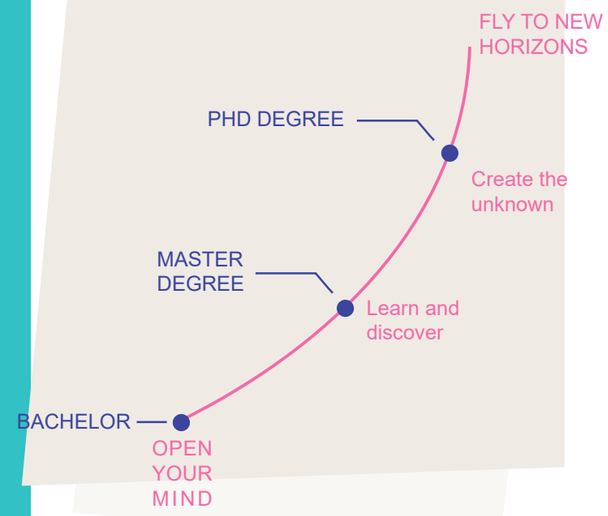
MATERIAL SCIENCE

Chemistry of materials, interfacial electrochemistry, physical-chemistry, inorganic chemistry with a focus on complex materials (polymers, hybrid materials, ceramics...).

> Master Control and Durability of Materials (CDM)

> Career Sectors:
Transportation (automotive, aeronautics), energy (production, transportation), glass industry, cement & concrete industry

Each EIPHI degree is divided into lectures, practical training and project activities all of them being taught in English. The master degrees propose both disciplinary and interdisciplinary courses as well as broad digital, societal, cultural, environmental, and entrepreneurial skills. A specific individual training program and augmented networking activities are given to EIPHI PhD students by combining the offers provided by the Doctoral Schools SPIM (Engineering Sciences and Microtechnologies) and Carnot-Pasteur (Maths, Physics and Chemistry).

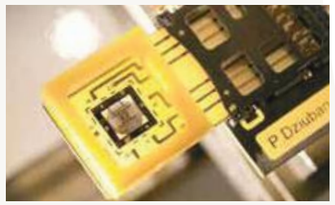


Top reasons to join EIPHI graduate school

- **Fellowships** for the best bachelor degree students and direct access to the PhD program for successful MSc students
- An **individual supervision** all along your curriculum, combining a personal project/thesis advisor and a mentor, to build a customized high-level training
- **Practical training** on high-tech facilities through internships and research projects in companies and labs supervised by high level scientists.
- **Openness** to cross and multidisciplinary sciences (physics, chemistry, computer science, engineering, social science …) a key ability for a successful career
- An inspiring international research environment and many **mobility** opportunities thanks to EIPHI's international network (European projects, several ERC grants…)
- Numerous **networking** opportunities through summer-schools, conferences, technological and industrial seminars

Excellence in research with world-class research laboratories

EIPHI graduate students are involved in world class research with FEMTO-ST, ICB, IMB and their partners by contributing or initiating multidisciplinary and innovative projects in close connection with industry. Guided by a personal supervisor, they are regularly exposed to extensive hands-on-lab experience, get access to cutting-edge technology platforms and work in an international environment.



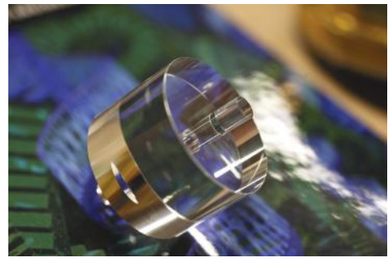
The EIPHI scientific program is mainly structured around 3 main topics:

Monitoring & Prediction of complex systems
- Prognostic & structural health monitoring/management
- Multifunctional sensors & (wireless) networks
- Photonic neuromorphic computing

(Self)-adaptive architectures
- Active metacomposites & metamaterials
- Active micro-nano-mechatronics
- Programmable matter

Compact, active and agile information processing devices
- Integrated micro-nanophotonic and phononic components
- Smart nonlinear and quantum systems at micro-nano-scale
- Ultrafast control
- Time-frequency microdevices

TRAINING SCHOOLS



THE 7TH EUROPEAN FREQUENCY AND TIME SEMINAR

TIME & FREQUENCY

The EFTS is a full-week crash course on Time & frequency founded in 2013 by Prof. Enrico Rubiola, with the help of the Labex FIRST-TF and of the Equipex Oscillator IMP. Since then, the seminar is repeated every year at FEMTO-ST, at the end of June or at the beginning of July. It is intended to provide education and training, and targets the broadest audience: engineers, Ph.D. students, postdoctoral fellows, young scientists, newcomers, etc. Lecturers and scientific council members are senior scientists with the major labs of the domain, in 6 European Countries and International Organizations.

The program includes 23 hrs of lectures, 12 hrs of labs, the astronomy session, museum visit, and social events. It is to be pointed out that the labs are true hand-on sessions in small groups, each with a lecturer. Thus, the capped number of 36 participants is set by the laboratory sessions – and always filled a few weeks after the registration opens. In 2019, the organization took 30 people, including invited and local lecturers, and staff members. The 36 participants came from 12 countries. For the first time, we had a majority of young scientists, as opposite to PhD students and private-economy employees, and a 90% majority of foreigners.

Looking closer at the program, we have a blend of four major topics: (i) metrology and oscillators, (ii) time scales and synchronization, (iii) atomic clocks, and (iv) applications. The first starts from the basic language of TF, to the subtleties of the cutting-edge oscillators and measurement methods. The realization of a time scale, and the clock synchronization as well, bring us to the awareness that space and time as separate entities are gone, and we live in a relativistic spacetime framework. In fact, the frequency accuracy of primary clocks ($\approx 10^{-16}$) is equivalent to the gravitational red shift if the clock is vertically shifted by 1 m (1.09×10^{-16}). This brings us to the lectures about clocks, the physical principles underneath, and the technology. Applications go with some surprises. Time is probably the hottest topic of security in information technology.

In 2019 we had two outstanding guests. Ekkehard Peik is leading a research on future clocks, based on isomeric transitions inside the nucleus of heavy atoms. Terry Quinn, emeritus director of the BIPM, gave a brilliant lecture on the SI (the international system of units, i.e., the framework underneath all the domains of metrology), and on the revolution of the SI, effective May 20, 2019. The Terry's lecture was available to everybody in the Campus of Besançon.

Website

http://efts.eu

SUMMER PROGRAM ON NUMBER THEORY AND RELATED TOPICS AT HARBIN INSTITUTE OF TECHNOLOGY, CHINA

OPTICS

Prof. Christian Maire, a Number Theoretician affiliated to the Optics Dept at FEMTO-ST, was co-organizer of the Summer Program « Number Theory and related topics at Harbin Institute of Technology (HIT)» in China. This event was held at the Institute for Advanced Study in Mathematics at HIT between June and August 2019.

The whole program included one summer school and seven mini-programs, as well as a series of colloquiums, aiming to bring together researchers in various fields of arithmetic, to learn about recent developments, to stimulate interaction between different areas, and to promote collaborations. The program covered various subfields of arithmetic and related topics, including explicit methods in algebra, arithmetic of elliptic curves, algebraic geometry, analytic number theory, representation theory, and coding theory. Hence, more than 80 research lectures were given by experts and talented young researchers coming from different countries: Austria, Belgium, Canada, China, Finland, France, Germany, Italy, Japan, Republic of Korea, Singapore, Thailand, USA, Vietnam.

Many highly recognized international leaders, having received a number of distinctions, have contribued to this program:

- **Bảo** Châu Ngô, Fields Medal 2010 and Professor at University of Chicago, was the chair of the Scientific Committee; he was also the organizer of two mini-programs.
- Ken Ribet, President of the American Mathematical Society (2017-19) and Professor at UC Berkeley, gave a lecture on Fermat's Last Theorem for a general audience.
- Loïc Merel, Director of the Mathematical Institute of Jussieu in Paris.
- Tamás Hausel, Professor at IST Austria.
- René Schoof, Professor at the Tor Vergata University in Rome.
- Ytang Zhang, Professor at UC Santa Barbara.

Website

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SPRING SCHOOL ON THEORY AND APPLICATIONS OF PORT-HAMILTONIAN SYSTEMS

ROBOTICS & AUTOMATION

The Spring School on Theory and Applications of Port-Hamiltonian Systems has been held from the 31st of March 2019 to the 5th of April 2019, in Fraueninsel (Chiemsee) Germany. It has been organized within the DFG-ANR project INFIDHEM and has been supported by the Université franco-allemande - Deutsch-Französische Hochschule, the Bund der Freunde TUM and the Franco-Bavarian University Cooperation Center.

The port-Hamiltonian approach, at the core of the spring school, allows for the structured modelling of complex, interconnected and heterogeneous multi-physical systems. It is the basis for control methods, which exploit the underlying physical structure or impose desired energetic behavior in closed loop. This international spring school PHS 2019 has gathered 14 lecturers among the most recognized international experts in the field including Yann Le Gorrec, researcher from FEMTO-ST Institute. The school reached 44 participants (PhD students, and advanced Master students) from engineering and applied mathematics, providing an accurate state of the art and overview of current research topics in the fields of:

• Control of distributed parameter systems;

• Structure-preserving numerical methods for multi-physics systems;

• Port-Hamiltonian formulation of irreversible thermodynamic processes.

Website

https://www.rt.mw.tum.de/en/phs2019/

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INTERNATIONAL SUMMER SCHOOL ON MICROGRIDS

ENERGY

SHARPAC team of FEMTO-ST and the FCLAB research federation organized an international summer school on microgrids from the 1st to 5th July 2019. Microgrids are small-scale power systems equipped with local energy sources, storage units and loads. They can operate without being connected to a larger electricity grid. Such systems are typically used in remote locations, but are also increasingly considered as a solution to improve the integration of renewable energy sources when combined with energy storage.

The school attracted academic and industrial attendees and speakers from 7 countries. Lectures, visits, a poster session as well as a round table enabled participants to learn and discuss about the state-of-the-art and current challenges of microgrids. A week-long project also challenged the audience to design and operate a simple microgrid powered by a photovoltaic plant. The event received financial support from CNRS and from GdR SEEDS. In addition to academic speakers, representatives from Typhoon HIL, General Electric and Enedis contributed to the school.

Website

https://events.femto-st.fr/microgrids-school-2019/

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RESEARCH

AWARDS

2019 CNRS BRONZE MEDALS

NON-CONTACT MICROROBOTICS

AUDE BOLOPION

ROBOTICS & AUTOMATION

The 2019 CNRS bronze medal has been awarded to a FEMTO-ST researcher, Aude Bolopion, for her work on non-contact microrobotics.

She works on the robotic manipulation of objects ranging from 10 µm to 1 mm, using forces induced remotely, without any direct contact with the objects. Several physical principles can be used to induce these forces: magnetic effects, electric or acoustic fields, or thermocapillary convection flows controlled with a laser. She develops modelling, design and control methodologies to control the trajectories of the objects. These manipulation principles are especially interesting for the assembly of electronic components, and even more for biomedical applications and highly selective cell sorting. The absence of direct contact with the cells guarantees the absence of contamination. More than eight PhD students, post-docs and interns work on that research topic under the supervision of Aude Bolopion.

Several national and international collaborations, with the "Université Libre de Bruxelles" (ULB), the "Federal Polytechnic School of Lausanne" (EPFL), the "Czech Technical University of Prague", the "French Blood Establishment" (EFS) and the "ISIR Institute" in Paris, in particular, support this project.

In a more general way, this distinction emphasizes the quality of the research in the domain of microrobotics performed in the FEMTO-ST Institute.

References

https://www.femto-st.fr/en/femto-people/audebolopion
https://teams.femto-st.fr/micro-and-nano-robotics/

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RESILIENT FUEL CELL SYSTEMS

NADIA YOUSFI STEINER

ENERGY

Fuel cell systems are fed by hydrogen and oxygen, which they turn into electricity on demand, and the by-products of the reactions are only water and heat. They are therefore particularly interesting for the clean and sustainable production of energy for stationary applications or transportation.

However, fuel cell systems are still facing cost, reliability and durability issues, which are the challenges behind the research led by Nadia Yousfi Steiner in the SHARPAC team, Energie department of the FEMTO-ST Institute. Indeed, the Diagnosis of the detection, isolation and identification of faults, allows an increased reliability of the systems, while prognosis leads to anticipation of the future operation performance and increases their lifespan. Diagnosis and prognosis are coupled with decision-making and control modules to allow the systems to manage themselves in an optimal way by using artificial intelligence. They can therefore self-heal by applying corrective actions to the faulty operating modes after a diagnosis, or adjust their operating point after detecting an abnormal accelerated degradation. These reconfigurable modules are thus the basis of resilient systems, which means they are more tolerant to faults and more resistant to degradation. The topic on the whole remains of great interest for research and industry at an international level.

After a few years in Germany, Nadia Yousfi Steiner gets back into academic research in 2014 at the University of Franche-Comté within the FEMTO-ST Institute where she holds a 6 years research chair of excellence on these topics. She is motivated by the need to work on these problematics, and wanting to be part of a mission: that includes scientific development and dissemination, and student education. Five years have passed, and she has been awarded a prestigious early carrier researcher award, a 2019 CNRS Bronze Medal. "This medal is a distinction, an honour for me and an acknowledgment for the whole team. It is a great encouragement to continue our current work, therefore bringing scientific answers to real problematics. Innovation is the key in order to find the necessary breakthrough solutions for the creation of new paradigms for a successful energetic transition."

References

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CNRS BRONZE MEDAL

The bronze medal is given in recognition of the initial work of promising researchers in their field. This distinction represents an encouragement to pursue well-engaged and already fruitful research. The bronze medal is awarded on the recommendation of a section of the National Committee for Scientific Research, composed of CNRS researchers, university lecturer-researchers and engineers. It is awarded each year to around forty researchers or teacher-researchers from a French scientific and technological public establishments.

2019 SPIE HAROLD E. EDGERTON AWARD

JOHN DUDLEY

OPTICS

The international society for optics and photonics SPIE, honoured John Dudley with its Harold E. Edgerton Award for the study of high-speed physical phenomena. The presentation was made during the World of Photonics Congress in Munich in June 2019.

The recognition was specifically for Dudley's pioneering applications of ultrashort-pulse measurement techniques in nonlinear fiber optics, including studies of ultrafast self-similarity, supercontinuum generation, and novel classes of optical soliton and optical rogue waves. The experimental and theoretical studies recognized by the Edgerton Award have been central to the development and application of a range of ultrafast technologies, and was instrumental in ensuring the uptake of the powerful frequency-resolved optical gating pulse characterization technique within the fiber optics and telecommunications fields. These techniques are now used by companies worldwide in source development and qualification.

The sponsor of the award SPIE is the international society for optics and photonics, an educational not-for-profit organization founded in 1955 to advance light-based science, engineering, and technology. The Society serves 257,000 constituents from 173 countries. The SPIE Harold E. Edgerton Award in High-Speed Optics is presented annually for outstanding contributions to optical or photonic techniques in the application and understanding of high speed physical phenomena. The development of new technologies and the new application of existing technologies are considered in the determination of the award.

References

https://spie.org/about-spie/press-room/press-releases/john-dudley-wins-the-2019-spie-harold-e-edgerton-award

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2019 IEEE UFFC G.W. CADY AWARD

SERGE GALLIOU

TIME & FREQUENCY

Serge Galliou's recent investigations on quartz resonator behavior at low temperatures have resulted in the highest Q.f product resonator ever for an acoustic or phonon system of10^{18} . He pioneered this work with the first publications reporting the measurement of high-Q factors in cryogenic quartz bulk acoustic wave resonators at 4K and mK published in 2008 and 2012.

This work experimentally sets the ultimate limits of oscillators based on bulk acoustic wave resonators. It provided the first verification of the Landau-Rumer regime, under which the phonon Q-factor is independent of frequency. Furthermore, a new source of loss was discovered which is the acoustic equivalent to Rayleigh Scattering. Galliou's work has improved our knowledge of limitations related to acoustic losses. It illuminates light on the origin of noise in acoustic resonators in connection with fundamental investigations of acoustic wave and thermal phonon interactions , or of the measurement of elastic coefficients.

New experiments and programs dealing with gravitational wave astronomy (concerned with low-loss materials) and quantum measurement have been spawned by from Galliou's work. Indeed, low-loss phonon-trapping cavities offer the opportunity to demonstrate the quantum behavior of mechanical systems when the condition hf > k^BT can be met. Although a thermal phonon occupation number close to 6 has already been achieved, investigations are still in progress with quartz crystal resonators potentially leading to extraordinarily large coherence times beyond the capability of any other competing technology.

References

https://ifcs-eftf2019.org/pages/2019-ifcs-award-recipients
https://ieee-uffc.org/awards/frequency-control-awards/cady-award/

facility: OSCILLATOR-IMP

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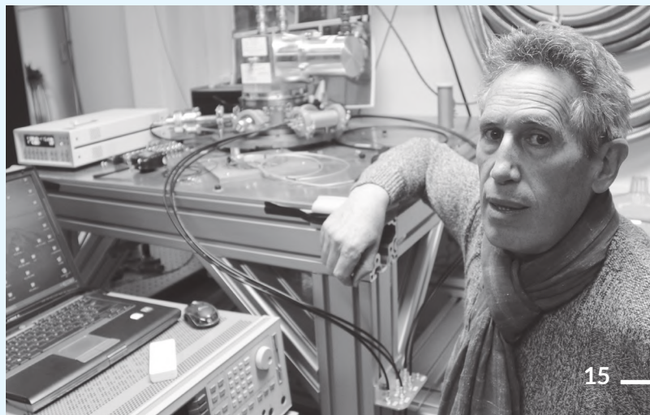
"**The IEEE W.G. Cady award** is presented annually at the IEEE International Frequency Control Symposium to recognize outstanding contributions related to the fields of piezoelectric or other classical frequency control, selection and measurement; and resonant sensor devices."



AWARDS

ASME ADAPTIVE SYSTEMS DYNAMICS AND CONTROLS TECHNICAL COMMITTEE BEST PAPER AWARDS

DESIGN AND EXPERIMENTAL VALIDATION OF A TEMPERATURE-DRIVEN ADAPTATIVE PHONONIC CRYSTALS LAB

APPLIED MECHANICS / MICRO-NANOSCIENCES & SYSTEMS

Elastic metamaterials are engineered structures that exhibit unusual properties, and can be used in a variety of applications. A new kind of composite metamaterial has been designed in FEMTO-ST to control elastic wave propagation in structures in an adaptive way: its behavior can be changed in real time by tuning the mechanical properties of the system. The metamaterial consists of a periodic distribution of metallic pillars, which are linked to a host plate through a highly dissipative polymeric interface whose properties can be changed in a radical way by temperature control. The metamaterial has been designed using 3D finite elements models which are able to take into account damping and temperature effects in order to properly describe the physical effects of interest. Two states are then obtained by changing the temperature of the polymeric interface: at 25°C the structure act as a mechanical filter (a bandgap occurs around a selected resonance frequency), while after a 40°C temperature increase, the structure vibrates like a homogeneous plate. This metamaterial has been manufactured and experimental tests have shown its ability to exhibit the two radically different mechanical behaviors as expected from the simulations. On this structure, edge modes have been also observed in the band gap, corresponding to energy transfer along the boundaries of the structure, which can be used to enforce the path on which the energy can be transferred.

The Adaptive Systems Dynamics and Controls Technical Committee of the American Society of Mechanical Engineers has awarded this paper, published in the Journal for Smart Materials and Structures, the accolade of Best Paper Award (Best published paper on Adaptive Structures during the previous calendar year).

References

K. Billon, M. Ouisse, E. Sadoulet-Reboul, M. Collet, P. Butaud, G. Chevallier, and A. Khelif. Design and experimental validation of a temperature-driven adaptive phononic crystal slab. Smart Materials and Structures, 28, 035007 (2019).

www.doi.org/10.1088/1361-665X/aaf670.

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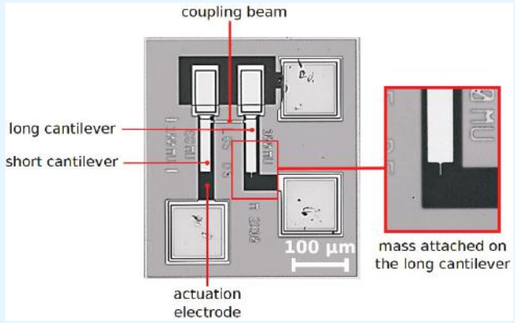
MODE LOCALIZATION IN TWO COUPLED NEARLY IDENTICAL MEMS CANTILEVERS FOR MASS SENSING

APPLIED MECHANICS

Detecting small particles for biochemical applications becomes realizable thanks to the use of MEMS mass sensors. Most of these sensors measure the resonance frequency shift of a resonator to detect a mass perturbation. Other sensing methods exist and one of them consists in using the phenomenon of mode localization. These devices measure the change in the vibration modes of weakly coupled resonators when a perturbation is introduced. It has already been shown that such devices have a higher normalized sensitivity, which can be two to three orders of magnitude higher than that of sensors using frequency shift. Compared to devices using single resonators, they also have the advantage of being less susceptible to change in the ambient condition. However, a problem encountered with these devices is a defect in manufacturing. The use of the mode localization requires identical resonators, but the presence of imperfections perturbs the initial device. To avoid this, we propose considering a sensor using two mechanically coupled microbeams with different lengths, and only the short cantilever is actuated with a combined AC/DC voltage. The electrostatic force on the short cantilever is then tuned to balance the system and compensate the difference. In order to design this sensor, we present an analytical model using Euler-Bernoulli beams. To validate this model, an experimental investigation is carried out by using devices fabricated with the Multi-User MEMS Processes. For the perturbation, the long cantilever is designed with a mass around 20 pg attached at its end. Instead of adding a mass to the device, we remove this part with a probe. Before removing the mass, the DC voltage is tuned to equilibrate the system and the frequency response shows two modes of vibration corresponding to the symmetric and anti-symmetric modes. When the mass is removed, the experimental results show localized vibrations, which are in good agreement with the theoretical results.



References

T. Rabenimanana*, V. Walter, N. Kacem, P. Le Moal, G. Bourbon, J. Lardiès

https://www.femto-st.fr/en/Research-departments/APPLIED-MECHANICS/Research-groups/mems-team

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EUROPEAN POWDER METALLURGY ASSOCIATION KEYNOTE PAPER AWARD

EXPERIMENTAL INVESTIGATIONS AND NUMERICAL SIMULATIONS ANALYSIS OF SINTERED MICRO-FLUIDIC DEVICES

APPLIED MECHANICS

This keynote paper award presentation received an extended oral presentation slot in the programme of EuroPM 2019 Conference in Maastricht and went on to be published in the journal of Powder Metallurgy. The technical program committee members have selected five keynote awards for the EuroPM conference from more than 350 technical papers and 1200 international delegates. It corresponds to a high-level conference to celebrate the 30th anniversary of the EuroPM conference.

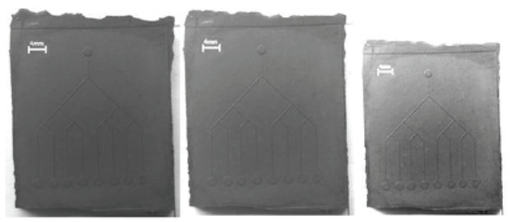
This paper investigates the use of numerical simulations to describe the sintering stage and associated the solid-state diffusion during a metal injection molding process for micro-fluidic components. A finite element method based on a thermo-elasto-viscoplastic model was established to describe the densification process of a 316L stainless steel porous component during solid-state sintering.

The finite element analyses were performed on a 3D micro-structured component with different powder volume loading taking into account the thermal debinding effect. The simulation results are in good agreement with the experimental ones. In the best results, the maximal final relative density is 99.94% and has been obtained for a 64 % vol. mixture considering the debinding shrinkage effect of the mixture. The comparison of the numerical and experimental results of the final relative density gives a maximum discrepancy around 2%. Our study explores the potential of virtual prototyping by numerical simulation and proposes decision support tools.

References

O. Dugauguez, A. Agne, J.M. Antonia, JM Torralba, T. Barriere, Experimental and numerical analysis of effects of supercritical carbon dioxide debinding on inconel 718 MIM components, Powder Technology, 355, 57 (2019). www.doi.org/10.1016/j.powtec.2019.07.011

A. Royer, T. Barriere, Y. Bienvenu, Influence of supercritical debinding and processing parameters on final properties of injection-moulded inconel 718, Powder Technology 336, 311 (2018). www.doi.org/10.1016/j.powtec.2018.05.047



316L stainless steel micro-fluidic replicas (powder volume loading of 64 vol.%) for different manufacturing processes after the (a) replication process, (b) thermal debinding stage, and (c) final solid-state sintering and (d) associated final displacement magnitude at the end of debinding and sintering simulations.

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SPIE PHOTONICS WEST 2019 BEST STUDENT PAPER AWARD

THICK GLASS CUTTING WITH A “LASER SWORD

OPTICS

Architecture, automotive, pharmaceuticals and electronics are areas where glass is increasingly present and necessary. However, cutting these hard and fragile materials is a difficult exercise. Mechanical cutting generates fracture initiation that weakens it, and it is necessary to carry out polishing or sandblasting operations after cutting to limit this fragility. Laser cutting, although significantly improved in recent years by the contribution of femtosecond lasers and spatial beam shaping, allowed cutting up to one metre per second but was limited to small thicknesses, of less than one millimetre.

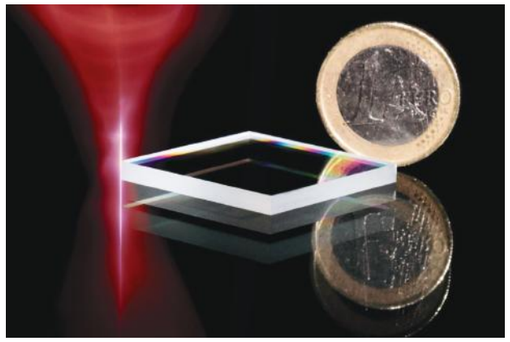
Remi Meyer and co-workers in the Optics department, within the ERC PULSAR project, have surpassed this limit. They have developed a tool for shaping very high energy laser pulses, literally creating a laser "sword" nearly one centimetre long and only a few hundred nanometres in diameter. This very high aspect ratio opens doors not only in high-intensity laser physics, but also in laser machining, where the team demonstrated the cutting of very thick glass, up to 1 cm, in a single pass. The surface finish is also identical to that of sandblasted glass, which a priori avoids the post-processing stage, which is currently is very costly in terms of energy.

This research has been communicated at SPIE Photonics West – the largest worldwide event in photonics - in the Frontiers in Ultrafast optics conference, where Remi Meyer was awarded the best student paper award.

References

R. Meyer, L. Froehly, R. Giust, J. Del Hoyo, L. Furfaro, C. Billet, and F. Courvoisier, “Extremely high-aspect-ratio ultrafast Bessel beam generation and stealth dicing of multi-millimeter thick glass”, Applied Physics Letters,, 114, 201105 (2019) www.doi.org/10.1063/1.5096868

facility: FRI-LIGHT



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MEMBERS AND TEAMS

THE MAN WHO TRICKED BIOMOLECULES TO SURFACES

VINCENT HUMBLOT

MICRO-NANOSCIENCES & SYSTEMS

Dr. Vincent Humblot recently joined the BioMicroDevices team of the MN2S research department as a CNRS senior researcher. After graduation from the University of Franche-Comté in 1998, he moved to the University of Liverpool, United Kingdom, to prepare a Ph.D. at the Leverhulme Centre for Innovative Catalysis. His Ph.D. dissertation was dedicated to a surface science approach of a model catalytic system, namely the adsorption of tartaric acid on nickel surfaces.

After earning his PhD, he worked for 3 additional years as a post-doctoral fellow in the Surface Science Research Centre in Liverpool, where he gained a deeper understanding of vibrational spectroscopies (FT-IR and XPS) as well as of scanning probemicroscopies (AFM and STM) applied to the study of model biointerfaces under ultra high vacuum conditions.

In 2004, he was appointed a CNRS researcher at Pierre et Marie Curie University (Paris 6), nowadays known as the Sorbonne University, in the Surface Reactivity Laboratory. There he worked on biointerfaces from ultra high vacuum (UHV) conditions to the liquid phase. His research activities were centered on surface/interface functionalisation and characterisation for bio integration and most importantly for biofouling studies. He considered various antimicrobial molecules, from antibiotics to antimicrobial peptides, and grafted them on various surfaces from pure metallic (titanium; stainless steel), oxides (TiO_2, Al_2O_3) to polymeric (PDMS, PMMA, PS ...). For 15 years, he has worked on surfaces functionalisation by self-assembled monolayers for the specific grafting of biomolecules being able to tune several chosen parameters such as surface density, orientation, reactivity, or surface-to-biomolecules distance.

Vincent joined FEMTO-ST in September 2019. He projects to research new surface functionalisation and characterisation strategies in order to graft microfluidic devices directly inside closed systems. He will also investigate the secretion of extracellular vesicles from bacteria under specific conditions, either as planktonic bacteria or as mature bacterial biofilms.

From a personal point of view, after 20 years or so of exile, Vincent is back in the motherland (nowadays known as "Bourgogne-Franche-Comté"), and he will certainly enjoy the sandy Fontainebleau forest mountain bike trials and is already back in the muddy races organized around Besançon.

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SYNERGY BETWEEN MECHANICAL MICRO-MANUFACTURING AND TRIBOLOGY TO ENHANCE PRECISION TOOLING

MICHAËL FONTAINE, GUY MONTEIL, MOHAMED ASSOUL, ALEXANDRE GILBIN, HASNAA MELIANI

APPLIED MECHANICS

Efficiency and life of tools used in industry are still a very important issue in mechanical manufacturing, especially when considering high productivity, downsizing of scale, visual aspects and precision. More and more materials are employed which are dificult to fabricate, productivity is critical and high precision becomes the norm. Here the idea is to realize the improvement of the working surfaces of tools in order to enhance their lifetime, the quality of the surfaces produced and even the quantity of lubricant used.

This work started in 2014 in the field of blanking and lead to the PhD of Vahan Malkhasyan and to the I-SITE project named Backup. A femto-second laser was used to study surface properties like wettability and friction on stainless steels. The TexDec project was launched in 2016 to study machining. The purpose was to propose and study new micro- and nano-structures to apply on cutting tools' working surfaces in order to improve their efficiency in difficult-to-cut materials. The field of precision turning was targeted with the financial support of two regional industrial partners, Baron and DDLG, and the Franche-Comté Region. Hasnaa Meliani successfully studied techniques like femto-second laser or Electro-Discharge Machining to produce structures at different scales on a tungsten carbide turning insert, validated by using the equipments of ENSMM, Applied Mechanics Department and MIFHySTO facilities. This work was a chance to develop partnerships with Alain Billard in MN2S dept, T. Matsumura in Tokyo, G. Wälder in Geneva and the Manutech Plateform in Saint-Etienne. A new project is in editing phase with the objective of enhancing complex 3D tools, especially dedicated to micro-manufacturing processes.
The authors want to thanks sincerely Guy Monteil, retired from summer 2019, for his relevance in launching such research topics gathering texturing and tooling in a region so concerned by these issues, but also for his precision and steadiness when conducting these works.

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TRENDING TOPICS

ARTIFICIAL INTELLIGENCE AT FEMTO-ST

ROBOTICS & AUTOMATION / COMPUTER SCIENCE / OPTICS / ENERGY

Artificial Intelligence (AI) is currently in vogue. This is because AI provides answers to numerous problems for which other algorithms are less efficient or inoperative, and over the past decade, deep learning has often achieved excellent results. The principle of many AI methods is to train a neural network with data such that the network is able to learn an abstract task for this particular data – such as pattern recognition. Several techniques are available for classification, prediction, or even learning of an unspecified task only through penalties and rewards, in which case we speak off reinforcement learning. Most of these methods rely on supervision, i.e. data is labeled and the system is guided towards learning the desired operation. Conversely, unsupervised algorithms work autonomously without indication, but they generally achieve less efficient results.

Within FEMTO-ST, many researchers develop and use new AI algorithms and hardware to perform a wide variety of tasks, some of them being detailed hereafter (the goal is not to be exhaustive).

In the DISC department, algorithms have been developed to make predictions on the number of per hour interventions operated by the Doubs firefighters[1]. Another group is currently developing tools concerning cryptographic security based on AI. For example, they automatically generate patterns of attacks in order to train AI algorithms to recognize different types of attacks and they propose efficient AI tools for steganalysis [2]. Algorithms are developed in partnership with colleagues from Dijon at the University of Bourgogne Franche-Comté to perform myocardial area segmentation from MRIs of patients after a heart attack. Other algorithms are developed in parallel, to segment medical kidney images of children with tumors [3]. Algorithms have also been developed too to remove noise from images, in a supervised [4] or unsupervised manner. Finally, approaches are currently investigated to detect anomalies in time series [5] encompassing, on the one hand, unsupervised learning to detect an abnormal state, and on the other hand, a second supervised model investigating when a specific anomaly has been recognized.

Within the AS2M department, AI algorithms are being developed for two main areas: industrial prognostics and health management (PHM) and medical diagnosis/prognosis [6-9]. The first example is the work done with ALSTOM for railways predictive maintenance. The algorithms used are for diagnostic and prognostics purposes. Another example is the work in progress on Sbra project which is an EU Interreg cooperation. The aim of this latter is to detect breast cancer in its early stage and it has two aims: (i) a technological approach based on impedance and temperature sensors, and (ii) a scientific aim is based on data collected from small sensors integrated into a bra.. For the scientific part, AI algorithms for detection are being developed while integrating the medical expertise.

Within the Optics department, researchers are developing new photonic computing hardware dedicated to neural network processing. Using conventional digital computers AI algorithms is highly inefficient, and a new types of computing processors are urgently needed. Here, photonic concepts have long been prime candidates for revolutionary AI-chips and promise to improve speed and energy efficiency by orders of magnitude. The Optics department at FEMTO-ST has been at the fore-front of photonic AI since the field's resurrection during recent years, and its world leading position was further strengthened in 2019. The team has published numerous articles in prestigious journals such a Physical Review Letters and Nature Machine Intelligence, showing that coupled nonlinear oscillators are deep convolutional networks [10], that photonic neural networks can successfully classify human actions [11], highlighted in [12], and is developing the theoretical framework for noise in neural network processors [13]. Daniel Brunner organized an international workshop (Konstanz, Germany), and edited the first book on photonic reservoir computing (DeGruyter) together with colleagues from Belgium and Spain [14]. Multiple new projects (ANR: ANACONDA, Volkswagen Foundation: NeuroQNet II, EC ITN: POST-DIGITAL) and international collaborations promise that FEMTO-ST will remain in a leading position in the future.

AI has been used for 20 years in the Energy department for different purposes regarding Fuel Cells. Indeed, the first results obtained on diagnostic were based on Fuzzy Logic at the beginning of year 2K [15]. Fuel Cells are multi-physical and multi-scale systems and their modeling is usually done with complex models based on the knowledge of physicochemical phenomena. 15 years ago, Artificial Neural Networks allowed us to develop some relevant behavior models [16]. Thanks to numerous data collected in recent years and to the experience acquired on methods based on Artificial Intelligence and particularly on neural networks, lots of prognostic approaches are developed based on data [17-18]. Some of these solutions result from a collaboration with the OPTIC and AS2M departments. Today, Deep Learning Neural Networks are investigated and allow the Energy Department to increase the lifetime of Fuel Cell systems in numerous applications. Indeed, these works are developed within industrial, european, national or regional projects and are validated on real applications (buses, car, trucks, stationnary applications, ...) [18]. The Energy Department is ready for the Third Age of Artificial Intelligence.

References

[1] S. L. C. Ñahuis et al., IEEE 6th Int. Conf. Control, Decision and Information Technologies (CoDIT) 1132 (2019). www.doi.org/10.1109/CoDIT.2019.8820671

[2] J.F. Couchot et al., IFIP Int. Confe.ICT Systems Security and Privacy Protection 327 (2017). www.doi.org/10.1007/978-3-319-58469-0_22

[3] L. Corbat et al., Expert Systems with Applications, 113200 (2020). www.doi.org/10.1016/j.eswa.2020.113200

[4] R. Couturier et al., Springer, Cham., Int. Conf. Neural Information Processing 554 (2018). www.doi.org/10.1007/978-3-030-04224-0_48

[5] J. Azar et al., Future Generation Computer Systems 96, 168 (2019). www.doi.org/10.1016/j.future.2019.02.005

[6] N. Omri et al., J. Manuf. Syst. 55 (2020). www.doi.org/10.1016/j.jmsy.2020.04.002.

[7] Y. Cheng et al., Applied Energy, 266, 114817 (2020). www.doi.org/10.1016/j.apenergy.2020.114817

[8] R. Zemouri et al., Elsevier Masson, Annales de Pathologie 39 (2), 119 (2019). www.doi.org/10.1016/j.annpat.2019.01.004

[9] A. Baltres et al., Breast cancer (2020). www.doi.org/10.1007/s12282-020-01100-4

[10] B. Penkovsky et al., Physical Review Letters 123, 054101 (2019). www.doi.org/10.1103/PhysRevLett.123.054101

[11] P. Antonik et al., Nature Machine Intelligence 1, 530-537 (2019). www.doi.org/10.1038/s42256-019-0110-8

[12] K. Lüdge et al., Nature Machine 1, 551 (2019). www.doi.org/10.1038/s42256-019-0124-2

[13] N. Semenova et al., Chaos 29, 103128 (2019). www.doi.org/10.1063/1.5120824

[14] (BOOK) Editors: Brunner, D.; Soriano, M.C.; Van der Sande, G.; De Gruyter "Photonic Reservoir Computing (Optical Recurrent Neural Networks)". (2019). https://www.degruyter.com/view/product/498491

[15] D. Hissel et al., Electrimacs Conference, Montréal, 2002.

[16] S. Jemeï et al., Journal of Power Sources 124 (2), 479 (2003). ISSN 03787753, www.doi.org/10.1016/S0378-7753(03)00799-7

[17] L. Vichard et al., IJH2E 45 (29),14953 (2020). www.doi.org/10.1016/j.ijhydene.2020.03.209

[18] (BOOK) S. Jemeï, "Hybridization, Diagnostic and Prognostic of Proton Exchange Membrane Fuel Cells - Durability and Reliability", Energy Series, 216 pages (2018), Wiley. ISBN:9781119563426, www.doi.org/10.1002/9781119563426

facilities: SPAC / MIMENTO

DATAZERO: DATACENTER WITH ZERO EMISSION AND ROBUST MANAGEMENT USING RENEWABLE ENERGY

COMPUTER SCIENCE / ENERGY / ROBOTICS & AUTOMATION

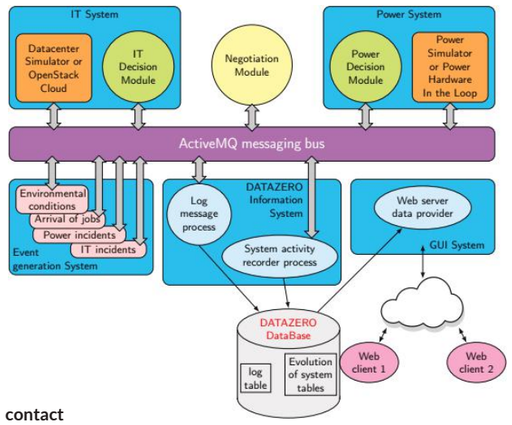
As the need for cloud services is growing steadily, the number and size of datacenters and their energy consumption has increased significantly over the past few years. Consequently, the energy efficiency and the CO_2 emissions of the datacenters is thus becoming a growing concern regarding climate change. Renewable energy, produced by solar panels and wind turbines, is seen as a promising solution to supply datacenters using locally generated energy and without greenhouse gases emissions. However, intermittent generation imposes a paradigm change in the way energy and computation activities are managed. For example, on the one hand, service placement and scheduling may be used on the IT (Information Technologies) side, and on the other hand, storage units can help to mitigate fluctuation in generation on the power supply side. These two means of flexibility have however only been considered separately so far, without much interaction between them.

The DATAZERO project aims at providing consistent solutions for ensuring high availability of IT services and avoiding unnecessary redundancies, under the constraints of the intermittent nature of electrical and services flows. Its contributions are manyfold: 1) proposing an electrical design of a datacenter operated only with renewable energy; 2) modelling the energy source production capacity, the IT load variation with degraded modes and the IT equipment consumption in presence of varying load; 3) propopsing algorithmic solutions for IT and electrical optimizations; 4) adjusting the balance between these two optimizations; 5) designing a middleware (see image) able to combine simulations and real experiments at the same time, allowing the assessment of the quality of our proposals on a set of predefined metrics.

The DATAZERO propject was completed at the end of 2019, but participants are all looking forward to continue exploring new ideas together and have submitted a DATAZERO2 to the 2020 ANR call for projects.

References

http://datazero.org



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SUBWAVELENGTH POLARIZATION OPTICS VIA INDIVIDUAL AND COUPLED HELICAL TRAVELING-WAVE NANOANTENNAS

OPTICS / MICRO-NANOSCIENCE & SYSTEMS

A wide variety of optical applications and techniques demand control of light polarization. Traditionally, manipulation of the polarization of light is realized with bulky optical elements, which utilize birefringent, dichroic or optically active media. A joint research program between Optics and MN2S departments and the MIMENTO technology facility has led to miniature components that allow access to new degrees of freedom in controlling the polarization of light. Based on the use of optical spin-orbit interaction in a plasmonic helical nanoantenna, this work is published in the journal Light Science and Applications from the Nature Publishing Group.

Their concept of helical travelling-wave nanoantenna offers an ultra-compact means of controlling the polarization state of light. The nanostructure of helical shape, fabricated at the FEMTO-ST Institute, uses surface plasmons and optical spin-orbit interaction to generate a circularly polarized collimated beam regardless of the incoming polarized waves. Incident light is coupled into a plasmon mode of the helical nanowire via a rectangular aperture nanoantenna that perforates a thin gold layer at the base of the helix. The polarization state of the beamed light can then be tuned simply by changing the geometrical parameters and handedness of the plasmonic structure. The small size of the helices means that several can be combined in a tiny area, leading to the concept of polarization patterning when the nanostructures show different geometrical parameters. The research team also demonstrated an array of 4 coupled structures packed together in a cubic wavelength, two with a left-handed helix and two with a right-handed helix (see Figure below), allowing tunable polarization control unachievable with conventional polarization optics. Potential applications include use in displays, data storage, microscopy and sensing.

Moreover, the successful development of an individual helical plasmonic nanoantenna at the apex of a fiber tip (Opt. Lett. 2019) has been highlighted by the multinational company Raith Nanofabrication with their Special Art Award 2019.

References

www.doi.org/10.1038/s41377-019-0186-2

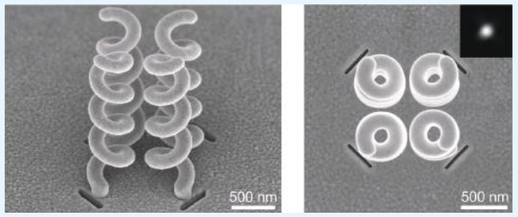
www.doi.org/10.1364/OL.44.004861.

https://www.nature.com/articles/s41377-019-0186-2

https://www.raith.com/company/micrograph-award/applications.html

https://www.insis.cnrs.fr/fr/cnrsinfo/polariser-la-lumiere-tres-petite-echelle-grace-aux-vortex-plasmoniques

facility: MIMENTO



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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

MICRO-NANOSCIENCES & SYSTEMS

Extra-cellular vesicles (EVs) are a superfamily of lipid bilayer membrane vesicular subsets that comprise exosomes, microvesicles and apoptotic bodies. EVs are released from all the cells of organisms in all the biofluids and display many physiological and pathological functions. Due to their cellular origin, their presence in complex media and their dimension covering two orders of magnitude (from tens nm to few µm), EV's preparation & characterization remain a tricky challenge for a growing scientific community all over the world.

During the last four years, our group has contributed to improvements of the analytical field on EVs by establishing a label-free nanobioanalytical facility combining "multiplex detection" (by Surface Plasmon Resonance Imaging), nanocharacterization (by Atomic Force Microscopy) and protein identification (by Mass Spectrometry). These results have contributed to the Minimal Information for Studies of Extracellular Vesicles ("MISEV") guidelines provided by the International Society for Extracellular Vesicles (ISEV) and have been published in the Journal of Extracellular Vesicle (Taylor & Francis Publisher, IF=11). Beyond the (pre-)analytical requirements, the MISEV2018 guidelines include tables and outlines of suggested methods, protocols and steps to follow to document specific EV-associated functional activities. The recommendations listed within this paper are so eagerly awaited by the scientific community that this article, published in Nov. 2018, is considered as a "hot paper in the field" in the Web of Science with almost 400 citations in 2019.

References

C. Théry et al. 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. Journal of Extracellular Vesicles 7 (1) 1535750 (2018). www.doi.org/10.1080/20013078.2018.1535750

S. Obeid et al.. Development of a NanoBioAnalytical platform for "on-chip" qualification and quantification of platelet-derived microparticles.Biosensors and Bioelectronics 93, 250–259 (2017).www.doi.org/10.1016/j.bios.2016.08.100

S. Obeid et al., NanoBioAnalytical characterization of extracellular vesicles in 75-nm nanofiltered human plasma for transfusion: A tool to improve transfusion safety.Nanomedicine: Nanotechnology, Biology, and Medicine 20, 101977 (2019). www.doi.org/10.1016/j.nano.2019.02.026

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

https://www.youtube.com/watch?v=L_TKKsjgQLo

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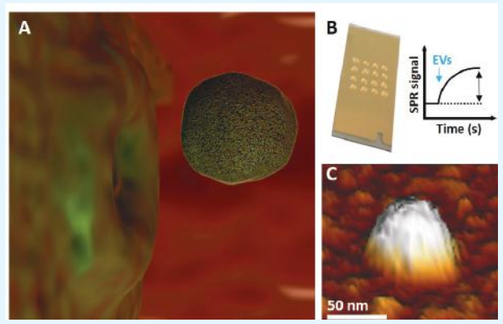
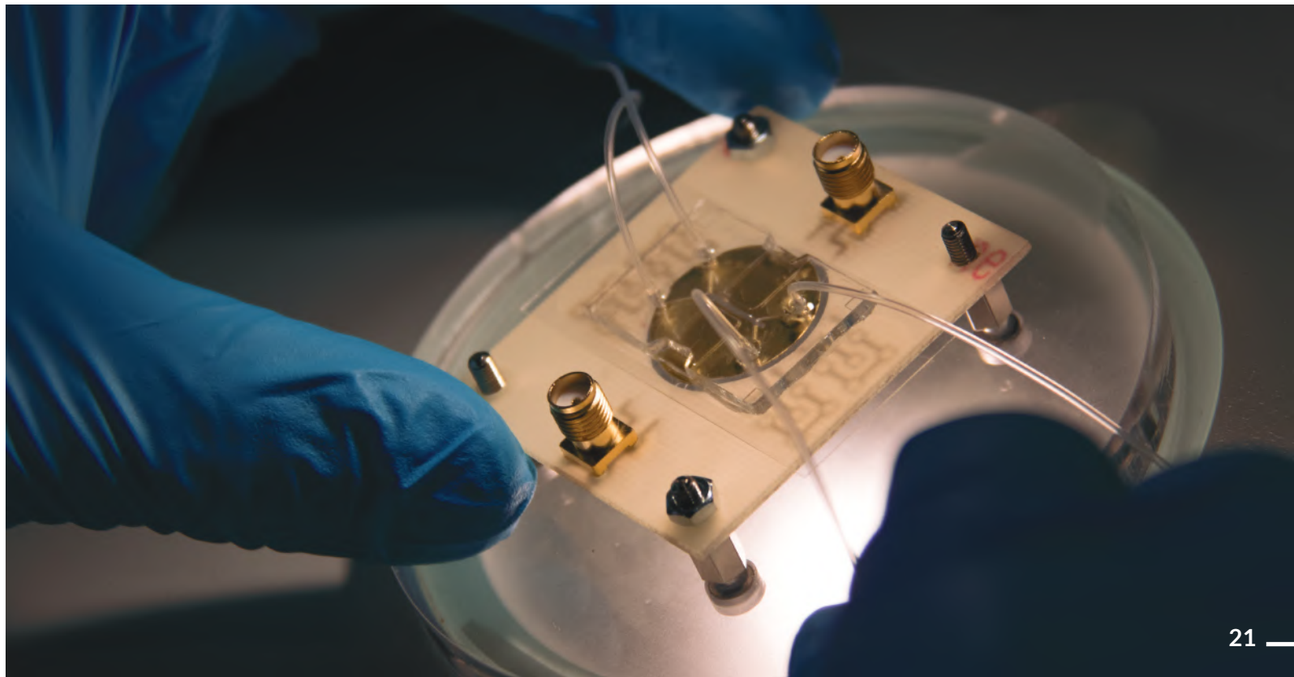


A) Blender view of EVs biogenesis from parent cell,
B) SPRi biochip for the specific immunocapture of EVs in complex media,
C) AFM imaging of a single EVs on an immuno-array of the biochip.



HIGHLIGHTS

PROBING THE BIOLOGICAL E-FIELD WITH A NANOPHOTONIC STRUCTURE

OPTICS

Non-intrusive, wide bandwidth and spatial resolution are terms often heard in electric field sensing. Despite of the fact that conventional electromagnetic field probes can exhibit significant operating performances, they fail in terms of perturbation of the E-field due to their loaded metallic structure. In particular, the well-known electro-optical technology offers an alternative to the classical metallic ones, but these probes, based on the Pockels effect require large interaction lengths which severely limit the sensing performances in terms of bandwidth and spatial resolution. The probes developed by the FEMTO-ST team focus on miniaturizing the interaction volume, photon lifetime and device footprint by taking advantage of the combination of a well-known electro-optic material, lithium niobate (LN), Lab-on-Fiber technologies and photonic crystals (PhC).

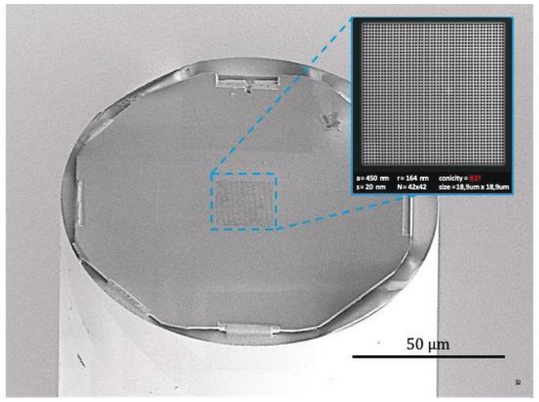
We demonstrate the operation of an all-dielectric E-field sensor whose ultra-compact footprint is inscribed in a 125 µm-diameter circle with an interaction area smaller than 19 µm x 19 µm and light propagation length of 700 nm. A nano-patterned sub-micrometer thin film located at the tip of a fiber can provide a sensing volume compact enough to achieve a bandwidth in the order of decades of THz. This submicrometer length provides outstanding bandwidth flatness, in addition to being promising for frequency detection beyond the THz range. Moreover, the miniturization also provides unique features such as spatial resolution under 10 µm and minimal perturbation to the E-field, accompanied by excellent linearity with respect to the E-field strength. All these specifications, summarized by the high versatibility of Lab-on-Fiber technology, lead to a revolutionary and novel fibered E-field sensor which can be adapted to a broad range of interests in the fields of telecommunications, health and military applications due to their outstanding performances in terms of EM invisibility, ultra-high spatial resolution, THz bandwidth, stability in chemical environments, high temperature and intense fields through a versatile and ultra-lightweight sensing head device.

References

V. Calero, M.-A. Suarez, R. Salut, F. Baida, A. Caspar, F. Behague, N. Courjal, L. Galtier, L. Gillete, L. Duvillaret, G. gaborit, M.-P. Bernal. An ultra wideband-high spatial resolution compact electric field sensor based on lab-on-fiber technology. Scientific Reports 9, 8058 (2019). www.doi.org/10.1038/s41598-019-44644-y

Funding of the project :

- French Directorate General of Armaments (ANR-13-ASTR-0019),
- The regional government of Bourgogne-Franche-Comté
- The French Society of Technological Transfer Acceleration (SATT-Sayens)



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SEPARATING THE CONTRIBUTIONS OF ZONA PELLUCIDA AND CYTOPLASM IN THE VISCOELASTIC RESPONSE OF HUMAN OOCYTES

ROBOTICS & AUTOMATION

The success of Assisted Reproductive Technologies (ART) is often linked to the quality of the chosen human oocytes. Significant research effort has therefore been dedicated to predicting the quality of an oocyte before and after fertilization with the prospect of reducing the risk of pregnancy arrest and increasing the implantation success. Mechanical characterization can be used to assess oocytes quality and such an approach is currently under investigation thanks to a collaboration between the soft matter Mechanics Lab at the University of Colorado and the FEMTO-ST Institute. Current similar studies have been hindered by the lack of accuracy in describing the mechanical contributions of each oocyte structure due to its high heterogeneity. To solve this problem, a novel approach has been developed to model the oocyte response taking into account some major components of oocytes, as well as different loading conditions. The model is a viscoelastic extension of the Hertz model and it incorporates the heterogeneity in the oocyte structure by assuming that the mechanical response is mostly dependent on a thick outer layer made of biopolymers called zona pellucida and on the cytoplasm. The model was validated with high-fidelity finite element simulations and calibrated with experiments performed at FEMTO-ST. It has then applied to develop an experimental protocol that is capable of accurately separating the viscoelastic contribution of zona and cytoplasm by simply varying the loading condition. This new protocol uses wide and sharp indenters. A partial validation of this protocol using wide indenters has been conducted at the AS2M department of FEMTO-ST using a flotation facility used as a nanoforce sensor. A new measurement facility (TRL 6) fully compatible with this protocol and all the ART constraints imposed by the Agency of Biomedicine has been developed by AS2M and is currently under investigation at Besançon Hospital.

References

J. Abadie, C. Roux, E. Piat, C. Filiatre, and C. Amiot, Sensors and Actuators, B: Chemical 190, 429 (2014). www.doi.org/10.1016/j.snb.2013.08.042

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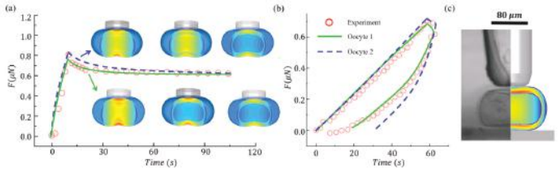

Example of a non-unique fitting solution where two human oocytes with different properties show a similar response in (a) stress-relaxation and (b) loading-unloading tests. (c) A comparison about the deformation profile between finite element and experiment for an oocyte.

POROUS ORGANIC POLYMERS BASED ON COBALT CORROLES FOR CO BINDING

TIME & FREQUENCY

Carbon monoxide (CO), known as the silent killer, is an invisible and odourless gas created by incomplete combustion of fossil fuels and responsible for ~30 000 poisonings in Europe and in the USA per year. The need to detect and accurately measure this gas is very important. Indeed, most of the commercial CO detectors based on electrochemical cells or semiconducting metal oxides such as SnO_2 and ZnO operate at high temperatures and suffer from relatively poor selectivity.

One crucial point consists of finding molecules or metal complexes able to selectively bind CO with a high affinity with a low cost and size. Porous materials like Metal–Organic Frameworks (MOFs), which are capable of binding to CO molecules, have recently been identified for CO adsorption and detection. However, they generally suffer from a lack of selectivity over O_2.

Porous Organic Polymers (POPs), known for their high surface area and porosity, were prepared by reacting tetraphenyl tetrahedral-shaped building blocks and the free base or the cobalt complex of corrole macrocyclic linkers. This synthetic method allowed us to construct new porous frameworks with high CO adsorption properties. The design principles as well as the relationship between the structure and the selective CO adsorption performance have been studied. The adsorption capacities and selectivities of CO were calculated from a multisite Langmuir isotherm model together with IAST theory. Spectroscopic studies (NMR, FTIR, UV-visible), kinetic sorption measurements and microscopic analyses made possible to provide a fairly complete description of the POPs, their porosity and the nature of solid–gas interactions. The POPs prepared by both methods show a high permanent porosity and outstanding CO adsorption properties with a high selectivity over N_2, O_2 and CO_2, up to 15700, 4000 and 1800, respectively. The two POP-CorCo offer confined molecular spaces for ascertaining a high accessibility of the metallocorrole active sites for gas binding on the cobalt atom, thus featuring high potential for applications in selective capture or sensing of CO versus N_2, O_2 and CO_2.

References

1. X. Jiang, M. Naitana, N. Desbois, V.Q uesneau, S. Brandès, Y Rousselin, W. Shan, W.R. Osterloh, V. Blondeau-Patissier, C.P. Gros, K.M. Kadish, Inorg. Chem. 57 (3), 1226 (2018). www.doi.org/10.1021/acs.inorgchem.7b02655

2. X. Jiang, W. Shan, N. Desbois, V. Quesneau, S. Brandès, E. Van Caemelbecke, W.R. Osterloh, V. Blondeau-Patissier, C.P. Gros, K.M. Kadish, New J. Chem. 42, 8220 (2018). www.doi.org/10.1039/C8NJ00300A

3. V. Quesneau, W. Shan, N. Desbois, S. Brandès, Y. Rousselin, M. Vanotti, V. Blondeau-Patissier, M. Naitana, P. Fleurat-Lessard, E. Van Caemelbecke, K.M. Kadish, K. C.P. Gros, Eur. J. Inorg. Chem. 38, 4265 (2018). www.doi.org/10.1002/ejic.201800897

4. W.R. Osterloh, V. Quesneau, N. Desbois, S. Brandès, W. Shan, V. Blondeau-Patissier, R. Paolesse, C.P. Gros, K.M. Kadish, Inorg. Chem. 59 (1), 595 (2020). www.doi.org/10.1021/acs.inorgchem.9b02855

5. W. Shan, V. Quesneau, N. Desbois, V. Blondeau-Patissier, M.L. Naitana, Y. Rousselin, C.P. Gros, Z. Ou, K.M. Kadish, J. Porphyrins Phthalocyanines 23, 214 (2019). www.doi.org/10.1142/S1088424619500214

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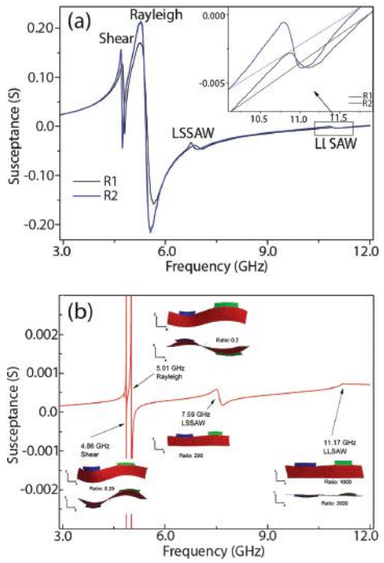
SAW DEVICES WITH Z-LINBO$_3$ LAYERS ON SAPPHIRE

TIME & FREQUENCY

Filter market demands have pushed the development of new piezoelectric materials to address the modern telecommunication challenges. Combining composite wafers with an epitaxial piezoelectric layer and a said high velocity and acoustic quality substrate is a promising way to answer those demands. However, the fabrication of high-quality $LiNbO_3$ (LN) films with reproducible physical properties is complicated by the difficulty in controlling volatile Li_2O incorporation into the film and of measuring its composition. So far, large-scale production of films with physical properties suitable for the applications targeted is not available. In this paper, lithium niobate films with controlled nonstoichiometry were deposited by means of pulsed injection metalorganic vapor phase deposition. We have demonstrated a high acoustical performance compatible with filter applications (K^2 up to 8%) for SAW devices operating in the frequency range of 3.7 GHz up to 5. 3 GHz and based on epitaxial (ZX)-LN films grown on sapphire. High quality factors can be achieved by reducing the h/p ratio by profiting from low losses of the sapphire substrate, which however implies electromechanical coupling reduction. Extremely high velocities (10 900 ms^{-1}) of LLSAW were also measured experimentally in the $LiNbO_3$/sapphire structure (resonance at 10.9 GHz).



The experimentally measured susceptance as a function of frequency of two SAW resonators (R1 and R2) with propagation directions along the X-axis (a).

The zoom on the longitudinal mode is given in the inset of (a). Simulated dependence of the imaginary part of admittance of SAW with k . 1.0 lm excited in a (ZXt)/0_ 158 nm thick LN film on C-sapphire (b). The displacements of each wave are illustrated, and the magnification ratio is indicated, as well.

References

A. Almirall, S. Oliveri, W. Daniau, S. Margueron, T. Baron, P. Boulet, S. Ballandras, S. Chamaly, and A. Bartasyte,
Appl. Phys. Lett. 114, 162905 (2019).
www.doi.org/10.1063/1.5086757

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MEMS CELL-BASED OPTICAL FREQUENCY REFERENCE

TIME & FREQUENCY / MIMENTO

The exploration of innovative approaches combining advanced quantum physics concepts, on-chip hybrid integration of MEMS vapor cell technologies with photonics devices and high-performance digital electronics constitutes an exciting research path towards the development of new-generation miniaturized atomic frequency references based on optical transitions.

In this area, FEMTO-ST has recently reported a novel laser frequency stabilization approach using a dual-frequency sub-Doppler spectroscopy (DFSDS) technique. In this system, alkali thermal atoms confined in a mm-scale vapor cell interact with two orthogonally-polarized counter-propagating dual-frequency optical fields, yielding the detection of high-contrast sign-reversed sub-Doppler optical resonances. The observation of these enhanced-absorption spikes has been explained in an extended theoretical model, established in collaboration with D. Brazhnikov from the Institute of Laser Physics (Novosibirsk, Russia). These high-Q factor (Q~5 10^7) optical resonances have been used for frequency stabilization of a diode laser, yielding a short-term frequency stability lower than 1 10^{-12} $\tau^{-1/2}$ to 10 s integration time. These short-term stability performances are already about 50-100 times better than those of commercial microwave CPT-based chip-scale atomic clocks (CSACs) and demonstrate the interesting promise of this approach for the development of MEMS cell-based optical frequency references (OFRs).

However, substantial efforts remain to be done to explore the full potential of this MEMS-cell OFR architecture. A proposal has been submitted to CNES to pursue these studies. In the future, this OFR could be associated with on-chip microresonator-based optical frequency combs used as optical-to-microwave frequency dividers for the generation of ultra-stable microwave signals.

References

Z. L. Newmann et al., Optica 6 (5), 680-685 (2019).
www.doi.org/10.1364/OPTICA.6.000680

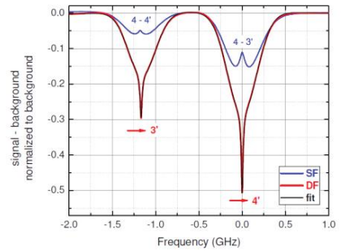
M. Abdel Hafiz et al., Optics Letters 41 (13), 2982 (2016).
www.doi.org/10.1364/OL.41.002982

D. Brazhnikov et al., Physical Review A 99, 062508 (2019).
www.doi.org/10.1103/PhysRevA.99.062508

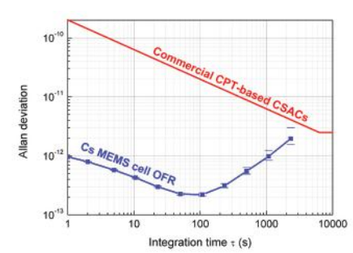
https://www.microsemi.com/product-directory/clocks-frequency-references/3824-chip-scale-atomic-clock-csac

https://teams.femto-st.fr/equipe-ohms/

facilities: MIMENTO / OSCILLATOR IMP



Top: Sub-Doppler resonances detected in a Cs MEMS cell. SF: single-frequency regime (saturated absorption), DF: dual-frequency regime.



Bottom: Preliminary fractional frequency stability of the lab-prototype Cs MEMS cell optical frequency reference (OFR) in comparison with typical performances of a commercial microwave chip-scale atomic clock (Microsemi CSAC SA-45) [4].

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GLASS BLOWING AT A WAFER-LEVEL : MICROFABRICATION OF AXICONS

MICRO-NANOSCIENCES & SYSTEMS

The developed method allows collective manufacturing of hundreds of conical microlenses made of glass, capable of generating non-diffracting light beams. These results pave the way for applications, particularly in biomedical imaging. They have been published and highlighted by Optics Letters and Optical Society of America (Newsroom, Optics & Photonics News) last summer.

Glass blowing is a technique known since ancient times. Air is blown into the heated glass, which deforms until it reaches the desired shape. This same principle can be applied on a microscopic scale, making it possible to collectively produce hundreds of glass microlenses using microfabrication techniques. Microcavities are first etched by dry etching into a silicon substrate. The structured silicon wafer is then anodically bonded to a borosilicate glass wafer at atmospheric pressure: gas inside the cavities is thus trapped. Then, the whole stack is heated: the glass viscosity decreases while the gas pressure inside the cavities increases leading to the generation of gas bubbles. The latter act as multiple pistons pushing the glass above them, to form a continuous profile on the opposite side of the glass substrate. To manufacture axicons, the process relies on a central circular cavity surrounded by concentric rings, able to straighten up the profile and make it conical. Finally, the rear surface of the silicon and the inner part of the blown glass are eliminated by lapping and polishing in order to release the microcomponents made of glass.

The long-term objective is to integrate these microlenses into microsystems, in particular to create miniaturized and low-cost biomedical imaging devices. In addition, the same collective manufacturing process could be used to obtain other lens shapes or more complex optical components.

References

J. V. Carrión, J. Albero, M. Baranski, C. Gorecki, N. Passilly, Optics Letters, 44 (13) 3282-3285 (2019).
www.doi.org/10.1364/OL.44.003282

https://projects.femto-st.fr/MOEMS-Group/en

Article highlighted in :

https://insis.cnrs.fr/fr/cnrsinfo/le-micro-soufflage-de-verre-pour-realiser-des-composants-optiques-miniatures

- Optical Society of America (OSA): https://www.osa.org/en-us/about_osa/newsroom/news_releases/2019/microscopic_glass_blowing_used_to_make_tiny_optica/
- Optics and Photonics news (OPN): https://www.osa-opn.org/home/newsroom/2019/june/micro-glass-blowing_creates_tiny_conical_lenses/
- Laser Focus World: https://www.laserfocusworld.com/optics/article/14037988/glassblowing-technique-creates-arrays-of-axicon-lenses

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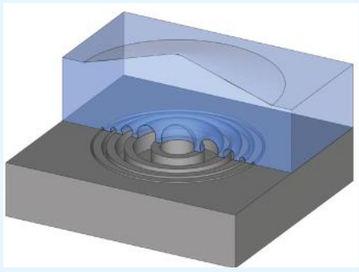
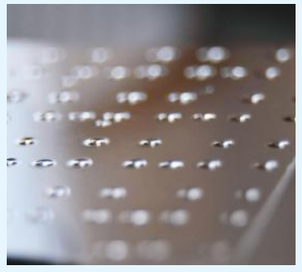


(a) Sketch of an axicon after glass blowing



(b) Photography of a piece of wafer of fabricated microaxicons.

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MAJOR REVIEW PUBLICATIONS IN OPTICS IN 2019

OPTICS

Staff of the Optics Department published three major review papers during 2019, with two covering nonlinear optics and optoelectronics, and another focusing on the historical strengths and future prospects of Fourier optics.

The first paper in Reviews of Modern Physics described a particular system known as an 'optoelectronic oscillator'. The operation of this device combines complex concepts from nonlinear dynamics with practical electronics and photonics to yield an entirely new approach to physical cryptography, precision frequency references for radars, and an exciting new facility in artificial intelligence. The second paper in Nature Reviews Physics described how linear and nonlinear propagation in optics can also be applied to the study of the generation of high amplitude `rogue waves' on the ocean. This research has significantly improved understanding of the mechanisms that drive rogue wave emergence, and has even suggested ways in which such destructive events may be predicted.

Finally, as part of a special issue of the Journal of the Optical Society of America A focusing on Classical Optics in France, members of the Optoelectronics and Photonics (OPTO) and Nonlinear Optics (NLO) groups contributed to a joint paper on Fourier optics and applications. This article provided the opportunity to highlight for an international audience the fact that the concepts of Fourier optics were developed in France during the 1940s by P. M. Duffieux, who eventually established the Optics research programme at the University of Franche-Comté. The review discussed how Fourier concepts continue as a major theme of research at FEMTO-ST with applications including ultrafast measurements, quantum information, material processing, and artificial intelligence.

The publication of these review articles reinforces the support of FEMTO-ST for research that combines elements of fundamental and interdisciplinary science with the strategic search for practical applications.

References

Y. K. Chembo, D. Brunner, M. Jacquot, L. Larger, Optoelectronic oscillators with time-delayed feedback, Reviews of Modern Physics 91, 035006 (2019). www.doi.org/10.1103/RevModPhys.91.035006

J. M. Dudley, G. Genty, A. Mussot, A. Chabchoub, F. Dias, Rogue waves and analogies in optics and oceanography, Nature Reviews Physics 1, 675 (2019). www.doi.org/10.1038/s42254-019-0100-0

L. Froehly, F. Courvoisier, D. Brunner, L. Larger, F. Devaux, E. Lantz, John M. Dudley, M. Jacquot, Advancing Fourier: space–time concepts in ultrafast optics, imaging, and photonic neural networks, Journal of the Optical Society of America A 36, C69 (2019). www.doi.org/10.1364/JOSAA.36.000C69

https://insis.cnrs.fr/fr/cnrsinfo/une-synthese-de-letat-de-lart-pour-les-oscillateurs-optoelectroniques

https://insis.cnrs.fr/fr/cnrsinfo/quand-loptique-eclaire-la-formation-des-vagues-scelerates

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PERFORMANCE EVALUATION OF SCHEDULING ALGORITHMS

COMPUTER SCIENCE

High-performance computing is mostly based on the smart distribution of tasks on potentially heterogeneous machines. This raises a large variety of scheduling problems: tasks known or not known in advance, heterogeneity of tasks and machines, optimization objectives... Most of these problems are NP-complete, i.e. finding the optimal solution (which task is performed on which machine and when) is not currently possible for quite large instances (more than a few dozen of tasks). The literature is full of heuristics proposals to solve these problems most efficiently. The analysis of these articles shows that there is considerable room for improvement in the experimental evaluation protocols.

We focus on the random generation of constrained instances to make the evaluation of experimental performance. This is based first of all on an analysis of the parameters relevant to the targeted applications (for instance the heterogeneity of the tasks). Next, the approaches to the random generation instances proposed in the literature have to be confronted with these parameters to estimate their coverage. For example, it has been shown in [1] that the most widely used method for generating cost matrices has a too low spread of case coverage. A similar result was given in [2] where it is shown that generating a constraint graph (this task must be executed before the next one), gave easy to solve instances with a probability that tends towards 1 when the size of the graph increases. Finally, once these analyses have been performed, we tackle the problem of generating constrained instances with given properties. The complexity lies in the richness of the instances and the techniques used are either Markov chains or analytics combinatorics based. For example, we have shown in [3] how to generate cost matrices uniformly while controlling the heterogeneity of tasks or machines.

References

[1] L.-C. Canon, L. Philippe, IEEE Trans. Parallel Distrib. Syst. 28(6), 1675 (2017).
www.doi.org/10.1109/TPDS.2016.2629503

[2] L.-C. Canon, M. El Sayah, P.-C. Héam, Springer, Euro-Par 2019: 61-73, LNCS 11725, 61 (2019).
www.doi.org/10.1007/978-3-030-29400-7_5

[3] L.-C. Canon, M. El Sayah, P.-C. Héam, IEEE HPCS 2018, 460 (2018).
www.doi.org/10.1109/HPCS.2018.00079

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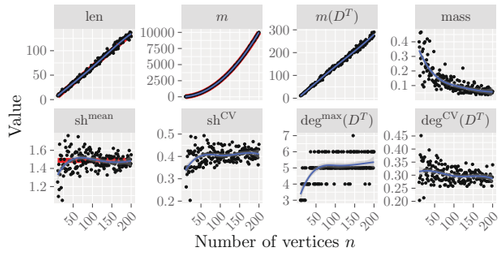

FUEL CELL NON-INVASIVE DIAGNOSIS THROUGH EXTERNAL MAGNETIC FIELD MEASUREMENT (PEM-DIMAG)

ENERGY

Fuel Cell technology, because of its potential for effectively alleviating environmental and resource issues, has been attracting considerable increasing attention. However, reliability and durability are currently two main barriers which prevent the process having wide applications. Among the solutions, fault diagnosis, dedicated to detecting, isolating, and analysing different faults, has proved to be beneficial for keeping fuel cell systems operating safely, reducing downtime and mitigating performance degradation.

Knowledge of the current density distribution inside the Fuel Cell can indicate an abnormal operation and thus offer an effective diagnostic approach. Magnetotomography is the only non-invasive current density mapping method based on the measurement of the external magnetic field surrounding the stack. Recent work by the SHARPAC team developed a new FC stack magnetic field measurement methodology. This new approach enables a more accurate analysis of the current distribution inside the Fuel Cell.

The PEM-DIMAG project will enable the development of innovative diagnosis procedures and current mapping methods for detecting default cell operation inside the volume of the FC stack, based on the new methodology. In this work, the magnetic field analysis of the fuel cell will make it possible to take into consideration magnetic 3D effects to improve the existing test bench.

The PEM-DIMAG project will include the following major steps:

- The modelling and the optimal design of the fuel cell test bench including the measurement system. For the magnetic model, both numerical (finite element) and analytical approaches will be considered.
- The characterization of the magnetic field of the fuel cell. Realization of numerous series of experiments to test the fuel cell in normal operation as well as in fault operation.

The elaboration of a dual diagnosis approach, to be tested individually: a current mapping-based diagnostic, using the mapping methods and a data-based diagnostic.

References

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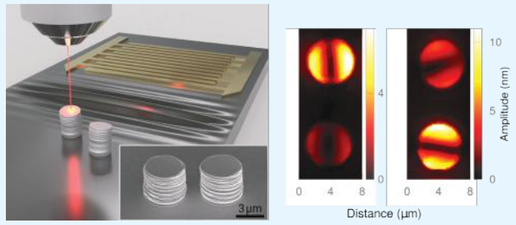
DIPOLE STATES AND COHERENT INTERACTION IN SURFACE-ACOUSTIC-WAVE COUPLED PHONONIC RESONATORS

MICRO-NANOSCIENCES & SYSTEMS

Mechanical motion is one of the most intuitive and recognizable physical effects, often considered as the bedrock of classical physics. But the manipulation of mechanical vibrations remain a critical and timely concern: over the past thirty years, the tremendous technological advances in micro- and nano-manufacturing processes have led to a massive resurgence of interest in the field. A number of strategies have been introduced to achieve exquisite control of mechanical oscillations at such micro- and nano-scales. Potential applications cover ultra-sensitive sensing to information processing, in both the classical and quantum regimes.

In most approaches, reaching such a level of control requires isolating the mechanical system from its environment, and most notably from its supporting substrate. We have instead proposed a strategy exploiting the long-standing history and well-established know-how of the FEMTO-ST Institute in the fields of surface acoustic wave (SAW) devices and phononics to demonstrate a reciprocal platform allowing either to coherently control mechanical systems through SAW, or rather, to channel SAW propagation at the substrate surface through mechanical resonator coupling. Direct imaging of the vector nature of the interaction through optical interferometry revealed the possibility to tune the mechanical coupling scheme. This, in turn, allowed controlling the resonators' polarisation states, opening exciting perspectives for the implementation of SAW-driven, all-electromechanical information processing systems. The possible control of the elastic displacement and hence of the strain distribution at the substrate surface also holds promises: outside SAW localization and waveguiding, the proposed platform could be used to trigger and control strain-mediated coupling, a mechanisms that has proven its relevance in optomechanical or nano-mechanical systems, but that also stands at the core of recent developments in nanomagnetism or spintronics.



References

L. Raguin, O. Gaiffe, R. Salut, V. Soumann, J.-M. Cote, V. Laude, A. Khelif & S. Benchabane, Nat Commun 10, 4583 (2019).
www.doi.org/10.1038/ s41467-019-12492-z

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EXPERIMENTAL ACTIVITY DESCRIPTORS FOR IRIDIUM-BASED CATALYSTS FOR THE ELECTROCHEMICAL OXYGEN EVOLUTION REACTION (OER)

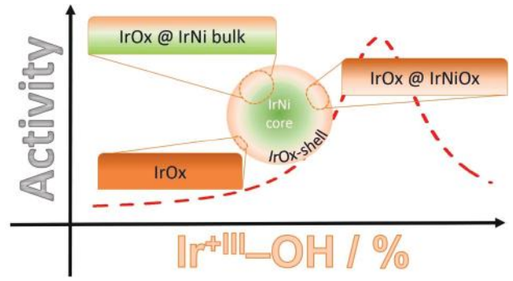
MICRO-NANOSCIENCES & SYSTEMS

Recent progress in the improvement of activity of anode catalysts for acidic electrochemical splitting of water was largely achieved through empirical studies of novel iridium-based bimetallic oxides. However, practical, experimentally accessible, yet general predictors of catalytic OER activity are lacking. This study investigates thin film model electrocatalysts iridium and iridium-nickel thin film model electrocatalysts for the OER and identifies a set of general ex-situ properties that allow the reliable prediction of their OER activity. Well defined Ir-based catalysts of varied chemical nature and composition were synthesized by magnetron sputtering. Correlation of physico-chemical and electrocatalytic properties revealed two experimental descriptors of OER activity that are able to predict trends in the OER activity of unknown Ir based catalyst systems. More specifically, our study demonstrates that the Ir^{III+} and OH-surface concentration of the oxide catalyst constitute closely correlated, and generally applicable OER predictors of activity. Based on these, an experimental volcano relationship of Ir-based OER electrocatalysts is presented and discussed.

Reference

C. Spöri, P. Briois, H. Nhan Nong, T. Reier, A. Billard, S. Kühl, D. Teschner, and P. Strasser, ACS Catalysis 9, 6653 (2019).
www.doi.org/10.1021/acscatal.9b00648

facility: SURFACE



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FACILITIES

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

- CLIPP (Clinical Innovation Proteomic facility)
- FLUIDIX (Facility for fluidic and thermal characterization of complex flows)
- FRILIGHT (Formation-Research-Innovation using Light facility)
- MIFHYSTO (Micromanufacturing, mechanics, micromachining, powder injection molding, metal additive manufacturing, surface treatment, filled polymers, metrology, material characterization)
- MIMENTO (Microfabrication for Mechanics, Nanosciences, Thermal Science and Optics)
- µROBOTEX (Micro and nano robotic facility with two hands)
- OSCILLATOR IMP (Oscillator Instability Measurement facility)
- SPAC (Hydrogen-Energy and Fuel Cell Systems)
- SURFACE (Development and characterization of thin-film materials)
- FRANCHE-COMTE MESOCENTRE (Numerical simulation, High Performance Computing)

References

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

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

MIFHYSTO

MICROMANUFACTURING, MECHANICS, MICROMACHINING, POWDER INJECTION MOLDING, METAL ADDITIVE MANUFACTURING, SURFACE TREATMENT, FILLED POLYMERS, METROLOGY, MATERIAL CHARACTERIZATION

The MIFHySTO facility (FEMTO-ST, UTINAM and ICB institutes) aims to develop, improve and hybridize mechanical micromanufacturing processes to produce micro-parts or components with submillimetre dimensions or with a micrometre precision. It has expertise in the main technologies used at this scale (µEDM, µmilling, swiss turning, Cceramic injection molding, metal Injection molding, hot embossing, metal additive manufacturing, surface, surface treatment, carbon nanotubes, ...).

It has many skills with components or assemblies metrology (nano-micro-CT Scan, 3D microscopy, 3D metrology) and on materials characterisation (X-ray diffraction, SEM, AFM, ...):

- Downscaling, understanding and mastering mechanical micromanufacturing processes
- Hybridization of mechanical micromanufacturing processes (clean room/ gray room, additive manufacturing, surface treatment, micromachining)
- Surfaces texturation and functionalization
- Surface and geometry metrology
- 3D microparts manufacturing

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MIMENTO

MICROFABRICATION FOR MECHANICS, NANOSCIENCES, THERMAL SCIENCE AND OPTICS

ISO 9001 certification

The MIMENTO technology center is identified as a reference centre for Micronano-optics, Micro-nano-acoustics, Micro-Opto-Electro-Mechanical Systems (MOEMS) and Micro-Robotics in the context of the "RENATECH" network (French national network for large facilities involved in technological research in the field of micro and nanotechnology). Mimento at FEMTO-ST is also mutualized with the technological facility CMi at EPFL (Switzerland).

It is managed by a technical team of fifteen engineers and technicians whose role is to support research projects in the centre (internal or external projects). It has a high-tech equipment park open to both academic and industrial partners in collaborative research:

- 1300 m^2 total space
- 865 m^2 of cleanroom (ISO 5 to ISO 7 ↔ class 100 to class 10 000)
- 230 m^2 of space for other activities (FIB, dicing / polishing, etc.)
- 17 M€ of high technology equipment
- 900 k€ per year running costs

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SPAC

HYDROGEN-ENERGY AND FUEL CELL SYSTEMS

The SPAC facility (operated by FCLAB, a CNRS-UTBM-UFC joint service unit) aims to design, evaluate, develop and integrate systems based on the use of the hydrogen energy vector. Thus, the complete hydrogen chain (production from renewable energy, storage, conversion to electricity and / or heat via fuel cells), as well as the use of hydrogen in transport or stationary applications are processed thanks to the unique means of this facility, available at scale 1:

- Test benches: PEM & SO fuel cell, PEM water electrolysis
- Experimental characterization under actual operating conditions (temperature, vibrations, hygrometry, electrical cycling, etc.)
- Test procedures: accelerated stress, long operation
- Design and validation of fuel cell system auxiliaries: air compressors, power electronics, control, electrical machines, etc.
- Artificial intelligence & state-of-health diagnosis, prognosis and remaining useful lifetime & fault/ durability tolerant control for hydrogen-energy systems
- Electrical hybridization (batteries, supercaps, flywheels)
- Hydrogen-based trigeneration & micro combined heat and power generation
- Solid-state storage of hydrogen
- PHIL Platform (Power Hardware In the Loop) for rapid prototyping

http://eng.fclab.fr/

contact : contact@fclab.org

CLIPP

CLINICAL INNOVATION PROTEOMIC FACILITY

The CLIPP, labelled Proteomics facility of the national network of infrastructures in Biology, Health and Agronomy (IBISA), is dedicated to the analysis of proteomes in biology and clinical practice. CLIPP is a facility for analysis and service in the areas of biotechnology and health at the national and international levels. It offers its expertise in the field of proteomics using know-hows in (bio) chemistry, physical chemistry, nano and micro-engineering, biostatistics and bioinformatics. These interdisciplinary skills enable the development and validation of original analytical procedures and methods which are in addition to conventional approaches of proteomics:

- Micro-nano-structurated biochip engineering and multiphysical coupling
- Detection and characterization of protein target in biological samples
- Nanobiocharacterization of biological targets (from molecule to cell)
- Biostatistical tools for big data analysis
- SPR/SPRi analysis - Atomic Force Microscopy (AFM)
- Coupling AFM and fluorescence
- Tunable Resistive Pulse Sensing (TRPS) technology

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µROBOTEX

MICRO AND NANO ROBOTIC FACILITY WITH TWO HANDS

Combining knowledge on microsystems, physical and chemical phenomena at nanoscale and control theory, this facility represents a unique environment for automated micro/nano-assembly and position/ force feedback manipulation and characterization of samples. Located at ENSMM in Besançon (France), µROBOTEX has been operational since 2014 and managed by the AS2M department of the FEMTO-ST Institute. µROBOTEX hosts various systems for handling and characterization of micro/nano-samples such as optical and electron microscopes, 6 DoF microrobots, laser interferometers and micro/nano-force sensors for biomedical application.

- 3D assembly of micro/nano systemes
- Manufacturing of micro/nano objects using origami and cutting
- Nondestructive 3D reconstruction of micro/nano objects
- Micro/nano objects characterization (carbon nanotubes, membranes, vegetable microfibers, etc.)
- Assembly of integrated optical components (resonators, photonic crystals, lab-on-fiber applications, near field tips, etc.)

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

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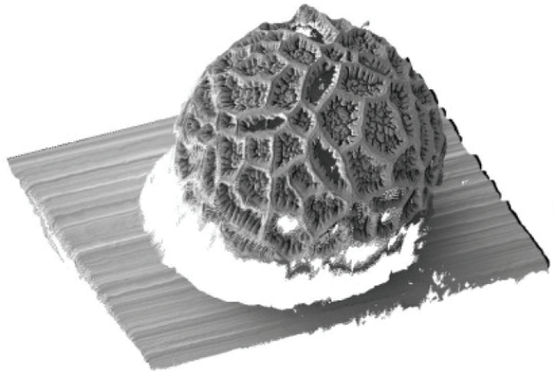
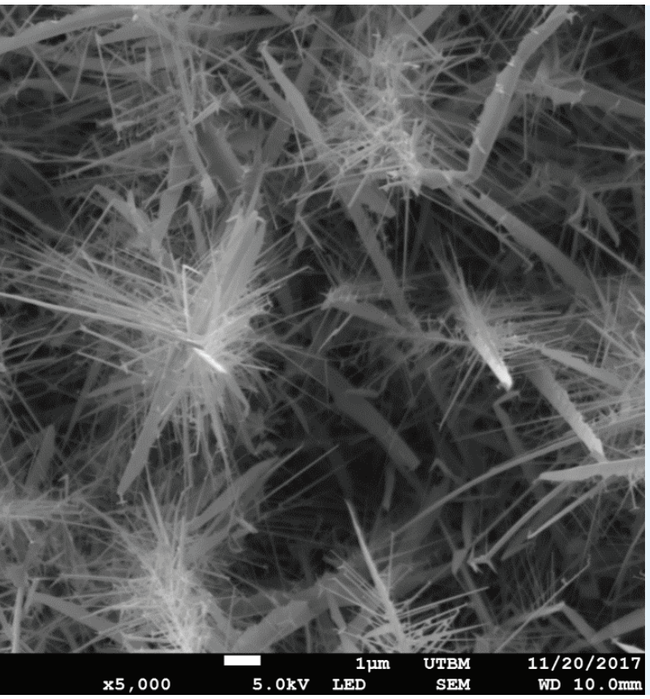


Nondestructive 3D reconstruction of a potamot pollen from SEM images (diameter is about 50 µm).



SURFACE

DEVELOPMENT AND CHARACTERIZATION OF THIN-FILM MATERIALS

ISO 9001 certification

The SURFACE facility is equipped with most of the physical vapor deposition technologies, also of an industrial scale: low-pressure cathodic arc deposition, magnetron sputtering (DC, pulsed DC, RF, HiPIMS) for the deposition of metallic and ceramic films of complex composition. We also have research-specific resources for the deposition of ultra-thin metallic and organic layers (heating by electron gun, electro-spray, liquid phase deposition by spin-coating ...). The SURFACE facility is also equipped with chemical (SEM-FEG + EDS, GDOES), structural (XRD), optical (UVvisible-NIR spectrometer), mechanical (NHT, pin on disc tribometer), and topographic from micro (surfometer) to nano scale (atomic force microscopy (AFM) and scanning tunneling microscopy (STM)) characterization techniques. Specific electrochemical characterization (corrosion, ionic conductivity measurement, electrical), for thermoelectric measurements (TFA) or gas sensors benches are also available.

- Application domains:
  - Mechanical: machining, anti-erosion, anti-friction
  - Energy: fuel cells, gas sensors, catalysis, thermoelectricity
- Industrial activity: DLC
- Development of coatings on demand

https://platforms.femto-st.fr/SURFACE/en

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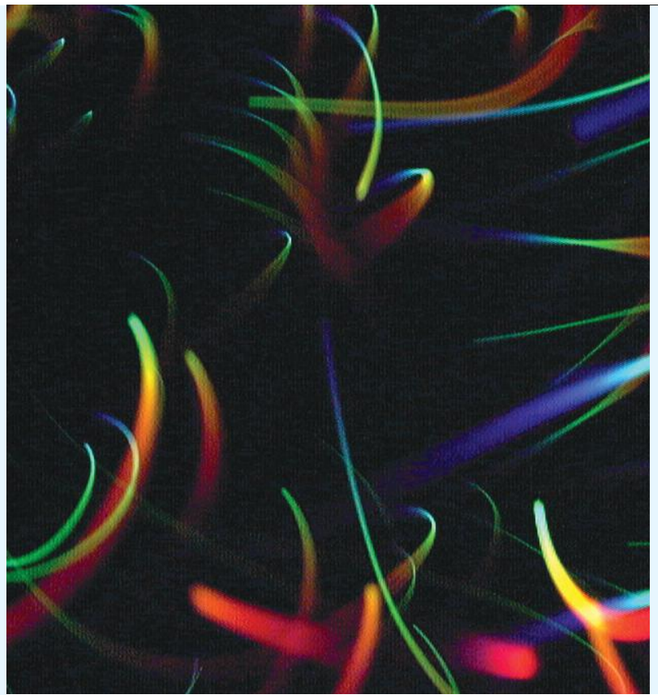

FLUIDIX

FACILITY FOR FLUIDIC AND THERMAL CHARACTERIZATION OF COMPLEX FLOWS

The FLUIDIX research facility (Institut FEMTO-ST) provides access to thermofluidic parameters of various flows through the development of new measurement methods and existing methods. The optical instrumentation implemented consists of laser sources, observation systems (visible or IR), anemometry systems, a set of infrared thermometry and spectrometers. Sensors and probes (thermoelectric effects) are manufactured in situ and then calibrated using specific benches. Means of testing (wind tunnels, supersonic ejector, vertical hydrodynamic vein and alternating flow veins) make it possible to test the metrological advances before deploying them on complex flows generated by industrial systems.

- Anemometry (hot wire, LDV, PIV, µPIV and stereo PIV), observation of phenomena (visible or IR), thermometry (infrared, spectrometric or microsensors and probes) -
- Spectrometry (network or TF) species detection, droplet size measurement
- Development and realization of specific measurement systems
- Adaptation to physical and industrial constraints

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OSCILLATOR IMP

OSCILLATOR INSTABILITY MEASUREMENT FACILITY

Oscillator IMP targets to be a leader in the measurement of noise, fluctuations, and short-term stability of oscillators and related components and devices in the entire radio spectrum, including microwave photonics. Oscillator IMP is intended to be accessible to Agencies, Research Institutions, and Private Companies. The scope of our achievements (phase noise, frequency stability, time interval, frequencies) extends from standard calibrations, at the state of the art under NF/EN 17025 accreditation, to the most advanced characterization of innovative oscillators, components, methods and measuring instruments. Our laboratory is associated with the LNE and recognized as such by the BIPM under the name LNE-LTFB. The accreditation 17025 makes it possible to offer to our calibration services guaranteed by the international agreements of mutual recognition. The quantities and metrological domains covered are listed in the national Calibration and Measurement Capabilities (CMCs) validated and published by the BIPM.

http://oscillator-imp.com/dokuwiki/doku.php

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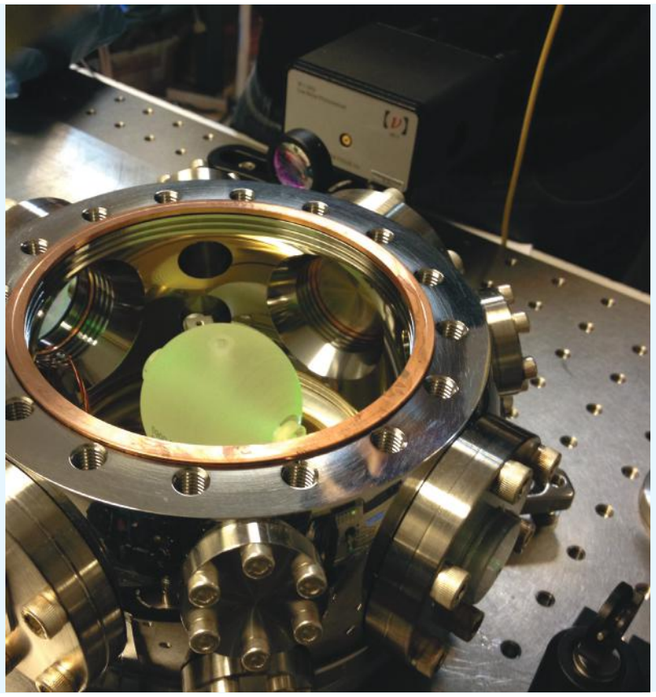

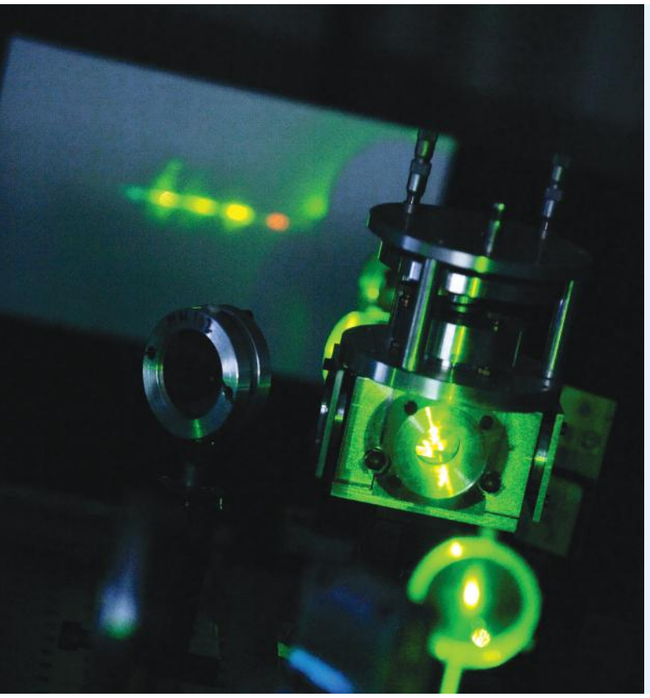

FRI-LIGHT

EDUCATION-RESEARCH-INNOVATION USING LIGHT FACILITY

FRI-LIGHT is a photonic facility that aims to offer and share a wide range of advanced scientific equipment dedicated to scientific research and higher education in photonics and optoelectronics, as well as to facilitate a technological transfer to industry. FRI-LIGHT includes equipment in photonics and electronics (lasers, signal generators and analyzers) and numerical tools in complex electromagnetic modeling.

FRI-LIGHT proposes visible and infrared widely-tunable tunable lasers operating from the continuous-wave to ultrashort (femtosecond) regimes. It also includes a series of optical spectrum analyzers covering the ultraviolet (UV) to the mid-infrared regime, for investigating complex nonlinear and quantum regime. These devices contribute to the development of complex and smart photonic and optoelectronic fiber-based systems such as optoelectronic oscillators, fiber optic sensors, new laser micro-nano-machining processes, biomedical applications, optical tweezers, reservoir computing or integrated quantum systems.

Example of developed expertises within FRI-LIGHT:

- Femtosecond laser filamentation with bessel beams and their applications to laser nanomachining
- Real-time characterization of supercontinuum light in optical fibers
- Novel modulation techniques for Brillouin distributed optical fiber sensors sold by iXblue Company.

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

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FRANCHE-COMTE MESOCENTRE

NUMERICAL SIMULATION, HIGH PERFORMANCE COMPUTING

The mésocentre of Franche-Comté provides high performance computing resources to the regional laboratories and companies. Its services cover from the provisioning of hardware resources to run large simulations to the user support when optimizing or designing high performance programs including the deployment of a large ecosystem of high performance applications:

- Computing optimization
- Parallel computing: shared memory and distributed memory
- High throughput computing
- Artificial Intelligence: deep-learning, machine-learning
- Deployment and tuning of simulation software
- Big-Data
- Analysis
- Its facilities are, among others, composed of the umière cluster, the main computing resource, of several GPU nodes, and an interactive node.

Overall the mésocentre provides more 3000 computing cores with 12 Tb of memory and 250 Tb of disk space that develop 180 Tflps of computing power (96 Tflps for CPUs and 84 Tflps for the GPUs) connected through a high bandwidth Inifinband network. These facilities allows to go one order further in the simulation size compared to a personal computer. Six departments of the FEMTO-ST Institute uses almost 2 million of computing hours every year on this computing facility (out of the total of million hours used in total by all other research institutes). The mésocentre participates to the network of regional computing center and interacts with GENCI to assist its users when requesting access to the national computing facilities.

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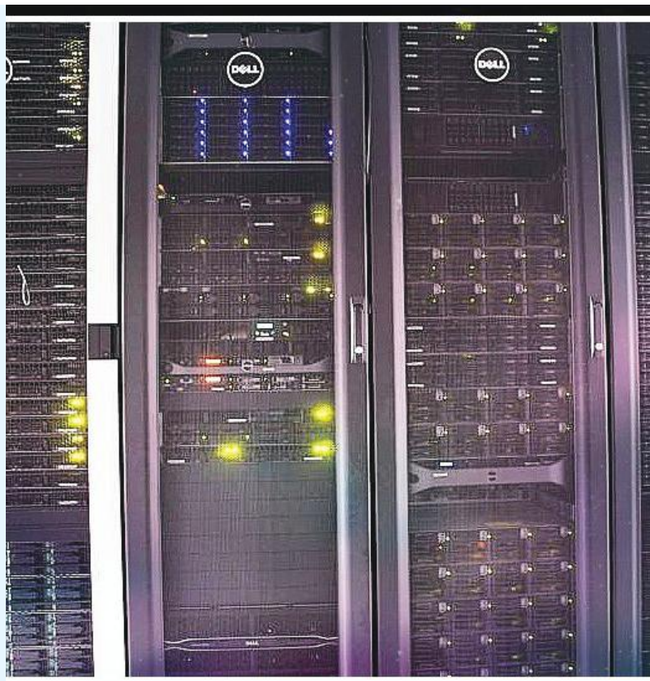


EVENTS

FEMTO-ST COLLOQUIUM

"FEMTO-ST Colloquium" is a series of invited talks of highly prestigious researchers, coordinated by FEMTO-ST, ICB and IMB. In 2019, we have welcomed Thomas W. Ebbesen, Université de Strasbourg (CNRS Gold Medal in 2019) for a talk entitled "The Alchemy of Vacuum" and Terry Quinn, former director of the International Bureau of Weights and Measures (BIPM) for a talk on "the story of the kilogram".

TERRY QUINN

Terry Quinn was educated at the Universities of Southampton and Oxford, England, and then worked in thermometry and radiometry at the National Physical Laboratory (NPL), Teddington, from 1962 to 1977 where, with John Martin, he developed the cryogenic radiometer, now universally used as the basis of radiometric and photometric measurements. He moved to the International Bureau of Weights and Measures (BIPM) in 1977 as Deputy Director and developed his interest in balances and weighing. He was Director from 1988 to 2003. He played a lead role in the establishment in 1999 of the global Mutual Recognition Arrangement for measurement standards, which now provides international recognition of national measurement capabilities in support of innovation and trade. He was closely involved over many years with the move to re-define the base units of the SI in terms of the fundamental constants of physics. He is Fellow of several prestigious scientific societies. Since retirement he has continued to write and lecture in matters related to metrology and the Metre Convention.

The story of the kilogram

This is the story of the kilogram. It begins on 19th March 1721, when five great savants of France drew up a plan to establish units of the metre and the kilogram to be taken from nature, and ends on 16 November 2018 when the 26th General Conference on Weights and Measures adopted the new definition of the kilogram, which finally brought to fruition the grand idea of 1791.

Reference

https://www.femto-st.fr/fr/L-institut/evenements/colloquium-terry-quinn-story-kilogram

THOMAS W. EBBESEN

Thomas W. Ebbesen is a physical chemist born in Oslo, Norway. He was educated in the United States and France, receiving his bachelor degree from Oberlin College (USA) and his PhD from the Curie University in Paris. He then did research in both the US and Japan, most notably at NEC, before returning to France in 1999 to help build a new institute (ISIS) at the University of Strasbourg. He is currently the head of the Center for Frontier Research in Chemistry and the Strasbourg Institute for Advanced Studies (www.usias.fr). He holds the chair of physical chemistry of light-matter interactions. The author of many papers and patents, Ebbesen has received numerous awards for his pioneering research on nanostructured materials including the 2014 Kavli Prize in Nanoscience for his transformative contributions to nano-optics. He is a member of the Norwegian Academy of Science and Letters and foreign member of the French Academy of Science.

The Alchemy of Vacuum, Hybridizing Light and Matter

Light-matter strong coupling can give rise to a multitude of exciting physical effects through the formation of hybrid light-matter states. The implications for molecules and material have remained mostly unexplored. After introducing the fundamental concepts, examples of modified properties of strongly coupled systems, such as charge and energy transport, and chemical reactivity will be given to illustrate the potential of light-matter states.

Reference

https://www.femto-st.fr/fr/L-institut/evenements/colloquium-thomas-w-ebbesen-lalchimie-du-vide

FRONTIERS IN PHOTONICS 2019

OPTICS

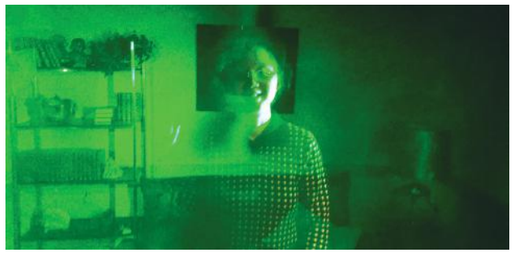
FEMTO-ST was delighted to host once again its regular Frontiers in Photonics Symposium which was held on Tuesday 19 November 2019, welcoming seven internationally renowned speakers to participate in the symposium.

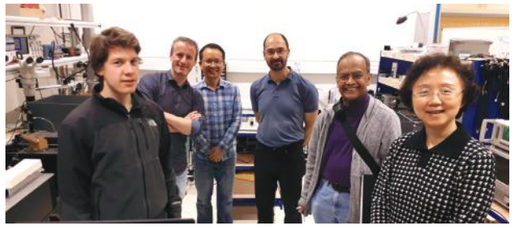
Given the particular proximity of the symposium date to the 11 November United Nations International Day of Science for Peace and Development, Dr Joseph Niemela from the UNESCO-ICTP institute in Italy kicked-off the Symposium with an inspiring presentation on Science for Sustainable Development. This was followed by a range of scientific talks covering state of the art research in nonlinear dynamics, biophotonics, integrated optics technologies, and advanced imaging. The invited speakers were Prof. Rajarshi Roy from the University of Maryland, Prof. Daniele Faccio from the University of Glasgow, Prof. Hui Cao from Yale University, Prof. Camille-Sophie Brès from EPFL Lausanne, and Prof. Sylvain Gigan from Sorbonne Université. In addition, Dr Nina Meinzer, Senior Editor of the prestigious journal Nature Physics, delivered an extremely interesting presentation describing the editorial process of selecting papers in Nature journals, as well as summarizing practical tips for writing papers.

The Symposium provided an opportunity to bring together more than 80 scientists, post-docs and PhD students around the broad theme of optics, and provided an informal environment for discussions and networking. The audience included Masters and PhD students from the EIPHI graduate School, as well as members of different departments of FEMTO-ST and the wider UBFC community including a delegation from the Institut Carnot de Bourgogne ICB. The invited speakers participated in laboratory visits with PhD students and postdocs, and were also treated to a tour of the historical holography exhibit of the Optics Department.

Reference

https://events.femto-st.fr/Frontiers-in-Photonics-2019/welcome-0





Professor Hui Cao from Yale University visits the Optics Department Hologram Museum, embedding herself in the historic hologram of "Le Salon," made in Besancon in 1978.

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FRENCH-POLISH MECHANICS SEMINAR 2019

APPLIED MECHANICS

This conference was organized by the FEMTO-ST Institute/Applied Mechanics Department in collaboration with the Warsaw University of Technology, the PAN (Polish Academy of Sciences), the University of Perpignan Via Domitia and INSA of Val de Loire. It was awarded as 'flag-ship' event for the 2019 French-Polish scientific year.

The French-Polish Mechanics seminar is an annual scientific event highlighting collaboration in the broad field of Mechanics. These events, alternatively organized in France and Poland, have permitted the strengthening and the diversification of the successful cooperation over the past 25 years.

French-Polish seminars are primarily intended for young French and Polish researchers to present their early research work. Their aim is to gather Mechanics and Physics researchers and engineers and mathematicians, who work in the following thematic fields of mechanical systems dynamics, identification of parameters for modelling mechanical processes, solid and fluid mechanics, mechanics of materials, contact mechanics, heat-transfer, numerical methods, two-phase flow, and visco-plasticity. This wide variety of topics lends to these seminars an eclectic nature, especially since the latest one has shed an original light on the vibration of structures and energy storage.

During this two-day event a total of 15 oral and 23 poster presentations were proposed. Each half day was introduced by an invited lecture of experts from the fields of mechanical friction, discrete elements modeling, mechanics of materials and mechanical vibrations.

About 30 polish participants attended the seminar. They came from universities and public research structures located all across the country: Warsaw, Poznan, Czestochowa, IPPT PAN, Institute of Aviation, ... The other foreign attendees were from USA and Maghreb. The total number of attendees was over 60.

Reference

https://frpl-meca2019.sciencesconf.org

EUROPEAN GNU RADIO DAYS

TIME & FREQUENCY

GNU Radio is the most widely used opensource radiofrequency digital signal processing framework for real time analysis or prototyping of synthetic signals. The European GNU Radio Days conference aims at fostering collaboration between European academia, industry, government agencies, and hackers.

This second edition of the GNU Radio Days conference was organized between June 17th and 19th, 2019 at the ENSMM site of FEMTO-ST. The program for this 3 days conference was shared between one day dedicated to 12 oral presentations and 6 poster/demonstrations, one day of tutorials focusing on the GNU Radio signal processing framework, and one last day of tutorials to a more restricted audience interested in the CPU/FPGA co-design framework developed at the Time & Frequency department. The purpose was hence to try to reach all types of audience interested in software defined radio, from the beginner willing to become acquainted with the framework and discover application scenarios, to experienced users and developers targeting new hardware platforms for acquiring and processing radiofrequency signals.

85 attendees, mostly French and from academia but with a third of the participants from Europe, enjoyed the oral presentation, tutorials and poster sessions with live demonstrations of radiofrequency signal analysis. Most significantly, Analog Devices' sponsoring providing one PlutoSDR board to each participant was the opportunity to demonstrate the flexibility of the OscIMP-Digital framework developed at the Time & Frequency department in the framework of the OscIMP project. This board combines a radiofrequency frontend with a Zynq System on a Chip combining an FPGA and a general purpose processor: the FPGA, classically dedicated to data acquisition, is configured for radiofrequency signal processing, the associated Linux drivers run on the embedded processor, and either the resulting dataset is streamed to a host computer or GNU Radio runs on the embedded processor.

References

https://gnuradio-fr-19.sciencesconf.org/

PlutoSDR board, https://github.com/oscimp/oscimpDigital

J.-M. Friedt, European GNU Radio Days 2019, GNU/Linux Magazine France 129 (2019).

European GNU Radio Days 2019

INNOVATION

FEMTO ENGINEERING

FEMTO Engineering is the technological development centre of the FEMTO-ST institute, at the crossroads of academic research and the need for innovation in industry. Its mission is to bridge the two sides of the technology readiness levels, identify the opportunities for markets and industries, and take the risk of demonstrating their relevance, daring to cross the so-called death-valley from science to society (& economy). FEMTO Engineering serves SMEs, large companies, and sometimes even academic groups. It can also be the environment where spin-off companies can develop. It is legally defined as a private-law and non-for-profit Foundation (FC'INNOV).

It is involved in new engineering developments in several technological fields :

- Energy - electric, magnetic and thermal modeling
- Optics, photonics and laser machining
- Electronics and radiofrequency metrology devices
- Micro-technologies for cleanrooms
- Robotics and micro-robotics
- The maturity level of the technological developments is situated between 3 and 7 on the TRL scale (Technology Readiness Level), and it can even reach 9 on some specific topics (high-tech commercialized products).

Services :

- Technological feasibility studies
- Integration of engineering processes in the design of machines, instruments and structures
- Developments of new manufacturing processes
- Prototyping pilot and small series

FEMTO Engineering was awarded Institut Carnot accreditation for the quality of its engineering partnerships.

Reference

http://www.femto-engineering.fr

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LAUNCH OF LABCOM FAST-LAB WITH GORGY TIMING

TIME & FREQUENCY

The joint laboratory FAST-LAB -Certified and Secure Time and Frequency Transfer- and the company Gorgy Timing (Grenoble) aims at promoting and shaping the interest of FEMTO-ST (Time & Frequency and Computer Science departments) for developing secure and certified time dissemination systems. Time dissemination has become a requirement for current interactions in a society meeting increased timing pressure in its exchanges. Improving the accuracy, traceability and safety has become mandatory for the time references of today's rail and air traffic, or in the context of distributed energy production of smart grids. Similarly, we address the secure timestamping of financial transactions as well as synchronizing distributed power generation and high bandwidth communication networks. In these 3 cases, the core information is ``time'' and, within the current deployment framework, security and tracking the timestamp information is only beginning.

The broad range of time sources, including historical Very Low Frequency sources which are currently neglected considering the ease of use of Global Navigation Satellite System (GNSS) networks, provides means for reducing jamming and spoofing risks. The safety of these critical timing services is a problem that we address by securing the timestamp exchange (cryptography and two way interactions between clocks exchanging messages). Making the best use of the sources of time and means of accessing these time representations are on the one hand addressed by combining multiple commercially available sources (GNSS, quartz oscillators) and on the other hand by developing dedicated systems meeting the unique requirements of redundancy (flexible software defined radio receivers able to adapt to jamming sources, composite sources dedicated to time transfer applications, time transfer over optical fibers such as White Rabbit).

FAST-LAB was inaugurated in July 2019, exhibiting the most significant results of the first 18 months.

References

G. Goavec-Merou, J.-M. Friedt, F. Meyer, Leurrage du GPS par radio logicielle, MISC HS (Feb. 2019)

G. Goavec-Merou, J.-M. Friedt, F. Meyer, Spoofing GPS, FOSDEM 2019 (Free Software Radio devroom)

https://www.fastlab-timing.com/

https://anr.fr/Projet-ANR-17- LCV2-0003#

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TRANSFER SUCCESS STORIES

TODAY, CRYOGENIC SAPPHIRE OSCILLATOR - A MATURE TECHNOLOGY

TIME & FREQUENCY

Research on Cryogenic Sapphire Oscillators (CSO) started in our lab in 1995. The CSO development has been successively supported by the French Space Agency (CNES), the DGA, the LNME, the county of Franche-Comté, and the European Space Agency (ESA). The project ELISA represents the outcome of all these efforts: the objective set by ESA was successfully fulfilled and we demonstrated for the first time the possibility of using a cryocooler while maintaining a state-of-the-art frequency stability. With an exceptional fractional frequency stability, i.e. better than 3×10^{-15} for an integration time ranging from 1 s to 10,000 s, the CSO allows the operation of the laser-cooled microwave atomic clocks at the quantum limit. It provides the means of improving the resolution of the space vehicles ranging and Doppler tracking provided by deep-space networks as well as those of very long baseline interferometry (VLBI) observatories. The CSO can also enhance the calibration capability of metrological institutes or help the qualification of high performance clocks or oscillators. Aware that there is a “niche market” for the CSO, we initiated in 2011 a voluntary economical valuation project codenamed ULISS: a new CSO was specially designed to be transported by road and travelled more than 10,000 km around Europe to be tested in various laboratories and industrial companies. The objective was to demonstrate, in the potential user’s sites, the performances of this new technology and to better understand the needs associated with each specific application. Eventually, the ULISS-2G project (ANR Emergence) allowed a significant increase in the level of TRL of our technology, making the CSO ready for commercialization.

FEMTO-Engineering has already built three CSOs for the US Naval Observatory (USNO). Recently, FEMTO-Engineering won the tender of the Italian National Metrological Institute (INRIM) to deliver a new unit, and has answered to two other international calls for tenders.

References

V. Giordano, S. Grop, B. Dubois, P.-Y. Bourgeois, Y. Kersalé, E. Rubiola, G. Haye, V. Dolgovskiy, N. Bucalovicy, G. Di Domenico, S. Schilt, J. Chauvin, and D. Valat, Review of Scientific Instruments, 83, 085113 (2012).
www.doi.org/10.1063/1.4747456

C. Fluhr, S. Grop, B. Dubois, Y. Kersalé, E. Rubiola, and V. Giordano, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, 63 (6), 915 (2016).
www.doi.org/10.1109/TUFFC.2016.2550078

V. Giordano, S. Grop, C. Fluhr, B. Dubois, Y. Kersalé, and E. Rubiola, Journal of Physics: Conference Series 723, 012030 (2016).
www.doi.org/10.1088/1742-6596/723/1/012029

C. Fluhr, B. Dubois, S. Grop, J. Paris, G. Le Tetû, and V. Giordano, Cryogenics 80, 164 (2016).
www.doi.org/10.1063/5.0007131

http://www.uliss-st.com/

http://www.femto-engineering.fr/en/time-frequency-recognized-expertise

facility: OSCILLATOR IMP

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CLIMA DESIGN OF MECHANICAL CONNECTIONS WITH HIGH VIBRATION-DAMPING PROPERTIES

APPLIED MECHANICS

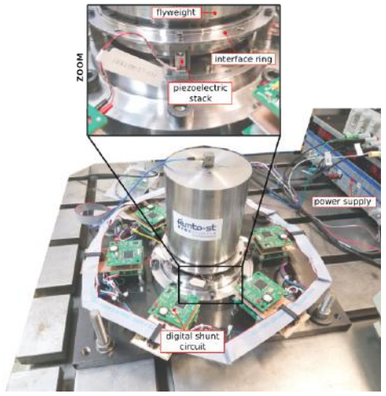
The year 2019 marked the end of the CLIMA project, involving AIRBUS, Cedrat Technologies, ADR, Texense, SOPEMEA, SDTools, AVNIR, QUARTZ, and FEMTO-ST laboratories. This very ambitious project aimed to propose new technological solutions for the design and construction of mechanical connections with high vibration-damping properties. This project had started in 2015, was supported by AIRBUS and financed by the "Single Inter-Ministerial Fund". The astech, minalogic, microtechniques and nuclear valley competitiveness clusters have approved the project as a priority project for industrial research.

The CLIMA project had three scientific ambitions:

- The first objective was to develop new passive technologies for vibration damping in assemblies. To achieve this, the functional surfaces have been geometrically designed and work has been undertaken on the materials in contact to ensure a good service life and achieve the best possible performance.

- The second objective was to embed sensors and actuators, as well as their control electronics in structural assemblies. Texense and FEMTO-ST have developed an original sensor implanted in a screw head, which measures the clamping force instantly and thus ensures the health of the assembled structure is monitored. This solution has been patented. In addition, a solution to drive the structure in real time by means of piezoelectric actuators has been developed with Cedrat Technologies. It takes advantage of the fact that vibration energy passes through the links that are mandatory zones of transfer. Consequently, the electromechanical coupling obtained by this implantation is very high.

- The third objective of this project was to develop dedicated numerical simulation tools. For this purpose, in collaboration with SDTools, computation software based on the use of harmonic balance has been developed. To use this code effectively, new models of link behavior have been developed. In addition, the ANR ARIAN project, which ran simultaneously with the CLIMA project, provided an opportunity for external collaboration with the CLIMA projects, which also made it possible to improve the model reduction techniques finally used in CLIMA.



Finally, CLIMA strengthened the links between FEMTO-ST and industry, which made it possible to sign several industrial PhD fellowship CIFRE contracts financing Camille JEANNOT's thesis with ADR or Emmanuel BACHY's with Thales.

References

N. Peyret, G. Chevallier, and J.L. Dion, International Journal of Applied Mechanics 8 (08), 1650097 (2016). www.doi.org/10.1142/S1758825116500976

H. Bouaziz, N. Peyret, M.S. Abbes, G. Chevallier, and M. Haddar, International Journal of Applied Mechanics 8 (06), 1650081(2016). www.doi.org/10.1142/S1758825116500812

N. Peyret, M. Rosatello, G. Chevallier, and J.L. Dion, Mechanism and Machine Theory 117, 48 (2017). www.doi.org/10.1016/j.mechmachtheory.2017.06.019

M. Krifa, N. Bouhaddi, G. Chevallier, S. Cogan, and N. Kacem, European Journal of Mechanics-A/Solids 66, 296 (2017). www.doi.org/10.1016/j.euromechsol.2017.08.003

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FIRST COMMERCIAL CROSS POLARIZED STAND ALONE TWIN-PHOTON SOURCE.

OPTICS & AUREA TECHNOLOGY

Photon entanglement has appeared to play a crucial role in the foundation of quantum physics and also in the ever-increasing requirements of quantum information processing, quantum communication, quantum metrology and quantum computing. Thus, the industrial development and the characterization of practical entangled photon sources at telecom wavelength are key elements for the deployment of emerging quantum applications.

Following a knowledge transfer strategy based on subsidized research joint ventures between FEMTO-ST Institute, expert in quantum frequency entanglement, and Aurea Technology, expert in quantum photonics, a self-contained high-brightness Cross-Polarized Entangled Photon Pair Source at telecommunications wavelength, based on spontaneous parametric down conversion in a Periodically Poled Waveguide (allowing for Quasi Phase Matching), has been developed in the joint lab created in 2018. All optical and electronics elements are embedded in a very compact module. This practical and compact photon source is driven by a USB communication port compatible with a computer. The main characteristics of the photon source, Coincidence-to-Accidental-Ratio (CAR), brightness, bi-photon spectrum, heralded efficiency, purity, and indistinguishability are measured by using integrated optical benches and a 2-channel very-low-noise InGaAs Geiger-mode single photon counter (G-SPAD). The proposed photon source measurements protocol is also available for the characterization of other photon sources technologies, such as for the emerging Quantum Dots and semiconductor photon sources.

Finally, the source has been tested by performing two experimental Bell inequality violations by creating polarization entanglement or by using the natural frequency entanglement of our source. Violation by more than five standard deviations Bell inequalities with our setups demonstrates that our photon source is a promising tool for the realization of various distance quantum information experiments.

References

http://www.aureatechnology.com/fr/

Joint presentation of FEMTO-ST and AUREA Technology at Photonics West 2019: https://www.spie.org/exhibitor/details.aspx?expo=SPIE-Photonics-West-2019&name=AUREA-Technology&&SSO=1

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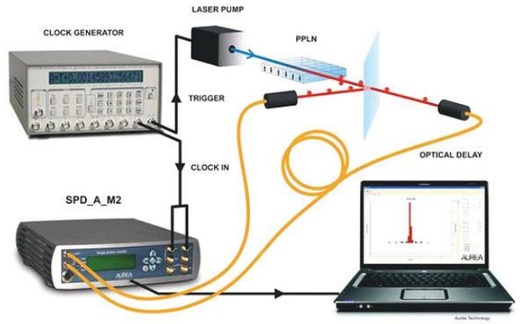

2019 PEPITE PRIZE FOR YOUNG CREATORS OF INNOVATIVE START-UPS

The PEPITE Prize was created by the French Ministry of Higher Education, Research and Innovation in 2014 to encourage entrepreneurship among young people in higher education and to strengthen support for the creation of innovative companies. In 2019, two young doctors from FEMTO-ST, Vladimir Gauthier and Romain Viala, received the PEPITE prize.

VLADIMIR GAUTHIER - CELL SELECT

ROBOTICS & AUTOMATION

The national prize has been awarded to Vladimir Gauthier for his start-up project Cell Select. Cell Select aims to develop innovative fluidic chips to perform highly selective cell sorting. The goal is to provide new tools for biologists in order to develop innovative medicines, based on the use of the patients immune cells. High selectivity cell sorting is achieved by combining two disciplines, micro-robotics and microfluidics. Lab on chip devices, based on microfluidics technologies, have proved to be a very efficient approach for cell sorting. Vladimir Gauthier implements control laws inspired from the micro-robotics field to improve the current devices, and to increase the selectivity of the cell sorters. A start-up will be created in 2020 to commercialize these cell sorters.

References

https://www.ubfc.fr/trier-des-globules-blancs-en-un-temps-record/

facility: MIMENTO

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ROMAIN VIALA - MICAD

APPLIED MECHANICS

The regional prize has been awarded to Romain Viala for his project MICAD. MICAD (Musical Instrument Computer Aided Design) is dedicated to the material used in musical instrument making. Nowadays, the woods used for instruments, called tonewoods, undergo numerous threats. MICAD aims at providing new materials, made with natural fibers, resins and balsa cores that imitate the vibroacoustic behaviour of tonewoods. These materials are less variables and less sensitive to moisture, which is a strong argument for their utilization by industry, which uses twenty times more tonewood than craftsmen. MICAD deals with a numerical method to obtain adequate composite recipes, non-destructive characterization, in consultation with to manufacturers.

References

R. Viala, V. Placet, and S. Cogan, Composites Part A: Applied Science and Manufacturing 106, 91 (2019). www.doi.org/10.1016/j.compositesa.2017.12.018

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ANANKE - SUCCESS IN PROGRESS

ENERGY

After nearly ten years of fundamental research to reach technological maturity, ANANKE was finally created in September 2017 in Belfort.

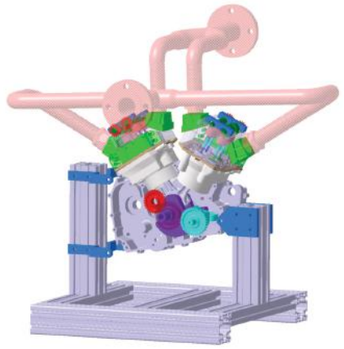
Specializing in the development of Externally Heated Valve Engines (EHVE), the company is still following its technological evolution and is close to implementing its first demonstrator.

Reducing their environmental footprint thanks to the conversion of waste heat is a key issue for both national and international manufacturers. This awareness enables ANANKE to stand as a strategic player in the energy transition. The technology developed by the company offers the opportunity for the most energy-intensive manufacturers to reduce their energy bills and boost their competitiveness while producing carbon-free energy. In addition, to providing heat and according to the customer's needs, the company has developed two cogeneration modules, one of which produces compressed air (ECOCOMPRESSEUR) and the other generates electricity (ECOGENERATEUR). The latter can be used on site or directly injected into the electricity grid.

Currently, four people are working full time on the project. A great deal of recruitment is in progress to strengthen the activity and market the solutions developed.

The success of the start-up, which hopes to achieve a turnover of more than €1M in the next two years, is also due to the support of regional organizations that have made a significant contribution to the technological development and the promotion of its innovations.

Many bodies have thus taken part in the construction and success of our project such as the county Bourgogne Franche-Comté, ADEME, Vallée de l'Energie, Bpifrance, Grand Belfort, ADNFC, Réseau Entreprendre but also FEMTO-ST, Aire Urbaine Investissement and the Université Bourgogne Franche-Comté.



References

http://www.ananke.company/fr/

Time lapse GEN3 :
https://www.youtube.com/watch?v=Ocs8sOcMQZY&t=1s

facilities: SPAC / FLUIDIX

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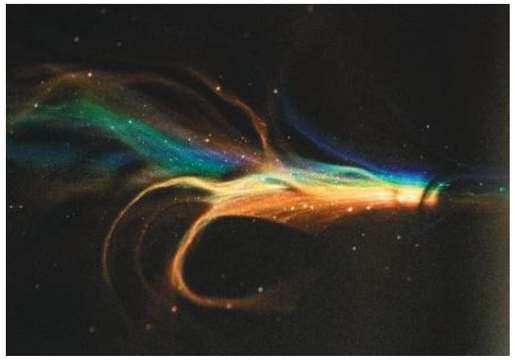
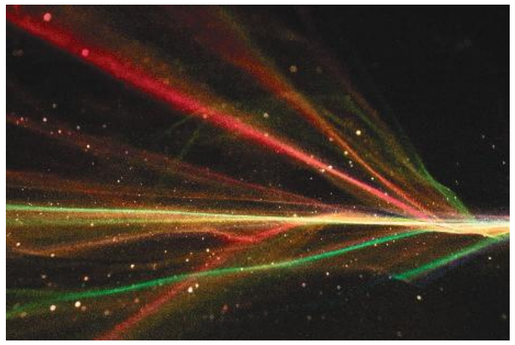
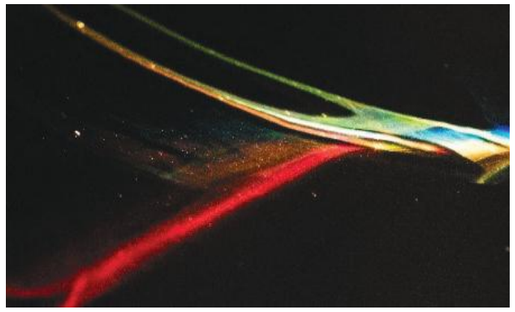
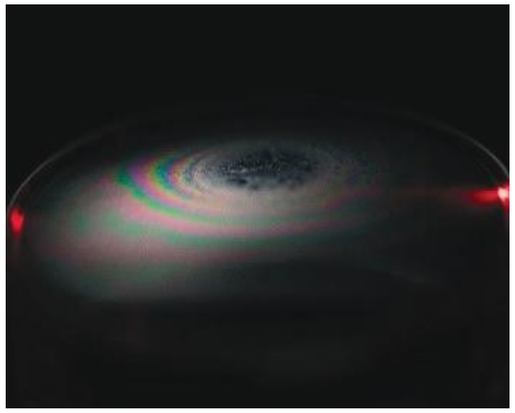
ANANKΣ

SOCIETY









CRAZY SOAP AND LASER FAIRY... WHEN ART MEETS SCIENCE...

OPTICS

Within the framework of an "Entrepreneurship" project of the Master PICS of the Graduate School EIPHI, and thanks to the presence in our institute of Sarah Ritter, photographer and artist in residency with us for more than a year, we have mobilized 7 students for 25 hours on the close link between "art and science". How do they live together? We relied on recent scientific results produced by several international teams (ref [1-3]): What happens when a laser is injected into a soap film a few hundred nanometres thick? The light remains confined within the thickness of the bubble and the tiny variations in the thickness of the bubble guide the laser along complex paths linked to the chaotic structure of the bubble. This guided path is also highly wavelength-dependent and we observe a separation of the different spectral components during propagation. This work, apart from an obvious artistic aspect, highlights certain aspects of the propagation of light in complex environments [4-5], as well as the complexity of chaotic dynamics. It is also a potential source for modelling the occurrence of an extreme event [2]. For our students, this was an opportunity to simultaneously put into practice: comprehension of physical phenomena, thinking about an experiment to be implemented, setting up of an adapted image shooting and restitutions of these by imagining scenarios. This has promoted forward their individual creativity and collective intelligence..., all this in a limited time.

References

[1] M. Mattheakis and G.P. Tsironis, Springer, Cham., Quodons in Mica, 425, (2015).

[2] A. Patsyk, M.A. Bandres, U. Sivan, and M. Segev, IEEE Conference on Lasers and Electro-Optics (CLEO), 1 (2019).

[3] A. Brandstötter, A. Girschik, P. Ambichl, and S. Rotter, Proceedings of the National Academy of Sciences 116 (27), 13260 (2019).

[4] S. Popoff, G. Lerosey, M. Fink, A.C. Boccara, and S. Gigan, Nature Communications, 1(1), 1 (2010).

[5] S.M. Popoff, G. Lerosey, R. Carminati, M. Fink, A.C. Boccara, and S. Gigan, Physical Review Letters, 104(10), 100601 (2010).

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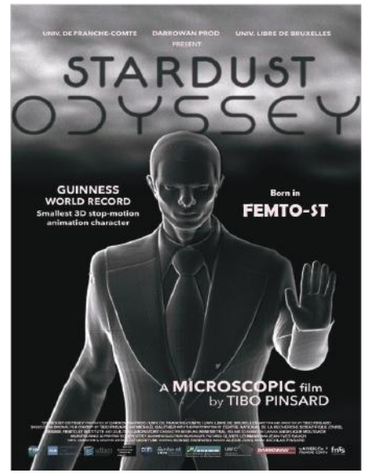
MICRO-NANOROBOTICS PAYS TRIBUTE TO DAVID BOWIE AND SETS A WORLD RECORD

ROBOTICS & AUTOMATION

Robotics and 3D printing pave the way of new methodologies for the future of industries, but can also be used for original artistic projects including technological challenges. Imagine a film studio smaller than the size of your finger, an actor whose height is smaller than the thickness of your fingernail, and a camera using electrons instead of photons: these are the filming conditions of the innovative film Stardust Odyssey carried out in FEMTO-ST.

The objective of this film project was to illustrate, in an original way, the capabilities of robotics & 3D printing on a microscale. The challenge was to realize a stop motion film with the smallest 3D figurines whose height is lower than 300µm. It requires the design and production of the microfigurines and also the ability to position them with a micrometric precision in front of an imager. The production of the microfigure with a 2-photons 3D printer has been carried out in the Université Libre de Bruxelles. At this scale, the best way to visualize a tridimensional object is the Scanning Electronic Microscope (SEM) operating in a vacuum chamber requiring metallization of the microfigurines. In order to position figurines in front of the detector, high precision miniaturized robots working in vacuum and developed in the FEMTO-ST Institute have been used. Each key technology has required ad-hoc developments to complete the film.

The film co-produced by the Université de Franche-Comté (UFC), the Université Libre de Bruxelles (ULB) and the film-maker Tibo Pinsard (Darrowan Prod), was released on November 27th, 2019, online on stardust-odyssey.com. The film paying tribute to David Bowie was also awarded by a Guiness Book record: the stop motion film with the smallest 3D figurines in the world.



References

stardust-odyssey.com

facility: µROBOTEX

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BUILDING INTERDISCIPLINARITY WITHIN THE SOC-TECH SEMINAR

Innovations are needed in order to face the technological, environmental, social and economic challenges of today's world. Some of them require interdisciplinary scientific cooperation. However, the research habits of scientific communities and stereotypes in other scientific fields are often detrimental to an interdisciplinarity approach.

The FEMTO-ST Institute has been an interdisciplinary research laboratory from the beginning. Collaborations between researchers in the engineering sciences and technology have been developed over a long time. However, the integration of human and social scientists within the Institute posed a new challenge: the interdisciplinary interaction between Engineering Sciences and Techniques (EST) and Human and Social Sciences (HSS). This integration was an opportunity to undertake a collective consideration of the conditions of interdisciplinarity between EST and HSS and more generally between all scientific fields of research.

Such an event was organized by the researchers belonging to the transversal research axis RECITS within FEMTO-ST through a scientific seminar called Soc-Tech (Society & Techniques) that they proposed in the year 2018-2019. It was financially supported by the CNRS in the framework of its national project « Quality of working Life ». Thought of as a collaborative experiment, the seminar was structured around 3 topics:

- The acceptability issue and the integration of social expectations in technological projects
- Feedback as regards interdisciplinary projects
- Epistemology and history of science, discussions on scientific practices in EST and in HSS.

Nurtured by those scientific discussions, participants produced a charter of good practices in interdisciplinary projects and a practical guide to help researchers involved in such projects.

Below is the charter which relates only to interdisciplinary projects. It supplements and does not substitute the principles that support any scientific project (such as intellectual honesty, scientific rigour…).

Moreover, it is worth noticing that interdisciplinary projects are developed in specific scientific disciplines (as far ! as interdisciplinarity may nurture disciplinary research) and they are not intended to replace disciplinary projects. Interdiscplinarity is not a goal as such but a means used to better answer a problematic situation. It has to be freely chosen by researchers and not imposed to them. It usually appears as a challenge (because it is harder, longer and it produces results that may be difficult to promote in scientific reviews). However it could lead to new scientific knowledge and innovations that could not be achieved through a purely disciplinary research, provided that some conditions are respected. The charter of good practices for interdisciplinary projects is an attempt to state those conditions. It is conceived as evolutionary and has to be enriched by further interdisciplinary cooperations over time.

Taking part in an interdisciplinary project implies:

1 – To be able to leave aside one's usual framework of analysis, to listen to other ways of thinking, to accept other methodologies, to be able to adopt another reference framework, and also to co-design the solution in order to avoid working in isolation.

2 – To accept that researchers' interests may be different in order to be able to look for the common interest and to keep discussing it throughout the duration of the project.

3 – To promote the balanced cooperation among scientific fields in order to avoid the domination of one.

4 – To be pedagogical by presenting one's ideas without technical jargon.

5 – To accept that all scientific fields do not need the same time to produce results when they are involved in an interdisciplinary project.

6 – To accept that interdisciplinary projects take more time than disciplinary ones due to the fact that they involve shared learning and require time to take a step back.

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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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