femto-st
SCIENCES &
TECHNOLOGIES

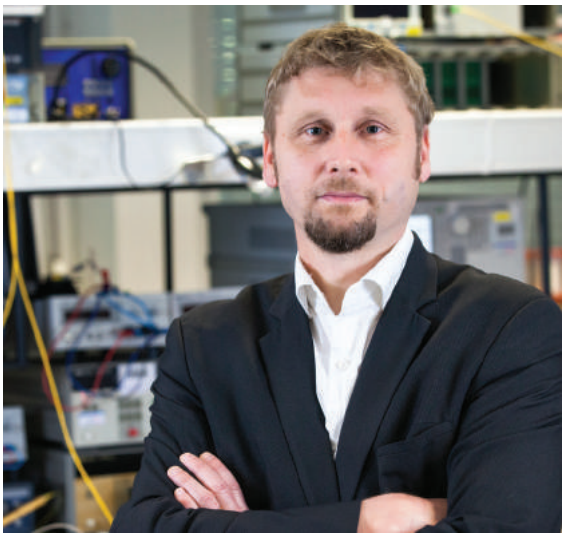
2015 ANNUAL REPORT

FEMTO-ST, a joint Research Institute from :

members of

Content

EDITORIAL



Cultivating innovation, from basic research to industrial partnership and spin-offs, developing micro and nano technologies, increasing the density of functions, integrating intelligence, for the engineering of components and systems with optimized performances.

With a staff of more than 750 people, the FEMTO-ST Institute is one of the largest Research Laboratory in France dedicated to Engineering Sciences and Information & Communication Technologies. FEMTO-ST is organized in seven scientific departments, covering Automatic Control, Acoustics & Phononics, Computer Science, Energy, Applied Mechanics, Micromechatronics, Microsystems & Nanotechnologies, Optics & Photonics, Time & Frequency Metrology.

A major event this year was the International Year of Light and Light-based Technologies (IYL) initiated by Prof. John Dudley, member of FEMTO-ST and Chairman of the IYL Steering Committee. IYL2015 was proclaimed in December 2013 by the UN General Assembly 68th Session. 2015 constituted a unique opportunity to hold events related to Light all over the world (about 5 000 events) including in our Region (100 events for more than 50 000 people). I would like to take this opportunity to thank all members of FEMTO-ST, permanent and non permanent staff, for their highly valuable involvement to make these events such a big success in Franche-Comté and beyond.

As expected from its broad area of expertise, FEMTO-ST takes part in many different scientific and technological projects, either leading or collaborating within several national and international projects. Through these collaborations, we develop fruitful partnerships with major Research Centers, but also with SMEs and large companies, as evidenced by the creation of the joint laboratory between FEMTO-ST and the SENSeOR company, called PhASES (Physical Acoustics, Sensors and Embedded Systems), or the three European Smart Specialisation Strategy (S3) projects initiated in 2015 and where FEMTO-ST is the academic partner.

This Annual Report can obviously not consist of an exhaustive report on FEMTO-ST's scientific, technological and transfer activities, awards and publications in 2015. Its objective is to give a brief overview to the reader through a few selected focuses, which emphasize a selection of achievements and highlights of the year. Some of them are aimed to illustrate the multi- and interdisciplinary actions which can be carried out at our Institute.

2015 was a very active year for the whole FEMTO-ST institute. All our achievements would not have been possible without the constant involvement, professionalism and creativity of the whole staff. All these persons must again be praised for their dedication.

FEMTO-ST is a joint research institute affiliated with the University of Franche-Comté (UFC), the National Center for Scientific Research (CNRS), the National Engineering Institute in Mechanics a Microtechnologies (ENSMM) and the University of Technology Belfort-Montbéliard (UTBM). Our efforts to always further improve our scientific excellence, as well as our efficiency in industrial partnerships and transfer, could not be possible without the support of this academic environment. Beyond Academia, I am also particularly grateful to the strong support brought by the French State, the European Union and the Region of Franche-Comté. Together with these funders and partners, we actively and permanently work towards a broader and better scientific, economic and societal impact of FEMTO-ST.

On behalf of the Management Committee of FEMTO-ST, I hope you will enjoy reading this report.

Nicolas Chaillet
Director of FEMTO-ST Institute
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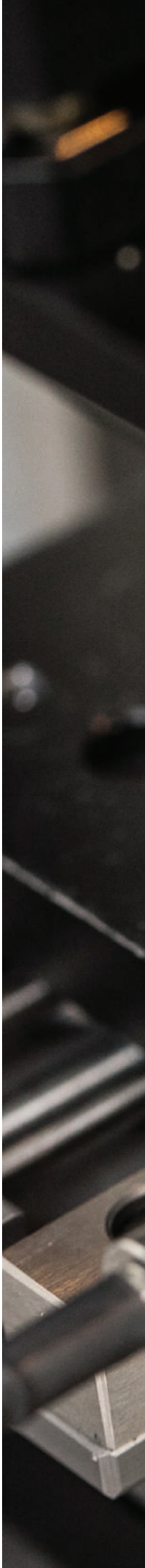
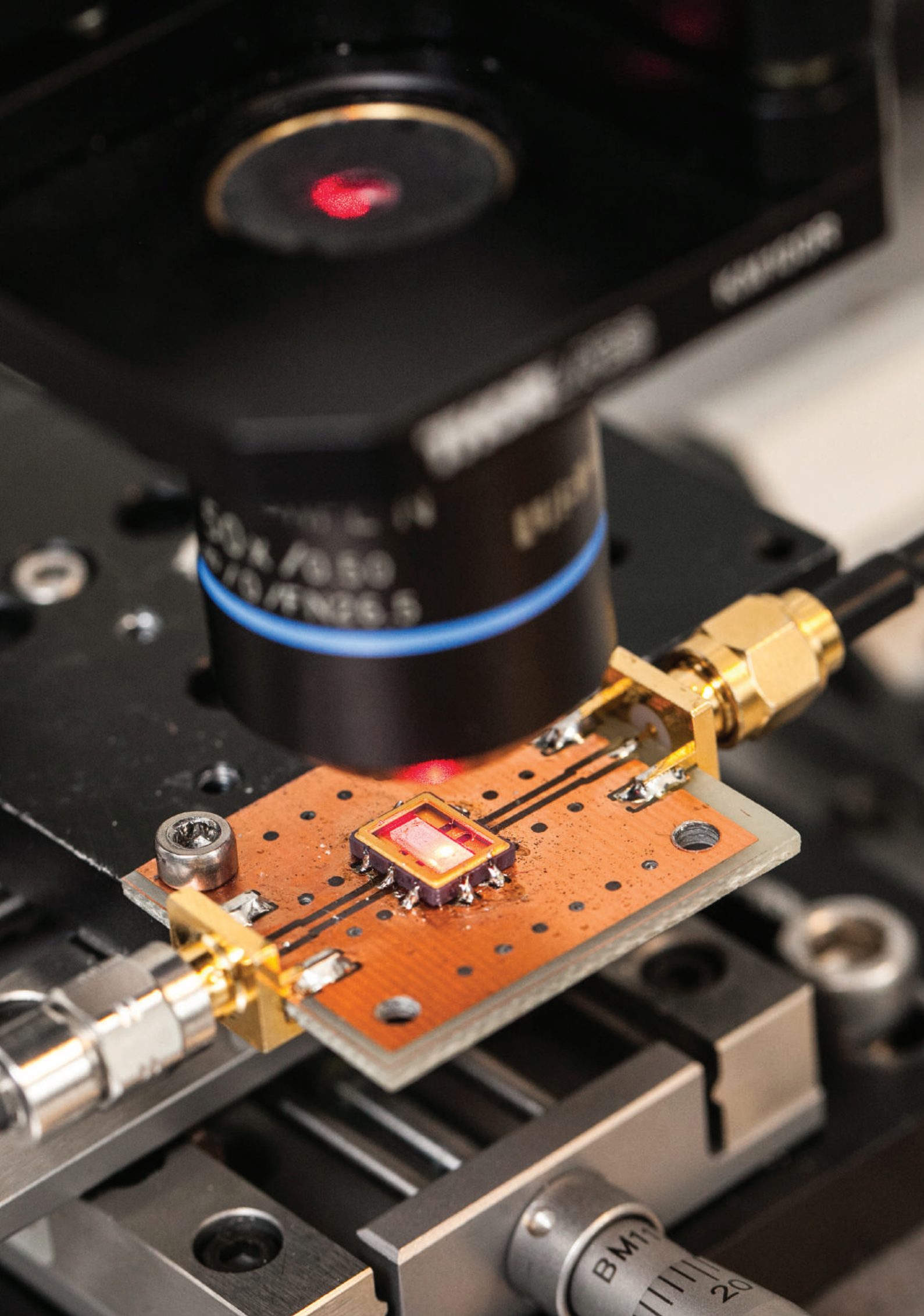




FEMTO-ST IN FIGURES...

The average staff of the institute in 2015 amounts to about 800 people. This comprises the permanent staff (professors, researchers, administrative and technical staff), as well as non-permanent staff (doctoral and post-doctoral students, administrative and technical staff, students, guests, visitors).

The distribution of staff at FEMTO-ST in 2015 was:

- Permanent Research staff: includes assistant, associate, and full professors (UFC, ENSMM, UTBM) and full time junior and senior researchers (CNRS)
- Contractual Researchers: PhD students, postdocs, invited professors
- Support for the Research: administrative and technical staff

The (non-consolidated) turnover of FEMTO-ST, excluding permanent staff salaries, consists of the annual allocation of its institutions (University of Franche-Comté, CNRS, ENSMM and UTBM), and its own resources obtained from research contracts with industrial and regional partners, and from national, European funding programs (FEDER, Interreg) and international programs (Ecole Polytechnique Fédérale de Lausanne, Collegium agreement SMYLE).

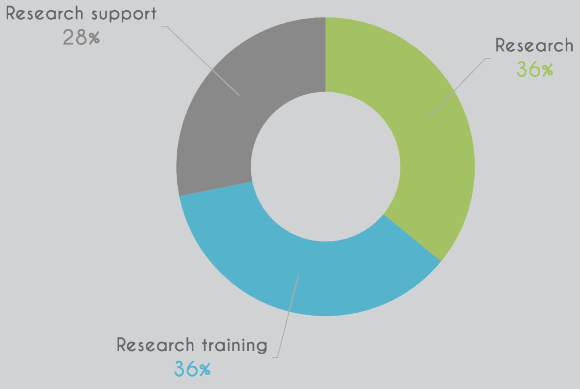
In 2015 the turnover of the institute representing a total budget of € 15.3 million can be broken down as follows:

- Annual funding from institutions (excluding calls for projects and doctoral contracts): 1.3 M€,
- Resources from contracts and research projects: 14 M€

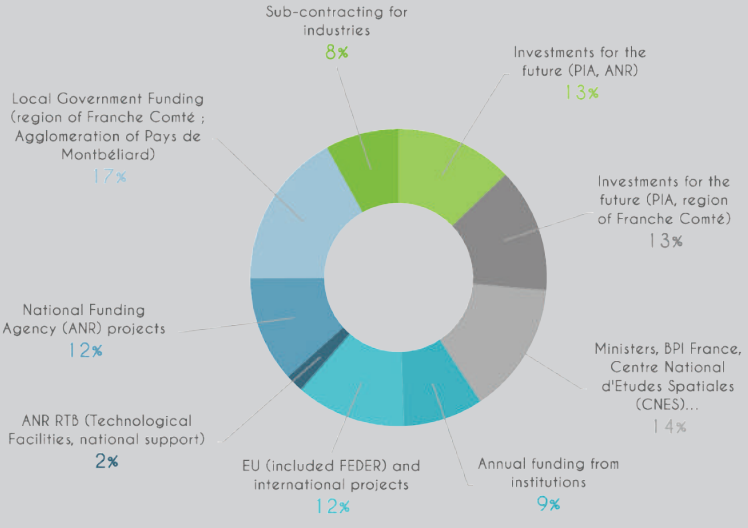
The detailed budget can be drawn up as follows:

- PhD fellowships (State funding)
- EU and international fundings
- ANR RTB: national funding for technological facilities
- ANR projects: national funding agency (excluding PIAs)
- Local government support, essentially from the Franche-Comté Region
- Direct contracts with private companies
- Institutional fundings (UFC, CNRS, ENSMM, UTBM)
- Other public resources (DGA, CNES, BPI France)
- PIA Region: Regional contribution to the projects of excellence PIA (e.g. Labex, Equipex)
- PIA ANR: national funding agency contribution to the PIA

STAFF @ FEMTO ST



FEMTO-ST BUDGET IN 2015



CONTACT

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CENTRAL SUPPORT SERVICES AND QUALITY ASSURANCE

FEMTO-ST is supported by several services to facilitate its various missions as an academic research institute in the field of engineering sciences. In a political ambition to improve its operational efficiency within all these missions, a Quality Certification initiative was launched in 2010, resulting today in an official AFAQ ISO 9001 certification for the activities of its operational services supporting the research activities in a broad sense.

The activities concerned by this certification are:

- Management
- Administration
- Micro- and Nano-fabrication platform, clean-room facilities
- Electronics and Instrumentation, design and prototyping services
- Mechanics, design and prototyping services
- Computer and Information Systems services
- Industry transfer and partnership
- Events, Advertisement, and Communication services

The main objective for the Quality Certification is to continuously improve the efficiency and the service quality provided by each of these essential support activities for the FEMTO-ST institute within its numerous missions, among which are top technical research results, efficient administrative and management environment, social and economical impact through interaction with industrial partners, and improved local national and international notoriety.

Together with the general administrative and technical support for all scientific departments in FEMTO-ST, specific technical support related to Mechanical Engineering expertise available for internal research and industrial service contracts is also certified by the Quality Assurance label ISO 9001. The expertise areas of concern cover Materials **&** Structures, Micro-analysis, Forming Processes, Vibrations **&** Acoustics, Scientific Computing as well as Engineering **&** Support Team.

At the beginning of 2015, AFNOR conducted a follow-up audit which confirmed the certification awarded two years earlier.

CONTACT

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Special focus on industry interactions through the Industry transfers and partnerships service

To reinforce its relations with the industrial world, the institute has a dedicated tool: Industry transfers and partnerships service (SRI).

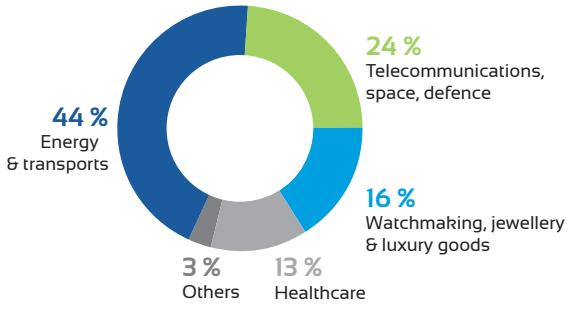
Joint laboratory
Over the past few years, the SRI was heavily involved in the creation of the joint laboratory PhASES ("Physical Acoustics, Sensors and Embedded Systems") with SENSeOR, whose inauguration took place on September 29th 2015 -see infra the specific section-.

The Village By CA in Franche-Comté,
towards the creation of an ecosystem of business and cooperative innovation with Crédit Agricole bank. On September 28, 2015, FEMTO Engineering and FEMTO-ST signed the letter of intent of the Village By CA together with local actors. The goal is to detect new ideas and develop talents that will provide tomorrow's business in our Region.

Business development
The SRI team participated in many different trade fairs and workshops to initiate new industrial partnerships, in France and in Switzerland (Micronarc Alpine Meeting, EPMT, MEDTEC, Rendez-Vous Carnot…).

Maturation projects
The SRI assisted researchers in setting up projects in collaboration with SATT Grand Est, UFC, Franche-Comté Regional Council and BPI. Examples of such actions with various scientific departments at FEMTO-ST are: Thin films (Optics, TF), Hybrid fuel cell system (Energy), Stirling engine (Energy), Microfluidics (MN2S), Biochips (MN2S), Tour solver optimization (AS2M), Micro fuel cell (MN2S)

Research contracts markets



CONTACT

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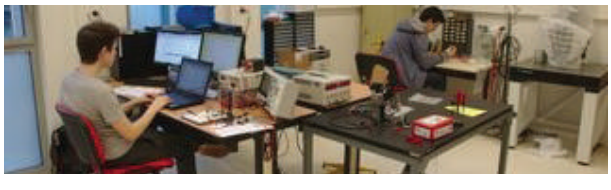
A rich higher education environment in engineering sciences

FEMTO-ST is involved through the teaching duties of its researchers, in various undergraduate curricula within areas of engineering sciences. This typically concerns, by alphabetical order, 4 sets of engineering science curricula or degrees: CMI (Cursus Master Ingénierie, Univ. of Franche-Comté in Besançon and Belfort), ENSMM (French engineering school in Besançon, delivering engineering degrees in mechanics and micro-mechatronics), ISIFC (engineering diploma from the Univ. of Franche-Comté, in Besançon), and UTBM (technology university of Belfort-Montbéliard delivering engineering degrees). Below are some typical examples illustrating the local education in engineering sciences, coupled to FEMTO-ST research.

CMI Cursus Master Ingénierie

Students in H3E, PICS and Scube CMI had the opportunity to be immersed in various research departments of FEMTO-ST (Energy, Optics, Mechanics, TF and MN2S) as part of several activities. A tour of the research facilities has been organized in the first year of undergraduate degree and it allowed the students to discover equipment, activities and experimental platforms available in the institute. Two rooms dedicated to student projects have been implemented in the Mechanics department and in the Temis building of FEMTO-ST. Scientific equipments dedicated to these project rooms were funded by Labex ACTION, IDEFI FIGURE and UFC: various projects at undergraduate level have taken advantage of these facilities: mechanical engineering and electronics in a drone, smart functionalities embedded in a tennis racket for vibrational comfort and performance analysis, activities around micro-CHP or fuel cells, optical design to build a telescope and laser vibrometer fabrication.

After one year of study, students of the Hydrogen-Energy, Energy Efficiency (H3E) CMI were offered a training period of 6 to 8 weeks in selected research laboratories in foreign countries. Those laboratories (namely in Italy, Germany, and for the first time Canada), are partners of FEMTO-ST in international projects.



ENSMM École Nationale Supérieure de Mécanique et des Microtechniques

A group of four students in engineering at ENSMM is one of the three winners of the CNES competition 2015 "Parabole" (see https://jeunes.cnes.fr/fr/web/CNES-Jeunes-fr/7991-projet-parabole-etudiants.php). This competition is dedicated to experiments in micro-gravity conditions taking place inside the Novespace A310-0G aircraft specialized in parabolic flights. The selected projects started in January 2016, and the final flight is planned in October 2016. Their project "µGravity: time in space" will consist in measuring the movement instabilities of French mechanical watches in micro-gravity in collaboration with TF department of FEMTO-ST. They are supported by various institutions of research and education as well as manufacturers of Franche-Comté.

ISIFC Institut supérieur d'ingénieurs de Franche-Comté

In 2015, a joint R&D project was realized with students from ISIFC (a biomedical engineering school from UFC). A new mechanical model was developed by finite elements to obtain better results to describe the vocal cords, and understand the impact of a tumor on their vibrational frequencies. The result allows a better behavior description compared to experimental data. This works was developed with the applied mechanics department of FEMTO-ST.

UTBM Université de technologie de Belfort-Montbéliard

The energy department of the FEMTO-ST Institute regularly hosts UTBM students. As part of a 3rd-year training period, a group of them developed an electronic module to complement the impedance spectroscopy equipment as part of a project to develop diagnostic methods for photovoltaic panels. This work will also complement the equipment for the characterization of fuel cells, electrochemical batteries and ultra-capacitors, in the FEMTO-ST Institute and FCLAB research federation.

On September 30, 2015, a presentation of the CIFRE – fellowship – PhD by Carole MIRANDA (ANRT) to students from ENSMM, ISIFC and master degree at UFC was organized by ENSMM, FEMTO-ST and the SPIM Doctoral School. Over 120 people (ENSMM and UFC students, FEMTO-ST researchers, CIFRE PhD Students and industrials) attended the event entitled 'Becoming a Doctor-Engineer - Information and Testimonials'.

CONTACT

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FLAGSHIP PROJECTS

Laboratory of Excellence (LabEx)

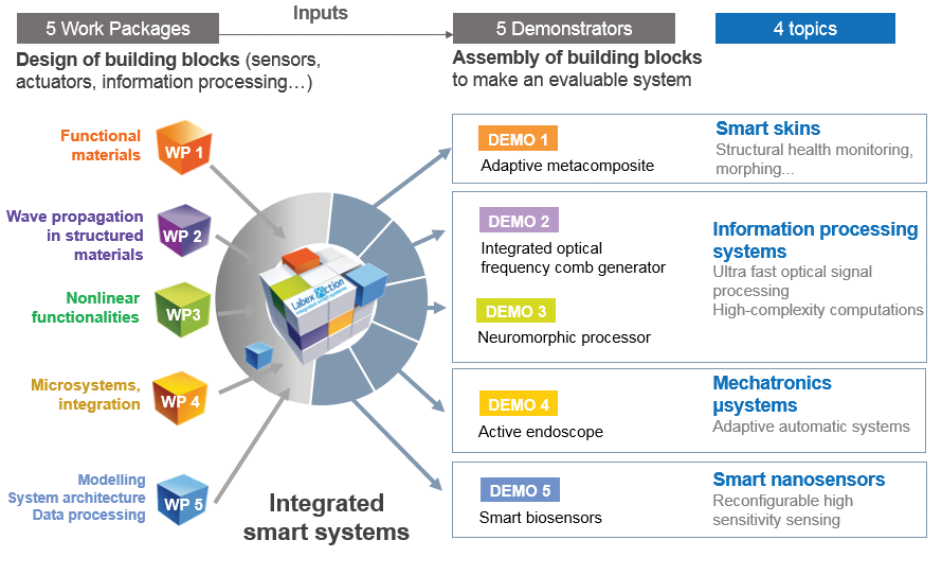
Labex Action
Integrated smart systems

ACTION

Towards smart matter
and highly integrated smart structures

Laboratory of Excellence ACTION - Smart systems embedded into matter

A long-term scientific program structured around 4 main topics and 5 demonstrator projects



Key figures

- Creation in 2012
- 3 research labs: FEMTO-ST, ICB (Dijon), LNIO (Troyes)
- 5 technological facilities: MIMENTO and Quartz-Tech (Besançon), ARCEN and PICASSO (Dijon), NANO'MAT (Troyes)
- Budget: 48 M€ over 8 years (ANR, Regional Councils of Franche-Comté and Bourgogne)
- Taskforce directly hired by ACTION since 2012: 19 PhDs and 22 post-docs

Key achievments in 2015

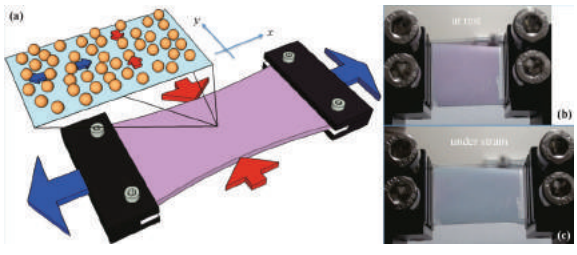
- 1,3M€ dedicated to research, valorization, education and dissemination projects
- 260 peer-review papers (2012-2015)
- 7 patents (insulation panels, plasmonic strain sensor…)
- Recruitment of 3 chairs of excellence adding to the two in progress:
  - J.-P. Aubry (FEMTO-ST and ENSMM), Materials for HQ resonators & applications
  - A. Coillet (LICB and Univ. Bourgogne), Nonlinear optics
  - J. Proust, LNIO and Univ. Techn. of Troyes), Plasmonic bio-sensors
- 8 merit scholarships laureates

femto-st SCIENCES & TECHNOLOGIES
ICB
utt Institut Charles Delaunay

One patent for a plasmonic strain sensor with a remarkable change of color (LNIO, SATT GE)

This innovative integrated sensor is intended for the health monitoring of structures.

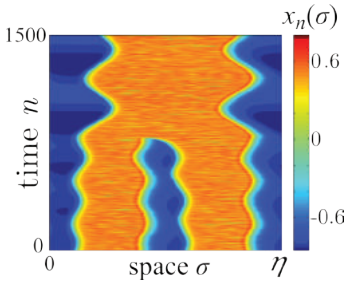
Coll. with ICB, University of Geneva, University of Calabria



BY STRETCHING THE TAPE, THE AVERAGE DISTANCE BETWEEN NPS BECOMES LARGER IN THE STRETCHING DIRECTION AND SHORTER IN THE PERPENDICULAR ONE AND IS ACCOMPANIED BY A CHANGE OF COLOUR FROM PURPLE-RED TO BLUE-VIOLET.

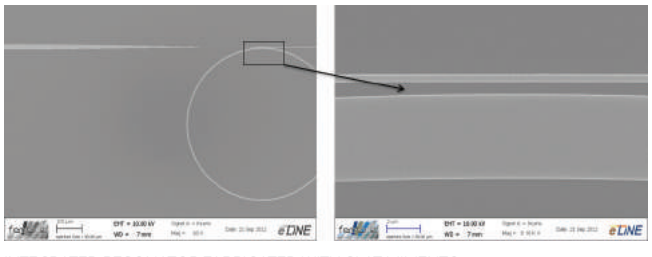
Two key peer-review papers in Nature Communications and Scientific Reports "Laser chimeras as a paradigm for multistable patterns in complex systems"

Coll. FEMTO-ST, Laboratory of Mathematics of Besançon.



A world record joint experiment in optical telecom transmission performed by a micro-resonator: 3x72 Gb/s 16-QAM error-free repeaterless optical transmission on 80 km. (Phys. Rev. Lett., 2015).

Coll. FEMTO-ST, Karlsruhe Institute of Technology



INTEGRATED RESONATOR FABRICATED WITH SI AT MIMENTO

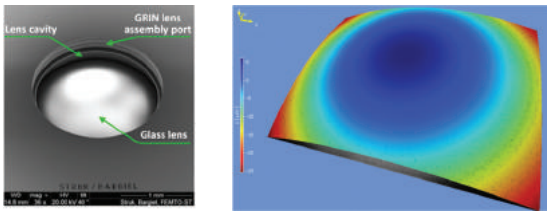
Design and fabrication of a working composite prototype which integrates a network of piezo-transducers for structural health monitoring.

Coll. FEMTO-ST, UTBM, Esperra SBARRO school

INTEGRATION OF A 50 PIEZOELECTRIC PATCHES IN A FIBRE-BASED COMPOSITE STRUCTURE

One paper in IEEE Sensors journal "Swept Source OCT endomicroscope Based on Vertically Integrated Mirau Micro Interferometer"
World record achieved by a micro mirror in terms of displacement (up to 4 mm)

Coll. FEMTO-ST, Univ. Florida



MIRAU PLANO-CONVEX LENS WITH A NEAR-PERFECT SURFACE CURVATURE

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Laboratory of Excellence (LabEx)

FIRST-TF

Facilities for Innovation, Research, Services and Training in Time and Frequency

FIRST-TF key figures

- Creation in 2011
- 5 research labs (core partners): LNE-SYRTE (Paris); FEMTO-ST, GéoAzur (Nice);
- LPL (Villetaneuse); UTINAM
- 54 associated labs, agencies and companies
- Budget: 6.5 M€ over 8 years

The first goal of FIRST-TF network is to show visibly the French coordination of the T/F research community, and to ensure the best overlaps and complementarities between the existing coordinations.

The second objective of FIRST-TF is to improve the capacity of T/F teams to propose collaborative research projects in the frame of large existing projects (for instance ACES/PHARAO, metrological fiber network utilization, ...) or for starting new projects, with high risks but also high potentiality.

The third objective of FIRST-TF aims at increasing the interactions between laboratories and industry, with the will to improve the transfer of technology and know-how.

The fourth objective of FIRST-TF is to build innovative education and training offers on T/F metrology, with envisaged thematic extensions to high precision measurements and their applications.

The last but not the least goal of FIRST-TF concerns outreach, and especially the popularizing operations towards schools and general public. Various aspects shall be explored: website dedicated to the popularization of T/F, public conferences, mobile exhibitions for schools, etc...

SILICON MEMS RESONATOR


CRYOGENIC SAPHIR OSCILLATEUR AT THE ESA DEEP SPACE ANTENNA IN MALARGÜE (AR)

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Equipment of Excellence (EquipEx)

Oscillator IMP

Oscillator Instability Measurement Platform

Oscillator IMP key figures

- 100% Besancon (5/6 FEMTO-ST, 1/6 Utinam)
- ANR 4.2 M€ (3.5 M€ phase 1, over 3.5 years)
- Region : 1.5 M€ in 2012-2013.
- 250 m² research building space at ENSMM.
- One ENSMM engineer (permanent, scheduled); Implementation will take 6 full-time engineers over 3 years, and the contribution of 20 researchers.

Gradually operational starting in 2014

- Five work packages: Microwave photonics, Microwaves and RF, General metrology, Time scale, Digital electronics.
- Kickoff May 31, 2013, at ENSMM, Besancon

Time, and equivalently frequency, is the most precisely measured physical quantity. Nonetheless, the demand for higher precision keeps growing, from fundamental science to everyday applications.

As a matter of fact, precision and accuracy depend on the amount of time measured, exactly as a molecule, an airplane or a planet cannot be "weighted" as precisely as a one-kilogram mass.

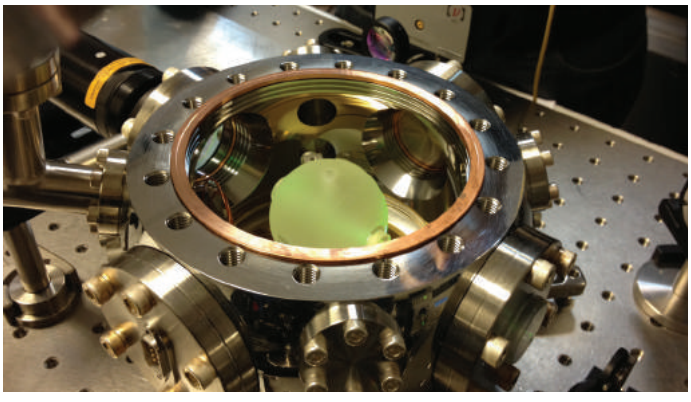
Scanning the technology, we notice that virtually all devices and systems rely on an oscillator stable for a suitably short measurement time τ. By contrast, the accuracy at long τ is provided by an external reference, and ultimately relies on primary atomic clocks. This pattern is found in radars, telecom, computer boards, particle accelerators, geodesy, space missions, GPS and navigation, photonic systems, internet timing, to mention a few. In these domains, frequency fluctuations and noise are more relevant than accuracy. The scope of "short τ" spans from µs to days, depending on the application.

Surprisingly, National Laboratories focus on absolute accuracy and on atomic clocks, and pay comparatively little attention to the world of "short τ" – oscillators, fluctuations and noise.

Even more surprisingly, one would recall the fact that the Galileo-Huygens pendulum enabled the precise measurement of short intervals (1 s to days) and opened the way to zillions of applications. By contrast, a small group of astronomers is sufficient for the task of adjusting the pendulums to the rotation of the Earth around the Sun.

The Oscillator-IMP project aims to be the world-leader facility dedicated to the measurement of noise and short-term stability of oscillators and related devices, including microwave photonics, widely available to Agencies, to research institutions and to private companies, in the spirit of global competition and economy.

This ambitious project benefits from the high profile of our Time and Frequency Department. Through the LNE-LTFB, we are already affiliated to the LNE (Laboratoire National de métrologie et d'Essais) and we already have the highest-level COFRAC accreditation for phase noise and frequency fluctuations. Still through the LNE-LTFB, we are one of the 8 laboratories listed by the BIPM (Bureau International des Poids et Mesures) for the measurement of frequency fluctuations. And the one and only laboratory listed by the BIPM for phase noise measurements.



A CORNUCOPIA OF PROJECTS IN PROGRESS OR ABOUT TO START:

A part of the PIA, or closely related to:

- Liquid-He etalon, target 3×10^{-17} laser stability (in progress);
- Spherical etalon, target 8×10^{-16} laser stability (operational);
- Small etalon, 1", target 2×10^{-15} laser stability (in progress);
- Two femtosecond lasers, accurate link between optical and µwave frequency (operational);
- Three liquid-He µwave sapphire oscillators, 3×10^{-16} stability (operational);
- Low-power liquid-He µwave sapphire oscillator (beta test);
- Three H masers, contributing to the int'l time UTC (operational);
- UTC(OP)B, a replica of the French official time scale UTC(OP) (beta test)
- Shielded chamber for EMC tests and pollution-free µwave/RF noise measurements (operational);
- Two-way microwave station for worldwide clock comparison at 100 ps accuracy (alpha test);
- Carrier-phase GPS for worldwide high-accuracy clock comparison (alpha test);
- CERN White Rabbit time/frequency distribution over optical-fiber Ethernet, 1 ns accuracy (in progress);
- Innovative digital instruments for the measurement of frequency stability and noise (in progress);
- Tree-cornered-hat statistics (in progress);
- Stability measurement of MEMS resonators (in progress);
- Distribution of the 100 MHz reference (H-maser) in all the lab rooms of the dept (in progress)
- Stable environment (PI temperature and humidity control) in a few lab rooms (alpha or beta test)

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Equipment of Excellence (EquipEx)

REFIMEVE+

Metrological Fiber Network with a European Vocation +

REFIMEVE+ key figures:

- **Created in 2012**
- **Partners in France: 18 Public labs, CNES, RENATER (NREN), IDIL (private company), Extensions under study, Link to other European Countries, Transfer of absolute time**
- **Budget: 6.7 M€ over 8 years**

REFIMEVE+ (REseau FIbré MEtrologique à Vocation Européenne+) is based on the technology developed by LPL and SYRTE for the ultra-stable frequency transfer over long-haul fibers on a public network. It was

experimentally demonstrated on a test section from Villetaneuse (close to Paris) to Reims that the clock signal can be transmitted, throughout the Internet academic network RENATER over 540km, with a «reproducing» accuracy of $2x10^{-19}$ after one day measurement time. This performance relies on the precision measurement of the roundtrip time, which enables the compensation of the delay introduced by the fiber, and of course of its fluctuations.

This result paves the way to clock comparison on a continental scale using clocks whose accuracy is of parts in 10^{-16}, and targets the 10^{-17} in a near future. REFIMEVE+ has the potential to replace the GPS as the standard method for clock comparison, pushing precision and accuracy to the level required by modern optical clocks.

The project aims at broadcasting the standard optical frequency to 21 French labs, and gradually extend to other European Countries. The broadcasting of absolute time is also under study.

While the highest-level of precise and accurate frequency comes from SYRTE, FEMTO-ST will have the second largest set of oscillators and atomic frequency standard in France. This is thanks to the Oscillator IMP Equipex, and also for physical experiments that require accurate and stable frequency at both ends of the fiber. The large set of oscillators and standards makes FEMTO-ST a privileged collaborator of SYRTE and LPL for testing the system, and also for physical experiments that require accurate and stable frequency at two ends of the fiber. While Oscillator IMP is specialized in the measurement of small fluctuations and noise, REFIMEVE+ aims to provide the highest absolute accuracy.

EXTENSIONS UNDER STUDY
LINK TO OTHER EUROPEAN COUNTRIES
TRANSFER OF ABSOLUTE TIME

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Equipment of Excellence (EquipEx)

µROBOTEX

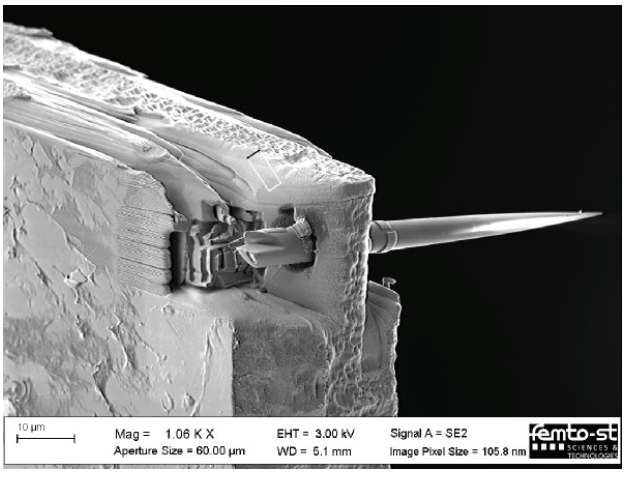
Exploring the nanoworld and building nanorobots able to interact with nano-objects are major challenges of today's research and require high performance equipment.

The µROBOTEX platform is a facility dedicated to the development of micro/nanorobotics and micro-assembly projects on objects whose dimensions are below 10µm. Access to the facility is open to academic and industrial partners for their research and/or development projects. µROBOTEX was funded by the EQUIPEX ROBOTEX (N° ANR-10-EQPX-44-01) of the PIA (Programme d'Investissements d'Avenir) and the Region of Franche-Comté. Equipment: 760,000 € (excl. tax), operation: 97,000 € (excl. tax) and Staff: 105,000 € (excl. tax).

µROBOTEX consists of a Scanning Electron Microscope (SEM), a Focusing Ion Beam (FIB) and a Gas Injection System (GIS). The SEM has a large chamber (500mm diameter x 300mm height) able to host a 6-degree-of-freedom microrobot, a laser interferometer and various tools for handling and characterization of micro/ nano-samples.

Located at ENSMM, in the AS2M department of FEMTO-ST institute, µROBOTEX has been operational since early 2014 and the first SEM imaging and FIB experiments have been successfully performed. In 2015, the platform allowed to demonstrate the first complex 3D assembly of an optical fiber through silicon substrates (see figure), and it also enabled an original characterization of mechanical disturbances generated by the environment and the microscope inside the vacuum chamber (Editor's pick in Review of Scientific Instruments, 2015)

The aim of µROBOTEX is to provide researchers in micro/ nanotechnologies with competitive instruments at an international level. Combining knowledge on microsystems, physical and chemical phenomena at the nanoscale and control theory, this facility represents a unique environment for automated micro/nano-assembly and position/force feedback manipulation and characterization of samples. One of the main goals of µROBOTEX is to improve robustness at the nanoscale through joint use of SEM-based visual servoing and control feedback with embedded force/ position sensors.



FIRST COMPLEX 3D ASSEMBLY OF AN OPTICAL FIBER THROUGH SILICON SUBSTRATE

Reference

M. Gaudenzi de Faria, Y. Haddab, Y. Le Gorrec, P. Lutz. Influence of mechanical noise inside a scanning electron microscope. Review of Scientific Instruments, 86, 045105 (2015).

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FUI Projects

MIM Netshape

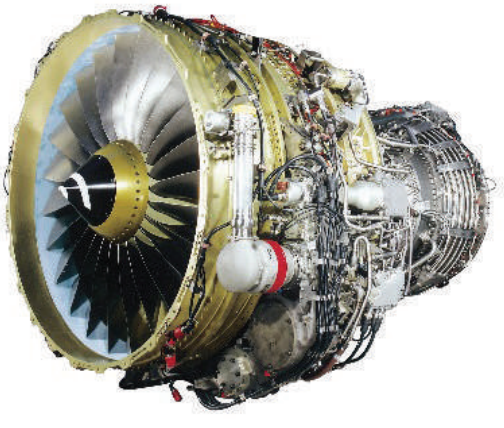
This project focuses on the development of Metal Injection Molding (MIM) Process applied with super alloy powders for airplane engines. The Polymer and highly loaded polymer team managed by Pr. J.-C Gelin at FEMTO-ST Institute/Applied Mechanics Dpt, is in charge of the elaboration of different MIM feedstocks for functional materials. Some new formulations with bio-sourced and biodegradable polymers have been investigated. The miscibility of different polymer binders has been investigated in order to obtain homogeneous mixture between these ingredients and metallic powders. The physical interaction between powders and binder ingredients has been studied. This includes the mechanical and thermo-physical characterization of the polymers, the powders and feedstock.

Some innovative and eco-friendly debinding processes to eliminate binder have been used and compared with standard thermal and solvent processes. New rheological models dedicated to highly loaded polymers have been proposed and identified by experiments. A sintering process has been studied in order to obtain very high density and isotropic shrinkage. Injected, debinding and sintering components have been analyzed by different methods in order to obtain parts without defects. The MIM process has been developed for airplane applications in order to obtain functional components strictly respecting mechanical properties and chemical contents.

This project is hosted by SNECMA and Alliance companies and Research & Technology Center, Safran Tech. MIM Netshape is funded through the CORAC DGA project (2011 – 2015).

Reference

D. Claudel, M. Sahli, T. Barriere, J.-C. Gelin. Material characterisation to identify the rheological behaviour for powder injection moulding. International Journal of Materials Research,106, 943 (2015).



AERONAUTIC ENGINES ARE FOR EXAMPLE INVOLVING SEVERAL MIM COMPONENTS

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CLIMA

"Conception de Llaisons Mécaniques Amortissantes" ("Mechanical connections design for vibration damping improvement")

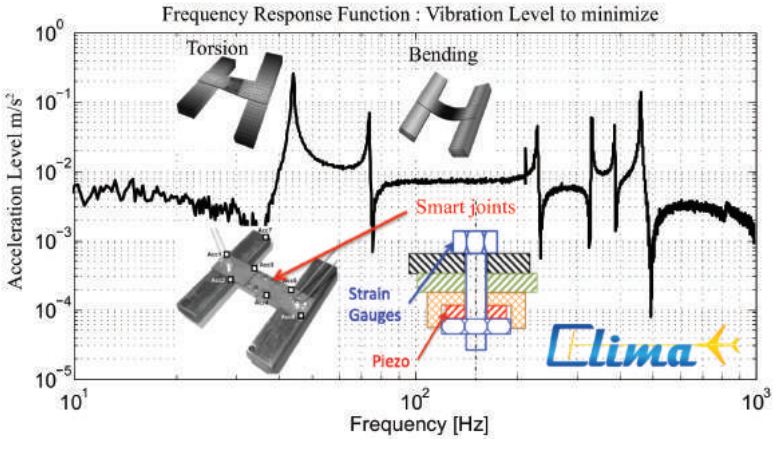
CLIMA is a collaborative research project that brings together a large company (AIRBUS), SME's (ADR, TEXYS, CEDRAT, SOPEMEA, ADERIS, SDTools, AVNIR) and research laboratories (QUARTZ and FEMTO-ST). Our project aims to design smart joints for improving the vibration damping of mechanical structures, mainly for aeronautic applications. CLIMA is a national project involving four competitiveness clusters: Astech, Microtechnics, Nuclear Bourgogne and Minalogic. CLIMA started in October 2015 and will end in October 2019. It is a continuation of the ANR project ARIAN with the perspective of technological achievements and of a higher Technology Readiness Level. The Applied Mechanics Dpt is involved in all work packages and is participating to CLIMA Demos.

The first work package focuses on the design of passive joints. Usually, these joints are designed to provide the highest strength to mechanical loadings. However, CLIMA aims to design joints that have been designed for vibration reduction. To achieve this goal, new materials and coatings are developed as well as original and optimized topologies.

The second work package led by FEMTO-ST, is focusing on smart connections that embed micro sensors and actuators. Thanks to our experience in the diagnosis of damage in composites, several techniques including acoustic emission are evaluated to detect bolt loosening or joint failure during the use of the structures. An innovative sensor based on strain gauges and micro electronic components has already been designed to be embedded in bolt heads for failure detection. Moreover, we try to add new functionalities to the joint that will allow to control stiffness and damping in real time in order to adapt them to the excitation loadings. Temperature and loadings are evaluated as stimuli for the stiffness and the damping control. The temperature will be used in polymer joints, whereas piezo-electric actuators are integrated inside the joints, thus allowing for variation of the tightening loads. Control and adaptation strategies are also targeted by CLIMA and will be addressed before the end of the project.

The third work package aims to develop a software dedicated to the design of joints including geometry and physics. As the problem is non linear and involves several scales, original computation techniques have been developed. The software will be able to simulate the physical behavior of the joints embedded in large scale structures such as aircraft parts. It is a Finite Element software based on elastodynamics including contact and friction at the micro-scale as well as meta-models coming from macro-scale experiments. Harmonic Balance Method is used to get steady state vibrations.

The fourth work package aims to provide training for engineers and students responsible to design assembled structures. All CLIMA results and methods will be integrated in a training platform available online for researchers and engineers.



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RIS 3
Regional Initiative for Smart Specialization Strategy

µD2

The Applied Mechanics Dpt of FEMTO-ST is involved in one of the three projects selected under the first call for projects RIS3 - Research **&** Innovation Strategies for Smart Specialization in Franche-Comté region.

Among regional specialties the microtechnology and luxury markets axis has been selected and this project is clearly in this field.

In addition to FEMTO-ST, four regional SMEs in the area of machining are involved in this project.

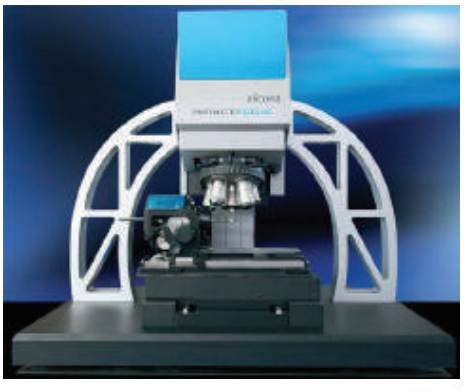
This project aims to increase knowledge in the field of bar-turning in order to improve the competitiveness of the industrial partners in the market of microcomponents. This project will aim to develop and share expertise through the cooperation between the industrial sector and academic partner, the former having the market knowledge in simulation, machining and advanced characterization, and the latter bringing an already recognized knowledge in the field of micro-machining.

For the FEMTO-ST institute this project is strategic because it is linked to the development of technology platforms at the European level and beyond, particularly the MIFHySTO platform (Microfabrication for miniaturization, functionalization and Hybridization Microtechnology and tooling systems) initiated in 2013 and located at ENSMM.

A cutting machine Star SB 12- Type G has been purchased thanks to the support of this platform by the regional Government. This equipment will be the main support for the experimental study on the machining processes.

The laboratory will also contribute to the experimental aspect through its equipment for process characterization and surface scanning of manufactured parts such as ultra-high precision 3D metrology.

For the FEMTO-ST Institute, this project is part of its cooperation policy with regional companies in the field of microtechnology and more particularly with SMEs also concerned by, and involved in the MIFHySTO platform.



HIGH PRECISION MICROSCOPE ALICONA AND A MEASURED RESULT

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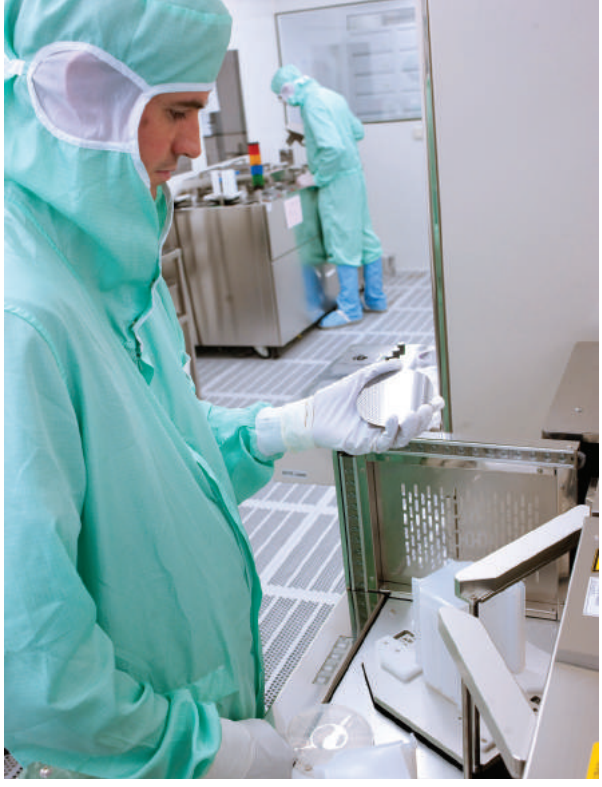

3S-MEMS

The 3S MEMS project is supported by the European Union under the FEDER program through the Smart Specialisation Strategy (S3) in Franche-Comté 2014-2020.

3S MEMS aims at implementing a fabrication chain for silicon MEMS (micro-electro-mechanical systems) oriented toward innovative sensors. With a budget of approximately €9 Million, the project involves four regional partners: companies SilMach (Project Coordinator), Percipio Robotics, Frec|n|sys, and the Technology Facility MIMENTO of the FEMTO-ST Institute via the University of Franche-Comté. The budget for the FEMTO-ST partner is around €4.6 Million, including a support of €3.4 Million (75%) from the European Union.

The 3S MEMS project will operate under a "fabless" model with the 3 industrial partners having no manufacturing facilities, these 3 partners thus obtaining access to the technologies of our cleanroom. Actual chip manufacturing will be supported by the MIMENTO technological facility, playing the role of a microsystem "foundry". Furthermore, training programs will be organized to encourage and help our students and young researchers to stay in our region and to work in the field of MEMS, thus contributing to the attractiveness and the development of the local production of microtechnological products.

The project was launched in June 2015 for a total duration of 54 months. It involves the entire clean room staff and will allow us to hire engineers dedicated to the project. 3S MEMS will contribute to the upgrading of equipment and infrastructure of the MIMENTO clean room, but also to staff training.

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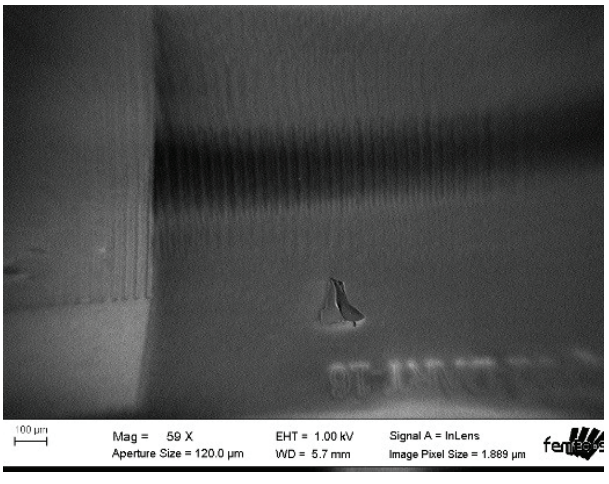
Smart-Inn

Passive components operating at frequencies covering the VHF band (30-300 MHz) and UHF (300 MHz - 3 GHz) are the key elements in the development of systems for professional and consumer mobile and embedded sensing resolution (radar applications). The dimensional specifications and constraints impose the use of acoustic wave components. In this context, local industrial companies combined their expertise and shared their development tools to innovate in the field of acousto-electric radio frequency components. Supported by the FEMTO-ST Institute and the Crystal Innov-platform (Rhône-Alpes), they develop the SMART-INN research project.

The current limits of RF passive components are diverse. They are partly due to the incomplete knowledge of certain material properties or technological limitations. To be able to offer a complete range, covering most of the current applications and preparing future markets, we must make progress on all these fields in synergy.



SCANNING ELECTRON MICROSCOPE IMAGE OF A SURFACE ACOUSTIC WAVE AT 113 MHZ GENERATED USING A BROADBAND FILTER OF «FAN SHAPE» TYPE.

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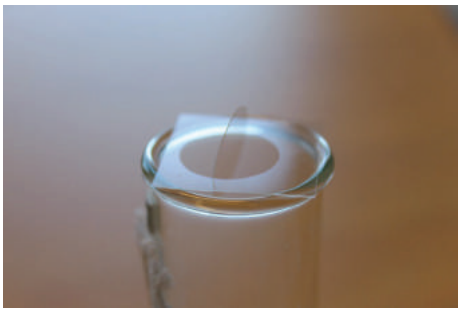
FEMTO Engineering, a growing activity

2015 confirmed FEMTO Engineering's ambition to generate economic activity, to keep in Franche-Comté PhD and engineers of excellence and to create expertise based on breakthrough technologies from FEMTO-ST research.

First of all, the staff was consolidated and the FEMTO Engineering team is now composed of 10 staff members, mainly doctors and engineers.

Secondly, FEMTO Engineering contributed to the development of proprietary technologies and signed contracts both with local companies and large international groups.



HIGH SPEED GLASS CUTTING 10MM/S < V <1M/S

1. Development of technologies from the laboratory

- **Optics: Femtosecond Laser Micromachining**

FEMTO Engineering further developed the technology of femtosecond laser machining by using Bessel beams.

- An aspect ratio over 2000 was obtained by nanomachining Lithium Niobate and achieving a hole with a diameter of 200nm and 500µm deep.

- High speed glass cutting at speeds of the order 100mm/s (also Quartz or Lithium Tantalate).

It has applications in glass industry, security, aeronautical, biomedical, telecommunication...

A second axis of development has been initiated at the end of the year: surface texturing using Bessel or Gaussian beams.

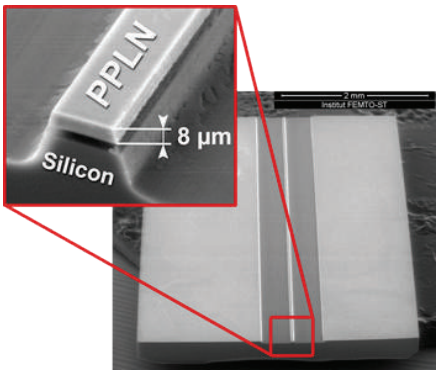
METAL AND DIELECTRIC SURFACE STRUCTURATION

- **RACE3 project with FEMTO-ST and Labex ACTION:**

In the framework of the RACE3 collaborative project supported by the «Labex ACTION» and the Région de Franche-Comté, FEMTO Engineering continued developing specific clean room technologies in order to transfer them to industry.

Several technological advances in the fabrication of periodically poled ferroelectric substrates, structures with high aspect ratio and single-crystal thin films have given rise to innovative devices for telecommunication, space or energy applications.

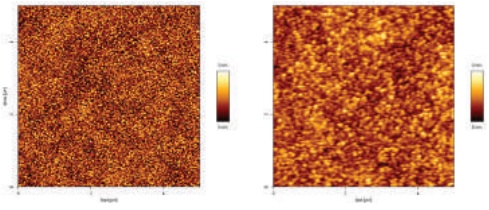
FEMTO Engineering was associated to FEMTO-ST in the April 2015 issue of OPTICS LETTERS for the project relative to the development of $LiNbO_3$ layers.



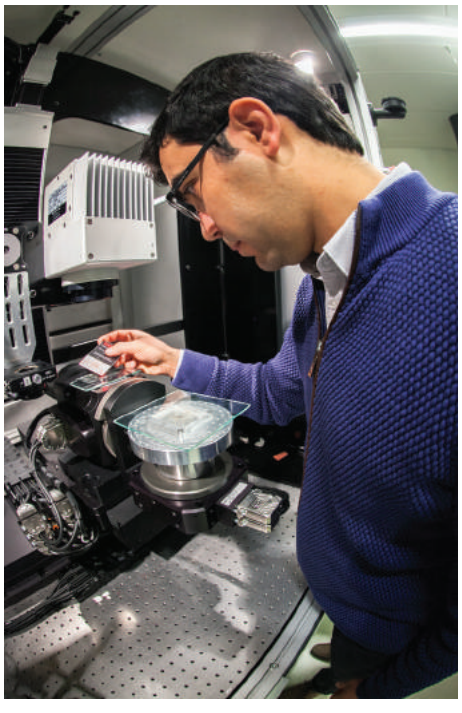
PERIODICALLY POLED LITHIUM NIOBATE RIDGE FOR PHOTONIC APPLICATIONS

- **Biomedical activities:**

The aim of this work is to propose a new gold/SiOx biochip dedicated to biosensor applications using Surface Plasmon Resonance (SPR) detection. In this study we demonstrate that thin layers of amorphous silicon oxide (SiOx) grown by inductively-coupled plasma enhanced chemical vapor deposition (ICPECVD) technology at lower temperatures can be successfully combined with biosensors.



CONTACT MODE AFM IMAGES OF
(A) GOLD SURFACE,
(B) GOLD/SIOX SURFACE



In particular, gold-amorphous silica (Au/SiOx) interfaces were investigated for their potential applications as SPR biochip. The work on gold/SiOx chips led to a communication:

E. Herth, R. Zeggari, J-Y. Rauch, F. Remy-Martin, W. Boireau, Interconnect Technology Conference and 2015 IEEE Materials for Advanced Metallization Conference (IITC/MAM), 2015 IEEE International. Grenoble 18-21 May 2015.

- **Time & Frequency, ultra-stable oscillators:**

This led to one paper in Applied Optics (March 2015): «Ultra-low phase noise all-optical microwave generation setup based on commercial devices», and one in IEEE Transactions on Microwave Theory and Techniques (April 2015) : «Tests of Sapphire Crystals Produced with Different Growth Processes for Ultra-stable Microwave Oscillators».

- **Energy:**

- Management of electrical energy for embedded and stationary systems (Hybrid **&** Fuel Cell Systems Research Team)

The energy transition leads to the implementation of multi-source systems to provide electrical energy in hybrid vehicles (auxiliary power unit) or in stand-alone power supplies. Energy management optimizes the use and the sizing of each system component according to their performances.

FEMTO Engineering took part into CETIP and GEOSEFA projects which led to several papers and communications.

- Energy, FCTECH

The SATT Grand Est subcontracted the maturation of FCTECH project to FEMTO Engineering. It is a maturation project of research conducted over the past several years by FEMTO-ST and the CNRS research federation FCLAB on Fuel Cell Systems. The goal of this project is to develop innovative solutions for electrical energy generation and management within multi-source systems, including fuel cells.

2. High-level specific developments for industry

- **Energy:** electromagnetism and thermal modeling for railway industry
- **Microfabrication in MIMENTO clean room facilities:** On demand projects using coating, etching, lithography, characterization, with application in watch manufacturing industry for example
- **Biomedical:** Design and manufacturing of chips for SPR
- **Optics:** feasibility study of laser cutting for biomedical applications, watch manufacturing industry…

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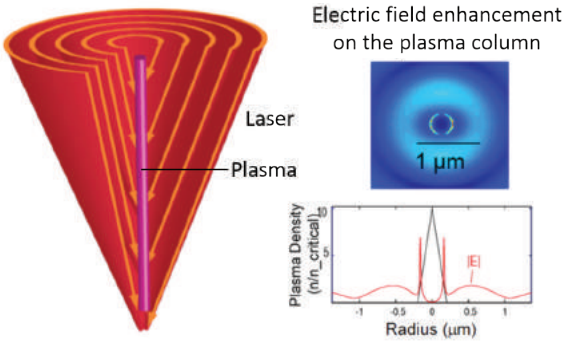
PULSAR: A new ERC Consolidator grant at FEMTO-ST

Femtosecond laser machining is now a key processing technology. The recent tremendous increase in commercially available femtosecond laser energy at high repetition rate opens a wealth of novel perspectives for mass production.

Being able to control the propagation of femtosecond laser pulses as they propagate inside a material enables control of the energy deposition mechanism. In this regard, we have made several advances in the field by using specific beam shapes (Bessel beams, accelerating beams) that were chosen because they do not distort while creating a free-electron plasma. This enabled us to create ultra-high aspect ratio channels in single shot, to realize curved laser processing or to generate tubular explosions in single shot within transparent materials.

However, even with high laser energies, the plasma created by the laser pulse becomes reflective within the first tens of femtoseconds and creates a shield that blocks further light propagation inside the target volume. It is therefore impossible to reach extreme degrees of material excitation and ablate high volumes with a single pulse. Laser processing remains usually limited to high-speed scanning point by point removal of ultra-thin nanometric layers from the material surface.

PULSAR ERC project aims at breaking this barrier. We will develop radically different concepts based on controlling the laser-plasma interaction at nanoscale: plasma generation, confinement, excitation and stability will be the key physical phenomena under study. Both experimental and modeling research programs will enable us to push the frontiers of laser materials processing in terms of precision, speed and predictability.



References

M. K. Bhuyan, F. Courvoisier, P. A. Lacourt, M. Jacquot, R. Salut, L. Furfaro. High aspect ratio nanochannel machining using single shot femtosecond Bessel beams. Applied Physics Letters, 97, 081102 (2010).

A. Mathis F. Courvoisier, L. Froehly, L. Furfaro, M. Jacquot, P. A. Lacourt. Micromachining along a curve: Femtosecond laser micromachining of curved profiles in diamond and silicon using accelerating beams. Applied Physics Letters 101, 071110 (2012).

C. Xie, V. Jukna, C. Milian, R. Giust, I. Ouadghiri-Idrissi, T. Itina. Tubular filamentation for laser material processing. Scientific Reports 5, 8914 (2015).

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HORIZON 2020

A Chair of Excellence @ ENSMM & with Labex ACTION

Professor Jean-Pierre Aubry

Optimization of high Q WGM optical resonator for single/multiple wavelengths sources

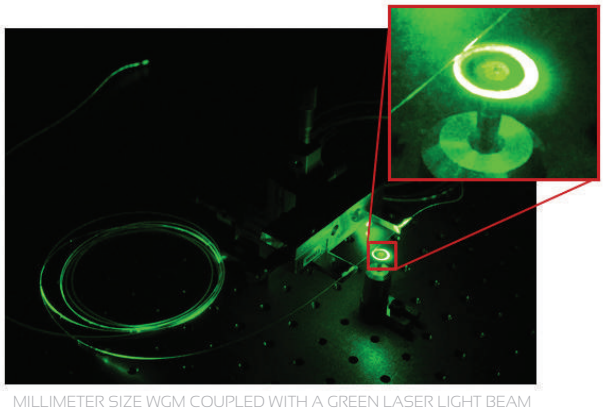
Opto-Electronic Oscillators (OEO) are being intensively studied, based on fiber or on disc resonators of millimeter or micrometer size, in order to offer low noise signal sources operating in the GHz range. Many materials have been tested, from silica to crystalline materials. Today's best performance is offered by CaF_2 discs operating at an optical wavelength of 1.5 µm. Attempts are being made toward manufacturing minimum size transportable devices. Such research activities are driven towards multiple-wavelength sources, for high data rate / narrow bandwidth communications. The generic concern is related to global navigation satellite system (GNSS)-free time transfer. The goal is to provide an accurate, traceable, and secure time dissemination towards critical infrastructure. Targeted domains are, among others, the Internet of Things (IoT), legal time stamping , smart grids, GNSS-free operational drone localization, etc.

A technological bottleneck is the optimization of the quality factor (Q) of disc resonators. Three directions are to be covered within the project:

i. Material choice, focusing on identification of Q-limit originated by raw material;

ii. Process development, focusing on the definition of an optimum geometry providing the best "optical energy trapping" at the disc periphery and optimum surface state;

iii. Device design, i.e how to associate an optimized disc resonator with a proper OEO loop.



MILLIMETER SIZE WGM COUPLED WITH A GREEN LASER LIGHT BEAM THROUGH A TAPERED FIBER

The output of these activities are expected to be the definition of a low noise GHz source that can enter an industry transfer process, including specification of materials and processes for disc resonator fabrication, definition of the interrogation electronics, and configuration of a multi-wavelength single source.

Jean-Pierre Aubry got his engineering degree in 1975. He obtained a PhD degree on Rare earth doped fluoride crystals in 1978. He spent most of his career in Industry. He joined as Technical manager the CEPE Dpt at Thomson CSF T&F subsidiary in 1979, and in 1996 he moved as technical manager to Oscilloquartz, a Neuchâtel-based Swiss company providing Time-Frequency and synchronization devices to the telecom market. He was CEO of the company from 1998 to 2012. He then created his own registered consulting company, "AubryConseil", focusing on industry-laboratory cooperation, providing his expertise to industries looking for the right support and laboratory cooperations in order to define mid term and long term strategies, and looking for the right industrialization path. General concern is in GNSS-free time dissemination, offering legal and traceable time reference to demanding networks, including cyber-security and accuracy.

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CONTACT

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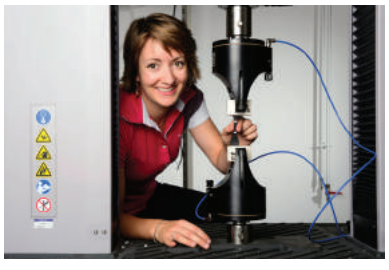
A L'Oréal-Unesco award for Pauline Butaud

"Pour les femmes et la science"



The L'Oréal-UNESCO For Women in Science Rising Talents 2015 Awards were presented to 20 promising young women, in order to support and encourage them to pursue their scientific careers. They were selected among 821 candidates by a jury chaired by Bernard Meunier (President of the French Academy of Science) and composed of members of the Académie des Sciences.

Women in Science encourages the vocations of girls in high school, supports women in research, and recognizes excellence in fields where women are underrepresented. Hence the objective is to reward not only the scientific excellence of the innovative research of the fellows, but also their ability to pass on their passion for science to future generations. They are invited in several high schools to promote science.

Pauline Butaud received her award for a project entitled "Shape memory polymers are invited in vehicles". Her project aims at developing tools for designing adaptive eco-composites for structural damping: using the outstanding damping properties of a biocompatible shape memory polymer, the mechanical properties of a multilayer honeycomb-based architecture can be tuned by temperature control. The temperature distribution to be driven is inhomogeneous and combines high static rigidity with high damping in specific frequency bands or structural zones. Using composite skins made of natural fibers guarantees a sufficiently low thermal diffusion in order to achieve the desired architecturing.

CONTACT

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FOR WOMEN IN SCIENCE
L'OREAL FONDATION

International Year of Light

The International Year of Light and Light-based Technologies 2015 (IYL 2015) was an official international observance declared by the United Nations with the goal of raising awareness of how the science and applications of light (photonics) impacts the citizens of the world.

IYL2015 has been amongst the most successful of any of the United Nations international years, with over 5,000 officially recognized activities, including scientific conferences, art projects and exhibitions, active learning workshops, festivals and many more. Activities were carried out in 148 countries and more than 15,000 media mentions worldwide (print and online media, newspapers, TV, radio) yield an estimated impact of the year on many hundreds of millions of people.

FEMTO-ST has been at the heart of the IYL2015 since its inception in 2009, as it was J. Dudley who chaired the international organization of the year working with the UNESCO Science Sector in Paris. FEMTO-ST also acted as a node of the IYL2015 Secretariat hosting an employee of the European Physical Society to coordinate international actions throughout 2015. Moreover, FEMTO-ST and the Labex ACTION were official IYL2015 Sponsors, and students from FEMTO-ST acted as volunteer helpers for the IYL2015 Opening Ceremony at UNESCO Paris in January 2015. Senior members of the direction of FEMTO-ST were invited participants at both the Opening & Closing Ceremonies of the year, and members of FEMTO-ST (J. Dudley and Y. Chembo) were invited to speak at many international IYL2015 activities in Europe, the United States, Asia and Africa.

On the local level, M. Jacquot from FEMTO-ST coordinated a regional IYL2015 project called LUX! Supported by the Region of Franche-Comté, the town of Besançon, and many other partners, a budget of 400k€ allowed LUX! to carry out over 100 actions, reaching more than 50000 people in Franche-Comté. Of particular note was a weekend of public outreach over 8-11 October 2015 that attracted 13000 members of the public, and an exhibit of holograms created at FEMTO-ST that ran for several months and that attracted 4000 visitors.

United Nations Educational, Scientific and Cultural Organization

In support of International Year of Light 2015

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http://www.light2015.org/

Student Chapter @ FEMTO-ST

The Student Chapter Association of FEMTO-ST consists of three parts working together: the OSA, SPIE and IEEE chapters. The purpose of the FEMTO-ST Student Chapter as a student organization is to increase members' professional and scientific performances in the different fields of science and technology. The chapter gives opportunities to students to improve their knowledge and communication skills, and increase their network through several educational and social events such as non-permanent seminars, workshops and scientific quizzes. It also encourages communications amongst members from the different departments of FEMTO-ST, and participates in the social life of the institute. We promote the discipline of Physics within the institute, university and local society. The association enhances the visibility of the students to the academic and industrial world. The Student Chapter is also aiming at popularizing science to a general audience during local or regional public events.
This year, the FEMTO-ST Student Chapter has especially organized a scientific quiz during the SMYLE Workshop in Arc-et-Senans, in cooperation with the EPFL Student Chapter. It has also participated in popular events such as the Time Fest ("Les 24h du Temps") as well as the LUX! project related to the International Year of Light. In addition to these events, the Chapter is organizing doctorate seminars on a regular basis, in order to train the PhD students for oral presentation. In cooperation with Dijon, the chapter also co-organizes every year a "Photonics Day" which is an opportunity to meet PhD students from the ICB laboratory. At the end of the year, the association has launched a new activity of scientific workshop in order to complement the doctorate seminars. The first workshop was about android development and was held in November.

CONTACT

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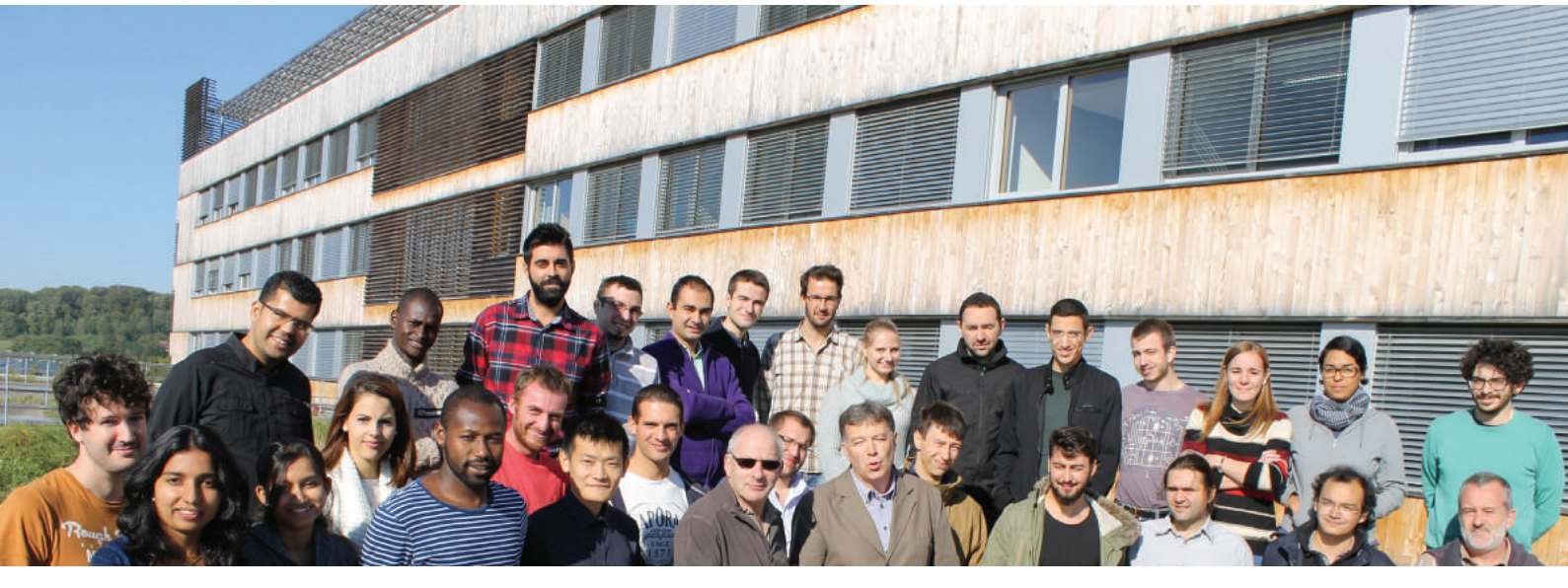
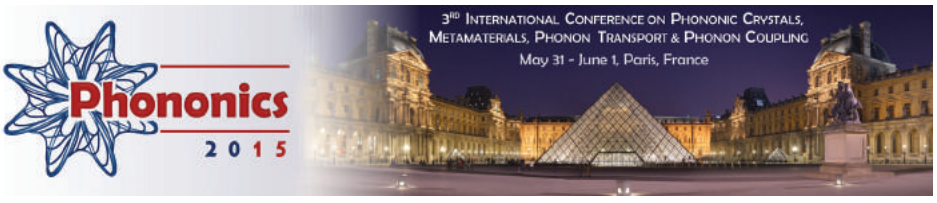


Phononics 2015



3rd International Conference on Phononic Crystals/Metamaterials, Phonon Transport and Phonon Coupling
Paris, May 31, 2015 – June 5, 2015

Phononics is a biannual international conference dedicated to phononic crystals, phononic metamaterials, phonon transport and phonon coupling. It is the primary event of the emerging field of phononics.
Phononics 2015 was the third edition of the conference. It was held in the center of the Latin quarter of Paris, in the beautiful Campus des Cordeliers. The conference was organized jointly by three of the foremost French research units active in the field of phononics: the Paris Institute for Nanosciences (INSP), the Institute of Electronics, Micro- and Nanoelectronics (IEMN), and FEMTO-ST. Researchers and students from these laboratories formed the local organizing committee.
The 5-day technical program was attended by more than 300 participants from all over the world. Prestigious awards of the International Phononics Society (IPS) were given during the week: the Brillouin Medal, the bloch award, and the Young Investigator Award. The technical program also included student paper competitions for the best oral and poster presentations.

CONTACT

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http://phononics2015.org

Awarded Spin-off: AUREA Technology@CLEO US 2015

In 2014, knowledge transfer strategy issued from the joint venture between FEMTO-ST Institute and Aurea Technology has allowed the company to win the "Honorable Mention" for the 2014 Innovation Award from CLEO/Laser Focus World for a self-contained high-brightness Entangled Photon Pair Source operating at telecommunications wavelength.

Beyond this first cooperation developed in the framework of a research project (PROJECT SAPHIR), AUREA and FEMTO-ST continued to interact on emerging applications such as single particles spectroscopy, biosensors and medical imaging. Supported by the innovative mindset of FEMTO-ST, in 2015, AUREA launched a new product-PICOXEA TCSPC Analyzer based on the integration of the world's most advanced Geiger-mode avalanche photodiode (SPAD) for ultra sensitive detection, a picosecond pulsed laser source for excitation and a Time to Digital Converter (TDC) for lifetime measurements. This new stand-alone solution is devoted to single photon level fluorescence spectroscopy and has numerous applications in microscopy, thin films and material (semiconductor, quantum dots…) characterization (industrial applications), but also in medically oriented research such as early cancer detection or theranostic.

The company exhibited this device at the famous international Conference on Lasers and Electro-Optics (CLEO) 2015, which took place on 10-15 May in San Jose, California, USA, and received the CLEO/Laser Focus World Innovation Award that recognizes outstanding companies having made major contributions to advancing the field of optics and photonics through recently launched products and services. This successful collaboration is an exemplary interaction about how applied research activities can lead to the development of innovative high-tech commercial products.

"LIVE DEMONSTRATOR" AT LASER WORLD OF PHOTONICS 2015: MEASUREMENT OF THE FLUORESCENCE LIFETIME OF PBS COLLOIDAL QUANTUM DOTS, WITH PICOXEA, THE AWARD WINNER.

http://www.cleoconference.org/home/reserve-exhibit-space/cleo-laser-focus-world-innovation-award.
http://opli.net/opli_magazine/eo/2015/aurea-technology-will-show-quantum-dots-lifetime-measurement-at-laser-world-of-photonics-2015-june-news/,
http://www.novuslight.com/laser-world-of-photonics-2015-aurea-quantum-dot-lifetime-measurement_N4255.html.

CONTACT

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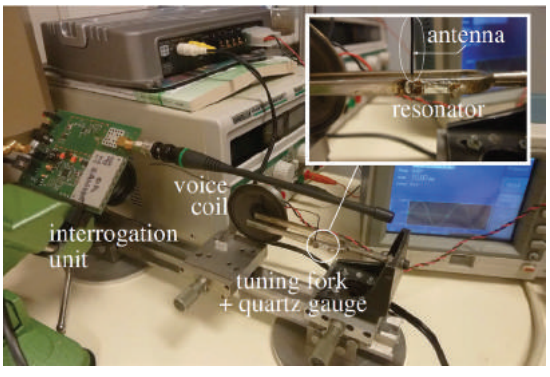
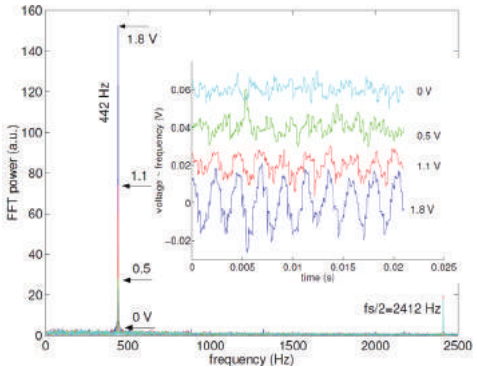
Birth of PhASE, a joint public-private laboratory

The inauguration of the joint laboratory PhASE - Physical Acoustics, Sensors and Embedded Systems - embodies the collaboration between FEMTO-ST and the company SENSeOR since its creation in 2006. The joint laboratory aims at defining convergent upstream research and development plans involving researchers at FEMTO-ST and the SENSeOR team: the main areas of interest deal with: (i) Innovative transducers architectures; (ii) Integration of these transducers in a way which is compatible with both a measure through a radio frequency link and a high-temperature operating condition (≥400 °C); (iii) The electronic measurement system; And (iv) the use of software methods for the processing of radiofrequency signals (Software Defined Radio). The expertise in metrology of the Time-Frequency Dpt provides original developments of wireless remotely interrogatable passive sensor systems. The implications .cover various disciplinary departments of FEMTO-ST, with the study of stress sensors (Applied Mechanics Dpt), characterization of the containment of elastic waves in the devices (MN2S and AS2M Dpts) or the prospects of using phononic crystals in sensor applications (MN2S Dpt).

Aspects of digital processing of radio frequency signals - the switchover from analogue to digital in the search for flexibility, reconfigurability and stable computing platforms - are consistent with the objectives of the Labex FIRST-TF in which measurement benches (phase noise, frequency counters, characterization of oscillator stabilities) exclusively based on digital processing of signals sampled at a radio frequency bandwidth (> 100 MS/s) are in development. The objective of the joint laboratory is to bring together all the skills necessary for a system approach to measure remotely interrogatable wireless passive sensors. This includes sensing elements, their encapsulation and implementation in hostile environment, the electronic measurement circuitry and the signal processing features allowing for the extraction of physical quantity of backscattered signals by RADAR cooperative target. Technology popularization and promotion to the general public is not overlooked.



SETUP FOR REMOTE MEASUREMENT FROM A SURFACE ACOUSTIC WAVE RESONATOR ACTING AS STRAIN GAUGE.



FOURIER TRANSFORM OF THE SIGNAL MEASURED THROUGH A RADAR READER (WIRELESS LINK, REFRESH RATE > 4KS/S.

Reference

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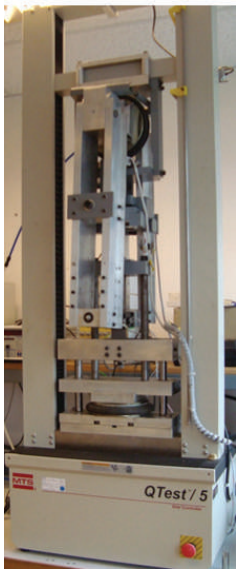
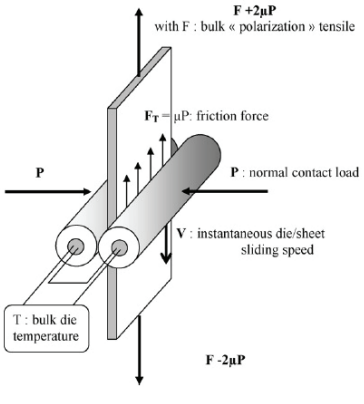
FOCUS ON SPIN-OFFS

AFULudine

A more environmentally friendly and easy clean lubrication of metals in industrial scale, in operations such as stamping, rolling, cutting...



OVERVIEW OF THE STRIP DRAWING TRIBOMETER



SYNOPSIS OF THE STRIP DRAWING TRIBOMETER

The stamping world (utensils, automobile, heat exchanger,...) is in need of a lubricant solution as a substitute for current oils containing chlorinated additives. Against this background AFULudine (Aperam-Femto-Utinam-Lubrification) is the result of a synergy between 3 complementary research entities.

The AFULudine solution is based on the creation of a Self Assembled Monolayer on the surface based on the development of specific organic molecules. For example, the determination of the limiting drawing ratio (LDR) is shown in figure below. This index allows to measure the ability of a grade/lubricant to support high "Deep Drawing" deformations. The higher is the LDR, the better is the formability and the lubrication condition. In real situations of industrial uses, the LDR value is equal to 2.24, but may be extended to 2.35 under well-controlled laboratory conditions, so there is still ample room for improvement!

Initial tests have been performed to validate the performance of the solution in an industrial context, and the results were good stampability, validation in an industrial environment and simplification of the process.

Historically, the tripartite collaboration started in 2013. Then, AFULudine became an incubated company in 2015 supported by the University of Franche-Comté and was awarded the first prize in both I-Lab and French-Tech competitions in 2015. The company will be created next September (2016).

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CONTACT

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MaHyTec

MAHYTEC is a company based in Dole, in the French Jura and created in 2008. It is specialized in the design and manufacturing of hydrogen storage systems.
MAHYTEC proposes compressed hydrogen storage systems, made of a polymer liner reinforced with composite materials, which are able to resist high pressure, but also solid state hydrogen storage systems. This technology relies on absorption of the hydrogen in a material, called hydride, allowing to store hydrogen at low pressure.

The competition Innovation 2030 calls for challenges from innovative companies all over the world. The jury, chaired by Anne LAUVERGEON, has selected 110 laureates from more than 1200 projects.
The project RHYMOVE presented by the MAHYTEC company is one of only 14 projects selected in the field of energy storage. It proposes an alternative solution benefiting from both technologies while minimizing the disadvantages.
The end goal of hydrogen vehicules is to maintain the current performances, i.e. rapid filling and a range of around 500km. Today, very high pressure storage (350 or 700 bars) can only guarantee fast filling and a similar range. However, we are well aware of the constraints related to this technology both in terms of cost and social acceptance.

The goal of the innovative, hybrid technology solution being rolled out by MAHYTEC is to overcome these difficulties and to boost storage compaction leading to a better integration into vehicles and mobile devices.

A grant of approximately €200,000 will ensure the development of this project and allows MAHYTEC to propose soon a prototype of the first hybrid hydrogen storage system.

D. PERREUX, P. ROBINET WERE INVITED IN 2014 FOR INNOVATION CHALLENGE RESULTS; THIS INNOVATION MIXES HIGH PRESSURE AND SOLID STORAGE TECHNOLOGIES

http://www.entreprises.gouv.fr/innovation-2030/rhymove-english?language=en-gb

http://www.mahytec.com/en/mahytec-laureate-of-worldwide-innovation-challenge

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MAHYTEC
Innovative Energy Solutions

SUCCESS STORIES DISCIPLINARY RESEARCH

Using shape memory polymers for the control of structural damping

Embedding smart materials in structures can open the way to the design of systems exhibiting new functionalities. Pauline Butaud's PhD was focused on the use of shape memory polymers to control structural vibrations. These materials exhibit a memory hysteresis which is practically associated with very high intrinsic damping properties when the memory effect is strong. The polymer of interest (tBA/PEGDMA) is elaborated at FEMTO-ST and is biocompatible.

The research work has started with a deep investigation of the thermomechanical properties of the shape memory polymer of interest using dynamic mechanical analysis. A rheological model based on time-temperature superposition has then been used to represent the viscoelastic behavior of the polymer on a wide frequency and temperature range.

Following this, an experimental campaign has been performed through various experimental techniques (static, modal, nano-indentation, ultrasounds, high frequency dynamic analysis, acoustic microscopy) to define the domain of validity, in frequency and temperature, of the model. For the various stress and strain levels, the various excitation types, and the various specimen shapes, the model has been found to provide results which are well correlated with the experiments. The last step in the work consisted in integrating the shape memory polymer into a composite sandwich structure to highlight the exceptional damping capabilities of the material. The power dissipation in the multilayer structure being related to the physical properties of the tBA/PEGDMA core, temperature control allows optimization of the damping over a given frequency range.

This project has been awarded a L'Oréal-Unesco grant 2015 "Pour les femmes et la science" with a jury composed by members of the French Academy of Sciences.

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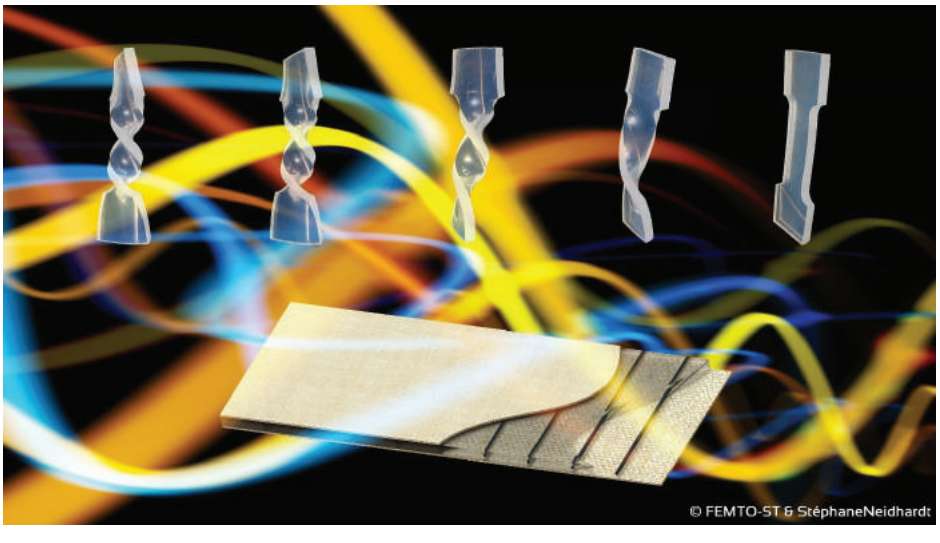
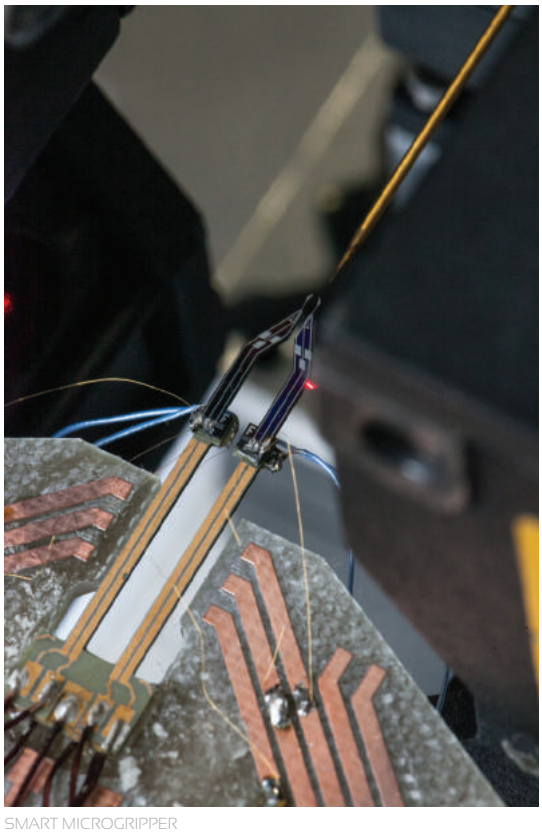


Robotic micro-assembly: realization of complex, accurate and automated tasks



SMART MICROGRIPPER

Microrobotics is a field of research that brings very promising solutions to characterize artificial and biological micro-objects (size ranging between one micrometer and one millimeter) but also to assemble microsystems in a 3D/out-of-plane way. Microrobotic tools, methods and strategies have notably been proposed to successfully achieve complex, automated and highly accurate tasks. This work addressed key issues such as the difficulty to act or sense at the microscale, the predominance of surface forces or the very high dynamics of manipulated objects and gripping tools.

To tackle these issues, an innovative agile (including 4 degrees-of-freedom) and tactile (including force sensors) microgripper has been developed. The physically-based dynamic model also allowed to confer this microgripper a smart behaviour. An advanced control system based on hybrid force-position impedance control associated with an original assembly strategy was the key to successfully take into account microscale specificities and then to succeed in achieving complex, automated and highly accurate micro-assembly tasks.

Assembly of a hybrid out-of-plane micro-optical-bench has been performed as a demonstrator and has shown that a positioning accuracy better than 1 µm can be achieved as well as cycle (pick, guide, release) time down to 1 s.

This work was mainly supported by the Franche-Comté Region and was essentially developed by Bilal Komati during his Ph.D. thesis in robotics (honoured by a national award by the robotics research group of the French National Center for Scientific Research). Several developments are in progress such as the assembly of photonic components and the development of dexterous manipulation.

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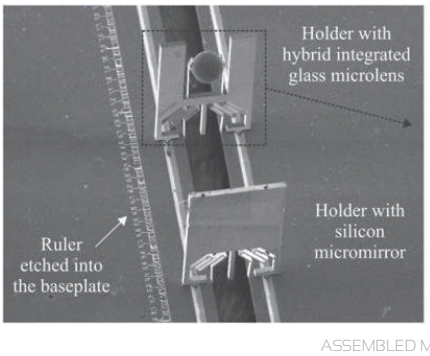
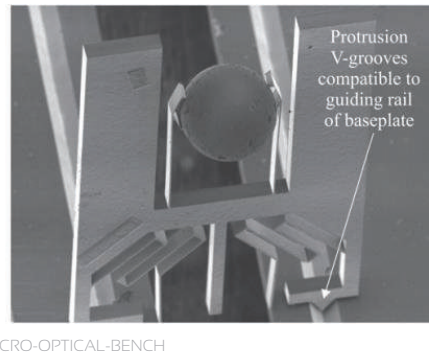
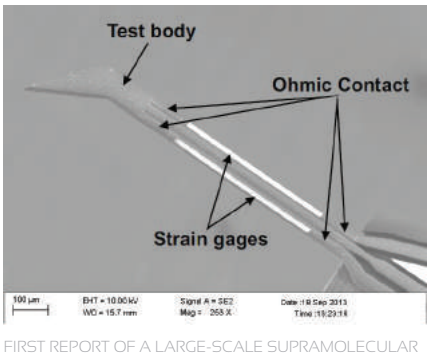




ASSEMBLED MICRO-OPTICAL-BENCH

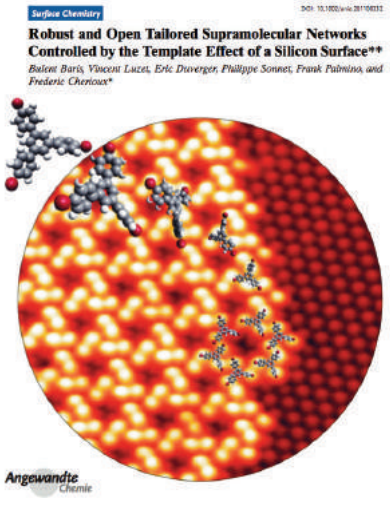


FIRST REPORT OF A LARGE-SCALE SUPRAMOLECULAR SELF-ASSEMBLY ON A SILICON SURFACE

Supramolecular self-assemblies on a silicon surface

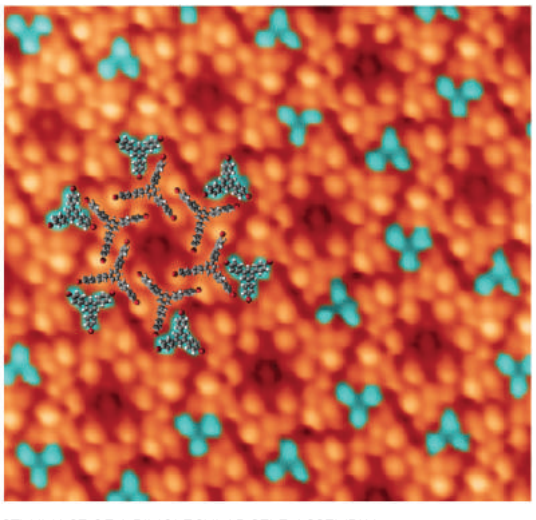
A ten-years story @ FEMTO-ST

Understanding the physical and chemical processes in which local interactions lead to ordered structures is of particular relevance in the realization of supramolecular architectures on surfaces. Due to the vast range of molecular structures and functionalities, spectacular patterns have been designed on metal surfaces, in particular since the use of molecular deposition in ultra-high vacuum, that have allowed to better explain the role of dispersion forces with respect to intermolecular forces. In contrast to metal surfaces, far fewer studies have focused on the spontaneous organization of supramolecular networks on semiconductor surfaces. The reason stems from the high reactivity of these surfaces. For example, the reactivity of silicon surfaces is controlled by the unsatisfied bonding orbitals that cause the formation of covalent bonds with organics through cycloaddition or hydrosilylation reactions. Nevertheless, as the construction of supramolecular structures on semiconductor surfaces is essential in tailoring the electronic properties of two-dimensional semiconductor crystals or in creating functional interfaces between organics and semiconductor materials, we have started in 2006 the investigation of the self-assemblies on silicon surfaces without any covalent bond between molecules and surface in 2006.



For the last ten years, by exploiting the weak reactivity of the B-Si(111)-(√3x√3) R30° surface, we have demonstrated the spontaneous organization of molecules into rich and large structures on silicon. From the synthesis of molecules with specific functional groups to the observation of molecular patterns with sub-molecular resolution by scanning tunneling microscopy and their rationalization with multiscale computer simulations, we have been able to develop a good understanding of the physical and chemical mechanisms involved in the formation of ordered molecular arrangements. We have deeply investigated the role of the subtle balance between molecule-molecule and molecule-surface interactions to control the morphology of supramolecular assemblies on silicon surfaces. For example, by using tailored molecules with a slight modification of geometrical parameters, molecule–molecule interactions can be tuned in order to obtain close-packed or open frameworks.

After the proofs-of-concept of the formation of large-scale (>1µm2) supramolecular self-assemblies on a silicon surface, we are currently using these networks in the field on molecular machines and in the field of energy.



STM IMAGE OF A BIMOLECULAR SELF-ASSEMBLY ON A SILICON SURFACE

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Wireless SAW sensors at high temperature

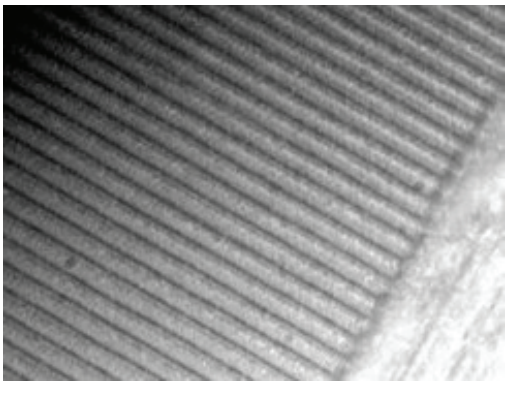
In a highly fragmented market for sensors, the share of wireless sensors is growing: for the only industrial applications, this share accounted for nearly $ 1 billion in 2012! Many "wireless" technologies are currently available to meet different demands. Among them, the technology of the elastic surface wave sensors (Surface Acoustic Waves) is receiving growing interest. In production for several years (e.g. the SENTRY system of Kongsberg using SAW temperature sensor, supplied since 2006), these sensors' unique properties suggest a strong and rapid growth in market share. Their major features are:

- passive sensors: no battery in the sensor (no maintenance, increased strength), maximum lifetime, no complex system of energy recovery,
- miniature wireless sensors: non-intrusive solution, remote access via an RF link, simplified installation,
- robust and reliable sensors: they can be used in harsh environments and are therefore particularly suitable for measurements at very high temperatures.

The scientific environment, in which wireless sensors at high temperature have been designed, asks for materials surpassing the physical limitations of those used today. Such SAW sensors will be dedicated to health-monitoring equipment in harsh environments. The scientific axis will target three main areas:

- "material": the objective is to make available the piezoelectric material for high temperature for the production of sensors. The main characteristics of these components are close or even identical to those at room temperature. This scientific work is done in partnership with other French academic laboratories,
- "SAW device": the objective here is to design and manufacture resonant sensors for measurements at very high temperatures including packaging aspects. The scientific research concerns the understanding of materials behaviors and modelling at high temperature. Many issues are raised: migration between materials, dewetting of thin layers, impedance adaptation behavior … This work was partly supported by the French RENATECH network and its FEMTO-ST technological facility,
- "system": the work will aim to demonstrate the contribution of new components for the wireless measurement at temperatures between 300 and 1000°C for different interrogation protocols.

Wireless SAW sensors at high temperature is one of the technological axis of the joint laboratory "Physical Acoustics, Sensors and Embedded Systems" (PhASES) between FEMTO-ST and the SENSeOR company.



CERAMIC CASE AFTER 5 HOURS AT 500°C, SEM IMAGE AFTER ANNEALING OF 700°C, SAW MIRRORS AFTER 20 HOURS AT 1000°C

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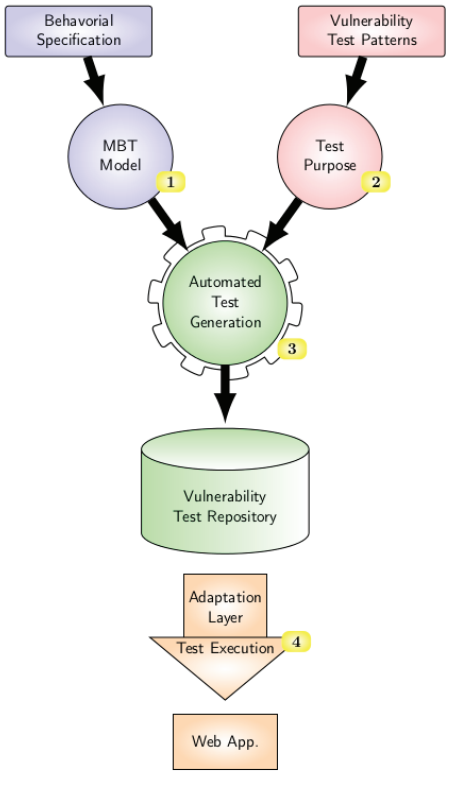
Preventing cyber attacks on Websites through model-based testing

Risks of cyber-security breaches have increased over the past ten years, and Web applications are clearly the most popular targets when speaking of cyber-attacks, as reported from specialized security agencies such as the OWASP group. The fact that modern society's reliance on the Web keeps increasing highlights the challenges of IT security, particularly in terms of data privacy, data integrity and service availability. Economically, the digital revolution has resulted in the fast growth of a new buoyant market, and it is therefore no surprise that organized crime has become the most frequently seen threat actor for Web application attacks.

As a consequence, a significant growth has been observed in application-level vulnerabilities, with thousands of vulnerabilities detected and disclosed annually in public databases such as MITRE CVE. The most common vulnerabilities found on these databases especially emphasize the lack of resistance to code injection, but other vulnerability kinds based on the logic of applications are also well represented. Often referred to as the « big 4 » of the Internet, Google, Apple, Facebook and Amazon have all been suffering recently from vulnerabilities inside their services. For instance, the iCloud scandal from 2014, where thousands of people had their private data disclosed, is a vivid example. Another famous example is the stored Cross-Site Scripting vulnerability inside Facebook Chat/Messenger that allowed hackers to access private messages of other users.

In this context, as part of the EU FP7 project RASEN, a research team of the DISC department of FEMTO-ST Institute has defined and successfully experimented a Pattern and Model-based Vulnerability Testing approach (PMVT for short). This approach aims to automatically produce vulnerability test cases that can be directly executed on a Web application under test in order to discover potential threats before hackers, and therefore to mitigate the risk of cyber-attacks.

A thorough experimentation on several real-life Web portals, including an e-Health commercial Web platform, allowed to successfully validate the PMVT approach. Experiments demonstrated it improves the precision of vulnerability testing and thus enables to conduct accurate attacks. Moreover, the automation of the test generation and test execution makes it possible to adopt an iterative testing approach, which could be efficient to manage vulnerability regression testing. Finally, comparison with existing automated vulnerability scanners showed its effectiveness to conduct complex and sophisticated attacks that current automated solutions are unable to perform.



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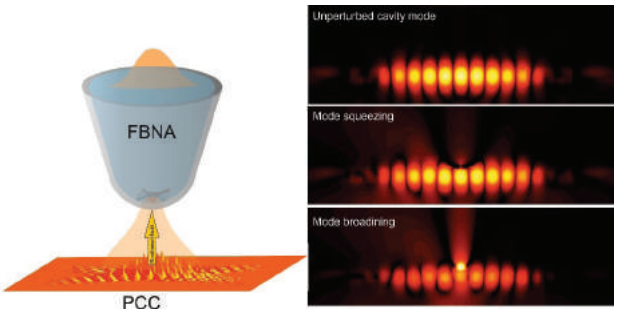
Resonance control of optical nano-cavities by fibered nano-antennas

Frequently, optical micro- and Nano-Cavities (NC) exhibit resonance properties, i.e. Resonance Wavelength (RW) and Quality factor (Q), which are slightly different from the expected ones. This discrepancy is linked to residual fabrication imperfections in the commonly used technological processes (DRIE, RIE, FIB, ALD…). To address this issue, it was previously proposed to thinly disturb the cavity by an external dielectric or metallic element to finely tune the cavity RW. Unfortunately, the proposed configurations so far allowed for either redshifting or blueshifting the resonance peak of the NC. Recently, a team from FEMTO-ST proposed an original configuration based on Fibered Bowtie Nano-aperture Antenna (FBNA) that allows double-way tunability (both red and blue shifts) of the RW of a Photonic Crystal Cavity (PCC). This was made possible thanks to the FBNA electromagnetic properties that simultaneously involve efficient magnetic and electric polarizabilities. The key point is that the weight of the electric and magnetic induced dipoles can be controlled independently through the FBNA-to-PPC distance. When an electric dipole is induced, the volume of the PCC resonant mode is spatially enlarged leading to larger RW. However, the induced magnetic dipole is manifested in a spatially squeezed PCC mode giving rise to smaller RW. Intensive numerical simulations demonstrated a redshift up to +0.65nm and a blue-shift as large as -5nm of the RW of a PCC fundamental mode without any significant deterioration of the quality factor. The first experimental study on the FBNA-to-PCC coupling started in 2014 at FEMTO-ST and is currently in progress. This original study opens the way to a complete post-production control of the resonance wavelength of high quality-factor optical cavities that are now key elements in a lot of domains such as non-linear optics, cavity quantum electrodynamics, terahertz and microwave sources…



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Combined heat and Power Generation: Recent Achievements

Micro scale combined heat and power (μCHP) generation is considered as a good candidate for energy savings and environmental benefits. It is emerging in residential or commercial lightening as well as remote installations for financial, environmental and energetic reasons. It is expected to reduce end user bills, CO_2 emissions and primary energy consumption. Among the competing technologies in μCHP, hot air engines are good candidates due to their high theoretical efficiency, low maintenance requirements, fuel flexibility, and low noise level.

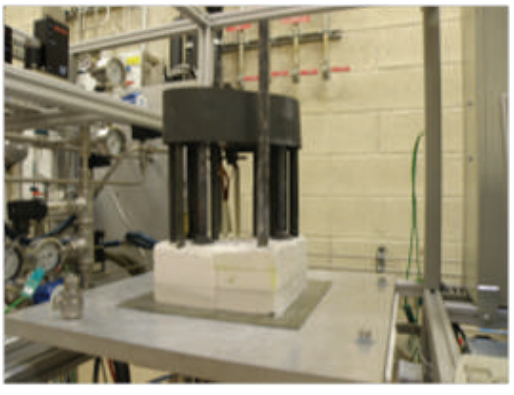
The technology developed at the ENERGY Department of FEMTO-ST includes Stirling (power ranging from μW to kW) and Ericsson (power ranging from kW to MW) engines.

The latest Stirling prototype (i.e., WStirling Project) has requested several years of modeling, design and testing. The optimization of the overall system operating with primary fuels, such as natural gas or liquid fuels, has been completed. This system is based on the association of an external combustion engine and a rotary power generator to power Information and Communication Technology equipment.

Another concept under study is an equipment based on an Ericsson machine. The Energine project, in association with the Assystem company through two CIFRE thesis grants aims at developing a small cogeneration system. The proposed system is characterized by its volumetric expansion chamber with metal bellows suitable for moderate cycle frequencies and internal air pressures. Another originality of the system is the external heat source. The ENERGY department of FEMTO-ST and the Assystem company are currently working on the realization of a feasibility demonstration via patents. Assystem company received the "Grand Prix National de l'Ingénierie 2015" award for the development of the Energine CHP technology based on the Ericsson cycle.

The Mistic project (Low Temperature Waste Heat to Electric Energy using Micro-Stirling Clusters) aims at developing enabling technology for waste heat recovery in industrial processes. The chosen concept consists in implementing clusters of miniature thermodynamic Stirling machines. The core technology is a multiphase piezoelectric smart membrane Stirling engine fabricated using mass MEMS machining, assembling and thin film technology. Expected performances would allow a large fraction of electric energy to be extracted from the low temperature waste heat. The relevance of the Stirling cycle for a microminiaturized generator has been demonstrated and basic underlying technologies for its fabrication are available through the project partners' facilities and capacities.

Considering the whole μCHP system, the heat source for the Stirling engine can also be obtained through a high-temperature fuel cell stack (Solid Oxide Fuel Cell – SOFC), using its thermal by-product. This innovative combined heat and power generation system has already been studied in the ENERGY department of FEMTO-ST in the framework of FCLAB (Fuel Cell Lab - http://www.fclab.fr/) research federation. Obtained experimental results feature very high electrical (over 0.5) and exergetic (over 0.6) efficiency abilities.



SOFC STACK CONSIDERED IN THE COUPLING WITH A STIRLING ENGINE.

Industrial and Academic Partners
Orange Labs, Assystems, SYMME (Université de Savoie), UMI-LN2 (Université de Sherbrooke, Canada), MN2S/FEMTO-ST

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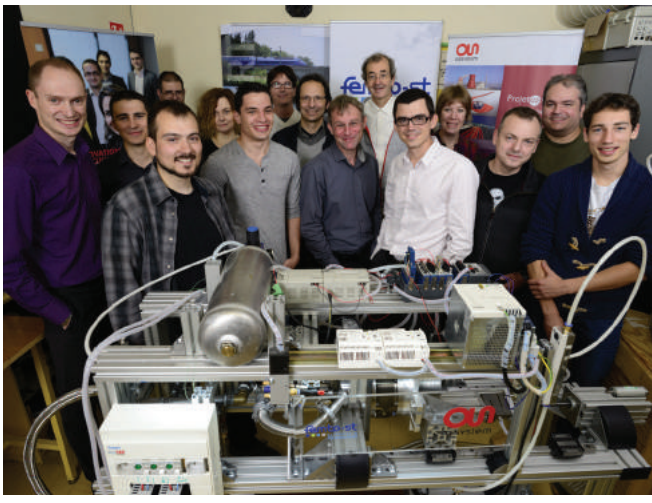
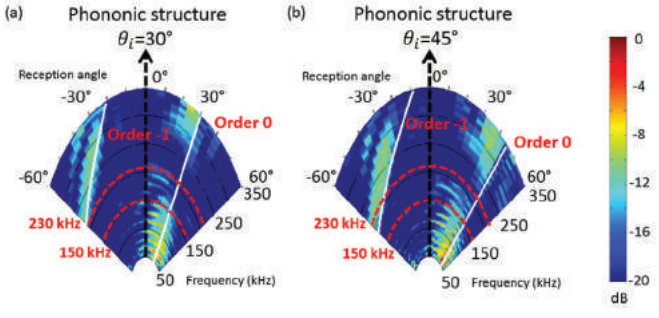
2015 AWARD FOR THE ENERGINE MICRO COMBINED HEAT AND POWER TECHNOLOGY



How diffraction limits ultrasonic screening in phononic structures

The understanding of wave phenomena has come to a turning point with the arrival of new artificial structures such as phononic crystals and acoustic metamaterials. Their counter-intuitive behavior never ceases to surprise and permits to overcome many challenges in the acoustic domain: one of these is the omnidirectionality of wave attenuation. In this regard, phononic crystals have been demonstrated to exhibit complete band gaps, or frequency ranges where no wave can be transmitted, whatever the direction of propagation.



ANGULAR SPECTROGRAMS OBTAINED EXPERIMENTALLY FOR A PHONONIC PLATE, FOR AN ANGLE OF INCIDENCE OF (A) ΘI=30° AND (B) ΘI=45°. THE WHITE LINES SHOW THE FREQUENCY LOCALIZATION OF THE ORDERS OF DIFFRACTION M=0 AND -1 OBTAINED ANALYTICALLY FROM THE GRATING LAW AS ΘM=ARCSIN(MΛA+SINΘI).

However, we could recently experimentally show that diffraction was playing an important role in the phenomenon of acoustic shielding provided by phononic structures. The system of interest is a plate that is periodically perforated with subwavelength slits and immersed in water. Ultrasonic transmission measurements have been performed for all directions of propagation in order to check the omnidirectionality of acoustic shielding. While a single slit acts as a Fabry–Perot resonator in the frequency range of interest, the coupling between adjacent slits provides an attenuation frequency band centered around the resonant frequency that is mostly independent of the angle of incidence. We could obtain transmission extinctions up to 20dB, with a relative bandwidth of 15%, up to an angle of incidence of 45°. Above this value, acoustic shielding appears to be degraded. We have shown that this degradation results from the m =−1 order of diffraction becoming propagating in the frequency range of interest. Because the onset frequency for a particular order of diffraction is chiefly determined by periodicity at the interface between solid and water, irrespective of the resonant frequency of the slits, it should be possible to design a phononic plate exhibiting omnidirectional acoustic screening. For instance, filling the slits with a different fluid in order to shift down the resonance frequency could provide a solution. Overcoming the diffraction limitation to acoustic screening may enable a much wider range of applications, particularly for underwater acoustics and ultrasonics.

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DiMEMS, Distributed intelligent MicroElectroMechanical Systems

Microelectromechanical systems (MEMS) have reached a position of design maturity and are therefore ready for the mass-production of micro-scale devices. Recent examples of mass-produced MEMS include accelerometers, inertial measurement unit (IMU) that are now included in airbag systems as well as in most of the recent smartphones or laptops, bubble ejection systems of inkjet printers or digital micromirror device (DMD), technology used for projection displays. As demonstrated in these examples, MEMS can be used either as single elements (accelerometers, IMU) or they can be grouped and can act together to reach a global goal (DMD). The latter is called distributed MEMS.

The main interest of MEMS is that they can be mass-produced, it is true for single MEMS as well as for distributed ones. It is therefore necessary to think of scalability up to millions of units when evoking distributed MEMS. Due to their small size, their low-cost and the fact that they can be mass-produced, millions of units can be used in a very small space. For example, a volume of less than $1m^3$ of 1mm-diameter silicon balls has a number of nodes comparable to the Internet. This parameter requires paradigm-shifts both in hardware and software parts in order to scale.

Past challenges focused on the engineering process of MEMS, but future challenges will consist in adding embedded intelligence to MEMS systems, so that they will be able to collaborate efficiently. This will require embedding MEMS sensors/actuators, electronics, communication capabilities, control of actuators and programs in the same component which will be called later a unit. It is possible to add a central processing unit but it can become a bottleneck, both in the hardware and software parts. A distributed architecture solves these problems. The use of the expression distributed intelligent MEMS (DiMEMS) has been suggested when referring to such an architecture.

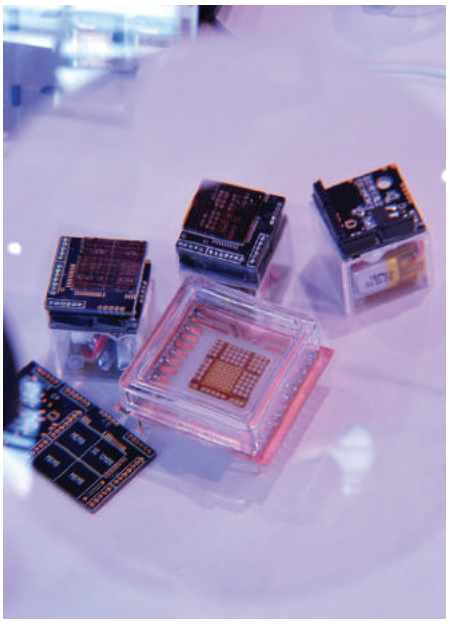
DiMEMS systems will be composed of thousands or even millions of systems which will raise new scientific challenges both for controlling and for programming such large ensembles. Scalability is therefore the main issue in this kind of new device. DiMEMS have the following characteristics: the need for synchronized actuation (local or global), the quality of the communication channel, the type of physical topology (mobile or static), and the type of logical topology (static or dynamic).

Several projects have been initiated in FEMTO-ST to study and develop these new systems.

Two multi-disciplinary projects have been initiated (Smart Surface and Smart Blocks) to study objects conveyance using DiMEMS. Another project called "Coordination and computation in Distributed Intelligent MEMS (CO2Dim)" studies the computer science part of DiMEMS systems. These projects are or have been funded by the National Agency for Research (ANR).

Another multi-disciplinary research topic concerns prognostic health management of DiMEMS to detect, predict and cope with failures of DiMEMS using distributed information.

Together with Carnegie Mellon University, we are building the next generation of programmable matter within the Claytronics project. With the help of the Labex ACTION, we are designing VisibleSim a simulator for the Claytronics project which could also target any kind of modular robots or DiMEMS system. Finally, we are studying a new kind of wireless network called nano-communication network using 1-10 THz bandwidth in order to integrate them into programmable matter.



A VIEW ON ONE PROTOTYPE OF SMART BLOCKS

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µRALP - Robot-Assisted Laser Phonosurgery

The µRALP project (Micro-Technologies and Systems for Robot-Assisted Laser Phonomicrosurgery) is a collaborative project funded by the European Union through the 7th Framework Programme (FP7) and its «CT- 2011.2.1 - Cognitive Systems and Robotics» subprogram. Started in January 2012 and ended in March 2015, it was devoted to the robotic assistance to the laser surgery of the vocal fold. Coordinated by the Istituto Italiano di Tecnologia (Genova), it involved two teams at FEMTO-ST (MiNaRoB/AS2M and PIM/Optics) as well as the Leibniz University in Hanover, the University Hospital (CHRU) in Besançon and the ENT department of the University of Genova.

Lasers form an increasingly common tool for precision treatment of pathological conditions on delicate and vital human organs. Laser phonomicrosurgery, which is a suite of complex otolaryngologic surgical techniques for the treatment of minute abnormalities in the larynx, is one such example. However, laser aiming control for this procedure relies completely on the dexterity of surgeons, who must operate through a microscope and deal with its poor ergonomics, and this can have a strong impact on the quality of the procedures. In addition, the laser beam is directed from a relatively large distance (400mm), resulting in accuracy and consistency problems, and requiring extensive surgeon training. In µRALP, a redesign of this surgical setup was proposed to create an advanced augmented micro-surgical system through research and development of real-time cancer tissue imaging, fluorescence-based diagnosis, surgeon-machine interfaces, assistive teleoperation, intelligent (cognitive) safety systems, and augmented-reality. From an optomechatronic point of view, the concept developed within µRALP is an endoscope which comprises a laser brought to the tip by a fiber, a fast scanning laser micromanipulator and a stereoscopic high-speed and multimodal imaging system.

The scientific and technical achievements of FEMTO- ST within this project are many:
- Design and realization of an optic assembly made of a pair of fiber bundles connected to a high-speed camera by appropriate optical components, allowing for fluorescence imaging and high-frequency stereoscopic laser tracking;
- Design, realization and low-level control of three functional laser micromanipulators;
- Use of epipolar geometry for augmented reality to the surgeon;
- Design and implementation of a stereoscopic image-based laser controller using trifocal geometry;
- Design and implementation of a fast image-based path tracking laser controller;
- Taking into account non-holonomic constraints;
- In tight collaboration with CHRU Besançon, fluorescence analysis of vocal fold exereses;
- Validation of the image-based controllers of the laser micromanipulator in cadaver trials.

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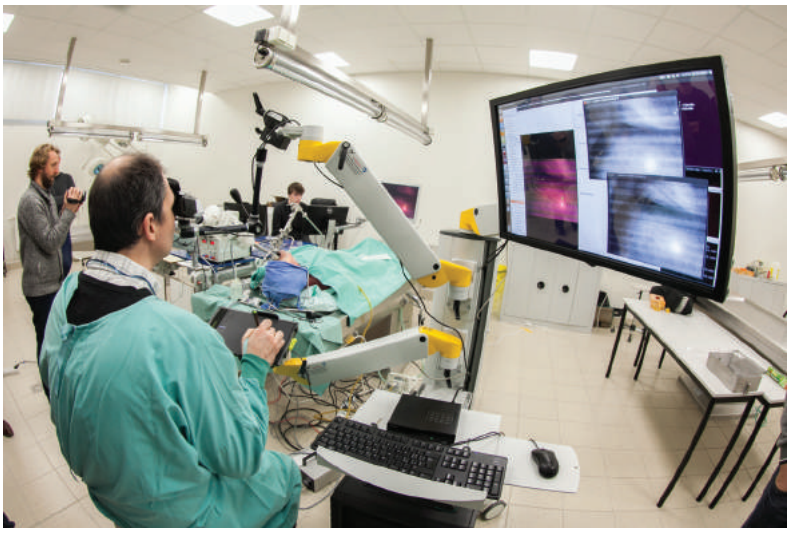

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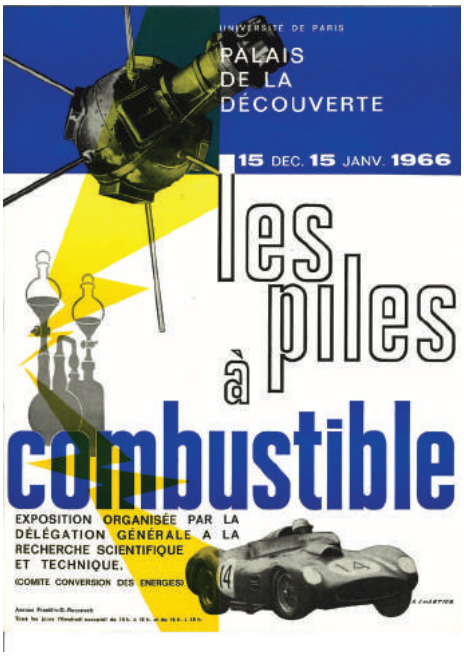
Social and Human Sciences - Analysis of fuel cell technologies

Developing and spreading new technologies for energy production is a complex, risky and uncertain process which requires significant public as well as private investments. Nowadays it is ruled in a sustainable growth innovation-oriented and shifted to a non-carbonated production system and a friendly-fossil energy consumption. The purpose is to mitigate the environmental impact of current production processes.

As a consequence deep changes are needed in most of the major societal functions (energy, transportation, housing, food). These changes have to be thought in a systemic perspective linking issues from the technological, economical, sociological and institutional approaches. They require multi-dimensional modifications in: usages, technologies, actors and networks, goods, minds and representations. Thus, beyond the analysis of the behavior of actors traditionally focused on cost reduction and profits optimization, our research aim to analyze space and time changes of this dimension. How do their interactions contribute to the mutation process of the major functions of the society? More specifically we studied the development of fuel cells technology, which is considered as one of the key technologies of sustainable transitions.

This emerging technology is facing many obstacles to move from laboratories to market. Because the success of a technology also depends on social issues, technical performances are usually not enough to support its implementation. We have to introduce a socio-economic approach in our analysis. Each technology is the consequence of complex interactions between many actors, historically situated and confronted to lock-in. Lock-in is also based on the current balance between actors and their representations of the technology. From an economic viewpoint, another challenge for the actors is to develop new business models, that is business models for sustainability, fostering new ways of creating and co-creating value in the emerging business ecosystem.



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